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Effectiveness of Copper Sulfate Pentahydrate, Mancozeb, and Hydrogen Dioxide in Controlling Anthracnose on Wintercreeper Euonymus[1]

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Abstract

Plants of three cultivars of wintercreeper euonymus (*Euonymus fortunei* (Turcz.) Hand.-Mazz. 'Emerald Gaiety', 'Emerald 'n Gold' and 'Canadale Gold') were sprayed to runoff weekly with one of three fungicide treatments in 2003 or one of four fungicide treatments in 2004 or water (control) to determine fungicide effectiveness in controlling anthracnose caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. Copper sulfate pentahydrate was applied at 0.4 or 0.6 g ai/liter (0.05 or 0.08 oz/gal) or mancozeb was applied at 1.8 g ai/liter (0.2 oz/gal) in 2003 and 2004 while hydrogen dioxide was applied at 1.1 mL ai/liter (0.1 fl oz/gal) in 2004. Plants were rated for disease symptoms monthly. Cultivars differed at every rating date at both sites in both years with 'Emerald 'n Gold' typically having the highest (worst) disease ratings. 'Canadale Gold' usually had the lowest (best) disease ratings while 'Emerald Gaiety' was intermediate in disease ratings. No differences in disease rating occurred among fungicide treatments in 2003, but plants treated with mancozeb had the lowest disease ratings in 2004. Inhibition of mycelial growth of two isolates of *C. gloeosporioides* from wintercreeper euonymus by mancozeb or copper sulfate pentahydrate was tested *in vitro* at 0, 1, 3.2, 10, 31.6, 100, 316, and 1000 ppm ai. Mycelial growth inhibition of both isolates increased curvilinearly as mancozeb or copper sulfate pentahydrate $\log_{10}$ concentration increased. Copper sulfate pentahydrate caused less than 50% inhibition of mycelial growth at all rates tested. The effective concentration to provide 50% inhibition (EC_{50}) of mancozeb on isolate 415 was 645.7 ppm and on isolate 423 was 602.6 ppm.

Index words: *Colletotrichum gloeosporioides*, disease control, *Euonymus fortunei*, fungicide.

Chemicals used in this study: Phyton-27 (copper sulfate pentahydrate); Protect (mancozeb) (a coordination product of zinc ion and manganese ethylene bis dithiocarbamate); ZeroTol (hydrogen dioxide); Snapshot 2.5 TG [(trifluralin) (2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine) and (isoxaben) (*N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide)].

Significance to the Nursery Industry

Anthracnose causes significant crop losses during production of wintercreeper euonymus. Identification of control measures that are effective in reducing disease will reduce economic losses due to poor plant quality or plant death. Alternatively, identifying ineffective practices can help producers adjust management programs to most cost effectively produce the crop. Use of fungicides that do not adequately control the target disease organism are costly and can adversely affect the environment. Several fungicides are labeled for control of anthracnose caused by *Colletotrichum gloeosporioides* on wintercreeper euonymus, but efficacy tests indicate that some of these fungicides are not effective. Results of this study indicate that mancozeb sometimes reduces but does not eliminate disease symptoms when used according to label directions, but copper sulfate pentahydrate and hydrogen dioxide failed to protect wintercreeper euonymus from anthracnose.

Introduction

With its often variegated foliage, wintercreeper euonymus is a popular evergreen landscape shrub used to add color to the landscape. Numerous cultivars have been described (2, 12). Each cultivar is prized for its particular pattern of growth and leaf variegation including green, white, yellow, gold, orange, pink, red, maroon and purple. Many nursery producers depend on wintercreeper euonymus for consistent profits due to the number of cultivars available and their popularity with consumers.

Wintercreeper euonymus, however, is susceptible to anthracnose caused by *C. gloeosporioides* during production and in the landscape. Symptoms of anthracnose include leaf and stem lesions, stem dieback, and defoliation. Anthracnose is difficult to control, and control measures are costly for nurseries. Because of the high cost of disease control, wintercreeper euonymus has been eliminated from production by some nurseries.

Evidence of increased fungicide resistance has been noted since anthracnose on wintercreeper euonymus was first described. Initially maneb, mancozeb, and chlorothalonil eliminated anthracnose symptoms on wintercreeper euonymus (6, 7), but in later studies efficacy was less (1, 4, 5, 8, 11). Other fungicides including thiophanate-methyl (4, 5, 8), copper hydroxide (1, 4, 5), azoxystrobin (1, 4), myclobutanil (1), trifloxystrobin (1, 8, 11), propiconazole (8) and iprodione (5) were tested with little success in controlling anthracnose symptoms. LaMondia (4, 5) found that resistance to multiple fungicides was common and suggested that use of several different fungicides in a tank mixture or rotation provided better control of *C. gloeosporioides* than the use of a single fungicide when chemicals with different modes of action were used. Ningen (8) tested chlorothalonil, trifloxystrobin, mancozeb, propiconazole, and thiophanate-methyl alone, in rotations, and in mixtures and found that mancozeb alone or in rotations with chlorothalonil provided

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better control of *C. gloeosporioides* than mixtures or rotations of fungicides without mancozeb or chlorothalonil. No fungicide, however, eliminated *C. gloeosporioides* symptoms.

The objectives of this study were to determine 1) the effectiveness of mancozeb, copper sulfate pentahydrate, and hydrogen dioxide in controlling anthracnose symptoms on wintercreeper euonymus plants in production, and 2) the effectiveness of mancozeb, and copper sulfate pentahydrate on mycelial growth inhibition of *C. gloeosporioides in vitro*. Mancozeb and copper sulfate pentahydrate are labeled for control of *C. gloeosporioides* on wintercreeper euonymus, but these fungicides have not provided acceptable control in nurseries during recent years. We found no published studies testing the effect of copper sulfate pentahydrate or hydrogen dioxide for control of anthracnose on wintercreeper euonymus.

Materials and Methods

2003. Rooted cuttings of wintercreeper euonymus (Greenleaf Nursery Co., Park Hill, OK) 'Emerald 'n Gold,' 'Emerald Gaiety,' and 'Canadale Gold' were planted in #1 containers with media consisting of pine bark:sand (6:1 by vol) amended with 3 kg/m^3 (5 lb/yd^3) dolomitic lime, 889 g/m^3 (1.5 lb/yd^3) 0N–20P–0K (triple superphosphate), 259 g/m^3 (0.4 lb/yd^3) 0N–0P–49.8K (KCl), 111 g/m^3 (0.2 lb/yd^3) trace elements (Frit 504 HF, Frit (U.K.) Ltd., Cambridge, UK), 889 g/m^3 (1.5 lb/yd^3) $FeSO_4$, 741 g/m^3 (1.3 lb/yd^3) 46N–0P–0K (urea), and 1.2 kg/m^3 (2 lb/yd^3) Fe_2O_3 (GU-49, Master Builders, Inc., Cleveland, OH) and placed under 47% shade. The study was initiated May 12 and terminated October 1 at the Oklahoma State University Nursery Research Station, Stillwater, OK, and initiated May 17 and terminated September 16 at Greenleaf Nursery Co., Park Hill, OK. Photosynthetic photon flux (PPF) was determined periodically using an Integrating Quantum/Radiometer/Photometer (Model No. LI-188B, LI-COR, Inc., Lincoln, NE). Maximum PPF was about 1073 µmol/m^2/s at plant height at both sites. Cuttings were randomly taken from presumably anthracnose-infected mother plants in the field. High disease incidence in the field eliminated the need to artificially inoculate. Symptomatic leaves and stems were collected from plants throughout the growing season and cultured on potato dextrose agar to confirm the identity of the causal organism. Plants at both sites were irrigated with about 2.5 cm (1 in) of water daily with overhead sprinkler irrigation. Snapshot (Dow AgroSciences, Indianapolis, IN) was applied on June 2 at Park Hill and June 9 at Stillwater at 112 kg/ha (100 lb/A) for weed control. Plants were hand-weeded as necessary thereafter. Standard nursery practices at Greenleaf Nursery determined timing of cultural activities such as shearing.

Plants were sprayed to runoff [about 89 mL/m^2 (2.5 fl oz/yd^2)] weekly with the following fungicide treatments: copper sulfate pentahydrate (Phyton Corp., Bloomington, MN) at 0.4 g ai/liter (0.05 oz/gal), copper sulfate pentahydrate at 0.6 g ai/liter (0.08 oz/gal), mancozeb (Cleary Chemical Corp., Dayton, NJ) at 1.8 g ai/liter (0.24 oz/gal) or water (control). Plants were rated for anthracnose symptoms when the study was initiated and at four week intervals thereafter until the end of the growing season. Disease ratings were on a scale of 1 to 12 based on the Horsfall-Barratt plant disease assessment system where: 1 = no diseased tissue, 2 = 1–3% diseased tissue, 3 = 4–6% diseased tissue, 4 = 7–12% diseased tissue, 5 = 13–25% diseased tissue, 6 = 26–50% diseased tissue, 7 = 26–50% disease free tissue, 8 = 13–25% disease free tissue, 9 = 7–12% disease free tissue, 10 = 4–6% disease free tissue, 11 = 1–3% disease free tissue, 12 = no disease free tissue (3).

The experimental design was a split-plot with 20 replications at each site. Fungicide was the main plot (4 treatments) and cultivar was the subplot (3 cultivars). Data were analyzed using PROC GLM (SAS Institute, Inc., Cary, NC). Means of significant interactions and main effects were separated using a protected least significant difference (LSD) procedure. The results at each site were analyzed independently. Only significant main effects or interactions are presented.

2004. The study described above was repeated with the addition of hydrogen dioxide (BioSafe Systems, Glastonbury, CT) at 1.1 mL ai/liter (0.14 fl oz/gal) as a fungicide treatment. The study was initiated May 17 and terminated October 8 at Stillwater and initiated May 19 and terminated October 4 at Park Hill. Snapshot was applied June 7 at Stillwater and June 3 at Park Hill for weed control. Maximum PPF was about 1210 µmol/m^2/s at both sites. Daily average high and low temperatures were recorded (Table 1) using a datalogger (Watchdog 425, Spectrum Technologies, Plainfield, IL).

Poison agar study. Leaf and stem samples with lesions were collected from wintercreeper euonymus and cultured to confirm the presence of *C. gloeosporioid*es. Two distinct isolates were selected for fungicide tests. The isolates differed in colony color and growth rate *in vitro*. Isolate 415 had white mycelium and a fast growth rate and isolate 423 had dark grey mycelium and a slower growth rate. Koch's postulates were tested and pathogenicity was confirmed for both isolates.

A solution containing 3.9 g (0.1 oz) potato dextrose agar and 90 ml (3 fl oz) water was prepared in each of seven 250 ml (8.5 fl oz) Erlenmeyer flasks. Flasks were covered with aluminum foil and autoclaved for 20 min. After autoclaving, the flasks were placed in a waterbath at 49C (120F) for ten minutes. Ten ml (0.3 fl oz) of stock solution at the appropriate concentration was added to each Erlenmeyer flask to create final concentrations of 1, 3.2, 10, 31.6, 100, 316, and 1000 ppm of fungicide. These concentrations were chosen because they provide equal intervals on a $\log_{10}$ scale. Sepa-

Table 1. Average daily high and low temperatures between rating dates for anthracnose damage on container-grown wintercreeper euonymus at Park Hill, OK, and Stillwater, OK, in 2004.

Location	Interval between rating dates	Average daily temperature (C) ± s.d.[z]	
		High	Low
Park Hill	May 20 to June 16	29.2 ± 2.1	20.1 ± 3.1
	June 17 to July 13	30.5 ± 2.8	20.2 ± 1.9
	July 14 to August 3	30.9 ± 2.4	20.3 ± 2.4
	August 4 to September 8	30.3 ± 2.4	18.8 ± 3.6
	September 9 to October 4	29.9 ± 2.5	16.4 ± 3.4
Stillwater	May 18 to June 14	33.0 ± 3.9	18.6 ± 3.8
	June 15 to July 14	33.6 ± 4.0	19.0 ± 2.5
	July 15 to August 9	33.9 ± 5.6	19.2 ± 2.5
	August 10 to September 10	33.1 ± 3.3	19.1 ± 4.4
	September 11 to October 8	31.7 ± 3.7	14.2 ± 4.6

[z]Average daily high and low temperatures were calculated by summing the daily high and low temperatures, respectively, through the dates shown and dividing by the number of days in the interval between rating dates. s.d. = standard deviation.

Table 2. Disease ratings of three cultivars (pooled over fungicide treatments) of wintercreeper euonymus in 2003 at Park Hill, OK, and at Stillwater, OK. n = 80.

Date	Disease rating[z]		
	'Emerald 'n Gold'	'Canadale Gold'	'Emerald Gaiety'
		Park Hill, OK	
June 19	2.1b[y]	1.4c	2.4a
July 23	2.7a	2.3b	2.3b
August 22	3.4a	3.2b	3.1b
September 16	4.6a	4.2b	3.9b
		Stillwater, OK	
June 10	1.4b	1.2b	1.9a
July 8	1.6a	1.2b	1.6a
August 4	5.5a	3.2c	4.0b
August 30	7.2a	4.3c	5.9b
October 1	8.2a	5.7c	6.9b

[z]Anthracnose disease ratings were based on the Horsfall-Barratt plant disease assessment system (see text).

[y]Mean separation by Protected LSD $P \leq 0.05$. Means within rows followed by the same letter are not significantly different.

rate solutions were prepared for each fungicide. Solutions from each fungicide and concentration were poured into each of five 9 cm (3.5 in) diameter plastic petri dishes (20 ml, 0.7 fl oz per dish) for each of the *C. gloeosporioides* isolates.

A 0.7 cm (0.3 in) diameter plug taken from the edge (active growth) of a mature *C. gloeosporioides* culture was placed upside down in the center of each dish. Each dish was sealed with parafilm to prevent contamination and placed in a dark growth chamber at 25C (77F). Mycelial growth was measured daily for 6 days after inoculation by measuring the diameter at the widest point and perpendicular to the widest point then averaging the two measurements. Growth inhibition was calculated using the following equation: % inhibition = [(isolate growth on non-amended media – isolate growth on fungicide-amended media) / isolate growth on non-amended media] × 100.

Both isolates and both fungicides were tested at the same time. The experiment was repeated three times. The growth chamber contained three shelves so dishes were randomized within fungicide and isolate by shelf. The fungicides were rotated on the shelves with each repetition so that both fungicides were tested on all shelves by the end of the study. Treatments were replicated 15 times (5 plates per isolate and fungicide repeated three times). Regression analysis was conducted using PROC REG in SAS (SAS Institute, Cary, NC) with inhibition as the response to $\log_{10}$ concentration. This analysis was performed for all combinations of fungicide and isolate. Initially a quadratic model was used, but in the event that the quadratic term was not statistically significant at $\alpha = 0.05$, this model was abandoned for a linear one. For any given model, the EC_{50} was calculated.

Results and Discussion

2003. 'Emerald Gaiety' had the highest disease ratings while 'Canadale Gold' had the lowest ratings on June 19 at Park Hill (Table 2). Ratings of 'Canadale Gold' and 'Emerald Gaiety' were similar but lower than those of 'Emerald 'n Gold' on all other rating dates.

At Stillwater, disease ratings of 'Emerald 'n Gold' and 'Canadale Gold' were similar but lower than those of 'Emerald Gaiety' on June 10 (Table 2). On July 8 disease ratings of 'Emerald 'n Gold' and 'Emerald Gaiety' were similar but lower than ratings of 'Canadale Gold'. On all other dates the highest ratings occurred on 'Emerald 'n Gold' while disease ratings of 'Emerald Gaiety' were intermediate and 'Canadale Gold' had the lowest ratings.

2004, Park Hill. Disease ratings of plants of 'Emerald 'n Gold' and 'Canadale Gold' were similar and lower than those of 'Emerald Gaiety' plants on June 16 (Table 3). 'Emerald Gaiety' had the highest disease ratings while 'Canadale Gold' had the lowest ratings, and ratings of 'Emerald 'n Gold' were intermediate on July 13 and August 3. Disease ratings of 'Emerald 'n Gold' and 'Emerald Gaiety' were similar but higher than those of 'Canadale Gold' on October 4.

Plants sprayed with mancozeb had lower disease ratings than plants receiving any other fungicide treatment or water control plants on August 3 and October 4 (Table 3).

Cultivar interacted with fungicide treatment for disease ratings on September 8 (Table 4). No differences in disease ratings occurred among cultivars within any fungicide treatment. 'Canadale Gold' plants that were sprayed with mancozeb had lower disease ratings than 'Emerald 'n Gold' or 'Emerald Gaiety' sprayed with water, either rate of copper sulfate pentahydrate, or hydrogen dioxide.

Table 3. Effect of cultivar (pooled over fungicide treatments) and fungicide treatment (pooled over cultivars) on disease ratings of wintercreeper euonymus at Park Hill, OK, in 2004. n = 100.

Treatment	Disease rating[z]			
	June 16	July 13	August 3	October 4
		Cultivar Main Effect		
Emerald 'n Gold	2.3b	2.5b	4.1b	6.5a
Canadale Gold	2.1b	2.1c	3.8c	6.3b
Emerald Gaiety	2.7a	2.7a	4.4a	6.5a
		Fungicide Main Effect		
Water	2.4a	2.6a	4.4a	6.7a
Mancozeb — 1.8 g ai/liter	2.4a	2.3a	3.5b	5.8b
Copper sulfate pentahydrate — 0.6 g ai/liter	2.6a	2.5a	4.1a	6.4a
Copper sulfate pentahydrate — 0.4 g ai/liter	2.4a	2.3a	4.2a	6.5a
Hydrogen dioxide — 1.1 mL ai/liter	2.2a	2.3a	4.3a	6.6a

[z]Anthracnose disease ratings were based on the Horsfall-Barratt plant disease assessment system (see text).

[y]Mean separation by Protected LSD $P \leq 0.05$. Means within main effect and column followed by the same letter are not significantly different.

Table 4. Effect of fungicide and cultivar on wintercreeper euonymus anthracnose disease ratings in 2004 at Park Hill, OK, on September 8 and at Stillwater, OK, on August 9. n = 100.

Fungicide	Cultivar	Disease rating[z]	
		Park Hill	Stillwater
Water	Emerald 'n Gold	4.2	9.7
	Canadale Gold	4.2	8.0
	Emerald Gaiety	5.0	9.1
Mancozeb — 1.8 g ai/liter	Emerald 'n Gold	3.8	6.4
	Canadale Gold	3.2	5.2
	Emerald Gaiety	3.7	4.7
Copper sulfate pentahydrate — 0.6 g ai/liter	Emerald 'n Gold	4.4	7.0
	Canadale Gold	3.7	6.0
	Emerald Gaiety	4.3	5.8
Copper sulfate pentahydrate — 0.4 g ai/liter	Emerald 'n Gold	4.1	7.4
	Canadale Gold	4.1	6.6
	Emerald Gaiety	4.6	6.7
Hydrogen dioxide — 1.1 mL ai/liter	Emerald 'n Gold	4.3	9.4
	Canadale Gold	4.1	7.2
	Emerald Gaiety	4.5	8.5
$LSD_{0.05}$ for differences among cultivars for the same fungicide		0.9	1.4
$LSD_{0.05}$ for differences among cultivars for different fungicide treatments		0.9	1.9

[z]Anthracnose disease ratings were based on the Horsfall-Barratt plant disease assessment system (see text).

2004, Stillwater. 'Emerald 'n Gold' and 'Canadale Gold' had similar disease ratings while 'Emerald Gaiety' had lower ratings on June 14 (Table 5). 'Emerald 'n Gold' had the highest disease ratings while 'Emerald Gaiety' had the lowest ratings, and ratings of 'Canadale Gold' did not differ from those of either of the other cultivars on July 14. Ratings of 'Canadale Gold' and 'Emerald Gaiety' were similar and lower than those of 'Emerald 'n Gold' on September 10 and October 8.

On July 14 plants treated with mancozeb had lower disease ratings than those treated with water, copper sulfate pentahydrate at 0.4 g ai/liter (0.05 oz/gal) or hydrogen dioxide (Table 5). Ratings of plants treated with mancozeb did not differ from those of plants sprayed with copper sulfate pentahydrate at 0.6 g ai/liter (0.08 oz/gal). Disease ratings did not differ between plants receiving 0.4 g ai/liter (0.05 oz/gal) and those receiving 0.6 g ai/liter (0.08 oz/gal) copper sulfate pentahydrate, nor did disease ratings differ between plants receiving water and hydrogen dioxide on July 14. On September 10, disease ratings differed among all fungicide treatments with plants sprayed with mancozeb having the lowest disease ratings while water control plants had the highest ratings. On October 8, plants sprayed with mancozeb had the lowest disease ratings while those treated with water or hydrogen dioxide had the highest disease ratings.

A fungicide by cultivar interaction occurred for disease ratings on August 9 (Table 4). 'Emerald 'n Gold' sprayed with water or hydrogen dioxide had higher disease ratings than 'Canadale Gold' but ratings of 'Emerald Gaiety' were similar to those of both 'Emerald 'n Gold' and 'Canadale Gold'. In contrast, 'Emerald 'n Gold' plants treated with mancozeb had higher ratings than 'Emerald Gaiety' plants, but ratings of 'Canadale Gold' did not differ from either other cultivar. No differences in disease ratings occurred among the cultivars with either copper sulfate pentahydrate treatment. 'Emerald Gaiety' treated with mancozeb had lower disease ratings than 'Emerald 'n Gold' treated with water,

Table 5. Effect of cultivar (pooled over fungicide treatment) and fungicide treatment (pooled over cultivars) on disease ratings of wintercreeper euonymus at Stillwater, OK, in 2004. n = 100.

Treatment	Disease rating[z]			
	June 14	July 14	September 10	October 8
		Cultivar Main Effect		
Emerald 'n Gold	2.4a	4.3a	8.0a	7.9a
Canadale Gold	2.3a	4.1ab	6.6b	6.3b
Emerald Gaiety	2.1b	3.9b	6.9b	6.5b
		Fungicide Main Effect		
Water	2.3a	4.5a	8.9a	8.4a
Mancozeb—1.8 g ai/L	2.0a	3.5c	5.4e	5.4c
Copper sulfate pentahydrate—0.6 g ai/L	2.3a	3.7bc	6.3d	6.1b
Copper sulfate pentahydrate—0.4 g ai/L	2.3a	3.9b	6.9c	6.5b
Hydrogen dioxide—1.1 mL ai/L	2.4a	4.8a	8.4b	8.0a

[z]Anthracnose disease ratings were based on the Horsfall-Barratt plant disease assessment system (see text).

[y]Mean separation by Protected LSD $P \leq 0.05$. Means within main effect and column followed by the same letter are not significantly different.

copper sulfate pentahydrate at either rate, or hydrogen dioxide. 'Emerald Gaiety' sprayed with mancozeb also had lower disease ratings than 'Canadale Gold' sprayed with water, 0.4 g ai/liter (0.05 oz/gal) copper sulfate pentahydrate, or hydrogen dioxide.

Poison agar study. A quadratic relationship existed between fungicide concentration and mycelial growth inhibition for both isolates with each fungicide tested (Fig. 1). Mycelial growth inhibition was less than 50% at all concentrations of copper sulfate pentahydrate, but EC_{50} of mancozeb on isolate 415 was 645.7 ppm and on isolate 423 was 602.6 ppm.

Statistical differences in disease ratings existed among the cultivars, but the horticultural significance was negligible early in both growing seasons at both sites. For example, average disease ratings were less than 3 (less than 7% of the plant affected) at Park Hill on June 19 and July 23, 2003, (Table 2) and June 16 and July 13, 2004, (Table 3) and at Stillwater on June 10 and July 8, 2003, (Table 2) and June 14, 2004 (Table 5). Increasing air temperatures may account for higher disease ratings as the growing season progressed. Ningen et al. (9) noted that anthracnose symptoms on wintercreeper euonymus increased as night temperatures increased. Similarly, although temperatures at the research sites were not measured in 2003, temperatures in 2004 were generally higher at Stillwater than at Park Hill (Table 1). This may explain the tendency for higher disease ratings at Stillwater than at Park Hill as the growing season progressed.

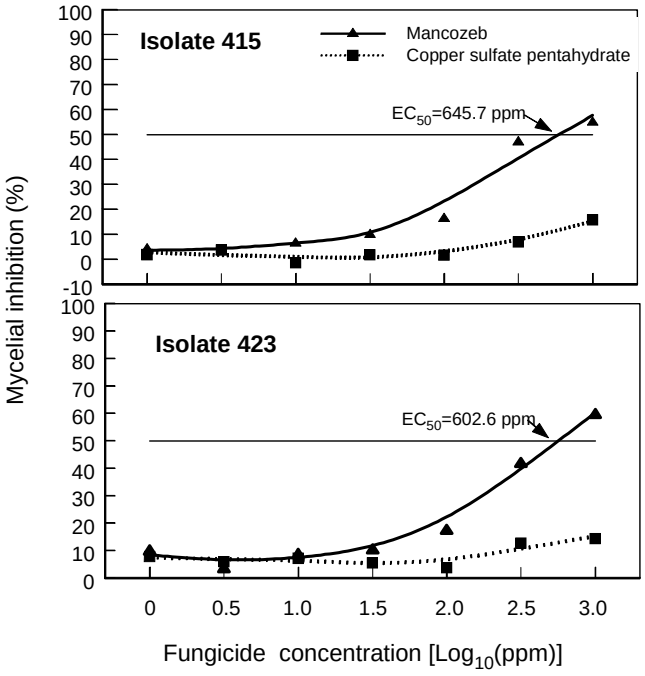

Fig. 1. Mycelial growth inhibition after 6 days at 25C (77F) of two isolates of *Colletotrichum gloeosporioides* from wintercreeper euonymus grown on potato dextrose agar amended with various concentrations of mancozeb or copper sulfate pentahydrate. The horizontal line indicates 50% inhibition. n = 105. Isolate 415, mancozeb ($y = 6.61 – 11.49x + 9.61x^2$, $r^2 = 0.48$); copper sulfate pentahydrate ($y = 6.33 – 11.02x + 4.64x^2$, $r^2 = 0.21$**). Isolate 423, mancozeb ($y = 14.23 – 20.92x + 12.14x^2$, $r^2 = 0.38$***); copper sulfate pentahydrate ($y = 10.36 – 8.24x + 3.26x^2$, $r^2 = 0.11$*). Significant at P = 0.05 (*), 0.01 (**), or 0.001 (***).**

Disease ratings of 'Canadale Gold' were among the lowest of the cultivars at both sites throughout both years. 'Emerald 'n Gold' generally had higher ratings than 'Emerald Gaiety' in 2003 at both sites and in 2004 at Stillwater, but 'Emerald Gaiety' generally had higher disease ratings than 'Emerald 'n Gold' at Park Hill in 2004. Previous studies have shown 'Emerald 'n Gold' to be more susceptible to anthracnose caused by *C. gloeosporioides* than 'Emerald Gaiety' (4, 6, 7, 8, 10) or 'Canadale Gold' (8, 10).

While copper sulfate pentahydrate at 0.6 g ai/liter (0.08 oz/gal) reduced disease ratings of *C. gloeosporioides* on wintercreeper euonymus at Stillwater late in the 2004 growing season (Table 5), plants treated with mancozeb generally had lower disease ratings than plants treated with other fungicides (Tables 3 and 5). Similar results occurred *in vitro*. Mancozeb reduced mycelial growth of *C. gloeosporioides* isolated from infected *E. fortunei* plants more than copper sulfate pentahydrate. LaMondia (5) found that over 91% of *C. gloeosporioides* isolates tested *in vitro* from Connecticut nurseries had EC_{50} values of less than 500 ppm ai copper hydroxide; whereas, Cole et al. (1) found that copper hydroxide did not affect mycelial growth *in vitro* of *C. gloeosporioides* isolates from Oklahoma nurseries. Results of this study are similar to those of Cole et al. (1) in that inhibition of mycelial growth of both isolates by the copper-based fungicide copper sulfate pentahydrate was less than 20% (Fig. 1).

Differences in fungicide mode of action have been used to explain their affect on mycelial growth inhibition of *C. gloeosporioides in vitro*. LaMondia (5) speculated that systemic fungicides prevented mycelial growth but not conidial germination while contact fungicides prevented conidial germination but not mycelial growth. In the current study both of the fungicides tested *in vitro* were contact fungicides. However, mancozeb inhibited mycelial growth more than copper sulfate pentahydrate. Copper sulfate pentahydrate provided minimal mycelial inhibition. This minimal response may indicate that *C. gloeosporioides* has developed resistance to copper-based fungicides.

Results of this study are similar to those of LaMondia (4, 5), Cole et al. (1), and Ningen (8) in that none of the fungicides tested provided acceptable control of anthracnose on wintercreeper euonymus. Since currently available fungicides have provided less than optimal control of *C. gloeosporioides* on wintercreeper euonymus in field and laboratory tests, growers should consider growing less susceptible cultivars and altering management programs to produce wintercreeper euonymus in an environment that minimizes plant stress. Ningen et al. (10) found that production of wintercreeper euonymus under high shade intensities with afternoon irrigation greatly reduced anthracnose symptoms compared to production in full sun or lower shade intensities with morning irrigation. Use of fungicides such as mancozeb that provide some control of anthracnose may further reduce anthracnose symptoms.

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