Field Evaluation of Various Fungicides to Control Cercospora Leaf Spot of Sugarbeet, Caused by Benomyl-Resistant Strains of Cercospora beticola*

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INTRODUCTION

Cercospora leaf spot of sugarbeet (*Beta vulgaris* L.), caused by *Cercospora beticola* Sacc., has caused recurring, widespread, and severe crop losses throughout the U.S.A. (1,2,5,7). The incidence and severity of Cercospora leaf spot caused by benomyl-resistant strains of *C. beticola* has increased in recent years in the sugarbeet growing areas of Minnesota, North Dakota and Arizona (3,4,6,9). Also, these benomyl-resistant strains were cross resistant to the related systemic fungicides thiophanate and thiabendazole (1,3). During the past 2 years, eight systemic and three protectant fungicides were evaluated extensively for their effectiveness in controlling Cercospora leaf spot in areas where benomyl-resistant strains of *C. beticola* predominate. The purpose of this paper is to identify the fungicide(s) that, alone or in combination, controlled benomyl-resistant strains of *C. beticola* in the field.

MATERIALS AND METHODS

Fungicides. The following chemicals were field-tested at the stated rates of the product for the control of Cercospora leaf spot of sugarbeet: benomyl [systemic; methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate], 0.6 kg/ha; CG-71818 experimental systemic (CIBA-Geigy Corp. Greensburo, NC), 1.7 kg/ha; imazalil [systemic; 1-°2,(2.4-dichlorophnyl)-2-(2-propenyloxy) ethyl+1-H-imidazole], 1.4 L/ha; mancozeb (protectant; coordinate product of zinc ion and ethylene bisdithiocarbamate), 2.3 kg/ha; nuarimol

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[systemic; alpha-(2-chlorophenyl)-alpha-(4-fluorophenyl)-5 pyrimidinemethanol], 1.4 l/ha; propiconazol [systemic 7-bromo-5-chloro-quinolin-8 yl acrylate], 0.4 L/ha; RH-5787 and RH-3866, two experimental systemics (Rohm & Haas Company, Philadelphia, PA), 1.7 and 1.1 L/ha, respectively; thiabendazole [systemic 2-(4-thiazolyl)-benzimidazole], 0.6 kg/ha; triphenyltin hydroxide (TPTH, protectant; Griffin AG Products Co., Inc. Valdosta, GA), 0.4 L/ha; and Uniroyal A-1055 experimental protectant (Uniroyal Chemical, Bethany, CT), 0.6 kg/ha. Additionally, a combination of mancozeb and TPTH was applied at 2.3 and 0.4 kg/ha, respectively.

Five applications of protectant and systemic fungicides were applied on a 10- and 14-day schedule respectively, beginning 11 days after inoculation. The chemicals were applied with a ground sprayer delivering 151.4 L/ha at 160 psi. Control plots were inoculated and sprayed with water.

Field trials. A randomized split-block design with four replicates was used. In 1984 and 1985 each plot consisted of two cultivars: AC 14 (American Crystal Sugar Company), and Beta 1230 (Beta Seed Company), planted in four 9-m rows spaced 56-cm apart. Only the inner two rows of each treatment plot were harvested. There were 12 chemical treatments and an untreated control plot for each cultivar. The herbicide Ro-Neet (S-ethylcyclohexyl-ethyl-thiocarbamate); Stauffer Chemical Co., Westport, CT) was applied at 3.0 L/ha 30 days before planting. Seedlings were thinned to one per 23 cm of row length. The herbicide Betamix (coordinated product of phenmedipham and desmedipham esters; Nor-Am Chemical Co., Willmington, DE) was applied at 6.2 L/ha 45 days after plant emergence. Forty days after planting, plants were inoculated with dried, ground *C. beticola* infected sugarbeet leaf material, mixed with talcum powder (1:22 w/w), at 4.5 kg/ha with a modified potato duster 60 days after planting. Ten days after inoculation *C. beticola* was isolated from the resultant lesions and evaluated *in vitro* for resistance to 5 ug/ml

of benomyl (3). In 1984 and 1985, benomyl-resistant strains accounted for 82 and 84%, respectively, of 500 single condium isolates recovered.

An overhead irrigation system that delivered approximately 5 cm of water/ha was utilized biweekly throughout the growing season to ensure a sustained and severe Cercospora leaf spot epidemic.

Plant Evaluation. We made three disease ratings, using a 0 to 10 scale where 0 is completely healthy and 10 is 100% leaf area infected at 30, 60, and 90 days after inoculation. Statistical analysis of disease severity data was performed at 90 days, the height of the epidemic. Sugarbeet root quality and dollar return/ha were obtained from the American Crystal Sugar Company Quality Laboratory, East Grand Forks, Minnesota. (Because error variances from both years were homogeneous, over all ANOVA's were performed on pooled sums of squares for both years.) Means in all tests were separated using Duncan's multiple range test at $P = 0.05$.

RESULTS

All the protectant fungicides resulted in significant increases in root yield, % sucrose, % recoverable sucrose in beet pulp and dollars returned/ha (American Crystal Sugar Co., Dry Formula) for cultivar AC 14 (Table 1). The tank mix of mancozeb and TPTH gave the greatest yield % sucrose and dollar return/ha as compared to the unsprayed control. Triphenyltin hydroxide alone was not significantly different from the mancozeb-TPTH tank mix, except in dollar return/ha ($1432 vs $1515, respectively). Mancozeb alone resulted in significantly less yield, % sucrose, and dollar return/ha when compared with TPTH alone, or in combination with TPTH. All three systemic fungicides, except RH-5787, thiabendazole, RH-3866, and benomyl showed significant increased yields, and % sucrose over the control. All except benomyl resulted in decreased disease severity as compared with the control. Propiconazol resulted in the highest yield, % sucrose, recoverable sucrose, dollar return/ha, and lowest disease

Table 1. Control of Cercospora leaf spot by several different fungicides applied five times on sugarbeet cultivar AC 14.

Treatment	Yield t/ha	Sucrose %	Recoverable sucrose(%)	Disease severity(%)	Return/ha $
Mancozeb 80 W plus Triphenyltin hydroxide 40% F	51.2 a+/	16.2 a	75.6 a	1.0 c	1515 a
Triphenyltin hydroxide	49.2 a	16.2 a	74.1 a	1.0 c	1432 b
Propiconazol 3.6% EC	46.8 b	16.0 a	73.8 a	1.0 c	1400 b
CG-71818 3.6% EC	45.2 c	15.5 ab	73.0 ab	21.0 b	1313 c
Mancozeb 80 W	45.2 c	15.3 b	72.0 ab	25.0 b	1292 c
Nuarimol 9% EC	43.8 d	14.8 b	71.1 ab	0.6 c	1242 cd
A-1055 15 W	42.8 d	14.8 b	70.1 b	30.5 b	1222 cde
Imazalil 20% EC	41.8 de	14.5 bc	69.3 bc	11.0 c	1152 e
RH-5787 2% EC	40.0 ef	14.3 c	69.2 bc	12.0 c	932 f
Thiabendazole 42.3% F	39.2 ef	14.3 c	69.0 c	36.0 b	875 f
RH-3866 2% EC	39.2 ef	14.3 c	66.0 d	13.5 c	805 fg
Benomyl 50 W	39.2 ef	14.3 c	62.8 e	70.0 a	792 g
Control	38.0 f	14.2 c	62.5 e	75.0 a	726 h

+/Mean values of eight pooled samples from two experiments. Mean in each column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

severity of any systemic tested. However, CG-71818 and nuarimol produced no significant differences from propiconazole in % sucrose, recoverable sucrose, or dollar return/ha. In plots treated with Uniroyal A-1055, yield, sucrose, % recoverable sucrose, and dollar return/ha were not significantly different from nuarimol or imazalil. Systemic fungicides RH-5787, thiabendazole, and RH-3866, significantly suppressed Cercospora leaf spot, resulting in small but significant increases in % recoverable sucrose and dollar return as compared with the control.

All systemic fungicides evaluated on sugarbeet cultivar Beta 1230, except for benomyl, resulted in significant increases in root yield, and dollar return/ha, and decreased disease severity as compared with the inoculated but unsprayed control (Table 2). Systemic fungicides RH 3866 and benomyl did not significantly increase % recoverable sucrose; however, RH-5787 showed a higher % sucrose and % recoverable sucrose than the control. Systemic fungicides propiconazol and nuarimol resulted in low disease severity ratings (1.4 and 2.9%, respectively) and the high yields, % sucrose, % recoverable sucrose, and dollar return. There were no significant differences between propiconazol and nuarimol. Experimental systemic fungicide CG-71818 provided good disease control, high yield, % recoverable sucrose and dollar return/ha. Thiabendazole and A-1055 were significantly different from each other in leaf spot control and the resulting % sucrose, recoverable sugar, or dollar return/ha. Imazalil did provide significant disease control, and higher % sucrose, % recoverable sucrose, and dollar return as compared with the control. Systemic chemical CG-71818 resulted in significantly less yield, % sucrose, % recoverable sucrose, and dollar return/ha as compared with propiconazol or nuarimol. Systemic fungicides RH-5787, RH-3866, and benomyl were not significantly different from each other in % sucrose and dollar return/ha. RH-5787 and RH-3866 did not significantly differ from each other except in the % sucrose recovered. Benomyl was not significantly different than the

Table 2. Control of Cercospora leaf spot by several different fungicides applied five times on sugarbeet cultivar Beta 1230.

Treatment	Yield t/ha	Sucrose %	Recoverable sucrose(%)	Disease severity(%)	Return/ha $
Propiconazol 3.6% EC	58.0 a+/	15.5 b	73.3 a	2.0 f	1740 a
Nuarimol 9%	56.0 a	15.5 b	73.5 a	3.0 d	1710 a
Triphenyltin hydroxide 40% F	53.7 ab	15.8 b	72.3 ab	1.0 f	1413 b
Mancozeb 80 W plus Triphenyltin hydroxide 40% F	55.0 ab	15.9 ab	74.9 a	1.0 f	1313 c
CG-71818 3.6% EC	50.8 b	14.9 c	71.0 b	8.0 f	1265 cd
Mancozeb 80 W	46.3 c	16.6 a	72.1 ab	3.0 f	1223 cd
Thiabendazole 42.3% F	46.2 c	16.2 a	74.2 a	26.0 c	1305 c
A-1055 15 W	46.2 c	16.8 a	72.9 ab	11.0 e	1212 d
Imazalil 20% EC	48.8 bc	15.3 bc	71.6 b	20.5 d	995 e
RH-5787 2% EC	42.4 d	13.4 d	67.6 c	50.0 b	892 f
RH-3866 2% EC	45.2 cd	13.1 de	65.5 d	46.0 b	852 f
Benomyl 50 W	38.8 e	13.7 d	64.2 d	75.0 a	790 fg
Control	38.8 e	12.9 e	65.6 d	75.0 a	750 g

+/Mean values of eight pooled samples from two experiments. Mean in each column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

control in root yield, % recoverable sucrose, disease severity, and dollar return/ha.

All the protectant fungicides tested on sugarbeet variety Beta 1230 resulted in a significant reduction of leaf spot severity and increases in root yield, % sucrose, % sucrose recovered, and dollar return/ha as compared with the control (Table 2). Triphenyltin hydroxide was not significantly different than propiconazol or nuarimol for all parameters. The tank mix TPTH and mancozeb was not significantly different than TPTH alone, except in dollar return/ha. Mancozeb did not perform significantly different from the tank mix, except for root yield.

Impurity analysis data (Na, K, and amino-N) indicated that the various fungicide treatments were not significantly different from each other regardless of cultivar. However, benomyl and the controls had significantly higher amino-N impurity values for both cultivars.

DISCUSSION

Tests of 11 different fungicides in 1984 and 1985 indicated that several systemic and two protectant fungicides were effective in suppressing benomyl-resistant strains of *C. beticola* in the field. However, both benomyl and thiabendazole failed to give sufficient disease control, and treated plants did not result in high quality sucrose or dollar returns.

Chemical effectiveness was somewhat dependent upon the inherent susceptibility of the particular sugarbeet cultivar in our trials. Coded cultivar trials have consistently indicated that AC 14 is somewhat more resistant to *C. beticola* than Betaseed 1230 (8). Therefore, the apparent efficacy of a particular protectant or system fungicide may be moderated by the host. In general, the systemic chemicals propiconazol and nuarimol resulted in consistent disease control, with subsequent high sucrose and dollar return. The protectant TPTH alone or in combination with mancozeb resulted in excellent disease control and sucrose recovery equal to propiconazol and nuarimol.

Since benomyl-resistant strains of *C. beticola* that have been found throughout the sugarbeet growing areas of Minnesota and North Dakota (3) also are cross-resistant to other benzimidazoles, and thiabendazole, currently the only systemic fungicides labeled for sugarbeets, the use of these and related compounds should cease. The possible future use of propiconazol and/or nuarimol, if registration can be achieved, in conjuction with TPTH alone or combined with mancozeb, should result in effective control of Cercospora leaf spot. Since ergosterol-suppressent systemics have resulted in the occurrence of resistant pathogen strains in other crop/fungus systems, the exclusive use of any selective systemic with single-site activity should be avoided.

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