Integrated disease management for new diseases of asparagus

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Integrated management of new asparagus diseases

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This document is the final report for the Australian and New Zealand asparagus growers' funded project "Integrated management of new asparagus diseases", and as such contains the details of all scientific work carried out in this project.

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Media summary

Three new asparagus diseases – asparagus rust, Phomopsis stem blight and asparagus anthracnose – were first detected in Queensland, Australia, in 2000. They are caused by fungal pathogens. These diseases had previously not been recorded on asparagus in either Australia or New Zealand.

Asparagus rust has spread to other states in Australia, including Victoria and New South Wales, but not Western Australia. Rust is most likely to spread widely because of its airborne urediniospores. Phomopsis stem blight and anthracnose could be spread through trade of contaminated asparagus seeds, crowns and spears. The potential importance of asparagus anthracnose outside of northern Australia remains low.

Both asparagus rust and stem blight cause significant crop losses. Growers from both countries have expressed concern about the damaging effects of these diseases and have requested an investigation to determine the extent and severity of infections in asparagus crops in Queensland since the first record of the diseases.

Collaborative research between the Department of Primary Industries and Fisheries, Queensland (DPI&F) and the New Zealand Institute for Crop & Food Research has investigated the spread of these diseases, pathogen identification, fungicide evaluation, resistant varieties, disease management, and postharvest control of the diseases.

The main outcomes of the project were:-

- Asparagus rust was the main disease observed in asparagus crops grown at Mundubbera, but was also present to a lesser degree at Mareeba, Biggenden and Warwick. Asparagus rust was not observed at Beerburrum. Phomopsis stem blight was most prevalent in asparagus crops grown at Warwick and Beerburrum. Asparagus anthracnose was found only in the tropical production area of Mareeba (Northern Queensland).
- *Puccinia asparagi,* a fungal pathogen, was found to cause asparagus rust, *Phomopsis asparagi* caused Phomopsis stem blight and *Colletotrichum gloeosporioides* caused asparagus anthracnose.
- Score® (difenoconazole) and Tilt® (propiconazole) fungicides were found to significantly reduce the incidence of asparagus rust in field trials. Benlate® (benomyl), Bravo® (chlorothalonil), Dithane® (mancozeb), Score® (difenoconazole) and Tilt® (propiconazole) fungicides were not effective against Phomopsis stem blight. Bravo gave consistent reduction in the incidence of Phomopsis stem blight, although this finding was not significant.
- Two varieties, Atlas and YMX 5811, appeared to be slightly more rust tolerant than the commercial standard variety, UC 157, as evidenced by significantly lower in disease incidence, number of lesions per stem and disease severity.
- Disease management studies indicated that none of the soil drenching of fungicides, debris removal or organic amendments reduced the incidence of Phomopsis stem blight.
- Germination of *Phomopsis asparagi* spores was completely inhibited by chlorine, bleach, Nylate®, Tsunami® and Vibrex®. Exposing Phomopsis spores to hot water treatment (48°C for 5 minutes) also significantly retarded germination. Germination of *Colletotrichum gloeosporioides* spores was also

completely inhibited by chlorine, bleach, Nylate® and Vibrex®. The germination of *Puccinia asparagi* urediniospores was significantly inhibited by all of the postharvest disinfectant treatments, with chlorine giving complete inhibition of spore germination.

These results and technologies have been successfully transferred during growers' meetings that were organised in Queensland, Victoria and New Zealand (Appendix A).

Technical summary

Three asparagus diseases, asparagus rust (caused by *Puccinia asparagi*), Phomopsis stem blight (caused by *Phomopsis asparagi*) and asparagus anthracnose (caused by *Colletotrichum gloeosporioides*) were first detected on asparagus in Queensland, Australia, in 2000. Both asparagus rust and stem blight caused significant crop losses. None of these diseases had previously been recorded on asparagus in either Australia or New Zealand.

Asparagus rust has spread to other states in Australia, including Victoria and New South Wales, but not Western Australia. Rust is most likely to spread widely because of its airborne urediniospores. The other two diseases are spread more slowly than rust, but are likely to eventually move to other states in Australia and New Zealand. Phomopsis stem blight and anthracnose could be spread through trade of contaminated asparagus seeds, crowns and spears. The potential importance of asparagus anthracnose outside of tropical growing regions i.e. northern Australia, remains low.

Collaborative research between the Department of Primary Industries and Fisheries, Queensland (DPI&F) and the New Zealand Institute for Crop & Food Research has investigated the spread of these diseases, pathogen identification, fungicide evaluation, resistant varieties, disease management, postharvest control of the diseases.

Field surveys showed that asparagus rust was the main disease observed in asparagus crops grown at Mundubbera, but was also present to a lesser degree at Mareeba, Biggenden and Warwick. Asparagus rust was not observed at Beerburrum. Phomopsis stem blight was most prevalent in asparagus crops grown at Warwick and Beerburrum. Asparagus anthracnose was found only in the tropical production area of Mareeba (Northern Queensland).

Pathogen identification was carried out using microscopic examination of different spore types and isolation of fungi from diseased materials. *Puccinia asparagi* was isolated from diseased asparagus materials showing rust symptoms. *Phomopsis asparagi* was isolated from diseased plants showing Phomopsis stem blight symptoms and *Colletotrichum gloeosporioides* was isolated from diseased plants showing anthracnose symptoms. Culture characteristics and fungal morphology were consistent with those described in CMI Descriptions of fungi and bacteria for these three pathogens.

Fungicide evaluation trials showed that Score® (difenoconazole) and Tilt® (propiconazole) significantly reduced the incidence of asparagus rust in field trials. Benlate® (benomyl), Bravo® (chlorothalonil), Dithane® (mancozeb), Score® (difenoconazole) and Tilt® (propiconazole) fungicides tested were not effective against Phomopsis stem blight. However, Bravo® gave consistent reduction in the incidence of Phomopsis stem blight thought not significant.

Resistant varietal trials indicate that two varieties, Atlas and YMX 5811, appeared to be slightly more rust-tolerant than the commercial standard variety, UC 157, as shown by significantly lower disease incidence, number of lesions per stem and disease severity.

Disease management studies indicated that soil drenching of fungicides, debris removal and organic amendments do not reduce the incidence of Phomopsis stem blight.

Postharvest disinfection using disinfectants showed that germination of *Phomopsis asparagi* spores was completely inhibited by chlorine, bleach, Nylate®, Tsunami® and Vibrex®. Hot water treatment (48°C for 5 minutes) also significantly retarded spore germination. Germination of *C. gloeosporioides* spores was also completely inhibited by chlorine, bleach, Nylate® and Vibrex®. The germination of *Puccinia asparagi* urediniospores was significantly inhibited by all of the postharvest disinfectant treatments, with chlorine giving complete inhibition of spore germination These disinfectants did not affect the quality and appearance of the treated spears.

Introduction

Review of relevant literature

Saccardo (1878) described *Phoma asparagi* Sacc.on *Asparagus officinalis* at Padua, Italy. This fungus was later reclassified as *Phomopsis asparagi* Bubak (1906). Phomopsis stem blight, caused by the fungus, is well known in Europe (Solla 1915) and the Middle East (Engler & Prantl 1900), and is a serious disease throughout asparagus production areas in Asia (Liu Hwang 1988, Xu et al.1996, Tanaka et al. 1987) and SE Asia (Anon. 1961). It was first detected in Australia in 2000 (Davis 2001b) where it was reported to kill plants and cause serious production losses (Cheah et al. 2003).

Phomopsis stem blight is transmitted through plant debris in soil (Kheswalla 1936). The fungus survives on infected stems buried in the soil during ploughing, or in the ground for 3-4 months. On diseased stems at the soil surface, the pathogen survives for more than 6 months.

All commercial asparagus cultivars are susceptible to Phomopsis stem blight (Davis 2002). Fungicide screening has indicated that benomyl, chlorothalonil and difenoconazole have significantly restricted disease development (Davis 2002, Beasley et al. 2004).

Puccinia asparagi D.C., the causal fungus of asparagus rust, was described in 1805 by deCandolle, whose description was later cited by Halsted (1898). In the United States the disease was first reported in New Jersey just before 1896 (Halsted 1898) and since then it had spread to the southern states, notably South Carolina. In 1902, severe outbreaks were reported from asparagus-growing centres in California (Kahn et al. 1952). In Australia, asparagus rust was first detected in south-eastern Queensland in 2000 (Davis 2001a). Since then it has spread south to Victoria and New South Wales.

Severe rust infection may result in premature foliage senescence and reduced carbohydrate storage in the crowns, which may lower yield in the following season (Kahn et al. 1952). This stress exacerbates and accelerates asparagus decline. Both spear weight and number are reduced by rust on susceptible cultivars.

Management of rust requires the integration of resistant cultivars, sanitation practices, and timely application of fungicides (Elmer et al. 1996). Rust caused little or no yield reduction in the partially resistant cultivars Jersey Giant and UC 157 (Johnson & Lunden 1992). Mancozeb was found to be effective in a field trial in Uganda (Ogawal et al. 1999). In Washington, mancozeb is recommended for rust control if more than 1% of the foliage is infected (Elmer et al. 1996).

Colletotrichum gloeosporioides is the causal pathogen of asparagus anthracnose (Davis 2002). Anthracnose has previously been reported as a serious stem disease of asparagus in the Northern Territory of Australia (Davis 2002). This disease is so far restricted to Queensland's tropical production areas (Cheah et al. 2003). Little is known about the epidemiology and control of asparagus anthracnose. No literature has been published on this disease in asparagus elsewhere in the world.

Background to experimental work

During the 2000/01 growing season, three new diseases of asparagus – Phomopsis stem blight, asparagus rust and asparagus anthracnose – were identified in Queensland, Australia (Davis 2001a, b). These diseases have not been recorded on asparagus grown in New Zealand and become a major concern to Australian and New Zealand asparagus growers and industries.

Benomyl fungicide has been found to reduce the incidence of Phomopsis stem blight (Davis 2002) and carbendazim is recommended for the disease control in China (Punithalingam 1990). Mancozeb was found to be effective against rust (Ogawal et al. 1999) and is recommended for rust control in the U.S.A (Elmer et al. 1996). Asparagus varieties UC 157 and Jersey Giant (Johnson & Lunden 1992) and Jersey Centennial (Howard et al. 1994) were reported to be partially resistant to rust

However integrated disease management is the best approach for control of these diseases. This report describes the results of field surveys, pathogen identification, fungicide evaluation, resistant varietal trials, disease management trials and postharvest disinfection treatments, aimed at improving disease control through integrated disease management.

Materials and Methods

1. Crop surveys

Regular field surveys were made on Queensland properties between 2003-2006 to study the spread and epidemiology of Phomopsis stem blight (caused by *Phomopsis asparagi*), asparagus rust (caused by *Puccinia asparagi*) and asparagus anthracnose (caused by *Colletotrichum gloeosporioides*). Surveys were performed on properties located at Mundubbera, Warwick, Mareeba, Beerburrum and Biggenden (Figure 1).

Figure 1 **Map of Queensland showing the location of asparagus production areas; Mundubbera, Warwick, Mareeba, Beerburrum and Biggenden.**

2. Pathogen identification

Field infections of asparagus diseases were diagnosed by one of two methods. If fungal spores or other distinguishing structures were present on infected material, diagnoses were made by observing these structures under hand lenses in the field or under a microscope. If no distinctive features were present on field material, fungal isolations were undertaken by placing pieces of surface sterilised lesion into Streptomycin-amended potato dextrose agar. Once in culture, pathogenic fungi were identified by observing their spores.

3. Fungicide evaluation

In-vitro screening

Isolates of *Phomopsis asparagi* (BRIP 42067) and *Colletotrichum gloeosporioides* (BRIP 39721) were grown on potato dextrose agar (PDA) at 25^{o}C under alternating 12-hour near-UV light. Spores of these fungal isolates were obtained by washing 14- to 21-day-old colonies growing on PDA with sterile distilled water and dislodging the spores with a sterile glass rod. The spores were then filtered through two layers of sterile

gauze, and the resultant spore suspension was adjusted to a concentration of 1×10^6 spores/ml using a haemocytometer.

Since *Puccinia asparagi* is an obligate parasite, requiring living host tissue for growth and reproduction (and therefore unable to be grown in culture), urediniospores were collected from rust-affected asparagus stems and stored temporarily in sealed glass chambers above silica gel prior to experimentation. Urediniospores were subsequently suspended in distilled water and the concentration adjusted as described above.

The spore suspensions were mixed with each of the selected fungicides (at two times the desired final concentration) in a ratio of 5 ml:5 ml. Aliquots (100 µl) of the suspensions were placed on water agar (WA) in Petri dishes using a micropipette and spread evenly with a sterile glass rod. Spore germination was determined after the Petri dishes were incubated for 24 hours at 25°C in darkness.

The fungicides screened against *Phomopsis asparagi*, *Colletotrichum gloeosporioides* and *Puccinia asparagi* were Benlate® (2 g/L benomyl), Spin Flo® (1 ml/L carbendazim), Bravo® (1.5 ml/L chlorothalonil), Kocide® (1 g/L copper hydroxide), Score® (1 ml/L difenoconazole), Rovral® (1 g/L iprodione), Tilt® (1 ml/L propiconazole) and Kumulus® (2 g/L sulphur).

Germination percentage was determined by counting the number of germinated and non-germinated spores in a field of view at ×100 magnification (ca. 30 spores). Five replicate Petri dishes and two samples (i.e. two fields of view) per Petri dish were used. Spores were considered germinated when the germ tube was longer than the diameter of the spore. Germ tube length was measured on 10 randomly selected spores on each of five replicate Petri dishes

The effect of fungicides on mycelial growth of *Phomopsis asparagi* and *Colletotrichum gloeosporioides* was quantified by placing a 5 mm diameter agar disc from a 7-day-old culture at the centre of a 90 mm diameter Petri dish containing fungicide-amended PDA. Inhibition of fungal growth was assessed by measuring the colony diameter (mm) after incubation at 25°C for 7 and 14 days in darkness. Ten replicate Petri dishes were used.

Field evaluation

Phomopsis and rust field trial - 2003/04 season

A field trial to determine the effectiveness of five different fungicides on Phomopsis stem blight (caused by *Phomopsis asparagi*) and asparagus rust (caused by *Puccinia asparagi*) was established near Warwick on summer regrowth of asparagus during January 2004. The field trial was carried out on established 'Grande' asparagus plants, which were approximately 10 years old.

Fungicides screened against *Phomopsis asparagi* and *Puccinia asparagi* were Benlate® (2 g/L benomyl), Bravo® (1.5 ml/L chlorothalonil), Dithane® (2 g/L mancozeb), Score® (1 ml/L difenoconazole) and Tilt® (1 ml/L propiconazole). The fungicides were prepared as per the manufacturers' instructions and applied to asparagus spears once (11 days after emergence only) or twice (11 days and 18 days after emergence). Fungicides were applied using a petrol-driven (Honda 2.5 hp pump) spray tank (Cropland) through an adjustable hollow cone nozzle (20 bar) at a rate of approximately 5 L/plot. For each

treatment the fungicide was sprayed until runoff. Experimental plots were 2 m in length, separated by 2 m of guard plants. Treatments were replicated four times in a randomised complete block design, with guard rows between each block.

Assessment of asparagus stems for Phomopsis stem blight and asparagus rust was performed 4 weeks after the second fungicide application. All stems from within the experimental plots were harvested, transported back to the laboratory and rated for disease. The number of Phomopsis and rust lesions per stem was recorded and the percentage of plants with disease symptoms calculated. The severity of Phomopsis stem blight lesions was also rated subjectively using the following scale: 0 = none; 1 = small lesions (<0.2 cm); 2 = spreading lesions; 3 = large lesions (>1 cm); 4 = pycnidia formation (Sonoda *et al.* 1997).

Phomopsis field trial - 2004/05 season

In the second season, a fungicide trial was established on a second property near Warwick on autumn regrowth of established asparagus (cv. Atlas) plants during March 2005. Fungicide treatments included Spin Flo® (1 ml/L carbendazim), Bravo® (1.5 ml/L chlorothalonil), Rovral® (1 ml/L iprodione) and Tilt® (1 ml/L propiconazole). These four fungicides were prepared as per the manufacturers' instructions and applied to asparagus fern 4 weeks after emergence. Fungicides were applied in the same fashion as the earlier field trial, at a rate of approximately 5 L/experimental plot. Asparagus stems were assessed for Phomopsis stem blight 4 weeks after the initial application of the fungicide treatments. The asparagus fern subsequently received a second application of fungicide, before a final rating was performed after another 4 weeks (8 weeks after the initial application, 12 weeks after emergence).

Rust field trial - 2005/06 season

A fungicide field trial was performed in Wentworth NSW on late summer regrowth of established asparagus (cv. Ida Lea) plants. Fungicide treatments included Barrack® (2.3 L/ha chlorothalonil), Tilt® (600 ml/ha propiconazole), Polyram® (3.5 kg/ha metiram), Folicur® (290 ml/ha), Dithane® (3 kg/ha mancozeb) and water. Fungicides were prepared as per the manufacturers' instructions and initially applied to asparagus fern 3 weeks after spear emergence. Two subsequent applications were made at 6 and 10 weeks after spear emergence. Fungicides were applied at a rate of 2.5 L/experimental plot (2 m in length), using a back pack sprayer.

Asparagus stems were assessed for rust lesions 5 weeks after the last spray application (15 weeks after spear emergence). The number of rust lesions per stem was counted, the percentage of plants expressing symptoms was calculated and disease severity was also subjectively rated using the following scale; 0 = no pustules, 1 = blisters forming, 2 = small discrete pustules, 3 = spreading pustules, 4 = large pustules with concentric rings of urediniospores.

4. Resistant screening for rust

Resistant varietal trial 1 – 2004/05
Resistant varietal trial 2 – 2005/06

Two field plot trials were established concurrently at Applethorpe Research Station (DPI&F, Queensland) in the 2004/05 season and 2005/06 season to determine the level

of tolerance or resistance exhibited by different asparagus varieties to asparagus rust (caused by *Puccinia asparagi*) in comparison to the Queensland commercial standard variety, UC157.

Eight asparagus varieties were screened during the 2004/05 season: Atlas, Grande, Purple Passion, Apollo (California Asparagus Seed & Transplants), Jersey Giant (Jersey Asparagus Farms), YMX 5814, YMX 5811 and YMX 5810 (Yates Seed Company). A further nine (New Zealand) asparagus varieties were screened during the 2005/06 season: Pacific 2000, Pacific Purple, JWC1, 73 × 22, 74 × 22, 3 × Phy 20, 3 × Phy 99, 6 × 178 and 6 × 24.

Experimental field plots were 1 m in length and the plots were spaced 0.5 m apart within each experimental block. Each experimental plot was replicated four times in a randomised complete block design, with guard plots at the ends of each block. Asparagus seedlings were planted at a depth of 15 cm and individual plants were spaced 20 cm apart within the experimental plots (i.e. 10 replicate plants of each variety in each experimental plot).

In both seasons, the asparagus varieties were planted in October and then artificially inoculated with *Puccinia asparagi* spores (collected from rust-affected asparagus stems in Mundubbera) 5 months later in March. Asparagus stems were then assessed for the incidence and severity of rust approximately 8 weeks after inoculation. The number of rust lesions per stem were counted, the percentage of plants expressing symptoms was calculated, and disease severity was also subjectively rated using the following scale; 0 = no pustules, 1 = blisters forming, 2 = small discrete pustules, 3 = spreading pustules, 4 = large pustules with concentric rings of urediniospores.

5. Disease management studies

Effect of pre-emergent soil and asparagus debris drenching treatments on the incidence and severity of Phomopsis stem blight

A field trial to determine the effectiveness of fungicide treatments on the level of *Phomopsis asparagi* inoculum carried over in the soil and on asparagus debris was established in Warwick on spring regrowth of asparagus (cv. UC157) during September 2004. Fungicide treatments included Benlate® (2 g/L benomyl), Bravo® (1.5 ml/L chlorothalonil), Dithane® (2 g/L mancozeb), Kocide® (1 g/L copper hydroxide), Score® (1 ml/L difenoconazole) and Tilt® (1 ml/L propiconazole). These six fungicides were prepared as per the manufacturers' instructions and applied to the surface of the soil and asparagus debris prior to spear emergence. Fungicides were applied using a petrol-driven (Honda 2.5 hp pump) spray tank through an adjustable hollow cone nozzle (20 bar) at a rate of approximately 5 L/experimental plot. The experimental plots were 2 m in length, separated by 2 m of guard plants. Treatments were replicated four times in a randomised complete block design, with guard rows between each block.

Asparagus stems were assessed for Phomopsis stem blight 8 weeks after the application of the fungicide treatments. All stems from within the experimental plots were rated for disease. The number of lesions per stem, the percentage of plants with symptoms of Phomopsis stem blight, and a subjective disease rating (0 = none; 1 = small lesions [<0.2 cm]; 2 = spreading lesions; 3 = large lesions [>1 cm]; 4 = pycnidia formation) were used to assess the severity of Phomopsis for individual stems of each treatment.

Effect of debris removal, mulching and soil amendments on the incidence and severity of Phomopsis stem blight

Two field trials to determine the effectiveness of different mulching treatments, debris removal and soil amendments on Phomopsis stem blight (*Phomopsis asparagi*) were carried out in Warwick. The first field trial was performed on spring regrowth of asparagus (cv. UC157) during September-November 2004. The second field trial was performed on autumn regrowth of asparagus (cv. Atlas) during February-April 2005. The first field site had a high level of Phomopsis infection, whereas the second site had only a low level of Phomopsis infection. The treatments were: asparagus debris and weeds removed, lucerne mulch, sorghum mulch and feedlot manure. The mulch treatments were applied to experimental plots before the emergence of asparagus spears. Experimental plots were 2 m in length, separated by 2 m of guard plants. The treatments were replicated four times in a randomised complete block design, with guard rows between each block.

Asparagus stems were assessed for Phomopsis stem blight 8 weeks after the removal of debris and weeds or the application of mulch/soil amendments. All stems from within the experimental plots were rated for disease. The number of Phomopsis lesions per stem, the percentage of plants with symptoms of Phomopsis stem blight, and a subjective disease rating (0 = none; 1 = small lesions [<0.2 cm]; 2 = spreading lesions; 3 = large lesions [>1 cm]; 4 = pycnidia formation) were used to assess the severity of Phomopsis for individual stems of each treatment.

6. Postharvest disinfection

Effect of postharvest disinfectants on *in-vitro* spore germination of *Phomopsis*, *Colletotrichum* and *Puccinia* and on asparagus spear quality during storage.

Four commercially available disinfectants were prepared as per the manufacturers' instructions (Table 1) and chilled in a refrigerator (ca. 3-4^{o}C) prior to experimentation. Bleach and chlorine were also tested, as well as a hot water treatment.

Table 1: Disinfectants for postharvest treatment of asparagus spears.

Treatment	Active ingredient	Source	Concentration (ppm)
Expel®	chlorine dioxide	Expel NZ Ltd	150
Nylate®	chlorine & bromine	Wobelea	10
Tsunami®	paracetic acid	Ecolab	50-100
Vibrex®	chlorine dioxide	Grayson	30-50
Bleach	sodium hypochlorite	n/a	150
Chlorine	calcium hypochlorite	n/a	150
Hot water dip[A]	-	-	-

[A] The hot water dip treatment involved immersion of asparagus spears in distilled water heated to 48^{o}C for 5 minutes.

Freshly harvested asparagus stems were collected from a farm near Warwick, Queensland, and transported (about 30 minutes) by road to the laboratory at Applethorpe Research Station. Asparagus spears were trimmed to ca. 25 cm in length and immersed in the chilled disinfectants (ca. 3-4^{o}C) for 5 minutes. In the case of the hot water treatment, the asparagus spears were immersed in a hot water bath set at 48^{o}C for 5 minutes, before being transferred to chilled water (ca. 3-4^{o}C) for a further 5 minutes. The control asparagus spears were immersed in chilled water for 5 minutes. Asparagus spears were then air-dried for approximately 10 minutes. There were 15 replicate asparagus spears per treatment.

Part 1 – Effect of postharvest disinfectants on* in-vitro *spore germination

Spores of *Phomopsis asparagi* and *Colletotrichum gloeosporioides* were obtained by washing 14- to 21-day-old colonies growing on PDA with sterile distilled water and dislodging the spores with a sterile glass rod. The spores were filtered through two layers of sterile gauze, and the resultant spore suspension was adjusted to a concentration of 1×10^{6} spores/ml using a haemocytometer. *Puccinia asparagi* urediniospores were collected from rust-affected asparagus stems, suspended in distilled water and the concentration adjusted as described above.

The spore suspensions were then mixed with each of the postharvest disinfectants (at twice the desired final concentration) in a ratio of 5 ml:5 ml. For the hot water treatment, the spore suspension was mixed with sterile distilled water and the McCartney bottle placed in a hot water bath set at 48^{o}C for 5 minutes. Aliquots (100 µl) of the suspensions were placed on water agar (WA) in Petri dishes using a micropipette and spread evenly with a sterile glass rod. Spore germination and germ tube elongation was determined after the Petri dishes were incubated for 24 to 48 hours at 25^{o}C in darkness.

Germination percentage was determined by counting the number of germinated and non-germinated spores in a field of view at ×100 magnification (ca. 30 conidia). Five replicate Petri dishes and two samples (i.e. two fields of view) per Petri dish were used. Spores were considered germinated when the germ tube was longer than the diameter of the spore. Germ tube length was measured on 10 randomly selected spores on each of five replicate Petri dishes.

Part 2 – Effect of postharvest disinfectants on asparagus spear quality

Asparagus spears were numbered with a black permanent marker and weighed before being randomly grouped into polyethylene bags and stored in a cold room at ca. 3-4^{o}C. The asparagus spears were then weighed every second day for 2 weeks and the data subsequently used to chart relative fresh weight (% initial fresh weight) over time and calculate average weight loss (mg/g/day). The quality of the asparagus spears was also rated subjectively every second day using the following scale: 1 = no observable quality loss; 3 = minor wilting; 5 = more pronounced wilting, senescence of bracts; 7 = spears rubbery and unsaleable; 9 = tissue collapse, development of soft rots. Ten replicate asparagus spears were used for each treatment.

Results

1. Crop surveys

No symptoms of asparagus anthracnose were found in asparagus crops grown at Mundubbera, Beerburrum, Biggenden or Warwick. Anthracnose was found only in the tropical production area of Mareeba (Northern Queensland). Phomopsis stem blight was most prevalent in asparagus crops grown at Warwick and Beerburrum. However, *Phomopsis asparagi*, the causal agent of this disease, was isolated from asparagus plants on several properties at Mundubbera. Asparagus rust was the main disease observed in asparagus crops grown at Mundubbera, but was also present to a lesser degree at Mareeba, Biggenden and Warwick. Asparagus rust was not observed at Beerburrum.

Mundubbera

Five properties were regularly surveyed (3-4 times/year) in Mundubbera. Asparagus rust was the most prevalent disease in this production area, the average incidence of asparagus rust was approximately 22%. However, the incidence of asparagus rust was highly variable (Figure 3) between different properties and also within different blocks on the same property, depending upon the age of the fern, plant health, fungicides used and weather conditions at the time of survey. *Phomopsis asparagi* was isolated from green stems on several properties during late 2003 and early 2004, following a particularly cool, wet spring. Since then, *Phomopsis asparagi* has been found on trash present in the inter-row spaces, but not on green stems, indicating that no further significant infection events have occurred. Up until the time of writing no significant production losses caused by Phomopsis infection have occurred in Mundubbera.

Mareeba

Four properties were surveyed in April 2004. All four properties surveyed had low levels of Cercospora leaf spot (caused by *Cercospora asparagii*). This disease causes small brown leaf spots (sometimes with purplish borders) and premature defoliation of asparagus fern. The disease does not appear to be as devastating as Phomopsis or anthracnose but can weaken the plant significantly. Asparagus rust was also found on all four properties at low levels. Anthracnose was only found on one property; the incidence of this disease was approximately 10%. *Phomopsis asparagi* was isolated from asparagus trash from two of the four properties, but no active lesions were found on green stems, and no significant production losses have been recorded from Phomopsis infection.

Warwick

Two properties in Warwick were surveyed several times per year until the asparagus plants were removed in late 2004. The average incidence of Phomopsis stem blight was quite high with approximately half (53%) of all stems being infected. The high level of disease was mainly attributed to the large amount of inoculum present, summer hail storms and prolonged periods of wet weather. Asparagus plants at one property were under extra stress because of sustained over-harvesting for a number of years. Rust was recorded at both properties but only at very low levels (ca. 3%).

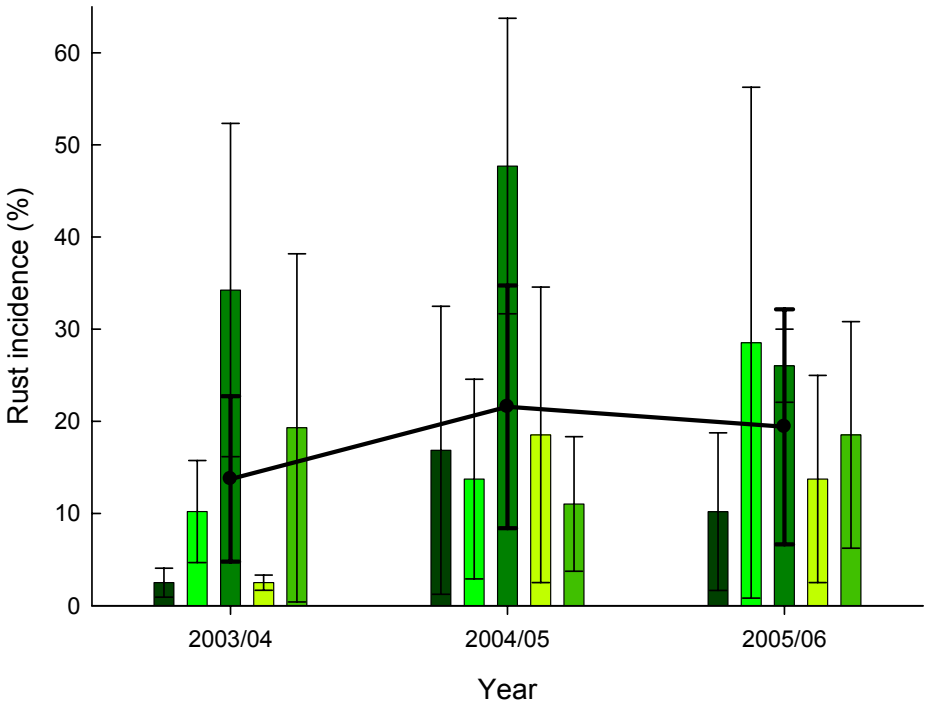

Figure 3 **Average asparagus rust incidence recorded at five different properties in Mundubbera (each property is represented using a different colour) during 2003/04, 2004/05 and 2005/06 seasons.** The bold line shows the average rust incidence for all five properties. Data presented are means ± s.e.

Beerburrum

One property at Beerburrum was surveyed. However, this asparagus crop, like the ones at Warwick, was also removed in 2004. The average incidence of Phomopsis stem blight on this property was approximately 32%. The disease appeared to be exacerbated by a very active and wet summer storm cycle. No asparagus rust was detected at this property.

Biggenden

One property at Biggenden was surveyed from 2004 onwards. The average incidence of asparagus rust on this property was approximately 15%. *Phomopsis asparagi* has been isolated from asparagus trash but so far no symptoms have been observed on green stems, and no production losses recorded.

Drought was a major problem for Queensland growers, and it was observed that asparagus crops with an appropriate fertiliser and irrigation regime showed increased plant growth and less disease symptoms. Crops with irrigation alone also showed better growth and less disease than those without irrigation. Survey findings suggest that an appropriate irrigation and fertiliser regime that promotes plant vigour and health lessens the symptoms of infection by these three diseases. Management of these new diseases requires the integration of resistant cultivars, sanitation practices, fertiliser, irrigation and timely application of fungicides.

2. Pathogen identification

Phomopsis stem blight (caused by *Phomopsis asparagi*)

Field symptoms

The first symptoms are discoloration of asparagus stem tissue, followed by the appearance of water-soaked oval-shaped lesions with light brown centres and slightly darker margins. As the lesions age, erumpent pycnidia begin to appear within the margins of the lesion. Conidia (Figure 4) are fusiform and acute at the apices (about 8 x 2 um) and can be discharged from pycnidia by immersion in water. Cross-sectioning the stem reveals extensive tissue necrosis and it is quite common for Phomopsis-affected stems to snap at the lesion and die (Figure 5). If subsequent re-growth also becomes infected, the plant can quickly use up its stored energy reserves in the corm and yields will be significantly reduced.

Figure 4 ***Phomopsis*** **asparagi spores.**

Figure 5 ***Phomopsis*** **stem blight lesions on asparagus.**

Asparagus rust (caused by *Puccinia asparagi*)

Field symptoms

Symptoms on stem are elongated lesions containing small, orange-red pustules arranged in concentric rings (Figure 6). Close examination reveals the presence of darker, elongated masses urediniospores (Figure 7). Three months later, black telia are evident in the stem pustules (Figure 8).

Figure 6 Asparagus rust lesions on asparagus stems.

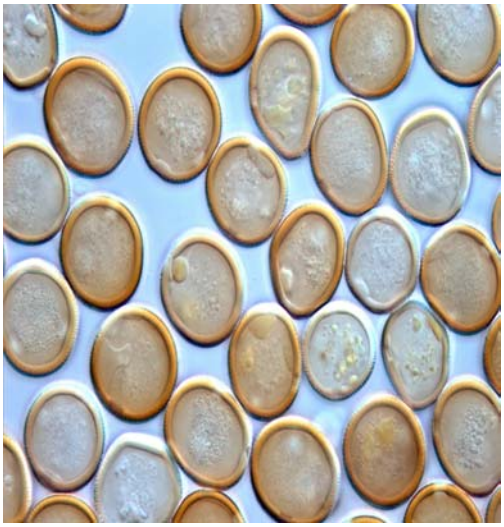

Figure 7 Urediospores of *Puccinia asparagi*.

Figure 8 Teliospores of *Puccinia asparagi.*

Asparagus anthracnose (caused by *Colletotrichum gloeosporioides*)

Field symptoms

Symptoms are brown oval-shaped lesions, which form concentric raised rings as the lesion ages (Figure 10). Orange-pink spores (Figure 11) may also become visible when conditions are favourable (Bright & Condé 1999).

Figure 10 Asparagus anthracnose lesions on asparagus.

Figure 11. Conidia of *Colletotrichum gloeosporioides*.

3. Fungicide evaluation

In-vitro screening

Effect of fungicides on spore germination and germ-tube elongation

All of the fungicides tested significantly retarded the germination and germ tube elongation of *Phomopsis asparagi* spores (Table 2). The three most effective fungicides were Benlate® (benomyl), Bravo® (chlorothalonil) and Kumulus® (sulphur). These three chemicals completely inhibited spore germination and germ tube elongation assessed after 24 hours of incubation. Spin Flo® (carbendazim), Tilt® (propiconazole) and Score® (difenoconozole) were also highly effective against *Phomopsis asparagi* (Table 2).

Table 2: Effect of fungicides on the germination and germ tube elongation of *Phomopsis asparagi* spores incubated for 24 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	5	5
Control	88.56 e[A]	41.8 c
Benlate® (benomyl)	0.00 a	0.0 a
Spin Flo® (carbendazim)	0.80 ab	0.2 a
Bravo® (chlorothalonil)	0.00 a	0.0 a
Kocide® (copper hydroxide)	24.78 d	17.8 b
Score® (difenoconazole)	4.91 b	3.0 a
Rovral® (iprodione)	17.59 c	13.6 b
Tilt® (propiconazole)	4.03 ab	2.4 a
Kumulus® (sulphur)	0.00 a	0.0 a

[A] Means followed by the same letter are not significantly different at P=0.05.

Only five of the eight fungicides tested significantly retarded the germination and germ tube elongation of *Colletotrichum gloeosporioides* spores (Table 3). These fungicides, in order of efficacy, were Bravo® (chlorothalonil), Kumulus® (sulphur), Benlate® (benomyl), Score® (difenoconazole) and Tilt® (propiconazole). Bravo® and Kumulus® both completely inhibited spore germination and germ tube elongation assessed after 24 hours of incubation (Table 3). Spin Flo® (carbendazim), Kocide® (copper hydroxide) and Rovral® (iprodione) were ineffective in retarding the germination of *Colletotrichum gloeosporioides* spores but these three chemicals did reduce germ tube elongation compared with the untreated spores (Table 3).

All of the fungicides tested significantly reduced the germination and germ tube elongation of *Puccinia asparagi* spores (Table 4). The four most effective fungicides were Bravo® (chlorothalonil), Kumulus® (sulphur), Score® (difenoconozole) and Tilt® (propiconazole). Benlate® (benomyl), which was one of the most effective fungicides against both *Phomopsis asparagi* and *Colletotrichum gloeosporioides*, was one of the least effective against *Puccinia asparagi*.

Table 3: Effect of fungicides on the germination and germ tube elongation of *Colletotrichum gloeosporioides* spores incubated for 24 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	5	5
Control	86.94 de[A]	435.4 f
Benlate® (benomyl)	10.97 b	59.0 ab
Spin Flo® (carbendazim)	80.87 d	158.8 cd
Bravo® (chlorothalonil)	0.00 a	0.0 a
Kocide® (copper hydroxide)	83.55 d	268.4 e
Score® (difenoconazole)	17.64 b	93.0 bc
Rovral® (iprodione)	92.60 e	206.6 de
Tilt® (propiconazole)	57.92 c	120.8 bc
Kumulus® (sulphur)	0.00 a	0.0 a

[A] Means followed by the same letter are not significantly different at P=0.05.

Table 4: Effect of fungicides on the germination and germ tube elongation of *Puccinia asparagi* spores incubated for 24 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	5	5
Control	47.22 e[A]	524.6 e
Benlate® (benomyl)	12.86 b	58.0 bc
Spin Flo® (carbendazim)	24.60 d	92.0 d
Bravo® (chlorothalonil)	0.28 a	6.6 a
Kocide® (copper hydroxide)	10.56 b	35.4 ab
Score® (difenoconazole)	4.02 a	21.6 a
Rovral® (iprodione)	18.48 c	80.0 cd
Tilt® (propiconazole)	4.18 a	23.6 a
Kumulus® (sulphur)	2.33 a	9.0 a

[A] Means followed by the same letter are not significantly different at P=0.05.

The colony growth of *Phomopsis asparagi* was significantly reduced by all of the fungicides tested (Table 5). The fungicides Benlate® (benomyl), Spin Flo® (carbendazim) and Tilt® (propiconazole) caused complete inhibition of *Phomopsis asparagi* colony growth, even after 14 days of incubation. Kumulus® (sulphur) was the least effective fungicide, only reducing colony diameter by 4 mm after 14 days incubation (Table 5).

Similarly, the colony growth of *Colletotrichum gloeosporioides* was also significantly reduced by all of the fungicides tested (Table 6). Kocide® (copper hydroxide) and Tilt®

(propiconazole) were the only two fungicides that completely inhibited *Colletotrichum gloeosporioides* colony growth, even after 14 days of incubation (Table 6). Retardation of colony growth was less pronounced than *Phomopsis asparagi* for the majority of fungicides tested.

Table 5: Effect of fungicides on colony growth of *Phomopsis asparagi* incubated for 7 and 14 days on potato dextrose agar.

Treatment	Colony diameter (mm)	
	7 days	14 days
No. of reps. (n)	10	10
Control	46.6 c[A]	84.0 d
Benlate® (benomyl)	5.0 a	5.0 a
Spin Flo® (carbendazim)	5.0 a	5.0 a
Bravo® (chlorothalonil)	5.1 a	6.1 a
Kocide® (copper hydroxide)	5.1 a	8.9 b
Score® (difenoconazole)	5.5 a	6.2 a
Rovral® (iprodione)	5.0 a	5.1 a
Tilt® (propiconazole)	5.0 a	5.0 a
Kumulus® (sulphur)	35.3 b	79.6 c

[A] Means followed by the same letter are not significantly different at P=0.05.

Table 6: Effect of fungicides on colony growth of *Colletotrichum gloeosporioides* incubated for 7 and 14 days on potato dextrose agar.

	Colony diameter (mm)	
Treatment	7 days	14 days
No. of reps. (n)	10	10
Control	66.2 f[A]	84.0 g
Benlate® (benomyl)	8.2 c	18.3 d
Spin Flo® (carbendazim)	7.1 b	11.0 b
Bravo® (chlorothalonil)	10.6 d	21.9 e
Kocide® (copper hydroxide)	5.0 a	5.0 a
Score® (difenoconazole)	5.4 a	15.3 c
Rovral® (iprodione)	5.9 a	17.4 cd
Tilt® (propiconazole)	5.0 a	5.0 a
Kumulus® (sulphur)	62.6 e	69.2 f

[A] Means followed by the same letter are not significantly different at P=0.05.

Field evaluation

Phomopsis and rust field trial - 2003/04 season

Phomopsis stem blight

The incidence of Phomopsis stem blight was quite variable for all of the fungicide treatments (i.e. some plants had numerous lesions while others had none). However, none of the five fungicides tested significantly reduced the incidence of Phomopsis stem blight compared with the untreated control (Table 7). Similarly, there was no significant difference in the number of lesions per stem for any of the fungicide treatments (Table 8). The severity of Phomopsis stem blight on asparagus fern sprayed with different fungicide treatments was also not significantly different (Table 9).

Table 7: Effect of fungicides on the incidence of Phomopsis stem blight (*Phomopsis asparagi*) on asparagus fern sprayed once (11 days after emergence) or twice (11 and 18 days after emergence).

	Incidence (%)		
Treatment	**One spray**	**Two sprays**	**Row means**
Control	26.20	-	26.20 a[A]
Benlate® (benomyl)	29.06	34.59	31.83 a
Bravo® (chlorothalonil)	34.25	20.28	27.27 a
Dithane® (mancozeb)	30.91	28.34	29.63 a
Score® (difenoconazole)	28.25	25.44	26.84 a
Tilt® (propiconazole)	21.03	29.85	25.44 a
Column means	28.28	27.70	

[A] Means followed by the same letter are not significantly different at P=0.05.

Table 8: Effect of fungicides on the number of *Phomopsis asparagi* lesions per stem on asparagus fern sprayed once (11 days after emergence) or twice (11 and 18 days after emergence).

	No. lesions/stem		
Treatment	**One spray**	**Two sprays**	**Row means**
Control	0.91	-	0.91 a[A]
Benlate® (benomyl)	1.45	1.85	1.65 a
Bravo® (chlorothalonil)	1.70	0.75	1.23 a
Dithane® (mancozeb)	1.12	1.55	1.33 a
Score® (difenoconazole)	1.34	1.04	1.19 a
Tilt® (propiconazole)	0.72	1.38	1.05 a
Column means	1.21	1.31	

[A] Means followed by the same letter are not significantly different at P=0.05.

There was no evidence that two fungicide applications (once at 11 days after emergence and again at 18 days after emergence) provided improved control of Phomopsis stem blight (Tables 7, 8, 9). However, there was an interesting trend with regard to the Bravo® (chlorothalonil) treatment. Although not significant, Bravo® gave consistent reductions in the incidence of Phomopsis stem blight, the number of lesions per stem and the subjective disease severity ratings (Tables 7, 8, 9).

Table 9: Effect of fungicides on the severity of Phomopsis stem blight (*Phomopsis asparagi*) rated subjectively on asparagus fern sprayed once (11 days after emergence) or twice (11 and 18 days after emergence).

	Disease severity		
Treatment	**One spray**	**Two sprays**	**Row means**
Control	0.67	-	0.67 a[A]
Benlate® (benomyl)	0.66	0.93	0.80 a
Bravo® (chlorothalonil)	0.81	0.47	0.64 a
Dithane® (mancozeb)	0.69	0.71	0.70 a
Score® (difenoconazole)	0.62	0.64	0.63 a
Tilt® (propiconazole)	0.47	0.64	0.56 a
Column means	0.65	0.68	

[A] Means followed by the same letter are not significantly different at P=0.05.

Asparagus rust

As was the case with the incidence of Phomopsis stem blight in the trial, the incidence of asparagus rust was also highly variable between experimental plots. However, two of the fungicides tested, Score® (difenoconazole) and Tilt® (propiconazole), were both found to significantly reduce the incidence of asparagus rust (Table 10). The data indicates that one application (11 days after emergence) of these fungicides was just as effective as two applications (11 and 18 days after emergence). Unfortunately there was no significant difference in the number of lesions per stem for any of the fungicide treatments, despite a very strong trend for both Score® and Tilt® (Table 11).

Table 10: Effect of fungicides on the incidence of rust (*Puccinia asparagi*) on asparagus fern sprayed once (11 days after emergence) or twice (11 and 18 days after emergence).

	Incidence (%)		
Treatment	**One spray**	**Two sprays**	**Row means**
Control	10.86	-	10.86 b[A]
Benlate® (benomyl)	17.73	13.04	15.39 b
Bravo® (chlorothalonil)	17.52	0.89	9.20 ab
Dithane® (mancozeb)	8.99	24.19	16.59 b
Score® (difenoconazole)	0.00	1.25	0.63 a
Tilt® (propiconazole)	1.87	0.00	0.94 a
Column means	9.49	7.88	

[A] Means followed by the same letter are not significantly different at P=0.05.

Table 11: Effect of fungicides on the number of *Puccinia asparagi* lesions per stem on asparagus fern sprayed once (11 days after emergence) or twice (11 and 18 days after emergence).

	No. lesions/stem		
Treatment	**One spray**	**Two sprays**	**Row means**
Control	0.14	-	0.14 a[A]
Benlate® (benomyl)	0.25	0.18	0.22 a
Bravo® (chlorothalonil)	0.39	0.01	0.20 a
Dithane® (mancozeb)	0.12	1.27	0.70 a
Score® (difenoconazole)	0.00	0.02	0.01 a
Tilt® (propiconazole)	0.04	0.00	0.02 a
Column means	0.16	0.30	

[A] Means followed by the same letter are not significantly different at P=0.05.

Phomopsis field trial - 2004/05 season

The results of the second-season Phomopsis stem blight spray trial were more pronounced (Table 12). While the level of infection was once again quite variable, a significant reduction in the number of *Phomopsis asparagi* lesions per stem was achieved by two applications for all fungicides trialled compared with the untreated control (Table 12). Although not significant, the incidence and severity of Phomopsis stem blight was also greatly reduced by two applications of these fungicides (Table 12).

Table 12: Effect of fungicides on the incidence, severity and number of *Phomopsis asparagi* lesions per stem on asparagus fern sprayed 4 weeks after spear emergence.

Treatment	**Incidence (%)**	**No. lesions/stem**	**Disease severity[A]**
	1st spray – 4 weeks post emergence		
Control	19.33 a[B]	0.35 a	0.67 a
Rovral® (iprodione)	11.69 a	0.31 a	0.43 a
Bravo® (chlorothalonil)	7.74 a	0.12 a	0.23 a
Spin Flo® (carbendazim)	13.13 a	0.46 a	0.34 a
Tilt® (propiconazole)	9.17 a	0.09 a	0.20 a
	2nd spray – 8 weeks post emergence		
Control	18.69 a	0.47 b	0.65 a
Rovral® (iprodione)	6.82 a	0.11 a	0.25 a
Bravo® (chlorothalonil)	3.13 a	0.03 a	0.13 a
Spin Flo® (carbendazim)	7.32 a	0.15 a	0.29 a
Tilt® (propiconazole)	4.17 a	0.04 a	0.17 a

[A] Subjective rating: 0 = none; 1 = small lesions (<0.2 cm); 2 = spreading lesions; 3 = large lesions (>1 cm); 4 = pycnidia formation.

[B] Means followed by the same letter are not significantly different at P=0.05.

Rust field trial - 2005/06 season

No discernable differences were observed between any of the treatments in the rust trial performed in Mildura (Table 13). Interestingly, most of the spores observed during rating were teliospores (black spore stage). In all rust trials performed in Queensland, urediniospores (red spore stage) have been more prevalent. The relative susceptibility of the two spore stages to different fungicides is not known and warrants further investigation.

Table 13: Effect of fungicides on the incidence, severity and number of *Puccinia asparagi* lesions per stem on asparagus fern sprayed 4 weeks and again at 8 weeks after spear emergence.

Treatment	Incidence (%)	No. lesions/stem	Disease severity[A]
Control	76.96 a[B]	4.97 a	2.70 a
Polyram® (metiram)	78.03 a	4.75 a	2.62 a
Tilt® (propiconazole)	76.56 a	8.49 a	2.32 a
Barrack® (chlorothalonil)	84.68 a	9.09 a	2.83 a
Folicur® (tebuconazole)	74.79 a	4.34 a	2.41 a
Dithane® (mancozeb)	73.10 a	5.76 a	2.38 a

[A] Subjective rating: 0 = no pustules, 1 = blisters forming, 2 = small discrete pustules, 3 = spreading pustules, 4 = large pustules with concentric rings of urediniospores.
[B] Means followed by the same letter are not significantly different at P=0.05.

4. Resistant screening for rust

Resistant varietal trial 1 - 2004/05 season

Two varieties, Atlas and YMX 5811, appeared to be slightly more rust-tolerant than the commercial standard variety, UC 157, as evidenced by significantly lower incidence, number of lesions per stem and disease severity (Table 14). Conversely, the variety Purple Passion was highly susceptible to rust, with all stems being affected by the disease and almost three times the number of lesions per stem as UC 157.

Resistant varietal trial 2 - 2005/06 season

There were no significant differences between the nine varieties tested (Table 15). The average level of asparagus rust was noticeably higher than the previous year. One variety, JWC1, performed fractionally better than the commercial standard variety, UC157, but this difference is negligible compared with those achieved in the variety trial carried out in the previous year.

Table 14: Comparison of the incidence of rust (caused by *Puccinia asparagi*), the number of lesions per stem and disease severity (rated subjectively) recorded on nine different asparagus varieties during the 2004/05 season.

Variety	Incidence (%)	No. lesions/stem	Disease severity[A]
UC 157	89.60 c[B]	5.19 b	2.49 c
Apollo	85.91 bc	3.99 ab	1.98 a
Atlas	81.18 ab	3.17 a	2.08 ab
Grande	84.05 bc	3.64 ab	2.11 ab
Jersey Giant	82.62 abc	5.03 ab	2.33 bc
Purple Passion	100.00 d	16.66 c	3.23 b
YMX 5810	83.50 bc	4.29 ab	2.22 abc
YMX 5811	75.81 a	3.24 a	1.93 a
YMX 5814	83.25 abc	4.57 ab	2.21 abc

[A] Subjective rating: 0 = no pustules, 1 = blisters forming, 2 = small discrete pustules, 3 = spreading pustules, 4 = large pustules with concentric rings of urediniospores.
[B] Means followed by the same letter are not significantly different at P=0.05.

Table 15: Comparison of the incidence of rust (*Puccinia asparagi*), the number of lesions per stem and disease severity (rated subjectively) recorded on nine different asparagus varieties during the 2005/06 season.

Variety	Incidence (%)	No. lesions/stem	Disease severity[A]
UC 157	94.35 a[B]	6.73 a	2.44 a
Pacific 2000	98.37 a	6.87 a	2.66 a
Pacific Purple	96.06 a	7.78 a	2.30 a
JWC1	89.50 a	4.32 a	2.18 a
73 x 22	97.61 a	6.41 a	2.64 a
74 x 22	97.46 a	6.12 a	2.56 a
3 x Phy 20	100.00 a	7.00 a	2.65 a
3 x Phy 99	97.09 a	6.17 a	2.57 a
6 x 18	97.61 a	6.45 a	2.79 a
6 x 24	92.70 a	5.30 a	2.47 a

[A] Subjective rating: 0 = no pustules, 1 = blisters forming, 2 = small discrete pustules, 3 = spreading pustules, 4 = large pustules with concentric rings of urediniospores.
[B] Means followed by the same letter are not significantly different at P=0.05.

5. Disease management studies

Effect of pre-emergent soil and asparagus debris drenching treatments on the incidence and severity of Phomopsis stem blight under field conditions

None of the fungicide treatments effectively reduced the level of inoculum in the soil, or that surviving on asparagus debris, to a point where Phomopsis stem blight was significantly reduced (Table 16). Although not significant, Bravo® was the only chemical to reduce the incidence, number of lesions per stem and disease severity compared with the untreated control (Table 16).

Table 16: Effect of pre-emergent fungicide treatments applied directly to the soil and asparagus debris on the incidence, number of lesions per stem and severity of Phomopsis stem blight (*Phomopsis asparagi*) on asparagus.

Treatment	Incidence (%)	No. lesions/stem	Disease severity[A]
Control	73.33 a[B]	2.28 a	1.94 a
Benlate® (benomyl)	79.58 a	2.50 a	2.57 a
Bravo® (chlorothalonil)	69.62 a	1.73 a	1.56 a
Dithane® (mancozeb)	78.21 a	2.55 a	1.89 a
Kocide® (copper hydroxide)	83.89 a	3.67 a	2.56 a
Score® (difenoconazole)	97.50 a	3.47 a	2.68 a
Tilt® (propiconazole)	74.03 a	2.41 a	2.07 a

[A] Subjective rating: 0 = none; 1 = small lesions (<0.2 cm); 2 = spreading lesions; 3 = large lesions (>1 cm); 4 = pycnidia formation.
[B] Means followed by the same letter are not significantly different at P=0.05.

Effect of debris removal, mulching and soil amendments on the incidence and severity of Phomopsis stem blight under field conditions

None of the treatments significantly reduced the incidence or severity of Phomopsis stem blight (Table 17). However, there was an interesting trend in both trials; lucerne mulch and sorghum mulch gave a consistent reduction in the incidence and severity of Phomopsis stem blight at high and low infection levels (Table 17).

Table 17: Effect of debris removal, feed lot manure and mulches on the incidence, number of lesions per stem and severity of Phomopsis stem blight (*Phomopsis asparagi*) on asparagus.

Treatment	Incidence (%)	No. lesions/stem	Disease severity[A]
Farm A – High infection level			
Control	80.45 a[B]	2.60 a	1.68 a
Debris removed	75.87 a	1.90 a	2.52 a
Feed lot manure	79.17 a	3.19 a	2.79 a
Lucerne mulch	43.65 a	0.92 a	1.15 a
Sorghum mulch	47.62 a	1.06 a	1.02 a
Farm B – Low infection level			
Control	10.42 a[B]	0.10 a	0.36 a
Debris removed	6.47 a	0.11 a	0.24 a
Feed lot manure	5.56 a	0.11 a	0.22 a
Lucerne mulch	2.50 a	0.03 a	0.10 a
Sorghum mulch	0.00 a	0.00 a	0.00 a

[A] Subjective rating: 0 = none; 1 = small lesions (<0.2 cm); 2 = spreading lesions; 3 = large lesions (>1 cm); 4 = pycnidia formation.
[B] Means followed by the same letter are not significantly different at P=0.05.

6. Postharvest disinfection

Effect of postharvest disinfectants on *in-vitro* spore germination of *Phomopsis*, *Colletotrichum* and *Puccinia* and on asparagus spear quality during storage.

Part 1 – Effect of postharvest disinfectants on* in-vitro *spore germination

Germination of *Phomopsis asparagi* spores was completely inhibited by chlorine, bleach, Nylate®, Tsunami® and Vibrex® (Table 18). Exposing *Phomopsis* spores to a hot water treatment (48°C for 5 minutes) also significantly retarded germination. All of the aforementioned postharvest disinfectant treatments also significantly retarded germ tube elongation. Expel® was the only postharvest disinfectant treatment that did not retard germ tube length compared with the untreated control (Table 18).

Table 18: Effect of postharvest disinfectants on the *in-vitro* germination (%) and germ tube elongation of *Phomopsis asparagi* spores incubated for 48 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	**5**	**5**
Control	71.54 d[A]	94.4 c
Expel® (chlorine dioxide)	61.83 c	91.0 c
Nylate® (chlorine & bromine)	0.00 a	0.0 a
Tsunami® (paracetic acid)	0.00 a	0.0 a
Vibrex® (chlorine dioxide)	0.00 a	0.0 a
Bleach (sodium hypochlorite)	0.00 a	0.0 a
Chlorine (calcium hypochlorite)	0.00 a	0.0 a
Hot water	8.12 b	25.0 b

[A] Means followed by the same letter are not significantly different at P=0.05.

Germination of *Colletotrichum gloeosporioides* spores was also completely inhibited by chlorine, bleach, Nylate® and Vibrex® (Table 19). The postharvest disinfectant Tsunami® also performed very well, with only several spores germinating following treatment. Hot water treatment of *Colletotrichum* spores was much less effective than hot water treatment of *Phomopsis* spores, although this treatment almost halved germ tube length compared with the untreated control. Expel® did not retard either spore germination or germ tube length compared with the untreated control (Table 19).

Table 19: Effect of postharvest disinfectants on the germination (%) and germ tube elongation of *Colletotrichum gloeosporioides* spores incubated for 24 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	**5**	**5**
Control	95.17 c[A]	341.4 c
Expel® (chlorine dioxide)	93.78 c	335.4 c
Nylate® (chlorine & bromine)	0.00 a	0.0 a
Tsunami® (paracetic acid)	0.71 a	1.0 a
Vibrex® (chlorine dioxide)	0.00 a	0.0 a
Bleach (sodium hypochlorite)	0.00 a	0.0 a
Chlorine (calcium hypochlorite)	0.00 a	0.0 a
Hot water	90.02 b	199.6 b

[A] Means followed by the same letter are not significantly different at P=0.05.

The germination of *Puccinia asparagi* urediniospores was significantly inhibited by all of the postharvest disinfectant treatments, with chlorine giving a complete inhibition (Table 20). However, Expel® and Vibrex® were not as effective as bleach, Nylate®, Tsunami® and a hot water dip at 48°C for 5 minutes. Similarly, germ tube elongation was also significantly retarded by all of the different postharvest treatments (Table 20).

Table 20: Effect of postharvest disinfectants on the germination (%) and germ tube elongation of *Puccinia asparagi* urediniospores incubated for 48 hours at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	**5**	**5**
Control	40.30 c[A]	391.4 c
Expel®	13.01 b	163.2 b
Nylate®	0.63 a	0.2 a
Tsunami®	0.34 a	0.2 a
Vibrex®	4.62 a	48.0 a
Bleach	0.56 a	0.2 a
Chlorine	0.00 a	0.0 a
Hot water	1.84 a	0.4 a

[A] Means followed by the same letter are not significantly different at P=0.05.

At the request of the Australian Asparagus Council, further postharvest disinfestation experiments were performed to determine the efficacy of bleach (sodium hypochlorite) and chlorine (calcium hypochlorite) at the lower concentration of 50 ppm. Exposing *Phomopsis*, *Colletotrichum* and *Puccinia* spores to either 150 ppm or 50 ppm bleach significantly reduced spore germination and germ tube elongation compared with the

untreated control (Table 21). There was also no significant difference between the two bleach concentrations.

The germination and germ tube elongation of *Phomopsis*, *Colletotrichum* and *Puccinia* spores was significantly inhibited by exposure to 150 ppm and 50 ppm chlorine (Table 22). For both *Phomopsis* and *Colletotrichum* spores there was no significant difference between 150 ppm and 50 ppm chlorine. However, 150 ppm chlorine was significantly more effective against *Puccinia* spores, as shown by lower spore germination and germ tube elongation than 50 ppm chlorine (Table 22).

Table 21: Effect of bleach (sodium hypochlorite) at 50 ppm and 150 ppm on the germination (%) and germ tube elongation of *Phomopsis asparagi*, *Colletotrichum gloeosporioides* and *Puccinia asparagi* spores incubated for 24 to 48 hours[A] at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	**5**	**5**
	Phomopsis asparagi	
Control	89.08 a[B]	74.0 a
Bleach - 50 ppm	0.20 b	0.2 b
Bleach - 150 ppm	0.00 b	0.0 b
	Colletotrichum gloeosporioides	
Control	87.78 a	574.4 a
Bleach - 50 ppm	0.83 b	10.6 b
Bleach - 150 ppm	0.00 b	0.0 b
	Puccinia asparagi	
Control	38.17 a	830.4 a
Bleach - 50 ppm	3.30 b	14.2 b
Bleach - 150 ppm	0.70 b	1.4 b

[A] *Colletotrichum gloeosporioides* spores were incubated for 24 hours at 25°C on water agar, *Phomopsis asparagi* and *Puccinia asparagi* spores were incubated for 48 hours at 25°C on water agar.
[B] Means followed by the same letter are not significantly different at P=0.05.

Table 22: Effect of chlorine (calcium hypochlorite) at 50 ppm and 150 ppm on the germination (%) and germ tube elongation of *Phomopsis asparagi*, *Colletotrichum gloeosporioides* and *Puccinia asparagi* spores incubated for 24 to 48 hours[A] at 25°C on water agar.

Treatment	Germination (%)	Germ tube length (μm)
No. of reps. (n)	**5**	**5**
	Phomopsis asparagi	
Control	82.57 a[B]	45.2 a
Chlorine - 50 ppm	0.20 b	0.0 b
Chlorine - 150 ppm	0.00 b	0.0 b
	Colletotrichum gloeosporioides	
Control	97.00 a	360.6 a
Chlorine - 50 ppm	0.15 b	0.8 b
Chlorine - 150 ppm	0.00 b	0.0 b
	Puccinia asparagi	
Control	61.95 a	692.6 a
Chlorine - 50 ppm	10.20 b	232.0 b
Chlorine - 150 ppm	0.95 c	8.8 c

[A] *Colletotrichum gloeosporioides* spores were incubated for 24 hours at 25°C on water agar, *Phomopsis asparagi* and *Puccinia asparagi* spores were incubated for 48 hours at 25°C on water agar.

[B] Means followed by the same letter are not significantly different at P=0.05.

Part 2 – Effect of postharvest disinfectants on asparagus spear quality

None of the postharvest disinfectant treatments tested displayed any adverse effects in terms of asparagus spear weight loss (Table 23). Changes in relative fresh weight (% initial fresh weight) were similar for all treatments (Figure 12). However, a 5-minute hot water dip at 48°C did result in a more rapid decline in spear quality (Table 23). Wilting and senescence of bracts was more pronounced in the heat-treated spears than in those exposed to the various postharvest disinfectants (Figure 12).

Table 23: Effect of postharvest disinfectants on asparagus weight loss (mg/g/day) and spear quality after 14 days of storage at 4°C.

Treatment	Weight loss (mg/g/day)	Quality after 14 days (subjective rating)[A]
No. of reps. (n)	**10**	**10**
Control	6.04 a[B]	2.6 bc
Expel® (chlorine dioxide)	5.98 a	3.2 b
Nylate® (chlorine & bromine)	5.67 a	1.6 c
Tsunami® (paracetic acid)	4.90 a	2.2 bc
Vibrex® (chlorine dioxide)	5.39 a	2.4 bc
Bleach (sodium hypochlorite)	5.01 a	1.8 c
Chlorine (calcium hypochlorite)	5.30 a	2.0 bc
Hot water	6.31 a	5.8 a

[A] Subjective rating: 1 = no observable quality loss; 3 = minor wilting; 5 = more pronounced wilting, senescence of bracts; 7 = spears rubbery and unsaleable; 9 = tissue collapse, development of soft rots.
[B] Means followed by the same letter are not significantly different at P=0.05.

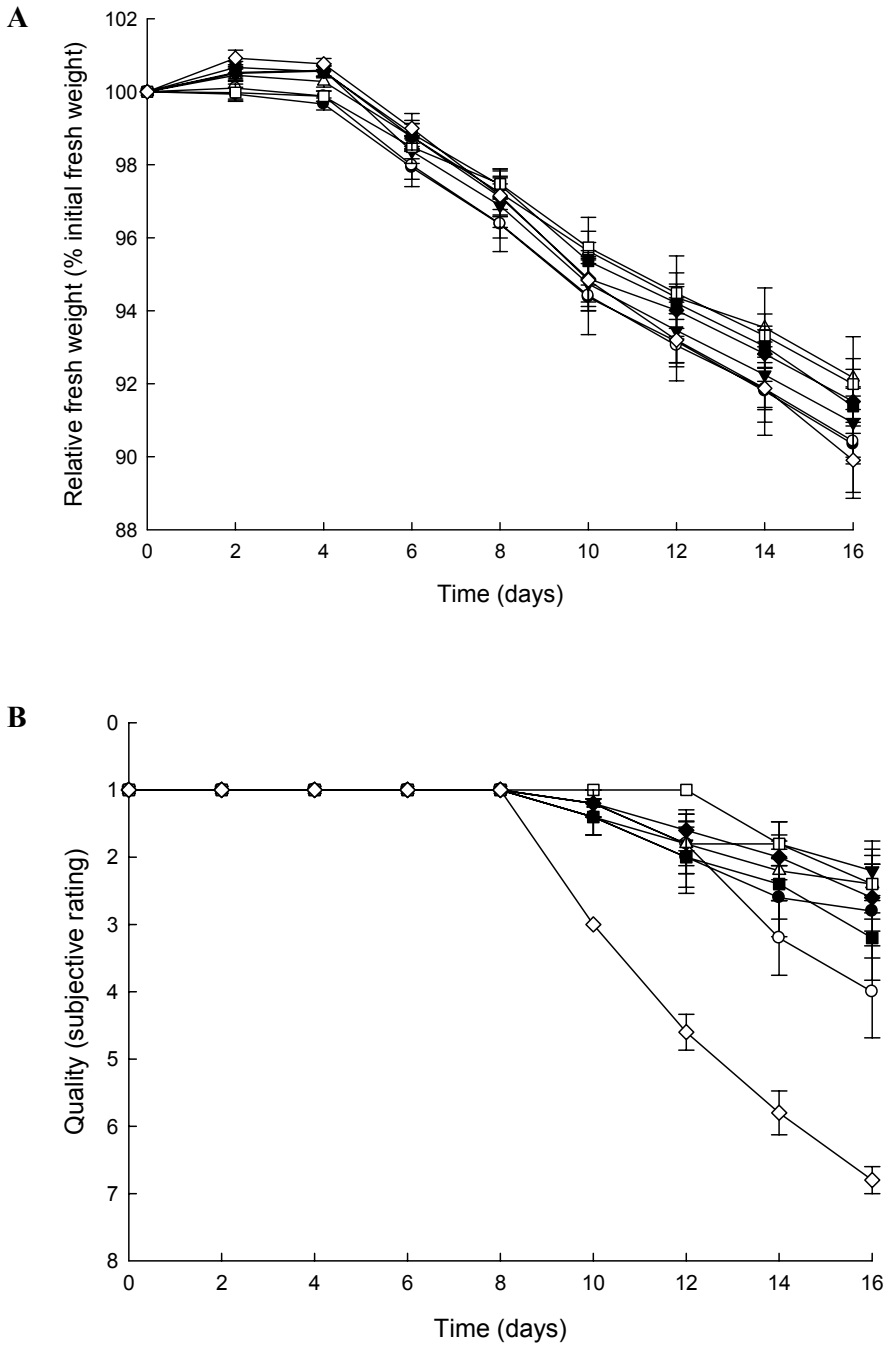

Figure 12 Changes in relative fresh weight (% initial fresh weight) (A) and quality (rated subjectively) (B) during postharvest storage at 4°C for untreated asparagus spears (○) and those treated with the following postharvest disinfectants; Expel® (●); Nylate® (▼); Tsunami® (△); Vibrex® (■); bleach (□); chlorine (◆); and hot water (◇). Data presented are means ± s.e. (n=10).

Discussion

Our survey showed that since asparagus rust was first found on a single property in south Queensland (Davis 2001a), it has spread to northern Queensland and Victoria (Cheah et al. 2005). Clearly, property quarantine measures and crop destruction have failed to contain the pathogen. Urediniospores of *Puccinia asparagi* are airborne and can travel long distances with the wind. Several rust pathogens have arrived in New Zealand from Australia, probably by natural wind dispersal of spores (McKenzie 1998). CLIMEX "Match Climates" simulations have shown that climates in locations where asparagus rust is already present are similar to New Zealand climates (Viljanen-Rollinson et al. 2006). Asparagus rust is likely to spread to New Zealand in the next few years (New Zealand Asparagus Council 2001). One strategy to minimise the impact of rust is for growers to monitor their asparagus crops carefully so that early detection of the disease is possible and early control measures can be taken.

Phomopsis stem blight is currently more restricted in Queensland than rust. The pathogen survives on infected stems buried in the soil during ploughing for about 3-4 months and transmission of the disease is much slower than urediniospores (Kheswalla 1936). Neither Phomopsis stem blight nor anthracnose has been found in other regions of Australia. Drought has been a major problem during the summer of 2002 to 2005. Our field survey suggested that crops with both appropriate fertiliser and irrigation regimes had increased plant growth and less disease. Crops with irrigation alone also tended to be healthier (greener) and have less disease than those without irrigation.

Field symptoms of these three fungal diseases and characteristics of these spores are consistent with those described in the literature for asparagus rust, Phomopsis stem blight and asparagus anthracnose. Cultures that grew from the spores were also consistent with those described in CMI Descriptions for *Puccinia asparagi* (Waterston 1965), *Phomopsis asparagi* (Punithalingam 1990) and *Colletotrichum gloeosporioides.* Pathogenicity of these pathogens has been proven in separate glasshouse fungicide screenings, which are not reported here.

Our field trial results have shown that difenoconazole and propiconazole fungicides reduced rust incidence but did not control Phomopsis stem blight. Mancozeb was found to be effective for controlling rust (Ogawal et al 1999) and is recommended for rust control in Washington State, USA (Elmer et al. 1996), and carbendazim is recommended for Phomopsis stem blight control (Punithalingam, 1990), but they were not effective against these diseases in the present trials. The lack of control of Phomopsis stem blight with fungicides may be due to the application technique used, rather than the inability of the fungicides to stop fungal growth (Horlock et al. 2005). The rapid growth of spears does not allow plant tissues to remain effectively covered by protectant fungicides. During our field surveys we observed that those growers who applied difenoconazole and propiconazole on their crops had reduced incidence of asparagus rust or Phomopsis stem blight (Horlock et al. 2005). It was also noticed that cultural practices such as early detection of disease on crops will help growers to take early action and apply effective fungicides before the disease spreads further (Cheah et al. 2005).

Asparagus varieties UC 157 and Jersey Giant were reported to be partially resistant cultivars (Johnson & Lunden 1992) and Jersey Centennial was tolerant to rust (Howard et al. 1994). Our resistant variety trial results indicated that two varieties, Atlas and YMX 5811, appeared to be more rust-tolerant than UC 157 and Jersey Giant. However

further trals should continue to find resistant/tolerant varieties for rust and Phomopsis stem blight.

Disease management studies showed that pre-emergent soil drenching of fungicides and removal of infected debris did not significantly reduce the incidence or severity of Phomopsis stem blight, indicating that the epidemiology of *Phomopsis asparagi* is not fully understood. However, growers have found one of the most effective management methods for these diseases is to reduce sources of inoculum (Cheah et al. 2005), particularly by removal of infected crop residues (Howard et al. 1994).

Postharvest disinfection tests showed that several disinfectants were highly effective in killing pathogen spores, but bleach or chlorine at 150 ppm did not give complete kill of *Puccinia asparagi* spores. At present, chlorine at 100 ppm is recommended in Australia for dipping of asparagus spears before they can be transported to other states. Based on these results, we recommend that spears should be dipped in 150 ppm of bleach or chlorine for better spore kill.

In New Zealand difenoconazole is already registered for control of Stemphylium spot on asparagus. The results from this paper indicate that difenoconazole and propiconazole fungicides and effective postharvest disinfectants (such as chlorine) could be used together for control of asparagus rust and Phomopsis stem blight. It is hoped that integrated disease management using early detection of disease outbreaks, appropriate fungicide applications to crops, and treatment of spears transported from affected areas, will provide a basis for management of asparagus rust and Phomopsis stem blight on asparagus, should they be spread to New Zealand.

Recommendations

(Note: A number of the recommendations are based on anecdotal evidence collected during the project and throughout the authors' research career. Growers may like to consult their local consultants or researchers for advise before adopting any management strategies).

Scientific

More basic research is needed into these diseases; for example into how rust has spread from Queensland to Victoria and why fungicides used against Phomopsis stem blight did not perform as well as suggested by the literature.

- Field surveys should continue to monitor the spread of these diseases, especially rust and Phomopsis stem blight. Cercospora leaf spot, caused by *Cercospora asparagi*, should also be monitored.
- Epidemiological studies should be made of these diseases in order to understand the mode of spores survival, disease spread and conditions condusived to infection on asparagus plants, to assist in effective fungicidal control.
- Methods of fungicide application should be carefully investigated to find the best application time and growth stage for effective control.
- Score® (difenoconazole) and Tilt® (propiconazole) are effective for rust control. These are triazole chemicals and likely to lose their effectiveness with overuse. It is recommended that no more than two applications of these fungicides are made in a crop per season.
- Resistant varietal trials should be continued to find resistant/tolerant varieties for asparagus rust and Phomopsis stem blight.
- There is evidence of resistance to rust in new Yates varieties (YMX). It should be possible to identify the genes using molecular techniques and to transfer the resistant genes to commercial varieties for production.
- Postharvest disinfection is recommended using bleach or chlorine at 150 ppm for all spears being sent to disease-free areas..
- Integrated disease management using cultural practices, resistant varieties and chemical management should be practiced for effective control of asparagus rust, Phomopsis stem blight and anthracnose.

Industry

Recommendations for Australian growers

Australian growers with asparagus crops affected by anthracnose, Phomopsis stem blight or asparagus rust should seriously consider incorporating the following cultural and chemical management methods.

Cultural management

Maintain crop health

We observed that crops that had an appropriate fertiliser and irrigation regime had increased plant growth and less disease within the same property. Even with irrigation (at plant base) alone, plants tended to be healthier (greener) and to show better growth and less disease than those without irrigation. We suggest that applying an appropriate

irrigation and fertiliser regime to promote plant growth and increase plant health is likely to minimise infection.

Early disease detection
We observed that early detection of diseases on the crops and applying control measures during the early stage of infection will also minimise the spread of the diseases within crops.

Reducing inoculum
Growers should attempt to keep the inoculum levels in their crops as low as possible. Practices to consider include:

- Remove volunteers as much as possible, especially in neighbouring fields that are not planted to asparagus.
- At the end of the crop cycle, make sure that all of the diseased trash is either broken down or removed prior to the growth of new fern. This is especially important over winter, as it will provide a "fresh start" to the new season.
- Consider an autumn harvest. As rust is most prevalent in late summer and early autumn, cutting down the fern during this period will remove the amount of susceptible material and reduce the level of infection.

Reducing humidity
Fungal pathogens prefer high levels of humidity for their growth, so keeping humidity as low as possible will reduce the pathogens' ability to infect and multiply. These practices include:

- Wider row spacings for new plantings.
- Plant new rows so the prevailing winds blow along the rows.
- Do not overhead-irrigate fern but use trickle irrigation at the plant base. If you must use overhead irrigation, time the irrigation so that the fern is wet for the least amount of time, i.e. do not water last thing in the afternoon so that the fern is wet all night.

Chemical management
Chemical management, i.e. the application of fungicides, is likely to be most effective for the management of rust. To this end a permit (PER 8074, Appendix B) has been sought for the use of Score® (difenoconazole), Tilt® (propiconazole) and Folicur® (tebuconazole) in Victoria and New South Wales (note: data to support this permit was gathered during project VX01024 - Strategies to control purple spot of asparagus). It is hoped that this permit will be extended to cover growers in Queensland in the near future.

Although permitted for use only against rust, the use of Tilt® or Score® to control rust should also reduce anthracnose symptoms.

If older fern (more than 3 months old) becomes heavily infected with rust, it will be more effective to cut down all of the infected fern (and remove from the field) and apply fungicides to new growth. There is no need to harvest in between cutting the old fern and letting the new fern grow. This will give the fungicide(s) you apply the best chance of working. Fungicides will not be effective in controlling rust in crops with greater than 25% infection.

Integrated disease management
Integrated disease management using the above methods, sanitation practices and resistant varieties, is the best approach to control these asparagus diseases.

Recommendations for New Zealand growers
All the above recommendations should also be applied by New Zealand asparagus growers. In addition, growers should also consider:

- Postharvest disinfectants (chlorine or bleach) should be applied to all spears prior to transport to New Zealand.
- Survey the crops carefully to ensure early detection of the diseases and application of control treatments as soon as possible.
- If growers have any queries about diseases on asparagus crops, please contact Dr L-H Cheah of Crop & Food Research at Palmerston North (06 355 6173).

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Victorian Field Trial Collaborators
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Appendix A

Technology Transfer

2003 activities

Manawatu Asparagus Field Day - 30 March 2003
L-H Cheah presented a growers' seminar entitled 'Asparagus Diseases and Management' at the Manawatu Asparagus Field Day in Bulls, New Zealand.

Mildura Field Walk - 6 April 2003
Christine Horlock attended an 'Asparagus Farm Walk' in Mildura, organised by the Asparagus Growers of Sunraysia, and gave a presentation on integrated management of new asparagus diseases. A brief handout entitled 'Asparagus Disease Control' was distributed at the field day.

New Zealand Grower Meeting - 4 June 2003
L-H Cheah produced two posters; 'New Asparagus Diseases in Queensland – Field Survey and Disease Management' and 'Management of Phytophthora rot of Asparagus' for the New Zealand Asparagus Council Conference, held in Rotorua.

Victorian Grower Meetings - 22 July and 29 July 2003
L-H Cheah attended two grower meetings in Victoria. The first was held in KooWeeRup by the Australia Asparagus Council on 22 July 2003 and the second was held in Mildura by the Asparagus Growers of Sunraysia on 29 July 2003. L-H Cheah presented a seminar entitled 'New Asparagus Diseases in Queensland' at both meetings.

Queensland Grower Meeting - 24 July 2003
The 2004 research plan was discussed with growers from Southern Queensland at a workshop held in Dalby. A copy of the research plan was forwarded to Queensland growers and Victorian grower groups (Australian Asparagus Council and the Asparagus Growers of Sunraysia) in September, along with other relevant information.

2004 activities

North Queensland Grower Meeting - 22 April 2004
Asparagus growers from North Queensland attended a meeting at the DPI&F Centre for Tropical Agriculture in Mareeba. Christine Horlock and L-H Cheah presented seminars relating to the management of new diseases of asparagus.

Mildura Field Walk - 16 May 2004
A presentation was given by Sally-Ann Henderson (Victorian Department of Primary Industries, Mildura) on behalf of the project team at the annual Asparagus Growers of Sunraysia Field Walk. Sally-Ann relayed information about the project, as well as raising general asparagus disease awareness amongst growers.

New Zealand Grower Meeting - 2-3 June 2004
A poster entitled '*Phomopsis* stem blight; field survey and fungicide screening' was presented at the New Zealand Asparagus Council Conference, held in Palmerston

North. The poster included an update on the latest progress on asparagus work in Australia and New Zealand, followed by a discussion on integrated management of these diseases.

Queensland Grower Meeting - 29 June 2004
Asparagus growers from Southern Queensland attended a meeting at the Dalby RSL Club. Christine Horlock spoke briefly on asparagus diseases with particular emphasis on Anthracnose, *Phomopsis* stem blight and Rust. Dean Beasley spoke in detail about experimental results. Discussions were held with growers about upcoming experiments and methods for disease management.

A written synopsis of this information was sent to growers who were unable to make the meeting in the form of a newsletter entitled 'Asparagus Disease News', with project contributors receiving full details of all experimental results, while non-contributing growers received general disease information only.

Victorian Grower Meetings - 27 July and 10 August 2004
As part of the Australian Asparagus Council (AAC) annual meeting, information from the Queensland Grower Meeting held at Dalby in June was presented to growers from the KooWeeRup region on the 27 July 2004. The same information was subsequently presented to growers from the Mildura region on the 10 August 2004, as part of the Asparagus Growers of Sunraysia (AGOS) annual meeting.

A copy of the newsletter ('Asparagus Disease News') was provided to the Presidents of both associations prior to their respective meetings for distribution and discussion among members. Sally-Ann Henderson also presented a report on her trip to Mundubbera for the April disease survey.

2005 activities

Victorian Grower Meeting - 17 March 2005
L-HCheah attended the Australian Asparagus Council grower meeting at KooWeepRup to present the latest experimental results and discuss general asparagus disease awareness information with growers from the KooWeeRup region.

New Zealand Grower Meeting - 1 June 2005
L-H Cheah attended the New Zealand Asparagus Council Conference to update growers on the project and discuss the latest experimental results. Integrated control strategies were discussed and a poster entitled 'Integrated Management for Asparagus Rust' was also presented at the meeting.

Queensland Grower Meeting - 27 June 2005
Asparagus growers from Southern Queensland attended a meeting at the Mundubbera DPI&F Office. General disease awareness information was presented by Christine Horlock and recent experimental results were presented by Dean Beasley. Discussions were also held with growers about upcoming experiments and methods for disease management.

A written synopsis of this information was sent to growers who were unable to make the meeting in the form of a newsletter entitled 'Asparagus Disease News', with project

contributors receiving full details of all experimental results, while non-contributing growers received general disease information only.

Victorian Grower Meeting - 26 July 2005
As part of the Asparagus Growers of Sunraysia Annual General Meeting, information from the Queensland Grower Meeting was presented by Sally-Ann Henderson to growers from the Mildura region.

2006 activities

New Zealand Grower Meeting – 15 June 2006
Cheah attended the N.Z. Asparagus Council Conference on 15 June 2006 to present a talk on 'Resistance of asparagus varieties to rust' with a poster. He also discussed integrated management strategies including chemical control for rust and Phomopsis stem blight.

Prepared and sent final newsletter to Australian and New Zealand asparagus growers.

Remind the N.Z. growers to check disease symptoms on their crops through 'Spearhead' magazine.

Appendix B

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT
PERMIT NUMBER -PER8074
This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 12 May 2006 to 11 May 2008.

Permit Holder:
AUSTRALIAN ASPARAGUS COUNCIL

Persons who can use the product under this permit:
All persons

CONDITIONS OF USE
Products to be used:
BRAVO 720 FUNGICIDE which contains 720 g/L of the active constituent chlorothalonil;

FOLICUR430 SC FUNGICIDE which contains 430 g/L of the active constituent tebuconazole;

SCORE FOLIAR FUNGICIDE which contains 250 g/L of the active constituent difenoconazole;

TILTxtra FUNGICIDE which contains 250 g/L of the active constituent propiconazole.

Directions for Use:
Crop Pest Rate
ASPARAGUS FERN PURPLE SPOT DISEASE chlorothalonil: 1.5-2 L/ha
(*Stemphylium vesicarium*)
ASPARAGUS RUST tebuconazole: 290 ml/ha
(*Puccinia asparagi*)
difenoconazole: 500 ml/ha
propiconazole: 600 ml/ha

Critical Use Comments:
CHLOROTHALONIL: Group Y fungicide to be applied at 14 day intervals at disease threshold, to a maximum of 5-6 applications. Do not exceed 3.2 L of Bravo/ha of crops within one season.

TEBUCONAZOLE: Group C fungicide applied at 14-28 day intervals to a maximum of 5-6 applications; to be sprayed immediately after disease symptoms are observed.

DIFENOCONAZOLE: Group C fungicide to be applied by boom spray during the fern growth stage only and reapplied at 10 day intervals as required. Do not apply to emerging spears and apply no more than 4 applications per year.

PROPICONAZOLE: Group C fungicide applied at 14-28 day intervals to a maximum of 5-6 applications; to be sprayed immediately after disease symptoms are observed. Do not apply more than 2 consecutive applications of any group C fungicides in any one season on the same paddock.

Withholding Period:
HARVEST: NOT REQUIRED WHEN USED AS DIRECTED

Jurisdiction:
NSW only; a permit is not required to legalise the use of any of the nominated fungicides in Victoria.

Additional Conditions:
THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

RESIDUES:
To allow produce from treated plants or animals to be supplied or otherwise made available for human or animal consumption the APVMA has established the following temporary maximum residue limits (TMRLs):
chlorothalinol T*0.1 mg/kg
tebuconazole T*0.02 mg/kg
propiconazole T*0.1 mg/kg

The permit holder is required to generate appropriate residue data on tebuconazole in Australia, during the life of this permit, for submission to the APVMA. Contact the APVMA to ascertain the appropriate type and extent of residue data required to allow this permit to be reissued.