Plant Pathology and Nematology

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Section Editor

Disease resistance and adaptability of Stellar and flowering dogwoods compared in North Alabama

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Significance to Nursery Industry: Over a five year period, longevity of Stellar® dogwood and flowering selections in a simulated full sun landscape setting was equal at a northeast Alabama site (USDA Hardiness Zone 7a). When compared with selected flowering dogwoods, Stellar dogwood cultivars Aurora®, Constellation®, Celestial™, Ruth Ellen®, and Stellar Pink® displayed superior resistance to spot anthracnose, powdery mildew, and Cercospora leaf spot. Cherokee Brave® was nearly as resistant to powdery mildew as the above Stellar® dogwood cultivars but was as susceptible to spot anthracnose and Cercospora leaf spot as the flowering dogwood cultivars 'Cherokee Princess', 'Cloud 9', and 'Rubra'. Little damage attributed to the dogwood borer was noted on any of the Stellar® dogwoods or flowering dogwood cultivars. Stellar® cultivars displayed superior aesthetics compared with the flowering dogwood cultivars due to the greatly reduced occurrence of the diseases spot anthracnose powdery mildew, and Cercospora leaf spot. Based on this and previous Alabama studies, Stellar® dogwoods are not well adapted below USDA Hardiness Zone 7a.

Nature of Work: Flowering dogwood (*Cornus florida*) is among the most popular small flowering trees in southern landscapes. The diseases, spot anthracnose, powdery mildew, and Cercospora leaf spot often negatively impact on the aesthetics, growth, and occasionally the health of flowering dogwood (3,4). In residential and commercial landscapes, establishment of resistant cultivars is the preferred method for avoiding damaging disease outbreaks. On flowering dogwoods, previous studies have focused primarily on spot anthracnose, more recently powdery mildew, and to a lesser extent on Cercospora leaf spot (1,3,4,8,12,13). The interspecific hybrid Stellar dogwood (*Cornus florida* x *C. kousa*) selections, which were recognized for their resistance to dogwood anthracnose (9), often proved to have superior powdery mildew resistance (4,8,12) when compared with flowering dogwoods. Previously, minimal bract and leaf spotting attributed to spot anthracnose was noted on all Stellar® dogwood selections except for Constellation® and to a lesser extent Ruth Ellen® (4). Conner and Bowen (1) noted that Stellar Pink® was highly susceptible to Cercospora leaf spot but sensitivity of other Stellar® dogwood cultivars to this disease was not reported. While Stellar® hybrid dogwood selections have a good disease resistance package, their survival rate was poorer at two other Alabama sites in comparison with flowering dogwood cultivars (2,4). The objective of this study was to compare the reaction of Stellar® dogwood cultivars with that of selected flowering dogwood cultivars to spot anthracnose, powdery mildew, and Cercospora leaf spot as well as assess their long term adaptability in North Alabama. Preliminary data from 2005 and 2006 were previously reported (2).

On March 5, 2004, flowering and Stellar® dogwood (*C. kousa* x *florida*) cultivars were transplanted from #5 containers into a Hartsell/Wynville soil on a site in full sun at the Sand Mountain Research and Extension Center in Crossville, AL (USDA Plant Hardiness Zone 7a), respectively, on 10 foot centers with 12 feet between rows. Prior to planting, soil fertility and pH were adjusted according to the recommendations of the Auburn University Soil Fertility Laboratory. A drip irrigation system was installed after planting and the trees watered over the study period as needed. Newly established trees were mulched with 0.5 to 1.0 inches of aged pine bark. In each study year, ammonium nitrate (33N-0P-0K) was broadcast at a rate of 300 lb/A of actual nitrogen. In May, a pre-emergent broadcast application of 2 qt/A of Surflan alone or when tank mixed with 1.0 lb/A of Gallery was made. Directed applications of Poast at 8 fl oz/A or MSMA at 3 pt/A were applied as needed to control escaped weeds.

The experimental design was a randomized complete block with five single tree replicates. Trees were not inoculated with any of the target fungal pathogens but depended on background populations for infection and subsequent disease development. At both sites, incidence of spot anthracnose on the bracts and leaves and powdery mildew, as well as Cercospora leaf spot-associated defoliation was visually rated on each tree using the Horsfall-Barratt rating scale (6) where 0 = no disease, 1 = 0 to 3%, 2 = 3 to 6%, 3 = 6 to 12%, 4 = 12 to 25%, 5 = 25 to 50%, 6 = 50 to 75%, 7 = 75 to 87%, 8 = 87 to 94%, 9 = 94 to 97%, 10 = 97 to 100 %, and 11 = 100% of the leaves with signs or symptoms of each disease. Spot anthracnose ratings on the bracts on dogwood blooms were taken on April 20, 2006; April 17, 2008; and April 14, 2009. Due to low bloom counts, spot anthracnose on the bracts was not rated in 2007. Leaf spot phase of spot anthracnose was rated on April 14, May 17, and July 8, 2005; April 20 and May 5, 2006; April 19 and May 16, 2007; May 12, 2008; and April 29, 2009. Powdery mildew incidence was assessed on May 17 and July 8, 2005; May 5, June 7, and July 7, 2006; May 16, June 1, and August 14, 2007 and April 29, May 26, and July 6, 2009. Defoliation due to Cercospora leaf spot were evaluated on July 8, August 29, September 14, October 20, 2005 and August 13 and September 25, 2009. Due to an extended drought in the summer of 2006, 2007, and 2008 at both study sites, ratings for Cercospora leaf spot were not recorded.

Horsfall and Barratt numerical values for the bract and leaf spot phases of spot anthracnose, powdery mildew, and Cercospora leaf spot at each rating date were transformed to percentage values for analysis and presentation (7). Spot anthracnose and powdery mildew ratings were compared among years using PROC MIXED procedure in SAS 9.1.3. Analysis of variance indicated that year effect on all diseases was significant, so subsequent analyses were segregated by year for each variable. Means were separated using Fisher's least significant difference (LSD) test ($P \leq 0.05$).

Results and Discussion: In contrast to a previous Alabama study (4), incidence of the bract spot phase of spot anthracnose was not always lower for the Stellar® than flowering dogwood cultivars. While similar bract spot ratings were reported for both dogwood taxa in 2005 (Table 1), significantly fewer spot anthracnose damaged blooms were noted on the Stellar® than flowering dogwood cultivars in 2009. In 2008, the flowering dogwood cultivars 'Cherokee Princess' and 'Cloud 9' but not Cherokee Brave® and 'Rubra' had higher bract spot ratings than all Stellar® dogwood cultivars. Few differences in the incidence of the bract spot phase of spot anthracnose were found between the Stellar® dogwood cultivars. Among the flowering dogwood cultivars, fewer spot anthracnose-damaged blooms were noted in 2005 on 'Cloud 9' and 'Rubra' compared with Cherokee Brave® and 'Cherokee Princess'. While all flowering dogwoods had similar bract ratings in 2008, damage levels were higher in 2009 for 'Rubra' than Cherokee Brave®, while ratings for 'Cherokee Princess' and 'Cloud 9' were intermediate. Overall, bract spot phase of spot anthracnose ratings for the Stellar® dogwood cultivars were lower in two of three years than 'Cloud 9' and 'Cherokee Princess' and only one of three years for 'Rubra' and Cherokee Brave®.

Lower ratings for the leaf spot phase of spot anthracnose for the Stellar® than flowering dogwood cultivars mirrored results of a previous Alabama study (4). Over the study period, Stellar® dogwood cultivars had similarly low ratings for the leaf spot phase of spot anthracnose (Table 1). While leaf spot incidence on the flowering dogwood cultivars and Stellar Pink® did not differ in 2005, disease ratings for the other Stellar® dogwood cultivars were lower. Among flowering dogwoods in 2006, fewer spot anthracnose-damaged leaves were noted on 'Cherokee Princess' compared with Cherokee Brave® and 'Rubra' but not 'Cloud 9'. In contrast, 'Cherokee Princess', 'Cloud 9' and 'Rubra' had higher percentage of spot anthracnose-damaged leaves than Cherokee Brave® in 2007, which had similar disease ratings as the Stellar® dogwood cultivars. Under low disease pressure in 2008, a higher percentage of spot anthracnose damaged leaves was recorded for the 'Rubra' than Stellar Pink®. Otherwise, ratings for cultivars in both dogwood taxa were similar. For 2009, incidence of the leaf spot phase of spot anthracnose was equally high for the flowering dogwood selections as compared with the Stellar® dogwood cultivars. While differences in the incidence of the leaf spot phase of spot anthracnose among the flowering dogwood selections were seen during the study period, all proved largely as susceptible to spot anthracnose as previously noted (4).

As has been previously reported (4,8), all Stellar® dogwoods were equally resistant to powdery mildew and with few exceptions had lower powdery mildew ratings than nearly all flowering dogwoods except for Cherokee Brave® in 2006 and 2007 (Table 2). When powdery mildew was observed on Stellar® dogwood cultivars, colony formation occurred from late spring through mid-summer along the mid- and lateral veins on a small percentage of juvenile leaves but not on the mature leaves in the inner canopy. Elevated powdery mildew susceptibility of Ruth Ellen® and Constellation® reported by Ranney *et al.* (12) was not observed (4, 8). In contrast to the Stellar® dogwoods, leaves of the flowering dogwood cultivars with the exception of Cherokee Brave®

suffered from heavy powdery mildew by late-June. Powdery mildew incidence was higher on ‘Cherokee Princess’ and ‘Rubra’ compared with Cherokee Brave® in three and four of five years, respectively, and ‘Cloud 9’ in four of five years (Table 1). Powdery mildew incidence on Cherokee Brave® was generally higher here as compared with a previous Alabama (4) and Tennessee (8) study. In contrast, ‘Cherokee Princess’, ‘Rubra’, and to a lesser extent ‘Cloud 9’ proved equally susceptible to powdery mildew as was previously noted (4,8).

Cercospora leaf spot-incited premature defoliation was seen only in 2005 and 2009 (Table 2). Unusually dry summer weather in 2006, 2007, and 2008 not only suppressed disease development but also caused a noticeable interveinal leaf scorch. Cercospora leaf spot-incited defoliation was generally higher for the flowering than Stellar® dogwood cultivars, which had similarly low disease ratings in 2005 and 2009 (Table 2). Among the flowering dogwoods in 2005, defoliation levels on Cherokee Brave® and ‘Cherokee Princess’ were higher than on ‘Cloud 9’ and ‘Rubra’ as well as on all Stellar® dogwood cultivars. While light to heavy defoliation was noted on all of the flowering dogwood cultivars in 2009, no Cercospora leaf spot-induced defoliation was observed on any Stellar® dogwoods. Among the flowering dogwood cultivars, Cherokee Brave® and ‘Rubra’ suffered heavier defoliation than ‘Cherokee Princess’ and ‘Cloud 9’, which had similar defoliation ratings. With the exception of ‘Cloud 9’, the flowering dogwood cultivars proved susceptible to Cercospora leaf spot, while the Stellar® dogwood cultivars displayed good disease resistance. Conner and Bowen (1) reported higher Cercospora leaf spot ratings for Stellar Pink® than on the flowering dogwood cultivars ‘Little Princess’, ‘Red Pygmy’, ‘Pumpkin Patch,’ Cherokee Brave®, ‘Cherokee Chief’, ‘Cherokee Princess’, and ‘Cloud 9’.

When compared with 28 flowering dogwood cultivars, survival of all Stellar® dogwood cultivars in a previous Central Alabama study was poor (4) and the cause of their rapid decline and death was not determined. At this northeastern Alabama site, equally high survival rate for Stellar® and flowering dogwood cultivars, despite a severe summer drought, was observed. Damage from the dogwood borer (*Synanthedon scitula*) was noted on one Stellar Pink® tree, while two ‘Rubra’ and one ‘Cherokee Princess’ flowering dogwoods may have succumbed to this pest. In a concurrent study in southwest Alabama, the Stellar® dogwoods succumbed within 3 years to a combination of dogwood borer and an ambrosia beetle (2).

Study results demonstrate that all Stellar dogwood cultivars (Celestial™, and Stellar Pink®, Aurora®, Constellation®, and Ruth Ellen®) have superior resistance to Cercospora leaf spot and confirmed previous observations of limited development of both phases of spot anthracnose and powdery mildew when compared with the flowering dogwood cultivars (4,8). Increased leaf retention on the Cercospora leaf spot-resistant Stellar® dogwood cultivars often resulted in greatly enhanced fall color display, while adjacent flowering dogwood cultivars are partially to wholly defoliated by early October. In contrast, Cherokee Brave®, ‘Cherokee Princess’, and ‘Cloud 9’ proved more susceptible to Cercospora leaf spot than previously reported by Conner and

Bowen (1). In years when significant Cercospora leaf spot development occurred, all of the above dogwood cultivars as well as 'Rubra' suffered higher defoliation than all Stellar® dogwood cultivars, which had similarly low defoliation ratings. Overall, 'Cloud 9' often suffered less Cercospora leaf spot-incited defoliation than 'Rubra' while the reactions of 'Cherokee Princess' and Cherokee Brave® were intermediate.

Despite their exceptional disease resistance package, Stellar® dogwoods are better adapted to the upper than lower South. At two Lower Coastal Plain sites in Alabama (2,4) [USDA Hardiness Zone 7b and 8a], tree survival was very poor as compared to this site in northeastern Alabama, Tennessee (8) and North Carolina (12), in USDA Hardiness Zones 7a, 6b, and 6a, respectively. While Orton (9) previously noted that Stellar dogwoods are highly resistant to the dogwood borer in New Jersey [USDA Hardiness Zone 6a], high mortality rates for these trees at one Alabama site was attributed to dogwood borer and/or ambrosia beetle (*Xylosandrus* sp.), both of which are aggressive pests on environmentally stressed trees (5,10). As was previously noted for flowering dogwood (11), establishment of Stellar® dogwoods on shaded rather than full sun sites may decrease tree vulnerability to the dogwood borer and possibly ambrosia beetle, which may extended their range into USDA Hardiness Zone 7b.

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Table 1. Occurrence of spot anthracnose on the blooms and leaves of Stellar® and flowering dogwood cultivars.

	Spot anthracnose[z]							
	Diseased blooms (%)[y]			Diseased leaves (%)[y]				
Dogwood selection	2005	2008	2009	2005	2006	2007	200	2009
Stellar dogwood (*Cornus kousa* x *florida)*								
Aurora	20 ab	4 c	2 c	0 b	0 c	2 c	1ab	0 b
Celestial	--	0 c	4 c	0 b	2 c	29 bc	1ab	1 b
Constellation	31 ab	5 c	11 c	2 b	2 c	3 c	1 ab	1 b
Ruth Ellen	9 ab	4 c	5 c	1 b	2 c	14 bc	1 ab	0 b
Stellar Pink	9 ab	0 c	0 c	3 ab	1 c	20 bc	0 b	0 b
Flowering dogwood (*C. florida*)								
Cherokee Brave	54 a	15 abc	42 b	10 a	43 a	1 c	11ab	5 a
Cherokee Princess	68 a	35 ab	68 a	16 a	10 b	66 a	3 ab	15 a
Cloud 9	8 b	44 a	69 a	29 a	28 ab	42 ab	5 ab	20 a
Rubra	5 b	28 abc	86 a	16 a	56 a	37 b	12 a	19 a

[z]Incidence of spot anthracnose on the blooms and leaves, which was assessed using the Horsfall and Barratt rating scale, was transformed for presentation to the percentage of spot anthracnose-damaged blooms or leaves.

[y]Spot anthracnose ratings, which are presented in the table, were recorded on the blooms on April 17, 2008; and April 14, 2009, and on the leaves on May 17, 2005; May 5, 2006; April 19, 2007; May 17, 2008; and April 29, 2009.

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

Table 2. Powdery mildew and Cercospora leaf spot on Stellar® and flowering dogwood cultivars.

Dogwood selection	Powdery mildew (% diseased leaves) [z]					Cercospora leaf spot[y] (% defoliation)	
	2005	2006	2007	2008	2009	2005	2009
Stellar® dogwood (*Cornus kousa* x *florida)*							
Aurora	4 c[x]	0 c	1 b	1 d	2 c	1 c[y]	0 d
Celestial	4 c	0 c	0 b	1 d	0 c	1 c	0 d
Constellation	7 c	0 c	1 b	2 d	5 c	19 bc	0 d
Ruth Ellen	2 c	0 c	1 b	1 d	21 c	8 c	0 d
Stellar Pink	13 c	0 c	0 b	2 d	2 c	6 c	0 d
Flowering dogwood (*C. florida*)							
Cherokee Brave	61 b	3 c	6 b	38 c	69 a	67 a	63 a
Cherokee Princess	95 a	88 a	63 a	91 a	79 a	65 a	16 c
Cloud 9	59 b	36 b	58 a	64 b	45 b	19 bc	17 c
Rubra	98 a	88 a	55 a	93 a	75 a	34 b	46 b

[z]Incidence of powdery mildew, which was assessed using the Horsfall and Barratt rating scale, was transformed for presentation to the percentage (%) of colonized leaves on July 8, 2005; June 7, 2006; June 1, 2007; June 23, 2008; and July 6, 2009.
[y]Cercospora leaf spot-incited defoliation, which was assessed using the Horsfall and Barratt rating scale on September 14, 2005 and September 25, 2009, was transformed for presentation to the percent (%) defoliation values.
[x]Means separation within columns was according to Fisher's protected least significant difference test ($P \leq 0.05$).

Organic Fungicides Evaluated for the Control of Entomosporium Leaf Spot on Photinia

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Key Words: *Photinia* x *fraseri* 'Birmingham', chemical control, Bonide Liquid Copper Fungicide, copper octanoate, Bonide All Seasons Horticultural and Dormant Spray Oil, paraffinic oil, Daconil Ultrex 82.5WDG, chlorothalonil

Significance to Nursery Industry: In recent years, the numbers of organic or biorational pesticides marketed through retail box stores and garden centers as well as internet vendors has greatly expanded. In contrast to many synthetic fungicides, relatively few studies have been conducted to assess the efficacy or organic fungicides on herbaceous and woody ornamentals for the control of diseases, particularly aggressive and destructive leaf spots and blights. Here, we compared the effectiveness of the OMRI listed organic fungicides Bonide Liquid Copper Fungicide (copper octanoate) and Bonide All Seasons Horticultural and Dormant Spray Oil (paraffinic oil) with the synthetic fungicide Daconil Ultrex 82.5WDG (chlorothalonil) standard for the control of Entomosporium leaf spot on 'red tip' photinia. While not as effective as Daconil Ultrex 82.5WDG, Bonide Liquid Copper Fungicide gave better disease control in 2010 but not 2011 than Bonide All Seasons Horticultural and Dormant Spray Oil, which failed to reduce Entomosporium leaf spot-associated leaf spotting and defoliation in 2011 when compared with the non-treated control. In addition, Bonide Liquid Copper Fungicide proved equally effective in controlling Entomosporium leaf spot when applied at 1- and 2-wk intervals. Overall, Bonide Liquid Copper Fungicide proved to be an effective organic alternative to the synthetic fungicide Daconil Ultrex 82.5WDG for controlling Entomosporium leaf spot on 'red tip' photinia.

Nature of Work: Entomosporium leaf spot, caused by the fungus *Entomosporium mespili* (= *E. maculatum*), is a common and damaging disease in nursery and landscape plantings of red tip photinia (*Photinia* x *fraseri* 'Birmingham') across the South. Indian hawthorn, flowering pear, loquat, and other photinia species such as *P. serrulata* and *P. glabra* are among the other common hosts for this disease (1,5).

Protective fungicide treatments are often required to maintain the health and beauty of red tip photinia in the landscape. Effective control of Entomosporium leaf spot on photinia can be maintained with weekly to twice monthly foliar applications of fungicides such as Zyban WSB (thiophanate-methyl + mancozeb), Daconil Weather Stik (chlorothalonil), and Eagle® 40W (myclobutanil) (2,3,9). When application intervals are extended beyond 2 weeks, the level of Entomosporium leaf spot control provided by fungicides such as Daconil Weather Stik 6F sharply declines (9). Hagan and Akridge

(8) recently showed that the retail fungicides Immunox Multipurpose Fungicide, RosePride Disease Control Concentrate, and Disease Control for Roses, Flowers & Shrub Concentrate as well as the commercial fungicide Daconil Weather Stik 6F when applied every two weeks through the winter and into early spring gave superior control of Entomosporium leaf spot on field grown ‘red tip’ photinia.

In recent years, demand for organic fungicides, which are considered to have fewer detrimental environmental and health impact than synthetic fungicides, for use on herbaceous and woody ornamentals as well as vegetables and fruit trees has greatly increased. While a variety of products are now marketed through retail outlets, data describing the efficacy of organic fungicides for the control of the majority of common leaf spot and blight diseases commonly found on landscape ornamentals does not exist. On field-grown flowering dogwood, Neem Concentrate (extract of neem oil), SunSpray Ultra Fine Oil (paraffinic oil), and Rhapsody [Serenade] (*B. subtilis* QST 713) proved less effective in controlling spot anthracnose and Cercospora leaf spot than Immunox Multi-Purpose Fungicide, Liquid Systemic Fungicide, and 3336 4.5F (6). In addition, the above organic fungicides had to be applied twice as often as Immunox Multi-Purpose Fungicide, Liquid Systemic Fungicide, and 3336 4.5F to obtain the same level of powdery mildew control. While control of powdery mildew on flowering dogwood with MilStop 85W (10) and Armicarb (11) has been reported, a similar product failed to adequately protect dogwood from powdery mildew in Delaware (12) and Tennessee (13) trials. The objective of this study was to assess the efficacy of two promising organic fungicides, Bonide All Seasons Horticultural and Dormant Spray Oil and Bonide Liquid Copper Fungicide for the control of Entomosporium leaf spot on established red-tip photinia in a simulated landscape setting.

Materials and Methods: In spring 2004, ‘Birmingham’ red-tip photinia (*Photinia* x *fraseri*) were transplanted from #1 containers into a Benndale fine sandy loam soil ($\leq$1% OM) at the Brewton Agricultural Research Center in Brewton, AL on 6 foot centers with 10 feet between rows. Photinia in the study block were exposed to E. mespili-incited leaf spot several years prior to study initiation. A drip irrigation system was installed at planting and plants were watered as needed. Prior to planting, soil fertility and pH were adjusted according to the results of a soil fertility test. In February of each year, aged pine bark was evenly distributed around the base of each plant. In late March, 1.8 oz of 16N-4P-8K analysis fertilizer or equivalent was evenly distributed around the base of each plant. Pre-emergent weed control was obtained with a broadcast application of 2 qt/A of Surflan + 1.0 lb/A of Gallery. Escape weeds were hoed or pulled by hand. Daconil Ultrex 82.5WDG was applied at 2-week intervals, the OMRI listed organic fungicides Bonide Liquid Copper Fungicide and Bonide All Seasons Horticultural and Dormant Spray Oil were applied at 1- or 2-wk intervals starting on January 28 to April 29, 2010 and January 10 to April 11, 2011. Fungicides were applied to drip with a CO_2-pressurized sprayer with a hand-held wand with a single adjustable hollow cone nozzle. Severity of Entomosporium leaf spot was rated on April 29, May 12, and June 10, 2010 and on April 12, April 26 , May 12 and May, 2011 using a modified Florida peanut leaf spot scoring system where 1 = no disease, 2 = very few leaf spots in canopy, 3 = few leaf spots in lower and upper canopy, 4 = some leaf spotting in lower and upper canopy and $\leq$ 10% defoliation, 5 = leaf spots noticeable and $\leq$ 25% defoliation, 6 = leaf spots numerous and $\leq$ 50% defoliation, 7 = leaf spots very numerous and $\leq$ 75% defoliation, 8 = numerous leaf spots on few remaining leaves and $\leq$ 90 % defoliation, 9 = very few remaining leaves covered with leaf spots and $\leq$ 95% defoliation, and 10 = plants defoliated (3). 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: In 2010, monthly rainfall totals for February, March, April, and June were below, to well below, the 30-yr average but were average to above average for January and May. For the following year, rainfall totals for February and May but not January, March, and April were well below, the 30-yr average for the study site.

Compared with the non-treated control, which suffered noticeable leaf spotting and in excess of 25% defoliation, all fungicides treatments in 2010 significantly reduced Entomosporium leaf spot severity (Table 1). Liquid Copper Fungicide and All Seasons Horticultural and Dormant Spray Oil gave the same level of disease control when applied at 1- or 2-wk intervals. Generally, symptoms on plants treated with the above organic fungicides were limited to light to moderate leaf spotting with little or no premature defoliation. Daconil Ultrex 82.5 WDG gave better control of Entomosporium leaf spot than All Seasons Horticultural and Dormant Spray Oil and Liquid Copper Fungicide when applied at 2-week but not at 1-week intervals.

In 2011, a significant reduction in Entomosporium leaf spot intensity was obtained with Daconil Ultrex 82.5WDG and Liquid Copper Fungicide but not All Seasons Horticultural and Dormant Spray Oil when compared with the non-treated control, which suffered from noticeable leaf spotting and approximately 60% premature defoliation (Table 1). In addition, disease ratings for All Seasons Horticultural and Dormant Spray Oil, which were not impacted by application interval, were significantly higher compared with Daconil Ultrex 82.5WDG and Liquid Copper Fungicide. Daconil Ultrex 82.5WDG gave better disease control than Liquid Copper Fungicide, which gave similar levels for Entomosporium leaf spot control when applied at 1- and 2-wk intervals.

When compared with the non-treated control, significant reductions in Entomosporium leaf spot severity were noted in with the organic fungicides All Seasons Horticultural and Dormant Spray Oil and Liquid Copper Fungicide in one of two and both study years, respectively. With both organic fungicides, similar disease ratings were recorded for the 1 and 2-week treatment schedules. Previously, a now discontinued formulation of paraffinic oil (SunSpray Ultra Fine Oil) gave significantly better powdery mildew control on flowering dogwood when applied on a 1- than a 2-week schedule (6). In contrast, All Seasons Horticultural and Dormant Spray Oil but not Liquid Copper Fungicide when applied at 1- and 2-week intervals proved equally effective in controlling Cercospora leaf spot on crapemyrtle (8).

As previously noted by Hagan and Akridge (6) on flowering dogwood, organic fungicides often do not provide the same level of disease control as synthetic fungicides. Here, disease ratings for All Seasons Horticultural and Dormant Spray Oil- and Liquid Copper Fungicide-treated photinia with exception of receiving weekly applications of the latter fungicide were significantly higher when compared with Daconil Ultrex 82.5WDG. Efficacy differences were most noticeable after the wet winter of 2011 when the All Seasons Horticultural and Dormant Spray Oil-treated photinia suffered considerable leaf spotting through the plant canopy and nearly 25% defoliation compared with a few leaf spots on scattered juvenile leaves on the Daconil Ultrex 82.5WDG-treated photinia. While the Liquid Copper Fungicide-treated plants did not suffer the level of leaf spotting and defoliation in 2011 when compared with those receiving All Seasons Horticultural and Dormant Spray Oil sprays, the level of leaf spotting was higher for photinia treated with the latter fungicide than Daconil Ultrex 82.5WDG. Given the marginal efficacy demonstrated by several synthetic fungicides in a previous study (7), Liquid Copper Fungicide proved that organic fungicide can deliver equivalent or better disease control as some of its synthetic counterparts but not Daconil Ultrex 82.5WDG.

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Table 1. Two organic fungicides compared with Daconil Ultrex for the control of Entomosporium leaf spot on established ‘red tip’ photinia.

Treatment and rate/100 gal	Application interval	ELS severity[z] 2010	ELS severity[z] 2011
Non-treated Control	--	5.2 a[y]	6.5 a[y]
Liquid Copper Fungicide[x] 0.8 gal	1 week	2.5 bc	3.2 b
Liquid Copper Fungicide 0.8 gal	2 week	2.7 b	3.6 b
All Seasons Horticultural and Dormant Spray Oil[x] 1.2 gal	1 week	2.8 b	4.8 a
All Seasons Horticultural and Dormant Spray Oil 1.2 gal	2 week	3.2 b	5.5 a
Daconil Ultrex 1.4 lb	2 week	1.2 c	1.8 c

[z] Entomosporium leaf spot (ELS) severity was rated on June 10, 2010 and May 25, 2011using a modified 1 to 10 Florida peanut leaf spot scoring system.
[y] Means separation in each column was according to Fisher’s protected least significant difference (LSD) test ($P \leq 0.05$).
[x] OMRI listed organic fungicide.

Developing a Method to Evaluate Plants Used in Constructed Wetlands for Susceptibility to Five Species of *Phytophthora*

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Index Words: *Phytophthora* spp., inoculation method, wetland plants, irrigation water

Significance to Industry: This methodology is the basis for an evaluation of wetland plants for susceptibility to species of *Phytophthora* present in runoff water at ornamental plant nurseries. It is the first step in the development of constructed wetlands that will utilize biological processes to remove both plant pathogens and agrichemical contaminants from irrigation water. Ecological treatment systems may enhance water conservation and reuse by nurseries as growers gain confidence in the capability of these treatment systems to eliminate plant pathogens.

Nature of Work: It is widely known that agriculture is the second largest consumer of the increasingly scarce supply of freshwater. In the United States, large ornamental nurseries utilize more than 37,800 kL of irrigation water each day (1). As competition for freshwater resources increase, the agriculture and horticulture industries need to identify alternative water sources to ensure continued, economically sustainable crop production. Recycled irrigation runoff water is one alternative source of water that typically is ignored by producers of horticulture commodities in the US. One major concern limiting reuse of irrigation water is the increased potential for disease incidence and severity initiated by pathogen propagules carried in recycled water (2).

To optimize the design of runoff channels and constructed wetland systems to facilitate the removal of propagules of *Phytophthora* species from runoff water, we must first identify plant species not susceptible to this group of plant pathogens. Species of *Phytophthora* cause some of the most damaging and economically important diseases affecting ornamental plants in both nurseries and landscapes (2,3,4). Therefore, the goal of this research was to develop a standard inoculation protocol for screening wetland plants for susceptibility to *Phytophthora* spp.

Five species of *Phytophthora* commonly found in irrigation water in nurseries in the southeastern US were used in this study (4,5; Jeffers, *personal observation*): *P. cinnamomi, P citrophthora, P. cryptogea, P. nicotianae,* and *P. palmivora*. Three isolates of each species—all recovered from ornamental plants in SC—were selected for this study. In addition, a fourth isolate of *P. citrophthora*, collected from the roots of *Saggitaria latifolia* growing in a vegetated nursery runoff channel in a Georgia nursery was used (16 isolates in all). Isolates were maintained on 5% clarified V8 agar at 20°C and were grown on 10% non-clarified V8 agar at 25°C to produce active colonies. Agar plugs (2 mm-diameter) were removed from the advancing margins of colonies and served as the inocula for all experiments.

To test susceptibility, plants must be exposed to a constant supply of inoculum (i.e., zoospores) over time. In a laboratory experiment, 48, plastic cups (200 mL each) were filled with 150 mL of 1.5% non-sterile soil extract solution (6,7) and placed on three trays in racks under ambient light (4.55 ± 1.0 µMol m^{-2} s^{-1}) and temperature (19-28°C). Nine agar plugs from one isolate were added to a cup, and each isolate was tested in three replicate cups to ensure reproducible results. One replicate of each isolate was placed on each tray in a 4x4 randomized block design. This experiment was conducted twice (trials 1 and 2) and results were combined for analysis.

The day after adding plugs, all experimental units were baited by floating leaf disks (5 mm in diameter) from *Rhododendron catawbiense* 'English Roseum' (six leaf disks per cup). After 2 days in trial 1 and 3 days in trial 2, leaf disks were removed, embedded in PARPH-V8 selective medium, and incubated for one day at 25°C (6,8,9). Presence of zoospores in each cup was quantified using a rating scale (0-5) based on the percentage of the perimeter of each disk that was visibly (30-70×) colonized by an isolate (Table 1). After disks were removed from each cup, six fresh leaf disks were added; this process continued for 30 days.

A second experiment was performed in the greenhouse using conditions similar to those that will be used during future plant susceptibility trials. Fifteen 1.9-L plastic containers were used for each of two solutions: Milli-Q water and non-sterile soil extract solution; both treatments were amended with 20 ppm N fertilizer solution (20-2-20 nitrate-special water soluble fertilizer; Southern Agricultural Insecticides, Inc.; Hendersonville, NC). Three plugs from each of the three isolates of a species of *Phytophthora* (nine plugs total for four species, 12 plugs total for *P. citrophthora*) were placed in the bottom of a container. Three replicate containers were used for each treatment—i.e., species by solution combination. One replicate of each treatment was placed in a greenhouse (28.1 ± 0.1°C during the day and 25.4 ± 0.1°C at night, 13.5 hr. light) on one of three benches in a completely randomized block design.

Methodology for baiting and quantifying presence of zoospores was the same as in the laboratory experiment; containers were baited every three days for 13 days. All data were analyzed using PROC GLIMMIX with the LSD and DIFF options to characterize the main effects and interactions of *Phytophthora* spp., treatment, and time on percentages of leaf disk perimeters colonized (SAS v.9.2, SAS Institute, Cary, NC).

Results and Discussion: In the laboratory experiment, data from the two trials were similar (P = 0.19), so trials were combined for analysis. Therefore, the data presented are mean values based on 18 observations for four species of *Phytophthora* (3 isolates × 3 replicate cups/isolate × 2 trials) and 24 observations for *P. citrophthora* (4 isolates ×

3 replicate cups/isolate × 2 trials). Zoospores produced by the five species of *Phytophthora* colonized rhododendron leaf baits throughout the 29-day period (Figure 1). We attribute reduced colonization percentages to decreased zoospore production from agar plugs, which resulted in a lower density of zoospores in solution. Zoospore production varied over time among the five species; it was most consistent with *P. palmivora* and most variable with *P. cinnamomi* (Figure 1). Zoospore production by *P. citrophthora* and *P. cryptogea* decreased over time (Figure 1).

In the greenhouse experiment, zoospores were produced by all species throughout the 13-day trial period. Bait colonization remained fairly constant for four of the species, but it declined steadily in pots infested with *P. cryptogea* (Figure 2). During the greenhouse experiment, the average temperature of container solutions was 28.1 ± 0.1°C during the day and 25.4 ± 0.1°C at night. Temperatures equal to or greater than 30 °C are known to negatively impact sporangium production and the optimum temperature for growth for *P. cryptogea* ranges from 20-25°C (3,10). Consequently, excessive daytime temperatures during the experiment may have adversely affected sporangium production and zoospore release by *P. cryptogea*.

Zoospores were produced and leaf baits were colonized in both solutions (Figure 2). However, there was a significant difference in bait colonization between the two solutions for three of the species of *Phytophthora*. *P. cinnamomi*, *P. citrophthora*, and *P. cryptogea* colonized leaf disks better on days 10 and 13 when baits were floated in Milli-Q water than when floated in non-sterile soil extract solution. Solution did not significantly influence bait colonization by zoospores of *P. nicotianae* and *P. palmivora*. This experiment currently is being repeated, and the effects of temperature and solution on zoospore production in a greenhouse setting will be further defined.

Most leaf baits consistently were colonized by zoospores of *Phytophthora* spp. released from a single set of agar plugs over time. However, results from the greenhouse experiment suggest that agar plug inoculum may need to be refreshed on a bi-weekly basis to ensure adequate inoculum presence in experiments with plants that will run longer than 14 days. The results of the experiments reported here are the basis of future experiments to evaluate the relative susceptibility of wetland plant species to infection by species of *Phytophthora* commonly found in nurseries of the southeastern US.

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Table 1. Rating scale used to quantify the amount of infection observed on leaf disk baits.

Rating Value	**Perimeter colonized (%)[a]**	**Midpoint value (%)[b]**
0	None	0
1	1 - 25%	12.5
2	26 - 50%	38.5
3	51 - 75%	63.5
4	76 - 99%	88.5
5	100%	100

[a] Estimated amount of the perimeter on a leaf disk visually colonized by *Phytophthora* spp.
[b] Midpoint value for the range of perimeter colonized; this number was used in statistical analyses.

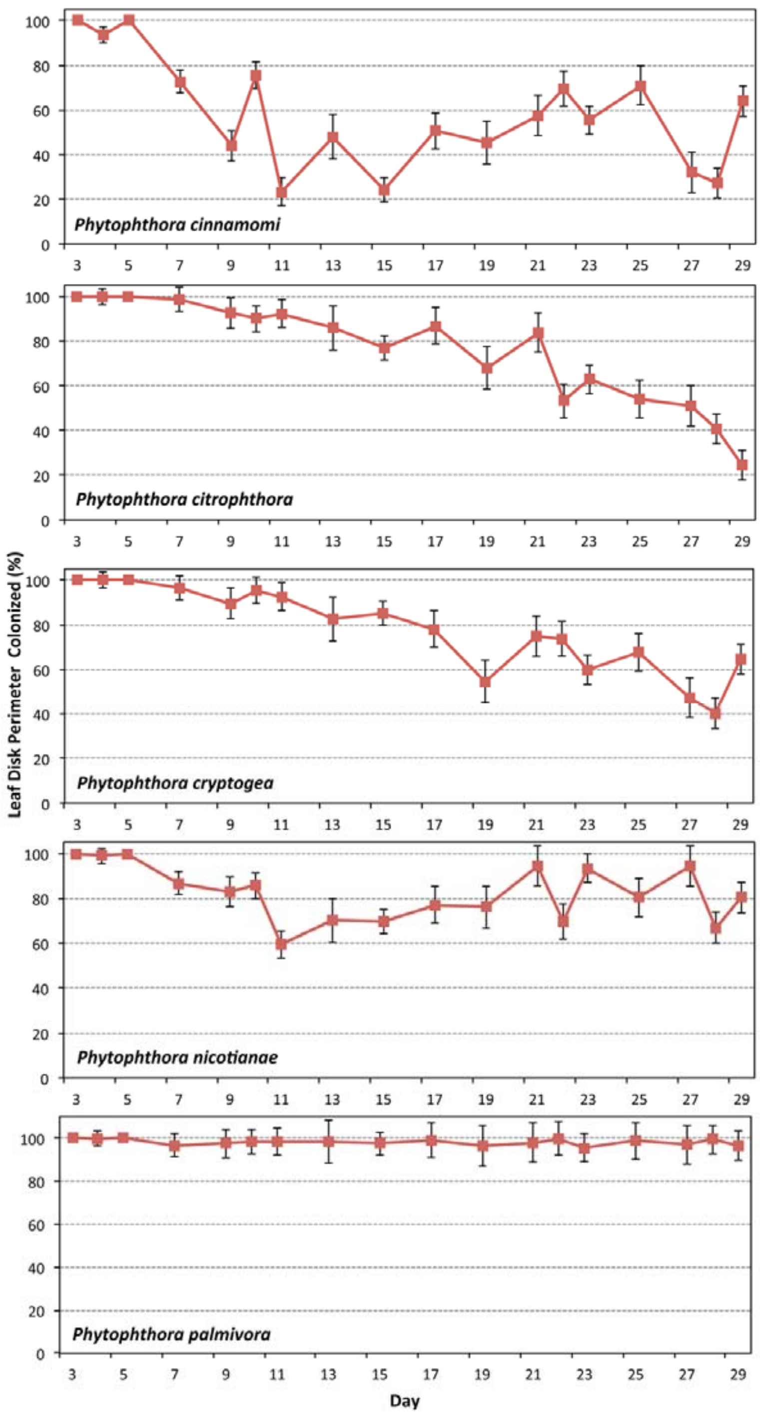

Figure 1. Colonization of leaf disk baits during exposure to zoospores from three or four isolates of each of five species of *Phytophthora* over 29 days under laboratory conditions. Leaf disks were used to bait non-sterile soil solution into which agar plugs containing hyphae of an isolate of *Phytophthora* sp. had been placed. Data are mean percentages of the perimeters of leaf disks that were colonized ± standard errors from all isolates in each of two trials, which were combined for analysis.

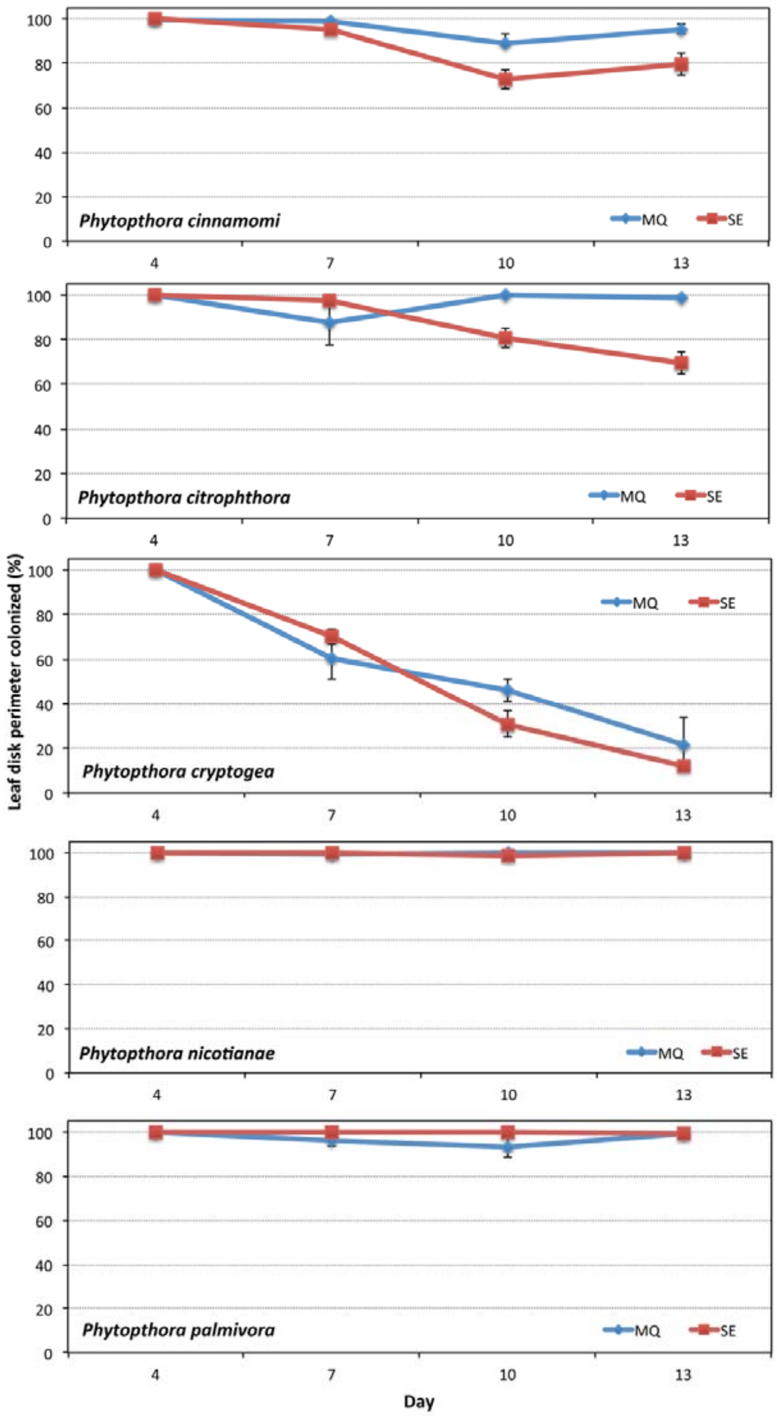

Figure 2. Colonization of leaf disk baits during exposure to zoospores from five species of *Phytophthora* in two different solutions over 13 days under greenhouse conditions. Leaf disks were used to bait Milli-Q water (MQ) and non-sterile soil extract solution (SE) into which agar plugs containing hyphae of three or four isolates of each species of *Phytophthora* had been placed. Data are mean percentages of the perimeters of leaf disks that were colonized ± standard errors.

Two Bacteria Effective Against Both *Macrophomina* Root Rot and Powdery Mildew in Flowering Dogwood

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Index words: Powdery mildew, *Cornus florida*, fungicides, biological control agents, *Macrophomina phaseolina*, resistance, *Erysiphe pulchra*

Significance to Industry: *Macrophomina phaseolina* (Tassi) Goid, is a destructive soil borne pathogenic fungus that causes charcoal rot, dry-root rot, wilt, leaf blight, stem blight and damping-off diseases in more than 500 plant species, across approximately 100 different genera including *Cornus* (2,7). Powdery mildew caused by *Oidium* spp., [*Erysiphe* (Sect. Microsphaera) *pulchra*] causes stunted growth, defoliation, reduced aesthetic value and a serious decline in plant health in flowering dogwood (*Cornus florida* L.) (1,5). Fungicides are commonly used to control *Macrophomina* root rot in a number of crop plants, and are routinely used to control powdery mildew in flowering dogwood. Problems associated with fungicide applications include cost to growers, environmental and health hazards to human applicators, and the destruction of other non-target organisms including beneficial microflora. Biological control agents (BCAs) provide a safer, environmentally-friendly, and presumably less expensive alternative products for controlling both powdery mildew and *Macrophomina* root rot. By combining BCAs with other user-friendly methods such as host resistance and cultural practices, it is possible to significantly reduce fungicide usage in nursery production of flowering dogwood.

Nature of Work: Flowering dogwood is native to southern region of the United States of America (USA), and common in other parts of the nation, as an ornamental plant in residential and public areas. It is an important under-story species in forest areas where its nutritious seeds provide valuable food for wildlife. Dogwood is an important nursery plant in Tennessee and neighboring states and provides income to many backyard farmers in rural areas. However, powdery mildew stunts plant growth and requires routine fungicide applications that are too expensive for small scale growers. Previous studies have shown that biological agents (BCAs) isolated from native plants in natural environments where fungicides have never been used have high potential in controlling powdery mildew in flowering dogwood (3,4,5,6). This study evaluates the effectiveness of individual microorganisms (BCAs) against two diseases, powdery mildew and *Macrophomina* root rot of dogwood. Two bacterial BCAs, B17A and B17B, were compared with other BCAs, two fungi (F13, and F16); two yeasts (Y4, and Y14), fungicide {thiophanate methyl (Cleary's 3336®)} and water control in controlling both

Macrophomina root rot as well as powdery mildew in flowering dogwood. This is the first study to evaluate effectiveness of these BCAs against *Macrophomina* root rot of flowering dogwood.

Materials and Methods: Following seed vernalization of *C. florida*, the young seedlings with newly emerged roots were planted in sterile Morton's Grow Mix™ #2 (Morton's; Horticultural Supplies, Inc., McMinnville, TN), using plastic containers with 2-3 seedlings per container and maintained in greenhouse environment. Treatments consisted of BCAs (i.e., B17A, B17B, F13, F16, Y4, and Y14), with fungicide and water treatments used as controls. Treatments were arranged in a randomized complete block design with a replication of three plastic containers per treatment, each containing 2-3 plants. Inoculum concentrations of the BCAs were 2-5 x 10^6 spores/propagules per ml for fungi, and 1-3 x 10^6 CFU per ml for bacteria and yeast. The fungicide was used at 18 fl oz/100 gallon, equivalent to 1 mL per 727.3 mL (v/v) of fungicide/water following manufacturer's recommended rate of 12-24 fl oz/100 gallon. Inoculum of the root rot pathogen, *M. phaseolina,* consisted of a suspension of approximately 2-5 x 10^4 spores/propagules per ml., prepared from 5 day-old colonies grown in potato dextrose agar (PDA).

Inoculation of dogwood seedlings with *M. phaseolina*; was done twice, during planting and three weeks after planting. Inoculation during planting was by root-dipping each seedling in the inoculum suspension before planting and the second inoculation was done by root-drenching using 5 mL of *M. phaseolina* inoculum of the same concentration, as described above. Plants were monitored for powdery mildew development from natural air-borne inoculum. As soon as the first symptoms of powdery mildew were observed, plants were sprayed with BCAs using concentrations described above. A spray interval of approx.10 days was followed starting in mid-July when the first disease symptoms were observed, and continued throughout the growing season. Effect of *M. phaseolina* on dogwood plant's health, was measured using growth and development characteristics including stem length and diameter, wet and dry weights. Observations were also made on persistence of green color on the leaves throughout the growing period. Disease severity readings (rating) to assess the relative effectiveness of each treatment on powdery mildew disease severity was based on a scale of 0-5 in which 0 = No infection; 1 = 1-10%; 2 = 11-25%; 3 = 26-50%; 4 = 51-75% and 5 = 76-100% of the foliage showing disease symptoms. Disease rating was recorded from July to early October.

Results and Discussion: Results on growth parameters showed that both B17A and B17B promoted plant growth in the presence of *M. phaseolina*. Plants treated with bacterial BCAs were superior to all other treatments in terms of stem length, minimum and maximum stem diameters, as well as wet and dry weights. The two bacterial BCAs had significant effect on stem length ($P<0.001$), and stem diameter ($P<0.0001$) compared to other treatments. Although there was no statistical significance between the two bacterial BCAs, B17A was consistently better than B17B (Figures 1 and 2). Plants treated with bacterial BCAs also had less root damage from *M. phaseolina* root rot pathogen compared to other treatments. They had no (or less) damage on the small roots which are normally used for water and nutrient uptake. The bacterial BCAs and fungicide treatments gave better results on powdery mildew disease control compared to other treatments ($P<0.001$) (Figure 3). Fungicide treatment gave slightly better powdery mildew control than the bacterial BCAs, but the difference was not statistically significant. The bacterial BCA-treated plants maintained greener color up to the end of the season than all other treatments. These results demonstrated a beneficial effect from bacterial BCAs on dogwood plants in the presence of *M. phaseolina* and powdery mildew. Improved plant growth from bacterial BCAs may be a combination of both their enhanced root rot and powdery mildew control. However, since fungicide treatment was more effective than the BCAs in powdery mildew control (Fig 3), it is reasonable to presume that the improved plant growth from the BCAs effect is mostly from root rot control.

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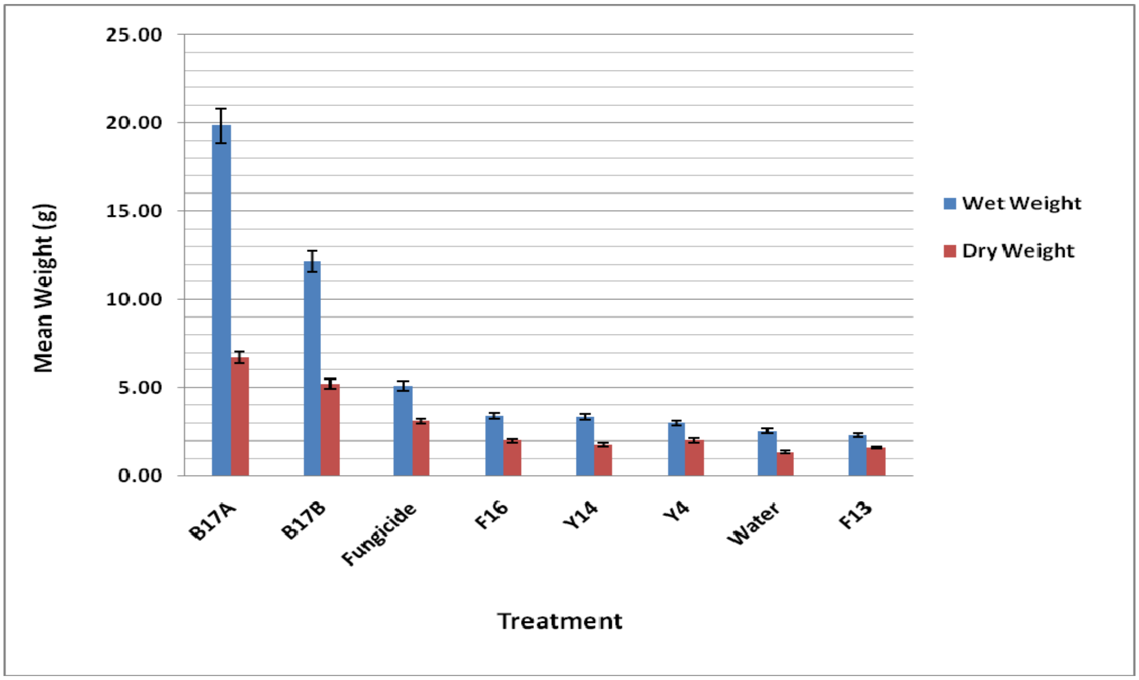

Figure 1: Mean wet and dry weights (g) of dogwood plants grown in the presence of *Macrophomina phaseolina* and sprayed with biocontrol agents (BCAs) bacteria (B17A and B17B), fungi (F13 and F16), yeasts (Y4 and Y14). Fungicide and water treatments were used as control. The plants were grown between June and October.

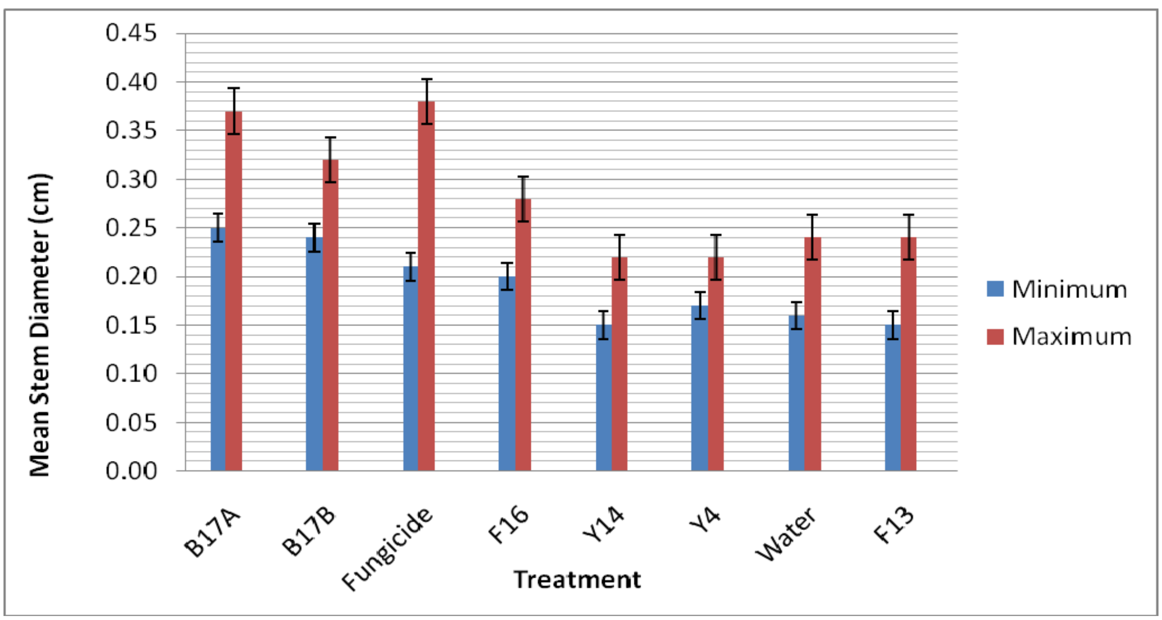

Figure 2: Mean minimun and maximum stem diameters (cm) of dogwood plants grown in the presence of *Macrophomina phaseolina* and sprayed with biocontrol agents (BCAs) bacteria (B17A and B17B), fungi (F13 and F16), yeasts (Y4 and Y14). Fungicide and water treatments were used as control. The plants were grown between June and October.

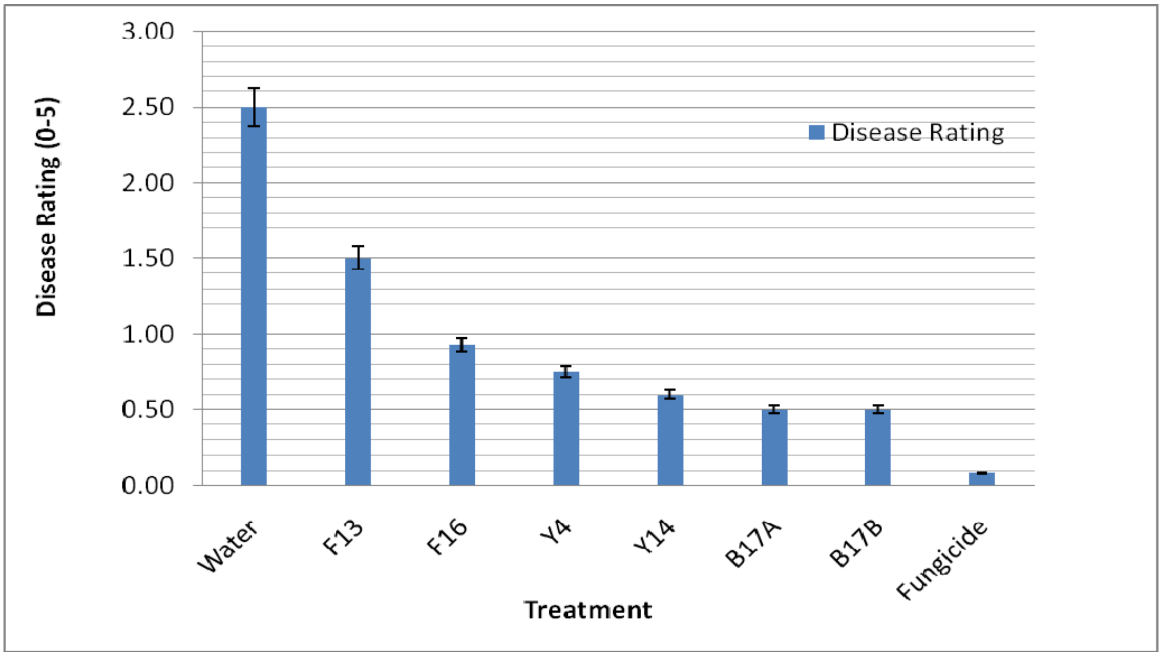

Figure 3: Disease rating (0-5) of powdery mildew on dogwood plants grown in the presence of *Macrophomina phaseolina* and sprayed with biocontrol agents (BCAs) bacteria (B17A and B17B), fungi (F13 and F16), yeasts (Y4 and Y14). Fungicide and water treatments were used as control.