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Short communication

The effect of three irrigation practices on phytophthora crown and root rot of apple trees under field conditions

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Abstract

The effect of microjet, drip, and two durations of sprinkler irrigation systems on phytophthora crown and root rot of apple trees was examined under field conditions. This eight year study indicates that crown and root rot caused by *Phytophthora cactorum* was most severe where young MM.106 rootstock trees were watered by microjet irrigation for 2.3 h each day. There was no difference in infection by *P. cactorum* when trees were irrigated either by drip or sprinkler irrigation systems. The MM.106 apple rootstock trees watered by drip irrigation for 2.6 h each day were least affected by phytophthora crown and root rot.

Phytophthora crown and root rot (PCRR) of apple trees (*Malus domestica* Borkh.), caused by *Phytophthora cactorum* (Lebert and Cohn) J. Schroet. is one of the most serious soilborne diseases in the Okanagan Valley of British Columbia (McIntosh, 1975; Utkhede, 1986). Several species of *Phytophthora* have been shown to require saturated soil conditions for zoospore release and dispersal in soil (Duniway, 1983). Saturated soil not only has a direct effect on pathogen behaviour but also can predispose some plants such as in alfalfa and rhododendron to more severe root rot (Blaker and MacDonald, 1981; Kuan and Erwin, 1980). Water stress can also predispose many hosts to more severe phytophthora root rot (Blaker and MacDonald, 1981; Duniway, 1977). It has been shown under greenhouse conditions that the incidence and severity of phytophthora root rot of fruit trees are closely related to soil moisture conditions (Mircetich and Matheron, 1976; Wilcox and Mircetich, 1985). On Red Delicious apple seedlings, long periods of flood irrigation resulted in more root rot by *P. cryptogea* compared with *P. cactorum* or *P. cambivora* (Browne, 1984). The formation of sporangia, and the release and movement of motile zoospores are favoured by moisture levels from field capacity to soil saturation. This indicates the important role that soil moisture plays in the development of phytophthora root rot. Because soil moisture plays such an important role in the development of phytophthora root and crown rot, control of this pathogen may be possible by careful management of irrigation water. Apple trees in the Okanagan Valley of British Columbia are commonly irrigated by either sprinkler, microjet or drip irrigation systems. Sprinkler irrigation systems are usually operated at intervals ranging from 7 to 15 days and apply water uniformly over the entire orchard floor whereas microjet and drip systems are usually operated daily (or every 2–3 days) and apply water to localized areas along the tree row. Information is lacking on the effect of different methods of irrigation on the incidence of PCRR. A field experiment, therefore, was conducted to examine the effect of three practices of irrigation on the development of PCRR of apple trees.

The field test was conducted in a sandy loam soil at the Agriculture Canada Kelowna Substation located in the Okanagan Valley of British Columbia. The total area of the trial was 75 m × 24 m. Soil from the test area contained 79, 25, 201, 131, 532, and 32 meq/100 g of N, P, K, Mg, Ca, and Na, respectively, 2.4% organic matter, and a soil pH of 5.3. One-year-old disease free

trees of the crown rot susceptible rootstock MM.106 were bench-grafted with 'Macspur' in February 1985 and planted on 22 April 1985. Tree spacing was 3.5 m between rows and 1 m between trees. Four treatments were arranged in a randomized complete block design with 4 replications. There were 24 trees per treatment planted in 3 rows. The outside rows served as guard rows to avoid interplot interference. The drips and microjets were located 1 m and 2 m, respectively, apart within a row. The sprinklers were located at 4 corners of the plot. The treatment were: microjet irrigation – 2.3 h daily, drip irrigation – 2.6 h daily, sprinkler irrigation – 1.5 h every 7 days, and sprinkler irrigation – 3.0 h every 7 days. The automatic operation of the irrigation system was controlled by an Irri-Trol C.Q. Battery Operated Controller #(Irri-Trol mfg. inc. Valencia, C.A. U.S.A.). The amount of water delivered to each tree per day was calculated for each treatment as follows: drip – 11 L, microjet – 29 L, sprinkler 1.5 h – 20 L, and sprinkler 3.0 h – 40 L.

Soil around each tree was infested with *P. cactorum* annually in mid-June. The soil was removed from the crown region to a depth of about 4 cm and replaced immediately after application of the pathogen. The procedure for inoculum preparation of *P. cactorum* has been described earlier (Utkhede and Smith, 1995). The stock suspensions were diluted to obtain approximately 1400 colony forming units (CFU) per ml. To infest soil, 10 ml of stock suspension of *P. cactorum* was diluted to 50 ml with sterile water and poured evenly around the base of the tree in mid-June. The soil was moist when inoculum was added to the soil The trees were irrigated with their respective irrigation methods immediately after the soil infestation with *P. cactorum*. During the growing season the experimental plot was irrigated as per treatments. Weeds, insects, and foliar diseases were controlled by standard orchard practices as prescribed for apples in the Production Guide for Interior Districts of British Columbia for the years 1985 to 1993 (Anonymous, 1985–1993).

The presence or absence of *P. cactorum* in the bark or roots of infected unhealthy trees was confirmed each year following the method used by Matheron et al. (1988). Ten bark/root pieces per tree were plated on a selective medium as described by Matheron et al. (1988). The plates were kept in darkness at 21 °C and examined daily for 5–7 days for growth of *P. cactorum*. Colonies typical of *P. cactorum* were examined under a microscope to confirm infection by the pathogen.

A disease rating (1 = healthy, 2 = initial, 3 = intermediate, 4 = terminal, 5 = dead) was assigned to each tree in late September of years 1988–1993. The extent of PCRR infection was determined by removing about 15 cm of soil from the base of trees. The PCRR infections were rated as follows: 1 = healthy – no infection at all; 2 = initial – less than one-fourth of the bark/roots at the crown region infected by *P. cactorum*; 3 = intermediate – about one-fourth to one-half of the bark/roots infected; 4 = terminal – more than half the bark/roots infected; 5 = dead – tree trunk is completely girdled, all roots are infected, and the tree is dead. The final percentage of dead and diseased trees resulting from infection by *P. cactorum* was determined in late September of 1993 based on isolation of the pathogen. All data were analyzed by Analysis of Variance (ANOVA) using plot averages (SAS Institute Cary, N.C.). Averages of trees within plot should tend to normality by Central Limit Theorem. Percentages were transformed into arcsine values prior to statistical analysis by the ANOVA procedure. Duncan's new multiple range test was used to compare treatments after an ANOVA showed significant differences among means.

Phytophthora cactorum was isolated from bark and root samples of all trees showing typical symptoms of crown and root rot. However, this fungus was not isolated from healthy trees not showing symptoms. The ANOVA procedure for disease rating from 1988–1993 showed that the effects of treatments were significant (data not shown). In all years, trees irrigated with microjets for 2.3 h each day had a significantly greater disease rating than trees irrigated with drip 2.6 h/day, or with sprinklers for 1.5 h or 3.0 h/wk (Table 1). Similar results were obtained for 1989, 1990, 1991, 1992, 1993, and also when the data were pooled together for all years. Significantly ($P = 0.05$) higher percentage of trees were infected by *P. cactorum* when trees were irrigated with microjet for 2.3 h/day (83.3%) compared to trees that were irrigated with drip for 2.6 h/day (69.8%), sprinkler for 1.5 h/wk (63.5%), and sprinkler for 3 h/wk (60.4%, Figure 1). Similarly, a significantly higher percentage of trees died during the six year period by *P. cactorum* infection with microjet irrigation compared to drip and sprinkler irrigations (Figure 1).

Our study indicated that apple trees in the Okanagan Valley of British Columbia irrigated with microjets for 2.3 h daily increased PCRR. Trees irrigated with drip for 2.6 h daily were less infected with *P. cactorum* compared with the trees irrigated with microjets for 2.3 h daily. Although the duration of irrigation was more or less similar for both irrigation methods, the

Table 1. Effect of 4 irrigation treatments on the disease ratings (1 = healthy, 2 = initial, 3 = intermediate, 4 = terminal, 5 = dead) of crown and root rot of apple trees caused by *P. cactorum*. The amount of water delivered to each tree per day was calculated for each treatment as follows: drip – 11 L, microjet – 29 L, sprinkler 1.5 h – 20 L, and sprinkler 3.0 h – 40 L

Treatment	Duration	Disease ratings						
		1988	1989	1990	1991	1992	1993	Mean
Microjet	2.3h/day	1.76* a	2.95 a	3.31 a	3.38 a	3.73 a	3.88 a	3.17 a
Drip	2.6h/day	1.18 b	1.77 b	2.28 b	2.46 b	2.67 b	3.01 b	2.22 b
Sprinkler	1.5h/week	1.17 b	1.86 b	2.36 b	2.50 b	2.69 b	2.99 b	2.26 b
Sprinkler	3.0h/week	1.10 b	1.86 b	2.30 b	2.39 b	2.71 b	2.99 b	2.23 b
	S.E.	0.11	0.13	0.20	0.20	0.14	0.11	0.13

* Means in the same column followed by the same letter are not significantly different (P = 0.01) according to Duncan's multiple range test.

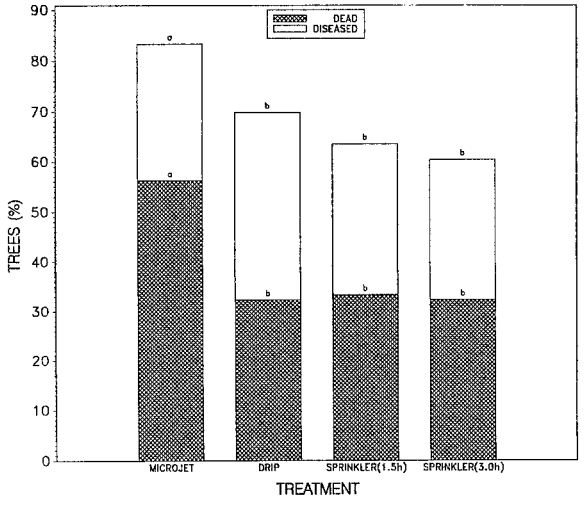

Figure 1. Final percentage of diseased and dead trees infected with *P. cactorum* are shown in this graph. The amount of water delivered to each tree per day was calculated for each treatment as follows: drip – 11 L, microjet – 29 L, sprinkler 1.5 h – 20 L, and sprinkler 3.0 h – 40 L. The value of percentage of diseased or dead trees followed by the same letter are not significantly (P = 0.05) different according to the Duncan's multiple range test.

amount of water delivered by these two methods was quite different. The amount of water delivered per tree per day by drip irrigation was about 3 times less than by microjets. This suggests that the irrigation by microjets delivered excess water daily to the soil which stimulated PCRR in apple trees. Excess soil moisture has been related consistently to the incidence of PCRR of fruit trees (Browne, 1984; Wilcox and Mircetich, 1985; Mircetich and Matheron, 1976). It is generally accepted that saturated soil conditions stimulate the production and release of zoospores and provide the medium in which zoospores move (Duniway, 1979; Gisi et al., 1980). It is likely that the excessive volume of water applied by the microjet irrigation treatment provided the saturated soil conditions conducive to the production and transport of *P. cactorum* zoospores. Saturated soil conditions may also increase root rot by reducing the ability of the host species to produce new roots to replace those infected by the pathogens. Lack of oxygen that develops in plant roots under excess soil moisture conditions have been suggested as a possible cause of predisposition of host plants to pathogens (Drew and Lynch, 1980). Wilcox and Mircetich (1985) have shown that the susceptibility of Mahaleb cherry trees to root and crown rot caused by Phytophthora species was increased during periods of reduced oxygen which developed during persistent flooding.

This study has shown that there was no difference in disease incidence between trees watered by drip irrigation or sprinkler system, although the amount of water delivered by these two methods of irrigation was substantially different. The drip method delivered 11 L while sprinkler – 1.5 h delivered 20 L of water per day per tree. The major difference between the two methods of irrigation is that the drip irrigation was operated every day while the sprinkler system was operated every 7 days. With sprinkler irrigation system operating every 7 days, there is a soil drying period between the two watering times. This probably allows reduction in *P. cactorum* inoculum. Feld et al. (1990) showed that when citrus seedlings were grown under a furrow-irrigation method (watered every 2 wk) which allowed the soil to dry sufficiently between irrigations, new feeder roots were continuously produced and the plants were significantly healthier than those grown under other methods. We did not find any difference in disease incidence on apple trees treated with sprinkler irrigation for 1.5 h and 3.0 h, although the amount of water delivered in latter system was double. This again could be related to the drying period between

the two watering times. The differences between the irrigation systems might also modify water spatial distribution in the soil around the root system, thereby affecting disease development. We used a crown and root rot susceptible rootstock in this test and results are applicable to MM.106 rootstock only and may not be applicable to crown and root tolerant rootstock, which needs further research.

In summary, good irrigation practices are essential to reduce prolonged periods of soil saturation which are conducive to infection of apple trees by *P. cactorum*. The microjet irrigation for 2.3 h each day could be damaging to apple trees where *P. cactorum* is a problem. Drip irrigation for 2.6 h each day may help prevent the spread of *P. cactorum*, since it apparently leads to a reduction in the formation and movement of zoospores. Watering 'Macspur' on MM.106 rootstock apple trees using a sprinkler system seems to help the host in reducing the PCRR although this method may increase the spread of the pathogen. Irrigating MM.106 rootstock apple trees with a drip irrigation system for 2.6 h each day seems to be the better practice to reduce the incidence of PCRR in soil where *P. cactorum* is a problem.

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