Control of sudden wilt in capsicum

Dr. Graham Stirling
Biological Crop Protection
Pty Ltd

Project Number: VG02020

VG02020

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

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

ISBN 0 7341 1073 1

Published and distributed by:
Horticultural Australia Ltd
Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

Know-how for Horticulture™

Horticulture Australia Ltd. Project number: VG02020

Project Leader:

Dr Graham R Stirling
Biological Crop Protection Pty. Ltd.
3601 Moggill Rd, Moggill, Qld 4070.

Phone: 07 3202 7419 or 0412 083 489
Fax: 07 3202 8033
Email: graham.stirling@biolcrop.com.au

Other Investigators:

Ms Lois M. Eden

Purpose of the report

Pythium root rot is the most important soil-borne disease problem in the Queensland capsicum industry. It can cause heavy losses to seedlings when temperatures are high or wet weather occurs within a few weeks of planting, and is thought to be involved in a disease of mature plants known as sudden wilt. This report describes research on the control of Pythium root rot on capsicum in tropical and subtropical environments. Evidence is presented which shows that reducing soil temperatures to levels that are unfavourable to heat-tolerant *Pythium* species is the most important control measure. Other useful management practices include improving the biological suppressiveness of soil with amendments of organic matter and reducing pathogen activity with chemicals such as metalaxyl, phosphite and silica.

Acknowledgments

This work would not have been possible without help from others. Ms Rosemary Kopittke advised on statistical analyses, Chrys Akem and Tony Parker helped with field trials in north Queensland, and Neil Halpin kept a watchful eye on trials in Bundaberg. Dale Reibel, Alan Napier and Joe Totorica cooperated with field trials at Bowen and Gumlu, while Don Halpin was an excellent co-operator at Bundaberg. Don managed our trials professionally and was always willing to accommodate experimental requirements that inevitably made his job more difficult. The Australian capsicum industry and HAL provided financial support for the project.

Date: 24 February 2005

MEDIA SUMMARY

Pythium root rot is the most important soil-borne disease in the Queensland capsicum industry. Seedlings suffer from root rot when temperatures are high and soil is wet during the first few weeks after planting, and *Pythium* is a component of a disease of mature plants known as sudden wilt. Growers have previously had relatively few options for reducing losses from root rot, but recent research has provided several potentially useful chemical and non-chemical control measures.

Dr Graham Stirling and Ms Lois Eden from Biological Crop Protection in Brisbane, who did the research on behalf of Horticulture Australia and the vegetable industry, found that reducing soil temperature was the key to controlling *Pythium* in capsicum crops. Species of *Pythium* that cause root rotting in tropical and subtropical areas thrive at soil temperatures of 35-40ºC, so practices such as changing from black plastic to white plastic mulch, planting into plant-based mulch that is grown *in situ*, or using a denser planting configuration to throw more shade on the bed (e.g. double rather than single rows), are all likely to reduce the impact of the disease.

Another useful control option is to use organic matter to enhance the soil's natural mechanisms of biological control. Experiments in vegetable-growing soils from Bundaberg showed that when the soil was amended with organic materials such as sugarcane trash and lucerne hay, losses due to Pythium root rot were reduced. Since the soil organisms that suppress *Pythium* took many months to develop and disease suppression was only obtained when microbial activity was high, it was necessary to incorporate the organic matter about 4-6 months before planting. Once the soil biology is enhanced with an organic amendment, it is important to preserve the new biological community by minimising tillage.

Three chemicals with potential to provide control of Pythium root rot were investigated. Drenches of metalaxyl were effective against the seedling stage of the disease; foliar sprays of phosphite reduced the amount of root rot in capsicum seedlings by about 30%, and silicon applied as a soil drench improved root health in glasshouse experiments. However, Dr Stirling warned that phosphite and EC formulations of metalaxyl are not yet registered for use on capsicums, while field studies on the efficacy and economics of using silicon for root disease control have not commenced.

TECHNICAL SUMMARY

Pythium root rot is the most important soil-borne disease in Australia's tropical and subtropical capsicum industry. *Pythium myriotylum*, *P. aphanidermatum* and other species of *Pythium* with high optimum temperatures kill seedlings when temperatures are high or soil is too wet during the first few weeks after planting, and are involved in a disease of mature plants that is known locally as sudden wilt. The objective of this work was to minimise the impact of Pythium root rot by modifying soil management practices, enhancing biological suppression of *Pythium* and controlling the pathogen with chemical and non-chemical treatments.

Previous work has shown that high soil temperatures and heat stress are important components of the Pythium root rot syndrome. The effects of changing plastic colour, modifying mulching practices and varying planting configurations were therefore investigated. Experiments with plastic colour showed that soil temperatures increased when black rather than white plastic was used as mulch, and this had a major impact on disease severity. In contrast, seedling mortality declined in plant-based mulches that were either laid manually or produced *in situ*, largely because soil temperatures were reduced. This result suggests that minimum till production systems in which seedlings are planted into *in situ* mulch should be further investigated from a soil health and disease minimisation point of view. Dense planting configurations (e.g. double rows) provided more shade than single rows and are therefore likely to improve control of Pythium root rot, particularly if they are used in conjunction with white rather than black plastic.

A series of experiments were done to investigate the role of organic matter in enhancing natural biological mechanisms of disease control. Incorporation of a forage sorghum green manure crop was found to exacerbate Pythium root rot if capsicum seedlings were planted within a month of incorporation, largely because *Pythium* is a good competitive saprophyte and is capable of colonising fresh organic matter. However, when organic matter was introduced 4-6 months before capsicums were planted, losses due to Pythium root rot were reduced. This effect was observed in field plots amended with sugarcane trash plus nitrogen; in bioassay plants grown in undisturbed cores containing soil previously amended with sugarcane trash, nitrogen and compost; and in a pot experiment with soil amended with sugarcane trash or lucerne hay. In all cases, root rotting was less severe as soil microbial activity increased.

Three chemicals with potential to provide control of Pythium root rot were also investigated. Metalaxyl was effective against the seedling stage of the disease, provided it was applied to potting mix just before seedlings were transplanted, or drenched around seedlings as they were planted. Phosphite was not as effective as metalaxyl, but foliar sprays increased phosphite concentrations in roots to levels known to control *Phytophthora*, a closely related root rotting pathogen, and reduced the severity of root rotting in capsicum seedlings by about 30%. Silicon was also a potentially useful control measure, as disease severity was reduced when SiO_2 was drenched around the roots of capsicum seedlings in the glasshouse. However, it may be some time before these products are available for use by vegetable growers. Phosphite and EC formulations of metalaxyl are not registered for use on vegetable crops, while field studies on the efficacy and economics of using silicon for root disease control are yet to commence.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

The Queensland capsicum industry

The tropical and subtropical capsicum industry, which is based around Bowen and Bundaberg in Queensland, is Australia's main capsicum production area during winter and spring. Planting commences in February and continues until September, which means that the Queensland industry has a dominant place in the market from May until December. Most of the capsicums are produced by specialised growers who purchase hybrid varieties from nurseries, transplant seedlings into raised beds covered with plastic, and water crops by trickle irrigation.

Pythium root rot of capsicum

Current methods of establishing capsicum crops are normally very successful, as less than 0.1% of capsicum seedlings are usually lost within a few weeks of planting. However, stunting and death of seedlings due to Pythium root rot is sometimes observed. The disease occurs most frequently at the end of rows, where water tends to accumulate due to inadequate drainage. However, widespread losses of seedlings can also occur, particularly following periods of extremely hot or wet weather. In a crop planted at Bowen in February 2003, for example, hundreds of seedlings in the rows closest to regularly-spaced windbreaks were stunted by Pythium root rot, probably because high temperatures and lack of air movement near the windbreaks exacerbated the disease. In another example, more than 30% of seedlings planted on black plastic in Bundaberg during January 2003 succumbed to Pythium root rot, largely because soil temperatures in beds were greater than 40ºC and more than 280 mm of rain fell in the first five days after planting. *Pythium aphanidermatum* and an unidentified *Pythium* sp. were associated with rotted roots at Bowen, while *P. aphanidermatum* was involved at Bundaberg.

Pythium root rot is also a component of an important disease of mature capsicum plants that is known locally as sudden wilt. Plants appear healthy until fruit set, when they wilt suddenly, drop their leaves and then die or produce small, unmarketable fruit. Outbreaks are unpredictable, with minor losses in some years and serious losses in others. Research done in a previous Horticulture Australia project (Stirling *et al.* 2003; 2004) indicated that severe root rotting always occurs before plants collapse with sudden wilt and several potential fungal pathogens were isolated from rotted roots. However, two species of *Pythium* (*P. myriotylum* and *P. aphanidermatum*) were the only fungi to cause severe root rotting in mature capsicum plants. Root rotting was much more severe at 35-40ºC than at 30ºC. High temperatures were also sub-optimal for capsicum, as root health was poor and shoot growth was markedly reduced at 35 and 40ºC in the absence of pathogens. Since soil temperatures greater than 35ºC may occur at certain times of the year in beds used for capsicum production, it was concluded that sudden wilt is the result of a pathogen × environment interaction in which heat-stressed plants are attacked by *P. myriotylum* or *P. aphanidermatum*.

Control options

Chemical controls are always the first option considered in the vegetable industry when control measures for plant diseases are being developed. However, in the case of Pythium root rot, available evidence suggests that environmental factors are important in exacerbating the disease. It is therefore unlikely that Pythium root rot will be controlled by concentrating only on chemical treatments that target the pathogen. Environmental modification must also be considered, particularly as it pertains to the physical factors (e.g. moisture and temperature) that impact on disease severity, and the biological factors that influence disease suppression.

Excessive soil moisture is recognised as a major factor influencing the severity of diseases caused by *Pythium* (Hendrix and Campbell 1973), and improved irrigation management is therefore one option for reducing losses from Pythium root rot. However, opportunities to change the way crops are watered are relatively limited. Most growers are aware that over-watering exacerbates root rot problems and take particular care to limit the amount of water applied to young seedlings. In mature crops, irrigation frequency is determined using computerised moisture monitoring equipment, which means that in the absence of uncontrollable factors such as heavy rainfall, soil moisture is usually as close as is practically possible to the levels required for optimal plant growth.

Evidence from previous studies (Stirling *et al.* 2004) clearly indicates that when soils are infested with *Pythium* species that have high optimum temperatures, soil temperature has a major effect on the severity of Pythium root rot. Root systems are largely destroyed by *P. aphanidermatum* and *P. myriotylum* at temperatures above 35ºC, whereas they cause little damage at 30ºC. This suggests that reducing soil temperatures by as little as a few degrees will have a major effect on disease severity. Options for achieving this include changing the colour of the plastic mulch, using a non-plastic mulch, avoiding growing crops during excessively hot weather, and changing planting configurations to provide more shade on the surface of the bed.

Although the effects of the biological environment on diseases caused by Pythium are poorly understood, Hoitink and Boehm (1999) showed that some *Pythium* species cause severe damage in relatively sterile potting mixes, whereas root rotting is suppressed when the potting mixes are microbially active. Since soils used for capsicum production in Queensland are low in microbial activity (Pung *et al*. 2003), it is therefore possible that losses from *Pythium* root rot could be reduced by improving their microbial status. Reducing tillage and increasing the amount of organic matter returned to soil are management options that should therefore be considered.

Project objectives

The objective of the work described in this report was to find control measures for Pythium root rot of capsicum that were effective against the seedling stage of the disease and also reduced the severity of sudden wilt in mature plants. The research had three main components: 1, Identifying chemical and non-chemical treatments that are effective against the *Pythium* species that cause root rot in tropical and subtropical environments; 2, Minimising the impact of Pythium root rot by reducing soil temperatures and 3, Enhancing biological suppression of *Pythium* by minimising tillage and increasing organic inputs into capsicum-growing soils.

CHAPTER 2. A BIOASSAY TO ASSESS THE POTENTIAL FOR PYTHIUM ROOT ROT IN CAPSICUM-GROWING SOILS

Introduction

Previous work in soils infested with *Pythium aphanidermatum* and *P. myriotylum* showed that these pathogens cause severe root rotting in capsicum at 35ºC but virtually no symptoms at 30ºC (Stirling *et al.* 2004). The fact that inoculum density is not necessarily related to disease severity means that there is little point in estimating levels of Pythium inoculum when predicting whether root rotting will occur in a particular soil, or determining whether an experimental treatment has been effective. This chapter describes a bioassay that can be used to assess the level of Pythium root rot likely to occur in field soil. Its main value is that it accounts for the fact that environment × host × pathogen interactions are important in the etiology of Pythium root rot in tropical and subtropical environments.

~~Methods~~

~~All experiments were done using capsicum seedlings (cv. Target) transplanted into 15 cm high, 6.5 cm diameter watertight pots containing 400 mL of soil. Pots were placed into temperature-controlled waterbaths and the soil was maintained at different temperatures.~~

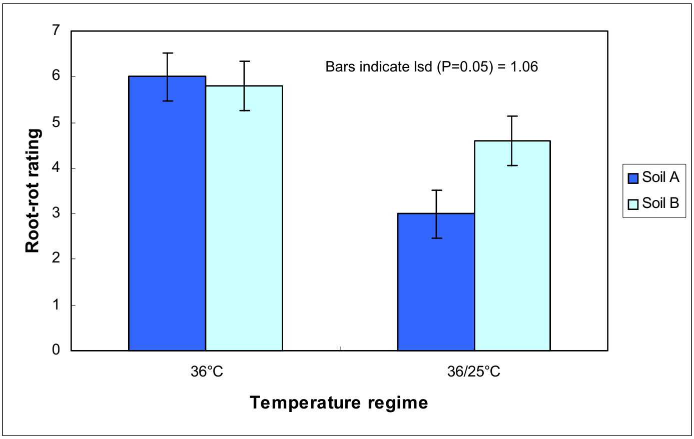
~~*Temperature required to eliminate pathogen activity*~~

~~A clay loam soil from Ayr with a history of vegetable growing was either heated at 50, 55, 60 or 65°C for 35 minutes, autoclaved at 121°C for 20 minutes or left unheated. Three replicate pots were then filled with each soil, 6-week-old capsicum seedlings were planted in the pots and plants were grown for 3 days at a soil temperature of 28°C followed by 10 days at 36°C. Roots were then washed and rated for root rotting using a 1 - 6 scale, where 1 = 0-5%, 2 = 6-24%, 3 = 25-49%, 4 = 50-74%, 5 = 75-99% and 6 = 100% of the roots were rotted. If root lesions were present, tissue was taken from the margin of the lesions and either surfaced sterilised in NaOCl and plated on P + S (potato dextrose agar amended with 0.12 g/L streptomycin) or washed in sterile distilled water and plated on 3P (cornmeal agar amended with 0.05 g/L penicillin; 0.05 g/L polymixin and 0.025 g/L pimaricin, Eckert and Tsao, 1962).~~

~~***Pathogenicity under different soil temperature regimes***~~

~~Roots of plants grown at a constant 36°C were severely rotted in both soils. However, when plants were grown at 36°C for only 8 hours a day, roots were more severely rotted in one soil than the other (Figure 2.3).~~

~~**Figure 2.3:** Effect of two soil temperature regimes, 36°C for 24 hours/day or 36°C for 8 hours/day and 25°C for 16 hours/day, on root rot in capsicum bioassay plants grown in two soils from Bundaberg.~~



Discussion

When capsicum plants were grown in field soil under temperature conditions that stressed the plant, severe root rotting was observed. However, when soil was heated to above 55°C and then bioassayed, symptoms were no longer evident, indicating that the root rotting had a biological cause. Interestingly, heating to 50°C for 35 minutes did not reduce the severity of root rot, indicating that the pathogens involved are relatively resilient to heat.

Pythium species with high optimal growth temperatures appeared to be the primary root rotting pathogens, as they were isolated from capsicum roots in all eight vegetable-growing soils. The soil from which *Pythium* was not recovered had a history of sugarcane rather than vegetables. These results show that *Pythium* is widespread in vegetable-growing soils, and that the fungus can destroy capsicum root systems when environmental conditions are favourable.

This bioassay is useful for assessing the root-rotting potential of soils to be used for capsicum production. However, the use of a constant temperature of 36°C created an environment that favoured the disease and probably overestimated the degree of root rotting that would occur in a field situation. A constant high temperature also meant that it was difficult to separate soils that differed in their root-rotting potential (see Figure 2.2). The severity of root rotting decreased when the temperature was reduced for part of the day, and such a temperature regime probably gives a better indication of what is likely to occur in the field. It is certainly more useful for comparing the root rot potential of different soils (see Figure 2.3).

On the basis of the above results, a high/low temperature regime was used for all the bioassays done later in this report (unless otherwise indicated). Assay soils were either collected from the field, or potting mix was assayed after it was inoculated with *Pythium* or left uninoculated. Capsicum seedlings were planted in 400 mL of soil and seedlings were grown for 3 days at 28°C to allow them to establish without damage from root pathogens. They were then transferred to a day/night soil temperature regime of 36°C for 8 hours followed by 22-25°C for 16 hours. Aboveground temperatures were maintained at 22-28°C throughout the day. After 10 days, the severity of root rot was rated on a 1 to 6 scale where 1 = 0-5%, 2 = 6-24%, 3 = 25-49%, 4 = 50-74%, 5 = 75-99% and 6 = 100% rotted roots.

CHAPTER 3. CONTROL OF PYTHIUM ROOT ROT BY REDUCING SOIL TEMPERATURE

Introduction

In soils that are infested with *Pythium* species that grow well at 35-40ºC, soil temperature has a major effect on the severity of Pythium root rot (Stirling *et al.* 2004). Root systems are largely destroyed by *P. aphanidermatum* and *P. myriotylum* at temperatures above 35ºC, whereas there is little damage at 30ºC. This suggests that reducing soil temperature by as little as a few degrees will have a major effect on disease severity. The following work aimed to verify this by comparing the level of root rot in experiments where soil temperature was altered by changing plastic colour or the type of mulch. An experiment was also done to see whether changing the planting configuration affected soil temperatures in capsicum beds.

~~The effect of mulch colour and mulch type on Pythium root rot (Ayr 2003)~~

~~*Methods*~~

~~In late March 2003, an experiment was established at Ayr Research Station using three different mulches: white plastic, white plastic painted black and a plant-based mulch. The experimental site was initially prepared by laying white plastic on beds with a single irrigation line down the centre. Plots 10 m long were then marked out and the plastic was either left unaltered, painted black (using acrylic low sheen paint) or removed completely. Capsicum seedlings (c.v. Aries) were then planted in double rows on either side of the irrigation line at a spacing of one plant per 27.5 cm of bed. The plant-based mulch was formed by spreading about 2.3 bales of a 1:2:2 mixture of sugarcane trash, grass hay and kenaf stems onto plots from which plastic had been removed. Initially, the mulch was 10-15 cm deep and was laid so that it was not in contact with the seedlings. Later, the mulch subsided to a depth of 5-10 cm. Temperature probes (Tiny Talk®) were placed in the centre of beds and data loggers were used to record hourly temperatures in each treatment at depths of 5 and 15 cm.~~

~~The effects of compost and Superzyme (a commercial biological product supplied by Zadco Pty. Ltd. and purported to contain *Trichoderma*, *Bacillus* and *Pseudomonas* spp.) were also examined in this experiment. Five replicate plots involving +/- compost and +/- Superzyme were therefore included within each mulch treatment, so that the final experimental design was 3 mulch~~

~~**Table 3.3:** Effect of plastic colour and planting pattern on marketable and sunburnt fruit produced by a capsicum crop planted on black and white plastic at Bundaberg in September 2004.~~

~~Plastic colour~~	~~Planting pattern~~	~~Fruit yield (kg/plant)~~			~~Fruit yield (kg/metre of bed)~~		
		~~Marketable~~	~~Sunburnt~~	~~Total~~	~~Marketable~~	~~Sunburnt~~	~~Total~~
~~White~~	~~Single centre row~~	~~1.91~~	~~0.06~~	~~1.97~~	~~8.43~~	~~0.24~~	~~8.67~~
~~Black~~	~~Single centre row~~	~~1.41~~	~~0.18~~	~~1.59~~	~~6.17~~	~~0.80~~	~~6.97~~
~~Black~~	~~Single northern row~~	~~1.25~~	~~0.19~~	~~1.44~~	~~5.43~~	~~0.85~~	~~6.28~~
~~Black~~	~~Double rows~~	~~0.89~~	~~0.11~~	~~1.00~~	~~7.83~~	~~0.99~~	~~8.82~~
~~l.s.d. (P = 0.05)~~		~~0.179~~	~~0.079~~	~~0.198~~	~~1.428~~	~~0.557~~	~~1.199~~

Discussion

Data from the experiment at Ayr in 2003 indicated that in the upper 15 cm of the bed, soil temperatures under black plastic in the first few weeks after planting were 3-7ºC higher than temperatures under the white plastic normally used in the tropical capsicum industry. This increase was high enough to markedly increase seedling mortality due to Pythium root rot, and clearly shows the importance of high soil temperatures in exacerbating this disease. Although black plastic is never likely to be used commercially for capsicums in the tropics, our results demonstrate that relatively small changes in temperature can have a major impact on disease severity in an environment where temperatures under white plastic in summer and early autumn often reach levels that are sub-optimal to capsicum. The results also suggest that even under white plastic, a week or two of extremely hot weather is likely to create environmental conditions that are conducive to Pythium root rot.

Although black plastic had a similar effect on soil temperatures and seedling mortality at Ayr in our trial the following year, *Pythium* was not readily isolated from affected plants. This suggests that at least some of the deaths in this experiment were due to heat stress, and again demonstrates the vulnerability of capsicum seedlings to soil temperatures above about 35ºC.

The plant-based mulch used in the 2003 field trial had the biggest impact on soil temperatures, and this resulted in seedling mortalities that were lower than under white plastic. Manually-laid mulches are never likely to be economically viable in the capsicum industry, but this result suggests that production systems in which seedlings are planted into *in situ* mulch should be further investigated from a soil health and disease minimisation point of view. Initial studies in Bundaberg (see Chapter 4 and Stirling 2005) have already demonstrated that the severity of Pythium root rot can be reduced by planting seedlings into undisturbed beds mulched with forage sorghum. Minimum till and *in situ* mulch cropping systems therefore have potential, but are likely to be most useful for crops planted in summer and early autumn, when temperatures in the tropics and sub-tropics are often sub-optimal for capsicums. Plant-based mulches may be detrimental to later plantings, as soil temperatures may be reduced to levels that affect plant growth.

Although planting position was varied in an experiment at Bundaberg in 2004, Pythium root rot did not occur because the previous crop was sugarcane and the field had been fallowed for 18 months prior to planting capsicum. The likely effect of planting position on the disease was therefore determined by examining the effects of treatments on soil temperature. A single row of capsicums on the northern side of the bed shaded the area where excessive heating often occurs, and from late October this resulted in soil temperatures that were similar to or even lower than those under white plastic. However, a larger area on the southern side of the bed was left unshaded, which meant that there was no net benefit from this approach. The double row of plants on black plastic was more useful, as soil temperatures on both sides of the bed were similar to those under white plastic. Such a planting arrangement is therefore likely to result in the best control of Pythium root rot, particularly if it is used in conjunction with white plastic. Double row planting is used extensively in north Queensland, possibly because growers have inadvertently found that it reduces heat stress and the severity of Pythium root rot. Although many plants in double rows toppled over in our trial, this is overcome in practice by selecting an appropriate variety, or by trellising.

Sudden wilt was not observed in the two years of this study, either in our experiments or in commercial plantings at both Bowen and Bundaberg. It is therefore not possible to conclude with certainty that practices that reduce soil temperature (e.g. shading, white rather than black plastic, plant-based mulches, double row planting) will have an impact on sudden wilt. However, our understanding of the pathogen × environment interactions involved in sudden wilt (Stirling *et al.* 2004) suggests that such practices should reduce disease severity.

CHAPTER 4. ENHANCING BIOLOGICAL SUPPRESSION OF *PYTHIUM* WITH ORGANIC MATTER

Introduction

Advances in modern agriculture, particularly the introduction of synthetic fertilisers and pesticides and the development of disease-resistant varieties, have allowed farmers to break the well-established link between organic matter and soil fertility (Hoitink and Boehm 1999). Crop rotation has largely been abandoned, green manure crops are rarely included in the farming system and by-products such as manures are seen as solid wastes rather than valued resources. As levels of soil organic matter have declined due to mineralisation over time, soil structure has deteriorated and diseases caused by soil-borne pathogens have reached epidemic proportions. This decline in soil health has reached its zenith in the vegetable industry, which is faced with more soil-related problems than any other agricultural industry in Australia. Soils used for vegetable production are almost devoid of microbial activity (Pung *et al.* 2003) and soil is often fumigated to control soil-borne diseases.

One way of reducing losses from soil-borne pathogens such as *Pythium* is to use organic matter to restore the soil's natural mechanisms of biological control. When green manures, animal manures and composts are added to soil, edaphic microorganisms recolonise the soil and help suppress pathogens through mechanisms such as competition, antibiosis, parasitism and predation (Hoitink and Boehm 1999).

One problem with using organic matter amendments to control competitive saprophytes such as *Pythium* is that they sometimes increase disease severity. Fresh organic matter and immature or inadequately-stabilised composts are colonised by the pathogen, and so there is an initial period when populations of *Pythium* in amended soil may increase. Later, when the incorporated organic matter has been colonised by soil microorganisms, the disease is suppressed, even though populations of the pathogen may remain elevated (Hoitink and Boehm 1999).

In the work reported in this chapter, the capacity of *Pythium* to grow saprophytically on various green manures, amendments and composts was confirmed, and experiments were done to see whether such materials could be used to enhance suppressiveness to the pathogen. Since forage sorghum is particularly suited for use as a green manure crop in the tropics and subtropics, it was often used as a source of organic matter.

~~Effect of compost on Pythium root rot (Ayr 2003)~~

~~Methods~~

~~This field trial was established at Ayr in 2003 and consisted of 3 mulch treatments × 2 compost treatments × 2 Superzyme treatments × 5 replicates. Details of the experiment and some of the results were presented previously (Chapter 3), but the effect of compost is covered in this chapter. The compost was prepared by a local grower and was incorporated to a depth of 15 cm prior to planting capsicums. The application rate was 10 t/ha.~~

~~Results~~

~~The main effects of adding compost are presented in Table 4.1. Compost did not affect the survival of plants, but it improved plant growth and root biomass. However, root rotting was more severe in soil amended with compost than it was in non-amended soil.~~

~~**Table 4.1:** Effect of compost on growth, yield and root rotting in an 11-week-old crop of capsicums grown at Ayr from March-June 2003.~~

~~Treatment~~	~~Plant survival (%)~~	~~Plant growth rating~~	~~Weight of fruit (g/plant)~~	~~Root rot rating~~	~~Fresh weight of roots (g/plant)~~
~~Compost~~	~~79.0~~	~~4.5~~	~~960~~	~~1.41~~	~~7.9~~
~~No compost~~	~~78.8~~	~~4.3~~	~~817~~	~~1.26~~	~~6.4~~
~~l.s.d. (P=0.05)~~	~~n.s.~~	~~0.18~~	~~n.s.~~	~~0.118~~	~~0.57~~

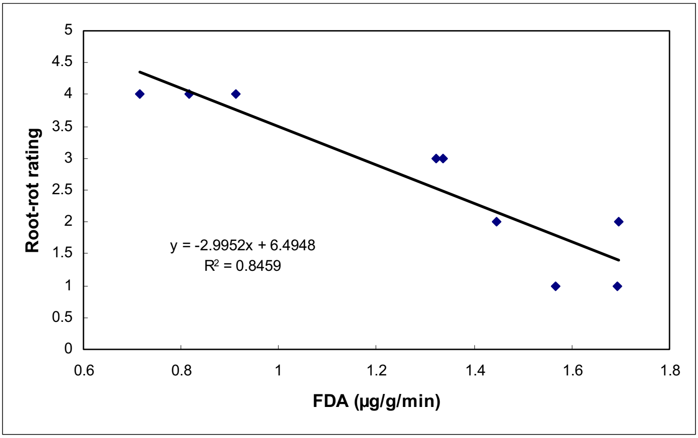
~~Effect of green manured forage sorghum on Pythium root rot (Bundaberg 2003)~~

~~Methods~~

~~Soil samples were collected from a field at Bundaberg in April 2003, soon after a forage sorghum crop had been planted. Further samples were collected in June, immediately after the forage sorghum was incorporated as a green manure, and in July, one month after incorporation. Each~~

~~Addition of either sugarcane trash or lucerne hay increased microbial activity (Table 4.5) and regression analysis showed that root rotting decreased as microbial activity increased (Figure 4.5).~~

~~**Figure 4.5:** Relationship between microbial activity and root rotting in capsicum plants grown for 10 days in amended and non-amended soil.~~



Discussion

Our results indicate that the addition of fresh forage sorghum tissue to soil can exacerbate Pythium root rot (Figure 4.1). One month after fresh plant material was incorporated into soil, the severity of root rotting in bioassay plants was much greater in amended than non-amended soil. Such an effect was not unexpected, as *Pythium* is known to multiply in soils where an appropriate organic source of nutrients is available. For example, when vetch is incorporated into soil as a green manure or free glucose is present in compost-amended potting mixes, populations of *Pythium* increase and root rotting becomes more severe (Watson 1973, cited by Hoitink and Boehm 1999; Chen *et al.* 1988).

Although green manured plant tissue can enhance Pythium root rot, the practice of green manuring is unlikely to cause major problems in the vegetable industry. *Pythium* is unable to multiply once plant tissue has begun to decompose and is therefore colonised by other microorganisms (Hoitink and Boehm 1999), which means that root rot is only likely to be enhanced for a relatively short period after plant tissue is ploughed in. Most vegetable growers incorporate green manure crops at least one month before laying plastic and do not plant until one or two months later, so there is usually ample time for suppressive microorganisms rather than *Pythium* to become dominant. The failure of forage sorghum to stimulate Pythium root rot on bioassay plants or to affect capsicums grown on black plastic in our experiment at Bundaberg in 2004, confirms that in practice, a green manure crop will normally suppress Pythium root rot or have no effect. Disease enhancement is most likely to occur when crops are planted within a few weeks of fresh organic matter being incorporated.

Amendments of sugarcane trash reduced the severity of Pythium root rot in the field (Table 4.2 and Stirling 2005), while our results with non-disturbed soil cores from the field and with amended soils that were incubated for 6 months in pots also demonstrated the potential of using organic amendments to enhance suppression. Root rotting in bioassay plants grown at temperatures capable of exacerbating Pythium root rot was less severe in soil amended previously with compost and sugarcane trash than in non-amended soil (Table 4.3), while similar effects were observed with lucerne hay and sugarcane trash in another experiment (Table 4.5). Since the bioassays in both experiments were done about 6 months after the amendments were first incorporated into soil, these results show that organically-amended soil remains suppressive to *Pythium* for a relatively long period.

Hoitink and Boehm (1999) noted that the rate of hydrolysis of FDA mimics the level of organic matter decomposition and is therefore related to the potential of potting mixes and organically-amended field soils to suppress root pathogens. It is therefore not surprising that suppression in our experiments was related to microbial activity. However, the level of microbial activity in the suppressive treatments (e.g. non-tilled soil amended with compost and sugarcane trash in one experiment and the lucerne hay and sugarcane trash treatments in another experiment) was much higher than is typical for Bundaberg vegetable-growing soils. This suggests that if suppression is to be achieved in the vegetable industry, major changes will be required in the way soils are managed.

Although compost was a component of a treatment that suppressed Pythium root rot in one experiment at Bundaberg, it had no effect when it was used on its own in a field trial at Ayr in 2003. Since the application rate of compost was approximately the same in both experiments, the dissimilar results may have been due to differences in the quality of the composts. The compost used at Ayr was relatively immature, and *Pythium* may have been able to use it as a food source. It is also possible that the biological status of Queensland's capsicum-growing soils is so poor that additional organic matter (e.g. sugarcane trash) may be needed with compost to raise soil microbial activity to the levels required to achieve suppression.

One unexpected result of this work was the finding that minimum tillage was an important component of the suppression achieved with organic amendments. In one experiment, amended soil was not suppressive to Pythium root rot when it was cultivated twice prior to planting, whereas its non-tilled counterpart was suppressive. Tillage is known to be detrimental to many components of the detritus food web (Wardle 1995), and so it is possible that tillage affected some of the organisms responsible for suppressing the pathogen in our experiment. Further work is needed to confirm this, but in the meantime, the role of tillage in exacerbating Pythium root rot should be further investigated.

CHAPTER 5. THE EFFICACY OF CHEMICALS AGAINST PYTHIUM ROOT ROT

Introduction

This chapter reports the results of experiments on the efficacy of three chemicals (metalaxyl, phosphite and silicon) that have the potential to provide some control of Pythium root rot.

Metalaxyl is mainly used to control root rots caused by *Phytophthora*, but it was chosen for use against *Pythium* because *Phytophthora* and *Pythium* are closely related, and because metalaxyl was effective against *Pythium* in several recent studies (e.g. Hoy and Schneider 1988; Hwang *et al.* 2001; Taylor *et al.* 2002). In Australia, granular formulations of metalaxyl can be applied to soil prior to planting vegetable crops, but post-plant treatments with EC formulations are only registered for use on pineapples.

Phosphites are a group of fungicides that act against both *Pythium* and *Phytophthora* by directly inhibiting the pathogen and eliciting a defence response in the host (Guest and Bompeix 1990). Phosphonic (phosphorous) acid is the phosphite most widely used for root rot control in Australia, and *Phytophthora cinnamomi* is the most common target (Pegg *et al.* 1990). Phosphite was examined in this study because it is sometimes effective against *Pythium* (Utkhede and Smith 1991; Walker 1991).

Silicon was investigated because of its suppressive effects on root rots caused by *Pythium ultimum* and *P. aphanidermatum* in hydroponic vegetable production systems (Chérif and Bélanger 1992; Chérif *et al.* 1994b). Its mechanisms of action are not completely understood, but silicon is thought to induce biochemical changes in the plant that initiate a defence response against the invading pathogen (Chérif *et al*. 1994a).

~~**Table 5.8:** Effect of metalaxyl on seedling mortality and yield of a capsicum crop planted at Ayr in March 2004.~~

~~Treatment~~	~~Seedling mortality (%)~~	~~Fruit yield (kg/metre of row)~~
~~No metalaxyl~~	~~21.6~~	~~4.01~~
~~Metalaxyl~~	~~14.1~~	~~4.51~~
~~l.s.d. (P = 0.05)~~	~~6.42~~	~~0.367~~

~~Efficacy of metalaxyl, phosphite and silicon at Bundaberg in 2004~~

~~Methods~~

~~This experiment was done on a grower's property at Bundaberg during the spring of 2004. Black plastic was laid on beds in July and a single row of capsicum seedlings was planted on 24 September 2004. Five chemical treatments were then applied to five replicate plots 12 m long. Metalaxyl (2 kg/treated ha) was applied through the irrigation system 5 or 7 weeks after planting, with Ridomil 250EC™ used at 5 weeks and Metalaxyl 250EC™ used at 7 weeks. SiO_2 (108 kg/treated ha) was applied through the irrigation system (as Kasil 2040™) at 5, 7 and 9 weeks after planting or SiO_2 (1000 µg/mL) was sprayed on foliage 5, 7 and 9 weeks after planting. The fifth treatment was and an untreated control. Phosphite (1 g/L) was applied in a split-plot design to half of each plot by spraying Anti Rot™ (200 g phosphite/L) onto plants at 5, 7 and 9 weeks.~~

~~Results~~

~~Pythium root rot was not observed in this trial and differences in yield due to treatment were not obtained. Metalaxyl applied 5 weeks after planting caused a leaf burn that was apparent for about 4 weeks. However, these leaf symptoms were no longer apparent at 12 weeks and the treatment did not have a detrimental effect on yield. Phytotoxicity was not observed when metalaxyl was applied at 7 weeks.~~

Discussion

The results of our studies in pots and the field indicated that metalaxyl reduced losses from Pythium root rot in capsicum seedlings. Granular or EC formulations applied prior to planting gave satisfactory control for at least four weeks. However, the problem with using pre-plant treatments in the vegetable industry is that they can only be applied at the time beds are prepared, and this often occurs 2-3 months before planting. Since metalaxyl is subject to biological degradation in soil (Droby and Coffey 1991), there is therefore potential for it to lose effectiveness by the time seedlings are planted. Also, efficacy may be lost due to enhanced microbial degradation if it is routinely used for root rot control.

The strategy most likely to work against the seedling stage of the disease is to apply metalaxyl to potting mix just before seedlings are planted, or to drench the chemical around seedlings as they are planted. Our results indicate that both these strategies are effective. Nurseries would have to apply metalaxyl to potting media, but growers could easily apply metalaxyl to transplants by adding it to the water that is drenched around seedlings when they are planted. However, the only metalaxyl formulations currently registered for use on vegetable crops are granules that must be applied to soil as a pre-plant treatment. Registration of an EC formulation that can be drenched onto seedlings before or at planting or applied via the irrigation system soon after planting would provide growers with a range of options for controlling Pythium root rot in vegetable seedlings.

When metalaxyl is applied before or at planting, it is unlikely that its residual activity would be good enough to prevent sudden wilt of capsicum, as the root rotting associated with sudden wilt occurs at the fruit-fill stage, and this is usually 6-10 weeks after planting. We therefore tested an EC formulation that could be added to irrigation water and applied through the trickle irrigation system prior to fruit-fill. Unfortunately, sudden wilt did not occur in our trials and so further work on the effectiveness of this approach will be required. When this work is done, some adjustments to our application rates and application schedule may have to be made, as slight phytotoxicity was observed when metalaxyl was applied to 5 week-old capsicums. Residue data will also have to be collected to confirm that the current 7-day withholding period for pre-plant applications is satisfactory for post-plant treatments.

Our results with phosphite were encouraging, as phosphite reduced root rotting caused by high-temperature *Pythium* species that are widespread on vegetable crops in tropical and subtropical environments. However, the effects of phosphite were relatively subtle, as root rotting was not reduced to the same extent as for metalaxyl. Root health improved when soil was drenched with phosphite, but the chemical had to be applied early so that roots could take it up before they were attacked by the pathogen. Foliar sprays will probably be more practical in the vegetable industry, and our results suggest that they are likely to provide useful control. In pots, for example, a single phosphite spray reduced the number of rotted roots on capsicum seedlings by about a third.

It is not possible to predict from our results whether phosphite will prevent the root rotting that is associated with sudden wilt. However, data from our field experiment at Bundaberg indicate that phosphite is translocated to the roots of mature plants when it is sprayed on foliage, as root phosphite concentrations ranged from 27-33 µg/g, depending on the number of sprays applied. Since previous work with *P. cinnamomi* on avocado has shown that root rotting is reduced at phosphite concentrations of 20-30 µg/g root (Whiley *et al.* 1995), it is possible that phosphite sprays will have a similar effect on *Pythium*, which is closely related to *Phytophthora*. However, it is likely that efficacy will vary, as environmental conditions and the level of root activity affect phosphite concentrations in roots (K. Pegg, pers. comm.). Given the unpredictable nature of sudden wilt and the strong environment × pathogen interactions involved in the disease, it will also be difficult to obtain the data required to confirm that phosphite is a useful control measure.

We obtained evidence from two pot experiments to show that the severity of Pythium root rot is reduced when SiO_2 is drenched around the roots of capsicum seedlings. However, these results should be treated with caution because limited data are available on the effects of silicon on root diseases in the field. One reason for caution is that silicon is relatively mobile in soil, and may be easily leached below the root zone under field conditions. Forms of silicon capable of affecting *Pythium* are also relatively expensive, and so application rates and the number of times that silicon can be applied will be limited by economics.

We conclude that strategic applications of the three chemicals used in this study are likely to be useful against both the seedling and sudden wilt components of the Pythium root rot syndrome. Metalaxyl will probably have the greatest impact, but registration is required for EC formulations that can be applied to seedling trays in the nursery, drenched around seedlings at the time they are transplanted or applied via irrigation water within a few weeks of planting. Phosphite is also likely to be useful, as the chemical is relatively non-toxic and is easy to apply as a foliar spray. When used in this manner on capsicums, phosphite is translocated to the root system at concentrations that should be sufficient to reduce root rotting. Drenches of SiO_2 are also worthy of further investigation, as the chemical is safe to use and initial results show that it reduces the severity of Pythium root rot in pots. Future research should aim to define the application rates and treatment schedule required to achieve satisfactory root rot control with silicon, and confirm that it is economically feasible to apply it to vegetable crops.