

Fig. 4. Medium leachate analysis for pH and electrical conductivity (EC) in 1998.

quirements. There was a sharp decrease in irrigation required from August to October with decreasing temperatures.

Yeager (1998) reported that monitoring both water use and discharge is essential in identifying water requirements and accumulation of soluble salts during times of inadequate rainfall. Effluent analysis during the month of August in this study determined nutrients (N, Phosphorus, Potassium, Calcium, Magnesium) were at acceptable levels and pH (7.8) at slightly higher than recommended (Fig. 3 and 4). Below normal rainfall high temperatures, and water evaporation may have been responsible for increased leachate electro conductivity (EC) and pH measurements (Fig. 4). Additional irrigation was required to leach accumulated salts.

The closed capture system could be used as an objective nursery irrigation management tool providing data to make informed decisions. Yearly accumulated data could eventually be transformed into an irrigation model for each species, media, and climate. Previous research has shown that effluent based irrigation could reduce fertilizer and irrigation requirements (Davis, et al., 2001). Monthly monitoring reports could provide adequate data for managing irrigation; as well as, monitoring nutrient availability and leaching.

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Control of Powdery Mildew on Leaves and Stems of Gooseberry

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ADDITIONAL INDEX WORDS. *Ribes uva-crispa*, *Ribes grossularia*, *Sphaerotheca mors-uvae*, efficacy, mineral oil, biological control, *Trichoderma*

SUMMARY. Powdery mildew (*Sphaerotheca mors-uvae*) severely infects young leaves and stems of gooseberry (*Ribes uva-crispa*) throughout the world. Environmentally friendly control measures are being sought as alternatives to sulfur or demethylation inhibiting fungicides. This study examined the effect of a mineral oil spray, the biological control agent *Trichoderma harzianum* Rifai strain T-22 (*Trichoderma*), a combination mineral oil + *Trichoderma*, and the chemical fungicide thiophanate, on powdery mildew severity in 'Industry,' a susceptible gooseberry. Mineral oil at 8 mL·L⁻¹ (1.0 fl oz/gal), *Trichoderma* at 4 g·L⁻¹ (0.5 oz/gal) and thiophanate at 1.45 mL·L⁻¹ (0.186 fl oz/gal), and mineral oil + *Trichoderma* mix was applied to plants until runoff at 2-week intervals from February 2002 through April 2002, on potted 'Industry' plants growing in a greenhouse in U. S. Department of Agriculture, Agricultural Research Service, National Clonal Germplasm Repository (NCGR), Corvallis, Ore. The percent of infected leaves per plant were calculated and the percent of infected stem surface areas were visually rated in mid-April. The fungicide, mineral oil, and mineral oil + *Trichoderma* treatment applications significantly reduced powdery mildew severity in

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both leaves and stems as compared with those of the unsprayed plants. The stem powdery mildew reduction levels of the mineral oil or a combination of mineral oil + *Trichoderma* treatments, were not statistically different than that of thiophanate, which is reported as commercially acceptable. We recommend mineral oil spray, or mineral oil + *Trichoderma*, as alternatives to fungicide control of powdery mildew on leaves and stems of young gooseberry plants.

Powdery mildew is a spring and summer disease of gooseberries in Asia, Europe, North America, Australia, and New Zealand (Diekmann et al., 1994). This disease can be severe in the rainy, mild climate of the Pacific northwestern United States. The fungus appears as a white powdery growth on the young leaf and stem surfaces and can cause stunting and a reduction in marketable fruit (Pscheidt, 2002).

Control recommendations for powdery mildew in fruit crops include inorganic sulfur in dust or wettable formulations, and demethylation-inhibitor fungicides (Dell et al., 1998; Pscheidt, 2002). A biological control containing the fungal hyperparasite *Ampelomyces quisqualis* in a mineral-oil-based surfactant is a mildew preventative (Pscheidt, 2002). *Trichoderma harzianum* isolates can control foliar and soilborne fungi including *Botrytis cinerea*, *Pseudoperonospora cubensis*, *Sclerotinia sclerotiorum* and *Sphaerotheca* spp. (Elad, 2000; Scheuerell and Mahaffee, 2000). The organism has multiple modes of action that inhibit or kill the pathogen (Elad, 2000). These organisms may not provide commercially accepted control with present formulations.

Mineral oil has proven effective in controlling powdery mildew on grapes (*Vitis vinifera*) (Dell et al., 1998), roses (*Rosa* spp.) (McWhorter, 1927) and hops (*Humulus lupulus*) (Pscheidt, 2002). Oil is effective in low concentrations, has little or no toxicity to animals, and is relatively inexpensive (Dell et al., 1998). Mineral oil was effective in reducing mildew infection in black currants (*Ribes nigrum*) (Hummer and Picton, 2001) and in reducing white pine blister rust (caused by *Cronartium ribicola*) on *Ribes* (Picton and Hummer, 2003). Calpouzios (1966) mentions two disadvantages: that oil may not be effective against some of plant diseases, and that it may cause phyto-

toxicity. The object of this study was to determine if mineral oil, *Trichoderma*, or a combination of mineral oil + *Trichoderma*, could reduce powdery mildew on leaves and stems of susceptible gooseberries in contrast with control from the recommended commercial fungicide, thiophanate.

Materials and methods

'Industry' was chosen for this study based on preliminary observations of naturally occurring powdery mildew in the cultivated gooseberries at NCGR-Corvallis. 'Industry' is highly susceptible to powdery mildew (Brennan, 1996). In January 2002, 'Industry' plants were placed in the greenhouse in Corvallis, Ore., in a completely randomized design with four replicates of five treatments with a total of 20 plants. This study was conducted on 2-year-old plants that had not reached full fruiting capacity.

The treatments were applied at 2-week intervals from February 2002 through April 2002. They included an unsprayed control, mineral oil (JMS Stylet Oil; JMS Flowers Farms, Inc., Vero Beach, Fla.), *Trichoderma* (Plantshield; Bioworks Inc., Geneva, N.Y.), thiophanate (Cleary 3336; W.A.

Cleary Chem. Co., Summerset, N.J.), and a combination of mineral oil + *Trichoderma*. JMS Stylet-Oil, a highly refined paraffinic mineral oil with an unsulfonated residue of 99.1%, was sprayed on treated leaves until runoff at 8 mL·L⁻¹. PlantShield, a biologically active formulation of *Trichoderma harzianum* strain T-22 in a clay substrate, was applied at a rate of 4 g·L⁻¹. Thiophanate, the recommended chemical control of mildew on gooseberries (Pscheidt, 2002), was applied at 1.45 g·L⁻¹. The mineral oil + *Trichoderma* treatment was applied mixed at the same rates as above. All sprays were applied using a handheld 1.51-L (0.4-gal) sprayer.

In mid-April, the powdery mildew infection of leaves and stems on current year's growth was visually assessed by observing the undersides of the leaves. Infected and total leaves of the plant were counted, and the percent of infected leaves per plant was calculated. Young, green stems were also rated for mildew damage and a percent infection rating was given per plant. The leaf and stem surface area covered by fungal infection was visually rated by estimating the percent of the leaf surface showing mildew damage on a whole plant

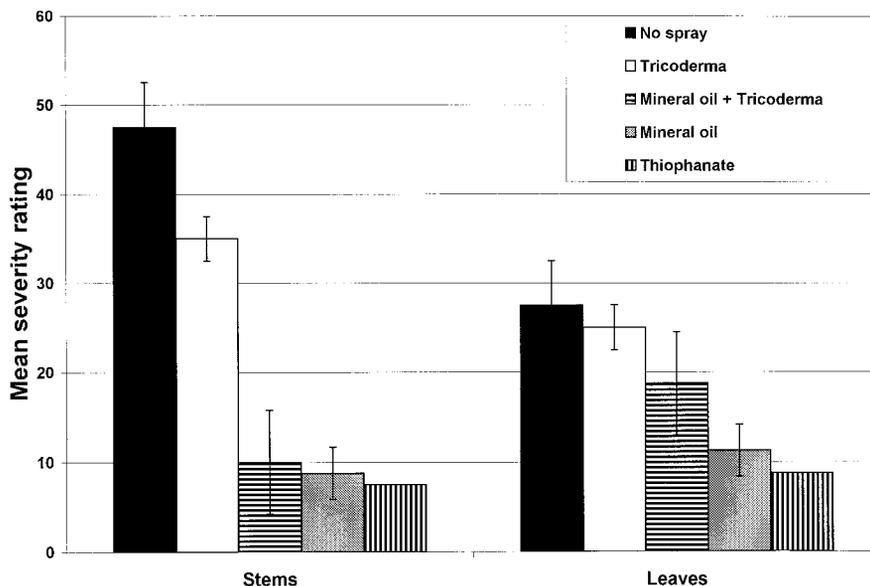


Fig. 1. Mean powdery mildew severity rating for leaves (percent infected leaves per plant) and stems (estimated percent area covered by infection), $n = 4$, for five treatments on 'Industry' gooseberry: 1) no spray, 2) *Trichoderma harzianum* strain T-22 in a clay substrate (*Trichoderma*) (Plantshield; Bioworks Inc., Geneva, N.Y.) at 4 g·L⁻¹ (0.5 oz/gal), 3) mineral oil (JMS Stylet Oil; JMS Flowers Farms, Inc., Vero Beach, Fla.) at 8 mL·L⁻¹ (1.0 fl oz/gal) + *Trichoderma* at 4 g·L⁻¹, 4) mineral oil at 8 mL·L⁻¹, and 5) thiophanate (Cleary 3336; W.A. Cleary Chem. Co., Summerset, N.J.) at 1.45 g·L⁻¹ (0.186 fl oz/gal) applied at 2-week intervals from Feb. 2002 through Apr. 2002. Disease severity ratings were taken on 21 Apr. 2002. Standard deviation = 0 for the mean thiophanate rating.

basis. Analyses of variance were applied to the percentages and ratings to determine significance of the treatments. Tukey's least square difference (LSD) test was applied to separate means.

Results and discussion

Analyses of variance for ratings on both leaves and stems were highly significant ($P < 0.0001$). All treatments were significantly better than the no-spray control for stem infection (Fig. 1). Thiophanate, mineral oil, or the mineral oil + *Trichoderma* treatments gave the best control ($P = 0.05$) for stem infection. For leaf infection, the thiophanate and the mineral oil treatments were significantly more effective at reducing powdery mildew than was *Trichoderma* alone or the no spray control (Fig. 1). The combination treatment was intermediate, providing significantly less control than the fungicide treatment but not significantly less than the oil treatment (Fig. 1). These results agree with previous studies for disease control using mineral oil (Hummer and Picton, 2001; Scheuerell and Mahaffee, 2000). The lack of powdery mildew control on leaves for mineral oil + *Trichoderma* may be due to an interaction between a component of the biological control and the oil that reduced the coating capacity of the oil on the leaf. *Trichoderma* alone did not significantly reduce leaf infection (Fig. 1). Unfortunately, in this treatment we observed an increased level of leaf necrosis not caused by mildew. This damage was not observed in the other treatments. The damage appeared in the same vicinity as the mildew area. We do not recommend *Trichoderma* alone to control powdery mildew on gooseberries.

The powdery mildew reduction of the mineral oil or the combination of mineral oil + *Trichoderma* treatments were not statistically different than that of the thiophanate, which is reported as commercially acceptable. We recommend the application of mineral oil or mineral oil + *Trichoderma*, as alternatives to fungicide in reducing powdery mildew in leaves and stems of young, greenhouse-grown gooseberry plants. Further study is needed to determine effective controls of gooseberry fruit mildew using environmentally friendly materials.

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