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Controlling *Pythium* and Associated Pests in Ginger

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by Mike Smith and Rob Abbas

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Foreword

The project marks the commencement of a research program that will attempt to identify treatments that ginger growers can use to control two serious soil-borne agents that threaten the viability of the ginger industry. *Pythium myriotylum*, responsible for a severe rhizome rot (Pythium Soft Rot), is the more serious of the two, and was first identified by ginger growers in the 2007/08 growing season, with some producers reporting total crop losses in some blocks. The other agent symphylids, are wingless soil inhabiting arthropods which feed on root tips of the ginger plant and impair the plant's ability to absorb nutrients thus seriously restricting plant growth and development. Damage caused by symphylids to ginger roots is also suspected to facilitate entry of *Pythium* into the plant.

The project tested eight chemical treatments that were considered to hold greatest promise in controlling the root rot disease, but none of the treatments were particularly effective.

The study has clearly demonstrated that the pathogen capable of causing Pythium Soft Rot in ginger is spread in contaminated soil and water, which has clear implications for the movement of machinery between blocks and the need for hygiene re machinery, implements and footwear. Likewise surface water draining across fields during heavy rainfall events can spread disease and contaminate water supplies used for irrigation. Furthermore, the study found that infected rhizomes and sections of the rhizome used for planting material (i.e. 'seed') can also spread the disease. Therefore strategies to control the spread of Pythium Soft Rot must rely on containment and strict hygiene to prevent cross contamination between blocks and farms.

This project was cooperatively funded by RIRDC (from core funds), Horticulture Australia Limited, the ginger industry and the Queensland Department of Employment, Economic Development and Innovation (DEEDI).

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New Plant Products R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

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Craig Burns
Managing Director
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Contents

Tables

Executive Summary

What the report is about

This report describes a research project aimed at identifying treatments that ginger growers can use to control two serious soil-borne pathogens that threaten the viability of the ginger industry, *Pythium myriotylum* (responsible for a severe rhizome rot) and symphylids (wingless soil arthropods).

Who is the report is targeted at?

This report is targeted towards the Australian ginger industry and agronomists involved in the industry.

Where are the relevant industries located in Australia?

The industry is concentrated in sub-tropical Queensland around the Sunshine Coast and Bundaberg regions.

The Gross Value of Production of the Australian Ginger Industry averages 8,000 tonnes per annum with a farm gate value of around $16M. The Australian Processing Sector is supplied with 55% of produce while the remainder is supplied to Fresh Markets. Fresh Market Ginger is distributed mainly in Capital City Markets of Brisbane, Newcastle, Sydney, Adelaide and Perth, Ginger for processing occurs mainly at Yandina Sunshine Coast (Buderim Ginger Limited) with three other processors accessing ginger for manufacturing between Brisbane and Bundaberg. The Australian Ginger Industry is concentrated in South-East Queensland between the Sunshine Coast and Bundaberg. There are currently 49 growers who are represented by 37 separate business entities. It is estimated the industry employs 200 full time farmhands with approx 385 casual staff helping out during peak harvesting periods. There are 3 major producers with 100 acres under production, 10 medium producers with approx 10 acres under production with the remainder being smaller producers with 1 to 2 acres under production.

Background

Pythium myriotylum, responsible for a severe rhizome rot (Pythium Soft Rot), is the more serious of the two and was first identified by ginger growers in the 2007/08 growing season, with some producers reporting total crop losses in some blocks. Symphylids are wingless soil inhabiting arthropods which feed on root tips of the ginger plant and impair the plant's ability to absorb nutrients thus seriously restricting plant growth and development. Damage caused by symphylids to ginger roots is also suspected to facilitate entry of *Pythium* into the plant.

Pythium Soft Rot is regarded as one of the most destructive diseases of ginger worldwide and disease epidemics caused by *Pythium myriotylum* were first recorded in Australia during the wet summer of 2007/08. During the 09/10 season it was estimated that of the 3,000 tonne early harvest used for processing, 1500 tonnes was lost due to the effects of Pythium Soft Rot and symphylids. Inability to meet market demand for ginger, both fresh and processed, was a real concern.

The industry regarded the need for research into pathogen control as a critical step to the industry's survival. The 45 members of the Australian Ginger Growers' Association agreed to introduce a voluntary levy system which will generate resources to support continuing research and will contribute substantially towards consolidating the industry. The levy system was formally introduced in April 2011 and will be managed for industry by the Rural Research and Development Corporation.

Aims/objectives

The current project, funded from April 2010 to June 2011, was developed to better understand the threat posed by *Pythium myriotylum* and symphylids to the ginger industry and to identify measures for their control.

Methods used

A number of chemical control strategies were evaluated during the scoping study. Eight agricultural chemicals, known to have some efficacy in controlling *Pythium* in other crops, were used as a seed dipping treatment and compared with carbendazim, the industry standard.

An opportunity was also taken to compare disease incidence and severity between adjoining areas of a field where one had three successive *Pythium*-infected ginger crops, with only a 4-5 month winter cover crop of oats between ginger plantings; and one that had a 16 months oats/weedy fallow/oats rotation between ginger crops.

Results/key findings

The study has clearly demonstrated that the pathogen capable of causing Pythium Soft Rot in ginger is spread in contaminated soil and water, which has clear implications for the movement of machinery between blocks and the need for hygiene re machinery, implements and footwear. Likewise surface water draining across fields during heavy rainfall events can spread disease and contaminate water supplies used for irrigation. Furthermore, the study found that infected rhizomes and sections of the rhizome used for planting material (i.e. ‘seed’) can also spread the disease. Therefore strategies to control the spread of Pythium Soft Rot must rely on containment and strict hygiene to prevent cross contamination between blocks and farms.

In terms of the chemical control strategies evaluated, a metalaxyl/phosphonate treatment and a Proplant® treatment showed the most promise in controlling Pythium Soft Rot in pot trials however they failed to achieve any practical levels of control in the field. Attention was also given to the use of pre-plant applications of metalaxyl and post-plant foliar applications of phosphonate, metalaxyl/mancozeb and strobilurin mixes and all failed to achieve significant levels of control. Likewise granular metalaxyl formulations were ineffective.

Research has clearly demonstrated that *Pythium myriotylum* is spread in soil, water and planting material (sections of rhizome called ‘seed’). Control using agricultural chemicals will prove problematic. For instance, 20% of seed treated with 200 ml/100 L metalaxyl and 500 ml/100 L phosphonate became infected with *Pythium* when inoculated in pot trials, whereas 72% became infected when seed was treated with 200 ml/100 L carbendazim, the industry standard. However when treated seed was planted into an infected field, 82% of the plants from the metalaxyl/phosphonate seed treatment plants showed Pythium Soft Rot, while over 90% of the plants from the carbendazim-treated seed treatment were infected by 14 January 2011. While these results are significantly different they hold little promise as a seed treatment at this stage. Likewise, pre-plant applications of metalaxyl (2 L in 2470 L/ha) and post-plant foliar applications of phosphonate (5 L of Phosic® 400 in 250 L/ha) failed to control *Pythium*. Foliar applications of Zee-Mil® 250 EC (2 L in 250 L/ha) and Amistar® (0.5 L in 250 L/ha), as well as Ridomil® 25G granular (13.5 kg/ha), also failed to achieve any practical levels of control. The use of a fallow and rotation crops that are non-hosts for *Pythium myriotylum* were more promising. A one year break from ginger (oats/ weedy fallow/ oats rotation) gave the most significant control as 25% of the ginger crop was showing signs of infection at early harvest in March 2011, whereas 95% of the non-fallowed ginger (3 consecutive seasons with only oats as a cover crop) were infected with Pythium Soft Rot. Culgoa oats, Pac F8500, Bettagraze, BQ Mulch, Corn H50, Lab and a Grass mix were sown in pots and inoculated with *Pythium*. None of these showed disease symptoms and we failed to isolate *Pythium myriotylum* from the roots.

In contrast to the Pythium Soft Rot studies, several agricultural chemicals (only one of which is currently registered in ginger, i.e., Regent® as a pre-plant soil use permit only) were found to be effective in controlling symphylids on ginger. Symphylid pressure was high in the field chosen to conduct the study and the untreated controls showed damage to root tips and root hairs resulting in low rhizome yield at early harvest. However when Confidor® Guard, Regent® and Talstar® were incorporated into the bed prior to planting, followed by two post-plant applications prior to early harvest, significantly lower levels of root damage were recorded, and consequently, higher yields were achieved compared to the untreated controls. Only the product containing chlorpyrifos failed to control symphylid damage to ginger roots.

An opportunity was taken to compare disease incidence and severity between adjoining areas of a field where one had three successive *Pythium*-infected ginger crops, with only a 4-5 month winter cover crop of oats between ginger plantings; and one that had a 16 months oats/weedy fallow/oats rotation between ginger crops. The incidence of Pythium Soft Rot was significantly lower in the ginger crop that had been fallowed for over a year. Studies with common rotation crops/cultivars used in the ginger industry and including oats, sorghum, corn, lab lab, brassicas and grass mixes, all failed to show disease symptoms in pot trials when inoculated with the pathogen. Furthermore the pathogen could not be isolated from the roots. Therefore the use of crops that are non-hosts for the pathogen responsible for Pythium Soft Rot, in combination with an appropriate fallow period between ginger crops, can be expected to lower disease pressure and increase levels of beneficial soil organisms thereby lowering disease incidence when ginger is again planted.

Implications for relevant stakeholders

These findings have implications in the control of Pythium Soft Rot in ginger. On-farm quarantine measures are needed to keep the disease out, if the farm is currently free from disease, while stringent quarantine and hygiene measures need to be in place to prevent its spread if the farm is currently infected.

The fact that *Pythium myriotylum* is spread in seed that can be used as planting material provides further justification and impetus for the need for a Clean Seed Scheme for the ginger industry.

Clean seed and quarantine are only part of the solution, but absolutely essential for those growers whose farms are disease-free, or for those considering buying or leasing land that has not had a history of ginger production.

Chemical control options have not proven successful, possibly due to the nature of the ginger’s growth during the season. Greater control of the disease can be obtained by paying more careful attention to drainage and increasing water infiltration.

Recommendations

Further work to control Pythium Soft Rot in ginger should be aimed at methods that improve drainage and increase water infiltration into soils and attention needs to be given to organic inputs and rotation practices that influence soil health and suppressiveness to disease. In the longer term, and through better control strategies for pests and diseases of ginger, the goal is to have a reliable domestic supply of ginger for the expanding fresh and processed market.

Introduction

Pythium Soft Rot (also known as Pythium Rhizome Rot) is one of the most destructive diseases of ginger worldwide (Dohroo 2005), with losses of 50–90% sometimes occurring in major production areas. Eleven species of *Pythium* were listed by Dohroo (2005) as causal organisms in different parts of the world, but the species most commonly associated with the disease are *P. myriotylum* and *P. aphanidermatum*. Symptoms may occur at any stage of crop growth, but are most commonly observed when the crop is growing rapidly during summer and autumn. In ginger plants, infection takes place through roots or via the collar region, with the first above ground symptoms being leaf yellowing and the collapse of affected shoots. Below ground, water-soaked lesions appear on the developing rhizome near the base of affected shoots, and under suitable environmental conditions, the rhizome then rots rapidly and is eventually destroyed (Dohroo 2005).

Pythium Rhizome Rot was first recorded in Australia during the wet summer of 2007/08 and the causal organism isolated was identified as *Pythium myriotylum* (Stirling *et al*. 2009). Previous to this the only *Pythium*-induced disease reported in ginger was a seed-piece rot that occurred when seed cut from rhizomes harvested from wet or poorly drained areas was stored under moist conditions (Pegg *et al.* 1974).

Dohroo (2005) noted that wet conditions, high soil water and relatively high soil temperatures were the most important factors influencing the development of rhizome rot in India and these are also important in Australia (Stirling *et al*. 2009). In fact, continuity of wetness may be as important for disease development as total rainfall, as the disease is clearly associated with free water and saturated soils. Under such conditions, zoospores disperse in soil water and spread the disease to adjacent clumps, although observations of greater downhill than uphill movement suggest that mass flow of water is also involved. The disease epidemics associated with *Pythium myriotylum* on ginger are relatively new to Australian ginger growers and therefore little is known of suitable control measures.

Phytophthora is a closely related genus and has two species, *P. cinnamoni* and *P. nicotiana*, affecting pineapple with the former being the more serious pathogen. Virtually all pineapple fields in Australia, except virgin ground, may contain a residual population of 5,000-10,000 chlamydospores which can remain viable for up to six years and these spores can be spread mechanically (on boots, machinery, soil wash, etc.) (Newett *et al.* 2009). Thus under wet or flooded conditions there is a massive germination of chlamydospores releasing mobile zoospores, which are largely responsible for the spread *P. cinnamoni* between roots and plants.

Chemical control strategies for the management of *Phytophthora* in pineapples and identified by Newett *et al.* (2009) include:

- **Fungicide pre-treatment of planting material**. Recent research has reiterated the importance of phosphorous acid (applied as a spray to crowns two weeks before fruit is harvested; crowns being the main form of planting material) in the control of *Phytophthora* in pineapple, and
- **Post-plant use of fungicides**. Metalaxyl in a high volume spray immediately after planting and repeated at 4 to 8 week periods, with at least a 4 week withholding period required prior to harvest.

The ginger industry also shares a similar pest (*Hansiella* (Symphyla: Scutigerellidae)) with the pineapple industry and one that is capable of causing serious damage to roots. The symphyla found in southeast Queensland attacking ginger is, as yet, an unidentified species of *Hansiella*, however Waite (1993) outlined the symptoms caused by *Hansiella unguiculata* on pineapples and described their life history. They occur on over 40% of the pineapple land in Queensland and favour well-aerated volcanic or gravelly soils. Populations are highest in soils that are high in organic matter and have an open structure as these provide food and facilitate their movement as they are unable to dig their own tunnels. They feed on the roots of many plants including many common weeds.

Symphyla management in pineapple was based on pre-plant applications of Lindane where there was a history of symphylid damage to the crop (Broadley *et al.* 1993). However suitable alternatives to Lindane are being evaluated and knowledge of symphylid behaviour can help in their control. For instance, by providing a mulch of decomposing plant material (as a food source) at or close to the surface (which will also keep conditions moist and not too hot) symphylids can be lured close to the surface and then are easily targeted by a pesticide application (Newett *et al.* 2009).

There is an urgent need within the ginger industry to control these two soil-borne agents. For instance in the 2010/2011 ginger growing season it was estimated that approximately 2,000 tonne of a projected 8,000 tonne harvest was lost due to the effects of Pythium Soft Rot and *symphylids*. If the processors are unable to supply the export market for ginger products from domestic producers there is pressure to seek a semi-processed rhizome from overseas producers. There is also expected to be a similar negative impact on ginger grown for the fresh market which in turn drives up prices for consumers.

As a consequence of these pressures the aim of this scoping study was to identify treatments that growers can use to control these two serious soil-borne pathogens that threaten the profitability and sustainability of the Australian ginger industry.

Objectives

This proposal is for an interim one-year project to continue research into the control of these serious soil-borne pathogens, and one that should identify key areas needed for future research.

Serious diseases and pests have emerged that are threatening the viability of the ginger industry. *Pythium myriotylum* is a devastating soil-borne disease of ginger first identified by ginger growers in the 2007/08 growing season (Stirling et al. 2009), with some producers reporting total crop losses in some blocks. Currently processors are not receiving adequate supply of ginger, therefore the disease not only is a threat to individual growers but also to processors that add value to the crop. Collectively the ginger industry is valued at $90 m per annum.

DEEDI have undertaken field trials in Australia and Fiji, funded by the ACIAR, to demonstrate the value of clean planting material and to investigate cultural practices and chemical control strategies to control and limit the spread of soil-borne diseases affecting ginger production.

The ultimate aim is to achieve:

- 50% adoption of practices to control Pythium Soft Rot and symphylids within 2 years after completion of research and dissemination of results
- Increased production of ginger both from existing farms and through take up of new land in the Mary Valley (as above)

Methodology

Pythium Soft Rot

Ginger rhizomes showing disease symptoms were washed thoroughly in water, dipped in ethanol and flamed briefly before tissue from the leading edge of lesions was transferred to media that were selective for *Pythium*. Isolations were done on a medium containing penicillin, polymixin and pimaricin (3P medium of Eckert and Tsao 1962). In addition, soil and water samples were collected from infected farms and the presence of *Pythium* was tested using a lupin seedling bioassay for soil samples and fresh young pineapple crown leaves were used as a 'bait' and immersed for 48 hours in dam water. *Pythium* isolates were identified using methods outlined by Van der Plaats-Niterink (1981). Growth rates at various temperatures were determined on potato carrot agar while sporangia, antheridia, oogonia and oospores were produced by transferring the fungus to autoclaved grass leaves floating in sterile water. The identity of isolates used in pathogenicity tests was also confirmed by sequence analysis of rDNA internal transcribed spacer (ITS) regions containing ITS1 and ITS2 and intervening 5.8 rDNA using the primer pair ITS1/ITS4 (White *et al*. 1990). *Pythium myriotylum* was identified as the causal organism and was cultured on autoclaved sorghum seed and used as an inoculum in pot and field trials at Maroochy Research Station.

Sections of the ginger rhizome used as planting material ('seed') was obtained from a certified 'seed' producer and used for all subsequent trial work. In the first *Pythium* pot experiment, 'seed' was treated by dipping for 5 min in a number of fungicidal products: carbendazim (200 ml/100 L), Ridomil® MZ (3.8 g/L), Maxam® XL (500 ml/100 L), metalaxyl (200 ml/100 L), Phospot® (500 ml/100 L), metalaxyl + Phospot® (at rates described), ProPlant® (30 ml/10 L) and Bordeaux Mix. Carbendazim is currently registered for use as a seed treatment in ginger. This experiment was established in a screen house at Maroochy Research Station on 17 September 2010. When plants had 1 or 2 shoots up to 50 cm long, each pot was inoculated with one *Pythium*-colonised seed. The mean maximum temperature during December and January was over 30°C and overhead sprinklers in the screen house provided a watering regime conducive for *Pythium* infection. After approximately 3 months, plants were assessed for disease severity on a 0-3 scale where 0 = no disease; 1 = some leaf yellowing; 2 = most shoots yellow or dead; 3 = rhizomes rotted and plants dead. Assessments were based on 25-28 plants for each treatment. *Pythium* was confirmed in a random selection of affected rhizomes at the end of the assays.

A second *Pythium* pot experiment was established in a screen house at Maroochy Research Station on 15 October to examine whether common cover crops can act as a host for *Pythium myriotylum*. Seed from the following crops was planted: Culgoa oats, Pac F8500, Bettagraze, BQ Mulch, Corn H50, Lab Lab and Grass Mix. The pots were inoculated with one infected grain of sorghum on 16 November and closely examined for symptoms after 3 months. Attempts were also made to isolate *Pythium* from the roots.

A *Pythium* disease nursery (26°38'S 152°56'E) was established at Maroochy Research Station following a previous project funded by the Australian Centre of International Agricultural Research to examine the effect of organic inputs, tillage and rotation practices on soil health and suppressiveness to soilborne pathogens of ginger (Smith *et al*. 2011). The block was on a sandy clay-loam and overhead irrigation was provided to ensure the soil was saturated to create a situation conducive to disease development. The site was further divided into an area that had three successive *Pythium*-infected ginger crops, with only a 4-5 month winter cover crop of oats between ginger plantings; and an area that had a 16 months oats/weedy fallow/oats rotation between ginger crops. The seed treatments described above were used ± a pre-plant application of metalaxyl (2 L in 2470 L/ha) sprayed on raised beds. The experiment was planted on 16 September 2010 with plots 4 m long and consisted of one bed 1.95 m wide. The experiment also incorporated a ± foliar spray program (5 L of

Phosic® 400 in 250 L/ha) applied at fortnightly intervals. Disease incidence and severity were recorded on 17 December 2010 and again on 14 January 2011.

The second *Pythium* field experiment used a standard, carbendazim 'seed' treatment ± a pre-plant application of metalaxyl (2 L in 2470 L/ha) sprayed on raised beds at Maroochy Research Station. This site was free of *Pythium* and no ginger crops had ever been grown. This experiment was established on 28 September 2010. A number of post-plant fungicide treatments were applied including: Zee-Mil® 250 EC (2 L in 250 L/ha), Ridomil® 25G (13.5 kg/ha), Amistar® (0.5 L in 250 L/ha) and two Phosic® 400 treatments (5 L and 10 L in 250 L/ha) after shoot emergence. The phosphonic acid treatments were applied fortnightly starting on 22 November 2010, while the other treatments were applied monthly. The trial site consisted of plots that were 8 m long with a bed width of 1.95 m. The centre of each plot was inoculated with a teaspoon of *Pythium myriotylum* colonised sorghum on 22 December 2010. The experiment was rated on 21 February 2011.

Symphylids

The experiment was established in a clay-loam soil on a ginger farm at North Arm, Queensland (26°31'S 152°57'E). The field had grown ginger for the previous three years with symphylid damage noted in all years. On 5 October 2010, pre-plant fertiliser (7.6% N, 9.2% P, 14.6% K and 5.8% S) was applied at 200 kg/ha to the whole site and then beds were formed to accommodate five treatments ± woodchip and four replicates in a randomised block design. The treatments included: an untreated control, Lorsban® at 5L/ha pre-plant and 3L/ha post-plant, Confidor® Guard at 3 L/ha pre-plant and 1.5 L/ha post-plant, Regent® at 500ml/ha pre-plant and 250 ml/ha post-plant, and Talstar® at 2 L/ha pre-plant and 500 ml/ha post-plant. Post-plant applications were made on 10 November and again, following a harvest on 19 January. Plots were 6 m long and consisted of one bed 1.95 m wide. Nitrogen (60 kg/ha) was applied as a side dressing through the overhead irrigation system, which was also used to water the crop and prevent sunburn damage. Weeds were controlled with pre-emergent herbicides and by spot spraying with a contact herbicide.

On 10 March 2009, at a time that coincided with Early Harvest in the ginger industry, plants were harvested from a 1m section of bed and fresh weight of rhizome and fresh weight of roots was recorded. The roots were rated for symphylan damage on a 0-5 scale (based on the percentage of the root system showing stunting, branching and witches brooming where 0 = none of the roots damaged and 1, 2, 3, 4 and 5 = 1-24%, 25-49%, 50-74%, 75-99% and 100% of the roots damaged, respectively).

Statistical Analysis

Experiments were assessed using analysis of variance followed by least significant difference test at P=0.01 or 0.05 (ANOVA; GenStat – Sixth Edition © 2002, Lawes Agricultural Trust). Percentage data were transformed via arcsine before analysis.

Results

Pythium Soft Rot

Pythium myriotylum can be spread in soil and water. Three soil samples collected from a commercial farm affected by Pythium Soft Rot had 63%, 87% and 93% of the lupin seedlings succumb to *Pythium* in the bioassay. In addition, soil adhering to machinery moving from the infested block at Maroochy Research Station to the ‘clean’ block, set up for further ginger experiments, resulted in 114 infection points in a block 10 m x 40 m. Of these, 19 infection points spread more than 1 m along the length of the bed with the greatest spread of 7 m. Furthermore, 20% of the ‘baits’ that were placed along the edges of the irrigation dam from the same commercial farm referred to above showed the presence of *Pythium.*

Pythium myriotylum can also be spread in infected planting material. For instance, 56% of discarded seed (sections of the rhizome used as planting material) collected from a commercial farm affected by Pythium Soft Rot failed to germinate, and of those that did, 23% showed symptoms of Pythium Soft Rot. In contrast, 95% of seed collected from a commercial seed-supplier germinated and none showed signs of Pythium Soft Rot.

With regard to the pot trial conducted at Maroochy Research Station, the standard carbendazim seed treatment showed the highest infection levels and the most severe *Pythium* symptoms. On the other hand, the metalaxyl/phosphonic acid mix gave significantly better control of *Pythium* under these regulated pot trial conditions compared to many of the other seed treatments (a synergistic effect noted). Maxam® XL, both at 0.5% and 1.0%, and Proplant® also gave significantly better control than the standard seed treatment.

Table 1. Effect of seed treatments on incidence and severity of Pythium Soft Rot in ginger in a pot trial.

Treatment	% Infection (17 Dec 2010)	% Infection (14 Jan 2011)	Rating (0-3)
Carbendazim	25%	72%	1.50 d
Metalaxyl	11%	40%	0.96 bcd
Phosic	29%	60%	1.29 cd
Met/Phosic	11%	20%	0.37 a
0.5% Maxam	18%	40%	0.62 ab
1% Maxam	18%	40%	0.83 abc
Ridomil	14%	56%	1.00 bcd
Proplant	21%	32%	0.79 abc
Bordx Mix	25%	64%	1.08 bcd

Ratings: 0 = green, healthy shoots; 1 = discolouration and sunken lesions on base of stem; 2 = discolouration of stems and yellowing of leaves; 3 = collapse and necrosis of stems

Table 2. Effect of a one year fallow on severity of Pythium Soft Rot in ginger.

	Fallow	Non-Fallow
Rating 17 Dec 2010	0.34 a	1.66 b
Rating 14 Jan 2011	1.44 a	3.91 b

Letters in row with a different letter are highly significant at P<0.01. Ratings: 0 = 100% of shoots green and healthy, 1 = 1-24% shoots yellow or dead, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of shoots yellow or dead.

Table 3. Effect of pre-plant application of metalaxyl on severity of Pythium Soft Rot in ginger.

	Metalaxyl	Nil
Rating 17 Dec 2010	1.77 ns	1.82 ns
Rating 14 Jan 2011	3.69 ns	3.56 ns

Table 4. Effect of post-plant applications of phosphonic acid on severity of Pythium Soft Rot in ginger.

	Phosphic	Nil
Rating 17 Dec 2010	1.81 ns	1.70 ns
Rating 14 Jan 2011	3.38 ns	3.39 ns

Table 5. Effect of seed treatment on severity of Pythium Soft Rot in ginger.

Treatment	Rating 17 Dec 2010	Rating 14 Jan 2011
Carbendazim	1.71 bc	3.54 bc
Metalaxyl	1.67 bc	3.29 ab
Phosic	2.00 cd	3.58 c
Metalaxyl/Phosic	1.96 bcd	3.31 ab
Maxam XL	1.62 b	3.29 ab
Ridomil MZ	1.79 bcd	3.25 a
Proplant	1.21 a	3.25 a
Bordeaux Mix	2.08 d	3.58 c

Letters in column with a different letter are significant at P<0.05. Ratings: 0 = 100% of shoots green and healthy, 1 = 1-24% shoots yellow or dead, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of shoots yellow or dead.

The one year fallow had a highly significant effect on limiting the severity of Pythium Soft Rot on ginger. The improved biology and good drainage in these sandier soils worked together to produce a crop for early harvest, while the blocks under 3 successive ginger crops experienced total crop failure. Disease pressure from the high inocula load was intense.

Also of interest was the Proplant® seed treatment, and to a lesser extent the Maxam® XL seed treatment, achieved some limited control of Pythium Soft Rot in this field trial, however it was not sufficient as a practical control measure. It does, however, lend some support to the pot trial results above, where Proplant® and Maxam® gave significantly better control of Pythium Soft Rot compared to the standard, carbendazim seed treatment. However the pre-plant treatment with metalaxyl and post-plant foliar applications of phosphonic acid achieved little in the way of *Pythium* control on ginger in this trial.

Symphylids

The symphylid pressure was high enough that the untreated controls showed significantly higher root damage, lower root mass and lower rhizome yield than the treatments where pesticides had been applied. The exception was the Lorsban treatment, which also showed high levels of root damage. The Talstar®, Regent® and Confidor® Guard treatments all gave significantly better control of symphylids compared to untreated controls.

Table 6. Effect of pre- and post-plant applications of pesticides on damage to ginger crop caused by symphylids (18 January 2011).

	Fresh wt Rhizome	**Fresh wt Roots**	**Severity Rating**		**Fresh wt Rhizome**	**Fresh wt Roots**	**Severity Rating**
Nil	1021 b	120.9 c	4.00 c	**+WC**	1038 ns	174.3 a	3.20 ns
Regent	1142 a	170.5 a	3.12 b	**-WC**	1170 ns	124.9 b	3.40 ns
Confidor	1162 a	162.9 ab	3.38 bc				
Lorsban	1107 a	128.6 bc	4.12 c				
Talstar	1089 ab	165.1 ab	1.88 a				

Letters in a column with a different letter are significant at P<0.05. Ratings: 0 = 100% of roots undamaged, 1 = 1-24% of roots damaged, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of roots damaged.

-WC	**Fresh wt Rhizome**	**Fresh wt Roots**	**Severity Rating**	**+WC**	**Fresh wt Rhizome**	**Fresh wt Roots**	**Severity Rating**
Nil	1129 ab	91.5 e	4.00 cd	**Nil**	912 b	150.2 bcd	4.00 cd
Regent	1344 a	158.0 bcd	3.25 bcd	**Regent**	939 b	183.0 abc	3.00 bc
Confidor	1189 ab	136.2 cde	3.25 bcd	**Confidor**	1134 ab	189.5 ab	3.50 cd
Lorsban	1140 ab	122.5 de	4.25 d	**Lorsban**	1074 ab	134.8 cde	4.00 cd
Talstar	1049 ab	116.2 de	2.25 ab	**Talstar**	1131 ab	214.0 a	1.50 a

Letters in columns under a specified heading (e.g. severity rating) with a different letter are significant at P<0.05. Ratings: 0 = 100% of roots undamaged, 1 = 1-24% of roots damaged, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of roots damaged. +WC are sections of bed covered with woodchip; -WC are without woodchip.

Table 7. Effect of pre- and post-plant applications of pesticides on damage to ginger crop caused by symphylids at Early Harvest (10 March 2011).

	Fresh wt Rhizome	Fresh wt Roots	Severity Rating		Fresh wt Rhizome	Fresh wt Roots	Severity Rating
Nil	2426 b	195.7 ns	4.00 ns	**+WC**	2475 ns	278.0 a	3.18 a
Regent	2605 a	229.9 ns	3.43 ns	**-WC**	2851 ns	153.4 b	4.41 b
Confidor	2788 a	197.8 ns	4.13 ns				
Talstar	2849 a	244.9 ns	3.53 ns				

Letters in column with a different letter are significant at P<0.05. Ratings: 0 = 100% of roots undamaged, 1 = 1-24% of roots damaged, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of roots damaged.

-WC	Fresh wt Rhizome	Fresh wt Roots	Severity Rating	**+WC**	Fresh wt Rhizome	Fresh wt Roots	Severity Rating
Nil	2323 b	138.9 c	4.50 cd		2528 ab	252.4 abc	3.50 abc
Regent	2968 ab	156.2 c	4.25 cd		2243 b	303.6 ab	2.60 a
Confidor	2961 ab	148.4 c	4.75 d		2616 ab	247.2 abc	3.50 abc
Talstar	3212 a	172.8 bc	4.05 bcd		2486 ab	316.9 a	3.00 ab

Letters in columns under a specified heading (e.g. severity rating) with a different letter are significant at P<0.05. Ratings: 0 = 100% of roots undamaged, 1 = 1-24% of roots damaged, 2 = 25-49%, 3 = 50-74%, 4 = 75-99%, 5 = 100% of roots damaged. +WC are sections of bed covered with woodchip; -WC are without woodchip.

The sawdust mulch gave a significantly higher fresh weight of roots compared to the other treatments and this is attributed to better recovery of roots from the mulch, whereas more root biomass was left unrecovered in the heavier soils. With regard to severity of symphylid damage and rhizome weight, there was no effect with sawdust mulch in what was a very wet spring/summer.

In terms of rhizome yield, calculated on a t/ha basis, the untreated control gave a significantly lower Early Harvest yield of 36.5 t/ha, whereas the other treatments ranged from 39.2 to 42.8 t/ha.

Implications

Pythium Soft Rot

Pythium myriotylum, the causal pathogen for Pythium Soft Rot in ginger, is spread in soil, water and infected planting material. This supports what is known of the disease in ginger and other vegetatively propagated crops. However it was important to be able to provide specific examples of its mode of transmission for the ginger industry so that its spread can be contained. For instance we have shown that *Pythium myriotylum* can be isolated from the soil from farms that have had the disease in ginger and that it can be spread from a contaminated block to a clean block (at Maroochy Research Station) on soil adhering to tractors and farm machinery. Furthermore we have isolated *Pythium myriotylum* from dam water, thus demonstrating that surface run-off is important in its spread on farms, and irrigation water can be further implicated in its spread. Finally the study has shown conclusively that *Pythium myriotylum* can be spread in infected planting material.

These findings have implications in the control of Pythium Soft Rot in ginger. On-farm quarantine measures are needed to keep the disease out, if the farm is currently free from disease, while stringent quarantine and hygiene measures need to be in place to prevent its spread if the farm is currently infected (see Appendix). The fact that *Pythium myriotylum* is spread in seed that can be used as planting material provides further justification and impetus for the need for a Clean Seed Scheme for the ginger industry. Central to the scheme is a need to start with tissue cultured plants and to ensure very strict standards of quarantine and hygiene as the rhizomes, and hence the seed, is being bulked-up for sale to commercial producers.

Clean seed and quarantine are only part of the solution and absolutely essential for those growers whose farms are disease-free, or for those considering buying or leasing land that has not had a history of ginger production. If a farm has had Pythium Soft Rot, what can be done to control the disease and to rehabilitate the soils?

An examination on the use of agricultural chemicals for Pythium Soft Rot control was a significant component of the scoping study. Although control was obtained with a metalaxyl/phosphonate seed treatment, as well as Proplant® and Maxam® XL, in pot trials; practical field control was not demonstrated. Furthermore pre-plant applications of metalaxyl (2 L in 2470 L/ha) and post-plant foliar applications of phosphonate (5 L of Phosic® 400 in 250 L/ha) failed to control Pythium Soft Rot. Likewise foliar applications of Zee-Mil® (2 L in 250 L/ha) and Amistar® (0.5 L in 250 L/ha), as well as Ridomil® 25G granular (13.5 kg/ha), failed to achieve any practical levels of control.

Chemical control options have not proven successful possibly due to the nature of the ginger's growth during the season. For instance, the plant is continually forming new, immature rhizomes and shoots during the warm, wet summer months when the crop is most susceptible to attack from *Pythium myriotylum* and when the pathogen is most active. The disease abates once the prevailing weather conditions become cooler and/or drier, and when the crop reaches maturity and the rhizome becomes tougher and more fibrous. Control therefore must pay more careful attention to drainage and increasing water infiltration into beds to prevent epidemics associated with sudden release of zoospores and the rapid spread of the pathogen in surface run-off. Evidence for limiting disease spread by improved drainage and water infiltration was seen with trial work at Maroochy Research Station on the sandy-loam soils where the spread was contained to small, localised areas of the bed. The spread of the disease on farms with heavier clays and prone to water-logging, during the same wet-weather event, was appreciable faster and with greater areas of beds affected.

A one year break from ginger (oats/weedy fallow/oats rotation) gave the most significant control and crop was harvested in March 2011, whereas the non-fallowed ginger (3 consecutive seasons with increasing incidence of Pythium Soft Rot disease) led to total crop failure by the end of January 2011; still over a month before harvest of immature rhizomes for factory processing. In addition, the pot trial with a range of cover crops suggests that many of the crops routinely sowed in rotation with ginger are either non-hosts or poor hosts for *Pythium myriotylum*. In order to relieve disease pressure on affected farms, the land should be spelled for as long as possible or at least until we have more information on the viability of the resting oospores in the production region's soils and climate. In the interim, alternative crops or pastures that will not allow the pathogen to multiply need to be grown as an alternative to ginger. In addition, other studies (Smith *et al.* 2011) have shown that soils can be managed to create suppressiveness to the pathogen responsible for Pythium Soft Rot and these practices include the use of organic amendments, stubble retention, and minimum tillage of cover crops. These practices should be encouraged.

Symphylids

In contrast to the chemical control strategies used for *Pythium myriotylum*, the control of symphylids was achieved with either Confidor® Guard at 3 L/ha pre-plant and 1.5 L/ha post-plant, Regent® at 500 ml/ha pre-plant and 250 ml/ha post-plant, and Talstar® at 2 L/ha pre-plant and 500 ml/ha post-plant. Lorsban® applied at 5 L/ha pre-plant and 3 L/ha post-plant, as well as the untreated controls, resulted in significantly more damage to roots and consequently lower yield. Early harvest yield of between 39.2-42.8 t/ha was achieved with the three treatments above, which is regarded as near normal yield in the absence of disease and pest pressure. It was also observed that the Lorsban® treatment and the untreated control had the highest incidence of Pythium Soft Rot, as well as the most damage to the root system caused by the symphylids.

Recommendations

The following are specific recommendation that will be useful in controlling Pythium Soft Rot in ginger and come from findings from this study and from the available literature on the subject:

- **Fallows** should utilize non-host species for *Pythium myriotylum*, such as tropical grasses or biofumigant species. Results from research show that summer fallows/rotations during a time when the disease is particularly aggressive in ginger are advantageous. They should be incorporated early, as should manures, to allow for breakdown. Three months is advisable for fallow crops but pastures should be incorporated 12 months before ginger is planted. Blocks with Pythium Soft Rot should be fallowed for a number of seasons.
- **Field Preparation** involves getting drainage right. Deep ripping, good surface drainage to avoid ponding, bed heights above 200 mm and good levels of organic matter to aid soil structure, allow for aeration and better water infiltration and support of beneficial soil organisms. The use of headlands and cross drains aid field drainage, as well as improving on-farm quarantine measures. Also ensure there is no off-field drainage from infected areas.
- **Soil pH and calcium levels** are critical as *Pythium* thrive in high pH soils and beneficials thrive in acid soils with good calcium levels above 75% of CEC. Maintain good soil calcium levels and pH levels of 5.5-6.0.
- **Clean Seed** free of *Pythium* is critical. Dipping of seed is currently being reviewed as contaminated soil in the dipping tanks may be contributing to the spread of *Pythium* in planting material. At this stage it may be prudent to either not dip seed or to apply fungicides as a non-recirculated spray. Allow seed to dry thoroughly prior to planting.
- **Water management** is important as *Pythium* is spread in water. Don't have runoff to adjacent paddocks, don't over-water early in the season before plants start to use water, use fine jets for cooling, use soil monitoring equipment, locate foot valves in deeper water away from in-flow areas and look at water treatment and silt collection methods. Fine jets are recommended for cooling ginger to prevent sunburn damage and help reduce surface run-off.
- **Practice good farm hygiene.** Note the ginger growers quarantine protocol (see appendix), especially when moving to other blocks and/or farms; consider [yours, other growers, suppliers] movement of vehicles and machinery and whether you may be introducing disease in this way. Try to isolate outbreaks by using headlands, cross drains and mulching methods.

With regard to specific control measures for symphylids:

- Blocks with a history of symphylids should be **fallowed** and treated at the bedding up stage, as well as post-planting stages, **utilising registered products**. Symphylid pressure is currently best controlled using summer fallows, autumn bare fallows and chemical treatments prior to planting. Note that symphylid damage may also create entry sites for *Pythium* infection.
- Ensure a **suitable soil tilth** prior to bedding up to create adequate soil-seed contact. Soils that are too crumbly and open also favour symphylid movement. If tilth is not suitable, roll beds to ensure soil-seed contact as it is critical for seed vigour and germination.

Appendices

Quarantine protocol for ginger farms

1. The growing area is fenced off and signage erected at every entry stating the area is a quarantine area and to keep out. A footbath should be located at entry to every growing area.
2. A delivery/farm interface area must be designated and constructed (preferably on a boundary) and this is as far as any delivery from external sources can go. ANY outside contractor stops at this point.
3. Ideally a concrete slab or hard pad that can be cleaned and sterilised, accessible from the road and the farm area. If mud or dirt has been brought to this area by delivery trucks it can be cleaned and sterilised before any farm machine enters. Water for cleaning this area is essential.
4. Runoff from this interface area should be directed to an area that is not utilised for either irrigation purposes or for growing. Preferably off-farm.
5. Note Ginger equipment sterilisation process
6. The entry point to the farm must be secured with a gate that is locked at all times, even if someone is working on the farm. At this entry point there must be a foot bath and preferably a vehicle sterilising station where vehicles can be high-pressure water blasted and/or sprayed on entry. This area can be made part of the delivery/farm interface for efficiency. Instructions should be signed at this point.
7. Only planting material from certified seed or an inspected farm seed source should be grown.
8. Farm workers MUST go through the sterilising process each time on entry, including vehicles. If farm workers vehicles move from farm to farm, it is advisable not to allow entry at all and pay more attention to the individual’s quarantine protocols.
9. If any contractor (e.g. electrician, concrete truck, etc) needs to enter the farm, this vehicle must go through the washing and spraying protocol before entry and a brief history on his previous farm visits needs to be undertaken. To avoid conflict, much of this can be done on the phone prior to the contractor arriving.
10. No outside fertilizer spreading contractor can be allowed access without extensive water blasting and sterilising protocols. The trucks should be checked for mud and dirt on any bulk delivery of poultry manure and if required cleaned before they enter the delivery/farm interface area.
11. Sawdust deliveries should be treated the same as poultry manure with all trucks checked prior to entry to the delivery/farm interface area. Any Manure/Sawdust/Bulk deliveries should try to be limited to the delivery/interface area.
12. Any farm machinery including new equipment must be sterilised on entry and preferably never leave.
13. All suppliers to the farm should be notified in writing that the farm is a quarantine area and entry is not permitted without authorisation and that appointments must be made preferably off-site if sales people wish to make a presentation.
14. Electricity supply meters should be at the gate before the entry area. If this is not possible, arrangements must be made for the meter reader to be met, sterilised and escorted for meter readings.
15. Any pallets or bins used for harvested product must be recently sterilised plastic or new cardboard. No wooden crates or pallets should enter the farm, but be delivered to the delivery/farm interface area.
16. Harvested product should leave through the delivery/farm interface by a transport contractor who is a party to the quarantine protocols.
17. Strict records must be kept of all movement in and out of the farm. Workers should sign in and out, any sterilising should be noted. Any contractor or delivery entries should be noted, dated and signed off by the authorised person. This should be done at the farm entry point utilising an entry book.

Sterilisation protocol for ginger farms

1. All machinery and vehicles coming onto or leaving the farm or moving between growing areas should be free of soil and crop debris. Sterilisation of equipment is critical in the control of spread of disease. Sterilisation of such things as bins, cutting benches and handling equipment is also required.
2. Care should be taken not to contaminate one vehicle with soil washed off the previous one! It is important that waste water drains to an area that is not utilized for growing or irrigation, preferably off-farm.
3. A range of disinfectant/detergent options have been investigated and the best disinfestation involved a thorough wash down followed by Castrol FarmCleanse® used at a rate of 1:10.
4. Wash down is best done on a hard area using a knapsack or pressure sprayer and allow to dry prior to rinsing off.
5. A foot bath using 1% bleach or 10% FarmCleanse® can be a good thing in the right place. It should be located at farm entry and block entry and placed on a hard area where there is no chance of picking up more dirt after dipping. The best dip is the use of a plastic tray lined with a foam sheet. A foot bath will not work on mud-covered boots!

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Controlling *Pythium* and Associated Pests in Ginger

by Mike Smith and Rob Abbas

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This report describes a research project aimed at identifying treatments that ginger growers can use to control two serious soil-borne pathogens that threaten the viability of the ginger industry, *Pythium myriotylum* (responsible for a severe rhizome rot) and symphylids (wingless soil arthropods).

This report is targeted towards the Australian ginger industry and agronomists involved in the industry.

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