Control of Hop Downy Mildew with Systemic Fungicides

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ABSTRACT

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Four systemic fungicides (metalaxyl, M 9834, propamocarb, and efosite aluminum) were evaluated for control of the systemic infection phase of hop downy mildew (*Pseudoperonospora humuli*) during 1979–1981. Metalaxyl applied to the soil surface over the perennial hop crown area in April resulted in nearly complete control and increased yields significantly. Treatment with M 9834 resulted in control comparable to metalaxyl up to 4 wk after application, but disease incidence increased sharply after 6 wk. Propamocarb and efosite aluminum were less effective than metalaxyl or M 9834 but gave substantial disease control. The possibility of using metalaxyl and a broad-spectrum fungicide in alternate years to avoid selection of fungal strains tolerant to metalaxyl is discussed.

Additional key words: fungicide resistance, fungicide tolerance

Hop downy mildew, caused by *Pseudoperonospora humuli* (Miy. & Tak.) Wils., is the primary disease problem on hops (*Humulus lupulus* L.) in the United States (1,7). *P. humuli* overwinters in the perennial rootstock (crown) of hop plants (3,7,8). Systemically infected buds emerge in spring and form distorted shoots called primary basal spikes. Zoosporangia produced on basal spikes function as primary inoculum. Abundant moisture and mild temperatures favor sporulation, spread of zoosporangia, and secondary infection by zoospores (3,7,8). When secondary infections occur on shoot meristems, they become systemic, resulting in the formation of secondary basal, lateral, or terminal spikes. Localized infections also occur, causing leaf spots, flower blight, and partial to complete fruit blight. Healthy hop crowns become infected either by movement of mycelium down systemically infected shoots or by zoospores (4,7,8). Oospores are produced, especially in infected fruits, but their role in the disease cycle has not been clearly established (3,7,8).

Infection of highly susceptible cultivars (eg, Cluster, Comet, and Talisman) usually results in crown rot and plant death. Thus, these cultivars are grown in Washington, Idaho, and California where hot and dry climates usually suppress disease development. Cultivars with some tolerance to crown rot (eg, Fuggle, Cascade, Bullion, and Brewer's Gold) are grown in the Willamette Valley of Oregon, where rainfall and mild temperatures during April and May favor disease development. However, mildew control on these cultivars is important because shoots, leaves, and fruits are susceptible to the disease. The protectant fungicide zineb and various copper formulations have been used to control hop downy mildew. However, poor control is achieved with these nonsystemic fungicides. Thus, field trials were conducted in Oregon during 1979–1981 to identify a systemic fungicide effective in controlling hop downy mildew.

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MATERIALS AND METHODS

Field trials with metalaxyl and M 9834. Metalaxyl (Ridomil 2 EC, Ciba-Geigy Corp.) was tested in 1979 at five commercial hop fields in the Willamette Valley (cultivars Cascade, Bullion, and Brewer's Gold). A total of 2,029 plants were treated with metalaxyl at 0.3 g/plant in 50 ml of water. In 1980, metalaxyl was tested at three commercial fields (Cascade, Bullion, and Brewer's Gold). Fungicide was applied at 0.3 and 0.6 g/plant in 100 ml of water. Eighty-four plants per rate were treated at each field plot. Metalaxyl was applied in 100 ml of water in 1980 to determine whether phytotoxicity observed in 1979 could be avoided by diluting the spray concentration. Metalaxyl was applied in both years in mid-April with a model 1730A Root-Lowell sprayer (8-L capacity) by distributing a coarse spray directly over the crown area when the longest emerging shoots were 5–10 cm long. Spikes (basal, lateral, and terminal) on metalaxyl-treated and control plants were counted at the time of metalaxyl application and at 2-wk intervals for 12 wk.

Control of hop downy mildew by metalaxyl and M 9834 (Galben 20% LC, Montedison Research Laboratories) was compared in 1981 at two commercial fields (Cascade and Bullion). Fungicides were applied as in 1979 and 1980 at 0.3 and 0.6 g/plant in 50 ml of water using 50 plants per treatment at each location. Spikes in treated and control plants were counted 1, 2, 4, 6, and 10 wk after application.

Yield trials were conducted at two fields in 1979 (Cascade and Brewer's Gold) and at one field in 1981 (Cascade). In 1979, three replicates of five plants each were selected from each treatment (metalaxyl and control) by use of a random numbers table. In 1981, six plants per treatment were selected by the same method. Vines were removed, picked with a small mechanical hop picker, and fresh weights of hop fruits were recorded.

Field trials with propamocarb and efosite aluminum. Propamocarb (Previcur-N 6 LC, Nor-Am, Inc.) and efosite aluminum (efosite Al; Aliette WP 80%, Rhone-Poulenc, Inc.) were tested at three commercial fields in 1980. Propamocarb was applied at 1.17, 2.34, and 4.68 g per plant. Efosite Al was applied at 0.22, 0.44, and 0.88 g/plant. Fungicides were applied in 100 ml of water in mid-April to 50 plants at each field plot. Disease control was determined by counting spikes in treated and control plants every 2 wk after application for 8 wk.

RESULTS

Field trials with metalaxyl and M 9834. Results of field trials with metalaxyl and M 9834 in 1979, 1980, and 1981 are presented (Table 1). No differences in disease control with metalaxyl or any of the other fungicides were observed between cultivars. In 1981, treatment with metalaxyl and M 9834 resulted in complete disease control for 4 wk after application. However, after 6 wk, 926, 92, and 34 spikes were observed on plants treated with 0.0, 0.3, and 0.6 g of M 9834 per plant, respectively. In comparison, only six and seven spikes were observed after 6 wk on plants treated with 0.3 and 0.6 g of metalaxyl, respectively. On plants treated with metalaxyl and M 9834, spikes became necrotic after 1–2 wk and were no longer inoculum sources.

Some chlorosis and necrosis of leaf margins occurred on plants treated with metalaxyl and M 9834 in 1979. However, this phytotoxicity caused no production problems and was greatly reduced by applying fungicide either prior to shoot emergence (R. M. Hunger and C. E. Horner, *unpublished*) or in 100 ml of water per plant. No phytotoxicity was observed following application of propamocarb or efosite Al.

Hop plants treated with metalaxyl or M 9834 yielded more hops than an equal number of control plants (Table 2). However, statistically significant yield increases were obtained only with metalaxyl.

Treatment with propamocarb and efosite Al resulted in statistically significant control of downy mildew (Table 3). This was especially true at the higher rates of propamocarb. Some spikes present at the time of fungicide application became necrotic, but many were unaffected and continued to support sporulation by the fungus.

DISCUSSION

A single application of metalaxyl at 0.3 g/plant (574 g/ha) in mid-April provided almost complete control of hop downy mildew until hot, dry weather in early July naturally inhibited the disease. Treatment with M 9834 provided disease control comparable to metalaxyl for 4 wk; after 4 wk, however, increased disease on plants treated with M 9834 resulted in lower yields compared with plants treated with metalaxyl.

Zaki et al (10) studied the translocation of radioactive carbon (^{14}C) in *Persea indica* plants following application of labeled metalaxyl as a soil drench. They concluded that labeled fungicide was readily taken up by *P. indica* roots and that radioactivity was translocated uniformly to the plant parts above. The abundant rainfall in the Willamette Valley of Oregon during April ensures that metalaxyl is drenched into the root zone, and we suspect that the high level of disease control obtained with metalaxyl may result from efficient uptake and translocation of the chemical. M 9834 is not as water soluble as metalaxyl (37 and 7,100 mg/L at 20 C: technical bulletins from Montedison Laboratories and Ciba-Geigy, Inc., respectively), and may not be as effectively taken up by hop roots. Less efficient uptake of M 9834 could explain the higher disease incidence observed after 6 wk on plants treated with M 9834 as compared with those treated with metalaxyl.

Propamocarb and efosite Al were not as effective as metalaxyl or M 9834 in controlling hop downy mildew. However, *P. humuli* strains tolerant to metalaxyl probably would be tolerant to M 9834 because cross-tolerance has been demonstrated in vitro (2). Thus, propamocarb and efosite Al may be desirable alternate controls of this disease if strains tolerant to metalaxyl occur because their chemical structures are unrelated to metalaxyl or M 9834.

Alternating applications of multisite fungicides with site-specific fungicides have been suggested to avoid development of fungal strains tolerant to site-specific fungicides (9). Thus, we feel that the occurrence of *P. humuli* strains tolerant to metalaxyl may be delayed or averted entirely if treatment with metalaxyl is alternated yearly with zineb or a copper fungicide. Metalaxyl was applied in 1981 under emergency registration to all commercial hop fields in Oregon planted with the cultivars Cascade, Bullion, and Brewer's Gold. Although weather conditions were extremely favorable for mildew development from mid-April through late June, virtually complete control of downy mildew was obtained by growers. Thus, primary inoculum for the following year should be reduced greatly, and application of zineb or a copper fungicide in alternate years should decrease the pressure to select for *P. humuli* strains tolerant to metalaxyl. This may be important because stable tolerance to metalaxyl has been reported in another species of *Pseudoperonospora* following intensive use of metalaxyl (5,6).

Table 1. Control of hop downy mildew in Oregon with metalaxyl and M 9834

Fungicide[y]	Rate (g/plant)	Total number of spikes observed after fungicide treatment[z]		
		1979	1980	1981
Control	0.0	19,858	814	1,968
Metalaxyl	0.3	90	1	7
Metalaxyl	0.6	...	1	7
M 9834	0.3	...	...	297
M 9834	0.6	...	...	139

[y] Fungicides were applied in 50 ml of water per plant in 1979 and in 100 ml of water per plant in 1980 and 1981.

[z] Tests were located at five commercial hop fields in 1979 (cultivars Bullion, Cascade, and Brewer's Gold), three fields in 1980 (Bullion, Cascade, and Brewer's Gold), and two fields in 1981 (Bullion and Cascade). Values presented are the total number of spikes counted six, six, and five times during 1979, 1980, and 1981 on 2,029, 252, and 100 plants, respectively.

Table 2. Effect of metalaxyl and M 9834 treatments on hop yields

Cultivar	Fungicide	Rate (g/plant)	Fresh weight of hop fruits (g)[z]	
			1979	1981
Brewer's Gold	Control	0.0	16,666.7	...
Brewer's Gold	Metalaxyl	0.3	20,766.7*	...
Cascade	Control	0.0	13,483.3	3,233.3 a
Cascade	Metalaxyl	0.3	23,816.7*	4,516.7 b
Cascade	Metalaxyl	0.6	...	4,650.0 b
Cascade	M 9834	0.3	...	3,566.7 a
Cascade	M 9834	0.6	...	4,016.7 ab

[z] Fresh weights are the averages of three replicates (five plants each) and six replicates (one plant each) in 1979 and 1981, respectively. In 1979, an asterisk indicates significant difference (unpaired *t* test; $P = 0.05$). In 1980, fresh weights not followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 3. Control of hop downy mildew in Oregon with propamocarb and efosite aluminum during 1980

Fungicide[x]	Rate (g/plant)	Number of spikes observed after fungicide application	
		Total[y]	Mean[z]
Control	0.0	404	134.7 a
Efosite Al	0.22	266	88.7 b
Efosite Al	0.44	178	59.3 c
Efosite Al	0.88	174	58.0 c
Propamocarb	1.17	158	52.7 cd
Propamocarb	2.34	111	37.0 de
Propamocarb	4.68	85	28.3 e

[x] All fungicides were applied in 100 ml of water per plant on 17 April 1980.

[y] Each value is the number of spikes on 150 plants at three commercial hop fields (cultivars Cascade, Bullion, and Brewer's Gold) observed three times after fungicide application.

[z] Means not followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test and split-plot-in-time analysis of variance.

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