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Comparison of Fungicides for the Control of Powdery Mildew on Dogwood[1]

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Abstract

Efficacy of selected registered fungicides and trifloxystrobin, was evaluated for the control of powdery mildew (*Erysiphe pulchra*) on container-grown flowering dogwood (*Cornus florida*). Bare-root trees were transplanted into a pine bark/peat moss substrate and maintained under a 47% shade cloth. All fungicide treatments significantly reduced the incidence of powdery mildew compared with the untreated control. During the trial period, the most consistent control of powdery mildew was given by azoxystrobin [Heritage® 50W] at 0.16 g ai/liter or propiconazole [Banner MAXX®] at 0.07 g ai/liter, respectively. In two of three years, myclobutanil [Eagle® 40W] at 0.24 g ai/liter was equally effective in controlling this disease as the above fungicides. Copper sulfate pentahydrate [Phyton 27®] at 0.74 g ai/liter gave similar control of powdery mildew in three of four years as propiconazole but was not quite as effective in controlling this disease as azoxystrobin. Paraffinic oil at 1% v/v [Sunspray Ultrafine Oil®] was slightly less effective in controlling powdery mildew than azoxystrobin or myclobutanil. However, no more than 6% leaves on the paraffinic oil-treated dogwood were colonized in any year by *E. pulchra*, compared with 75% colonization for the untreated controls. Although thiophanate methyl [3336™ 4.5F] at 0.84 g ai/liter and triadimefon [Bayleton® WSP] at 0.16 g ai/liter reduced powdery mildew incidence compared with the untreated control, the level of leaf colonization in three of four years was significantly higher than other fungicides. Trifloxystrobin [Compass™ 50W] at the 0.04 g ai/liter rate gave better control of powdery mildew when applied at 1- and 2-week intervals than on a monthly schedule. In contrast, the 0.08 and 0.16 g ai/liter rate of this fungicide were almost equally effective in controlling this disease at 1-, 2-, and 4-week intervals. When applied on the same schedule, myclobutanil (0.24 g ai/liter) gave the same level of powdery mildew control as all three rates of trifloxystrobin. In 1999, moderate to excellent control of powdery mildew with trifloxystrobin, propiconazole, and azoxystrobin resulted in a significant gains in tree dimensions and trunk caliper over those recorded for the untreated flowering dogwood. No symptoms of phytotoxicity were associated with the use of any of the fungicides screened.

Index words: flowering dogwood**,** *Cornus florida***,** chemical control, *Erysiphe pulchra*, Bayleton WSP, Cleary's 3336, Banner Maxx, Phyton 27, Eagle 40W, Heritage 50W, Compass 50W, Sunspray Ultrafine Oil, Quinone outside inhibitor, QoI fungicide, strobilurin fungicide.

Species used in this study: *Cornus florida, C. florida* 'First Lady, and *C. florida* 'Cloud 9'.

Significance to the Nursery Industry

Label rates of propiconazole [Banner MAXX®], myclobutanil [Eagle® 40W], and azoxystrobin [Heritage® 50W] consistently gave excellent control of powdery mildew on flowering dogwood. Copper sulfate pentahydrate [Phyton 27®] and paraffinic oil [Sunspray Ultrafine Oil®] were nearly as effective in controlling this disease as propiconazole, myclobutanil, and azoxystrobin. In an ongoing field trial, however, the 1% v/v rate of paraffinic oil damaged the leaves on flowering dogwood growing in full sun. So, this product may be safe to use only on heavily-shaded flowering dogwood. The strobilurin or QoI (Quinone outside inhibitor) fungicide trifloxystrobin [Compass™ 50W] at rates of 0.04 to 0.16 g ai/liter (1 to 4 oz/100 gal) was often as effective in controlling powdery mildew on flowering dogwood as myclobutanil. While the 0.04 g ai/liter rate worked best when applied on a 1- or 2-week schedule, monthly applications of the 0.08 and 0.16 g ai/liter rates of trifloxystrobin were often as effective in controlling powdery mildew control. For the best control under heavy disease pressure, higher rates of trifloxystrobin should be applied at 2-week intervals. Repeated use of strobilurin fungicides such as azoxystrobin and trifloxystrobin for disease control, particularly of powdery mildew, may result in a control failure due to resistance. Efficacy of these fungicides can be safeguarded by limiting the use of a strobilurin fungicide alone to no more than 1/3 of the total number of applications to a given crop per production cycle or growing season and by making no more than two consecutive applications of this class of fungicide. If a strobilurin fungicide is tank mixed with another fungicide with a different mode of action, then ½ of the total applications may include this class of fungicide. Similar resistance avoidance guidelines have also been established concerning the use of triazole (SBI or sterol biosynthesis inhibitor) fungicides such as propiconazole, triadimefon, and myclobutanil. In addition to obvious disease control, significant increases in tree growth in 1999 were obtained with several rates of trifloxystrobin, as well as recommended rates of propiconazole, myclobutanil, and azoxystrobin. Under heavy disease pressure, thiophanate methyl [3336™ 4.5F] and triadimefon [Bayleton® WSP] were considerably less effective against powdery mildew on flowering dogwood.

Introduction

Flowering dogwood (*Cornus florida* L.) is one of the most widely cultivated small flowering trees found in residential and commercial plantings in the southeastern United States. Showy bracts, attractive fall color, red fruit clusters, and wide-

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spread adaptation across this region account for the popularity of flowering dogwood with consumers (4).

Since 1994, powdery mildew, caused by the fungus *Erysiphe pulchra* (Cooke & Becke) U. Braum & S. Takamatsu comb. nov. [syn. = *Microsphaera pulchra*, *M. penicillata*], is the most common disease seen on flowering dogwood in landscapes, as well as on field- and container-grown trees (2, 3, 6). Although disease-related damage on established flowering dogwood appears to be largely cosmetic, slowed shoot elongation, reduced caliper diameter, and death of year-old seedlings have recently been attributed to severe outbreaks of powdery mildew (10).

Cultivars and native 'seedling' flowering dogwoods differ considerably in their susceptibility to powdery mildew. Several cultivars of flowering dogwood, particularly Cherokee Brave™, Cherokee Chief™, 'Bay Beauty', and 'Weavers White', are resistant to powdery mildew and also to spot anthracnose caused by *Elsinoe cornii* (6). Recently, Mmbaga and Sauve (11) reported that 'Fragrant Cloud' and Cherokee Brave™ were moderately resistant to powdery mildew. However, the majority of trees in Alabama's landscapes are native 'seedling' trees or cultivars that are susceptible to powdery mildew.

Since powdery mildew emerged as a widespread and damaging disease, information is available concerning the efficacy of synthetic and biorational fungicides for control of this disease in production or landscape settings. In a recent Tennessee trial, propiconazole [Banner MAXX®], thiophanate-methyl + chlorothalonil [Spectro™ 90], myclobutanil [Systhane® 20EW and Systhane® 40W], and Terraguard® 50W, controlled powdery mildew on field grown 'Rubra' flowering dogwood (15). Windham et al. (15) noted that the percentage of symptomatic leaves on trees treated with the above fungicides ranged from 10 to 25% compared to nearly 100% on the untreated controls. In contrast, bimonthly applications of potassium bicarbonate [First Step™] failed to protect 'Rubra' flowering dogwood from powdery mildew (15). Mulrooney and Gregory (13) noted that paraffinic oil [Sunspray Ultrafine Oil™] and myclobutanil were equally effective in controlling this disease but potassium bicarbonate again was relatively ineffective against powdery mildew. Over a three-year period, the soaps Ajax® and Equate®, as well as potassium bicarbonate [Armicarb®] were nearly as effective in controlling powdery mildew and suppressing ascocarp formation of *E. pulchra* as thiophanate-methyl [3336™ 4.5F], azoxystrobin [Heritage® 50W], copper sulfate pentahydrate [Phyton 27®], and propiconazole on container and field grown dogwood (9, 10). Mmbaga and Sheng (9) also noted that more ascocarps developed when fungicide treatments were terminated in August than in October. Finally, stem caliper and tree height was significantly increased by the synthetic fungicides propiconazole, thiophanate-methyl, azoxystrobin, and several biorational fungicides (10).

Trifloxystrobin, which is marketed for use on amenity crops under the trade names Compass™ 50W and Compass O™, is classified as a strobilurin or QoI (Quinone outside inhibitor) fungicide. This fungicide is absorbed into the waxy leaf cuticle and has demonstrated translaminar movement through the leaf but is not redistributed through the xylem like the systemic QoI fungicide azoxystrobin (1). Trifloxystrobin is a broad spectrum fungicide that has activity against numerous diseases, including powdery mildew on a variety of annuals, perennials, and small flowering trees. Previously, Windham et al. (15) obtained a high level of control of powdery mildew on flowering dogwood with trifloxystrobin applied at 0.08 and 0.16 g ai./liter on a 2-week schedule. In a Delaware study (12), 0.04, 0.08, and 0.16 g a.i./liter of trifloxystrobin, when applied at 2-, 3-, and 4-week intervals, respectively, restricted powdery mildew development to less than 2% of the leaves of 'seedling' flowering dogwood . In this same study, all rates of trifloxystrobin also proved as effective in controlling this disease as the registered fungicides azoxystrobin and myclobutanil (12).

Trials were initiated on container-grown flower dogwood in 1997 and continued through 2003 to identify efficacious fungicides for the control of powdery mildew. In addition, the efficacy of the strobilurin fungicide trifloxystrobin [Compass™ 50W] was evaluated over a range of application rates and treatment intervals for the control of powdery mildew on flowering dogwood.

Material and Methods

Plant culture. Bare-root flowering dogwoods were potted in #3 containers filled with in pine bark:peat moss (3:1 by vol) or 100% pine bark amended with 4.9 kg (14 lb) of 17–7–12 Osmocote, 2.1 kg (6 lb) of dolomitic limestone, 0.7 kg (2 lb) of gypsum, and 0.5 kg (1.5 lb) of Micromax per cubic meter (per cubic yard) of potting mixture. The trees were maintained on a clam shell-covered bed under 47% shade cloth. The blocks of trees were watered daily with overhead impact sprinklers. While 'seedling' flowering dogwoods were used in 1997, the cultivars 'First Lady' and 'Cloud 9' were used in 1999, 2001, 2002, and 2003, respectively. A randomized complete block design with six or eight replications of one plant per treatment was used. Blocks of plants were rerandomized following each fungicide application. All studies were conducted at the Ornamental Horticulture Research Center in Mobile, AL.

Fungicide evaluations. Fungicides were applied to runoff with a CO_2-pressurized backpack sprayer at the intervals specified below. In 1997, 2001, 2002, and 2003, recommended rates of commercial fungicides were evaluated for the control of powdery mildew on flowering dogwood. Fungicides evaluated in 1997 were triadimefon [Bayleton® WSP, Bayer Environmental Science, Kansas City, MO] at 0.16 g ai/liter, thiophanate-methyl [3336™ 4.5F, Cleary Chemical Corp. Somerset, NJ] at 0.84 g ai/liter, propiconazole [Banner MAXX®, Syngenta Crop Protection, Greensboro, NC] at 0.07 g ai/liter, copper sulfate pentahydrate, [Phyton 27®, Phyton Corp., Edina, MN] at 0.74 g ai/liter, and myclobutanil [Eagle® 40W, Dow AgroSciences LLC, Indianapolis, IN] at 0.24 g ai/liter. In 2001, azoxystrobin [Heritage 50W™ (Syngenta Crop Protection, Greensboro, NC] at 0.16 g ai/liter and paraffinic oil [Sunspray Ultrafine Oil®, Farnam Companies Inc., Phoenix, AZ] at the rate of 1% v/v (10 ml/liter) were added. The non-ionic surfactant Sil-Spread™ [Southern States, Richmond, VA] at 2.0 ml/liter of spray volume was added to myclobutanil, azoxystrobin, and triadimefon. Fungicides were applied at 2-week intervals from March 30 until August 16, 2000; May 2 to July 24, 2001; May 24 to August 14, 2002; and May 7 to July 29, 2003. Canopy height and width were also recorded on August 14, 2001, to calculate a growth index (GI) according to common horticultural practice (7).

Application rate and timing comparisons for trifloxystrobin. In 1999, the efficacy of selected rates of trifloxystrobin [Compass™ 50W, Bayer Environmental Science, Kansas City, MO] was compared with propiconazole at 0.06 g ai/liter, myclobutanil at 0.24 g ai/liter, and azoxystrobin at 0.16 g ai/liter for the control of powdery mildew on 'First Lady' flowering dogwood. The 0.02 g ai/liter rate of trifloxystrobin was applied on a 1-week schedule compared to a 2-week schedule for the 0.04 and 0.08 g ai/liter rates of the same fungicide. While the application interval for myclobutanil and azoxystrobin was 2 weeks, propiconazole was applied on a 3-week schedule. Fungicides were applied from April 12 through October 6, 1999.

In 2001, 2002, and 2003, the 0.04, 0.08, and 0.16 g ai/liter rates of trifloxystrobin were applied at 1, 2, and 4-week intervals, respectively, to 'Cloud 9' flowering dogwood. Myclobutanil, which was applied at 0.16 g ai/liter every 2 weeks, was included as a commercial standard. The non-ionic surfactant Sil-Spread™ at 2.0 ml/liter of spray volume was added to trifloxystrobin and myclobutanil. Fungicides were applied to run-off from May 2 to July 24, 2001; May 24 to August 13, 2002; and May 27 to July 29, 2003.

Disease assessment. Fungicides were applied to run-off with a CO_2-pressurized backpack sprayer at the previously specified intervals. Incidence of powdery mildew on the leaves was rated using the Horsfall and Barrett rating scale where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus *E. pulchra*. In the general screening trials, incidence of powdery mildew was recorded on October 1, 1997; July 10, 2001; September 9, 2002; and July 10, 2003. In the trifloxystrobin trials, powdery mildew ratings were logged on July 7, 1999; July 10, 2001; September 9, 2002; and August 6, 2003. Canopy height and width were also recorded on September 29, 1999, and August 14, 2001, to calculate a growth index (GI) according to common horticultural practice (7).

Significance of application rate and interval effects on fungicide efficacy was tested by analysis of variance. Means for the disease rating for each fungicide treatment were compared with Fisher's protected least significant difference (LSD) test with the level of significance at P = 0.05. Since the ranking of the treatments in the general fungicide screening trial and trifloxystrobin trials differed significantly (P = 0.05) between years, the disease rating data was not pooled across years.

Results and Discussion

Fungicide efficacy. Although all treatments significantly reduced the incidence of powdery mildew compared with the unsprayed control in 1997, significant differences in the level of disease control among the fungicides were observed (Table 1). Myclobutanil and copper sulfate pentahydrate were equally effective in controlling powdery mildew. On the trees receiving applications of the above fungicides, disease development was restricted to a few unobtrusive colonies of *E. pulchra* on approximately 3 to 4% of the leaves. In comparison, thiophanate-methyl and triadimefon gave significantly less control of powdery mildew than myclobutanil and copper sulfate pentahydrate. The percentage of disease leaves on the thiophanate-methyl and triadimefon-treated dogwoods, which exceeded 12% and 25%, respectively, was well below the approximately 87% rate of leaf colonization observed on the untreated controls.

In the 2001, 2002, and 2003 general fungicide screening trials, propiconazole, myclobutanil, and azoxystrobin consistently gave the best control of powdery mildew (Table 1). Only a few isolated colonies of the powdery mildew fungus *E. pulchra* were noted on a few, scattered leaves of the trees treated with propiconazole, myclobutanil, or azoxystrobin. Incidence of *E. pulchra*-colonized leaves on the dogwood treated with paraffinic oil and copper sulfate pentahydrate was in the range of 1% to less than 12%. Thiophanate-methyl and triadimefon failed to provide adequate protection from this disease, especially in 2001 and 2003 when powdery mildew pressure was high. Powdery mildew incidence on the untreated controls ranged from a low of approximately 35% of leaves colonized in 2002 to over 80% in 2001 and 2003. In addition, extensive colonization of the entire surface of most leaves, as well as noticeable leaf deformation was observed on the untreated controls in 2001 and 2003.

Trifloxystrobin efficacy. In 1999, all rates of trifloxystrobin, as well as recommended rates of propiconazole, myclobutanil, and azoxystrobin, significantly reduced the incidence of pow-

Table 1. Efficacy of selected fungicides applied on a two-week schedule for the control of powdery mildew on container-grown flowering dogwood.

Fungicide	Application rate g ai/liter	Incidence of powdery mildew[z]			
		1997	2001	2002	2003
Triadimefon	0.16	5.3b[y]	4.2b	2.5b	5.6b
Thiophanate-methyl	0.84	4.1c	3.8b	2.2bc	6.3b
Propiconazole	0.07	2.5d	2.0d	1.0c	2.6cd
Copper sulfate pentahydrate	0.74	1.9d	3.5bc	2.2bc	3.0cd
Myclobutanil	0.24	1.6d	3.2bcd	1.2c	2.2de
Azoxystrobin	0.16	—[x]	2.3c	1.2c	1.6e
Paraffinic oil	1% v/v	—	3.8b	1.8bc	3.3c
Untreated control	—	9.0a	7.8a	5.5a	7.6a

[z]Incidence of powdery mildew on the leaves was rated using the Horsfall and Barrett rating scale where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus.

[y]Means in each column that are followed by the same letter are not significantly different according to Fisher's Protected Least Significance (LSD) test (P = 0.05).

[x]— = not evaluated in 1997.

Table 2. Comparison of trifloxystrobin with selected fungicides for the control of powdery mildew and tree dimension of container grown 'First Lady' flowering dogwood, 1999.

Fungicide	Application Rate g ai/l	Application Interval wk	Incidence of powdery mildew[z]	Growth Index[y]	Tree caliper (cm)
Trifloxystrobin	0.02	1	1.8d	141.1bc[x]	19.0c
Trifloxystrobin	0.04	2	4.3b	157.9a	19.8abc
Trifloxystrobin	0.08	2	3.0c	162.0a	21.2ab
Propiconazole	0.06	3	2.1cd	149.0ab	20.1abc
Myclobutanil	0.24	2	1.6d	156.0a	21.4a
Azoxystrobin	0.16	2	1.4d	153.0ab	19.2bc
Untreated control	—	—	12.0a	133.1c	14.8d

[z]Incidence of powdery mildew on the leaves was rated using the Horsfall and Barrett rating scale where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus.

[y]Growth index = (height + width 1 + width 2) / 3.

[x]Means in each column that are followed by the same letter are not significant different according to Fisher's Protected Least Significance (LSD) test (P = 0.05).

dery mildew compared to the untreated control (Table 2). As indicated by a disease rating of 12.0, all of the leaves on the untreated controls were colonized by *E. pulchra*. Although the percentage of leaves on all of the fungicide-treated trees was low, significant differences in disease incidence were noted. Disease incidence was higher on the trees treated bimonthly with 0.04 and 0.08 g ai/liter of trifloxystrobin compared with weekly applications of the 0.02 g ai/liter rate of the same fungicide. Also, significantly fewer colonized leaves were observed on the flowering dogwood treated with myclobutanil and azoxystrobin than on those trees with the two higher rates of trifloxystrobin at the same treatment interval. The highest rate of trifloxystrobin and propiconazole gave the same level of control of powdery mildew.

In 2001, trifloxystrobin, when applied over a range of labeled application rates and treatment intervals, significantly reduced the incidence of powdery mildew on 'Cloud 9' flowering dogwood, as compared with the untreated control (Table 3). Nearly 50% of the leaves of the untreated controls were noticeably colonized by *E. pulchra*. At the 0.04 and 0.08 g ai/liter rates, trifloxystrobin gave significantly better disease control when applied on a 1- and 2-week schedule than when applied at monthly intervals. Disease incidence on the trees treated with the two lower rates of trifloxystrobin at 1- and 2-week intervals was similar. Incidence of powdery mildew on flowering dogwood treated with the highest rate of trifloxystrobin at 1-, 2-, and 4-week intervals did not significantly differ. With the exception of the 0.04 and 0.08 g ai/liter rates applied monthly, trifloxystrobin proved equally effective in controlling powdery mildew on flowering dogwood as the fungicide standard myclobutanil.

As indicated by a disease rating of 5.6 where 15 to 20% of the leaves on the unsprayed control were colonized, powdery pressure was relatively low in 2002 (Table 3). The level of powdery mildew colonization on all the trifloxystrobin-treated flowering dogwood was similar. For most rates of trifloxystrobin at all three treatment intervals, very little if any leaf colonization by *E. pulchra* was noted. Also, all rates of trifloxystrobin were equally effective in controlling this disease.

For 2003, the level of leaf colonization by *E. pulchra* was significantly higher for the unsprayed control compared with for all of the trifloxystrobin treatments (Table 3). At all rates of trifloxystrobin, powdery mildew incidence increased as

Table 3. Influence of application rate and interval on the efficacy of trifloxystrobin for the control of powdery mildew and the growth of container-grown 'Cloud 9' flowering dogwood.

Fungicide	Application Rate g ai/l	Application Interval wk	Incidence of powdery mildew[z] 2001	2002	2003	Growth index 2001
Trifloxystrobin	0.04	1	2.2cde[y]	1.0b	1.7c	105
Trifloxystrobin	0.04	2	2.5cd	1.2b	2.7bc	97
Trifloxystrobin	0.04	4	4.8b	1.0b	3.7b	104
Trifloxystrobin	0.08	1	1.7ef	1.0b	2.0c	104
Trifloxystrobin	0.08	2	2.0def	1.0b	2.0c	95
Trifloxystrobin	0.08	4	4.2b	1.0b	3.3bc	103
Trifloxystrobin	0.16	1	1.5f	1.0b	1.7c	100
Trifloxystrobin	0.16	2	2.5cd	1.0b	2.0c	108
Trifloxystrobin	0.16	4	2.8c	1.2b	2.5bc	96
Myclobutanil	0.24	2	1.8ef	1.4b	2.5bc	92
Unsprayed Control	—	—	6.7a	5.6a	6.7a	106

[z]Incidence of powdery mildew on the leaves was rated using the Horsfall and Barrett rating scale where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus.

[y]Means in each column that are followed by the same letter are significantly different according to Fisher's Protected Least Significance (LSD) test (P = 0.05).

the treatment interval was lengthened from 1- to 4-weeks. At each treatment interval, disease incidence on the trees treated with all three rates of trifloxystrobin was similar. When applied at 1-, 2-, and 4-week intervals, no significant differences in powdery mildew control were noted between any rate of trifloxystrobin and the myclobutanil standard. The percentage of diseased leaves for any of the trifloxystrobin treatments was below 12%.

Tree growth. The impact of powdery mildew on tree growth appeared to be related to disease severity in a particular year. In the 1999 trial, severe powdery mildew development on the unsprayed 'First Lady' flowering dogwood had an adverse affect on tree growth. The growth index (GI) and trunk caliper logged for the untreated trees were significantly lower than those for all of the fungicide-treated trees (Table 2). Although the lowest rate of trifloxystrobin gave excellent disease control, the GI for these trees did not differ significantly from that recorded for the unsprayed controls. In contrast, the GI for flowering dogwoods treated with the 0.04 and 0.08 g ai/ liter rate of trifloxystrobin were higher than those for the lowest rate of this same fungicide. Trunk caliper for the flowering dogwood sprayed with the highest rate of trifloxystrobin was significantly higher than the trunk caliper recorded for trees treated with the lowest rate of the same fungicide. Trees treated with the 0.04 g ai/liter rate of trifloxystrobin had a similar trunk caliper as did the flowering dogwood treated with the 0.02 g ai/liter rate of the same fungicide. Generally, the GI and trunk caliper for trees treated with propiconazole, myclobutanil, and azoxystrobin were similar to the results recorded for the two highest rates of trifloxystrobin. In 2001 , the GI of untreated dogwoods was not significantly different from those recorded for the flowering dogwood treated with propiconazole, myclobutanil, thiophanate-methyl, copper sulfate pentahydrate, and paraffinic oil (data not shown).

Due to low disease pressure in 2001, application rate and treatment interval for trifloxystrobin had no impact on tree growth (Table 3). The height for the myclobutanil-treated trees was similar to that recorded for the dogwood receiving all rates of trifloxystrobin.

While triadimefon, thiophanate-methyl, propiconazole, copper sulfate pentahydrate, myclobutanil, azoxystrobin, and paraffinic oil are registered for the control of powdery mildew on a wide range of herbaceous and woody ornamentals, significant differences in the level of powdery mildew control provided by the above fungicides was noted in all four years of comparative trials we conducted. Propiconazole, myclobutanil, and azoxystrobin gave the most consistent and effective control of powdery mildew on flowering dogwood. Typically, the few leaves colonized by *E. pulchra* on flowering dogwood treated with the above fungicides had no detrimental impact on tree aesthetics. The superior activity of propiconazole and myclobutanil for the control of powdery mildew on flowering dogwood has been reported in previous studies in Tennessee (9, 15). Mmbaga and Sheng (9) also noted a sizable reduction in ascocarp formation on the propiconazole-treated flowering dogwood, which could also result early season suppression of this disease the following year.

In at least one year, copper sulfate pentahydrate, and paraffinic oil were slightly less efficacious in controlling powdery mildew than were propiconazole, azoxystrobin, or myclobutanil. However, both of these fungicides, as well as propiconazole, myclobutanil, and azoxystrobin proved significantly more effective in controlling this disease compared with thiophanate-methyl and triadimefon. While paraffinic oil appears to be a biorational or organic alternative to the above synthetic fungicides, an objectionable mottling and marginal leaf burn was noted in 2003 and 2004 on field-grown 'Rubra' flowering dogwood in full sun that were treated at 1- or 2-week intervals in the spring and summer with this product (5).

As previously noted by Windham et al. (15), trifloxystrobin demonstrated excellent activity against powdery mildew on flowering dogwood. When applied monthly, the 0.08 and 0.16 g ai/liter rates of this fungicide often gave effective control of powdery mildew. The 0.04 g ai/liter rate of trifloxystrobin was more efficacious when applied at 1- and 2-week intervals than on a monthly schedule. Windham et al. (15) obtained excellent control of powdery mildew on field grown 'Rubra' flowering dogwood with the 0.16- and 0.32-g ai/liter rates of trifloxystrobin applied on a 2-week schedule but not with monthly treatments of the 0.32-g ai/liter rate of the same fungicide. Under the heavy disease pressure seen in the 1999 study, treatment intervals may have to be reduced to 2 weeks or less in order to maintain effective disease control.

While the application rate and treatment interval for trifloxystrobin evaluated here match the information on the product label, repeated applications of this or other strobilurin fungicides such as azoxystrobin over an extended period of time on vegetable, fruit, amenity turf, and cereal crops can result in control failures due to the selection of strobilurin-resistant fungal plant pathogens, especially powdery mildew fungi (1). According to FRAC [Fungicide Resistance Action Committee, <www.frac.info/>] guidelines, the risk of control failures due to resistance can be greatly reduced by insuring that applications of a strobilurin fungicide make up no more than 1/3 of the total fungicide applications and that no more than two consecutive applications of a strobilurin fungicide are made. In addition, tank-mixing or alternating fungicides with different modes of action also are effective strategies for reducing the risk of a control failure. When a strobilurin fungicide is applied alone or tank mixed with another type of fungicide, no more than 50% of the total fungicide application in that growing season should include any strobilurin fungicide. Resistance avoidance guidelines similar to those developed for strobilurin fungicides have been published by FRAC for triazole [SBI or sterol biosynthesis inhibitor] such as myclobutanil, propiconazole, and triadimefon.

Historically, the impact of powdery mildew diseases on woody landscape plants has been considered largely cosmetic (4, 8). Few published reports have noted a correlation between reduced shoot growth with severe outbreaks of powdery mildew on any ornamental. In the 1999 trifloxystrobin study, the GI of the untreated controls was significantly lower than those recorded for all treatments except for the lowest rate of trifloxystrobin. Similar powdery mildew-related reductions in the growth of untreated 'seedling' and Cherokee Brave™ flowering dogwood have recently been observed in Tennessee (10). Increased shoot elongation and stem caliper on flowering dogwood were obtained with propiconazole alone or when alternated with potassium bicarbonate, as well as with Equate® soap and azoxystrobin (10). When pow-

dery mildew pressure was relatively low, differences in tree dimensions or GI were not observed between the untreated and the fungicide-treated flowering dogwood in this and an earlier Georgia study (2).

In summary, propiconazole [Banner MAXX®], azoxystrobin [Heritage® 50W], and myclobutanil [Eagle® 40W] proved to be highly effective in controlling powdery mildew on flowering dogwood. Systemic Fungicide™ (fertilome®) contains the same active ingredient (propiconazole) as Banner Maxx® and is available at garden centers and other retail outlets. Myclobutanil, which is marketed under the trade name Immunox™ (Spectracide®), also gave good control of powdery mildew on flowering dogwood. Copper sulfate pentahydrate [Phyton 27®] also proved to be an effective control option for both the nursery and home landscape. Due to the high risk of damage to the leaves of flowering dogwood growing in full sun, paraffinic oil [Sunspray Ultrafine Oil®] may not be an acceptable biorational or organic substitute for the other fungicides screened, particularly on flowering dogwood not shaded by other trees. Use of the new strobilurin fungicide trifloxystrobin [Compass™ 50W], which gave effective control of powdery mildew over a range of rates and treatment intervals, is targeted for use by the commercial greenhouse and nursery industry. Triadimefon [Bayleton® WSP] and thiophanate-methyl [3336™ 4.5F and Halt™ Systemic] gave inconsistent control and are not the fungicides of choice for managing powdery mildew on flowering dogwood.

Literature Cited

1. Bartlett, D.W., J.M. Clough, J.R. Godwin, A.A. Hall, M. Hamer, and R. Parr-Dobzanski. 2002. Review: The strobilurin fungicides. Pest Manag. Sci. 58:649–662.

2. Britton, K.O. 1994. Dogwood cultivar evaluations for disease resistance, 1993. Biological and Cultural Tests for the Control of Plant Diseases 9:159.

3. Daughtrey, M.L. and A.K. Hagan. 2001. Dogwood diseases. p 124–132. *In*: Diseases of Woody Ornamentals and Trees in Nurseries. R. Jones and M. Benson, eds. APS Press. St. Paul, MN. 482 pp.

4. Dirr, M.A. 1998, Manual of Woody Landscape Plants. 5th Ed. Stipes Publishing Co. Champaign, IL 1187 pp.

5. Hagan, A.K., J.R. Akridge, and M.E. Rivas-Davila. 2004. Control of powdery mildew, spot anthracnose, and Cercospora leaf spot on field-grown flowering dogwood trees. Proc. Southern Nursery Assoc. Res. Conf. 49:254–259.

6. Hagan, A.K., B. Hardin, C.H. Gilliam, G.J. Keever, J.D. Williams, and J. Eakes. 1998. Susceptibility of cultivars of several dogwood taxa to powdery mildew and spot anthracnose. J. Environ. Hort. 16:147–151.

7. Keever, G.J. 1993. Promotion of branching in nandina (*Nandina domestica* Thunb.) 'Harbor Dwarf' with ASC-66952. J. Environ. Hort. 11:141–143.

8. McRitchie, J.J. 1994. Powdery mildew of flowering dogwood. Florida Dept. Agric. Cons. Ser. Plant Path. Cir. 368.

9. Mmbaga, M.T. and H. Sheng. 2002. Timing of fungicide applications in dogwood powdery mildew control. Proc. Southern Nursery Assoc. Res. Conf. 47:265–272.

10. Mmbaga, M.T. and R.J. Sauve. 2004. Management of powdery mildew in flowering dogwood in the field with biorational and synthetic fungicides. Can. J. Plant Sci. 84:837–844.

11. Mmbaga, M.T. and R.J. Sauve. 2004. Multiple resistance in dogwoods (*Cornus* spp.) to foliar pathogens. J. Arboriculture 30:101–107.

12. Mulrooney, R.P. 2001. Evaluation of fungicides for control of powdery mildew on flowering dogwood, 2000. Fungicide and Nematicide Tests 56:OT9.

13. Mulrooney, R.P. and N.F. Gregory. 2003. Evaluation of biorational fungicides for control of powdery mildew on flowering dogwood. Fungicide and Nematicide Tests 58:OT034.

14. Windham, M.T., A.S. Windham, M.A. Halcomb, D.E. Deyton, and C.E. Sams. 1999. Control of powdery mildew on flowering dogwood using soybean oil. Proc. Southern Nursery Assoc. Res. Conf. 44:226–228.

15. Windham, M.T., A.S. Windham, and M.A. Halcomb. 2000. Control of powdery mildew in dogwood with fungicides. Proc. Southern Nursery Assoc. Res. Conf. 45:207–208.