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Impact of Application Rate and Interval on the Control of Powdery Mildew and Cercospora Leaf Spot on Bigleaf Hydrangea with Azoxystrobin[1]

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Abstract

Efficacy of azoxystrobin (Heritage 50W™) was assessed over a range of application rates and intervals for the control of powdery mildew (*Erysiphe polygoni)* and Cercospora leaf spot (*Cercospora hydrangea*) on bigleaf hydrangea (*Hydrangea macrophylla*) 'Nikko Blue'. Rooted hydrangea cuttings were transplanted in a pine bark/peat mixture. In 1998 and 1999, azoxystrobin at 0.16 g ai/liter and 0.32 g ai/liter, as well as 0.24 g ai/liter myclobutanil (Eagle 40W™) and 0.84 g ai/liter thiophanate methyl (3336 4.5F™), greatly reduced the incidence of powdery mildew compared with the untreated control where 75% of the leaves of were infected by the causal fungus. When applied at 1-, 2-, and 3-week intervals, both rates of azoxystrobin were equally effective in both years in preventing the development of powdery mildew on bigleaf hydrangea. In 1998, all fungicides except for thiophanate methyl protected bigleaf hydrangea from Cercospora leaf spot. In the last two trials, the incidence of powdery mildew increased significantly as the application rate for azoxystrobin decreased from 0.16 to 0.04 g ai/liter and the application interval was lengthened from 1 to 3 weeks. In general, all rates of azoxystrobin applied on a 3-week schedule failed to provide the level of powdery mildew control needed to produce quality bigleaf hydrangea for the florist and landscape market. When applied at 2-week intervals, myclobutanil was equally or more effective in controlling powdery mildew than any rate of azoxystrobin applied on the same schedule. When compared to the untreated controls, significant reductions in the incidence of powdery mildew on bigleaf hydrangea were obtained with weekly applications of paraffinic oil. No symptoms of phytotoxicity were associated with the use of any of the fungicides screened.

Index words: disease control, *Erysiphe polygoni*, *Cercospora hydrangeae*, Heritage 50W, Eagle 40W, 3336 4.5F, SunSpray Ultra-Fine Oil, paraffinic oil, strobilurin fungicide, QoI fungicide, Quinone outside inhibitors.

Species used in this study: bigleaf hydrangea (*Hydrangea macrophylla*) 'Nikko Blue'.

Significance to Nursery Industry

Azoxystrobin (Heritage 50W™) was the first broad-spectrum strobilurin or QoI (Quinone outside inhibitor) fungicide registered for the control of foliar and soil-borne diseases on herbaceous and woody ornamentals. At the 0.16 g ai/liter [4.0 oz/100 gal] rate, this fungicide was as effective in controlling powdery mildew and Cercospora leaf spot in 1998 on hydrangea as the industry standard myclobutanil (Eagle 40W™) and superior to thiophanate methyl (3336 4.5F™). Azoxystrobin rates as low as 0.04 g ai/liter [1.0 oz/100 gal] significantly reduced the incidence of powdery mildew on hydrangea, which is caused by the fungus *E. polygoni*. When applied on a 3-week schedule, azoxystrobin failed to consistently provide effective control of powdery mildew. To insure effective control of powdery mildew on bigleaf hydrangea, application of the 0.04- to 0.16-g ai/liter rates of azoxystrobin should be made at no longer than 2-week intervals. Exclusive use of azoxystrobin or alternating applications with a related fungicide such as trifloxystrobin (Compass O™) over an extended period of time, particularly in a nursery or greenhouse will result in a control failure due to resistance. To safeguard their efficacy, a strobilurin(s) fungicide, when applied alone, can make up no more than 1/3 of the total number of applications in a disease management program on any ornamental crop and no more than two consecutive applications of a fungicide in this class should be made. When tank-mixed with a fungicide that has a different mode of action, azoxystrobin application may total up to 1/2 of those made to a specific ornamental crop. Paraffinic oil (SunSpray Ultra-Fine Oil™) also has good activity against powdery mildew and would be an effective alternative to synthetic fungicides or be a rotation partner in a strobilurin resistance management program.

Introduction

Bigleaf hydrangea (*Hydrangea macrophylla* (Thunb. ex J. A. Mirr) Ser.), which is best adapted to USDA Hardiness Zones 6 to 9, is widely used in landscape plantings across Alabama and is a staple crop for the florist industry nationwide (3). While bigleaf hydrangea typically are not prone to devastating disease outbreaks in landscape, nursery, or greenhouse settings, under ideal environmental conditions several diseases will decrease plant aesthetics in the landscape and salability of container-grown plants (13).

Outbreaks of powdery mildew, which is caused by the fungus *Erysiphe polygoni* DC., commonly occur on bigleaf hydrangea, particularly in the greenhouse (13). Symptoms, which are often most severe on tightly packed container stock, include extensive chlorosis or yellowing of the leaves, premature defoliation, and sometimes a sizable reduction in leaf area and shoot elongation (6, 10).

Cercospora leaf spot, which is caused by the fungus *Cercospora hydrangeae* Ellis & Everh., occurs most often in landscape plantings of bigleaf hydrangea and is occasionally found on container stock in a nursery. Typically, this disease

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is not as serious a threat to the market value of greenhouse-grown bigleaf hydrangea as powdery mildew, but heavily spotted and partially defoliated container stock is not salable. Symptoms of Cercospora leaf spot, which usually appears in late summer to early fall, include a 'frog-eye' spotting of the leaves beginning on the lower limbs and progressing upward through the canopy and outwards towards the shoot tips, as well as premature defoliation (6, 13).

Cultural practices such as surface watering and wide plant spacing reduce the incidence of powdery mildew and Cercospora leaf spot in landscape plantings. However, protective fungicide treatments may be required to prevent powdery mildew and consistently produce quality bigleaf hydrangea (13). Currently, several fungicides are registered for the control of powdery mildew and Cercospora leaf spot on bigleaf hydrangea, but limited information is available on their efficacy for the management of either disease. Previously, Morrison (7) noted that protective chlorothalonil or mancozeb programs significantly reduced the severity of Cercospora leaf spot on bigleaf hydrangea 'Nikko Blue'.

Azoxystrobin, which is classified as a strobilurin or QoI (Quinone outside inhibitor) fungicide, has activity against a wide array of plant pathogenic fungi and currently is marketed for use on field, vegetable, and amenity crops (1). Residues of this fungicide not only have protective activity on the leaf surface but also have demonstrated translaminar and systemic movement through adjacent leaf layers and into new growth, respectively (1). In recent Alabama studies, azoxystrobin has demonstrated activity against Phytophthora shoot blight (*Phytophthora parasitica*) on annual vinca (4), powdery mildew (*Microsphaera pulchra*) on flowering dogwood (8), Alternaria leaf spot (*Alternaria tagetica*) on marigold (5), and southern stem rot (*Sclerotium rolfsii*) on aucuba (9) that is equal to and often superior to that of other registered fungicides. Williams-Woodward (11) also saw significant reductions in powdery mildew severity on bigleaf hydrangea with preventative treatment program with 0.08 g ai/liter azoxystrobin applied at 2-week intervals.

However, limited information concerning the influence of application rate and treatment interval on the efficacy of azoxystrobin for the control of a wide range of target diseases of ornamental crops is available. This paper summarizes the impact of application rate and treatment interval on control of powdery mildew and Cercospora leaf spot on container-grown bigleaf hydrangea in a simulated nursery setting and compares the performance of this fungicide with that of other registered fungicides.

Material and Methods

Plant culture. Rooted cuttings of bigleaf hydrangea (*Hydrangea macrophylla* 'Nikko Blue') were transplanted into #1 (C-650) 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 per cubic meter (per cubic yard) of potting mixture. Transplant dates were June 1, 1998, October 22, 1999, September 6, 2000, and August 14, 2001. In 1998, plants were maintained outdoors on a clam shell-covered bed under 47% shade cloth. Since the studies in 1999, 2000, and 2001 were conducted in late fall into the early winter, the plants were placed in a heated plastic greenhouse. Regardless of the location, the blocks of hydrangea were watered daily with overhead impact sprinklers. All studies were conducted at the Ornamental Horticulture Substation in Mobile, AL.

Fungicide comparison. The experimental design was a randomized complete block with six or ten replicates that contained one plant per fungicide treatment. Fungicide treatments were applied to run-off with a CO_2-pressurized sprayer. In 1998 and 1999, azoxystrobin (Heritage 50W™, Syngenta Crop Protection, Greensboro, NC) was applied at rates of 0.16 and 0.32 g ai/liter. For the 2000 and 2001 studies, application rates were reduced to the 0.04, 0.08, and 0.16 g ai/liter rates listed on the azoxystrobin label. In all of the above studies, applications of azoxystrobin were made at 1-, 2-, and 3-week intervals. The ergosterol biosynthesis inhibitory fungicide (EBI) myclobutanil (Eagle 40W™, Dow AgroSciences, Indianapolis, IN), which was applied at 0.24 g ai/liter on a 2-week schedule, was included in all four trials as a commercial fungicide standard. Thiophanate methyl (3336 4.5F™, Cleary Chemical Corp., Somerset, NJ) at 0.84 g a.i./liter, which was applied weekly in 1998 and 1999. In 2000 and 2001, weekly applications of 1% by vol (10 ml/liter) of paraffinic oil (SunSpray Ultra-Fine Oil™, Farnam Companies Inc., Phoenix, AZ) was applied. The non-ionic surfactant Sil-Spread (Southern States, Richmond, VA) at 2.0 ml/liter of spray volume was tank-mixed with azoxystrobin and myclobutanil. Fungicides were applied to drip at the above treatment intervals from June 2 to September 24, 1998, October 27 to December 7, 1999, September 22 to November 11, 2000, and from November 1, 2001 to January 3, 2002. Depending on study duration, 7 to 16 weekly, 3 to 8 bimonthly, and 2 to 5 applications at three-week intervals were made.

Disease assessment. Incidence of powdery mildew and Cercospora leaf spot was assessed using the Horsfall and Barratt rating scale where 1 = 0%, 2 = 0–3%, 3 = 3–6%, 4 = 6–12%, 5 = 12–25%, 6 = 25–50%, 7 = 50–75%, 8 = 75–87%, 9 = 87–94%, 10 = 94–97%, 11 = 97–100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus or displaying symptoms of Cercospora leaf spot. In 1998, ratings for powdery mildew and Cercospora leaf spot were recorded on September 23 and November 12, respectively. For the remaining studies, incidence of powdery mildew was assessed on December 16, 1999, January 5, 2001 and December 18, 2001.

Significance of application rate and interval effects on fungicide efficacy were 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 a level of significance at $P \leq 0.05$. Where the effects of application rate were significant, regression analysis was done to assess linear effects. An analysis of variance was used to determine if the fungicide treatment × year interaction for disease incidence in the 1998 and 1999 trials, as well as for the 2000 and 2001 trials, was significant.

Results and Discussion

A significant fungicide treatment × year interaction ($P \leq 0.0001$) for the incidence of powdery mildew in 1998 and 1999 was recorded, therefore disease incidence data collected in both years are presented separately.

All fungicide treatments significantly reduced the incidence of powdery mildew and Cercospora leaf spot in 1998,

Table 1. Efficacy of azoxystrobin applied at selected rates and treatment intervals for the control of powdery mildew and Cercospora leaf spot on bigleaf hydrangea 'Nikko Blue' compared with that of registered fungicides in 1998 and 1999.

Fungicide	Application		Disease incidence[z]		
			Powdery mildew		Cercospora leaf spot
	Rate g a.i./liter	Interval week	1998	1999	1998
azoxystrobin	0.16	1	1.0	1.2	1.0
azoxystrobin	0.16	2	1.1	1.0	1.0
azoxystrobin	0.16	3	1.0	1.2	1.0
azoxystrobin	0.32	1	1.0	1.2	1.0
azoxystrobin	0.32	2	1.0	1.0	1.0
azoxystrobin	0.32	3	1.0	1.3	1.0
thiophanate methyl	0.84	1	3.3	1.0	2.8
myclobutanil	0.24	2	1.0	1.0	1.0
unsprayed control	—	—	7.8	6.5	5.7
LSD ($P \leq 0.05$)[y]			0.3	1.0	0.6

[z]Incidence of powdery mildew and Cercospora leaf spot was assessed using the 1 to 12 Horsfall and Barratt rating scale where 1 = no disease, 2 = 0–3%, 3 = 3–6%, 4 = 6–12%, 5 = 12–25%, 6 = 25–50%, 7 = 50–75%, 8 = 75–87%, 9 = 87–94%, 10 = 94–97%, 11 = 97–100%, and 12 = 100% of the leaves colonized by *E. polygoni* or displaying symptoms of Cercospora leaf spot.

[y]Mean separation within columns was according to Fisher's least significant difference test ($P \leq 0.05$).

when compared to the unsprayed control (Table 1). As indicated by a powdery mildew rating of 7.3, *E. polygoni* colonized between 75 and 87% of the leaves of the unsprayed control. In contrast, no colonies of *E. polygoni* were observed on the hydrangea treated at 1-, 2-, and 3-week intervals with the 0.16 and 0.32 g ai/liter rates of azoxystrobin. When applied every 2 weeks, myclobutanil was as effective in protecting hydrangea from powdery mildew as all rates of azoxystrobin. Although thiophanate methyl was significantly less effective in controlling this disease than azoxystrobin or myclobutanil, the symptoms and signs of powdery mildew on the hydrangea treated with this fungicide, which were restricted to a small percentage of leaves, were unobtrusive.

In 1998, the 'frog eye' leaf spot pattern characteristic of Cercospora leaf spot on hydrangea was observed on more than 20% of the leaves on the unsprayed plants (Table 1). Both rates of azoxystrobin at all application intervals completely protected hydrangea in 1998 from Cercospora leaf spot. Myclobutanil was as effective in controlling Cercospora leaf spot as azoxystrobin. While the incidence of Cercospora leaf spot on the thiophanate methyl-treated hydrangea was significantly lower compared to disease levels on the unsprayed plants, azoxystrobin and myclobutanil gave significantly better disease control than thiophanate methyl.

In 1999, efficacy of azoxystrobin for the control of powdery mildew on hydrangea was similar to the results obtained in the previous year. Few colonies of *E. polygoni* appeared on leaves of hydrangea treated at 1-, 2-, and 3-week intervals with 0.16 or 0.32 g ai/liter of azoxystrobin (Table 1). Myclobutanil and thiophanate methyl were as effective as azoxystrobin in managing powdery mildew on hydrangea. Since the 1999 study was conducted in a heated plastic greenhouse, Cercospora leaf spot did not develop.

The significant treatment × year interaction term ($P \leq 0.0001$) for disease incidence in 2000 and 2001 demonstrated that considerable differences in the efficacy of some fungicide treatments for the control of powdery mildew were recorded and that the data for disease incidence cannot be pooled across years.

For the 2000 trial, application rates for azoxystrobin were reduced to correspond to those on the label of the formulated product (Table 2). As indicated by a powdery mildew rating of 11.5 for the unsprayed control, disease pressure was higher than has been seen in the previous two years. Although the incidence of powdery mildew on the azoxystrobin-treated hydrangea was significantly lower when compared to the unsprayed control, considerable differences in the disease ratings on hydrangea treated with this fungicide were noted across application rates and treatments intervals. As the treatment interval was lengthened from 1 to 3 weeks, the incidence of powdery mildew increased linearly for all rates of azoxystrobin. The linear regression equations describing the response to lengthening treatment intervals were $y = -1.5 +$

Table 2. Impact of application rate and treatment interval on the efficacy of azoxystrobin for the control of powdery mildew on greenhouse-grown bigleaf hydrangea 'Nikko Blue' in 2000 and 2001.

Fungicide	Application		Incidence powdery mildew[z]	
	Rate g a.i./liter	Interval week	Jan 5, 2001	Dec 18, 2001
azoxystrobin	0.04	1	1.0	2.8
azoxystrobin	0.04	2	2.5	2.6
azoxystrobin	0.04	3	5.5	5.5
azoxystrobin	0.08	1	1.6	2.0
azoxystrobin	0.08	2	2.6	1.6
azoxystrobin	0.08	3	4.9	6.6
azoxystrobin	0.16	1	1.4	2.0
azoxystrobin	0.16	2	1.5	2.3
azoxystrobin	0.16	3	5.1	5.3
paraffinic oil	1% v/v	1	3.1	2.4
myclobutanil	0.24	2	1.1	1.9
unsprayed control	—	—	11.5	8.3
LSD ($P \leq 0.05$)[y]			0.9	0.7

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

[y]Mean separation within columns was according to Fisher's least significant difference test ($P \leq 0.05$).

2.25x ($R^2 = 0.96$), y = –0.2667 + 1.65x ($R^2 = 0.95$), and y = –1.0333 + 1.85x ($R^2 = 0.77$) for the 0.04, 0.08, and 0.16 g ai/liter rates of azoxystrobin, respectively. In the above equations, y refers to disease incidence and x refers to application interval in weeks.

Differences in powdery mildew incidence that was noted between the rates of azoxystrobin applied on a 1-week schedule were not significant. With disease ratings between 1.0 and 1.6, incidence of this disease on the hydrangea treated weekly with azoxystrobin was limited to the development of a few small, isolated colonies of the causal fungus *E. polygoni*. A significant increase in the incidence of powdery mildew was noted between the 1- and 2-week treatment intervals with the 0.04- and 0.08-g ai/liter rates of azoxystrobin. On the hydrangea treated with the 0.16 g ai/liter rate of azoxystrobin at 1- and 2-week intervals, the level of powdery mildew control was similar. Regardless of application rate, azoxystrobin applied at 3-week intervals failed to effectively protect the leaves of hydrangea from colonization by *E. polygoni*. As indicated by disease ratings that ranged from 4.9 to 5.5, signs and/or symptoms of powdery mildew were noted on at least 10% of the leaves on the plants treated with azoxystrobin on a 3-week schedule. Paraffinic oil, which was applied weekly, was significantly less effective in controlling powdery mildew than all rates of azoxystrobin applied at 1- and 2-week intervals. As indicated by a disease rating of 1.1, very little development of powdery mildew was seen on the myclobutanil-treated hydrangea.

When compared to the unsprayed control, the incidence of powdery mildew was significantly lower on the fungicide-treated hydrangea in December 2001 (Table 2). As was noted in the previous study, powdery mildew significantly intensified as the interval between applications of all rates of azoxystrobin increased. For the azoxystrobin at 0.04, 0.08, and 0.16 g ai/liter, respectively, the increase in powdery mildew incidence that was noted as application interval was lengthened from 1 to 3 weeks is best described by the linear regression equations of y = 0.933 + 1.35x ($R^2 = 0.70$), y = –1.2 + 2.3x ($R^2 = 0.69$), and y = –0.1 + 1.65x ($R^2 = 0.82$). In the above equations, y refers to disease incidence and x refers to application interval in weeks.

At all application rates of azoxystrobin, level of leaf colonization by *E. polygoni* was unobtrusive on bigleaf hydrangea treated at 1- and 2-week intervals. At the 1-week interval, the 0.08- and 0.16-g ai/liter rate of azoxystrobin gave better control of powdery mildew than the 0.04-g ai/liter rate of the same fungicide. When applied on a 2-week schedule, 0.08 g ai/liter of azoxystrobin controlled powdery mildew better than the lower rate but was equally effective controlling this disease as the higher rate of the same fungicide. In addition, powdery mildew incidence on hydrangea treated at 1- and 2-week intervals with azoxystrobin at either 0.04, 0.08, or 0.16 g ai/liter did not significantly differ. At all rates of azoxystrobin, a significant decline in the level of control of powdery mildew was noted between the 2- and 3-week treatment intervals. As indicated by powdery mildew ratings between 5.3 and 6.6, a sizable percentage of the leaves were colonized by *E. polygoni* was observed on the hydrangea treated at 3-week intervals with azoxystrobin.

In the December 2001 study, myclobutanil was as effective in controlling powdery mildew as the 0.08- and 0.16-g ai/liter rates of azoxystrobin applied at 1- and 2-week intervals (Table 2). When applied at 3-week intervals, both the latter rates of azoxystrobin failed to control powdery mildew as well as the myclobutanil standard. Unlike the previous year, hydrangea treated at the lowest rate of azoxystrobin at all application intervals had powdery mildew ratings higher than for those treated with myclobutanil. Generally, weekly applications of paraffinic oil gave the same level of control of this disease as azoxystrobin applied at 0.04, 0.08, and 0.16-g ai/liter on a 1- and 2-week treatment schedule.

Generally, azoxystrobin across a range of labeled application rates demonstrated excellent activity against powdery mildew on hydrangea. In the two later studies, relatively minor differences in the level of powdery mildew control were noted when the 0.04-, 0.08-, and the 0.16-g ai/liter label rates of azoxystrobin were applied on a 1- or 2-week schedule. Typically, signs of powdery mildew on the hydrangea treated at 1- or 2-week intervals were restricted to a few scattered colonies of *E. polygoni* on the upper surface of one or two leaves. When applied on a 3-week schedule, azoxystrobin failed to consistently control powdery mildew on hydrangea. In the first two studies, both rates of azoxystrobin that were applied every 3 weeks effectively suppressed the disease development. In contrast, noticeable and unacceptable levels of *E. polygoni* colonization of the leaves of plants treated at 3- but not 2-week intervals with the 0.04-, 0.08-, and the 0.16-g ai/liter rates this fungicide were noted in the two later studies.

When applied at 3-week intervals in 1998 and 1999, azoxystrobin at 0.16 g ai/liter was as effective in controlling powdery mildew as were bimonthly applications of myclobutanil and more efficacious than thiophanate methyl. Under heavier disease pressure for the studies initiated in 2000 and 2001, the 0.16-g ai/liter rate of azoxystrobin applied on a 1- and 2-week schedule consistently gave the same level of powdery mildew control as bimonthly applications of the fungicide standard myclobutanil. Significant reductions in disease intensity were noted with the low 0.04- and intermediate 0.08-g ai/liter rates of azoxystrobin and the standard myclobutanil program gave better control of powdery mildew when applied on the same schedule in both studies. When applied as a preventive treatment to bigleaf hydrangea, azoxystrobin at 0.08 g ai/liter applied at 2-week intervals was more effective in slowing spread of this disease in a Georgia study than several synthetic and biological fungicides except for myclobutanil and copper hydroxide (11). In contrast, curative treatments of this same rate of azoxystrobin applied on the same schedule failed to appreciably slow the spread of powdery mildew (12). Strobilurin (QoI) fungicides such as azoxystrobin do not have the plant growth regulatory side effects, which include shortened internodes as well as reduced leaf area index and vegetative dry weight, that are occasionally observed after repeated applications of selected ergosterol biosynthesis inhibitory (EBI) fungicides on some woody ornamental crops (1, 2). However, exclusive use of a strobilurin fungicide over an extended period of time on certain greenhouse vegetable, fruit, amenity turf, and cereal crops has resulted in catastrophic control failures due to the selection for resistant isolates of fungal plant pathogens, particularly powdery mildew fungi (1). Although not as efficacious in controlling powdery mildew as azoxystrobin or myclobutanil, paraffinic oil greatly reduced the incidence of this disease on bigleaf hydrangea and may be an excellent rotation partner in a disease management program with strobilurin or EBI fungicides.

Cercospora leaf spot appeared on big leaf hydrangea only in 1998 when the study was conducted outdoors under a 47% shade cloth. When applied at 1-, 2-, and 3-week intervals, the 0.16-g ai/liter rate of azoxystrobin, as well as myclobutanil at the 2-week schedule, displayed excellent efficacy in controlling Cercospora leaf spot on hydrangea. Although significant reductions in Cercospora leaf spot incidence were also obtained with thiophanate methyl, when compared to the unsprayed control, this fungicide was less effective in controlling this disease than azoxystrobin or myclobutanil. Additional studies need to be done to confirm the efficacy of azoxystrobin for the control of Cercospora leaf spot on bigleaf hydrangea.

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