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Phytophthora cryptogea as a cause of root rot of raspberry in Australia; resistance of raspberry cultivars and control by fungicides

W. S. WASHINGTON
Plant Research Institute, Department of Agriculture and Rural Affairs, Swan Street, Burnley, Victoria 3121, Australia

Phytophthora cryptogea was isolated from field plantings of the red raspberry cultivars Glen Clova, Canby and Willamette which showed wilting, dieback, stem lesions and root rotting. Pathogenicity of *P. cryptogea* to raspberry was demonstrated in glasshouse experiments. Twelve cultivars of raspberry were screened for resistance to the disease by growing them in artificially infested soil. Glen Clova and Canby were highly susceptible whilst Chilcotin, Nootka, Haida and Puyallup were resistant. Soil treatments with either metalaxyl, phosphorous acid or fosetyl aluminium controlled the disease. This is the first record of a phytophthora root rot of raspberry in Australia, and the first demonstrating the pathogenicity of *P. cryptogea* to raspberry.

INTRODUCTION

In Victoria the only serious root disease of red raspberry (*Rubus idaeus* L.) until recently was white root rot (Wade 1951), caused by a *Vararia* sp. (Pascoe *et al.*, 1984). In spring of 1984, however, 2-year-old raspberries (cv. Glen Clova) at the Potato Research Station (PRS) Toolangi, southern Victoria, showed wilting, stem lesions, dieback and root rotting which were not characteristic of white root rot. The symptoms resembled those of phytophthora root rot (Converse & Schwartze, 1968; Johnson *et al.*, 1972; Montgomerie & Kennedy, 1980; Seemüller *et al.*, 1986). *Phytophthora cryptogea* Pethyb. & Laff. was subsequently isolated from these plants. *P. cryptogea* had not previously been shown to be a pathogen of raspberry and because this planting was an important source of new cultivars for the industry, the etiology, distribution and control of the disease was investigated.

MATERIALS AND METHODS

Survey

Plants of the cultivars Glen Clova and Canby which showed symptoms of dieback and root rot were sampled in October 1984 from the foundation planting at the PRS, Toolangi. Plant pieces from cane lesions and affected roots were surface-sterilized and transferred to water agar or P10VP media (Tsao & Ocana, 1969). Soil samples from around the roots of affected plants were assayed by the pear bait method (Greenhalgh, 1978). Similar tests were made on plants of the cultivar Willamette from a planting at the Irrigation Research Institute (IRI), Tatura, northern Victoria, where symptoms of dieback and root rot were evident.

In February and April 1985, a total of 185 samples of either plants or soil from around the roots of plants were collected from throughout the foundation stock (11 cultivars) and the multiplication stock (four cultivars) at the PRS, and tested for the presence of *Phytophthora* spp. as described above.

Resistance testing

An isolate of *P. cryptogea*, identified by Dr J. D. Stamps of the CAB International Mycological Institute (IMI 294909, VPRI 12589), from diseased raspberry cv. Glen Clova, was grown on vermiculite/V8 juice broth at 20°C for 4 weeks (Heather *et al.*, 1977). This inoculum was mixed with pasteurized soil containing equal parts of a mixture of loam, sand and peat (by volume), pH 6·8 at a rate of 2% by weight. Soil for control treatments contained 2% by weight of the same broth without *P. cryptogea*.

Table 1. Reaction of raspberry cultivars to root rot caused by *Phytophthora cryptogea*

Cultivar	Number of dead plants (max. 10)	Disease rating[a]		
		Foliage	Root	Combined foliage and root
Chilcotin	0	0·4	1·2	0·8
Nootka	0	0·4	1·3	0·8
Haida	0	1·0	1·6	1·3
Puyallup	0	1·1	1·9	1·5
Willamette	1	1·1	2·2	1·6
Fairview	1	1·4	2·9	2·1
Marcy	2	1·7	2·7	2·2
Heritage	3	2·3	3·2	2·7
Meeker	6	3·2	3·6	3·4
Skeena	6	3·1	3·8	3·4
Canby	9	3·8	4·0	3·9
Glen Clova	10	4·0	4·0	4·0
SED		0·44 (df = 88)	0·39 (df = 79)	0·37 (df = 88)

[a] Rating system for foliage or root disease 67 days after inoculation on a scale of 0, 1, 2, 3 and 4; where 0 = healthy—less than 50% chlorotic or necrotic leaves (or rotted roots), 1 = 50–74%, 2 = 75–94%, 3 = 95–99%, and 4 = dead—100% necrotic leaves (or rotted roots).

Rooted raspberry suckers were removed from healthy plants in spring. After growth for 4 weeks in a glasshouse, 10 plants of each cultivar were replanted into 10-cm-diameter pots (volume 600 ml) containing the soil amended with *P. cryptogea*, and 10 into unamended soil. Treatments were randomized on benches in a glasshouse (at 15–28°C). Plants were waterlogged for 1 day each week, and watered when necessary on all other days. Observations on disease development were made at weekly intervals. Sixty-seven days after inoculation, treatments were assessed by recording plant mortality and assessing the health of shoot and root growth using rating systems described in Table 1. Isolations were made from necrotic roots, and roots were also placed in sterile distilled water (SDW) and observed for the presence of sporangia of *P. cryptogea*.

Fungicide testing

Fungicides were tested for the control of phytophthora root rot in glasshouse experiments using cv. Glen Clova. Eight days after inoculation, fosetyl aluminium (Aliette 80 W) or phosphorous acid (unneutralized) were applied as a soil drench, or metalaxyl (Ridomil 5 G) was applied to the soil surface, at the rates shown in Table 2. Pots in all treatments received a total of 40 ml of water at treatment. Observations on disease development were made at weekly intervals. Eighty-eight days after inoculation disease was assessed as described previously. The survival of *P. cryptogea* in the soil was estimated by testing two soil samples per pot by the pear baiting method, and by isolating from seven root pieces per plant onto P10VP media. Shoot and root dry weights were also recorded.

RESULTS

Survey

P. cryptogea was isolated from cane lesions and necrotic roots, and baited from the soil around the roots of plants of cvs Glen Clova and Canby from the foundation planting, PRS, Toolangi and cv. Willamette from the planting at IRI, Tatura. These plants showed tip wilting, leaf scorching, dieback and death of canes and rotted roots. Some plants also showed a grey or brown discoloration extending upwards from the roots, which was especially apparent when the epidermis was removed. The same pathogen was also baited

Table 2. Effect of fungicides on root rot of raspberry (cv. Glen Clova) caused by *Phytophthora cryptogea*

Treatment	Number of dead plants (max. 10)	Foliage weight (g)	Root weight (g)	Disease rating[a]			Recovery of *P. cryptogea* by	
				Foliage	Root	Combined foliage and root	Pear bait of soil (max. 20)	Root isolation onto P10VP media, % roots (of 70)
Metalaxyl 2·5 g a.i./m^2	0	2·156	3·199	0·4	1·1	0·7	0	0
Phosphorous acid (2 g/l) 10 g/m^2	1	1·698	3·952	1·1	1·8	1·4	16	21·1
Fosetyl Al 20 g a.i./m^2	3	1·973	3·308	1·7	2·1	1·9	14	11·1
Inoculated control	10	1·612	1·531	4·0	4·0	4·0	18	23·6
Uninoculated control	0	2·570	3·594	0·2	0·1	0·1	0	0
SED		0·411 (df = 36)	0·716 (df = 36)	0·53 (df = 27)	0·41 (df = 27)	0·46 (df = 27)		

[a] Rating system for foliage or root disease 88 days after inoculation on a scale of 0, 1, 2, 3 and 4; where 0 = healthy—less than 50% chlorotic or necrotic leaves (or rotted roots), 1 = 50–74%, 2 = 75–94%, 3 = 95–99%, and 4 = dead—100% necrotic leaves (or rotted roots).

from soil around the roots of symptomless plants of cvs Skeena, Haida and Nootka from the foundation planting, Toolangi. *Phytophthora* spp. were not detected in soil or roots from the multiplication planting at the PRS, Toolangi. *Pythium* spp., including *Pythium ultimum* Trow., were commonly isolated from necrotic roots of otherwise healthy-looking plants of all cultivars.

Cultivar reactions

Inoculated plants were assessed after 67 days and cultivars were ranked in order of decreasing resistance, on the basis of plant mortality and disease ratings (Table 1). Chilcotin, Nootka, Haida and Puyallup were the most resistant to the disease, while Willamette, Fairview and Marcy

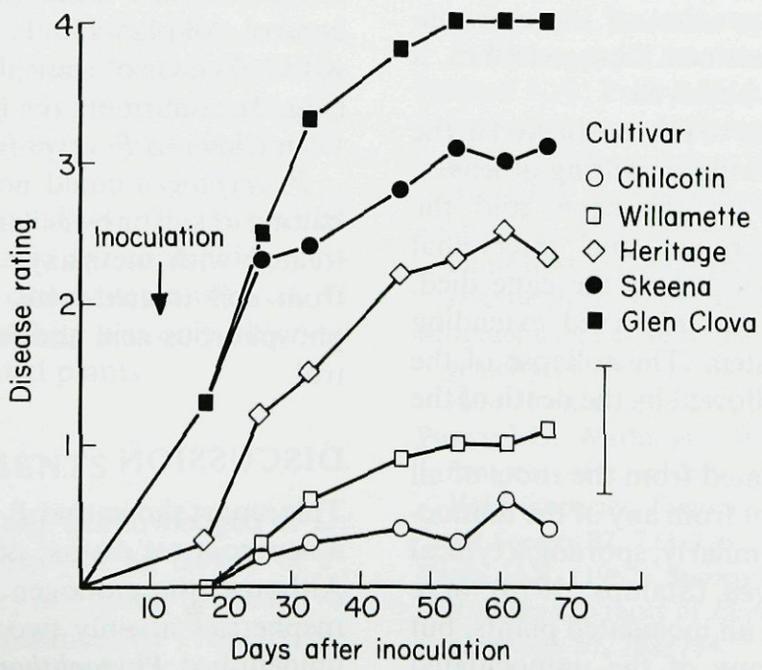

Fig. 1. Change in disease rating over time for five raspberry cultivars inoculated (↓) with *Phytophthora cryptogea*. Bar = LSD ($P = 0·05$) 67 days after inoculation.

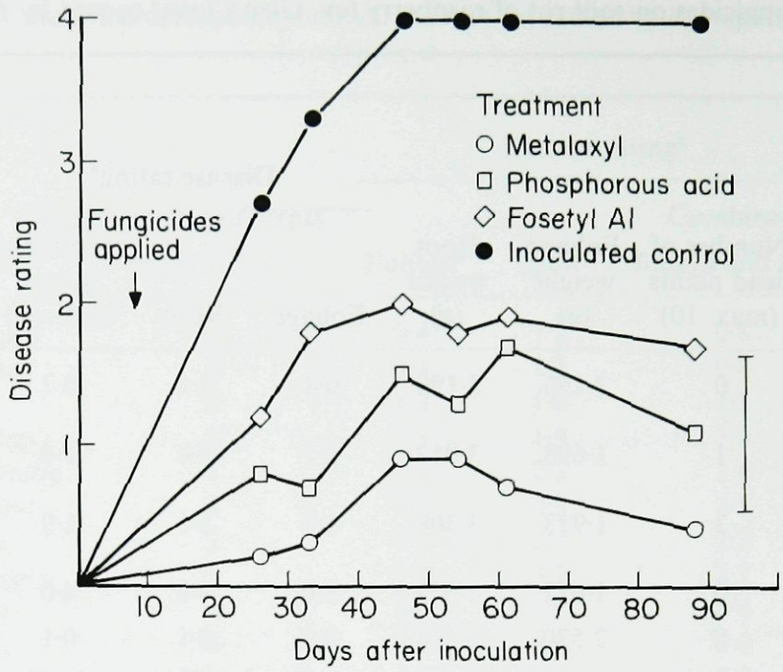

Fig. 2. Change in disease rating over time for Glen Clova raspberry plants inoculated with *Phytophthora cryptogea* and treated with fungicides. Bar = LSD ($P < 0{\cdot}05$) 88 days after inoculation.

were less resistant. Heritage, Meeker, Skeena, Canby and Glen Clova were the least resistant (Table 1). The disease developed rapidly on these susceptible cultivars and 30 days after inoculation differences were apparent between the most resistant and the least resistant cultivars (Fig. 1). By the end of the experiment all inoculated plants of Glen Clova had died, while uninoculated plants of this and other cultivars remained healthy. In contrast none of the inoculated plants of Chilcotin, Nootka, Haida and Puyallup died, although growth of plants of the last two cultivars was considerably weaker than that of the uninoculated control plants. Between these extremes, a range of responses was observed.

Symptoms were similar to those observed in the field, with a slight yellowing or wilting of leaves, especially at the base of the cane, and the development of a marginal and interveinal chlorosis in older leaves, before the cane died. Often a brown lesion was observed extending from soil level up the stem. The collapse of the shoot tip was usually followed by the death of the entire plant.

P. cryptogea was isolated from the roots of all inoculated plants but not from any of the uninoculated control plants. Similarly, sporangia typical of those of *P. cryptogea* (Stamps, 1978) were observed on roots from all inoculated plants, but not from roots from any of the uninoculated controls, after incubation in SDW.

Fungicide testing

Each of the fungicide treatments controlled the disease and reduced the number of plants which died. Metalaxyl was the most effective (Table 2, Fig. 2). Root dry weights of plants from the fungicide treatments were not significantly different ($P = 0{\cdot}05$) from those of the uninoculated controls, but were greater than those from the inoculated control. Disease ratings of plants from all the fungicide treatments were not significantly different from one another but were significantly less than those from plants in the inoculated control. All plants in the inoculated control died within 46 days of transplanting into infested soil (Fig. 2), confirming the high susceptibility of cv. Glen Clova to *P. cryptogea*.

P. cryptogea could not be recovered by pear baiting of soil or by isolation from roots of plants treated with metalaxyl but was readily baited from soil treated with fosetyl aluminium and phosphorous acid and from the inoculated control.

DISCUSSION

This report shows that *P. cryptogea* is the cause of a new root rot disease of raspberry in Australia. Although the pathogen has been isolated from raspberries at only two sites in Victoria, other unidentified *Phytophthora* species have been associated with similar symptoms in raspberries at

seven other plantings throughout Victoria (W. S. Washington, unpublished data). Waterston (1937) first reported a *Phytophthora* species (*P. citricola* Sawada) to be associated with a raspberry dieback. Since then at least six other species of *Phytophthora* have been implicated in raspberry dieback and root rot: *P. cinnamomi* Rands (Brien & Dingley, 1959), *P. fragariae* Hickman (Pepin, 1967), *P. erythroseptica* Pethyb. (Converse & Schwartze, 1968), *P. cryptogea* (Boeswinkel, 1982), *P. cactorum* (Leb. *et* Cohn) Schroeter (Wilcox & Nevill, 1985) and *P. megasperma* Drechsler (Duncan *et al.*, 1987). This is the first report, however, demonstrating the pathogenicity of *P. cryptogea* to raspberry.

A range of resistance to the disease was observed among the raspberry cultivars tested. Similarly, Converse & Schwartze (1968) and Converse (1973) compared a small number of cultivars for their reaction to *P. erythroseptica* in glasshouse and field inoculation studies, whilst Daubeny & Sjulin (1984) and Barritt *et al.* (1979, 1981) compared many cultivars in field plantings which were presumed to be infected with *P. erythroseptica*. Comparison of the results of these tests with those of the present study indicate that some cultivar reactions to *P. erythroseptica* and *P. cryptogea* are similar. For example cvs Skeena, Glen Clova and Canby (with the exception of Canby in one report) are consistently ranked as among the least resistant to root rot. However, other cultivar reactions are less consistent. Willamette, ranked as moderately resistant in the present study, was considered to be moderately to highly susceptible in the other studies. Again, Chilcotin, Nootka, Haida and Puyallup, ranked as resistant in the present study, were found to be midway between highly resistant cultivars (e.g. Newburgh and Sumner) and highly susceptible cultivars (e.g. Canby).

The effectiveness of metalaxyl, fosetyl aluminium and phosphorous acid for controlling phytophthora root rot was clearly demonstrated. At the rates tested, phytotoxicity was only observed on some metalaxyl-treated plants.

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