Response to Artificial Infection by *Phytophthora cactorum* of Four Apple Scion Cultivars on Three Rootstock

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Abstract. A 10-year field experiment was conducted on 20-year-old apple trees (*Malus domestica* Borkh.) inoculated with *Phytophthora cactorum* (Leb. & Cohn) Schroet. to study the influence of the scion cultivar on rootstock susceptibility. The rootstock MM.111 was less susceptible to *P. cactorum* than M.7 when 'Golden Delicious' was the scion, but there were no differences when 'Delicious', 'Haroldred Delicious', or 'McIntosh' were the scions. Similarly, the rootstock M.26 was less susceptible than M.7 when 'McIntosh' was the scion, but there were no differences when 'Delicious', 'Haroldred Delicious', or 'Golden Delicious' were the scions. These results suggest that the influence of scions on rootstock susceptibility to *P. cactorum* crown rot is variable.

Phytophthora cactorum, an important pathogen of apple trees, causes crown rot in mature apple orchards in British Columbia (Utkhede, 1986). This pathogen is responsible for tree deaths in most apple-growing regions of the world (McIntosh, 1975). Outbreaks of crown rot are random and depend on excess soil water, suitable temperatures, and host susceptibility (Sewell and Wilson, 1974).

Marked differences in the resistance of apple rootstock to crown rot have been noted (Barritt et al., 1990; McIntosh, 1975; Sewell and Wilson, 1959; Utkhede and Quamme, 1988). M.9 and M.4 are resistant, but not immune; MM.111 and M.7 are moderately resistant and MM.104, MM.106, and M.26 are susceptible to crown rot. Several assays have been developed to assess resistance. Some breeding programs include screening for resistance at the seedling stage (Cummins and Aldwinckle, 1982; Tobutt, 1985), although the value of such tests is uncertain (Harris and Tobutt, 1986). Inoculating cut woody shoots has been used in various forms by many workers to measure the resistance of apple trees to *P. cactorum* (Dakwa and Sewell, 1981; McIntosh, 1975).

Several researchers have been frustrated by their inability to produce infection through artificial inoculation under orchard conditions. Borecki and Millikan (1969) found that inoculating 4-year-old budded rootstock with an agar plug containing *P. cactorum* was the most reliable method under field conditions. Utkhede (1984) infected 2-year-old MM.106 rootstocks under field conditions with 5-mm agar plugs

containing actively growing *P. cactorum*. Inducing crown rot experimentally in 17-year-old rootstock under orchard conditions has been only slightly successful (Harris, 1990).

Variations in cultivar resistance to crown rot associated with rootstock were demonstrated by Dakwa and Sewell (1981) and Sewell and Wilson (1973a, 1973b).

We studied crown rot in an established orchard by inoculating trees of four scions on three rootstock. Trees were 20 years old at the start of the experiments in 1981.

The trial was conducted at the Kelowna Substation of Agriculture Canada Research Station, Summerland, on soil with pH 6.9. Graft unions were ≈ 30 cm above soil (gravelly sandy loam) level. The cultivars were 'Delicious', 'Golden Delicious', 'Haroldred Delicious', and 'McIntosh', and rootstock were MM.111, M.7, and M.26. Eight single-tree replicates were arranged in randomized blocks with split plots. The three rootstock were main plots, and four scion cultivars were subplots. Tree spacing was 5×3 m.

Each tree was inoculated, as described by Borecki and Millikan (1969), on 20 Aug. 1981

and thereafter in the second week of June every year until 1988 with four 5-mm agar plugs containing actively growing *P. cactorum*. The soil was removed from the crown region to a depth of ≈ 6 cm, and inoculum plugs were inserted in holes (5 mm in diameter, 2 mm deep) made with a cork borer. The soil was replaced and all trees were irrigated immediately after inoculation. Thereafter, the trees were irrigated for 8 h every 10 days with under-tree sprinklers between the trees. Normal insect, weed, and foliar disease control measures were carried out uniformly over all treatments.

Fruit yields were measured from 1982 to 1988. After the trial was terminated in 1990, the tree tops were cut off with a chainsaw, and the stumps were removed by a tractor equipped with a backhoe. Roots were evaluated visually for crown rot damage immediately after removing them. The evaluation was based on the extent of infection, expressed as a percentage, of the crown region of the tree.

The presence of *P. cactorum* in the bark and roots of infected trees was confirmed using the method of Matheron et al. (1988) and a selective medium (10 plates per sample) containing cornmeal agar amended with 5 mg Pimaricin, 300 mg vancomycin hydrochloride, and 25 mg of pentachloronitrobenzene per liter. Infected bark samples from the margins of active cankers on the trunk were processed in a similar manner. The plates were examined daily for 5 to 7 days for *P. cactorum* growth. Typical *P. cactorum* colonies were examined under a microscope to confirm infection by the pathogen. Data were analyzed by general linear model (GLM) procedures (SAS Institute, Cary, N.C.). All data were analyzed for statistical significance by the GLM procedure. Duncan's new multiple range test was used to compare treatments when analysis of variance (ANOVA) showed significant differences among means.

Bark and root samples from all trees with typical crown rot symptoms contained viable *P. cactorum*. *Phytophthora cactorum* was not isolated from any of the healthy crown and root tissues. The range of infection was from 10% to 100% in individual trees.

Degree of crown rot varied with the scion cultivar (Table 1). MM.111 was less suscep-

Table 1. *Phytophthora cactorum* crown rot infection (percent crown area affected) induced by inoculating 20-year-old trees of four cultivars on three rootstocks in an established orchard.

Rootstock	Scion cultivar			
	Delicious	Golden Delicious	Haroldred Delicious	McIntosh
	Crown rot infection (%)			
MM.111	81.4 a ²	55.6 b	73.7 a	75.6 ab
	A ¹	B	AB	AB
M.7	72.5 a	87.0 a	81.9 a	86.5 a
	B	A	A	A
M.26	71.7 a	70.8 ab	78.3 a	72.0 b
	A	A	A	A

¹Mean separation within columns (lowercase letters) by Duncan's multiple range test at $P \leq 0.05$.

²Mean separation within rows (uppercase letters) by Duncan's multiple range test at $P \leq 0.05$.

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Table 2. Effect of *Phytophthora cactorum* infection in three rootstocks on apple fruit production (7-year average, kilograms/tree) of four scion cultivars.

Rootstock	Scion cultivar			
	Delicious	Golden Delicious	Haroldred Delicious	McIntosh
		Yield (kg/tree)		
M.111	13.3 a ^c B ^y	55.7 a A	42.4 a AB	53.3 a AB
M.7	18.9 a C	57.1 a A	22.2 b C	39.7 b B
M.26	14.8 a B	26.0 b A	29.0 b A	21.8 c AB

^aMean separation within columns (lowercase letters) by Duncan's multiple range test at $P \leq 0.05$.

^bMean separation within rows (uppercase letters) by Duncan's multiple range test at $P \leq 0.05$.

tible to *P. cactorum* than M.7 when 'Golden Delicious' was the scion (Table 1). Similarly, M.26 was less susceptible than M.7 when 'McIntosh' was the scion. No difference in susceptibility was observed between the three rootstock when 'Delicious' and 'Haroldred Delicious' were scions (Table 1). These observations indicated that the influence of scion cultivars on rootstock susceptibility to *P. cactorum* crown rot is variable. In one case, M.26 with 'McIntosh', which is considered susceptible, was more resistant than M.7. This result implies that scion-rootstock combinations may play a role in resistance to *Phytophthora* infection. This finding would have to be supported by more combinations and data. Dakwa and Sewell (1981) showed that MM.111 was more susceptible to *P. cactorum* infection when 'Cox's Orange Pippin' rather than 'Worcester Pearmain' was the scion.

Generally, 'Golden Delicious' produced high apple yields with all three rootstock (Table 2). Interestingly, although the percent-

ages of infection in rootstock were high, fruit production was not greatly affected. For example, on average, 71% of the area was affected by crown rot in rootstock with 'Golden Delicious' scions, but production per tree was high for this scion. Most of the trees appeared healthy and produced fruit until 1990. It appears that a substantial *P. cactorum* infection may be necessary before a tree becomes non-productive or is killed.

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