Know-how for Horticulture™

Integrated management of greenhouse cucumber and capsicum diseases

Len Tesoriero
NSW Agriculture

Project Number: VG00069

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HORTICULTURE AUSTRALIA

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Disclaimer

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CONTENTS **PAGE**

MEDIA SUMMARY

The project has focussed on major disease problems in greenhouse cucumbers and capsicums. Extensive disease surveillance over the three year course of the project has updated Australian pathogen records. New Australian records include the detection of a whitefly-transmitted virus, a fungal wilt disease and a fungal leaf spot on cucumbers.

Wilts associated with fungal root and stem rots were found to contribute to an estimated 30% of crop losses in cucumbers throughout Australia. The fungi, *Fusarium oxysporum* f. sp. *radicis-cucumerinum* and a range of *Pythium* species were found responsible for these extensive crop losses, often occurring in combination as a disease complex.

As a direct result of the crop surveys, trials into the control of this disease were initiated, in order to identify cultural, chemical and biological options. The integrated management of this disease through hygiene and sanitation, temperature and moisture control, chemical use and the introduction of microbial biological agents enabled greenhouse vegetable producers to reduce crop losses and maximise efficiency on-farm.

Hygiene and sanitation proved crucial to the management of Fusarium root and stem rot, as the fungus was shown to be spread aerially and with sciarid flies. Reducing extremes in temperature and root zone moisture limits the potential for infection. Any of eight different species of the water mould *Pythium* were identified. Some are known to be associated with high temperatures and others with low temperatures.

Of the chemical and microbial biocontrols evaluated, neither were found not to be curative. In some cases biocontrols halved losses in affected crops. Chemicals performed better (losses one-sixth of untreated plants) but there are problems with the lack of relevant crop registrations and untested compatibility with other biocontrols. These factors inhibit their adoption in disease management programs.

Trials were also aimed at the development of bioassays for rapid screening of microbial biocontrols but results were inconsistent. The addition of microbial biocontrols in some assays induced greater losses, and better results were achieved with small-scale greenhouse trials and on-farm trials.

Future research is required to develop improved chemical and microbial biocontrols, and appropriate use-patterns. Combinations of compatible microbial biocontrols that have different modes of action are required to obtain wider efficacy for disease complexes occurring on greenhouse cucumbers. Another approach is cross-protection, for example where non-pathogenic *Fusarium* isolates successfully control similar wilt diseases on tomatoes in overseas research.

TECHNICAL SUMMARY

A number of important diseases of greenhouse cucumbers and capsicums have been identified in this project through surveillance activities in major production areas of Australia. Of particular note was the first detection in Australia of a root and stem rot caused by the fungus *Fusarium oxysporum* f.sp. *radicis-cucumerinum*. This disease is now known to occur in all other major greenhouse cucumber production areas of the world and is considered to be one of the primary causes of crop losses. When affected plants were analysed further in this study, *Fusarium* was found to occur in combination with any of ten species of another root pathogen, *Pythium*. In many cases combinations of these pathogens were shown to accelerate disease development, hastening the onset of wilting symptoms and resulting in increased mortality.

Other highlights of the disease surveillance were the detection of the fungus, *Alternaria alternata* causing a leaf spot disease. Previously, another species of this fungus (*A. cucumerina*) was the only fungus causing a similar leaf disease on cucumbers in Australia. Plants sprayed for Downy Mildew with the strobilurin fungicide, Amistar®, were observed to have also been controlled of Alternaria Leaf Spots. An extension to the existing label or specific permits for these diseases is recommended.

Virus-like disease symptoms were observed in several NSW and SA crops. Plants were sometimes stunted, leaved displayed downward rolling and yellowing between veins. These symptoms could have easily been confused with certain nutritional disorders, but a number of observations of crops suggested they were caused by an infectious agent. Laboratory diagnosis revealed that a virus is responsible and is consistent with Beet pseudo-yellows virus. This virus is transmitted by greenhouse whiteflies and is known to occur in greenhouse cucumber crops overseas.

Several trials were conducted to evaluate the efficacy of chemical and biological controls for the root rot diseases. Economical control was achieved with chemical drenches of benomyl with either furalaxyl, or propamocarb. However, these chemicals have no current registrations or permits for use as drenches on cucumbers. Furthermore, benomyl was recently withdrawn from sale in Australia and has been shown to be incompatible with several biological controls (including certain predatory insects and mites). Alternative chemicals for control of *Fusarium* have been identified but need evaluation and permits for their use sought. Biological control of these diseases with a product containing the fungus, *Trichoderma harzianum*, was variable. In some bioassays and on-farm trials this product appeared to reduce disease severity of *Fusarium*. In some cases plant losses were halved with these treatments. However, *Trichoderma* afforded no suppression of a root rot disease caused by *Pythium aphanidermatum*. In contrast, a biocontrol product with the bacterium *Bacillus subtilis* as its active ingredient, did reduce symptoms of *P. aphanidermatum*, but had no effect on *Fusarium*. Combinations of these two biocontrols appeared to be incompatible and did not suppress disease in any of the on-farm trials where both *Fusarium* and *Pythium* were present. Similarly, a biostimulant (fulvic acid) failed to suppress these diseases in any on-farm trials. Another feature of these trials was that chemical and biological treatments were not effective when applied after disease symptoms had appeared (i.e. as curatives). In contrast, the best efficacy of these products was achieved when the first drench was applied to seedlings (i.e. as preventatives).

Various cultural controls for these diseases were identified in this project. Disease incidence and severity were reduced when environmental stresses were minimised, and vice versa. For example, extremes in temperatures were more conducive to the development of *Pythium* root rots. On one hand, high temperatures (>30^{o}C) were associated with root rots caused by *P. aphanidermatum* and *P.deliense*, whereas low temperatures (<10^{o}C) were conducive to disease expression by *P. irregulare* and an unidentified *Pythium* sp. In contrast, greenhouse structures with regulated environmental controls had much lower levels of these diseases. High moisture levels in the root zone were also strongly associated with increased incidence and severity of *Pythium* and *Fusarium* diseases, particularly in combination with temperature extremes.

Poor on-farm hygiene and sanitation enabled these diseases to spread rapidly. Even where new substrate media (sawdust and cocopeat) were used, these pathogens spread rapidly and resulted in approximately one-third of plants dying within sixteen weeks of transplanting. *Fusarium*, in particular, was shown to spread aerially from typical pink spore masses that formed on affected stems. This is consistent with overseas experience with this disease. Spread of *Fusarium* and *Pythium* was demonstrated with fungus gnats (sciarid flies). This exacerbated damage caused by their larvae feeding on cucumber roots and was often associated with the greatest losses in surveyed crops and some greenhouse trials. Handling infected plants was also identified to spread *Fusarium*, particularly via spores from the pink masses that cover affected stems. Wounds on stems facilitated *Fusarium* infections. Fresh cuts after pruning or picking fruit, and growth cracks on lower stems, were common infection points.

This project has identified a serious disease complex responsible for big losses in greenhouse cucumber production. Chemical, cultural and biological management strategies for this disease have been identified. We have commenced evaluation of chemical and biological options, but further work is needed to overcome their current limitations. Chemicals that are biorational (compatible with other IPM practices) and microbial biocontrols that work more consistently and with greater efficacy need to be developed urgently.

INTRODUCTION

Greenhouse production of cucumbers and capsicums has developed rapidly in the last decade. It provides larger urban areas of Australia with a ready supply of fresh products with minimal transport costs. Other advantages are the more efficient use of water resources, fertilisers and reduced environmental degradation. Protective structures provide a strategic capacity to feed large urban areas and market stability when adverse weather conditions affect outdoor production systems.

Plant diseases can cause significant losses to greenhouse cucumber crops and currently require a high chemical use for their control. Greenhouse-grown capsicums appear to suffer from fewer diseases to date but this situation is likely to change as the industry develops and plant pathogens spread. Soil-borne diseases have led some growers to rely upon fumigation treatments. Besides the high annual cost of these treatments, poor application practices and easy reintroduction of pathogens due to poor hygiene and sanitation have resulted in frequent disease outbreaks. Some fumigants are also known to have a negative impact on the environment by leaching into groundwater or depleting the ozone layer. Furthermore, they are highly toxic chemicals that pose a significant risk to farm workers and neighbours.

Many growers have adopted soilless production systems as a means of avoiding many diseases. However, diseases such as Pythium and Fusarium root rots are just as important in these production systems. This problem is exacerbated by the fact that there are no chemicals registered for most soil-borne pathogens in cucumbers. Similar problems exist for some foliar diseases (eg. Botrytis blights and rots).

There has been a rapid development and availability of biological control products worldwide, yet many of these products have not been objectively evaluated for efficacy. Similarly, many products have not been validated as part of integrated crop management systems for Australian conditions. Some research work in New Zealand demonstrated that the use of the microbial biocontrol, *Trichoderma*, had only little effect on controlling a Pythium root rot of cucumbers. Furthermore, the way the product was applied made a significant difference to its efficacy.

This project sought to identify and evaluate improved disease management strategies and facilitate their adoption through on-farm trials, educational resources and workshops. Surveillance in the major Australian production areas updated our records on the disease incidence and distribution on greenhouse cucumbers and capsicums.

Adoption of improved and safer disease management strategies based on IPM is necessary for the environmental and economic sustainability of the greenhouse cucumber and capsicum industries. We urgently need to developing safer chemical, biological and cultural options that: reduce direct losses; comply with food safety standards regarding chemical residues; lessen OH&S hazards to crop workers; and protect neighbours and the environment. This is especially pertinent in peri-urban areas of production.

I. National survey of greenhouse cucumber & capsicum diseases

Introduction

Over 240 samples were formally collected and diagnosed during the project from 2001-2004

These included:

- targeted surveys for rot rots and viral diseases
- samples collected from site visits and in response to grower concerns
- samples submitted to the Plant Health Diagnostic Service at EMAI

See Appendix 1 for list of samples and determinations.

Methods

Disease Surveys

Twenty-six properties were surveyed and/or samples were received from NSW (Sydney Basin, Gosford, Picton, Coffs Harbour, Milton and Sunrasia), seven from South Australia (North Adelaide Plains, Virginia), two from Queensland (Townsville & Bundaberg) and one from Western Australia (South Perth). Further state records were obtained from relevant government authorities.

Results and Discussion

Results of disease surveys and state records are listed in Tables 1 and 2. The first targeted survey in NSW coincided with the commencement of the winter 2001 crop. Many growers had commenced using cocopeat as a root substrate. This provided an opportunity to access and compare root diseases (rots, damping-off and wilts) in four media: cocopeat; sawdust; compost mix; and NFT. Several *Pythium* species and *Fusarium oxysporum* were the major root pathogens detected.

Excess root zone moisture was found to be a common factor associated with higher incidence and severity of *Pythium* rots and wilts. Certain farms using higher irrigation rates in cocopeat and compost media suffered significant losses. An experiment at the National Centre for Greenhouse Horticulture, Gosford showed a strong correlation between NFT and *Pythium* root infection that resulted in almost a complete plant losses. In contrast, plants growing in cocopeat bags in this facility were largely unaffected.

The fungal disease, Gummy stem blight, was commonly found associated with longitudinal splitting of lower stems. This often resulted in wilting and death of mature plants. The longitudinal splits were likely to have been caused by a combination of rapid plant growth and large diurnal temperature ranges.

The fungi *Alternaria alternata* and *A. cucumerina* were detected on leaf spots in NSW and SA. These are the first Australian records of a leaf spot disease caused by *A. alternata*. This pathogen has previously been recorded in Greece (Vakalounakis, 1990). Since no curative fungicides are specifically registered for these diseases in

Australia, the NSW greenhouse growers' association and the NSW vegetable IDO were contacted to seek a permit or an extension to the label registration of azoxystrobin (Amistar ®).

It should also be noted that there are a number of gaps in chemical registrations for both cucumbers and capsicum diseases. There are no chemicals registered for control of Botrytis rots, Black root rot, Fusarium root and stem rot, and Rhizoctonia root rot on cucumbers. There are no registrations for the control of Pythium root rots except for seedling mix amendments of metalaxyl as a granular formulation. This treatment is inappropriate where seeds are germinated in rockwool block, and does not afford sufficient protection for post-transplant onset of disease, especially where a disease complex is formed with *Fusarium*. The problem with chemical use in greenhouse cucumbers is that it is difficult to comply with withholding periods as fruit is picked regularly (every 2-3 days) at certain times of the year. There is a need to obtain registrations for 'soft' chemicals and microbial biocontrols.

The incidence of Black root rot was restricted to the Sydney Basin in this study and was much lower than in previous crop surveys in the early 1990s (Tesoriero, unpublished). This largely reflects the move from soil to soilless (bagged media and rockwool) production. The only incidence where this disease was recorded in a soilless medium (composted greenwaste bags) was adjacent to tunnel houses where soil production has persisted.

A virus disease found commonly on cucumbers in NSW and SA was identified as Beet pseudo-yellows virus (also called Cucumber yellows virus). This is the first report of this virus on cucumbers in Australia. It has been previously reported in Tasmania on weed species (Duffus & Johnstone, 1981). This virus is transmitted by greenhouse whiteflies.

TABLE 1. List for greenhouse cucumber diseases in Australian greenhouse cucumbers

NOTE: This list is not to be used for quarantine purposes. State records for several diseases are incomplete for greenhouse production.

DISEASE	PATHOGEN	NSW	SA	QLD	WA	COMMENTS
Fungal						
Alternaria leaf spots	*Alternaria cucumerina* *Alternaria alternata*	✓ ✓	✓ ✓	✓	✓	*A. alternata* not previously recorded
Anthracnose	*Colletotrichum orbiculare*	✓	✓	✓	✓	
Botrytis Rots (Grey Mould)	*Botrytis cinerea*	✓	✓	✓	✓	Mainly found as flower infection and associated with abortion of young fruit. Also stem rots.
Black Root Rot	*Phomopsis sclerotioides*	✓				Records from compost media & soil
Black Root Rot	*Thielaviopsis* sp. (=*Chalara* sp.)	✓	✓			
Damping-off	*Rhizoctonia solani*	✓	✓	✓	✓	Wilting seedlings
Damping-off / Root rot	*Pythium* spp.	✓	✓	✓	✓	Species vary with seasons (temperature)
Fusarium foot rot & wilt	*Fusarium solani* *Fusarium oxysporum*	✓	✓	✓	✓	Disease complex with *Pythium* species
Root rot	*Phytophthora* sp.	✓				
Downy mildew	*Pseudoperonospora cubensis*	✓	✓	✓	✓	
Powdery mildew	*Sphaerotheca fuliginea* (anamorph = *Oidium* sp.)	✓	✓	✓	✓	
Gummy stem blight	*Didymella bryoniae* (anamorph = *Phoma cucurbitacearum*)	✓		✓		Associated with splitting of lower stems
Sclerotinia Rot	*Sclerotinia sclerotiorum*	✓	✓	✓	✓	
Bacterial						
Angular leaf spot	*Pseudomonas syringae* pv. *lachrymans*	✓	✓	✓	✓	
Bacterial leaf spot	*Xanthomonas campestris* pv. *cucurbitae* *Pseudomonas syringae* pv. *syringae*	✓ ✓		✓		Seedling leaf lesions
Bacterial seedling blight	*Acidovorax avenae* subsp. *Citrulli* *Acidovorax konjaci*	 ✓		✓		Seed-borne disease Cocktail cucumber seedlings

DISEASE	PATHOGEN	NSW	SA	QLD	WA	COMMENTS
Viruses						
Mosaic Diseases	Cucumber Mosaic Virus	✓	✓			
	Tomato Spotted Wilt Virus	✓	✓			Mild leaf mosaic masked by thrips injury
	Zucchini Yellow Mosaic Virus	✓	✓	✓		
Cucumber Yellows	Beet Pseudo-Yellows Virus	✓	✓			First record on cucumbers in Australia
Nematodes						
Root Knot	*Meloidogyne* sp.	✓	✓	✓	✓	

TABLE 2. LIST FOR GREENHOUSE CAPSICUM & CHILLI DISEASES

NOTE: This list is not to be used for quarantine purposes. State records for several diseases are incomplete for greenhouse production.

DISEASE	CAUSE	NSW	SA	QLD	WA	COMMENTS
Alternaria rots	*Alternaria* sp.	✓	✓	✓		
Anthracnose	*Colletotrichum* spp.	✓	✓	✓		
Downy Mildew	*Peronospora tabacina*	✓	✓			Old records, not from greenhouse crops
Collar & Root Rot	*Rhizoctonia solani*	✓	✓	✓	✓	
Grey Mould	*Botrytis cinerea*	✓	✓	✓	✓	
Powdery Mildew	*Leveillula taurica* (*anamorph=Oidiopsis* sp.)	✓	✓	✓	✓	
Root Rot	*Pythium* spp.	✓	✓	✓	✓	
Root Rot	*Fusarium* spp.	✓	✓	✓	✓	
Root Rot	*Phytophthora* spp.	✓	✓			
Sclerotinia Rot	*Sclerotinia sclerotiorum*	✓	✓	✓	✓	
Verticillium Wilt	*Verticillium dahliae*	✓		✓		
Bacteria						
Bacterial Wilt	*Ralstonia solanacearum*			✓		
Bacterial canker	*Clavibacter michiganensis*			✓		
Bacterial Leaf spot	*Xanthomonas campestris*	✓		✓	✓	
Bacterial Leaf spot	*Pseudomonas syringae*	✓				

DISEASE	CAUSE	NSW	SA	QLD	WA	COMMENTS
Viruses						
Mosaic	Pepper Mild Mottle Virus	✓	✓	✓		
	Cucumber Mosaic Virus	✓	✓	✓	✓	
	Potato virus Y	✓	✓	✓		
	Tomato Aspermy Virus		✓			
	Tomato Spotted Wilt Virus	✓	✓	✓	✓	
Nematodes						
Root Knot Nematodes	*Meloidogyne* spp.	✓	✓	✓	✓	

II. Information Transfer

Extension activities and outputs were done collaboratively with two separately-funded HAL projects, and via Vegetable IDOs. Farm visits provided one-on-one discussion of specific disease management issues.
Below is a summary of group presentations, training, extension outputs and scientific publications arising from this project to date:

Industry workshops & seminars

- Rossmore, Sydney, June 2002 – Disease recognition workshop
- Virginia, SA, March 2002 - Disease recognition & project progress seminar
- Virginia, SA, April 2004 – Project summary seminar
- Bundaberg, Qld., 2004 – Project review/summary and IPM workshop
- Perth 2004 – Project summary, and disease recognition and management workshop

Contributions to technical resources

- *Know your diseases* (Section #6); *Plant health management* (in Section#1); and *Registered chemicals for common diseases in greenhouse vegetables* (Handy Guide #5) in Integrated Pest Management in Greenhouse Vegetables – Information Guide (Goodwin *et. al*, 2002).
- *Fungal diseases, Bacterial diseases, Viral diseases* & *Nematodes* in Pests, Diseases, Disorders and Beneficials in Greenhouse Vegetables: Field Identification Guide (Goodwin *et. al*, 2002).
- *Common diseases of greenhouse cucumbers.* Wall poster for growers (Tesoriero & James, 2004).

Conference papers, posters and abstracts

- Paper presented at the AHGA Conference, Central coast, NSW, 2001 (Tesoriero, 2001)
- Abstract & Poster presented at IX International Fusarium Workshop, Sydney, 2003 (Tesoriero *et. al.*, 2003)
- Paper presented at AHGA Conference, Melbourne, 2003 (Tesoriero, 2003)
- Paper & poster presented at the 3rd Australasian Soil-Borne Diseases Symposium, Barossa Valley, South Australia, 2004 (Tesoriero *et. al*, 2004)

III. Tests to confirm identity & pathogenicity of *Fusarium* & *Pythium* isolates

Introduction

Farm surveys of Australian greenhouse cucumber crops identified a fungal wilt and stem rot as the most significant disease. A *Fusarium oxysporum* and various species of *Pythium* were consistently isolated from wilting plants. Observations of affected plants also noted that stems infected with *Fusarium* often developed pink-coloured fungal spore masses (sporodochia). Air-borne spread of the disease is not typical of diseases previously attributed to *Fusarium* (*F. oxysporum* f.sp. *cucumerinum*) in Australia. Disease symptoms are consistent with Greek (Vakalounakis, 1996) and Canadian (Punja & Parker, 2000) reports that have described a new strain of *Fusarium* (*F. oxysporum* f.sp. *radicis-cucumerinum*). Host range and taxonomic studies were required to characterise the Australian isolates. Further trials were designed to assess the relative aggressiveness of the different species of *Pythium*, and to determine the combined effects of combined infections of *Fusarium* and *Pythium* in cucumbers.

~~Methods~~

~~A series of experiments were designed to confirm pathogenicity of fungal isolates and to develop rapid and reliable bioassay methods. Diagnostic investigations of diseased plants in farm surveys revealed that most plants were infected with both *Fusarium oxysporum* and any one of eight different *Pythium* species. The first series of trials were conducted in various media, (Growool®, cocopeat or a commercial mix based upon composted green-waste). The second set of assays investigated a method where cucumber seedlings were suspended in plastic cups. Trial methods are detailed separately below.~~

~~A disease severity index (Table 3) was developed during the trials to score relative growth, wilting and hypocotyl rot symptoms. This was used for trials of pathogenicity and later for evaluation of microbial biocontrol efficacy.~~

~~Table 3. Disease Severity Index for *Fusarium* & *Pythium* Rots~~

~~SCORE~~	~~SYMPTOMS~~	~~AND/OR~~	~~AND / OR~~
~~0~~	~~No visible symptoms~~		
~~1~~	~~Pale-coloured hypocotyl or stem base~~	~~Stunting~~	~~No wilting; or leaves angled down~~
~~2~~	~~Yellow / brown hypocotyl or stem base~~	~~Stunting~~	~~Slight wilt and /or yellowing~~
~~3~~	~~Fungal mycelium visible or brown hypocotyl lesion or stem base~~	~~Stunting~~	~~Moderate wilt (leaves angled down, dehydration in 20-40% of leaves) and leaf yellowing~~
~~4~~	~~Brown, necrotic lesion or stem base~~	~~Stunting~~	~~Severe wilt (leaves angled down, dehydration in 40-100% of leaves) and leaf yellowing~~
~~5~~	~~Dead (Permanently wilted)~~		

Plants were monitored regularly for 33 days. All dead plants were plated to agar media to confirm fungal infection. Stem heights of surviving plants were measured at Day 33. Stems and leaves were dried in oven for 4 days and weighed.

Results

Table 9. Mean Disease Severity Rating and % Mortality

TREATMENT	**DISEASE SCORE DAY 33**	**% MORTALITY DAY 33**
Control	0.09 a	0 a
Fusarium #7	4.76 c	87 b
Pythium #6	2.42 b	0 a
Fusarium #7+ *Pythium* #6	4.47 c	64 b

Table 10. Mean Dry Weights and Stem Lengths

TREATMENT	**DRY WEIGHT (g)**	**STEM LENGTHS (cm)**
Control	3.30 a	43 a
Fusarium #7	1.33 c	13 d
Pythium #6	2.16 b	32 b
Fusarium #7+ *Pythium* #6	1.35 c	25 c

Conclusions

We confirmed that *Fusarium* and *Pythium* isolates from diseased cucumbers were the causal agents. *Fusarium* isolates reproduced a root and stem rot disease in inoculated cucumber seedlings. Typical hypocotyl lesions formed as well as pink spore masses (sporodochia) on affected stems. Vascular colonisation by *Fusarium* led to plants collapsing as observed in field surveys. Some control plants became infected late in the trials, confirming aerial transmission of this pathogen. Transmission was also demonstrated with sciarid flies and their larvae. *Pythium* isolates (*P. irregulare*, *P. aphanidermatum* and *P.spinosum*) were also shown to cause root rot diseases and resulted in many plants permanently wilting. In three trials (#1, 5, & 10) there appeared to be synergistic interactions between certain *Fusarium* and *Pythium* isolates. The combined inoculation of *Fusarium* and *Pythium* greatly increased the severity of disease expression, and hastened permanent wilting. Further work is required to determine, more accurately, the nature of this interaction.

IV. Farm scores for incidence and distribution of wilting cucumber plants

Trial 7

Aims

Collect disease incidence and distribution data from commercial greenhouse crop. Make photographic records of disease symptoms and isolate pathogens.

Method

Wilting and healthy mature plants were counted in a multispan greenhouse. Cucumber plants (cvs *Montana* and *Cobra*) were growing in 'cucumber mix' (a commercially composted green-waste product) in 5-litre bags. Each bag had been sown with two seedlings at the first true leaf stage. One row of cv. *Montana* and eight rows of cv. *Cobra* filled one span. Rows consisted of 80 bags running in an East-West direction. Diurnal temperatures ranged from 5-30^{o}C. Further counts were taken of seedlings planted into used 'cucumber mix' and an adjacent span containing cocopeat bags that had previously grown tomatoes. Treatments were: cvs *Mascot* and *Ornella* in 'cucumber mix' previously used for cucumbers; and cv. *Ornella* in cocopeat, previously used for tomatoes. Plants (except to cv. *Ornella* in used cocopeat) were scored at 66 days after transplanting for wilting and brown stem lesions.

Results

Typical symptoms of the disease were wilting plants with orange-pink stem cankers. Other plants wilted in their lower leaves only. They were mostly accompanied by a bronzing or brown lesion 0-20 cm from base of plants. Results are summarised in Table 11.

Table 11. Incidence of diseased plants in farm surveys

Cucumber cv.	**Root substrate**	**Total plants**	**# Wilting**	**% Affected**
Montana	Cuc mix (new)	160	33	21
Cobra	Cuc mix (new)	1280	807	63
Mascot	Cuc mix (used)	104	38	54
Ornella	Cuc. Mix (used)	66	38	58
*Ornella**	Cocopeat (used)	1400	172	12

*counts at 4-leaf growth stage (14 days after transplanting). Rows 1-3 had a large disease 'hot-spot' towards the Western end of the house.

Conclusions

High plant losses were recorded (21-63% of plants wilting by 66 days). Twelve percent of plants (cv. *Ornella*) had wilting symptoms 14 days after transplanting. Previous use of media did not appear to influence the level of disease. The cultivar, *Cobra*, appeared to be more susceptible to this disease than cv. *Montana*. However, more objective work is required on cultivar susceptibility. There is no known resistance to these diseases in greenhouse cucumbers, but more tolerant cultivars may be useful in an integrated approach to reduce losses.

Results & Conclusions

Rockmelon (*Cucumis melo*) cultivars were the most susceptible hosts (Table 13). Cucumber (*Cucumis sativus*) and then Watermelon (*Citrullus vularis*) were next most susceptible. Other cucurbits and capsicums were tolerant to disease. These results are consistent with published host susceptibility determinations for *Fusarium oxysporum* f.sp. *radicis-cucumerinum* (Vakalounakis, 1996).

Table 13. Host Range of *Fusarium oxysporum* (isolate 01/1092 ex. Greenhouse cucumber)

Host Plant	**Cultivar**	**% of plants permanently wilted**		
		Day 12	**Day 21**	**Day 35**
Cucumber	Crystal salad	0	58	92
Rockmelon	Hales Best	58	100	100
	Pablo	Trace	75	92
Watermelon	Sensation	0	Trace	8
Pumpkin	Butternut	0	0	0
Squash	Green buttons	0	0	0
Zucchini	Black Beauty	0	0	0
Capsicum	Californian Wonder	0	0	0

VI. Evaluation of microbial biocontrols, chemical & cultural controls for diseases

Introduction

Trials were carried out on NSW Agriculture sites and on greenhouse growers' properties to investigate biological control agents and to compare their effectiveness with conventional fungicides for control cucumber diseases. Trials are outlined below.

A. Efficacy of biocontrol products with *Trichoderma* and *Bacillus* to *Fusarium oxysporum* in cucumber seedlings.

Methods:
The biocontrols used were Trich-A-Soil® (*Trichoderma harzianum*) & Companion® (*Bacillus subtilis*). Two rates of each biological control were used:
Trich-A-Soil®, Rate 1 = 20g/L (1×10^9 spores/ plant = 2×10^7 spores/ml)
Trich-A-Soil®, Rate 2 = 40g/L (2×10^9 spores/ plant = 4×10^7 spores/ml)
Companion®, Rate1 = 20ml/L (1.5×10^7 CFU/plant = 3×10^5 CFU/ml)
Companion®, Rate2 = 40ml/L (3×10^7 CFU/plant = 6×10^5 CFU/ml)

The trial consisted of 8 treatments:

1. Control inoculum : Nil
2. Control inoculum : Trich-A-Soil®, Rate 2
3. Control inoculum : Companion®, Rate 2
4. Fusarium inoculum : Nil
5. Fusarium inoculum : Trich-A-Soil®, Rate 1
6. Fusarium inoculum : Trich-A-Soil®, Rate 2
7. Fusarium inoculum : Companion®, Rate 1
8. Fusarium inoculum : Companion®, Rate 2

Cucumber seeds (cv *Tarduna*) were planted in Growool® cubes and treated with biological controls the day after and then weekly for 5 weeks. Biological controls were poured onto surface of Growool® blocks. Water was used for the nil treatment.

Sixteen-day-old seedlings were inoculated with *Fusarium* culture 02/263 (9.4×10^6 conidia per plant = 4.7×10^5 conidia /ml). Fusarium culture had been isolated from a cucumber plant with root rot and wilt. Inocula was drenched through surface of Growool® blocks. Control treatments consisted of plant roots drenched with agar suspension minus fungal inoculum. Plants were arranged in randomised blocks (8 replications x 3 plants) in greenhouse on plastic trays, (min/max temperatures: 15-35°C). Plants were regularly monitored for 28 days after *Fusarium* inoculation. They were watered and fertilised as required and disease symptoms recorded using disease severity index. At the end of trial stem heights of surviving plants were measured and stems and leaves were dried in oven for 4 days and weighed. Root and stem tissue from permanently wilted plants and 1 plant from each replicate and treatment were plated on agar to confirm fungal infection.

Discussion and conclusions

Economical control was achieved with chemical drenches of benomyl with either furalaxyl, or propamocarb. However, these chemicals have no current registrations or permits for use as drenches on cucumbers. Furthermore, benomyl was recently withdrawn from sale in Australia and has been shown to be incompatible with several biological controls (including certain predatory insects and mites). Alternative chemicals, such as fludioxanil, for control of *Fusarium* need evaluation and permits for their use sought.

Biological control of these diseases with a product containing the fungus, *Trichoderma harzianum*, was variable. This product appeared to reduce disease severity in two of the five on-farm trials. In some cases plant losses were halved with these treatments. The bacterium *Bacillus subtilis* reduced disease in only one of the five trials where it was assessed. Combinations of the two biocontrols appeared to be incompatible and did not suppress disease in any of the on-farm trials where both *Fusarium* and *Pythium* were present. Similarly, a biostimulant (fulvic acid) failed to suppress these diseases in any on-farm trials. Another feature of these trials was that chemical and biological treatments were not effective when applied after disease symptoms had appeared (i.e. as curatives). In contrast, the best efficacy of these products was achieved when the first drench was applied to seedlings (i.e. as preventatives).

Poor on-farm hygiene and sanitation enabled these diseases to spread rapidly. Even where new substrate media (sawdust and cocopeat) were used, these pathogens spread rapidly and resulted in approximately one-third of plants dying within sixteen weeks of transplanting. *Fusarium*, in particular, was shown to spread aerially from typical pink spore masses that formed on affected stems. This is consistent with overseas experience with this disease.