

Evaluation of Powdery Mildew Resistance in *Hydrangea macrophylla*¹

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Abstract

Powdery mildew, *Erysiphe polygoni* DC, can be a significant problem on *Hydrangea macrophylla* (Thunb.) Ser. in the landscape in late summer to fall and during greenhouse propagation or production of potted plants. Because very little information related to sources of resistance is available, 90 *H. macrophylla* cultivars were evaluated for resistance to powdery mildew over a 3-year period. This included 69 *H. macrophylla* ssp. *macrophylla* and 18 *H. macrophylla* ssp. *serrata* (Thunb.) Makino cultivars, along with three cultivars that are hybrids between the two subspecies. Significant differences among cultivars to powdery mildew were found in all three study years. Three cultivars, 'Amagi Amacha', 'Shirofujii' and 'Veitchii', were among the most resistant each year. 'Diadem', 'Komachi', and 'Omacha' were highly resistant in 2006 and 2008, but only moderately resistant in 2007. 'Komachi' and 'Shirofujii' were considered unsuitable for breeding purposes as they do not appear to produce fertile flowers. 'Veitchii' was the only member of *H. macrophylla* ssp. *macrophylla* with a high level of powdery mildew resistance; while all other resistant cultivars were members of *H. macrophylla* ssp. *serrata*, not all members of this subspecies are resistant. Results of this study will be useful in breeding powdery mildew resistant *H. macrophylla*.

Index words: bigleaf hydrangea, mountain hydrangea, powdery mildew, host plant resistance, cultivar evaluation.

Significance to the Nursery Industry

Powdery mildew resistance was evaluated in 90 cultivars of *H. macrophylla* over a 3-year period. 'Amagi Amacha' and 'Veitchii' were identified as the best cultivars for use in breeding powdery mildew resistant *H. macrophylla*. 'Diadem' and 'Omacha' were also identified as potentially useful sources of resistance. 'Veitchii' was the only member of *H. macrophylla* ssp. *macrophylla* with a high level of powdery mildew resistance; while all other resistant cultivars were members of *H. macrophylla* ssp. *serrata*, not all members of this subspecies are resistant. Using host plant resistance is the desired method of providing protection against powdery mildew in bigleaf hydrangea; the information provided in this report should be useful in developing such a breeding program.

Introduction

Hydrangea macrophylla is a popular ornamental shrub that is cultivated both as a garden and a pot plant. In the landscape, it grows 0.9 to 1.8 m (3 to 6 ft) in height with a similar spread, producing showy flowers in early to mid-summer. As a florist's crop, it is forced into bloom in a greenhouse usually in time for Easter and Mother's Day sales (1). Over 700 *H. macrophylla* cultivars have been described, but only about 1/4 of these are available in the U.S. trade (4, 13). While initially considered hardy only to USDA cold hardiness zone 6, the introduction of remontant (reflowering) selections such as 'Bailmer' (marketed as Endless Summer®) and 'Penny Mac' has expanded the area of the country in which the species will flower reliably (4). The recent introduction from Europe and Japan of new cultivars with interesting flower colors and inflorescence forms has further stimulated the interest of landscapers and gardeners in this species.

While four subspecies of *H. macrophylla* have been recognized (10), only two are grown commercially. *Hydrangea macrophylla* ssp. *macrophylla*, which is known by the common names of bigleaf, garden, French or florist hydrangea, is used both in the landscape and as a greenhouse crop. It is native to Japan and is found in coastal areas from sea level to approximately 150 m (500 ft) in elevation. *Hydrangea macrophylla* ssp. *serrata* is found in mountainous areas of Japan and northern Korea at elevations up to 1500 m (5000 ft) and is referred to as mountain hydrangea. McClintock (10) differentiated *H. macrophylla* ssp. *macrophylla* and *H. macrophylla* ssp. *serrata* by their leaf and inflorescence sizes and Bertrand (2) was able to separate the two subspecies using a combination of 28 qualitative and five quantitative morphological criteria. Some recent publications and many nursery catalogs refer to *H. macrophylla* ssp. *serrata* as *H. serrata* (4, 8, 9, 13); however, molecular data indicate that the subspecies designation is correct (11).

Powdery mildew, caused by *Erysiphe polygoni* DC, can be a significant problem on *H. macrophylla* in the landscape in late summer to fall and during greenhouse propagation or

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production of potted plants (1, 4). In addition to the presence of unattractive white mycelium on leaf surfaces, symptoms also include extensive chlorosis or yellowing of the leaves, premature defoliation, and reduction in leaf area and shoot elongation (5, 12). Symptoms are most severe on plants grown in heavily shaded areas with limited air movement and high humidity, such as in tightly packed container culture or in greenhouses. While powdery mildew usually does not kill plants in landscape settings, it does reduce the aesthetic quality, plant vigor and economic value of infected plants. Chemical controls for powdery mildew in *H. macrophylla* exist (6), but they increase the cost of production and are impractical for use by homeowners.

Host plant resistance is the desired method of providing protection to powdery mildew in bigleaf hydrangea; however, very little information related to sources of resistance is available. There have been anecdotal reports indicating that cultivars belonging to *H. macrophylla* ssp. *serrata* are more resistant than *H. macrophylla* ssp. *macrophylla* cultivars. Dirr (4) evaluated 27 *H. macrophylla* ssp. *macrophylla* and 8 *H. macrophylla* ssp. *serrata* cultivars for powdery mildew resistance. 'Veitchii' was the only *H. macrophylla* ssp. *macrophylla* cultivar that did not show signs of powdery mildew. Experimental design details and a statistical analysis were not presented for that study. The objective of this study was to evaluate a large number of *H. macrophylla* cultivars for resistance to powdery mildew and identify cultivars suitable for resistance breeding.

Materials and Methods

This study was conducted at the Tennessee State University Otis L. Floyd Nursery Research Center (TSU-NRC) in McMinnville, TN. Ninety cultivars of *H. macrophylla* were evaluated in this study (Table 1), including 69 *H. macrophylla* ssp. *macrophylla* and 18 *H. macrophylla* ssp. *serrata* cultivars. Subspecies assignment for cultivars was based on Bertrand (3), Dirr (4), Mallet (8), Mallet et al. (9), and van Gelderen and van Gelderen (13). Three cultivars that appeared, based on molecular data, to be hybrids between the two subspecies (11) were also included. Where references differed on spelling of cultivar name, the preferred spelling listed in the cultivar checklist (3) was used. Foreign letters in cultivar names were eliminated in the text, but are included in Table 1. Synonyms are provided in Table 1 only when they are English translations of a foreign name or confirmed re-namings of cultivars (7). Where valid synonyms exist, we refer to the plant under the name by which we acquired it.

In April 2006, rooted cuttings of 75 cultivars were obtained from Bell Family Nursery (currently Amethyst Hill Nursery, Aurora, OR), potted into #3 containers, and placed in a hoop house. Rooted cuttings of 'Bailmer' and 'Penny Mac', which had been propagated at the TSU-NRC in summer 2005, were handled in the same manner. In November 2006, plants were cut back to approximately 20 cm (8 in) in height and transferred to #7 containers. Cuttings from an additional 13 cultivars were rooted at the TSU-NRC during Summer 2006. These rooted cuttings were potted into #3 containers and placed in the hoop house in November 2006. In November 2007, all plants were again cut back to 20 cm (8 in) in height. Those plants that were still in #3 containers were transplanted to #7 containers at that time.

Plants were initially transplanted into a shredded pine bark medium amended with 7.6 kg·m⁻³ (12.8 lb·yd⁻³) 19-5-9

Osmocote Pro fertilizer (Scotts-Sierra Horticultural Products Co., Marysville, OH), 0.9 kg·m⁻³ (1.5 lb·yd⁻³) Micromax (Scotts-Sierra Horticultural Products Co.), 0.6 kg·m⁻³ (1.0 lb·yd⁻³) iron sulfate and 0.6 kg·m⁻³ (1.0 lb·yd⁻³) lime. When plants were moved from #3 to #7 containers, this same medium with half-rate controlled-released fertilizer was used. In March 2007 and 2008, all plants in #7 containers were top-dressed with 107 g (3.8 oz) 19-5-9 Osmocote Pro fertilizer, while those in #3 containers received 46 g (1.6 oz).

Plants were grown under 63% shade in a hoop structure and micro-irrigated using spray stakes. The shadehouses were covered with plastic each winter. Plants were arranged in a completely randomized block design using three single-plant replications. The randomization pattern was set up using all 90 cultivars and those cultivars that were added in Fall 2006 were inserted into the already established order.

Plants were evaluated for severity of powdery mildew on September 1 and 21, 2006, October 5, 2007, and October 16, 2008, on a scale of 0 to 6 where 0 = no signs of powdery mildew, 1 = > 0 but < 2%, 2 = 2 to < 10%, 3 = 10 to < 25%, 4 = 25 to < 50%, 5 = > 50 but < 100%, and 6 = 100% of foliage had signs of powdery mildew. Data for each evaluation date were analyzed using the PROC GLM Model of SAS (SAS Institute Inc., Cary, NC). The least significant difference (LSD) test was used to separate means at the P < 0.05 level.

Results and Discussion

Significant differences in amount of powdery mildew among cultivars were observed at each evaluation date (Table 1). Data from the September 1, 2006, evaluation are not presented as they have previously been reported (14). Also, since the disease continued to progress from the September 1 to September 26, the later set of 2006 data is more indicative of resistance than the earlier readings. Throughout the rest of this paper, 2006 data refer to the September 26 disease readings.

The 2006 mean disease index ratings ranged from 0 (highly resistant) to 5.3 (highly susceptible). 'Amagi Amacha', 'Blue Billow', 'Komachi' and 'Pretty Maiden' showed no signs of powdery mildew in any replication. Although powdery mildew was observed on 'Veitchii', which conflicts with observations made by Dirr (4), the amount of leaf colonization was low and the cultivar was partitioned in the most resistant group. A high level of resistance (mildew rating of under 2.0) was also found in 'Bailmer', 'Blauer Prinz', 'Blaumeise', 'Diadem', 'Fasan', 'Fuji Waterfall', 'Hokaido', 'Lemon Wave', 'Miyama-yae-Murasaki', 'Omacha', 'Shiro-fuji', 'Taube', 'Todi' and 'Tricolor'. Five (6%) of the cultivars tested were highly susceptible to powdery mildew, having disease ratings of 5.0 or greater.

All three plants of 'Lemon Wave' died between the 2006 and 2007 evaluations, reducing the number of cultivars in the study to 89 for the 2007 evaluation. Disease ratings ranged from 1.3 to 5.0 and no plants were free of powdery mildew in 2007. A high level of resistance was found only in 'Amagi Amacha', 'Shirofuiji' and 'Veitchii'. Disease ratings of 5.0 or greater were recorded for 40 (45%) of the cultivars evaluated in 2007.

'Blue Billow', 'Chiri-san-Sue', 'Konigstein', and 'Lemon Zest' were dropped from the study prior to the 2008 rating due to the death of two or more plants of each of these cultivars, dropping the number of cultivars evaluated in 2008 to 85. Disease ratings ranged from 0.5 to 5.3. Only a single plant

Table 1. Powdery mildew disease ratings for 90 *Hydrangea macrophylla* cultivars over a 3-year period.

Cultivar ^z	Subspecies ^y	Disease ratings ^x		
		September 21, 2006	October 05, 2007	October 06, 2008
Akishino Temari	ser	—	2.7de	1.0fg
All Summer Beauty	mac	3.3bcdefg ^w	4.7ab	5.0ab
Altona	mac	2.7defghi	5.0a	5.0ab
Amagi Amacha	ser	0.0l	1.7ef	1.3fg
Amethyst	mac	4.3abcd	5.0a	5.0ab
Ami Pasquier	mac	2.7defghi	5.0a	5.0ab
Ayesha	mac	2.3efghij	5.0a	5.0ab
Bailmer (Endless Summer)	mac	1.3hijkl	2.7de	3.7de
Beauté Vendômoise	mac	4.0abcde	5.0a	5.0ab
Benigaku	ser	2.7defghi	5.0a	5.0ab
Blauer Prinz (Blue Prince)	mac	1.0ijkl	4.0abc	3.3e
Blaumeise	mac	1.7ghijkl	3.0cd	5.0ab
Blue Billow	ser	0.0l	3.7bcd	—
Blue Bird	ser	4.0abcde	4.3ab	5.0ab
Blue Deckle	hybrid	2.0fghijk	4.0abc	5.0ab
Blue Wave	mac	4.7abc	5.0a	5.0ab
Bodensee	mac	4.3abcd	4.3ab	5.0ab
Bouquet Rose	mac	3.3bcdefg	5.0a	5.0ab
Charme	mac	2.3efghij	4.3ab	5.0ab
Chiri-san Sue	ser	—	3.7bcd	—
Coerulea	ser	3.3bcdefg	5.0a	5.0ab
Diadem	ser	0.7jkl	2.7de	1.5f
Domotoi	mac	5.0ab	5.0a	5.0ab
Dooley	mac	4.7abc	4.3ab	5.0ab
Enziandom	mac	5.3ab	5.0a	5.0ab
Fasan	mac	0.3kl	4.7ab	4.3bcd
Forever Pink	mac	2.7defghi	5.0a	5.0ab
Frillibet	mac	3.7abcdef	4.3ab	5.0ab
Fuji Waterfall (Fujinotaki)	mac	1.7ghijkl	4.3ab	4.7abc
Général Vicomtesse de Vibraye	mac	2.3efghij	5.0a	5.0ab
Geoffrey Chadbund	mac	3.3bcdefg	4.7ab	5.0ab
Gerda Steiniger	mac	4.0abcde	5.0a	5.0ab
Gertrude Glahn	mac	3.7abcdef	5.0a	5.0ab
Glowing Embers	mac	2.5efghi	4.5ab	5.0ab
Goliath	mac	3.7abcdef	5.0a	5.0ab
Grayswood	ser	3.3bcdefg	4.7ab	5.0ab
Hadsbury	mac	—	5.0a	4.7abc
Hallasan	ser	—	3.7bcd	5.0ab
Hamburg	mac	4.3abcd	5.0a	5.0ab
Hanabi	mac	—	5.0a	5.0ab
Harlequin	mac	—	4.3ab	5.0ab
Hobella	mac	—	5.0a	5.0ab
Hokaido	ser	0.7jkl	4.0abc	3.7de
Holstein	mac	3.7abcdef	5.0a	4.7abc
Intermedia	ser	4.0abcde	5.0a	5.0ab
Jōgosaki	mac	—	5.0a	5.0ab
Kluis Superba	mac	2.3efghij	4.7ab	5.0ab
Komachi	ser	0.0l	3.0cd	1.5f
Königstein	mac	2.0fghijk	5.0a	—
La France	mac	3.3bcdefg	5.0a	5.0ab
Lady in Red	mac	—	4.0abc	4.0cde
Lanarth White	mac	2.3efghij	4.3ab	5.0ab
Lemon Wave	mac	0.3kl	—	—
Lemon Zest	mac	—	4.3ab	—
Libelle	mac	5.0ab	5.0a	5.0ab
Lilacina	mac	5.3a	5.0a	5.0ab
Madame Emile Mouillère	mac	2.7defghi	5.0a	5.0ab
Madame Faustin Travouillon	mac	2.0fghijk	4.3ab	4.3bcd
Maréchal Foch	mac	3.7abcdef	5.0a	5.0ab
Mariesii	mac	—	4.3ab	5.0ab
Mathilda Gütges	mac	3.3bcdefg	4.7ab	5.0ab
Merritt's Supreme	mac	2.3efghij	4.7ab	4.7abc
Miranda	ser	2.7defghi	4.7ab	4.3bcd
Miss Belgium	mac	4.7abc	5.0a	5.0ab
Miss Hepburn	mac	4.3abcd	5.0a	5.0ab
Miyama-yae-Murasaki	ser	0.3kl	3.7bcd	1.7f
Mousmee	mac	4.7abc	5.0a	5.0ab
Nachtigall	mac	3.3bcdefg	4.0abc	4.7abc
Nigra	mac	4.0abcde	5.0a	5.0ab

Table 1. Continued...

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Cultivar ^z	Subspecies ^y	Disease ratings ^x		
		September 21, 2006	October 05, 2007	October 06, 2008
Nikko Blue	mac	3.3bcdefg	4.3ab	5.0ab
Omacha	ser	0.3kl	2.7de	1.3fg
Oregon Pride	mac	3.7abcdef	4.7ab	4.7abc
Otaska	mac	3.0cdefgh	4.7ab	5.0ab
Parzival	mac	4.3abcd	5.0a	5.0ab
Penny Mac	mac	3.0cdefgh	4.7ab	5.0ab
Pretty Maiden (Shichidanka)	ser	0.0l	3.7bcd	3.3e
Preziosa	hybrid	5.3a	5.0a	5.0ab
Rosea	mac	—	4.3ab	4.0cde
Seafoam	mac	2.3efghij	4.7ab	5.0ab
Shirofujii	ser	0.3kl	1.3f	0.5g
Sir Joseph Banks	mac	—	4.0abc	5.0ab
Sister Therese (Soeur Thérèse)	mac	4.7abc	5.0a	5.3a
Souvenir du Président Doumer	mac	3.0cdefgh	4.7ab	5.0ab
Taube	mac	1.7ghijkl	3.7bcd	4.0cde
Tödi	mac	1.0ijkl	4.7ab	4.7abc
Tokyo Delight	hybrid	4.7abc	5.0a	5.0ab
Tovelit	mac	3.7abcdef	5.0a	5.0ab
Tricolor	mac	0.3kl	5.0a	5.0ab
Trophy (Trophée)	mac	3.3bcdefg	5.0a	5.0ab
Veitchii	mac	0.7jkl	1.3f	1.7f

^zNames in parentheses indicate synonyms or trademarked names. Synonyms are provided only where they are English translations or confirmed re-namings of cultivars; the synonym listed first is the name under which we acquired the plant.

^ymac = *Hydrangea macrophylla* ssp. *macrophylla*; ser = *H. macrophylla* ssp. *serrata*. Cultivars listed as hybrids are hybrids between the two subspecies as determined by simple sequence repeat markers (11).

^xResistance was evaluated on a scale of 0 to 6 where 0 = no signs of powdery mildew, 1 = < 2% of foliage had signs of powdery mildew, 2 = < 10% of foliage had signs of powdery mildew, 3 = < 25% of foliage had signs of powdery mildew, 4 = < 50% of foliage had signs of powdery mildew, 5 = > 50%, but < 100% of foliage had signs of powdery mildew, and 6 = 100% of foliage had signs of powdery mildew.

^wMeans within a column with different letters are significantly different according to the Least Significant Difference test ($P < 0.05$).

of ‘Shirofujii’ showed no mildew symptoms. A high level of resistance was also found in ‘Akishimo Temari’, ‘Amagi Amacha’, ‘Diadem’, ‘Komachi’, ‘Miyama-yae-Murasaki’, ‘Omacha’, ‘Shirofujii’, and ‘Veitchii’. Sixty (71%) of the cultivars had mean disease readings of 5.0 or greater in 2008.

Disease ratings were higher in 2007 and 2008 than in 2006. Based on the data from just the 74 cultivars that were evaluated all 3 years, mean disease ratings over all cultivars were 2.9 in 2006, 4.4 in 2007 and 4.5 in 2008. The lower disease ratings in 2006 were probably due to two factors. The final disease evaluation in 2006 was made 2 and 3.5 weeks earlier than in 2007 and 2008, respectively. Disease severity increased as the season progressed and may not have peaked by September 21, 2006. Also, the hoop house where the plants were grown had never before been used for hydrangeas. Natural inoculum may have built up in the facility during the course of the experiment. Cultivars rated as moderately to highly resistant in 2006, but highly susceptible in 2007 and 2008, may have been inadequately exposed to inoculum in 2006.

Three cultivars, ‘Amagi Amacha’, ‘Shirofujii’ and ‘Veitchii’, were among the most resistant in all study years. ‘Diadem’, ‘Komachi’ and ‘Omacha’ were highly resistant in 2006 and 2008, but only moderately resistant in 2007. Molecular marker analysis of genetic relationships among *H. macrophylla* cultivars showed that ‘Amagi Amacha’, ‘Komachi’, ‘Omacha’, and ‘Veitchii’ are not closely related (11); therefore, it is possible that these cultivars represent different sources of powdery mildew resistance. ‘Shirofujii’ and ‘Diadem’ were not included in the molecular marker

study, so their relationship to the other resistant cultivars is unknown.

‘Veitchii’, which is the only mildew resistant cultivar that is a member of *H. macrophylla* ssp. *macrophylla*, has already been used for developing mildew resistant germplasm. Hybridization of ‘Veitchii’ with ‘Bailmer’ resulted in a mildew-resistant and remnant selection named ‘Blushing Bride’ (4). It is encouraging that resistance was recovered in the F_1 generation. Of the six *H. macrophylla* ssp. *serrata* cultivars with resistance to powdery mildew, ‘Komachi’ and ‘Shirofujii’ have hose-in-hose double flowers and do not appear to produce any fertile flowers. This, of course, makes them unsuitable as parents in a breeding program. In contrast, ‘Amagi Amacha’, ‘Diadem’, and ‘Omacha’ have lacecap inflorescences with large numbers of fertile flowers. While hybrids between *H. macrophylla* ssp. *macrophylla* and *H. macrophylla* ssp. *serrata* have been identified and appear to be fertile (11), no attempts to utilize ‘Amagi Amacha’, ‘Diadem’ or ‘Omacha’ in hybridizations to *H. macrophylla* ssp. *macrophylla* have been reported. At this point it is not known whether these three cultivars will only be useful for improving powdery mildew resistance within *H. macrophylla* ssp. *serrata* or if they can be used for genetic improvement of both subspecies.

Some, but not all, *H. macrophylla* ssp. *serrata* cultivars were highly resistant to powdery mildew. For example, ‘Blue Bird’ and ‘Intermedia’ were among the most susceptible cultivars in all 3 years. Of the three cultivars that are hybrids between *H. macrophylla* ssp. *macrophylla* and *H. macrophylla* ssp. *serrata*, a high level of susceptibility was

found in 'Preziosa' and 'Tokyo Delight' all 3 years and in 'Blue Deckle' in 2007 and 2008.

This study agrees with previous reports (4) that 'Veitchii' is resistant to powdery mildew. Our overall results also agree with that study's report of high to moderate levels of susceptibility in 'All Summer Beauty', 'Dooley', 'General Vicomtesse de Vibraye', 'Holstein', 'Madame Emile Mouillere', 'Nikko Blue' and 'Preziosa' and of moderate to high levels of resistance in 'Miyama-yae-Murasaki'. However, for several cultivars, the disease assessments differ. Dirr (4) rated 'Ami Pasquier', 'Ayesha', 'Frilibet', 'Goliath', 'Lilacina', 'Miranda', 'Sister Therese', 'Souvenir du President Doumer' and 'Tokyo Delight' as moderately resistant (rating of 2 on scale of 1 to 5), while we found all of these cultivars to be highly susceptible, especially in 2007 and 2008. In the earlier study, 'Pretty Maiden' was rated as resistant as 'Veitchii' (score of 1); although it was in the most resistant category in our 2006 rating, it only showed moderate resistance in 2007 and 2008. None of the cultivars that appeared moderately to highly resistant in this study was considered to be susceptible by Dirr (4). The difference in results between the two studies could be due to difference in time of evaluation. Dirr's ratings were made on September 18, 2001, while ours were made later in the growing season, especially during 2007 and 2008. Our 2006 data more closely matches results reported by Dirr than do data that we collected the two following years. Some of the cultivars that appeared to have some resistance in that previous study may have been scored as susceptible if rated 2 to 4 weeks later.

In summary, this report identifies 'Amagi Amacha' and 'Veitchii' as the best cultivars for use in breeding powdery mildew resistant *H. macrophylla*. 'Diadem' and 'Omacha' also may be useful sources of resistance. Two cultivars ('Komachi' and 'Shirofuji') with powdery mildew resistance are not suitable for inclusion in a breeding program because they do not appear to produce fertile flowers. 'Veitchii' was the only member of *H. macrophylla* ssp. *macrophylla* with a high level of powdery mildew resistance; while all other resistant cultivars were members of *H. macrophylla* ssp. *serrata*, not

all members of this subspecies are resistant. The information provided in this report should be useful in selecting parents for *H. macrophylla* breeding efforts.

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