Evaluation of Biorational Products for Powdery Mildew Management in *Cornus florida*[1]

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Abstract

Between 1997 and 1999, 21 biorational products were evaluated for powdery mildew control on dogwood seedlings and compared with the traditional fungicides Banner® (propiconazole), ConSyst™ WDG (chlorothalonil and thiophanate methyl) and Cleary's 3336 F® (thiophanate-methyl) in a shadehouse environment. Selected products were also evaluated in rotation with Banner®, where Banner® application was made once for every three applications. Among the biorational products the household soaps, Palmolive®, Ajax®, and Equate®, the potassium bicarbonate salt Armicarb™, and the antitranspirant Vapor Gard® were most effective in reducing powdery mildew severity. However, Vapor Gard® stunted plant growth, and Palmolive® caused some phytotoxicity. While Safer Soap®, M-Pede®, Triact™, Neem Gold®, Kaligreen™, and Ultrafine® oil were not as effective in controlling powdery mildew as the fungicides, the increase in plant growth was similar. Spray regimes that included the biorational and Banner® generally gave better disease control and enhanced plant growth over the biorational products alone. While Banner® and ConSyst™ were highly effective in controlling powdery mildew, Cleary's 3336 F® gave inconsistent results and proved only moderately effective. Overall, plant growth correlated negatively with powdery mildew severity for the biorational products ($r = -0.58$) and biorational/Banner rotation ($r = -0.54$).

Index words: *Microsphaera pulchra*, *Phyllactinia guttata*, *Oidium* spp., powdery mildew, dogwood, biorational product.

Species used in this study: flowering dogwood (*Cornus florida L.*).

Chemicals used in this study: Cleary's 3336 F (thiophante methyl), dimethyl 4,4´-o-phenylenebis-3-thiophanate; Banner (propiconazole), 1-[[2-(2,-4-dichlorophenyl)-4-propyl-1,3-dioxolan-2yl]methyl]-1H-1,2,4-triazole; Consyst (chlorothalonil & Thiophanate methyl), Tetrachloroisophthalonitrile & Dimethyl 4-4-0-phenylenebis-3-thiophanate.

Significance to the Nursery Industry

This study has demonstrated that biorational products can play an important role in powdery mildew disease management on dogwood and that effective disease management can be attained with reduced amounts of fungicides. Ajax® was as effective as the fungicide Banner® (propiconazole) and better than Cleary's 3336 F® (thiophanate methyl). When used with fungicide rotations, Equate®, Armicarb™, M-Pede®, and Safer Soap® were adequately effective for nursery production. Even though Palmolive was highly effective, additional research is needed to eliminate leaf injury. Since the household soaps are not registered as pesticides by EPA, additional research exploring the possible registration of Ajax® and Equate® soaps is also needed. The greatest potential for a biorational product in nursery production is as a component of an integrated disease management system that incorporates the judicial use of fungicides with rotations of biorational products. This would reduce the amount of fungicide used per season. Results from this study will also ben-

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efit the landscape industry and be highly useful to nursery production systems where fungicides might be avoided for environmental or economic reasons.

Introduction

In the southeastern United States, powdery mildew is one of the most important constraints to flowering dogwood (*Cornus florida L.*) production. In addition to reducing the aesthetic value of plants, severe powdery mildew results in stunted growth, reduced shoot and root dry matter, and delay in the marketing or reduction in the grade of diseased trees. Fungicide applications have become a routine practice in bare root and B & B dogwood production. For effective control, treatments must start at bud break and continue throughout the remainder of the growing season (3, 11). Such intensive treatments have increased production costs and raised environmental concerns. Intensive fungicide use can destroy or disrupt non-target beneficial microflora in the phyllosphere and potentially lead to the development of new disease problems (9). Development of resistance which can result from the overuse of selected fungicides, is also a concern (9). Recommendations to manage fungicide resistance include: (a) limiting the number of applications of resistance-prone fungicides, (b) rotating fungicides with different modes of action, and (c) applying fungicides when the pathogen population is small or as a preventative measure (9). While it is important to provide information on effectiveness of traditional fungicides for the control of powdery mildew, it is also essential to evaluate non-traditional products that can be used as alternatives to synthetic fungicides and thus provide options for reducing the total amount of fungicides used.

Disease control compounds that are relatively harmless to the environment and non-target organisms have been unofficially designated as 'biorational' compounds (10). Biorational compounds that control powdery mildew in other crop systems include bicarbonate salts (4, 12), hydrophobic extract of neem seed oil (5), horticultural oils (1, 5, 6, 12), and antitranspirants (6, 10). These products have not been evaluated for the control of powdery mildew of flowering dogwood. The objective of this study was to evaluate biorational compounds for the management of powdery mildew and to assess their potential as alternatives to synthetic fungicides.

Materials and Methods

From 1997 to 1999, 21 products were tested in shadehouse with 50% shade. 16 products were evaluated in repeated trials, while five products were discontinued after a one-year evaluation because they failed to demonstrate sufficient potential for reducing disease severity. The list of the biorational products, application rates, and the year of evaluation are presented in Table 1. Biorational products that were evaluated for one season and not listed in Table 1 were: Surround® (Kaolin clay) at a rate of 30 g/liter (25 lb/100 gal), nitrate salt (KNO) at a rate of 4.3 g/liter (0.57 oz/gal), Milsana® (BAS 114 UBF) at 1% (v/v) concentrate, Soft Soap® at 18 ml/liter (2.3 fl oz/gal), and Suave® hand washing soap at 18.3 ml/liter (2.4 fl oz/gal). Treatments with fungicides, ConSyst™ WDG (chlorothalonil and thiophanate methyl), Banner®, and Cleary's 3336 F® at recommended rates presented in Table 1 were included for comparison with the biorational products.

In 1997 and 1998, seed that were collected from a powdery mildew susceptible cultivar 'Cherokee Princess', were sown in February and seedlings transplanted into #3 containers in April. Plants used in the 1997 were discarded after the experiment and new seedlings were planted for the 1998

Table 1. List of biorational products and fungicides evaluated for powdery mildew disease management from 1997–1999.

			Evaluation year		
Product name	**Product/fungicide**	**Application rate**	**1997**	**1998**	**1999**
Palmolive®	dish washing soap[z]	18.3 ml/L (= 1.8%)		+	+
Equate®	hand washing soap[z]	18.3 ml/L (= 1.8%)	+	+	+
Ajax®	dish washing soap[z]	18.3 ml/L (= 1.8%)		+	+
Safer Soap®	insecticidal soap	21.9 ml/L (= 2.2%)	+	+	+
M-Pede®	insecticidal soap	25 ml/L (= 2.5%)	+	+	+
Triact®	plant extract[y]	10.0 ml/L (= 1.0%)	+	+	
Neem Gold®	plant extract[y]	10.0 ml/L (= 1.0%)		+	+
Ultrafine® oil	horticultural oil	14.0 ml/L (= 1.4%)	+	+	
Armicarb™	potassium bicarbonate salt	6.6 g/L (5.5 lb/100 gal)	+	+	+
Kaligreen™	potassium bicarbonate salt	3.6 g/L (3 lb/100 gal)		+	+
Vapor Gard®	antitranspirant	20.0 ml/L (2.0%)	+	+	
Transfilm®	antitranspirant	20.0 ml/L (2.0%)	+	+	
Kleen Kill®	biocleaner[x]	7.8 ml/L (= 0.8%)		+	+
K_2HPO_4	phosphate salt	4.3 g/L (3.6 lbs/100 gal)	+	+	
AQ 10™	microbial pesticide[w]	0.05 g/L (0.04 lb/100 gal)	+	+	
Jungle Rain™	foliage cleaner[v]	32.0 ml/L (= 3.2%)		+	+
Total Grow®	fertilizer	5.8 g/L (4.8 lb/100 gal)	+	+	
Cleary's 3336 F®	fungicide: thiophanate-methyl	0.78 ml/L (10 fl oz/100 gal) (1997) 1.56 ml/L (20 fl oz/100 gal) (1998–99)	+	+	+
Banner®	fungicide: propiconazole	0.31 mL/L (4.0 fl oz/100 gal)	+	+	+
Consyst™	fungicide: cholorothalonil and thiophanate-methyl	1.2 g/L (1.0 lb/100gal)	+	+	

[z]Triclosan as ingredient.

[y]Plant extract from neem oil.

[x]Also called Bacto-Zyme® (Biocontrol Network, Brenwood, TN) comprised of protease and cellulase enzymes as active ingredients.

[w]Microbial pesticide derived from *Ampelomyces quisqualis*.

[v]Foliage cleaner comprised of peppermint and citrus oil.

Table 2. **Effect of biorational products in controlling powdery mildew on seedlings of flowering dogwood in a shadehouse environment as compared to three synthetic fungicides (1997–1999).**

		Mean powdery mildew severity (1–5 scale)[z]			
Product name	**Product/fungicide**	**1997**	**1998**	**1999**	**Overall mean**[y]
Banner®	propiconazole	0.9ijk	1.3nop	1.1gh	1.1
Consyst™	chlorothalonil & thiophanate-methyl	0.9ijk	1.0p		1.0
Cleary's 3336 F®	thiophanate-methyl	3.3bc	1.1op	2.5bcde	2.3
Palmolive®	soap (triclosan)		1.6mno	1.0h	1.3
Ajax®	soap (triclosan		1.8lm	1.0h	1.4
Vapor Gard®	antitranspirant	1.0ijk	2.6ghij		1.8
Equate®	soap (triclosan)	1.5defgh	2.2ijkl	2.3cde	2.0
Armicarb™	bicarbonate salt	2.1bcd	2.7hi	1.9def	2.2
Safer Soap®	insecticidal soap	1.7cdefg	3.0defg	1.7fgh	2.1
Ultrafine® oil	horticultural oil	1.6cdefg	2.8efgh		2.2
Triact®	plant extract[x]	1.1ghijk	3.3cde		2.2
M-Pede®	insecticidal soap	1.8bcdef	3.1cdef	1.9def	2.3
Klean Kill™	Enzymes[w]		2.1k	2.9b	2.5
Transfilm®	antitranspirant	2.3bc	2.6ghij		2.5
Kaligreen™	bicarbonate salt		3.0defg	2.0def	2.5
Neem Gold®	plant extract[s]		2.7fghi	2.5bcde	2.6
K_2HPO_4	phosphate salt	1.2ghijk	4.1b		2.7
Jungle Rain®	peppermint and citrus oil[v]		3.1cdef	2.6bcd	2.9
AQ-10™	microbial fungicide[u]	1.3efghij	4.3b		2.8
Total Grow®	fertilizer	2.5b	3.6c		3.1
Control	water	3.8a	4.8a	3.9a	4.2

[z]Disease readings taken in August 1997and 1998 and in September 1999 where 1 = 1–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75 and 5 = 75–100% plant infection. Disease severity readings followed by same letters in the same date of sampling are statistically similar at p = 0.05 according to Statistical analysis systems (SAS) Linear models (9).

[y]Overall mean from two- or three-year data LSD = 0.6.

[x]Plant extract from neem oil.

[w]Also called Bacto-Zyme (Biocontrol Network, Brenwood, TN) comprised of protease and cellulase enzymes as active ingredients.

[v]Foliage cleaners with peppermint and citrus oil (Biocontrol Network, Brenwood, TN).

[u]Microbial pesticide from *Ampelomyces quisqualis*.

experiments. At the end of the 1998 experiment, the seedlings were transplanted to #5 containers and carried over to the 1999 season. All plants were watered daily by drip-irrigation; starter fertilizer was applied in late April using 15–30–15 (nitrogen-phosphorus-potassium) plant food (1 teaspoon/gal of water), Osmocote controlled release fertilizer 14–14–14 (NPK) was applied in May at the rate of 50 g (1.8 oz)/container.

To ensure a continuous source of inoculum, *M. pulchra* infected flowering dogwood were scattered randomly within the experimental area. Treatment regimes, which were initiated when colonies of *M. pulchra* were first observed, began in the first week of May in 1997 and 1999 and in the first week of June in 1998. A randomized complete block design was used with a replication of 10 plants per treatment. Fungicides and biorational products were applied to run-off at two-week intervals using CO_2 gas sprayers (R & D Sprayers, Apolousas, MS).

Selected products were also evaluated in rotation with the systemic fungicide Banner® where three applications of a biorational products were followed by one fungicide application. All treatments were terminated on the last week of August or in early September to coincide with commercial practices.

Disease severity was evaluated monthly for three months starting one month after the first treatment (early June to late August or in early September). A 1–5 rating scale was used in where 1 = 1–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 75–100% of plant foliage showed signs or disease symptoms of powdery mildew. Tree vigor was evaluated in early September 1997 and 1998 using a 1–5 scale based on increases in tree height and overall size in where1 = severely stunted growth with plant height of 10–15 cm (3.9–5.9 in) with no lateral branches, 2 = 15–25 cm (5.9–9.8 in) in height with 1–2 branches, 3 = 25–35 cm (9.8–13.8 in) in height with 3–4 branches, 4 = 35–50 cm (13.8–19.7 in) in height with 4–5 branches and 5 = > 50 cm (19.7 in) in height with > 4 branches. Sample plants representing the 1–5 scale were used to aid growth assessment.

Data were analyzed using the statistical analysis system (SAS) general linear models procedure (7). Multiple comparisons between pairs of mean disease severity from different treatments using a series of t tests were conducted following SAS procedures in PROC. ANOVA (7). Correlation and regression analysis procedures available in SAS (7) were used to assess the relationship between disease severity and plant growth in different treatments (2).

Results and Discussion

The earliest signs and symptoms of powdery mildew were observed in the first week of May 1997 and 1999 and in the first week of June 1998. Powdery mildew disease severity increased over time, and the highest disease readings in the non-treated control plants were recorded at the end of August 1997 and 1998, and in early September 1999 (Table 2). Powdery mildew disease severity was highest in 1998 as compared to 1997 and 1999, indicating that the 1998 environment was very favorable to powdery mildew infections

(Table 2). While total rainfall was highest in 1997, most of the rainfall (80%) occurred in May and June. Total rainfall in 1998 was slightly less than in 1997, but the rainfall was evenly distributed in May–August. In addition, mean monthly temperatures in May–August were relatively moderate in 1998, as compared to the high temperatures of July 1997 and July to August 1999.

In 1997, Banner® and Consyst™ were most effective in reducing powdery mildew severity, followed by the biorational products Vapor Gard®, Triact®, K_2HP0_4, the biocide AQ10®, Equate®, Ultrafine® oil, and Safer Soap® (Table 2). Surround® was not at all effective in controlling powdery mildew (data not shown). Tree growth improved as a result of powdery mildew control from most of the products (data not shown), but Vapor Gard® stunted plant growth and Palmolive® caused some necrotic patches on the leaf lamina especially near the tip. Improved disease control was noted when Banner® was rotated with the biorational products (Table 3). The 0.78ml/liter (10 fl oz/100 gal) rate of Cleary's 3336 F® was not effective in controlling powdery mildew.

Of the biorational products tested in 1998, Palmolive® soap had the best activity against powdery mildew control and was as effective as the Banner®, and Cleary's 3336 F® in controlling this disease (Table2). Ajax®, Equate®, and Klean Kill® were also highly effective in reducing disease severity, followed by Vapor Gard®, Transfilm®, Armicarb™, and Neem Gold® (Table 2). As was noted in 1997, Vapor Gard® stunted plant growth, and Palmolive® caused some leaf injury. Even though Safer Soap®, M-Pede®, and Neem Gold® were only moderately effective in reducing powdery mildew disease severity, they improved plant growth similar to fungicides (data not shown). The Kaligreen™ formulation of potassium bicarbonate salt was not as effective as that of Armicarb™ (Table 2). Overall, plant growth correlated negatively with powdery mildew disease severity with a correlation coefficient of $r = –0.58$ for the biorational products and $r = –0.54$ for the biorational/Banner® rotation.

In 1999, overall powdery mildew severity was low. Palmolive® and Ajax® were most effective in reducing disease severity, followed by Safer Soap®, Armicarb™, M-Pede®, Equate®, and Kaligreen™ (Table 2). Ajax® was as effective as Palmolive® in reducing disease severity and was not phytotoxic. Although the same rate was used, Cleary's 3336 F® was not as effective in controlling powdery mildew in 1999 as compared to the previous year. The plant extract Milsana®, nitrate salt, Suave® and Soft Soap® were not effective in reducing powdery mildew severity (data not shown). Spray regimes that included biorational and Banner® did not improve disease control over the biorational products alone, but plant growth was enhanced (data not shown).

Results from the three-year evaluation varied slightly from one year to the next, but some products were consistently better than others in controlling powdery mildew. When the performance of the different products was averaged, Palmolive®, Ajax®, Equate®, Safer Soap®, Armicarb™ and Vapor Gard® were better than other products. After repeated evaluations, the overall effectiveness of Cleary's 3336 F® (1998–1999) was categorized as moderate (Table 2).

Environmental factors, temperature and moisture in particular, are known to influence powdery mildew disease severity (8); therefore, it is reasonable to attribute the three-year disease severities to the temperature and rainfall patterns of May to August 1997–1999. In 1997, rainfall total was high and mostly occurring in May and June, while July was relatively dry and hot. Such weather patterns may have suppressed disease development. In 1998, moderate temperatures coupled with frequent light rainfall that was well distributed throughout the growing season favored powdery mildew disease development and high disease severity. In 1999, the low disease development may be attributed to the prevailing hot and dry weather patterns characterized by high temperatures and low total monthly rainfall.

The best biorational products in controlling powdery mildew over the three-year period were Ajax®, Palmolive®,

Table 3. Effect of biorational and Banner® (propiconazole) rotations in controlling powdery mildew on seedlings of flowering dogwood where Banner® was applied once for every three applications of a biorational product between 1997 and 1999.

		Mean disease severity (1–5 scale)[z]			
Product name	**Product/fungicide**	**1997**	**1998**	**1999**	**2–3 year mean[y]**
Banner®	propiconazole	0.9ijk	1.3nop	1.1gh	1.1
Equate®	soap (triclosan)	0.7k	2.2efg	1.8efg	1.6
Armicarb™	bicarbonate salt	0.7k	1.2jkl	1.8efg	1.2
Vapor Gard®	antitranspirant	1.2ghijk	1.8ghi	2.7bc	1.9
Safer Soap®	insecticidal soap	0.7k		2.2efg	1.5
M-Pede®	insecticidal soap	1.3efghij	1.8ghi	1.9def	1.7
Triact®	plant extract[x]	2.0bcde	2.5ed		2.3
Kaligreen™	bicarbonate salt	2.2efg		2.8b	2.5
Ultrafine® oil	horticultural oil	0.8jk	2.5ed		1.7
Transfilm®	antitranspirant	1.1ghijk	3.0bc		2.2
K_2HPO_4	phosphate salt	1.2ghijk	3.3b		2.3
Total Grow®	fertilizer	1.5defgh	3.1b		2.3
Control	water	3.8a	4.8a	3.9a	4.2

[z]Disease readings taken in August 1997 and 1998 and in September 1999 where 1 = 1–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75 and 5 = 75–100% plant infection. Disease severity readings followed by same letters in the same date of sampling are statistically similar at p = 0.05 according to Statistical analysis systems (SAS) Linear models (9).

[y]Overall mean from two- or three-year data LSD = 0.6.

[x]Plant extract from neem oil.

and Vapor Gard®, followed by Equate®, Safer Soap®, and Armicarb™, but phytotoxicity from Palmolive® and stunted growth from Vapor Gard® are undesirable. Ajax®, Armicarb™, Equate®, and Safer Soap® had no adverse effects on the plants and showed the strongest potential in powdery mildew disease management either individually or in rotation with a synthetic fungicide (Tables 2 and 3).

While M-Pede®, Triact™, Neem Gold®, Kaligreen™ and Ultra Fine Sunspray® oil showed only moderate success in controlling powdery mildew, the level of suppression was sufficient to significantly improve plant growth. M-Pede®, Safer Soap®, Ultrafine® oil, Triact™, and Neem Gold® are commercially available and labeled for use on ornamental plants for insect control. Although Triact™, now sold as Triact 70 (Olympic Horticultural Products, Bradenton, FL), and Neem Gold® (Bio-Control network, Brentwood, TN) are also marketed for the control of powdery mildew disease on ornamental plants, they were not really as effective as the above biorational products. The potassium bicarbonate salt formulations marketed as Armicarb™ (Church and Dwight Co. Inc. Princeton, NJ) and Kaligreen™ (TOAGOSEI Co. Ltd., Tokyo, Japan) have also been registered for powdery mildew control on ornamental plants and showed good potential for reducing dogwood powdery mildew. However, Armicarb™ gave consistently better disease control than Kaligreen™ (Tables 2 and 3). Since none of these products caused leaf injury, their efficacy might be enhanced by weekly applications.

The household soaps, Ajax® and Equate® were at least as effective as Armicarb™ and are potential alternatives to synthetic fungicides (Table 2). They are not registered as pesticides by EPA and cannot legally be used in commercial nurseries. Follow-up research exploring the possible registration of Ajax® and Equate® soaps under different names will allow a broader use of the products. Ajax® is considered to be adequately effective for commercial nursery production; reductions in disease severity were similar to those obtained with synthetic fungicides.

Kleen Kill™ is a commercially available biocleaner containing protease and cellulase enzymes as active ingredients. Because the powdery mildew pathogen is mostly outside the plant tissue, the product was thought to have good potential, and the enzymes were expected to digest fungal mycelia on leaf surfaces. Since the enzymes can also digest plant tissue, a very low concentration was used. Perhaps the concentration could be increased to improve efficacy without digesting the plant tissues; however, the product was discontinued from further evaluation because it was less effective than the soaps at the concentration tested.

These results clearly show that biorational products may play a significant role as alternatives to synthetic fungicides in powdery mildew management. These products can help reduce the amount of traditional fungicides used in powdery mildew management in dogwood production. Biorational products may be especially useful to the landscape industry and in nursery production systems where synthetic fungicides might be avoided for environmental or economic reasons. ConSyst™ and Banner® were clearly highly effective in controlling powdery mildew.

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