Nitrogen and Flowering Dogwood. I. Impact of Nitrogen Fertilization Rate on the Occurrence of Spot Anthracnose, Powdery Mildew, and Cercospora Leaf Spot and Their Effect on Tree Growth[1]

A.K. Hagan[2], J.R. Akridge[3], and K.L. Bowen[4]
Department of Entomology and Plant Pathology
Auburn University, AL 36849

Abstract

Impact of nitrogen (N) rate on spot anthracnose, powdery mildew, and Cercospora leaf spot as well as their impact on the growth of field-grown 'Cloud 9' and 'Cherokee Chief' flowering dogwood was assessed in 2003, 2004, and 2005. From 2001 to 2005, ammonium nitrate was applied at 4.1, 8.3, 16.5, 33.0 and 66.0 g N·m^{-2} (37.5, 75, 150, 300, 600 lb N·A^{-1}). Heritage 50W fungicide was applied to one 'Cherokee Chief' and 'Cloud 9' flowering dogwood in each plot, while the second was untreated. Powdery mildew and Cercospora leaf spot were impacted by N rate more than spot anthracnose. In two of three years, powdery mildew intensified, particularly on the non-treated trees, as N rates increased. Cercospora leaf spot intensity (AUDPCI) and defoliation (AUDPCD) on the fungicide-treated and non-treated trees was influenced by N-rate in two of three and one of three years, respectively. Regardless of fungicide treatment, Cercospora leaf spot incited leaf spotting and defoliation was often lower at the two highest than the two lowest N rates. A reduction in the bract and leaf spot phases of spot anthracnose at the highest N rate was noted in 2004. While spot anthracnose was negatively correlated with trunk diameter in all three years and tree height in 2003 and 2004, Cercospora leaf spot intensity and defoliation were negatively correlated with tree height and trunk diameter in all three and two of three years, respectively. Powdery mildew had no impact on tree height or trunk diameter. Heritage 50W not only controlled spot anthracnose and powdery mildew but also slowed Cercospora leaf spot development sufficiently to enhance leaf retention and fall color.

Index words: spot anthracnose, Cercospora leaf spot, powdery mildew, growth suppression, shoot elongation, trunk diameter, tree height, fall color, chemical control, Heritage, azoxystrobin.

Species used in this study: *Cornus florida* 'Cherokee Chief' and *C. florida* 'Cloud 9'.

Significance to the Nursery Industry

While spot anthracnose, powdery mildew and Cercospora leaf spot often have a detrimental impact on aesthetics of flowering dogwood, little is known of the influence of N fertility on their severity. Beginning in 2001, ammonium nitrate was applied at rates of 4.1, 8.3, 16.5, 33.0, and 66.0 g actual nitrogen per m^2 (g N·m^{-2}) (37.5, 75, 150, 300, 600 lb N·A^{-1}) per year to 'Cloud 9' and 'Cherokee Chief' flowering dogwoods. Incidence of the bract and leaf spot phases of spot anthracnose was influenced by N rate in one of three years. When a link between N rate and either phase of spot anthracnose was seen, reduced disease occurred only at 66 g N·m^{-2} (600 lb·A^{-1}). Powdery mildew intensified with increasing N rates in 2003 and 2005. On the non-fungicide treated trees, reduced leaf spotting and defoliation due to Cercospora leaf spot was associated with the two highest N rates in two of three and one of three years, respectively. Cercospora leaf spot and spot anthracnose but not powdery mildew may have a detrimental impact on tree growth as defined by a negative correlation between these diseases with tree height and/or trunk diameter. For field nursery plantings, applying the recommended 27.5 g N·m^{-2} (250 lb N·A^{-1}) rate should not intensify powdery mildew but would not help suppress Cercospora leaf spot and spot anthracnose. The 4.9 to 14.4 g N·m^{-2} (44 to 130 lb N·A^{-1}) recommended for landscape plantings will not slow the intensification of Cercospora leaf spot and spot anthracnose. Heritage 50W fungicide not only controlled spot anthracnose and powdery mildew but also slowed Cercospora leaf spot-induced defoliation sufficiently for a superb foliage color display in November. Manipulating N rates proved much less effective than a preventative fungicide program in controlling diseases on flowering dogwood.

Introduction

While nitrogen is a key component for plant growth (27), relatively little is known of its impact on the development of diseases of shrubs and trees (16). On Kentucky bluegrass, increased powdery mildew severity may be stimulated by lush top growth produced by excessive N fertilization (2). Elevated N fertility also increased fire blight severity on apple (28) and Phytophthora dieback on rhododendron (14). In contrast, resistance of black walnut to anthracnose was enhanced with supplemental N applications (20, 21). Severity of Alternaria leaf spot and leaf spot diseases incited by bacteria in the genera *Xanthomonas* and *Pseudomonas* on several tropical herbaceous and woody plants declined with increasing N rates (4). On flowering dogwood (*Cornus florida* L.), increasing N rates may reduce dogwood anthracnose severity when weather patterns are less than ideal for disease development (1). Otherwise, nothing is known of the impact of N fertility on spot anthracnose, powdery mildew, or Cercospora leaf spot on flowering dogwood.

The impact of N rate on growth and health of flowering dogwood is not well documented. In a forest setting, Curlin (5) reported that increasing N rates from 0 to 32 g N·m^{-2} (293 lb N·A^{-1}) were accompanied by an increase in the trunk

[1]Received for publication December 1, 2007; in revised form May 9, 2008.

[2]Professor. haganak@auburn.edu
[3]Superintendent, Brewton Agricultural Research Unit.
[4]Professor.

diameter of flowering dogwood. In contrast, no increase in the growth of southern magnolia and live oak in a fine sandy soil occurred above 40 g N·m^{-2} (360 lb·A^{-1}) (8). Smith and Gilliam (27) reported that 14.4 g N·m^{-2} (130 lb·A^{-1}) per year was sufficient for maintaining the health and beauty of landscape trees and shrubs. Currently, N rate recommendations for established landscape trees are 4.9 to 14.4 g N·m^{-2} (44 to 130 lb N·A^{-1}) and 9.9 to 19.3 g N·m^{-2} (87 to 174 lb N·A^{-1}) for quick-release and slow-release forms of nitrogen, respectively (26). For field-grown nursery stock including flowering dogwood, optimum annual N rate is 27.5 g N·m^{-2} (250 lb·A^{-1}) (16).

Diseases not only diminish the floral and foliage display of flowering dogwood but may also slow tree growth. Bract spotting and distortion are the most notable symptoms of spot anthracnose, caused by *Elsinore corni* Jenkins and Bitanic, which is common on flowering dogwood grown in full sun (6). In Alabama (11) and Tennessee (19), powdery mildew, caused by the fungus *Erysiphe pulchra* (Cooke & Bechke) U. Braum & S. Takamatsu comb. nov. [syn. = *Microsphaera pulchra, M. penicillata*], slowed the growth of container-grown flowering dogwood. Cercospora leaf spot, caused by *Pseudocercospora cornicola* (Tracy & Earle) Guo & Lin [syn. = *Cercospora cornicola*], accelerates the rate of leaf abscission to the point that heavily diseased trees show little if any fall color (10). The influence of N rate on the development of spot anthracnose, powdery mildew, and Cercospora leaf spot on flowering dogwood was studied in a simulated landscape planting. The relationship between spot anthracnose, powdery mildew, and Cercospora leaf spot with tree growth was also investigated.

Materials and Methods

Bare-root 'Cherokee Chief' and 'Cloud 9' flowering dogwoods were potted in January 2000 into #5 containers filled with a pine bark:peat moss medium (3:1 by vol) amended with 4.9 kg (14 lb) of Osmocote 17–7–12, 2.1 kg (6 lb) of dolomitic limestone, 0.7 kg (2 lb) of gypsum, and 0.5 kg (1.5 lb) of Micromax m^{-3} (yd^{-3}) of potting mixture. In February 2001, trees were transplanted into a Benndale (A) fine sandy loam [coarse-loamy, siliceous, semiactive, thermic Typic Paleudults] (< 1% organic matter) with a pH of 6.1 at the Brewton Agricultural Research Unit in Brewton, AL (USDA Plant Hardiness Zone 8a), where winter rye (*Secale cereale*) had previously been killed with Roundup® (glyphosate, Monsanto Co., St. Louis, MO). According to the results of a pre-plant soil fertility assay, Mehlich 1 extractable concentrations of phosphorus, potassium, magnesium, and calcium were 29, 41, 56, and 360 mg·kg^{-1} of soil (58, 82, 113, 720 lb·A^{-1}), respectively (7). Centipedegrass (*Eremochola ophiuroides*) alleys separating all trees was periodically mowed but not fertilized during the study period. A drip irrigation system with a single emitter per tree was installed before tree establishment and the trees were watered as needed. A 0.3 m^{-2} (8.6 ft^{-2}) circle of approximately 2.5 cm (1 in) of aged pine bark mulch was maintained around the base of each tree. Murate of potash (0–0–60 K_2O) at 85 g (3.6 oz) per tree was evenly distributed over the mulched area on February 26, 2003, and March 9, 2004. A separate application of superphosphate (0–0–46 P_20_4) at 85 g (3.6 oz) per tree was made on March 9, 2004. Directed applications of 0.68 kg ai·ha^{-1} (1 lb·A^{-1}) of Gallery® DF (isoxaben, Dow AgroSciences LLC, Indianapolis, IN) plus 2.2 kg ai·ha^{-1} (2 qt·A^{-1}) of Surflan® T/O (oryzalin, United Phosphorus, Trenton, NJ) were made to the mulched area each year for pre-emergent annual weed control. Escaped weeds were controlled with hand weeding and spot applications of Finale® 1E (glufosinate-ammonium, Bayer Environmental Science, Kansas City, MO) at 1.9 g a.i.·liter^{-1} (2 fl oz·gal^{-1}). Trunk sprays of Dursban® 2E (chlorpyrifos, Dow AgroSciences LLC, Indianapolis, IN) were made on May 14, 2002, as well as in 2004 on March 24 and April 27 to protect the trees from the dogwood borer *Synanthedon scitula* (Harris).

A split-split plot design consisting of 120 trees in 6 replications with nitrogen rate as the main plot, dogwood cultivar as the split plot, and fungicide treatment as the split-split plot was used. Ammonium nitrate (33N–0P_2O_5–0K_2O) was applied at 4.1, 8.3, 16.5, 33.0 and 66.0 g of actual nitrogen·m^{-2} (37.5, 75, 150, 300, 600 lb N·A^{-1}) per year, which corresponds to 10.4 g, 20.7 g, 41.4 g, 82.9 g, and 165.5 g (0.37, 0.73, 1.46, 2.92, and 5.8 oz) of ammonium nitrate per tree. From 2001 through 2005, half of each rate of the ammonium nitrate was evenly distributed over the mulched area around each tree in April and in June. Each main plot included of a pair of 'Cherokee Chief' and 'Cloud 9' flowering dogwoods, which were planted on 5.0 m (16 ft) centers. Heritage 50W fungicide (azoxystrobin, Syngenta Professional Products, Greensboro, NC) at 1.6 g a.i.·liter^{-1} (4 oz·100 gal^{-1}) of spray volume was applied to one randomly selected 'Cherokee Chief' and 'Cloud 9' flowering dogwood in each plot while the second tree of each cultivar remained non-treated. Fungicide were applied with a CO_2-pressurized sprayer at two-week intervals from April 20 to July 27, 2001; April 10 to July 10, 2002; March 21 to July 10, 2003; April 1 to July 7, 2004; and April 19 to July 27, 2005.

Spot anthracnose, powdery mildew, and Cercospora leaf spot were rated using the Horsfall and Barratt rating scale (15) where 1 = 0%, 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 leaves showing signs or symptoms of the above diseases. Cercospora leaf spot-induced defoliation was also rated using the above scale. Spot anthracnose ratings on the bracts were taken on April 7 and April 23, 2003; March 24 and April 4, 2004; and on April 4 and April 11, 2005. Leaf spot phase of spot anthracnose was rated on April 23, May 27, June 13, and July 16, 2003; April 20, May 7, and June 16, 2004; and April 22, May 12, June 20, and July 24, 2005. Powdery mildew was rated on May 27, June 13, and July 16, 2003; May 20, June 16, and July 8, 2004; and May 12, June 20, and July 24, 2005. Leaf spotting and defoliation due to Cercospora leaf spot were evaluated on August 19, September 20, October 1, October 15, October 30, and November 15, 2003; July 8, August 2, August 24, September 30, October 27, November 9, and November 30, 2004; and July 23, August 22, September 2, October 5, October 18, November 5, and November 16, 2005. Tree height and trunk diameter measurements, which were made 10 cm (4 in) above the soil line, were taken on February 13, 2001; December 3, 2001; February 17, 2003; January 13, 2004; January 8, 2005, and January 10, 2006. Disease ratings were not recorded for 2001 and 2002.

In each year, area under the disease progress curve (AUDPC) was calculated for intensity and/or defoliation for the leaf spot phase of spot anthracnose, powdery mildew and Cercospora leaf spot (25). The AUDPC values for the above diseases along with ratings for the bract spot and leaf

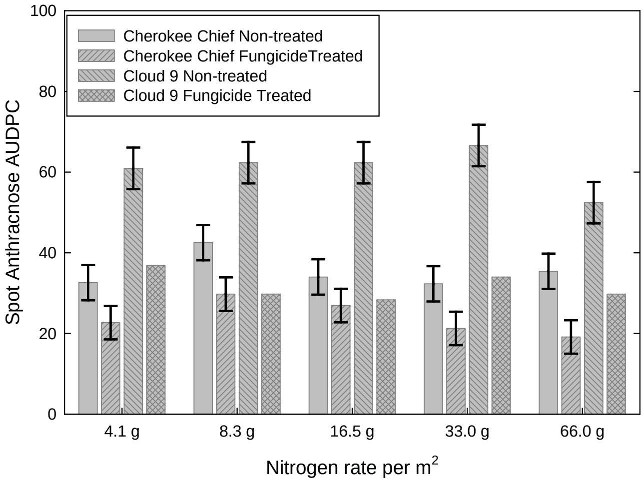

Fig. 1. Impact of nitrogen rate on the leaf spot phase of spot anthracnose on untreated and Heritage 50W-treated Cherokee Chief and Cloud 9 flowering dogwoods in 2004.

spot phases of spot anthracnose were subjected to analysis of variance (ANOVA) according to a split-split plot design using the GLM procedure in SAS (24). The main factor in this arrangement was N rate, the split plot was cultivar, and the smallest unit was fungicide treatment. Significance of interactions was first evaluated. Means were separated using Fisher's protected least significant difference test (LSD) at $P \leq 0.05$. Correlation coefficients between AUDPC values for each disease to differences in tree height and trunk diameter for the non-treated and fungicide-treated trees of both flowering dogwood cultivars between study initiation in 2001 and 2003, 2004, and 2005 were calculated using the CORR procedure in SAS and data from individual plots (24).

Results and Discussion

Bract spot phase of spot anthracnose. In 2003 and 2004, the bract spot phase of spot anthracnose on the non-treated and fungicide-treated trees was not affected by N rate. Nitrogen rate also had no impact on the bract spot phase on the non-treated trees of both cultivars as well as the fungicide-treated 'Cherokee Chief' flowering dogwoods in 2005. However, bract damage on the fungicide-treated 'Cloud 9' flowering dogwoods was significantly lower at 33.0 and 66.0 g N·m^{-2} (300 and 600 lb N·A^{-1}) where approximately 25% of bracts were damaged compared with 90% for trees receiving 4.1 g N·m^{-2} (37.5 lb N·A^{-1}) (data not shown).

Leaf spot phase of spot anthracnose. While N rate did not impact AUDPC values for the leaf spot phase of spot anthracnose on the non-treated or fungicide-treated trees of either cultivar in 2003 and 2005 (data not shown), N rate influence on disease intensity in 2004, which differed by cultivar and fungicide treatment, was inconsistent. Spot anthracnose AUDPC ratings for non-treated 'Cherokee Chief' flowering dogwoods were lower at 4.1 and 33.0 g N·m^{-2} (37.5 and 300 lb N·A^{-1}) than at 8.3 g N·m^{-2} (75 lb N·A^{-1}) (Fig. 1). In contrast, non-treated 'Cloud 9' trees that received 33.0 g N·m^{-2} had higher leaf spot AUDPC ratings compared to those receiving 66.0 g N·m^{-2}. Spot anthracnose AUDPC values for fungicide-treated 'Cherokee Chief' flowering dogwoods were lower at 66.0 g N·m^{-2} (600 lb N·A^{-1}) than 8.3 g N·m^{-2} (75 lb N·A^{-1}). The leaf spot phase of spot anthracnose on the fungicide-treated 'Cloud 9' trees was not influenced by N rate.

The link between reduced occurrence of the bract and leaf spot phases of spot anthracnose with increasing N rate was weak. In two of three years, N rate had no impact on the bract spot phase intensity on the non-treated or fungicide-treated trees of either cultivar. When N rate influenced the bract spot phase on non-treated or fungicide-treated trees, the least bract spotting occurred at 66.0 g N·m^{-2} (600 lb N·A^{-1}). Leaf spot phase ratings were similar across all N rates in 2003 and 2005. While a trend toward reduction in the leaf spot phase at higher N rates was noted on the non-treated and somewhat on fungicide-treated flowering dogwoods in 2004, tree aesthetics was not enhanced.

Powdery mildew. Incidence of powdery mildew on non-treated trees of both cultivars was lower in 2003 and 2004 than 2005 (Table 1). In all three years, little if any disease intensification was seen after the mid- to late-June rating date (data not shown).

Table 1. Impact of cultivar selection and fungicide treatment on powdery mildew and incidence of the bract and leaf spot phases of spot anthracnose.

	Spot anthracnose[z]						Powdery mildew[z]		
	Bract spot phase[y]			Leaf spot phase[x]			Avg. rating[x]		
Cultivar	2003	2004	2005	2003	2004	2005	2003	2004	2005
Cherokee Chief									
Fungicide treated[w]	3.5c[v]	3.3c	4.2c	2.8d	1.4c	3.4c	1.1b	1.0b	1.2b
Non-treated	6.4b	6.3b	11.8a	4.8b	2.1b	6.9b	2.5a	3.0a	6.2a
Cloud 9									
Fungicide treated[w]	6.2b	6.4b	7.0b	3.9c	1.9b	6.7b	1.0b	1.0b	1.1b
Non-treated	9.0a	9.1a	11.7a	7.6a	3.6a	9.7a	2.4a	3.3a	5.8a

[z]Spot anthracnose and powdery mildew were rated using the 1 to 12 Horsfall and Barratt rating scale.

[y]Data for the bract spot phase was recorded on April 7, 2003; April 4, 2004; and April 11, 2005.

[x]Ratings for leaf spot phase of spot anthracnose and powdery mildew were averaged across rating dates.

[w]Treated with Heritage 50W fungicide.

[v]Means followed by the same letter in each column are not significantly different according to Fisher's least significant difference (LSD) test ($P = 0.05$).

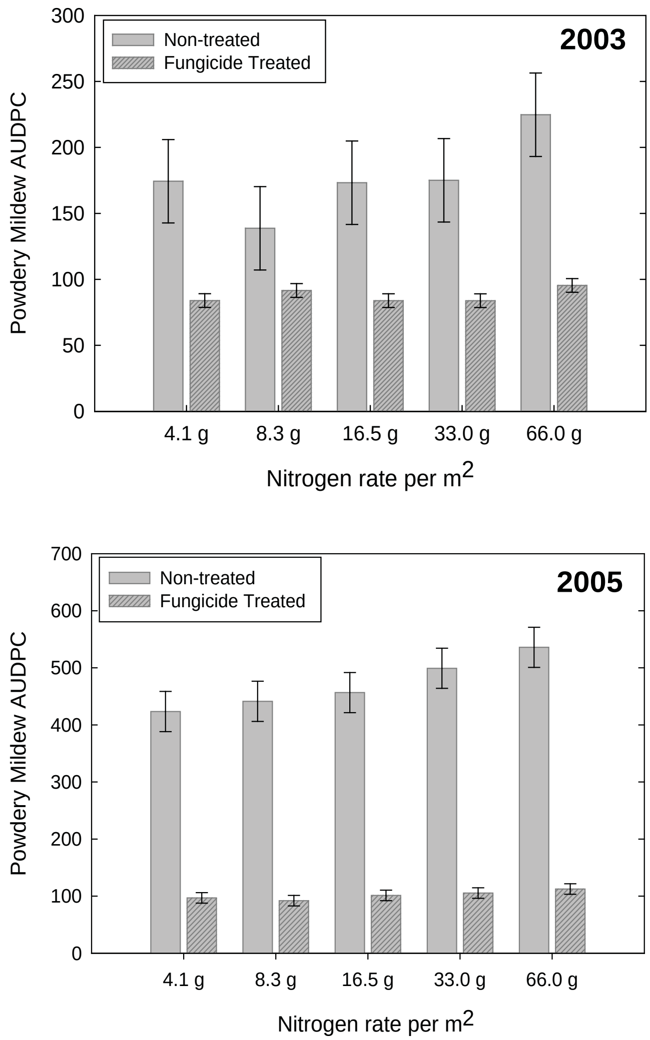

Fig. 2. Impact of nitrogen rate on the season-long incidence of powdery mildew (AUDPC) on the leaves of flowering dogwood that were treated with Heritage 50W fungicide or non-treated in 2003 and 2005.

Since powdery mildew incidence on 'Cloud 9' and 'Cherokee Chief' flowering dogwoods as well as for N treatment ranking was similar in 2003, 2004, and 2005, disease ratings for each year were pooled across cultivars but segregated by fungicide treatment. Powdery mildew incidence on the non-treated or fungicide-treated trees in 2004 was not impacted by N rate. While powdery mildew incidence on the non-treated trees in 2003 was lower at 8.3 g N·m^{-2} (75 lb N·A^{-1}) than 66.0 g N·m^{-2} (600 lb N·A^{-1}), ratings at the remaining N rates were intermediate (Fig. 2). For the fungicide-treated flowering dogwoods, highest disease ratings were noted at 8.3 and 66.0 g N·m^{-2} (75 and 600 lb N·A^{-1}), while the least powdery mildew was seen at 4.1, 16.5 and 33.0 g N·m^{-2} (37.5, 150, and 300 lb N·A^{-1}). On the non-treated trees in 2005, powdery mildew intensified as N rate increased (Fig. 2). Powdery mildew ratings were lower at 4.1, 8.3, and 16.5 g N·m^{-2} (37.5, 75, and 150 lb N·A^{-1}) than at 66.0 g N·m^{-2} (600 lb N·A^{-1}). While N rate had a similar impact on disease development on the fungicide-treated trees, less than 2% of the leaves were colonized (data not shown).

In 2003 and 2005, powdery mildew incidence intensified as N rate increased. In those years, differences in powdery mildew levels were observed between the 8.3 and 66.0 g N·m^{-2} (75 and 600 lb N·A^{-1}). Powdery mildew intensification as influenced by N rate was more noticeable on the non-treated than fungicide-treated trees. Increased powdery mildew on Kentucky bluegrass (2), barley (22), and wheat (23) were associated with higher N rates that stimulated production of lush but vulnerable top growth. Response of powdery mildew to N inputs may have been greater in 2003 and to a lesser extent in 2004 if disease pressure in those years equaled that seen in 2005.

Cercospora leaf spot. Due to a non-significant N rate × cultivar interaction in 2003, 2004, and 2005 for Cercospora leaf spot intensity (AUDPCI) and defoliation (AUDPCD) for the non-treated and fungicide-treated dogwoods, data for each of the above parameters was pooled for cultivars but separated by fungicide treatment.

In 2003, N rate had no influence on Cercospora leaf spot AUDPCI values on the non-treated and fungicide-treated trees (Fig. 3). A significant N rate × fungicide interaction ($P = 0.013$) illustrated that N rate had a significant impact on Cercospora leaf spot defoliation (AUDPCD) on the fungicide-treated where higher AUDPCD values on the fungicide-treated trees were noted at 4.1 g N·m^{-2} (37.5 lb N·A^{-1}) compared with the three highest N rates but not on the non-treated trees.

In 2004, AUDPCI and AUDPCD values for the non-treated and fungicide-treated trees significantly declined as N rate increased (Fig. 3). For both the non-treated and fungicide-treated trees, AUDPCI values at 4.1 and 8.3 g N·m^{-2} (37.5 and 75 lb N·A^{-1}) were significantly higher compared with those at the two higher N rates. Non-treated trees at the two highest N rates had similar AUDPCI values. Defoliation as defined by AUDPCD values was significantly higher for the non-treated and fungicide-treated trees at the two lowest N rates than at 33.0 and 66.0 g N·m^{-2} (300 and 600 lb N·A^{-1}), which had similar AUDPCD values.

While Cercospora leaf spot AUDPCI and AUDPCD values for the non-treated trees were similar across all nitrogen rates in 2005, both of these values declined as N rate increased on fungicide-treated trees (Fig. 3). Lowest AUDPCI values on the fungicide-treated trees were noted at 66.0 g N·m^{-2} (600 lb N·A^{-1}) compared with those at the four lower N rates, which were similar. Overall defoliation was lower at 66.0 g N·m^{-2} (600 lb N·A^{-1}) compared with 4.1 and 8.3 g N·m^{-2} (37.5 and 75 lb N·A^{-1}). Fungicide-treated trees receiving 16.5 and 33.0 g N·m^{-2} (150 and 300 lb N·A^{-1}) had AUDPCD values were similar to those at the higher or lower N rates.

In contrast to powdery mildew, Cercospora leaf spot intensity and defoliation declined as N rates increased. Increasing N rates have also been linked with a reduction of walnut anthracnose (20, 21) along with leaf spot diseases of tropical herbaceous and woody plants incited by the fungi in the genus *Alternaria* along with *Xanthomonas* and *Pseudomonas* bacteria (4). For Cercospora leaf spot, N effects on leaf spot intensity (AUDCPI) and defoliation (AUDPCD) were more often observed for the fungicide-treated than non-treated trees. On the fungicide-treated trees, significant differences in leaf spot intensity and defoliation were noted in two of three and all three years, respectively. When N rate had a significant impact on AUDPCI or AUDPCD, fungicide-treated trees at 4.1 g N·m^{-2} (37.5 lb N·A^{-1}) and to a slightly lesser extent 8.3 g N·m^{-2} (75 lb N·A^{-1}) consistently had higher leaf spot and defoliation ratings compared with 66.0 g N·m^{-2}. In one and two years, AUDPCD values at 16.5 and 33.0 g N·m^{-2} (150 and 300 lb N·A^{-1}), respectively, were similar to those for the highest N rate. On the fungicide-treated trees, increased leaf retention at the higher compared with lower N rates enhanced fall color into November (Hagan, personal observation). For the non-treated flowering dogwoods, N rate impacted Cercospora leaf spot in only 2004. The pattern of increased AUDPCI and AUDPCD values at the two lowest than the two highest N rates on the fungicide-treated trees was repeated on the non-treated flowering dogwoods.

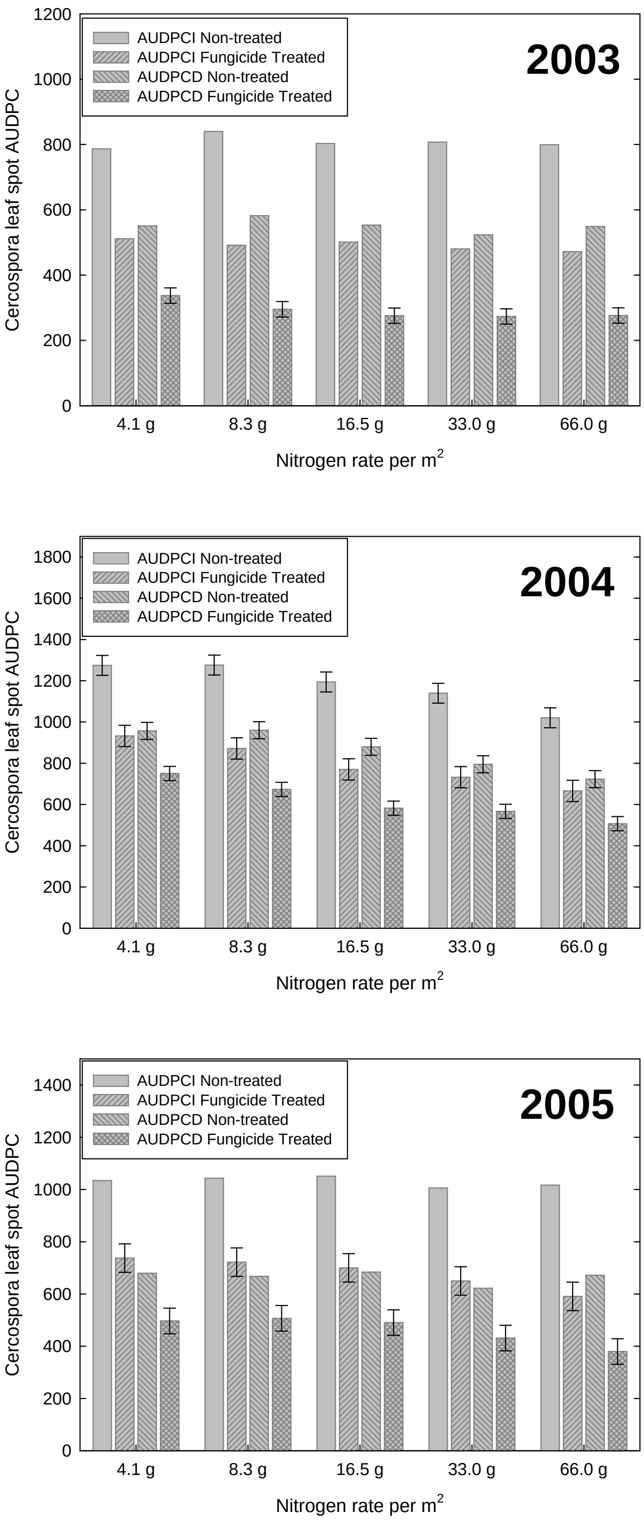

Fig. 3. **Impact of nitrogen rate on the level of leaf spotting (AUDPCI) and premature defoliation (AUDPCD) attributed to Cercospora leaf spot on flowering dogwood in 2003, 2004, and 2005.**

Tree growth. As indicated by negative r values, correlation analysis showed that the leaf spot phase of spot anthracnose and Cercospora leaf spot may have a detrimental impact on tree growth. Cercospora leaf spot intensity [AUDPCI] was negatively correlated in 2003, 2004, and 2005 with tree height and trunk diameter (Table 2). Negative correlations between tree height and trunk diameter with Cercospora leaf spot-induced defoliation [AUDPCD] were noted in two of three years. The leaf spot phase of spot anthracnose was negatively correlated with tree height and trunk diameter in all three years and in two of three years, respectively. Powdery mildew incidence was not correlated with changes in tree height or trunk diameter. While significant, relatively low correlation coefficients (r values) listed in Table 1 indicates that other factors, particularly N rate, also influence tree growth.

Previously, severe powdery mildew outbreaks, where nearly 100% of the leaves were colonized by the causal fungus *E. pulchra*, were associated with sizable reductions in tree height and/or trunk diameter of container-grown flowering dogwood (11, 18). In this study, powdery mildew pressure, which was considerably less than that noted in

Table 2. **Correlation coefficients and probability of r when AUDPC[z] values of the indicated diseases were compared with differences in tree height and trunk diameter of flowering dogwood from study inception.**

	Tree height		Trunk diameter	
Disease	**R Value**	**P Value**	**R Value**	**P Value**
		2003		
Cercospora leaf spot				
Intensity[y]	–0.30	0.0012	–0.33	0.0003
Defoliation[x]	–0.27	0.0038	–0.38	0.0001
Spot anthracnose[w]	–0.23	0.017	–0.36	0.0001
Powdery mildew	0.09	NS[v]	0.07	NS
		2004		
Cercospora leaf spot				
Intensity	–0.38	< 0.0001	–0.39	< 0.0001
Defoliation	–0.36	0.0002	–0.36	0.0002
Spot anthracnose	–0.35	0.0001	–0.35	0.0001
Powdery mildew	–0.17	NS	–0.16	NS
		2005		
Cercospora leaf spot				
Intensity	–0.21	0.0282	–0.23	0.0144
Defoliation	–0.16	NS	–0.14	NS
Spot anthracnose	–0.32	0.0008	–0.15	NS
Powdery mildew	0.08	0.04	–0.16	NS

[z]AUDPC is the area under the disease progress curve, which is a reflection of disease over the entire season.

[y]Intensity is the incidence of disease occurrence on each tree.

[x]Defoliation = AUDPCD.

[w]Leaf spot phase of spot anthracnose.

[v]NS = not significant.

previous studies with container-grown flowering dogwood (11, 18), did not negatively influence tree growth. In contrast, the leaf spot phase of spot anthracnose and Cercospora leaf spot were often negatively correlated with tree height and/or trunk diameter. Previously, the above diseases were thought to affect only tree aesthetics and not interfere with the growth of flowering dogwood (4, 9).

Dogwood cultivar. Cultivar selection impacted the occurrence of all diseases. Ratings for the bract spot and leaf spot phases of spot anthracnose were higher for non-treated 'Cloud 9' in two of three years and all three years, respectively, than 'Cherokee Chief' (Table 1). In two of three years, leaf spot phase ratings for the fungicide-treated 'Cloud 9' and non-treated 'Cherokee Chief' were similar. Previously, Hagan (12) observed that 'Cherokee Chief' was less susceptible than Cloud 9' to spot anthracnose. As noted by Mmbaga and Sauve (19), 'Cloud 9' and 'Cherokee Chief' were equally susceptible to powdery mildew (Table 1). Of the two cultivars, 'Cloud 9' proved most susceptible to Cercospora leaf spot. For non-treated trees, higher AUDPCI values for 'Cloud 9' than 'Cherokee Chief' were reported in 2004 ($P = 0.019$) and 2005 ($P = 0.0001$) (data not shown). Significant differences in Cercospora leaf spot AUDPCI values between the fungicide-treated 'Cloud 9' and 'Cherokee Chief' flowering dogwoods were also noted in 2004 ($P = 0.0001$) and 2005 ($P = 0.0001$) (data not shown). While 'Cherokee Chief' was less susceptible to Cercospora leaf spot than 'Cloud 9', premature leaf shed levels were so high by October that no fall color display was seen on either cultivar. In a recent Alabama study (9), 'Cloud 9', while less susceptible to Cercospora leaf spot than several other flowering dogwood cultivars, suffered heavier leaf spotting and premature defoliation when compared with the Stellar® series hybrid dogwoods.

Fungicide program. Heritage 50W, which previously was shown to control powdery mildew on container-grown flowering dogwood (11, 18), not only controlled this disease but also the bract and leaf spot phases of spot anthracnose on field-grown trees (Table 1). When compared with the non-treated trees, fewer individual lesions as well as little bract or leaf distortion were seen on the fungicide-treated flowering dogwoods (Hagan, personal observation). While fungicide applications were terminated by mid-July, Cercospora leaf spot development was suppressed for several months. In fact, an intense deep red to maroon fall color display was noted in late October through mid-November on the Heritage 50W-treated trees of both cultivars, while the adjacent non-treated trees were defoliated.

In this study, we showed that N rate influenced the development of powdery mildew, Cercospora leaf spot, and to a lesser extent both phases of spot anthracnose. Increased Cercospora leaf spot-related leaf spotting and defoliation is more likely on flowering dogwood maintained at the recommended landscape N rates of 4.9 to 14.4 g $N \cdot m^{-2}$ (44 to 130 lb $N \cdot A^{-1}$) (26) compared with the 27.5 g $N \cdot m^{-2}$ (250 lb $N \cdot A^{-1}$) rate recommended for field nursery plantings (15). In contrast, N rates probably would have to exceed 16.5 g $N \cdot m^{-2}$ (150 lb $N \cdot A^{-1}$) before powdery mildew would intensify. Maintaining recommended N rates in the landscape or field nursery will not reduce the occurrence of the bract or leaf spot phases of spot anthracnose. In settings where brilliant fall color is desired, protective fungicide applications will have far more impact on leaf retention compared with any adjustments in N rate.

Literature Cited

1. Anderson, R.L., J. Rauschenberger, J.L. Knighten, S.E. Dowsett, and C. Henson. 1992. Effectiveness of cultural techniques, with emphasis on fertilization to control dogwood anthracnose. p. 53–56. *In*: Results of the 1992 dogwood anthracnose impact assessment and pilot test in the Southeastern United States. J.L. Knighten and R.L. Anderson, eds. USDA For. Serv. South Region Prot. Rep R8-PR 24.

2. Britton, M.P. 1969. Turfgrass diseases. p. 309-310. *In*: Turfgrass Science. A.A. Hanson and F.J. Juska, eds. Agronomy Monograph 14. ASA, Madson, WI.

3. Bowen, K.L., B. Young, and B. Behe. 1995. Management of black spot in rose in the landscape in Alabama. Plant Disease 79:250–253.

4. Chase, A.R. 1991. Greenhouse ornamental crops, pest management systems for diseases. p. 709–728. *In*: Handbook of Pest Management, 2nd ed. Vol. 3. D. Pimental, ed. CRC Press, Boca Raton, FL.

5. Curlin, J.W. 1962. Dogwood responds to nitrogen fertilization. J. Forestry 60:718–719.

6. 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.

7. Donohue, S.J. 1992. Reference soil test methods for the southern region of the United States. Univ. of Georgia. Sou. Coop. Ser. Bull. 374.

8. Gilman, E.F., T.H. Yeager, and D. Kent. 2000. Fertilizer rate and type impacts magnolia and oak growth in a sandy landscape soil. J. Arboriculture 26:177–182.

9. Hagan, A.K., J.R. Akridge, and R. Dawkins. 2006. Comparison of flowering and hybrid dogwood to diseases at two locations in Alabama. Proc. Southern Nursery Res. Conf. 51:187–190.

10. 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 Res. Conf. 49:254–258.

11. Hagan, A.K., J.W. Olive, J. Stephenson, and M. Rivas-Davila. 2005. Comparison of fungicides for the control of powdery mildew on dogwood. J. Environ. Hort. 23:179–184.

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

13. Hagan, A.K., M.E. Rivas-Davila, J.R. Akridge, and J.W. Olive. 2005. Resistance of shrub and groundcover roses to black spot and Cercospora leaf spot, and impact of fungicide inputs on the severity of both diseases. J. Environ. Hort. 23:77–85.

14. Hoitink, H.A., M.E. Watson, and W.R. Farber. 1986. Effect of nitrogen concentration in juvenile foliage of rhododendron to Phytophthora dieback severity. Plant Disease 70:292–294.

15. Horsfall, J.G. and R.W. Barratt. 1945. An improved grading system for measuring plant disease. Phytopathology 35:655 (abstr.).

16. Ingram, D.L., B. Roach, and M. Klahr. 1998. Effects of controlled-release fertilizers on growth and nutrient content of field-grown nursery crops. Proc. Southern Nursery Res. Conf. 43:124–127.

17. Mizell, R.F. and A.K. Hagan. 2000. Biological problems and their management in urban soils: IPM of arthropods and diseases. p. 119–155. *In*: Managing Soils in the Urban Environment, Agronomy Monograph 39. R.B. Brown, J.H. Huddleston, and J.L. Anderson, eds. Society of Agronomy. Madison, WI.

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

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

20. Neely, D. 1981. Application of nitrogen fertilizer to control anthracnose on black walnut. Plant Disease 65:580–581.

21. Neely, D. 1986. Total leaf nitrogen correlated with walnut anthracnose resistance. J. Arboriculture 12:312–315.

22. Oerke, E.C. and F. Schonbeck. 1990. Effect of nitrogen and powdery mildew on the yield formation of two winter barley cultivars. J. Phytopathology 130:89–104.

23. Olesen, J.E., L.N. Jorgensen, J. Petersen, and J.V. Mortensen. 2003. Effect of rates and timing of nitrogen fertilizer on disease control by fungicides in winter wheat. 2. Crop growth and disease development. J. Agric. Sci. 140:15–29.

24. SAS Institute. 2006. SAS/SAST User's Guide, Vers. 9.1. SAS Institute Inc. Cary, NC.

25. Shaner, G. and R.E. Finney. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in wheat. Phytopathology 67:1051–1056.

26. Smiley, E.T., S.J. Lily, and P. Kelsey. 2002. Best Management Practices: Trees and Shrub Fertilization. International Society of Arboriculture, Champaign, IL.

27. Smith, E.M. and C.H. Gilliam. 1979. Fertilizing landscape and field grown nursery crops. OSU Coop. Ext. Ser. Bull. 650.

28. Tattar, T.A. 1989. Diseases of Shade Trees. Acad. Press. San Diego, CA.