Pathology and Nematology

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Section Editor

Impact of Fungicide Selection and Application Interval on the Control of Rust and Biomass Yield of an Ornamental Switchgrass

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Index Words: Chemical control, *Puccinia emaculata*, *Panicum virgatum*, Daconil Ultrex 82.5WDG, chlorothalonil, Eagle 40W, myclobutanil, Heritage 50WDG, azoxystrobin

Significance to Nursery Industry: Rust is an endemic leaf disease of ornamental switchgrass, which not only greatly reduces late summer plant aesthetics but also reduces plant growth and possibly long-term plant health. While all fungicides screened reduced rust intensity in both study years when compared with the non-fungicide treated control, the best control was obtained with Eagle 40W. While slightly less effective than Eagle 40W, Heritage 50WDG showed superior efficacy in 2011 and 2012 against switchgrass rust when compared with Daconil Ultrex 82.5WDG. The least rust damage and most attractive plants were obtained with a weekly fungicide treatment schedule. Rust intensified as application intervals were progressively lengthened from 1 to 4 weeks with the non-treated control suffering the heaviest rust damage. Biomass yields were significantly influenced by fungicide selection and application interval with the efficacious Eagle 40W and Heritage 50WDG providing superior biomass yield response. There was an overlap in biomass yields between application intervals. Yield response declined as the intervals between fungicide applications lengthened with the non-treated control having the lowest biomass yield. Overall, either Eagle 40W or Heritage 50WDG applied at 2-week intervals should provide sufficient control to provide for maximum growth and optimum aesthetics of ornamental switchgrass in the nursery or landscape.

Nature of Work: A damaging rust disease on switchgrass (6), caused by the fungus *Puccinia emaculata*, has been reported in feed stock (cellulosic biomass) plantings at multiple locations in Arkansas (5), Iowa (2), and Tennessee (8). Disease outbreaks in ornamental switchgrass plantings have also been reported in Alabama (3,4) and Illinois (6) as well as North Carolina and Tennessee (7). Jacobs and Terrell (6) also noted the detrimental impact of rust on the aesthetics of ornamental switchgrass selections. Significant differences in the rust severity among ornamental switchgrass selections have been noted in recent trials in Alabama (4), Illinois (6) and Tennessee (7). Black *et al.* (1) reported that rust first appears in field plantings of 'Alamo switchgrass in late May and continues to intensify into late August or early September. A similar pattern of disease development has been observed in Alabama in field-grown ornamental switchgrass (Hagan, personal observation). The production and establishment of resistant selections is the preferred method of avoiding damaging rust outbreaks, however, fungicides may be required, particularly in a production nursery, to protect as well as maintain the quality of susceptible varieties. In a preliminary report (3), Eagle 40W and Heritage 50W when applied at 2 week intervals gave superior rust control.

Efficacy of a variety of commercial fungicides for the control of rust on ornamental switchgrass is summarized as is the impact of fungicide inputs on biomass yield of switchgrass.

The switchgrass cv 'Cloud 9' was transplanted from no.1 containers on January 13, 2011 into a Benndale sandy loam soil (≤ 1% organic material) at the Brewton Agricultural Research Unit (USDA Hardiness Zone 8a). Prior to planting, soil fertility and pH were adjusted according to the results of a soil fertility assay. A drip irrigation system was installed at planting and the plants were watered as needed. Pre-emergent weed control was obtained with a broadcast application of 2 qt/A of Surflan + 2 qt/A Princep. Escaped weeds were hand pulled. In late March or early April, 2.1 oz of 16-4-8 analysis fertilizer was applied to each plant. A factorial design arranged in a split plot with six single-plant replications was used. Daconil Ultrex, Eagle 40W, and Headline 50WDG applied to drip at 1, 2, 3 or 4-wk intervals from June 15 until September 6, 2011 and June 1 to September 6, 2012 with a tractor-mounted sprayer and hand wand with a single flood-type nozzle tip. Rust intensity was visually rated on June 24, July 20, August 21 and September 23, 2011 and May 2, May 30, June 25, July 27, and August 31, 2012 using a modified Florida 1 to 10 peanut leaf spot rating scale where 1 = no disease, 2 = very few lesions/pustules in canopy, 3 = few lesions/pustules noticed in canopy, 4 = some lesions/pustules in canopy and $\leq$ 10% leaf death, 5 = lesions/pustules noticeable and $\leq$ 25% leaf death, 6 = lesions/pustules numerous and $\leq$ 50% leaf death, 7 = lesions/pustules very numerous and $\leq$ 75% leaf death, 8 = numerous lesions/pustules on remaining green leaves and $\leq$90% leaf death, 9 = very few remaining green leaves covered with lesions/pustules and $\leq$ 95% leaf death, and 10 = all leaves dead. Biomass harvest involved cutting 2 inches above the soil surface and then weighing the bundled shoots of each plant on January 25, 2012 and January 23, 2013. Shoot samples were weighed wet, oven dried for 48 hr, and weighed dry to determine dry biomass yield. Significance of treatments and interaction were evaluated using PROC MIXED procedure in SAS. For non-normal data, statistical analyses were done on rank transformations of data, which were back transformed for presentation. Since the fungicide x application interval for rust intensity and biomass yield were not significant, data were pooled across fungicides and application interval. Means were separated using Fisher's least significant difference (LSD) test ($P \leq 0.05$).

Results and Discussion: Cumulative monthly rainfall totals for the May through September study period in 2011 and 2012 were 15.7 and 30.3 inches, respectively, which were well below (2011) and similar (2012) to the 29.9 inch historical average. Mean monthly temperatures were above the historical average for the months of May through September in each study.

As indicated by a non-significant fungicide * application interval interaction, ranking of the rust intensity and biomass yield data was similar across all fungicide treatments and application intervals.

While all fungicides significantly reduced rust intensity in both study years when compared with the non-treated control, significant differences in the level of disease control were noted among fungicide treatments (Table 1). When averaged across application intervals in 2011 and 2012, Eagle 40W gave better rust control than Heritage 50WDG and Daconil Ultrex 82.5WDG with the latter fungicide displaying the least efficacy against switchgrass rust. Rust intensified as the interval between fungicide applications increased from 1 to 3 weeks. At the 3- and 4-week application intervals, similar rust intensity levels, which were lower when compared with the non-treated control, were noted in both study years.

The influence of fungicides on the biomass yield of switchgrass was more noticeable in 2012 than the previous year (Table 1). In 2011, biomass yield was higher for the Eagle 40W-treated than Heritage 50WDG-treated switchgrass or the non-treated control. Ranking for the biomass yield of the Bravo Ultrex-treated switchgrass was similar to the non-treated control, as well as Eagle 40W and Heritage 50WDG treatments. In 2012, similarly higher biomass yields were recorded for Eagle 40W and Heritage 50WDG as compared with Daconil Ultrex and the non-treated control. Biomass yield was impacted by application interval in 2012 but not 2011. In 2012, similar biomass yields were recorded for the 1 and 2 week treatment intervals. In addition, similar yields were obtained at the 2 and 3 week along with the 3 and 4 week intervals. The non-treated control produced the lowest biomass yield.

Switchgrass rust not only had a detrimental impact on plant esthetics but also greatly reduced plant growth as indicated by significant reductions in biomass, particularly in 2012. While Eagle 40W proved more effective in controlling rust on ‘Cloud 9’ switchgrass than Heritage 50WDG, equally high biomass yields were obtained with both fungicides. Daconil Ultrex showed the poor efficacy against rust and failed to increase biomass yields above those recorded for the non-treated control. Under severe rust pressure, weekly applications of one or alternations of the former two fungicides may be required to maximize the aesthetics but not growth of vulnerable switchgrass varieties. In the landscape and possibly nursery settings, however, a two week treatment schedule with Eagle 40W and/or Heritage 50WDG may be sufficient to maintain plant aesthetics and growth.

As was noted earlier by Hagan and Akridge (3), Eagle 40W and Heritage 50WDG gave effective rust control while Daconil Ultrex 82.5WDG did not. Not surprisingly, disease control declined as the interval between fungicide applications increased. While not obvious to the naked eye in the field, study results show that rust significantly slows switchgrass growth, as indicated by sizable reductions in biomass yield recorded with Daconil Ultrex and non-treated control as well as when application intervals were extended from 1 to 4 wk. In the nursery on a rust susceptible switchgrass variety, weekly applications of Eagle 40W and/or Heritage 50WDG may be required to meet commercial aesthetic standards and maximum growth rate but a 2-week interval may be sufficient in most situations where rust control is desired.

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Table 1. Fungicide selection and application interval influence rust intensity and biomass yield of 'Cloud 9' switchgrass.

	Rust intensity		Biomass yield	
Sources (*F* value)	2011	2012	2011	2012
Fungicide	100.57***[x]	40.73***	4.04*	20.18***
Application interval	63.50***	57.56***	0.55	8.33***
Fungicide x application interval	1.45	1.11	1.52	1.35
Treatment and rate (per 100 gal)				
Non-treated control	6.0 a	7.0 a[w]	1.9 b	4.9 b
Daconil Ultrex 82.5WDG	4.0 b	5.9 b	2.2 ab	5.5 b
Eagle 40W	2.1 d	4.3 d	2.3 a	8.1 a
Heritage 50WDG	3.5 c	4.7 c	2.1 b	7.3 a
Application interval				
1 wk	2.1 d	3.4 d	2.4 a	8.1 a
2 wk	3.1 c	5.1 c	2.3 a	7.3 ab
3 wk	3.7 b	5.7 b	2.3 a	6.4 bc
4 wk	4.0 b	5.7 b	2.2 a	6.0 c
Non-treated control	6.0 a	7.0 a	1.9 a	4.9 d

[z]Rust intensity was rated on September 23, 2011 and August 31, 2012 using a modified Florida 1 to 10 peanut leaf spot ratings scale.
[y]Biomass yield is expressed as pounds (lb) of dry matter per plot.
[x]Significance of *F* values at the 0.05, 0.01, and 0.001 levels are indicated by *, **, or ***, respectively.
[w]Means in each column that are followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

Efficacy of Fungicides for the Control of Rust on Switchgrass

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Index Words: Chemical control, *Puccinia emaculata*, *Panicum virgatum*, Concert II, Daconil Ultrex, Heritage 50WDG, Banner MAXX. Eagle 40W, 3336 4.5F, Medallion 50W, Palladium 62.5WG, biomass.

Significance to Nursery Industry: Rust is a significant threat to container and landscape plantings of ornamental switchgrass. The fungicides Eagle 40W and Heritage 50WDG when applied at 2-week intervals effectively controlled rust on the rust-susceptible switchgrass selection 'Dallas Blues'. In contrast, 3336 4.5F, Banner MAXX, Medallion 50W, Concert II, and Palladium 62.5WG failed to protect switchgrass from rust. By late summer, the Eagle 40W- and Heritage 50WDG-treated switchgrass showed good color with low levels of leaf death in the lower canopy, while the canopy of those treated with the remaining fungicides was brown due to severe rust-related leaf death. When compared with the non-treated control, significant biomass yield gains were obtained in both study years with Eagle 40W and Heritage 50WDG but not the remaining fungicides. Overall, rust reduced switchgrass top growth, as indicated by sharp declines in biomass yield, up to 50%.

Nature of Work: A damaging rust disease on switchgrass (6), which is caused by the fungus *Puccinia emaculata*, has recently been reported in feed stock plantings at multiple locations in Alabama (Hagan, personal observation), Arkansas (4), Iowa (1), and Tennessee (7). Outbreaks of this disease in ornamental switchgrass plantings have also been reported in Alabama (3) and Illinois (5), as well as North Carolina and Tennessee (6). Jacobs and Terrell (5) also noted the detrimental impact of rust on the aesthetics of ornamental switchgrass selections. Significant differences in the rust severity among ornamental switchgrass selections have been noted in recent trials in Illinois (5) and Tennessee (6). The production and establishment of resistant selections is the preferred method of avoiding damaging rust outbreaks. However, fungicides may be required, particularly in a production nursery, to protect as well as maintain the quality of finished container stock. In a preliminary report (2), Eagle 40W and Heritage 50W gave superior rust control. Efficacy of a variety of commercial fungicides for the control of rust on ornamental switchgrass is summarized as is the impact of fungicide inputs on biomass yield of switchgrass.

The switchgrass cv 'Dallas Blues' was transplanted from no.1 containers on January 13, 2010 into a Benndale sandy loam soil (≤ 1% organic material) at the Brewton Agricultural Research Unit (USDA Hardiness Zone 8a). Prior to planting, soil fertility and pH were adjusted according to the results of a soil fertility assay. A drip irrigation system was installed at planting and the plants were watered as needed. Pre-emergent

weed control was obtained with a broadcast application of 2 qt/A of Surflan + 2 qt/A Princep. Escaped weeds were hand pulled. In late March or early April, 2.1 oz of 16-4-8 analysis fertilizer was applied to each plant. A randomized complete block design with six single-plant replications was used. Fungicide treatments were applied to drip with a tractor mounted sprayer using a hand wand with a single flood-type nozzle tip at 2-week intervals from June 15 to September 6, 2011 and June 1 to September 6, 2012. Medallion 50W was replaced with Concert II in 2012. Rust intensity was visually rated on June 24, July 20, August 21 and September 23, 2011 and May 2, May 30, June 25, July 27, and August 31, 2012 using a modified Florida 1 to 10 peanut leaf spot rating scale where 1 = no disease, 2 = very few lesions/pustules in canopy, 3 = few lesions/pustules noticed in canopy, 4 = some lesions/pustules in canopy and $\leq$ 10% leaf death, 5 = lesions/pustules noticeable and $\leq$ 25% leaf death, 6 = lesions/pustules numerous and $\leq$ 50% leaf death, 7 = lesions/pustules very numerous and $\leq$ 75% leaf death, 8 = numerous lesions/pustules on remaining green leaves and $\leq$90% leaf death, 9 = very few remaining green leaves covered with lesions/pustules and $\leq$ 95% leaf death, and 10 = all leaves dead. Biomass harvest involved cutting 2 inches above the soil surface and then weighing the bundled shoots of each plant on January 25, 2012 and January 23, 2013. Shoot samples were weighed wet, oven dried for 48 hr, and weighed dry to determine dry biomass yield. For non-normal data, statistical analyses were done on rank transformations of data, which were back transformed for presentation. Significance of treatment effects was tested by analysis of variance and Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

Results and Discussion: Cumulative rainfall totals for the May through September study period in 2011 and 2012 were 15.7 and 30.3 inches, respectively, which were well below (2011) to similar (2012) to the 29.9 inch historical average. Average temperatures were above the historical average for the months of May through September in each study.

In 2011, rust severity was significantly lower on the Heritage- and Eagle-treated switchgrass when compared with the other fungicide treatments and the non-treated control (Table 1). Banner MAXX 1.3MEC gave better rust control than Daconil Ultrex 82.5WDG, Palladium 62.5 WDG and 3336 4.5F but not Medallion 50W. Similarly high rust ratings were recorded for Palladium-treated switchgrass and the non-treated control.

While all treatments significantly reduced rust severity when compared with the non-treated control in 2012, superior rust control was obtained with Heritage 50W and Eagle 40W (Table 1). Banner MAXX 1.3MEC gave better rust control than 3336 4.5F, Daconil Ultrex 82.5WDG, Concert II, and Palladium 62.5WDG, all of which gave equally poor rust control on switchgrass.

In both study years, the superior rust control obtained with Eagle 40W and Heritage 50W was reflected in higher biomass yields as compared with the other fungicide treatments and non-treated control (Table 1). While significant reductions in rust were

obtained with all remaining fungicides, biomass yield for the remaining fungicide treatments and the non-fungicide treated control did not differ in either study year. In 2012, the Palladium-treated switchgrass had lower biomass yields than those receiving Banner MAXX and Concert II.

Fungicides differed greatly in their efficacy for controlling rust on 'Dallas Blues' switchgrass in a simulated landscape planting. As previously noted (2), Eagle 40W and Heritage 50WDG provided effective control of switchgrass rust when applied at two week intervals. Treated plants had good canopy color and limited rust-related leaf death at the end of the study period. In addition, biomass yields were 40 to 50% higher in 2011 and 2012, respectively, with Eagle 40W and Heritage 50WDG as compared with the remaining fungicides and the non-treated control, which had few if any healthy leaves when the studies were terminated in late August to mid-September. While Banner Maxx 1.3MEC often proved more efficacious against rust than the other fungicides, biomass yields for this fungicide treatment and the non-treated control were similar in both study years. The remaining fungicides, which failed to give effective rust control, also failed to boost biomass yield above those recorded for the non-treated control.

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Table 1. Impact of fungicides on rust severity and biomass yield of 'Dallas Blues' switchgrass.

	Rust[z]		Biomass yield[y]	
Fungicide and rate/100 gal	2011	2012	2011	2012
Non-treated control	7.9 a	8.0 a	3.6 b	6.4 bcd
3336 4.5F 20 fl oz	7.3 b	7.0 b	3.9 b	7.2 bcd
Banner MAXX 1.3MEC 8 fl oz	6.7 c	5.7 c	4.2 b	7.9 b
Daconil Ultrex 82.5WDG 1.4 lb	7.2 b	7.2 b	3.1 b	6.1 cd
Eagle 40W 8 oz	4.4 d	4.7 d	6.0 a	12.7 a
Heritage 50WDG 4 oz	5.1 d	4.3 d	5.8 a	12.3 a
Medallion 50W 4 oz	7.0 bc	--	3.7 b	--
Concert II 35 fl oz	--	6.7 b	--	7.8 bc
Palladium 62.5WG 6 oz	7.3 b	7.2 b	3.7 b	5.9 d

[z]Rust intensity was rated on September 23, 2011 and August 31, 2012 using a modified Florida 1 to 10 peanut leaf spot ratings scale.
[y]Biomass yield is expressed as lb dry matter per plot.
[x]Means in each column that are followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

Sugar Maple Cultivar Response to Anthracnose

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Significance to Nursery Industry: In a simulated landscape planting in North Central Alabama, sugarmaple (*Acer saccharum*) varieties varied greatly in their susceptibility to anthracnose. Lesion formation in the lower leaf canopy was noted in early to mid-May and noticeable leaf shed on susceptible varieties was seen by July with those same cultivars suffering moderate to heavy defoliation by September. As a result, fall color display was far superior on the resistant cultivars such as Legacy, Fall Fiesta, Autumn Blush, and Autumn Faith as compared with the susceptible cultivars such as Fairview, Flax Mill Majesty, Gold Spire, Morton, Seneca Chief, Sugar Queen, and Sweet Shadow.

Sugar maple (*Acer saccharum*) is a superior shade tree and a number of cultivars are adapted to southern landscapes (2). Anthracnose caused by *Discula* sp. (teleomorph: *Apiognomonia acerina*) can greatly reduce the vigor and aesthetic value of many maples including sugar maple (3). Leaf spots, which often are centered on the veins, are circular to irregular in shape and reddish brown in color sometimes with a small tan center (3). The objective of this study is to assess the reaction of a selection of sugar maple cultivars maintained in a simulated landscape setting to anthracnose.

Sugar maple cultivars were planted on February 9, 2001 into a Hartselle fine sandy loam (≤ 1% organic material) at the North Alabama Horticulture Research Center in Cullman, AL (USDA Hardiness Zone 7a) on 20 ft centers with 20 ft between rows. Prior to tree establishment, soil fertility and pH were adjusted according to the results of a soil fertility assay. While 0.75 lb of actual nitrogen was evenly spread under the canopy of each tree in Apr, May, and Jun from 2002 through 2010, trees were not fertilized in 2011 and 2012. Centipedegrass alleys between individual trees were periodically mowed. Anthracnose intensity was visually rated on September 30, 2011 and September 15, 2012 using a modified Florida 1 to 10 peanut leaf spot rating scale where 1 = no disease, 2 = very few lesions in canopy, 3 = few lesions noticed in lower and upper canopy, 4 = some lesions noticed in lower and upper canopy and $\leq$ 10% defoliation, 5 = lesions noticeable and $\leq$ 25% defoliation, 6 = lesions numerous and $\leq$ 50% defoliation, 7 = lesions very numerous and $\leq$ 75% defoliation, 8 = numerous lesions on few remaining leaves and $\leq$ 90 % defoliation, 9 = very few remaining leaves covered with lesions and $\leq$ 95% defoliation, and 10 = trees defoliated (1). All statistical analyses were done on rank transformations of data. For presentation, data are back transformed. Means were separated using Fisher's least significant difference (LSD) test ($P \leq 0.05$).

Results and Discussion: As indicated by anthracnose ratings between 2.6 and 3.9, light to moderate leaf spotting along with little or no defoliation was observed in 2011 on Legacy, Autumn Faith, Autumn Blush, and Fall Fiesta sugar maple (Table 1). Commemoration, Wright Brothers, and Bonfire with disease ratings between 4.4 and 5.5 suffered noticeable leaf spotting throughout the tree canopy and 20 to 35% defoliation. In contrast, defoliation levels ranging up to 90% with heavy spotting on the few remaining leaves were recorded for Green Mountain, Gold Spire, Flax Mill Majesty, Sweet Shadow, Sugar Queen, Seneca Chief, and Morton sugar maple. Heavy defoliation was also noted on Apollo, Endowment, and Fairview.

Anthracnose ratings often were lower in 2012, particularly for anthracnose susceptible varieties, as compared with the same month in 2011 for a many sugar maple cultivars (Table 1). While minimal leaf spotting was observed on Legacy and Fall Fiesta as indicated by disease ratings of 1.4 and 1.8, respectively, similar levels of moderate leaf spotting along with little or no defoliation, as indicated by disease ratings between 3.2 and 3.8, were noted on Apollo, Autumn Faith, Autumn Blush, Bonfire, Commemoration, Green Mountain, Steeple, and Wright Brothers sugar maple. Cultivars with anthracnose ratings similar to the heavily defoliated Sugar Queen included Fairview, Gold Spire, Seneca Chief, and Sweet Shadow.

Sugar maple cultivars differ considerable in their reaction to anthracnose incited by an *Apiognomonia acerina*. Over the two year study period, the least leaf spotting and premature defoliation was observed on Legacy and Fall Fiesta sugar maple. Other cultivars with relatively low two year disease ratings and minimal defoliation included Autumn Blush and Autumn Faith. In contrast, sugar maple cultivars that proved highly susceptible to anthracnose and as a result minimal fall color display included Fairview, Flax Mill Majesty, Gold Spire, Morton, Seneca Chief, Sugar Queen, and Sweet Shadow.

Table 1. The reaction of selected sugar maple cultivars to anthracnose in a simulated landscape planting in north central Alabama.

	Disease rating*			Disease rating*	
Sugar maple variety	2011	2012	Sugar maple variety	2011	2012
Apollo	6.7 bc**	3.8 de	Gold Spire	9.1 a	6.2 ab
Autumn Blush	3.7 fgh	3.2 de	Green Mountain	5.8 cde	3.4 de
Autumn Faith	3.2 gh	3.4 e	Legacy	2.6 h	1.4 g
Bonfire	5.5 cde	3.7 de	Morton	7.4 abc	5.1 bc
Commemoration.	4.4 efg	3.0 ef	Seneca Chief	7.8 ab	7.2 ab
Endowment	6.6 bcd	4.6 cd	Sugar Queen	7.9 ab	8.8 a
Fairview	7.2 bc	6.3 ab	Sweet Shadow	8.0 ab	6.0 ab
Fall Fiesta	3.9 fgh	1.8 fg	Wright Brothers	5.0 def	3.8 de
Flax Mill Majesty	8.2 ab	5.5 bc	--	--	--

*Anthracnose was rated on September 30, 2011 and September 15, 2012 using a modified Florida 1 to 10 peanut leaf spot rating scale.

**Means for each study year that are followed by the same letter are not significantly different according to Fisher's protected least significant difference ($P \leq 0.05$) test.

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Determining the Mechanism of Action of Bacterial Biological Control Agents Against Powdery Mildew in *Cornus florida*

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Index words: Biological control agents, powdery mildew, *Cornus florida,* secondary metabolites

Significance to Industry: *Cornus florida* (Flowering dogwood) is a nursery tree known for its aesthetic value, and is mainly grown in the eastern North America. It is a source of income to Tennessee farmers, and an important commodity in nursery and landscape industries. It is also a source of food and shelter to wild animals and birds. Foliar diseases affect the overall growth and aesthetic value of dogwood trees; thus, fungicide applications have become a routine practice in nursery production of dogwoods. This practice has increased production costs and reduced net income to farmers (9). Fungicide resistance as well as concerns over personal and environmental safety due to accidental fungicide toxicities has led to a search for alternative methods of disease control (6, 9). The objective of this research was to evaluate epiphytic and endophytic bacteria that have previously shown potential as biological control agents (BCA) for powdery mildew in flowering dogwoods (10). This study was undertaken to confirm previous results and determine mechanism of action in selected BCAs.

Nature of Work: In the past, flowering dogwood used to be disease-free and commercial production was low cost and profitable. However, starting in the 1970's, dogwood anthracnose disease caused by *Discula destructiva* appeared (12), and fungicides applications to control the disease became necessary. In 1994, powdery mildew appeared and quickly spread in the southeastern United States causing destruction of millions of dogwood seedlings (7). Powdery mildew has therefore been classified as the most damaging disease in flowering dogwood (10) necessitating fungicide applications season-long. Powdery mildew is not problematic in native areas that have never been exposed to chemical fungicides (10), thus suggesting that fungicide use against *D. destructiva* may have destroyed protective epiphytes that normally provided a buffer against foliar pathogens (10, 15).
Increased production costs and reduced net income to dogwood farmers (9) as well as concerns over fungicide resistance and fungicide toxicity hazards have led to a search for alternative methods for powdery mildew management (9, 6). Bio-pesticides and BCAs have the potential to reduce the amount of chemical fungicides used in dogwood production. Biological Control Agents are presumably pathogen-

specific and help preserve other non-target micro-organisms including saprophytic bacteria that have been reported to control fungal diseases in plants (3). Such biological agents are environmentally friendly and sustainable. Previous studies have reported that bacterial BCAs' suppressed fungal spore germination and/or growth (2). Preliminary studies suggested that the bacterial BCA's mechanism of action may be associated with antibiosis from naturally produced secondary metabolites by the bacteria. Several studies have reported biological control agents that inhibit fungal growth, but the anti-fungal compounds were rarely identified or mentioned (4, 13). Previous studies have also reported anti-fungal volatile compounds that are produced by BCAs (4). This study was conducted to confirm previous results on biological control of powdery mildew in dogwood and identify antimicrobial volatile compounds that are produced by the selected BCA**.**

Efficacy of BCAs on powdery mildew infection: Experiments were conducted to confirm the efficacy of six bacterial isolates as biocontrol agents in seedlings of dogwood cultivar 'Cherokee Princess'. Randomized complete block experimental design with four replicates were used in greenhouse, and shadehouse environments. Six bacterial isolates were grown in nutrient agar at room temperature for 36 hours, and aseptically scrapped to nutrient broth and shaken overnight. Bacterial suspensions of approximately 1.5 $x10^6$ CFU/mL were applied on dogwood leaves by using hand held spray bottles and leaves were sprayed to run-off every 7-10 days. Conventional fungicide thiophanate methyl (Cleary's 3336F®) was used as a positive control and water was a negative control. The source of powdery mildew infection was air-borne spores from previously infected plants randomly placed at the experimental area. Disease development was monitored from June to August of 2011 and 2012. The bacterial BCAs that showed significant control against powdery mildew were further tested for secondary metabolites

Preparation of samples for secondary metabolites production: Bacterial strains were grown in nutrient agar using sterilized bottles covered with silicon lids so as to maximize the trapping of volatiles that may be produced by these bacteria. Volatiles produced were detected and identified by using Gas Chromatograph Mass-Spectrometry (GC/MS). Solid phase micro-extraction fiber with Helium as a carrier gas was used. The fiber was exposed to 48 h-old cultures for ten minutes for absorption of the volatiles without touching the media or bacterial colonies. The fiber was then retracted and exposed to the GC injector port for desorption. The injector temperature was set at 220 ºC, and detector temperature at 265 ºC. Desorption in hot injector was programmed with initial temperature of 28 ºC and held for 1 minute, then increased at 4 ºC min^{-1} to 180 ºC then held for 2 min. This gave a total run time of 41 minutes per sample. Equipment used for this study was a Varian 3800 gas chromatograph equipped with an ion-trap mass spectrometer (Varian Saturn 2000) available at Tennessee State University, Nashville; Chemistry Department.

Results and Discussion: Out of the six potential BCAs tested, four were confirmed to have significant impact in suppressing powdery mildew disease severity. Two of

these, B17A, and B17B had been reported previously (8), and similar anti-pathogen results was observed in this study. Isolates IMC 3" and IMC 8"1 are endophytes isolated from the xylem tissue of the flowering dogwood. Although previous studies have suggested that the bacterial BCA's mechanism of action may be associated with antibiosis from naturally produced bacterial secondary metabolites, the compounds were not identified. This is the first study in which bacterial secondary metabolites have been identified from these BCAs. The GC-MS spectra showed different peaks signifying different secondary metabolites produced by these bacteria as shown in Figure 1. These compounds include cycloheptasiloxane tetradecamethyl, cyclopentasiloxane tetradecamethyl, cyclotetrasiloxane octamethyl, cyclopentasiloxane decamethyl, Furaltadone and -1,1 -dimethylethyl-3-methyl as shown in Table 1. Compounds that have been reported to have antimicrobial, antibiotic properties, and polymers to antibiotics (1, 5, 11, 14) were identified in this study. Example, Furaltadone that was identified in this study, has antibiotic as well as chemotherapeutic properties (14). Thus, it is reasonable to assume that antibiosis mechanisms of action are involved in powdery mildew control by these bacteria.

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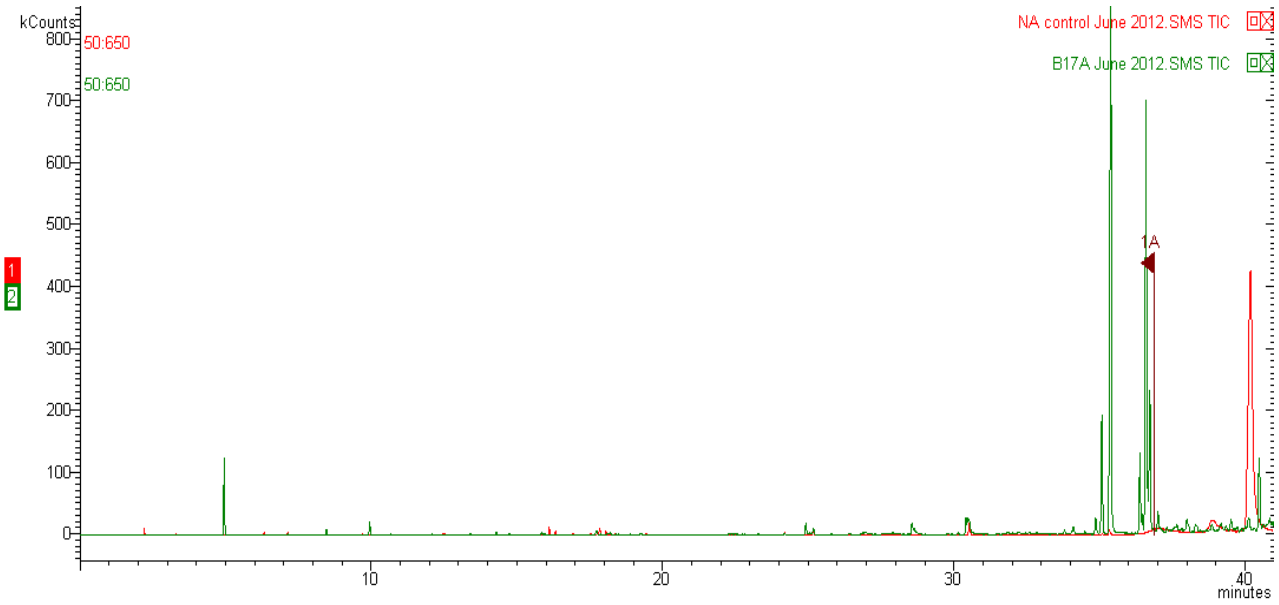
Table 1. Volatile organic compounds emanating from the autrient agar (NA) media/micro-organisms

Source	Compound	Functions
Media Fungicide	-Control -Methoxy-phenyl-oxime (thiophanate methyl)	N/A Antifungal
Media+B17A	-1,1-dimethylethyl-3-methyl	Intermediate to antibiotic preparation (1)
Media+B17B	-Furaltadone -cycloheptasiloxane tetradecamethyl	Antibiotic, chemotherapeutic (14) Antimicrobial (11; 1)
Media+IMC3	-Cyclopentasiloxane tetradecamethyl -Cyclotetrasiloxane octamethyl	Antimicrobial (5) Antimicrobial (5)
Media+IMC8	Cyclopentasiloxane decamethyl	Antimicrobial and Polymer attached to antibiotics (5)

Figure 1. An example showing spectra of B17A against control.



Management of Cherry Leaf Spot Disease in Flowering Cherry

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Index words: *Blumeriella jaapii, Cylindrosporium padi,* Ornamental cherry, *Prunus serrulata* disease management.

Significance to the Industry: Cherry leaf spot disease (CLS) caused by the fungus *Blumeriella jaapii (B. jaapii)* has been reported as a constraint in nursery production of ornamental cherry also known as flowering cherries (1, 3). Cherry leaf spot is among the most important diseases affecting cherry trees, causing premature defoliation, reduced shoot growth, and increased susceptibility of trees to winter injury; and some plant death (1, 3). Most of the literature on this disease is on fruiting cherries grown in cooler regions in northern Great Lakes and the northwest regions of the United States (US) and other areas (4, 6). Similarly, disease management for CLS in flowering cherries uses fungicide spray programs formulated for fruiting cherries in cooler climatic zones (10) and their results may not necessarily apply to the warmer climate of the southeastern United States where most of the ornamental cherries are grown. Recent studies in Tennessee, showed that perpetuation of CLS from year to year are through leaf debris and dormant buds where *B. jaapii* overwinters (Joshua and Mmbaga, data unpublished). Economic disease management strategies for Tennessee and other southeastern states need to incorporate information on the source and timing of infection. By taking preventative measures, nursery growers could reduce their production costs and reduce crop losses through the proper timing and selection of fungicides in rotation. The overall objective of this study was to evaluate fungicides for disease management using timing of spray programs that are based on research data generated locally in McMinnville, TN.

Nature of Study: Flowering cherry trees (*Prunus* species) are popular landscape plants mainly grown for their springtime floral displays of beautiful and colorful flowers. They are also cherished for their fall foliage color and ornamental bark. The significance of the aesthetic qualities of the cherry tree are demonstrated in the annual Cherry Blossom Festivals from “Kwanzan” cherry in Washington, D.C. and Macon, Georgia to the historic Tidal Basin cherries planted in Washington, D.C. Any disease that causes premature defoliation and reduced shoot growth of flowering cherry impacts its value. Cherry leaf spot disease is one of the most important diseases affecting cherry trees. In addition to causing premature defoliation and reduced shoot growth, CLS increases susceptibility of trees to winter injury; and causes some plant death (1, 3). Split barks resulting from winter injuries significantly diminish the tree aesthetic value, longevity and marketability. This study was conducted to evaluate fungicides and fungicide rotations for controlling CLS on ornamental cherry.
Four fungicides were evaluated individually and in rotations of two or three fungicides on ‘Okame’ and ‘Yoshino’ cultivars grown in a shade house environment covered with

65 % shade cloth. A replication of four individual plants per treatment was used for each cultivar and plants were arranged in randomized complete block design with water as a control treatment. Treatments were applied on 10-14 day intervals and plants were sprayed to runoff. The rate of application followed manufacturers' guides and spraying commenced in early May before leaf spot symptoms were observed and terminated at the end of September. Fungicides, active ingredients and rate of application are presented in Table 1. Treatments were also done in grower's field using a replication of eight individual trees of cultivar 'Kwanzan' and fungicides trifloxystrobin and captan in rotations. Spray program was started at petal drop and continued every 10-14 d. Disease development was monitored and severity of infection was assessed based on a scale of 0–5, in which 0 = no symptoms, 1 = 1%–10%, 2 = 11%–25%, 3 = 26%–50%, 4 = 51%–75% and 5 = 76%–100% of leaf tissue covered with disease symptoms based on visual estimation by one number of independent scorers (11). Disease symptoms consisting of leaf spots or shot holes and leaf yellowing were evaluated in the first year of this study, but in the second year of this study defoliation was also measured and percentage of plant defoliated in relation to the whole tree was assessed. Statistical analysis was performed using the general linear model procedure of Statistical analysis systems (SAS institute Inc. 2008) and analysis of variance (ANOVA) with multiple comparisons between the mean using least significant difference according to SAS version 9.1 software (14).).

Results and Discussion: Results on fungicide evaluations in shade house environment identified the most effective fungicides used individually and in rotations as summarized in Tables 2, 3. Disease development was variable over time, and cultivar 'Yoshino' developed more disease than 'Okame ' and had significantly more leaf spots and leaf yellowing than 'Okame' indicating that it may be more susceptible to CLS. Overall mean disease severity and mean defoliation showed that fungicides captain and flint were individually, most effective while Bordeaux was least effective and also caused leaf burn.. Copper compounds have been reported to be effective in the control of CLS on tart cherry when administered with spray timings and hydrated lime (13). Although that was followed in our study, Bordeaux mixture had undesirable effects of phytotoxicity. Defoliation was lowest in treatments with orius, flint, and captan in rotations with flint, captan in rotations with orius, and captan in rotations with flint and orius (Tables 2, 3). Overall, disease severity was low in shadehouse environment and defoliation was highest in June followed by July, but differences in fungicides were not clear cut. Plants put out new leaves and by the end of August when this study was terminated, defoliation was less the 30%, and did not seem to have impacted plant growth.

The effect of fungicide sprays on CLS in the field environment was more dramatic with severe leaf spot, leaf yellowing and defoliation of almost 80 percentage on non-sprayed trees while sprayed trees had less than 15% defoliation (Figs 1 and 2). Rotations of fungicides captan and trifloxystrobin (Flint 50WG™) was highly effective in controlling CLS disease in field environment where overall disease incidence was quite high. The high disease symptoms in field environment compared to the shadehouse environment

is probably due to a higher amount of primary inoculum from previously infected leaf debris as well as more suitable environment. Previously, growers had problems controlling CLS with fungicides that are labeled for CLS management. The timing of fungicide sprays was suspected to be the main problem and that fungicide sprays by growers may have been initiated too late when infection was already well established. However, low fungicide efficacy may have also contributed to the problem and needed evaluation. In this study, fungicide spray program was based on previous studies that had confirmed availability of primary inoculum before leaves open in spring (Joshua and Mmbaga, unpublished data). Results from this study confirmed that good timing of spray application starting at petal drop was highly effective in controlling CLS in Tennessee and is likely to be effective at other southeastern regions with similar climate.

The use of fungicide rotations is a common practice to prevent the development of fungicide resistance that lead to disease control failures (8). All fungicides evaluated in this study have previously been reported on to control CLS in fruit trees (1). Results from this study identified individual fungicides and some rotations of two or more fungicides that were highly effective in reducing CLS disease on flowering cherry. Fungicides used in this study have different modes of action; captan has both protective and curative mode of action that prevents respiration of various species of fungi and bacteria (12). Orius is absorbed through the leaves, providing curative, preventative and eradicative actions against diseases in stone fruits and grapes (9). Flint provides preventative action by interfering with fungal respiratory and energy production to inhibit initial infection and secondary spread of the disease (2). Both flint and orius are systemic fungicides, which allow the absorption of their active ingredient into the plant for better disease control (9). Orius is a sterol demethylation inhibitor (DMI) fungicide and several studies have reported DMI fungicides as effective in controlling CLS (4, 5, 7). Orius has been reported to work effectively in rotation with strobilurin fungicides like flint to reduce fungicide resistance (9). However in our results, orius was not effective in controlling CLS when administered individually, but was effective when used in rotations with Flint. Overall, results from this study showed fungicides that are effective in controlling CLS; good timing of spray application starting at petal drop provided protection to young leaves as they opened and provided good CLS control under high disease pressure.

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Table 1. Fungicide evaluated and rates of application for cherry leaf spot control.

Treatment	Fungicide Trade names[1]	Fungicide active ingredient	Rate of application
Individual fungicide	Captan™	Captan	1.25g/L
	Bordeaux™	Copper sulphate, hydrated lime and water	4.45g : 54.48g :1L water
	Flint 50WG™	Trifloxystrobin	0.53g/L
	Orius 20Q™	Tebuconazole	0.32g/L

[1]Captan™ Southern Agricultural Insecticides Inc., Palmetto, FL 34220); Bordeaux™ (PBI/ Gordon Corporation., Kansas city, MO 64101; Flint 50WG™, Bayer Crop Science., Research Triangle Park, NC 27709; Orius 20Q™ Makhteshim Agan of North America Inc., Raleigh, NC 27609.

Table 2. The effect of fungicide treatments in controlling cherry leaf spot disease in flowering cherry as measured by mean disease severity in shade house environment in 2011.

Treatments[1]	Mean disease severity[2]					
	June		July		August	
	Yoshino	Okame	Yoshino	Okame	Yoshino	Okame
Water	2.50 ab	2.00 a	2.75 ab	2.00 a	2.00 a	2.50 a
Bordeaux & Flint & Orius	2.75 a	0.88 c	1.75 b	1.75 ab	1.50 a	2.00 ab
Bordeaux & Orius	3.00 a	1.00 c	2.50 ab	1.00 b	1.75 a	1.75 bc
Orius	2.25 ab	1.75 ab	2.25 ab	1.00 b	1.75 a	1.50 bcd
Flint	1.50 b	1.00 c	2.00 ab	1.50 ab	1.50 a	1.25 cd
Captain	1.50 b	0.75 c	3.00 a	1.25 ab	1.50 a	1.25 cd
Bordeaux	2.75 a	1.25 bc	2.25 ab	1.00 b	1.75 a	1.00 d
Bordeaux & Flint	2.38 ab	1.00 c	2.75 ab	1.00 b	2.25 a	1.00 d
Captan & Flint	2.25 ab	0.88 c	2.25 ab	1.00 b	1.50 a	1.00 d
Captan & Flint & Orius	2.00 ab	0.75 c	2.25 ab	1.00 b	2.00 a	1.00 d
Captan & Orius	2.00 ab	1.00 c	2.00 ab	1.00 b	1.50 a	1.00 d
$LSD_{(0.05)}$	1.19	0.64	0.99	0.99	1.02	0.52

[1]Fungicides Bordeaux mixture (copper sulphate and lime mixture); Orius 20Q™ (Tebuconazole); Flint™ (Trifloxystrobin); Captan™ (Captan) were individually or in rotations as indicated at 14 d intervals.

[2]Mean disease severity and defoliation readings using a 0-5 scale in which 0= no disease, 1= 1-10, 2= 11-25, 3=26-50, 4= 51-75 and 5= 76-100% of plant showing disease symptoms (12). Means with the same letter are not significantly different at P=0.05.

Table 3. The effect of fungicide treatments in controlling cherry leaf spot disease in flowering cherry as measured by plant defoliation in shade house environment in 2011.

Treatments[1]	Plant Defoliation[2]					
	June		July		August	
	Yoshino	Okame	Yoshino	Okame	Yoshino	Okame
Water	49.42 a	42.51 a	31.58 a	10.56 a	18.06 ab	32.04 a
Bordeaux, Flint & Orius	54.17 a	6.60 bc	9.36 a	10.43 a	12.53 abc	30.58 ab
Orius	37.58 a	19.89 b	24.01 a	2.96 ab	5.81 bc	11.63 abc
Bordeaux & Orius	71.40 a	6.71 bc	15.29 a	1.21 ab	12.39 abc	9.80 bc
Bordeaux &Flint	53.44 a	8.58 bc	20.34 a	1.00 ab	29.16 a	4.12 c
Bordeaux	62.25 a	8.07 bc	14.75 a	1.00 ab	16.65 ab	2.37 c
Captain	34.22 a	4.58 c	34.81 a	2.37 ab	11.29 abc	5.43 c
Flint	36.36 a	7.08 bc	13.10 a	5.43 ab	12.89 abc	4.00 c
Captan & Flint	49.56 a	7.29 bc	14.59 a	0.56 b	3.42 bc	5.43 c
Captan & Orius	52.71 a	11.16 bc	17.98 a	0.56 b	2.37 c	3.88 c
Captan, Flint & Orius	42.51 a	2.89 c	17.39 a	1.00 ab	9.18 abc	1.00 c
$LSD_{(0.05)}$	7.27	4.08	8.34	5.37	5.93	6.25

[1]Fungicides used in rotations as indicated, Bordeaux mixture (copper sulphate and lime mixture); Orius 20Q™ (Tebuconazole); Flint™ (Trifloxystrobin); Captan™ (Captan); at 14 d intervals.

[2]Mean disease –severity and defoliation readings using a 0-100% in which 0 = no disease, and 100% of plant defoliated. Means with the same letter are not significantly different at p=0.05 according to analysis of variance (Proc GLM) least significant differences on square root transformed data ($\sqrt{X} + 0.5$) (14).

Figure 1. The effect of fungicide treatments on cherry leaf spot in flowering cherry as measured by (a) mean disease severity and (b) plant defoliation in field environment.

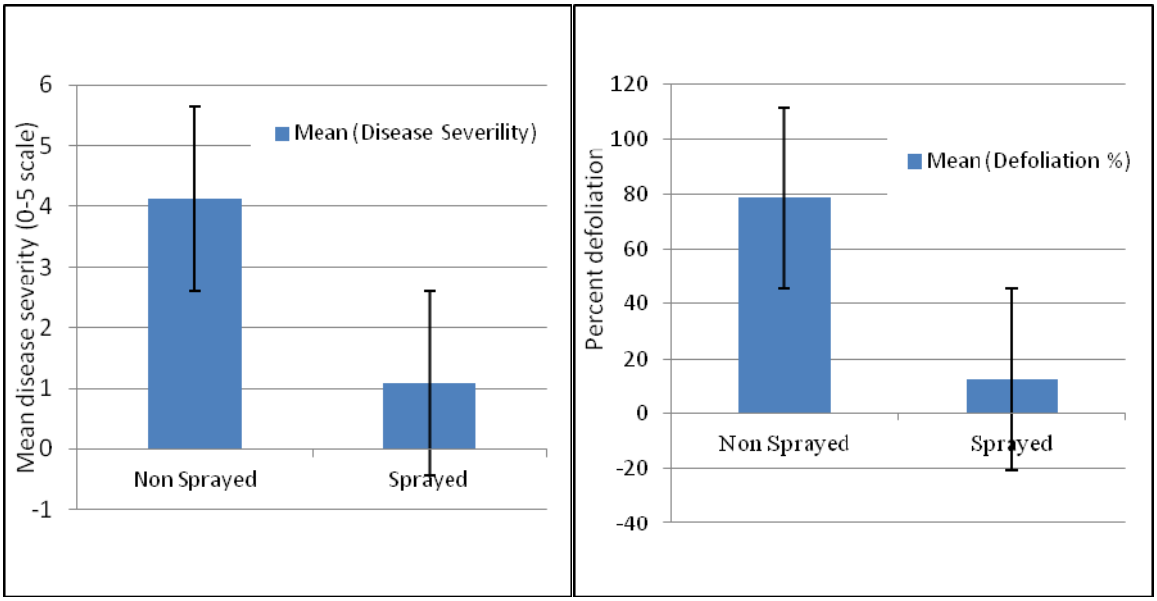
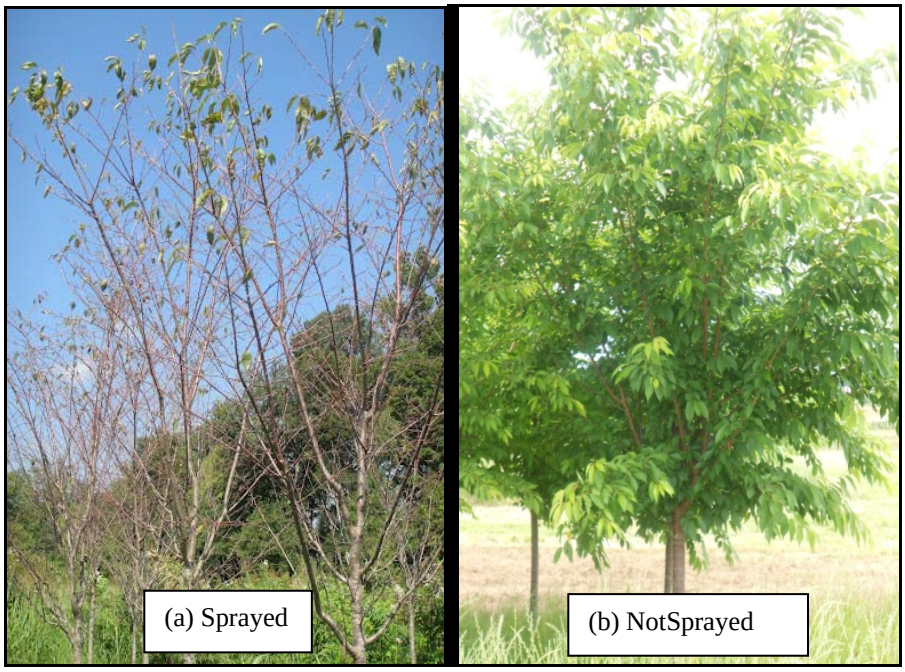


Figure 2. Plant defoliation associated with cherry leaf spot disease in field nursery. The plants in (a) were sprayed with fungicide and those in (b) were not sprayed.



Using Social Media for Ornamental Plant Pathology and Entomology Extension Education

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https://www.facebook.com/SoilPlantPestCenter

Index Words: Facebook, social media, plant diseases, insects

Significance to the Industry: Staff at the Soil, Plant and Pest Center have used social media (Facebook) in their educational programs to: give tips on diagnosing plant problems, alert growers of active pest and disease outbreaks, alert growers of new pests, use digital imaging to illustrate posts, list a calendar of industry and educational events. Social media has allowed us to reach a new audience that we have not reached using traditions educational methods. Social media has also expanded the geographic area of our audience nationally and internationally.

Nature of Work: Extension staff, at a plant diagnostic clinic, have the opportunity to observe a wide range of insects, plant pathogens, and various plant problems throughout the year. Each year, there are new pests and diseases identified that have the potential to damage ornamental plants in production facilities as well as landscapes. Traditional methods of communicating this information to growers, landscape managers, and Extension agents includes: newsletters, blogs, site visits and group meetings. Professionals working in the green industry need timely information on insect pests and plant diseases in order to avoid costly losses in nurseries and/or landscape plantings. The staff at the Soil, Plant and Pest Center (SPPC) created a business page on Facebook to provide current information to assist green industry professionals at identifying and managing plant pests and diseases. Daily posts to the Facebook page were based on: observations of the staff at the center while making farm visits, specimens submitted to the lab or from calls or emails from Extension agents and green industry professionals.

Social media has advantages over traditional forms of outreach such as newsletters and blogs. Facebook content is available to persons that “like” your page. Once a person starts following your page, your posts will be found in the newsfeed on their page. Much of the content is also visible to persons that are “friends” of users that follow your page. Also, users may share posts to their pages which expands the “footprint” of the page over a wide geographic area. While this page was originally created to serve an audience in Tennessee, users from all regions of the U.S and over 20 countries have become followers of the page.

Results and Discussion: Over 1,000 Facebook users “liked” the Soil, Plant and Pest Center Facebook page in 2012. Persons that follow the page include all phases of the

green industry, professionals and novices alike. Persons following the page included: nursery producers, greenhouse growers, landscape contractors and managers, master gardeners, garden center staff, botanical garden staff, and the general public. During 2012, over 750 updates were uploaded to the on the page; most had digital images to illustrate the pest/disease.

One of the advantages of using Facebook is the analytical data available to page administrators. Data includes gender and relative age of users. We found our page users were nearly evenly split among men and women. This is unusual for most agriculturally based outreach where men are primarily the target audience. Surprisingly, we found that our users were evenly distributed in the following age groups: 25-34, 35-44, 45-54, and 55-64. College age adults (18-24) and senior citizens (65+) were our least numerous users. Roblyer et al (1) found that while college students readily adopted Facebook, professors were reluctant to use it for educational purposes. In a non-traditional setting, we found the opposite was true. Our most frequent page visitors are between 25-64 years of age.

Data from Facebook analytics helped us target our audience based on their interaction with previous posts. We found that the most popular content were original posts, illustrated by one or more digital images. Conversely, we found that posts that were simply links to web pages, news articles, etc. were rarely viewed by our users. Over 22,000 unique engaged visitors interacted (view, read, commented) with the page during 2012. In our Extension reporting system for annual reports we used the engaged users as direct contacts, as same as those contacted via: email, phone calls, or office visits. Content from the SPPC Facebook page reached over 133,000 Facebook users in over 70 countries. The majority of the users on our page are from the U.S.; users from other countries in descending order include: Turkey, Italy, Sudan, Spain, India, Iraq, Thailand, Portugal, Serbia and the United Kingdom. Locally, we found that we were able to grow our user base by promoting our page at group meetings and field days. It's unclear how the international audience discovered our page; possibly through contacts in the U.S. or through the search option on Facebook.

There are pros and cons to using Facebook as a means of educating clients. An advantage is the ability to update the audience in a timely manner. Clients that you may only see once a year at a regional educational meeting where they are updated on the past year's problems, can be kept up-to-date on via daily posts. Also, Facebook is relatively easy to use. Text and images can be uploaded quickly to share with your audience. Whereas the SPPC has received increased name recognition from the page, it has not translated into increased specimens or income to our lab. It's possible that the posts and illustrations on the page have helped clients resolve plant problems without sending a specimen to our lab. Challenges in maintaining an active Facebook page include the time required to photograph, compose and upload posts. Also, the page allows followers to post questions and images of plant problems. Fortunately, only a small number of the users request assistance via the page. We still encourage users to contact their local Extension agent and use a plant disease/insect clinic at their state's land grant university.

While the page has been popular with green industry professionals, master gardeners and the general public, it has not been widely used by county Extension agents. This is somewhat surprising as many of their clients ask about horticultural plant problems. Many Extension agents in Tennessee have very diverse audiences, making it difficult to specialize in an area such as horticulture, specifically consumer horticulture. Also, the fragmentation of horticultural information among web pages and social media makes it more difficult to quickly retrieve pertinent information needed for clients. As social media use increases and additional departments, Extension offices and working groups develop their own pages, this fragmentation of information will continue to increase.

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A First Report of Downy Mildew on Impatiens in Tennessee

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Index words: downy mildew, impatiens, *Plasmopara obducens*, *Impatiens walleriana*

Significance to Industry: Garden impatiens, *Impatiens walleriana*, is the most widely used annual bedding plant in the U.S. It is primarily used in color beds that are in full to partial shade by landscape contractors and home gardeners. In 2012, downy mildew caused by *Plasmopara obducens*, was observed in landscape plantings and garden centers on garden impatiens in all regions in Tennessee. This is a first report of downy mildew on garden impatiens in a landscape setting in Tennessee.

Nature of Work: Downy mildews of bedding plants have been in the news frequently in the past ten years. Different species of fungi can cause downy mildew on vascular plants. One of the most infamous downy midews is blue mold of tobacco. In a single season, blue mold can cause extreme damage to tobacco as it move from the Caribbean to Canada via air currents moving south to north. In ornamentals, there have been various outbreaks of downy mildew to plants such as: *Alyssum, Aster, Buddleia, Coleus, Coreopsis, Lamium, Ocimum, Rosa* and *Rudbeckia.* Garden impatiens, *Impatiens walleriana*, is the most popular annual bedding plant in the U.S. It may represent 15% to 20% of bedding plant sales for many garden centers each spring. Unfortunately, downy mildew caused by the fungus *Plasmopara obducens* represents a serious threat to this herbaceous ornamental. In Europe, this disease has essentially ended the use of garden impatiens as a bedding plant (1). In 2011 and 2012, parts of the midwestern and northeastern U.S. have experienced destruction in greenhouse production and landscape beds that rivaled the outbreak in Europe.

Most of these downy mildews are sporadic in occurrence and are caused by several different fungal species. Downy mildew of rose for instance, is a threat each spring to potted roses that are maintained in cool, humid polyhouses at nurseries and garden centers. Damage to roses can be dramatic. Infected leaves drop prematurely, leaving a stark, denuded plant.

In the fall of 2011 and throughout 2012, greenhouses, garden centers, commercial and residential landscapes were scouted for the signs and symptoms of impatiens downy mildew. The symptoms include: stunted plants, curled leaves, severe leaf drop, lack of flowering, light colored leaves and leaves that have stippling similar to spider mite injury. The signs of downy mildew are white sporulation (sporangia) on the abaxial surface of an impatiens leaf. Microscopically, the fungus produces a dark, brown, double-walled oospore in stem tissue late in the season.

Results and Discussion: In early June 2012, downy mildew of impatiens was reported in GA and NC. The first specimens of impatiens infected with downy mildew in Tennessee were from a residential planting in Nashville (Davidson County) on June 16, 2012. Within two days, specimens were received at the Soil, Plant and Pest Center from a wholesale nursery/garden center in Memphis and from a residential landscape in Murfreesboro (Rutherford County). During the summer of 2012, downy mildew was confirmed in Chattanooga (Hamilton County), Knoxville (Knox County) and Johnson City (Washington County). In January and February 2013, downy mildew of impatiens was confirmed in two wholesale greenhouses and in May 2013, downy mildew was found during a routine inspection of a garden center, all in Middle Tennessee, by plant inspectors with the Tennessee Department of Agriculture, Division of Regulatory Services.

As downy mildew of impatiens was a disease new to gardeners and green industry professionals in the Southeast, many may have attributed the decline and defoliation of their impatiens to drought, insect damage or other problems. It is critical that production and maintenance employees be trained to recognize the signs and symptoms of downy mildew. All incoming plants to production and retail facilities should be inspected. This should be continued throughout the production cycle. Leaf wetness should be limited to less than four or five hours per day by careful watering and monitoring relative humidity. Fungicides should be used during production to keep plants healthy.

It is recommended that garden impatiens not be planted into beds that were infested the previous year. In October 2012, stem tissue of infected garden impatiens was examined for the presence of oospores. In every case, oospores were observed in infected plants. It is likely that these oospores have survived and will infect impatiens planted into infested beds in 2013. As there are no garden impatiens resistant to downy mildew, the most effective means of avoiding downy mildew is to shift to disease resistant plants such as *Begonia, Coleus*, New Guinea impatiens, SunPatiens and *Torrenia*. Fungicide sprays are impractical for most landscape plantings to protect impatiens from downy mildew.

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Resistance to Foliar Leaf Spots in Hydrangea

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Index Words: Big leaf hydrangea, *Cercospora hydrangeae*, *Colletotrichum gloeosporioides, Hydrangea macrophylla*, *Hydrangea serrata*, Lacecap hydrangea, Mophead hydrangea, Mountain hydrangea.

Significance to Industry: Forty seven cultivars of *H. macrophylla* and ten cultivars of *H. serrata* were evaluated for resistance to Cercospora leaf spot and anthracnose in full sun. Three cultivars of *H. macrophylla* were found to be resistant to Cercospora leaf spot whereas no cultivars of *H. serrata* were resistant. When cultivars were evaluated for resistance to anthracnose, twenty cultivars of *H. macrophylla* and seven cultivars of *H. serrata* were found to be resistant. Resistant cultivars can be used by landscapers and nursery owners to reduce problems in the landscape and reduce pesticide usage. Resistant cultivars can also be used by plant breeders to produce superior genotypes for the nursery trade.

Nature of Work: *Hydrangea macrophylla* (big leaf hydrangea, mophead hydrangea and lacecap hydrangea) and *H. serrata* (mountain hydrangea) are popular ornamentals throughout much of the continental United States. Most hydrangeas can be grown in variable environments ranging from full sun to full shade. In full shade, powdery mildew (*Erysiphe polygoni*) can be a serious problem and cause deformed leaves and poor plant growth. Windham et al. (3) found that cultivars of *H. macrophylla* and *H. serrata* varied in resistance to powdery mildew and found the cultivars Amagi Amacha, Diadin, Endless Summer, Shirofuji and Veitchii were very resistance to the disease. Leaf spots such as Cercospora leaf spot (*Cercospora hydrangeae*) and anthracnose (*Colletotrichum gloeosporioides*) usually start as small leaf spots on the lower foliage. Leaf spots of Cercospora leaf spot have reddish/purplish borders and necrotic centers and seldom enlarge to more than the diameter of a dime. Leaf spots of anthracnose are brown to black with concentric rings and may elongate to be larger than a quarter in diameter. Both leaf spots can cause defoliation. Li et al. (2) found that the level of hydrangeas resistance to Cercospora leaf spot was variable depending of the amount of shading the plants were grown in. In full sun, most cultivars were susceptible whereas in full shade, all tested cultivars were rated as resistant. Fungicides have been recommended for controlling Cercospora leaf spot (1).

Three gallon containers of fifty seven hydrangea cultivars (47 of *H. macrophylla* and 10 of *H. serrata*) were transplanted into a field (full sun) at the UT Plateau Research and Education Center located near Crossville, TN. Plants were mulched and irrigated and fertilized as needed. In 2012, lesions suspected as being due to anthracnose and Cercospora leaf spot were collected twelve plants and taken to the lab for microscopic examination. Identification of both anthracnose and Cercospora leaf spot were

confirmed. Plants were rated for Cercospora leaf spot and anthracnose using the following scale: 0 = no disease; 1 ≤ 2% of foliage with leaf spots; 2 ≤ 10% foliage with leaf spots; 3 ≤ 25% of foliage with leaf spots; 4 ≤ 50% of foliage with leaf spots; 5 < 100% foliage with leaf spots; 6 = 100% foliage with leaf spots. Data were analyzed using PROC ANOVA (SAS) and means were separated using the Student Newman Keul's Test (p=0.05). The data reported here are from year one of a three year study.

Results and Discussion: In this study, cultivars with means that were statistically not different from a rating of 1.0 were considered to be resistant. Three cultivars of *H. macrophylla* (Fuji Waterfall, Trophy and Veitchii) were found to be resistant to Cercospora leaf spot. No plants were found to be entirely free of the disease. No cultivars of *H. serrata* were found to be resistant to the disease. Twenty cultivars of *H. macrophylla* (Ami Pasquier, Ayesha, Domotoi, Enziandom, Hadsburg, Harlequin, Jogasaki, Lady in Red, Merritt's Supreme, Nachtigall, Oregon Pride, Parzival, Seafoam, Sir Joseph Banks, Sister Therese, Taube, Todi, Tovelit, Trophy, and Veitchii) were found to be resistant to anthracnose. Seven cultivars of *H. serrata* (Blue Bird, Hokkaido, Intermedia, Komacha, Miyama Yae Murasuki, Omacha, Preziosa) were also resistant. The cultivars Preziosa and Veitchii were free of disease (all plants rated 0). The cultivars Trophy and Veitchii were the only cultivars rated as resistant to both diseases. When data from this study are compared to data of a previous study that rated all the cultivars used in this study for powdery mildew resistance (3), only the *H. macrophylla* cultivar Veitchii was resistant to powdery mildew, Cercospora leaf spot and anthracnose.

Studies are needed to determine how hydrangea plants resist foliar leaf spot diseases. Since some cultivars were resistant to one disease, but not the other, we hypothesize that mechanisms of resistance for the two leaf spot diseases are not the same. However, resistance to three diseases in the cultivar Veitchii demonstrates that it is possible to 'pyramid' genes for resistance.

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Inoculation of *Canna flaccida* with zoospores from two species of *Phytophthora*

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Index words: vegetative buffer, wetland plants, irrigation water

Significance to Industry: Constructed wetlands and vegetative buffers filter excess nutrients from runoff water. By using these technologies, nurseries can recycle runoff water and pump it back into irrigation systems. However, recontamination of crops with plant pathogens, such as *Phytophthora*, is of concern. Thus, it is important to screen plants commonly found in constructed wetlands or vegetative buffers for their susceptibility to species of Phytophthora or to determine of the plants could serve as an inocula source, before their use in a filtration system. The following research assessed the susceptibility of the wetland plant *Canna flaccida* to *Phytophthora cinnamomi* and *P. citrophthora* and evaluated the activity of the zoospore inocula released.

Nature of Work: The increasing demand for freshwater for irrigation agriculture dictates the need for the reuse of irrigation runoff. Filtering irrigation runoff water through vegetated buffers or constructed wetlands before reuse is ecologically advantageous because it reduces the overall amount of water used, cleans runoff water of excess nutrients and chemical contaminants, and provides a habitat for wildlife (2,3,7). One factor limiting reuse of irrigation runoff is that of recycling pathogen contaminants.

Phytophthora is an aggressive plant pathogen with motile zoospores that can swim easily in water (1). Once infected with *Phytophthora*, plants exhibit either root or crown rot or other various symptoms (1). Species of *Phytophthora* have been found in ornamental nurseries and orchards, in irrigation water, and in waterways draining production areas into retention ponds (3). To ensure the health of the wetland or vegetative buffer, wetland plants should be screened before use for their susceptibility to *Phytophthora*. *Canna flaccida* (Golden canna) is a wetland plant native to the southeastern United States. It may be suited for use in vegetative buffers or constructed wetlands cleansing production runoff if it is not susceptible to infection by species of *Phytophthora*. The goal of this study was to assess the susceptibility of *Canna flaccida* to two species of *Phytophthora* and to evaluate the activity of the zoospore inocula released.

Phytophthora cinnamomi and *P. citrophthora* were selected for this study, both species have been found in the irrigation water of ornamental nurseries (4,5). Three isolates of each species were selected and cultured first on 5% clarified V8 agar at 25°C and then

transferred to non-clarified V8 agar, also at 25°C. After 3 days growth on the non-clarified agar for 3 days, 2 mm-diameter plugs were cut along the growing edge of the mycelial mat of each isolate and used for inoculation per the methods developed by Ridge et al. (6).

Experimental treatments consisted of 2 species of *Phytophthora* - *P. cinnamomi* and *P. citrophthora* with *C. flaccida* (6 experimental units/species), one *Phytophthora* positive control with *P. cinnamomi* or *P. citrophthora* without *C. flaccida* (3 experimental units/species), and *C. flaccida* without *Phytophthora* inocula (6 experimental units). Each experimental unit (EU) consisted of one *Canna flaccida* plant, with soil removed from root system and root system washed with both insecticidal soap (Insecticidal Soap Insect Killer; Garden Safe; Central, SC) and a 10% bleach solution, which was seated into 5 cm aerator cups and then placed into a inverted petri plate at the surface of a 1.9 L plastic pot. Each EU was filled with Milli-Q water and spiked with 20 mg/L N fertilizer (20-2-20 nitrate-special water soluble fertilizer; Southern Agricultural Insecticides, Inc.; Hendersonville, NC). Three agar plugs of each of the three isolates (9 plugs per experimental unit) were placed into each EU with a *Phytophthora* positive treatment.

In order to assess the pathogenicity of zoospore inocula, 6 leaf baits were placed into each EU. The leaf bait discs were punched from *Rhododendron catawbiense* 'English Roseum' leaves. The EUs were baited one day after initial exposure, and then repeatedly baited every 3 days. After 3 days, the floating leaf bait discs were removed, dried with paper towel, and imbedded into PARPH-V8 selective medium. Plates were held in an incubator at 25°C for 3 days. After 3 days, the mycelial growth around the baits were evaluated on a scale from 0 to 5, and an inoculum score assigned, with 0 denoting no *Phytophthora* growth, and 5 that the entire circumference of the leaf bait had *Phytopthora* growth. The experiment was conducted over 29 days to track the activity of zoospores over time. Nine additional agar plugs were added to each EU at day 14, as zoospore release from agar plugs was less consistent after 14 days (6)

At day 29, the *C. flaccida* plants were removed from the EUs and the root systems rinsed and blotted dry with paper towel. Half of the roots were surface disinfested by soaking in a 10% bleach solution for one minute and then rinsed with water, while the remaining half were simply rinsed with water. Eight, 1-mm pieces were cut from both the tips of the roots and from the midpoint between the root tip and crown of both water and bleach rinsed roots. Root pieces were plated on PARPH-V8 media and held at 20°C for three days. After three days, any root pieces that were surface disinfested and yet had *Phytophthora* growth were considered infected, and any water rinsed root pieces that had *Phytophthora* growth were marked as infested (Table 1).

The influence of time and exposure to *P. cinnamomi* or *P. citrophthora* on leaf disc bait inoculum score were evaluated using analysis of variance ($\alpha > 0.1$). Chi-square analyses were conducted using a binomial model with Firth adjusted maximum likelihood estimates to evaluate differences in infestation and infection of *Canna flaccida* roots by species of *Phytophthora*. Data were analyzed using JMP v10.0 (SAS Institute, Cary, NC).

Results and Discussion: Colonization of leaf disc baits within each EU was a direct indicator of zoospore release into solution from sporangia produced on the agar plugs. The inoculum score from the leaf disc bates served as an indirect measure of zoospore density and activity within the experimental solutions. Zoospores consistently infected leaf baits of the EUs with *Phytophthora* positive treatments throughout the 29-day experiment. Leaf baits were consistently infected by zoospores of both species of *Phytophthora* over time, as inoculum scores were consistently greater than zero (Figure 1). Zoospore release, as quantified by the inoculum score, was consistent and very active over the 29-day experiment for *Phytophthora cinnamomi* (Figure 1A).

Zoospore release and activity within the *P. citrophthora* treatments were less consistent (Figure 1B). Zoospore activity in the *P. citrophthora* no plant treatment was slightly variable over time, yet stabilized with the addition of new agar plugs. Zoospore activity within the *P. citrophthora* with plant treatment declined to a greater extent until day 13, when fresh agar plugs were added; this new inocula stabilized zoospore activity for until 25 days after exposure, when zoospore activity declined to < 1 (Figure 2B).

Phytophthora cinnamomi infected and infested more *C. flaccida* plants than did *P. citrophthora* ($P < 0.0004$; Table 1). Surface disinfesting *C. flaccida* roots significantly decreased the number of plants with infestations of *Phytophthora* ($P < 0.0001$). An infestation by *Phytophthora* occurs when zoospores capable of causing an infection are detected on the surface of the roots. All plants exposed to *P. cinnamomi* during the experiment were infested with *P. cinnamomi*, and 5 of 6 plants exposed to *P. citrophthora* wee infested.. When the surfaces of the roots were bleached, any observed infection by *P. cinnamomi* originated from within the root; thus *P. cinnamomi* infected 4 of the 6 plants while *P. citrophthora* infected only 1 of 6 plants (Table 1).

This experiment was designed to investigate the susceptibility of *C. flaccida* to two different species of *Phytophthora*. Our results demonstrate that *C. flaccida* is more susceptible to *P. cinnamomi* than to *P. citrophthora*. Further experiments with *C. flaccida* are needed to characterize the relative susceptibility of this wetland plant to *Phytophthora* and to determine if it should be used when establishing vegetative buffers or constructed wetlands.

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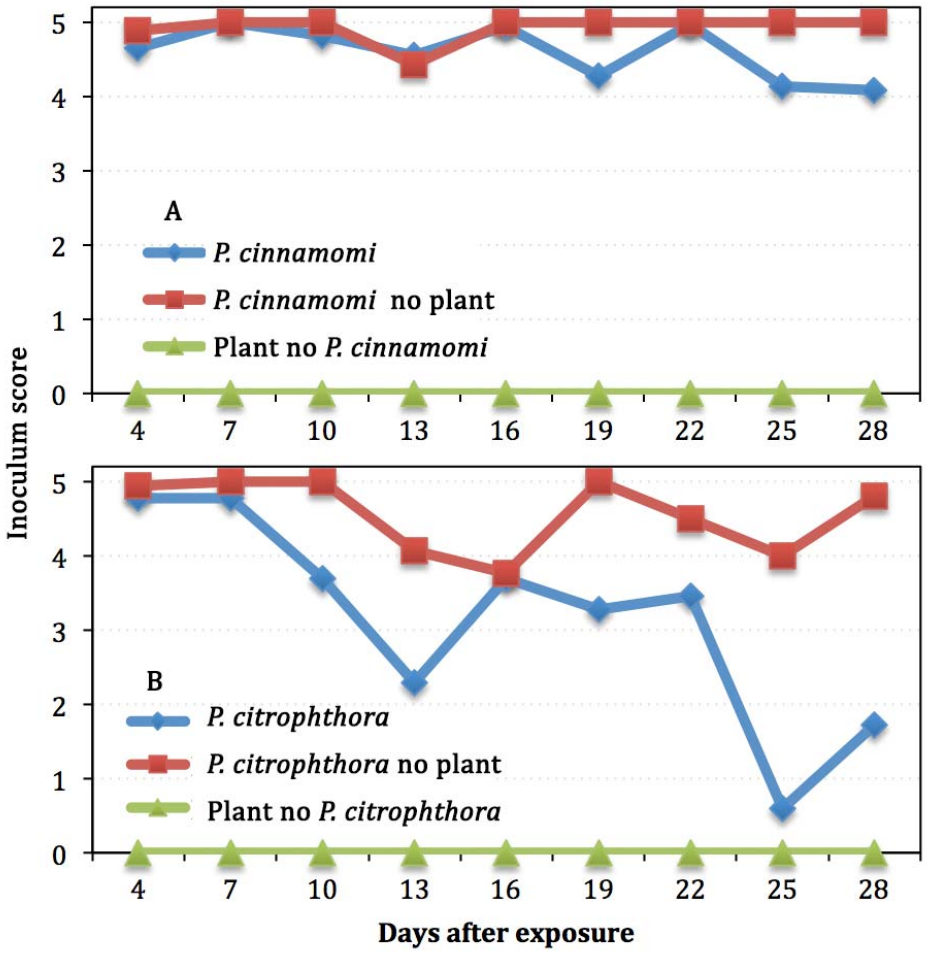

Figure 1. Severity of leaf bait disc infection by (A) *Phytophthora cinnamomi* and (B) *P. citrophthora* over 28 day exposure experiment. Inoculum score 0 = no infection, 3 = 50% of leaf disc infected, and 5 = 100% leaf disc infection. Each data point represents an average inoculum score (*n* =36).

Table 1. Number and percent *Canna flaccida* (golden canna) plants infested or infested with *Phytophthora cinnamomi* or *P. citrophthora* after 28-day continuous, hydroponic exposure.

	Water-rinsed roots[z]		Surface-disinfested roots[y]	
Species	**No.[x]**	**%**	**No.**	**%**
P. cinnamomi	6/6	100.0	4/6	66.6
P. citrophthora	5/6	83.3	1/6	16.6
Species[w]: $P > \chi^2$	0.0004			
Treatment[v]: $P > \chi^2$	< 0.0001			
Treatment x species	0.3902			

[z] Roots were rinsed in tap water and blotted dry before pieces were excised and placed in PARPH-V8 medium.

[y] Roots were disinfested in 10% bleach for 60 s, rinsed in tap water, and blotted dry before pieces were excised and placed in PARPH-V8 medium.

[x] Numbers of plants from which each species of *Phytophthora* was isolated out of the total numbers of plants used.

[w] Probability of a greater χ^2 value in a Binomial model with Firth Adjusted Maximum Likelihood estimates with 1 degree of freedom comparing the two species of *Phytophthora*.

[v] Probability of a greater χ^2 value in a Binomial model with Firth Adjusted Maximum Likelihood estimates with 1 degree of freedom comparing the two rinse treatments.