 

Comparison of Synthetic and Organic Fungicides for the Control of Spot Anthracnose, Powdery Mildew, and Cercospora Leaf Spot on Flowering Dogwood in Alabama

Bulletin 668
April 2007

Alabama Agricultural Experiment Station
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Auburn, Alabama

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Web publication, April 2007

Cover images: Typical pink to purple spots on bracts of spot anthracnose-damaged bloom of 'Cloud 9' flowering (left) conpared with the spot free blooms of 'Cherokee Chief' flowering dogwood (right).

Comparison of Synthetic and Organic Fungicides for the Control of Spot Anthracnose, Powdery Mildew, and Cercospora Leaf Spot on Flowering Dogwood in Alabama

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INTRODUCTION

Across the southeastern United States, flowering dogwood (*Cornus florida* L.) is not only a staple in landscape and commercial plantings but also a major commodity for field and container nurseries. Showy bracts, attractive fall foliage color, red fruit clusters, and a widespread adaptability account for the popularity of this tree with consumers and landscapers *(7)*.

Fungus-incited diseases often reduce the beauty and health of flowering dogwood in production nurseries as well as in the landscape. Spot anthracnose, caused by the fungus *Elsinore corni*, may badly deface and distort flower bracts and juvenile leaves, particularly on trees in full sun, but does not have a detrimental impact on tree vigor *(1,14)*. Powdery mildew, caused by the fungus *Erysiphe pulchra [Microsphaera pulchra, M. penicillata]* has emerged as the most damaging disease on flowering dogwood in the nursery, landscape, and forested sites across the South *(2,5,10,16,21,26)*. Although disease-related damage on flowering dogwoods in the landscape appears largely cosmetic, slowed shoot growth, reduced trunk growth, and seedling death have been linked to severe powdery mildew outbreaks *(12,18,24)*. Previously, Cercospora leaf spot, caused by the fungus *Pseudocercospora cornicola [Cercospora cornicola]*, has been considered a minor disease of flowering dogwood *(3,5)*. Hagan et al. *(7)* recently noted that flowering dogwoods damaged by this disease were too heavily defoliated by early October for any display of fall color.

Control of this disease complex presents producers, homeowners, and landscape managers with a serious challenge in maintaining the beauty and vigor of flowering dogwood. While a few flowering dogwood cultivars have good resistance to powdery mildew and/or spot anthracnose, the vast majority are either native seedling trees or a cultivar that is susceptible to both diseases *(10,18)*. Results of an ongoing Alabama study *(8)* indicate that several popular cultivars of flowering dogwood are highly susceptible to Cercospora leaf spot, while five Stellar® hybrid dogwood culti-

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vars *(8)* as well as 'Pigmy', 'Red Pigmy', and 'Pumpkin' flowering dogwood *(4)* may have partial resistance. Unfortunately, the Stellar® hybrid dogwood cultivars are not adapted for landscape use in Central and South Alabama *(8)*.

Since the majority of flowering dogwoods in landscape plantings are susceptible to the above diseases, fungicides are a possible control option. While few studies concerning the efficacy of fungicides for the control of spot anthracnose on flowering dogwood have been published *(14)*, EPA-registered synthetic fungicides include one or more formulations of Heritage 50W [azoxystrobin], Daconil Ultrex/Garden Fungicide [chlorothalonil], Kocide 101 77W/Kocide 3000 [copper hydroxide], Dithane M-45/Fore [mancozeb], Eagle 40W/Immunox [myclobutanil], Disease Control for Roses, Flowers, and Shrubs [tebuconazole], and 3336 4.5F/3336 50W/Halt 50W [thiophanate-methyl] *(1,11)*. Effective control of powdery mildew on flowering dogwood has been obtained with the synthetic fungicides Heritage 50W *(12,17)*, Phyton 27 [copper sulfate pentahydrate] *(17)*, Eagle 40W *(12,19,25)*, Banner MAXX [propiconazole] *(25)*, 3336 50W *(12,17)*, Compass 50W [trifloxystrobin] *(12,25)*, and triflumazole *(25)*. Among organic fungicides, good control of powdery mildew on flowering dogwood was obtained with SunSpray Ultra Fine Oil *(12,19)*. While Mmbaga and Sauve *(17)* reported control of powdery mildew with Armicarb [potassium bicarbonate], a similar product failed to protect dogwood from powdery mildew in two other studies *(19,25)*. Household soaps Ajax and Equate, which are not EPA-registered pesticides, were nearly as effective in controlling this disease as synthetic fungicides *(17)*. In addition to improved tree aesthetics obtained by controlling powdery mildew, increases in trunk diameter and tree height have also been seen with synthetic fungicides *(12,17)*. Since Cercospora leaf spot has never before caused any concern, information concerning the activity of fungicides for the control of this disease on flowering dogwood is not available.

A field trial was initiated in 2003 to assess the effectiveness of selected synthetic and organic fungicides, including products for home landscape use, for the control of spot anthracnose and powdery mildew on flowering dogwood in a simulated landscape setting. In addition, the residual effect of the spring–early summer fungicide program on the development of Cercospora leaf spot and the impact of fungicide treatments on tree growth was also evaluated.

METHODS

Tree maintenance. In February 2001, 'Rubra' flowering dogwoods were transplanted from No. 5 containers into a Benndale sandy loam soil ($\leq$ 1 percent organic material) at the Brewton Agricultural Research Unit (USDA Hardiness Zone 8a), which is located approximately 45 miles northeast of Pensacola, Florida. Prior to planting, soil fertility and pH were adjusted according to the results of a soil fertility assay done by the Auburn University Soil Testing Laboratory. Newly established trees were mulched with 0.5 to 1.0 inches of aged pine bark. Each year, fresh bark mulch was evenly distributed around the base of each tree. A drip irrigation system was installed at planting and the trees were watered as needed. On February 25 and March 3 2003, 2.9 ounces of murate of potash (0N-0P-60K) and 2.1 ounces of 16N-4P-8K fertilizer, respectively, was distributed around each tree. On March 9 2004, 0.2

pounds of super phosphate (0N-46P-0K) was evenly distributed around the base of each dogwood, while on April 12 2005 0.7 ounce of ammonium nitrate (34N-0P-0K) was spread over the bark mulch. The pre-emergent herbicides Gallery at 1 pound per acre and Surflan at 2 quarts per acre were applied on May 19 2003, April 21 2004, and March 18 2005. Finale 1E at 2 fluid ounces per gallon was applied for post-emergent grass control on May 6 and September 4 2003, as well as on April 21 2004 and May 23 2005. Trunk sprays of 0.5 fluid ounces per gallon of Dursban 2E were made on March 24 and April 27 2004 to control dogwood borer.

Fungicide treatments. Fungicides were applied to run-off with a CO_2-pressurized sprayer with single nozzle on a hand-held wand from April 4 to July 1 2003, April 7 to June 30 2004, and May 19 to June 29 2005. While Rhapsody was applied weekly, Neem Concentrate (clarified extract of neem oil) and SunSpray Ultra Fine Oil were applied at 1- and 2-week intervals. Synthetic fungicides Eagle 40W, Immunox Multi-Purpose Fungicide, 3336 50W, and Liquid Systemic Fungicide were applied at 2-week intervals. Application rates for all fungicide treatments are listed in Table 1.

Tree growth. Tree height and trunk diameter were recorded on February 18 2003, January 14 2004, January 18 2005, and January 10 2006. Differences in tree height and trunk diameter over time were determined by subtracting the initial height or diameter measurement from the final measurement for each of those growth parameters.

Disease assessment. Incidence of spot anthracnose on the bracts and leaves, powdery mildew, and Cercospora leaf spot were visually rated using the Horsfall and Baratt Rating Scale (1 = no disease, 2 = 0 to 3 percent, 3 = 3 to 6 percent, 4 = 6 to 12 percent, 5 = 12 to 25 percent, 6 = 25 to 50 percent, 7 = 50 to 75 percent, 8 = 75 to 87 percent, 9 = 87 to 94 percent, 10 = 94 to 97 percent, 11 = 97 to 100 percent, and 12 = 100 percent of the leaves diseased or prematurely shed). Spot anthracnose was rated on the leaves on April 23, May 29, and June 18 2003; May 7 2004; and April 22, May 12, and June 20 2005. Spot anthracnose was rated on the bracts on April 7 2004, April 11 2005, and April 7 2006. Ratings for powdery mildew were taken on May 29, June 18, and July 16 2003; May 20, June 16, and July 8 2004; and May 12, June 20, and July 22 2005. Cercospora leaf spot-related leaf spotting and defoliation was rated separately on August 18, October 3, and October 30, 2003; August 2, August 24, September 30, and October 27 2004; and July 22, August 22, September 2, October 5, October 18, and November 5 2005. In addition, the leaves of all dogwoods were periodically examined for symptoms of fungicide-caused phytotoxicity.

Weather conditions. In 2003, monthly rainfall totals were near normal for April, May, August, and September, well above normal for June and July, and well below average for October. During this same period, daily temperatures were near normal and no extended periods of hot, dry weather occurred. For the following year, monthly rainfall totals reached or exceeded the historical average for all months except for October. In addition, daily temperatures were near normal and no extended periods of unusually hot, dry weather were noted. While daily temperatures were near normal for much of the 2005 growing season, unseasonably dry weather occurred from early April to late May and again in October. Due to several tropical weather systems and almost daily afternoon thunder showers, rainfall totals for the months of June, July, and August were unusually high.

Table 1. Control of Spot Anthracnose on the Bracts and Leaves of 'Rubra' Flowering Dogwood with Organic and Synthetic Fungicides

	Application			Flower bracts[1]			Leaves		
Fungicide	Rate/gal	Rate/100 gal	Interval (week)	2004	2005	2006	2003	2004	2005
Organic									
Neem Concentrate	1.0 fl oz	0.8 gal	1	4.7	11.7	8.6	4.8	1.5	7.5
Neem Concentrate	1.0 fl oz	0.8 gal	2	5.0	12.0	8.8	5.7	2.0	7.5
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	1	6.7	11.3	7.2	4.8	1.2	6.8
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	2	6.7	12.0	10.7	3.3	1.6	6.2
Rhapsody	3.8 fl oz	3.0 gal	1	4.7	11.0	7.3	4.0	1.5	6.0
Synthetic									
Immunox	1.0 fl oz	0.8 gal	2	2.0	4.5	4.0	1.7	1.0	3.3
Eagle 40W	--	8 oz	2	2.7	4.0	4.5	2.0	1.0	3.0
3336 50W	--	1 lb	2	1.8	4.3	3.2	2.2	1.2	3.2
Liquid Systemic Fungicide	0.5 fl oz	0.4 gal	2	2.4	3.8	4.4	2.2	1.0	2.5
Untreated Control				8.3	11.0	11.3	5.3	2.7	6.8

[1]Spot anthracnose incidence, which was rated on a 1 to 12 Horsfall and Barratt rating scale, was assessed on the bracts on April 7 2004, April 11 2005, and April 7 2006 and on the leaves on April 23 2003, May 7 2004, and May 12 2005.

RESULTS AND DISCUSSION

Spot anthracnose on bracts. In all three years, the pin head-sized brown spots with a purple halo characteristic for spot anthracnose were first seen as the bracts and juvenile leaves unfurled. Spot anthracnose damage sometimes was so severe that the bracts failed to fully unfurl. While symptoms continued to appear on immature leaves following a heavy shower into late June, little if any disease spread was seen through the rest of the summer.

Fungicides applied in 2003 had a significant impact on the incidence of spot anthracnose on the bracts and the percentage of aborted flower buds seen the following spring. When compared with the untreated controls, all fungicides except for SunSpray Ultra Fine Oil noticeably reduced the incidence of spot anthracnose damage on the bracts in 2004 (Table 1). On the untreated controls, spotting and deformation of the bracts was seen on more than 75 percent of the blooms compared with about 6 percent of the blooms on the Immunox, Liquid Systemic Fungicide, 3336 50W, and Eagle 40W-treated dogwoods. These synthetic fungicides also reduced the percentage of aborted flower buds to near zero. While some reduction in percentage of aborted buds was obtained with Rhapsody and Neem Concentrate, these organic fungicides did not control this phase of spot anthracnose as well as the synthetic fungicides. Despite higher disease pressure in 2005, the level of spot anthracnose-associated bract damage and bud abortions was greatly reduced by Immunox, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide (Table 1). Incidence of diseased bracts on trees treated with the above fungicides ranged from an unobtrusive 7 to 12 percent compared with nearly 100 percent for the untreated controls. In contrast, disease ratings for the Rhapsody, Neem Concentrate, and SunSpray Ultra Fine Oil programs were similar in 2005 to the near 100 percent rating for the untreated controls. In 2006, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide limited bract spotting to less than 10 percent of the blooms compared with 50 percent of the blooms with SunSpray Ultra Fine Oil and Rhapsody (Table 1). Spot anthracnose ratings for both of the Neem Concentrate and the bimonthly SunSpray Ultra Fine programs did not greatly differ from the 97 percent damage level of the untreated controls.

Eagle 40W, Immunox, 3336 50W, and Liquid Systemic Fungicide gave excellent control of spot anthracnose on the bracts. Typically, bract damage on flowering dogwood treated with these fungicides was restricted to a few, scattered spots. Bract discoloration and deformation as well as premature bract loss that characterizes severe spot anthracnose outbreaks was not seen on the synthetic fungicide-treated dogwoods. Such a carryover of disease control from one year to the next is highly unusual. Trivellte and Mmbaga *(22)* showed that fall applications of organic and synthetic fungicides slowed powdery mildew onset the following spring enough to delay the first fungicide application by 6 weeks. Eagle 40W *(20)*, Banner MAXX *(23)*, and 3336 50W *(6)* are systemic fungicides that move up with the transpiration stream and eventually accumulate at the leaf tip and margin. In host tissues, all of the above fungicides have curative or eradicant activity against some plant pathogenic fungi, particularly powdery mildews *(20)*. Over the 10- to 12-week treatment period, enough of these fungicides penetrated the tender shoots and flower buds to kill the dormant conidia or hyphae of the causal fungus of spot anthracnose.

In contrast to the carryover of spot anthracnose control on the bracts by the synthetic fungicides, the organic fungicides SunSpray Ultra Fine Oil, Neem Concentrate, and Rhapsody, which have only contact activity on the leaf surface, did not give consistent control of the bract spot phase of spot anthracnose the following year. When compared with the untreated control, bract spotting was reduced with Neem Concentrate in only 2004. Bract spotting levels were lower for the 1- but not the 2-week SunSpray Ultra Fine Oil programs compared with the untreated control in 2006. In that year, disease ratings for the 1-week SunSpray Ultra Fine Oil program were similar to Eagle 40W, Immunox, and Liquid Systemic Fungicide. In 2004 and 2006, Rhapsody reduced the incidence of spot anthracnose damage on the bracts compared with the untreated control but gave poorer disease control than the synthetic fungicides.

Spot anthracnose on leaves. When compared with the untreated control, incidence of the leaf spot phase of spot anthracnose was reduced with most of the fungicide programs except for both the Neem Concentrate and the weekly SunSpray Ultra Fine Oil programs on April 23 2003 (Table 1). Spot anthracnose was seen on about 4 percent of the leaves of the dogwoods treated with Immunox, Eagle 40W, Liquid Systemic Fungicide, and 3336 50W compared with 15 percent of leaves on the untreated controls. Spot anthracnose control with the synthetic fungicides was similar across all 2003 rating dates (data not shown).

For 2004, spot anthracnose ratings were well below those seen in the previous year. On May 7 2004, leaf spot symptoms were found on less than 6 percent of the leaves of the untreated control. All treatments except for the bimonthly Neem Concentrate program reduced the incidence of spot anthracnose compared to the untreated control (Table 1).

In 2005, Immunox, Eagle 40W, 3336 50W, and Systemic Fungicide gave the best control of spot anthracnose. Approximately 6 percent of the leaves on the Immunox-, Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods showed symptoms compared with nearly 50 percent of leaves on the untreated control (Table 1). On May 12, spot anthracnose leaf ratings were also lower for the 2-week SunSpray Ultra Fine Oil and Rhapsody treatments than for the untreated controls. However, neither of these treatments was as effective in controlling spot anthracnose as Immunox, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide. While Immunox, Eagle 40W, Liquid Systemic Fungicide, and to a lesser extent 3336 50W, controlled spot anthracnose through June 20, Neem Concentrate, Sun Spray Ultra Fine Oil, and Rhapsody failed to protect flowering dogwood from this disease.

Over the three-year study period, the synthetic fungicides Eagle 40W, Immunox, Liquid Systemic Fungicide, and 3336 50W consistently gave good control of the leaf spot phase of spot anthracnose, and the low level of leaf spotting had no effect on leaf structure or tree aesthetics. The level of spot anthracnose control obtained with the retail/residential products Immunox and Liquid Systemic Fungicide was comparable to that provided by the commercial products Eagle 40W and 3336 50W.

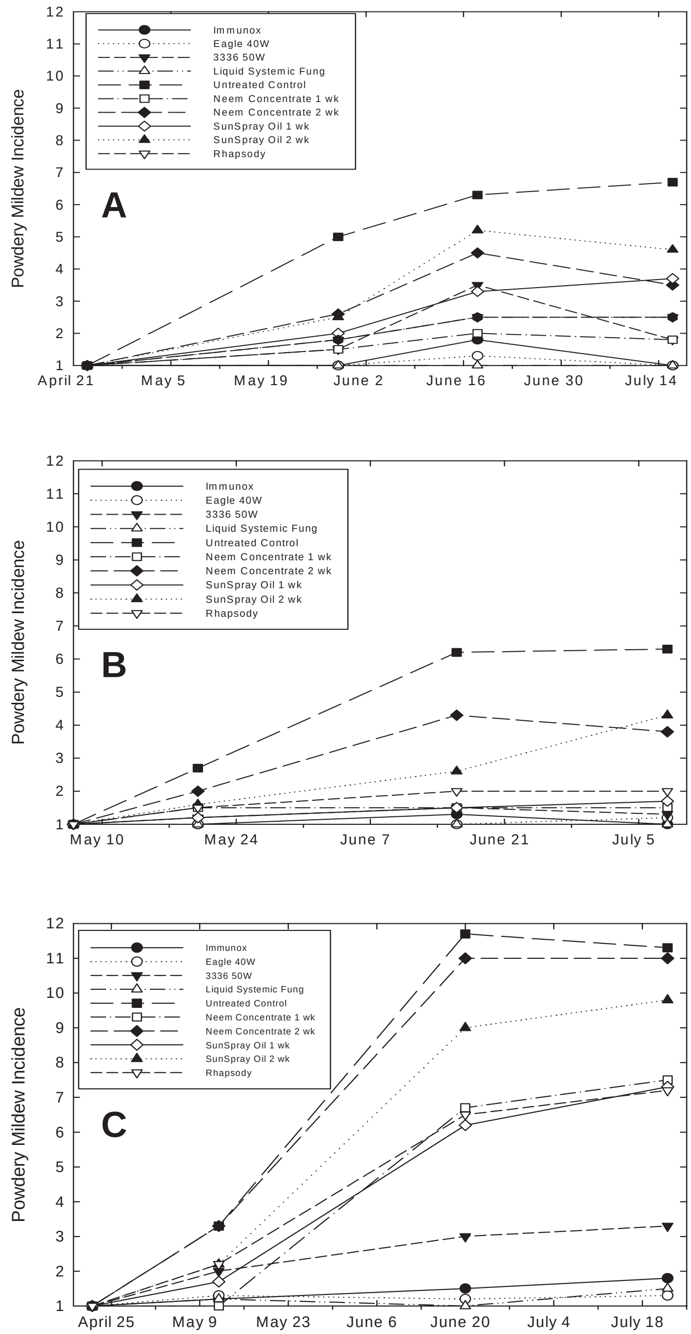
The organic fungicides Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody failed to control the leaf spot phase of spot anthracnose as well as the synthetic fungicides (Table 1). Discounting the low disease pressure year of 2004, no reduction in spot anthracnose ratings were obtained with either Neem Concentrate program when compared with the untreated control. Surprisingly, SunSpray Ultra Fine Oil applied at 2-week intervals reduced the leaf spot levels in 2003 and 2005 below that for the untreated control and weekly program with the same fungicide. Spot anthracnose ratings for this fungicide program were similar to those for 3336 50W and Liquid Systemic Fungicide. When compared with the untreated controls, Rhapsody gave some control of the leaf spot phase of spot anthracnose but was less effective than the synthetic fungicides against this disease.

Powdery mildew. On May 29 2003, feathery white colonies of the causal fungus of powdery mildew were seen on approximately 12 percent of the leaves on the untreated control. Fungal colonies were found on about 30 percent and 50 percent of leaves on the untreated dogwoods on June 18 and July 16, respectively (Figure 1A). In contrast, less than 2 percent leaf colonization was noted at all rating dates on the Immunox-, Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods. Effectiveness of the weekly Neem Concentrate and Rhapsody treatments for the control of powdery mildew was often comparable to that obtained with Immunox, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide. When compared with the untreated control, SunSpray Ultra Fine Oil applied at 1- and 2-week intervals reduced powdery mildew incidence but did not give the same level of control as the synthetic fungicides.

In 2004, powdery mildew first appeared on the leaves between May 7 and May 20. While this disease intensified between May 20 and June 16, little if any increase in powdery mildew was seen through the rest of the summer. Generally, incidence of powdery mildew on all rating dates was higher on the untreated control than on the fungicide-treated dogwoods (Figure 1B). On June 18, poorest disease control was given by the bimonthly Neem Concentrate program (Table 2). However, less than 10 percent of the leaves on the Neem Concentrate-treated trees were colonized compared with more than 25 percent for the untreated control. Weekly applications of Neem Concentrate and SunSpray Ultra Fine Oil controlled powdery mildew as well as Immunox, Eagle, 3336 50W, and Liquid Systemic Fungicide. On flowering dogwood treated with the synthetic fungicides, fungal colonies were found on less than 1 percent of the leaves.

Powdery mildew pressure was higher in 2005 than in the two previous years. Between May 12 and June 20, the percentage of colonized leaves on the untreated control jumped from more than 3 percent to nearly 100 percent (Figure 1C). Similar increases in disease incidence were also recorded for the bimonthly Neem Concentrate and SunSpray Ultra Fine Oil treatments. Powdery mildew ratings for the bimonthly Neem Concentrate program and untreated controls were similar at all 2005 rating dates. Weekly Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody, which reduced powdery mildew incidence compared with the untreated control, gave poorer disease control than Immunox, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide. In June and July, fungal colonies were restricted to less than 3 percent of the leaves on the synthetic fungicide-treated dogwoods compared with more than 25 to 50 percent of the leaves on the Neem Concentrate-, SunSpray Ultra Fine Oil-, and Rhapsody-treated

Figure 1A-C. Impact of fungicides on the incidence of powdery mildew on 'Rubra' flowering dogwood in 2003 (Fig.1A), 2004 (Fig. 1B), and 2005 (Fig. 1C).



flowering dogwood.

As was reaffirmed in this study, Eagle 40W *(12,19,25)* and Liquid Systemic Fungicide [= Banner MAXX] *(12,17,25)* gave excellent control of powdery mildew on flowering dogwood. Over the three-year study period, a very low level of leaf colonization by the powdery mildew fungus on the Eagle 40W-, Immunox-, and Liquid Systemic Fungicide-treated dogwoods was seen, particularly under high disease pressure in 2005. As previously reported by Hagan et al. *(12)*, 3336 50W was slightly less effective in controlling powdery mildew than Eagle 40W, Immunox, or Liquid Systemic Fungicide. In a second study *(17)*, however, 3336 50W proved as effective in controlling powdery mildew on field-grown flowering dogwood as Banner MAXX.

Activity of the organic fungicides Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody was better against powdery mildew than spot anthracnose. In 2003 and 2004 when powdery mildew pressure was moderate, weekly and to a lesser extent bimonthly applications of the above organic fungicides noticeably reduced disease incidence. Weekly Neem Concentrate and Rhapsody treatments gave the same level of control as the synthetic fungicides. When applied weekly, SunSpray Ultra Fine Oil gave the same level of powdery mildew control in 2003 and 2004 as 3336 50W. Previously, Hagan et al. *(12)* noted a similar level of powdery mildew control on flowering dogwood when SunSpray Ultra Fine Oil and 3336 4.5F were applied at 2-week intervals. Under heavier powdery mildew pressure in 2005, Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody failed to control this disease as effectively as Eagle 40W, Immunox, Liquid Systemic Fungicide, and 3336 50W. Previously, SunSpray Ultra Fine Oil applied bimonthly was not as effective in controlling powdery mildew as Eagle 40W or Immunox applied on the same schedule *(19)*. In addition, the bimonthly Neem Concentrate and SunSpray Ultra Fine Oil treatments did not control powdery mildew as well as weekly applications of the same fungicides. A similar decline in

TABLE 2. SUPPRESSION OF CERCOSPORA LEAF SPOT-ASSOCIATED DEFOLIATION ON 'RUBRA' FLOWERING DOGWOOD WITH ORGANIC AND SYNTHETIC FUNGICIDES

	———Application———			—Cercospora leaf spot— Defoliation rating[1]		
Fungicide	Rate/ gal	Rate/ 100 gal	Interval (week)	Aug 19	Oct 3	Oct 30
Organic						
Neem Concentrate	1.0 fl oz	0.8 gal	1	1	4.0	5.3
Neem Concentrate	1.0 fl oz	0.8 gal	2	1.5	4.8	6.0
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	1	1	4.7	5.8
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	2	1.8	5.4	6.4
Rhapsody	3.8 fl oz	3.0 gal	1	1.3	5.7	6.8
Synthetic						
Immunox	1.0 fl oz	0.8 gal	2	1	4.0	5.0
Eagle 40W	--	8 oz	2	1	2.7	5.2
3336 50W	--	1 lb	2	1	2.5	5.0
Liquid Systemic Fungicide	0.5 fl oz	0.4 gal	2	1	2.6	5.2
Untreated Control				2.5	6.3	7.8

[1] Defoliation associated with Cercospora leaf spot was rated using the 1 to 12 Horsfall and Barratt rating scale.

powdery mildew control on flowering dogwood with organic fungicides such as Armicarb and the household soaps Palmolive, Ajax, and Equate when application intervals were extended from 1 to 2 weeks was recently reported by Mmbaga and Sauve *(17)*.

Cercospora leaf spot. While the angular brown leaf lesions diagnostic for Cercospora leaf spot appear as early as late June, typically symptoms were not noticeable on untreated dogwoods until late July to mid-August, which was approximately 4 weeks after the last fungicide application was made (Figures 2 and 4). This disease intensified over the next 6 to 8 weeks until nearly all but the youngest leaves at the shoot tips were damaged or prematurely shed. Within 4 weeks of disease onset, noticeable premature shedding of the spotted and often yellowed (chlorotic) leaves was seen on the untreated controls (Figures 3 and 5). By late October, untreated dogwoods, which had lost more than 90 percent of their leaf canopy, displayed little fall color.

While all fungicides reduced the incidence of Cercospora leaf spot compared with the untreated control on August 19 2003, differences in the level of disease suppression were seen between fungicide treatments. Immunox, Eagle 40W, 3336 50W, and Liquid Systemic Fungicide, which limited spotting to less than 2 percent of the leaves, were equally effective in slowing disease spread. In contrast, Cercospora leaf spot symptoms were noted on that same date on nearly 40 percent of the leaves on the untreated dogwoods. Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody did not slow disease spread as effectively as the synthetic fungicides.

Overall, defoliation levels on the untreated controls, which were very low on August 19 2003, reached 35 percent on October 3 and exceeded 80 percent by October 30. By the final rating date, defoliation levels for the Immunox-, Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods were 12 to 15 percent. Defoliation ratings for both Neem Concentrate and the weekly SunSpray Ultra Fine Oil treatments did not differ greatly from those of the Immunox-, Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwood. Although some reduction in defoliation was obtained with the bimonthly SunSpray Ultra Fine Oil program, disease ratings for Rhapsody and the untreated control were similar.

While a few diseased leaves were seen as early as mid-June 2004, the rate of Cercospora leaf spot development on the untreated controls accelerated between July 8 and August 2 (Figure 2). When compared with the untreated controls, disease spread was slowed by all fungicide treatments at all rating dates. The percentage of diseased leaves on the untreated controls rose from nearly 20 percent on August 2 to more than 90 percent on September 30 compared with only 3 to 10 percent of the leaves diseased on the Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods on September 30 (Figure 2A). While some disease control was obtained with both of the Neem Concentrate programs, as well as the bimonthly SunSpray Ultra Fine Oil and Rhapsody treatments, none was as effective in slowing the spread of Cercospora leaf spot as Eagle 40W, 3336 50W, and Liquid Systemic Fungicide (Figure 2B). Disease incidence on trees treated weekly with SunSpray Ultra Fine Oil, Eagle 40W, and Liquid Systemic Fungicide was similar. While Cercospora leaf spot continued to intensify between September 30 and November 9, lowest disease levels were seen on the Eagle, 3336 50W, Liquid Systemic Fungicide, Immunox, and weekly Neem Concentrate-treated trees. Also, some reduction in leaf spot ratings was obtained with the weekly

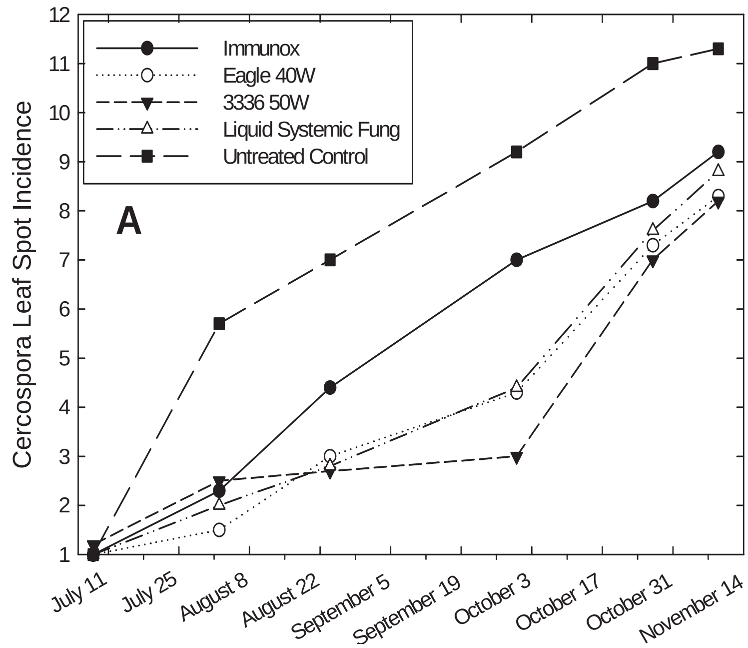
SunSpray Ultra Fine Oil program.

Although a low level of Cercospora leaf spot-incited defoliation was seen on the untreated controls on August 24 2004, premature leaf loss was noticeable on September 30. The untreated control suffered early, 50 percent premature leaf shed compared with approximately 3 percent for the Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods (Figure 3A). When compared to the untreated controls, weekly Neem Concentrate and SunSpray Ultra Fine Oil programs also reduced the level of Cercospora leaf spot-related defoliation (Figure 3B). While the untreated controls had lost more than 90 percent of their leaf canopy by October 27, the Eagle 40W-, 3336 50W-, and Liquid Systemic Fungicide-treated dogwoods suffered from just over 25 percent premature leaf shed. In addition, the weekly Neem Concentrate program was as effective as the latter synthetic fungicides in slowing Cercospora leaf spot-induced defoliation. Some slowing of defoliation was also obtained with the Immunox, weekly SunSpray Ultra Fine Oil, bimonthly Neem Concentrate, and Rhapsody programs.

In 2005, Cercospora leaf spot appeared between June 20 and July 22 (Figure 4). During the next 6 weeks, leaf spotting intensified on the untreated controls to the point that nearly 90 percent of the leaves were diseased compared with about 3 percent for the synthetic fungicide-treated dogwoods (Figure 4A). On September 2, leaf spot levels were again reduced by all fungicide treatments. However, Liquid Systemic Fungicide, Eagle 40W, and 3336 50W slowed disease spread better than Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody (Figure 4A and 4B). Leaf spot levels were also lower for trees treated weekly than bimonthly with Neem Concentrate and SunSpray Ultra Fine Oil. By October 5, the level of Cercospora leaf spot suppression given by Liquid Systemic Fungicide, Eagle 40W, and 3336 50W began to decline. Disease incidence reached approximately 12 percent for Liquid Systemic Fungicide to nearly 40 percent for Eagle 40W on that date compared with 3 percent for both treatments on September 2. In addition, Cercospora leaf spot ratings for the Immunox-, Neem Concentrate-, SunSpray Ultra Fine Oil-, and Rhapsody-treated dogwoods were also below those recorded for the untreated controls. On November 5, the percentage of diseased leaves exceeded 95 percent for the untreated controls compared with less than 50 percent for Liquid Systemic Fungicide to about 65 percent for Eagle 40W and 3336 50W.

On September 2 2005, disease-related defoliation was seen on the untreated controls as well as trees that were treated bimonthly with Neem Concentrate and SunSpray Ultra Fine Oil (Figure 5B). While defoliation levels through this date were lower for the weekly than bimonthly Neem Concentrate and SunSpray Ultra Fine Oil treatments, defoliation ratings for the above organic fungicide were similar by October 5. In contrast, the Liquid Systemic Fungicide-treated dogwoods suffered less than 3 percent defoliation compared with approximately 90 percent for the untreated control on September 2 (Figure 5A). At the last three rating dates, all fungicide-treated dogwoods had lower defoliation ratings than the untreated controls. Over the same rating period, Rhapsody and the weekly Neem Concentrate treatments were nearly as effective in slowing the rate of leaf loss as Immunox, Eagle 40W, and 3336 50W. On November 5, Liquid Systemic Fungicide slowed Cercospora leaf spot-incited premature defoliation

Figure 2A-B. Impact of synthetic (Fig. 2A) and organic (Fig. 2B) fungicides on the incidence of Cercospora leaf spot on 'Rubra' flowering dogwood in 2004.



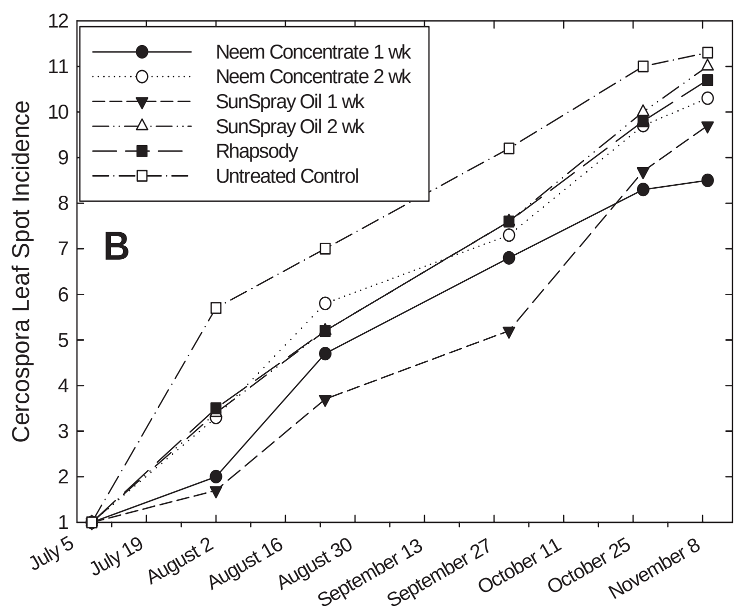
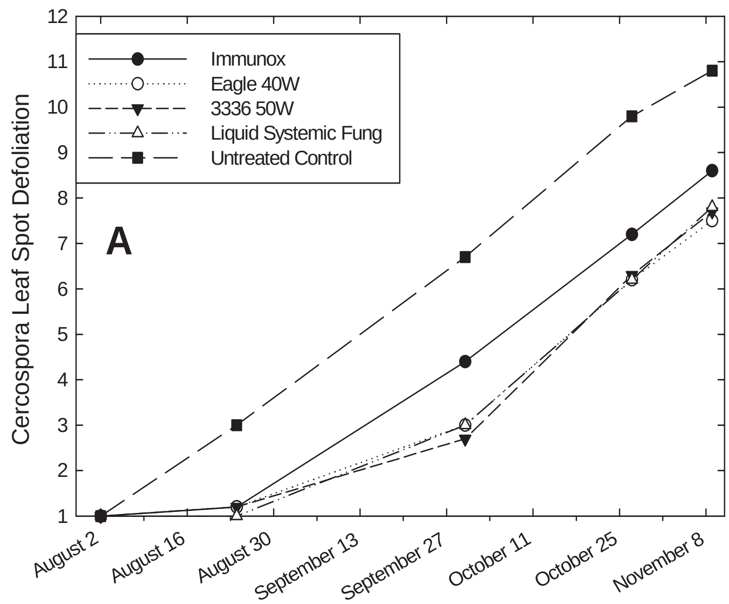


Figure 3A-B. Impact of synthetic (Fig. 3A) and organic (Fig. 3B) fungicides on premature defoliation associated with Cercospora leaf spot on 'Rubra' flowering dogwood in 2004.



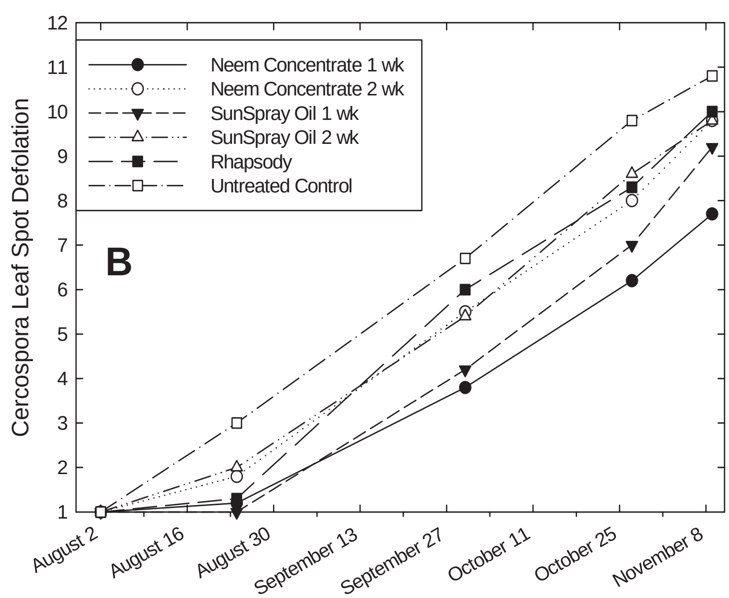
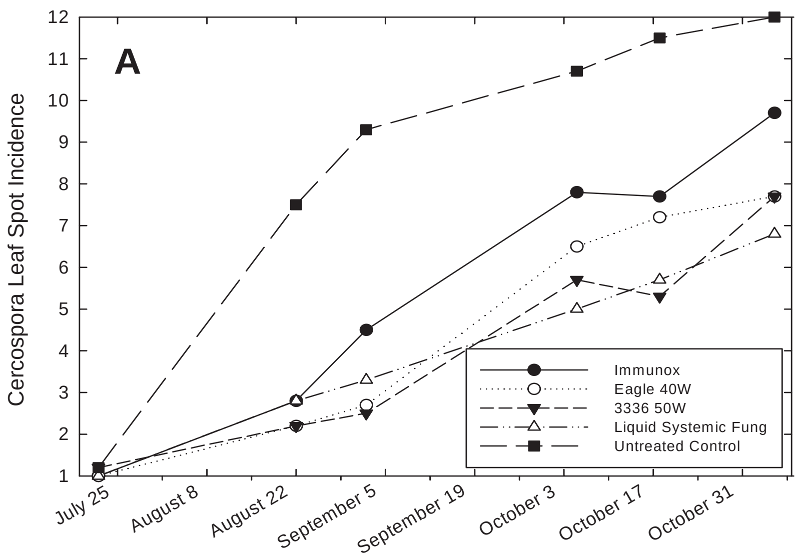


Figure 4A-B. Impact of synthetic (Fig. 4A) and organic (Fig. 4B) fungicides on the incidence of Cercospora leaf spot on 'Rubra' flowering dogwood in 2005.



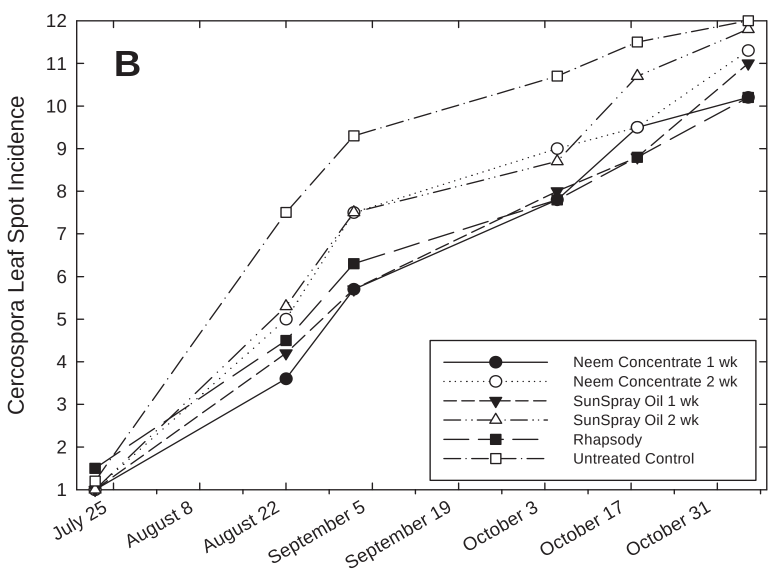
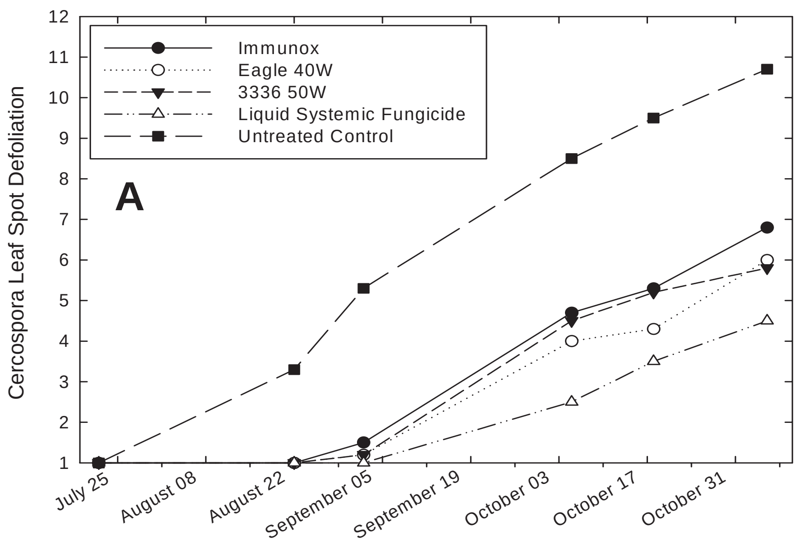
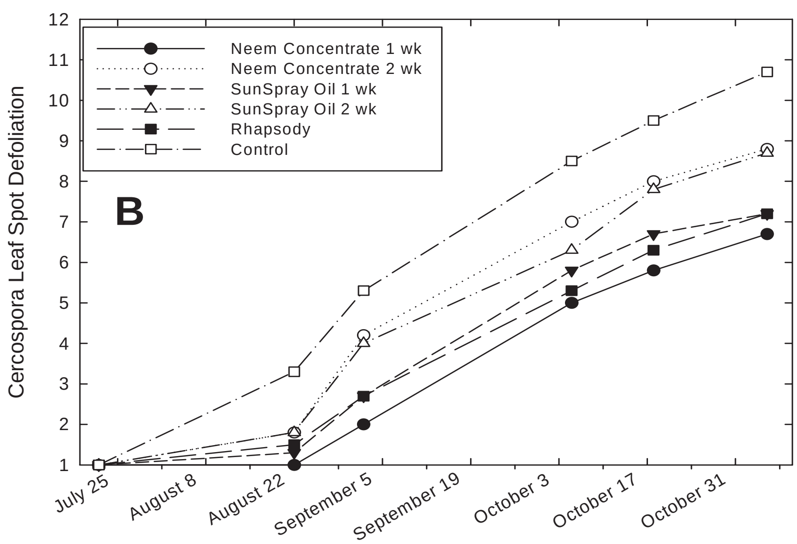


Figure 5A-B. Impact of synthetic (Fig. 5A) and organic (Fig. 5B) fungicides on Cercospora leaf spot-incited defoliation on 'Rubra' flowering dogwood in 2005.





better than all of the other fungicide treatments except for 3336 50W and Eagle 40W.

Although this study was designed to compare the effectiveness of synthetic and organic fungicides for the control of spot anthracnose and powdery mildew on flowering dogwood, most treatments also suppressed the spread of Cercospora leaf spot. While the fungicide applications stopped each year around July 1, their impact on the development of Cercospora leaf spot was seen through late October or early November. The most dramatic reduction in Cercospora leaf spot-related leaf spotting and defoliation as well as the best fall color display were provided with the synthetic fungicides Eagle 40W and 3336 50W as well as the residential/retail Liquid Systemic Fungicide. While the retail/residential fungicide Immunox slowed disease development better than most of the organic fungicides, higher leaf spotting and premature defoliation were recorded for this treatment than for the commercial formulation of this same fungicide, Eagle 40W.

While the organic fungicides Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody slowed Cercospora leaf spot development, none proved as effective in delaying disease spread as Eagle 40W, Liquid Systemic Fungicide, and 3336 50W. However, leaf spotting and defoliation levels recorded for the weekly Neem Concentrate and SunSpray Ultra Fine Oil programs were similar to those obtained with the retail/residential product Immunox. Better control of Cercospora leaf spot was given by weekly than bimonthly applications of Neem Concentrate and SunSpray Ultra Fine Oil. Overall, the weekly Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody programs gave a similar level of Cercospora leaf spot control on flowering dogwood.

Phytotoxicity. Among the fungicides screened over the three-year study period, only SunSpray Ultra Fine Oil was phytotoxic to flowering dogwood. In all three years, a mosaic of yellow and green areas as well as interveinal yellowing along the larger veins was seen on the leaves of the SunSpray Ultra Fine Oil-treated flowering dogwoods. Typically, these symptoms were more noticeable, particularly during the summer months, on the trees treated on a weekly than bimonthly schedule with this fungicide. These symptoms did not progress to a marginal leaf burn or increase the rate of defoliation. In recent studies, SunSpray Ultra Fine Oil did not damage the leaves of flowering dogwood grown on full-sun *(19)* or shaded sites *(12)*. However, SunSpray Ultra Fine Oil-induced leaf spotting or yellowing has been noted on other container-grown woody ornamentals *(13)*. Differences in flowering dogwood cultivar sensitivity to SunSpray Ultra Fine Oil may be responsible for the variation in phytotoxicity that was noted between these studies.

Tree growth. Superior disease control obtained with some fungicides did not translate into increased tree height or trunk diameter when compared with the untreated control. Tree growth as measured by the difference between final and initial tree height was similar for the fungicide-treated and untreated flowering dogwoods (Table 3). However, Liquid Systemic Fungicide-treated ‘Rubra’ flowering dogwoods were shorter than those treated with Immunox, Neem Concentrate, and SunSpray Ultra Fine Oil at 2-week intervals. Trunk diameter was higher for the dogwood treated with Immunox, Liquid Systemic Fungicide, Eagle 40W, and weekly with Neem Concentrate than for the untreated controls.

Plant growth regulator (PGR) activity associated with the extended use of tri-

TABLE 3. IMPACT OF FUNGICIDE TREATMENTS APPLIED OVER A THREE-YEAR PERIOD ON THE GROWTH OF 'RUBRA' FLOWERING DOGWOOD

	Application			Increase in tree growth	
Fungicide	Rate/ gal	Rate/ 100 gal	Interval (week)	diameter in	height in
Organic					
Neem Concentrate	1.0 fl oz	0.8 gal	1	0.95	34.7
Neem Concentrate	1.0 fl oz	0.8 gal	2	1.02	40.6
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	1	1.03	38.2
SunSpray Ultra Fine Oil	1.0 fl oz	0.8 gal	2	1.13	40.6
Rhapsody	3.8 fl oz	3.0 gal	1	1.06	37.5
Synthetic					
Immunox	1.0 fl oz	0.8 gal	2	1.26	42.3
Eagle 40W	--	8 oz	2	0.89	33.5
3336 50W	--	1 lb	2	1.13	37.1
Liquid Systemic Fungicide	0.5 fl oz	0.4 gal	2	0.93	26.1
Untreated Control				0.95	30.8

azole (Ergosterol Biosynthesis Inhibiting) fungicides like myclobutanil and propiconazole may be partially responsible for some differences in tree height *(5)*. However, Hagan et al. *(12)* recently noted that significant increases in canopy dimensions (height and width) and trunk diameter of dogwoods treated with myclobutanil and propiconazole exceeded those of the untreated controls. Mmbaga and Sauve *(17)* also saw the largest increases in trunk diameter on propiconazole-treated flowering dogwoods. On container-grown flowering dogwood, fungicides may be more likely to boost tree growth when powdery mildew pressure was high.

SUMMARY

In summary, the synthetic fungicides Liquid Systemic Fungicide, Eagle 40W, Immunox, and 3336 50W often gave superior control of spot anthracnose, Cercospora leaf spot, and powdery mildew than did the organic fungicides Neem Concentrate, SunSpray Ultra Fine Oil, and Rhapsody. Overall, the organic fungicides gave more effective control of powdery mildew compared with spot anthracnose and Cercospora leaf spot. In addition, Neem Concentrate and SunSpray Ultra Fine Oil had to be applied at 1-week intervals to obtain powdery mildew control comparable to the level provided by synthetic fungicides. Efficacy of all organic fungicides for the control of powdery mildew sharply declined when disease pressure was high. Due to significant leaf phytotoxicity, SunSpray Ultra Fine Oil should not be applied in to flowering dogwood growing in full sun.

Among the synthetic fungicides, the most effective control of the above diseases was obtained with the commercial product Eagle 40W and Systemic Liquid Fungicide, which can be purchased at garden centers and other retail outlets. While 3336 50W controlled spot anthracnose and Cercospora leaf spot as well as Eagle 40W and Liquid Systemic Fungicide, the former fungicide was slightly less effective in controlling powdery mildew. Halt 50W, which contains the same active ingredient as 3336 50W, is also sold at garden centers. The level of powdery mildew and spot anthracnose control obtained with Eagle 40W and Immunox, which contain the same active ingredient, was similar. The retail/residential fungicide Immunox did not control Cercospora leaf spot as well as Eagle 40W. Poorer residual control of Cercospora leaf spot with the Immunox could be attributed to a lower application rate compared with the commercial formulation Eagle 40W.

Exclusive use of a benzimidiazole fungicide such as 3336 50W or Halt [thiophanate-methyl] as well as the triazole fungicides Eagle 40W or Immunox [myclobutanil] and Liquid Systemic Fungicide or Banner MAXX [propiconazole] over an extended period of time can result in control failures due to resistance in target plant pathogenic fungi. Such control failures are far more likely to occur in a nursery production than in a landscape setting, particularly with the benzimidiazole class fungicides *(6)*. According to FRAC [Fungicide Resistance Action Committee, www.frac.info/frac/index.htm] guidelines, the risk of a control failure due to resistance can be minimized by restricting the use of benzimidiazole or triazole fungicides to no more than half of the total number of fungicide applications made to a given target plant(s) per production cycle or growing season. While alternating a benzimidiazole and triazole fungicide is an acceptable resistance avoidance strategy, rotating or tank-mixing a broad spectrum synthetic [i.e. chlorothalonil or mancozeb] or possibly organic fungicide with a benzimidiazole and/or triazole fungicide is the preferred method of reducing the risk of a control failure due to tolerance or resistance in target plant pathogenic fungi.

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APPENDIX

List of linked figures:

Figure A1. Spot anthracnose on leaves of flowering dogwood.

Figure A2. Spotting of the bracts of flowering dogwood due to spot anthracnose.

Figure A3. Typical pink to purple spots on bracts of spot anthracnose-damaged bloom of ‘Cloud 9’ flowering (left) compared with the spot free blooms of ‘Cherokee Chief’ flowering dogwood (right).

Figure A4. Healthy bracts of ‘Rubra’ flowering dogwood (left) compared with those severely distorted by spot anthracnose (right).

Figure A5. White cottony material covering surface of dogwood leaf is the causal fungus of powdery mildew. Untreated dogwood is shorter and has sparser, smaller leaves than the fungicide-treated tree.

Figure A6. Spotting and discoloration of the leaves of flowering dogwood due to Cercospora leaf spot. Close up of typical angular to oval leaf spots with gray center and maroon to brown halo associated with Cercospora leaf spot on flowering dogwood.

Figure A7. While the leaf spotting and premature leaf drop due to Cercospora leaf spot is usually not noticeable in late August (right), this diseased ‘Rubra’ dogwood (left) lost more than 75 percent of its leaves by early October.

Figure A8. Appearance of (A) untreated and (B) 3336 50W-, (C) Immunox-, and (D) Neem Concentrate-treated ‘Rubra’ flowering dogwood on October 4 2005. Note the sparse leaf canopy on the untreated dogwood compared to those protected with a fungicide.

Figure A9. Immunox-treated ‘Rubra’ flowering dogwood on (A) August 24, (B) October 4, and (C) November 2. Note full leaf canopy, absence of fallen leaves around tree, and deep red fall leaf color as late as early November.

Figure A10. 3336 50W-treated ‘Rubra’ flowering dogwood on (A) August 24, (B) October 4, and (C) November 2. Note the full leaf canopy in the first two images and the deep red fall leaf color. Some leaf shed can be seen by November 2.

Figure A11. ‘Rubra’ flowering dogwood treated weekly with Neem Concentrate on (A) August 24, (B) October 4, and (C) November 2. Note the full leaf canopy in the first images and the heavy leaf shed seen on November 2.

Figure A12. ‘Rubra’ flowering dogwood treated every 2 weeks with Neem Concentrate on (A) August 24, (B) October 4, and (C) November 2. Note the full leaf canopy in the first image, noticeable leaf shed seen on October 4, and the near complete defoliation on November 2.

Figure A13. ‘Rubra’ flowering dogwood treated every 2 weeks with SunSpray Ultra Fine Oil on (A) August 24, (B) October 4, and (C) November 2. Note the full leaf canopy in the first image, heavy leaf shed seen as early as October 4, and the nearly defoliated tree on November 2.

Figure A14. Unsprayed ‘Rubra’ flowering dogwood on (A) August 24, (B) October 4, and (C) November 2. When compared with the full leaf canopy seen in the first image, increasing heavy leaf shed can bee seen on October 4 and finally November 2.

Figure A15. SunSpray Ultra Fine Oil phytotoxicity to the leaves of ‘Rubra’ flowering dogwood.

Figure A16. Blooms of ‘Rubra’ flowering dogwood that are free of symptoms of spot anthracnose.

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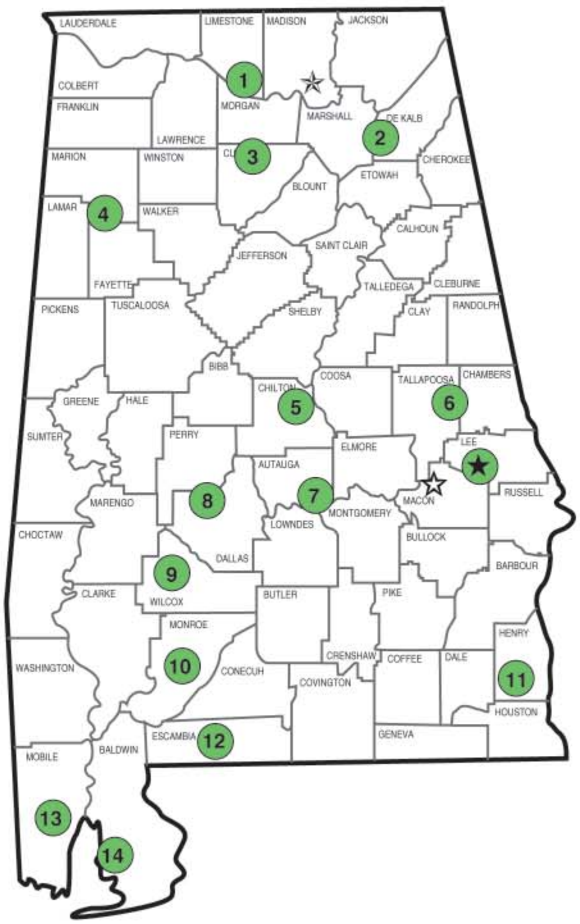

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