Evaluation of Dogwood and Birch Species and Cultivars for Resistance to Key Insect Pests and Diseases[1]

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Abstract

Ten cultivars of dogwoods (*Cornus* spp.) were evaluated in multi-year trials for relative reisistance to the dogwood borer, *Synanthedon scitula* (Harris); cold injury; canker disease, *Botryosphaeria dothidea*; spot anthracnose, *Elsinoe corni*; and powdery mildew, *Oidium* sp., *Microsphaera* sp., and *Phyllactinia* sp. Similarly, eight cultivars of birch (*Betula* spp.) were evaluated for resistance to the birch leafminer, *Fenusa pusilla* (Lepeletier); Japanese beetle, *Popillia japonica* Newman; aphids, *Hamamelistes spinosus* Shimer; the bronze birch borer, *Agrilus anxius* Gory; and leaf-spot, *Cryptocline betularum*. All cultivars of *C. florida*, *C. kousa* and *C. kousa* x *florida* were susceptible to dogwood borer, although the *C. florida* cultivars were surviving better than the others. *Cornus mas* and *C. kousa* cultivars were relatively resistant to powdery mildew while *C. florida* x *kousa* hybrids and *C. florida* 'Cherokee Brave' were intermediately resistant. *Betula platyphylla szechuanica* 'Purpurea' was highly susceptible to the bronze birch borer, whereas *B. nigra* and *B. n.* 'Heritage' were the most susceptible birches to aphid damage. *Betula jacquemontii* was highly susceptible to Japanese beetle defoliation. *Betula pendula*, *B. nigra*, and *B. n.* 'Heritage' were most susceptible to defoliation by birch leaf spot. This study suggests that dogwood and birch cultivars vary in susceptibility to key insect pests and diseases. Planting relatively resistant cultivars may be useful in managing perennial pests in urban landscapes.

Index words: *Cornus* spp., *Betula* spp., dogwood borer, powdery mildew, bronze birch borer, birch leafminer, Japanese beetle, aphids.

Species used in this study: *Cornus florida*; *C. f.* 'Cherokee Chief'; *C. f.* 'Barton White'; *C. f.* 'Cloud 9'; *C. kousa* 'Milky Way'; *C. k.* 'National'; *C. f.* x *k.* 'Galaxy'; *C. f.* x *k.* 'Constellation'; *C. f.* x *k.* 'Star Dust'; *C. mas* 'Gold Glory'; European White birch *(Betula pendula)*; Whitebarked Himalayan birch *(B. jacquemontii)*; Asian White birch *(B. platyphylla szechuanica)*; *B. p. s.* 'Purpurea'; *B. populifolia* 'Whitespire'; Paper birch *(B. papyrifera)*; River birch *(B. nigra)*, and *B. n.* 'Heritage.'

Significance to the Nursery Industry

The demonstrated ability of plants to resist or tolerate key pests is a critical component of Integrated Pest Management (IPM) and Plant Health Care (PHC) programs seeking to implement host plant resistance. With recent restrictions on pesticide use in landscapes, alternative forms of pest management, such as host plant resistance, are becoming more important. This multi-year field study examined the relative resistance of dogwoods (*Cornus* spp.) to the dogwood borer, cold injury, canker disease, spot anthracnose, and powdery mildew, and cultivars of birch (*Betula* spp.) to the birch leafminer, Japanese beetle, aphids, the bronze birch borer, and leaf-spot. The results of this study confirm earlier reports of susceptibility in birch to Japanese beetle defoliation (e.g. *B. jacquemontii*), contradicts reports of dogwood borer resistance (e.g. *C. kousa*), identifies additional resistant cultivars, and provides resistance ratings for cultivars not previously evaluated. Incorporating pest resistant dogwood and birch cultivars and species into landscapes can result in reductions in pesticide use while managing pest populations at acceptable levels.

Introduction

Although the biological reasons are not fully understood, various cultivars within plant species may be more or less prone to attack by arthropod pests and plant pathogens. Even relatively small biochemical, physical or phenological differences between cultivars may affect feeding preferences, survival, and population growth of plant pests.

For many pest problems, use of resistant or tolerant cultivars can significantly reduce plant damage (3). Experience from the National Crabapple Evaluation Program in Kentucky has demonstrated the feasibility of obtaining consistent disease resistance ratings from blocks of different cultivars in the field (4, 5, 6). In a similar field study, flowering crabapple, linden, and rose cultivars in Kentucky were evaluated for attractiveness to Japanese beetle feeding (13). Cultivars of prostate, spreading, and upright junipers were evaluated for Kabatina tip blight in the field and for bagworm feeding on cuttings taken to the laboratory (7, 8, 9). Such studies form the basis of Extension Service recommendations of pest resistant ornamental landscape plant cultivars for clients and for all the 'green' industry including nurserymen, landscapers and designers (15). While these and other similar studies are valuable, much more work is needed to evaluate the numerous landscape plant species and cultivars not yet tested, to address new insect and disease outbreaks, and to make evaluations in diverse geographical locations. Lack of reliable information limits landscape managers from making wider use of resistant cultivars.

Breeding programs for woody ornamentals are often more concerned with desirable horticultural or aesthetic characteristics than with resistance to pests. Few cultivar resistance

[1]Received for publication October 27, 2000; in revised form March 2, 2001. This research was supported in part by the nursery industry through contributions to **The Horticultural Research Institute, 1250 I Street NW, Suite 500, Washington, DC 20005**. We thank Evergreen Nursery Company, Sturgeon Bay, WI, J. Frank Schmidt and Son Nursery, Boring, OR, and Rabbit Run Nursery, Richmond, KY, for donating plants. Jack Doney, David Held, Jason Scanell, Betty Kreuger and Nicole Mason assisted with this project. We extend special thanks to Daniel A. Potter and Ric Bessin for reviewing the manuscript.

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evaluations have been made for woody plant species, and there has been almost no research on this topic in the southeastern United States. Resistance in woody plants is strongly related to general vigor, so regional differences in host susceptibility are likely to be important. Nonetheless, cultivars do exist that are resistant to certain arthropod pests and diseases, and selection of these genotypes can potentially reduce pest problems (11, 12, 16).

The objective of this study was to determine levels of insect and disease resistance among important cultivars of dogwood and birch. Specifically, we examined resistance of 10 cultivars of dogwood (*Cornus* spp.) to the dogwood borer, *Synanthedon scitula* (Harris); cold injury; canker disease, *Botryosphaeria dothidea*; spot anthracnose, *Elsinoe corni*; and powdery mildew, *Oidium* sp., *Microsphaera* sp., *Phyllactinia* sp. and eight cultivars of birch (*Betula* spp.) to the birch leafminer, *Fenusa pusilla* (Lepeletier); Japanese beetle, *Popillia japonica* Newman; aphids, *Hamamelistes spinosus* Shimer; the bronze birch borer, *Agrilus anxius* Gory; and leaf-spot, *Cryptocline betularum*. Some preliminary results have been published (1, 2).

Materials and Methods

Cultivars of dogwood and birch representing a range of genotypes (See the section on Species used in this study.) were obtained from commercial nurseries in 1991 (dogwoods) and 1994 (birch). At the time of planting, the age and height of experimental plants ranged from 1 to 2 yrs, and from 0.15 m (0.5 ft) to 1.85 m (6.0 ft). For insect evaluations, birches and dogwoods were planted in adjacent common plots on a Maury silt loam soil at the University of Kentucky Horticultural Research Farm in Lexington, KY. Cultivars were replicated 10 times (except for *B. nigra* for which we could only obtain five plants) and were planted in a randomized complete block design on 3.1 m (10.0 ft) centers. Plants were mulched and watered at time of planting, and were watered weekly during the first growing season if there was no rainfall. Plots were mowed regularly each season and new mulch was applied as needed about every second year. After the establishment year, no additional water was applied. During this experiment (1991–2000) annual and growing season (April–October) rainfall levels were normal to above normal (42–55 inches annually and 26–30 inches for the growing season), except in 1999 (34 and 16 inches, respectively) when the plots were subject to a severe drought. A second site, about 75 m from the aforementioned one, was established in the same manner for disease evaluations. Thus, there were two sites, each with identical sets of birch and dogwood cultivars growing in similar environments.

Pruning of plants in the insect assessment plots was done early each growing season to remove diseased or dead branches, preventing unwanted disease factors on these plots. Plants in disease assessment plots were treated with insecticides to control insect pests such as borers. Plants in the dogwood insect assessment plots were treated with fungicides primarily to control powdery mildews (Banner, 1.26 ml/gal; Cleary's 3336, 3.375 g/gal; first treatment in late May with 3 or 4 more treatments every 2 to 3 wks; materials were alternated). Also, as the birches attained heights of 3.1–4.6 m (10.0–15.0 ft), lower branches on birch trunks were removed up to 1.2 m (4.0 ft) to allow maintenance equipment to move through the plots. Dogwood cultivars included *Cornus florida* (white), *C. f.* 'Cherokee Chief', *C. f.* 'Barton White', *C. f.* 'Cloud 9', *C. kousa* 'Milky Way', *C. k.* 'National', *C. f.* x *k* 'Galaxy', *C. f.* x *k.* 'Constellation', *C. f.* x *k.* 'Star Dust', and *C. mas* 'Gold Glory.' Birch cultivars included *Betula pendula* (European White), *B. jacquemontii* (Whitebarked Himalayan), *B. platyphylla szechuanica* (Asian White), *B. p. s.* 'Purpurea', *B. populifolia* 'Whitespire', *B. papyrifera* (Paper), *B. nigra* (River), and *B. n.* 'Heritage.'

Evaluations of insect pest damage on dogwood and birch cultivars were recorded in 1996, 1998 and 2000 by using the following rating system: 0 = No pest activity (0% damage), 1 = Low pest activity (1–33% damage or one borer), 2 = Moderate pest activity (34–66% damage or two borers), 3 = Severe pest activity (67–100% damage or ≥ three borers). Dogwoods were evaluated on May 28, 1998, and June 14–15, 2000, for the primary pest, the dogwood borer, *Synanthedon scitula* (Harris) (Lepidoptera: Sesiidae) by examining trunks and lower branches for borer activity including dead areas with feeding galleries, loose bark, frass, and silk webbing. Distinct areas of borer activity were counted as separate borers and occasionally borer larvae were found when removing bark above damaged areas. Birch pests evaluated included the bronze birch borer, *Agrilus anxius* Gory (Coleoptera: Buprestidae), aphids, *Hamamelistes spinosus* Shimer (Homoptaera: Aphididae), Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae), and birch leafminer, *Fenusa pusilla* (Lepeletier) (Hymenoptera: Tenthredinidae). Birch leafminer and Japanese beetle damage was evaluated on August 21, 1996, and July 24, 1998, by visually estimating the percent damaged foliage on each tree. Aphid damage was evaluated on May 16, 1996, and May 28, 1998, by visually estimating the percent damaged foliage on each tree. Bronze birch borer damage was evaluated on May 28, 1998, and June 14, 2000, by counting emergence holes in each tree. Old emergence holes were not counted.

Evaluations of disease damage on dogwoods were done in 1994 and 1997 and on birch in 1996. In 1994, dogwoods were evaluated for cold injury, canker disease, *Botryosphaeria dothidea*, and spot anthracnose, *Elsinoe corni*, on June 22 and for powdery mildew, *Oidium* sp., on July 17. Cold injury evaluations were done by estimating the percentage of foliage and shoots showing symptoms related to cold temperatures. Powdery mildew was rated as follows: 0 = none, 1 = trace, 2 = 1–5% leaves with fungal signs, 3 = 6–10% leaves with fungal signs. Spot anthracnose was rated as follows: 0 = none, 1 = trace to 5% leaves with spots. Canker disease was rated by estimating percent twigs and branches showing canker symptoms and signs.

In 1997, dogwoods were again evaluated for powdery mildew, *Microsphaera* sp., *Phyllactinia* sp., on June 10, July 3, August 3, and September 4. Because powdery mildew had become more severe each year, evaluation was done by estimating the percentage of leaves infected and percentage of leaf area affected on infected leaves. A powdery mildew index was derived from incidence and severity estimates recorded as 0 to 10 with 10 = 100%.

In 1996, birch were evaluated for leaf-spot, *Cryptocline betularum*, on July 10, August 13 and 21, and October 8. Trees were evaluated by visually estimating percentage of leaves with leaf-spot symptoms (incidence), and mean proportion of affected tissues on symptomatic leaves (severity). A general index of leaf-spot was calculated the same way as for powdery mildew on dogwoods.

Table 1. Reactions of dogwoods (*Cornus* sp.) to dogwood borer (*Synanthedon scitula*), 1998 and 2000.

	1998		2000	
Species/cultivar	Avg ratings[z]	% infested	Avg ratings[z]	% infested
Cornus florida wild type	2.0ab[y]	90	1.4a[y]	70
C. florida 'Cherokee Chief'	1.5abc	90	1.0a	60
C. florida 'Barton White'	1.4abc	70	1.3a	60
C. florida 'Cloud 9'	1.1 bc	50	0.7a	40
C. kousa 'Milky Way'	2.1ab	89	0.9a	44
C. kousa 'National'	2.9a	100	0.9a	60
C. kousa x *florida* 'Galaxy'	2.1ab	88	1.5a	88
C. kousa x *florida* 'Constellation'	2.2ab	83	1.5a	83
C. kousa x *florida* 'Star Dust'	1.8abc	80	1.7a	80
C. mas 'Gold Glory'	0.2c	10	0.0a	0

[z]Rating system: 0 = No pest activity (0 borers); 1 = Low pest activity (1 borer); 2 = Moderate pest activity (2 borers); 3 = Severe pest activity (≥ 3 borers)

[y]Means followed by the same letter do not differ significantly (Tukey (HSD), P = 0,05)

Analysis and presentation of data. Insect damage ratings were subjected to one-way analysis of variance. Where significant differences in ratings were indicated, Tukey's HSD multiple range test also was computed. The 1994 dogwood disease and cold injury ratings were subjected to the Duncan's New Multiple Range Test. The 1997 dogwood powdery mildew evaluations were subjected to the Waller-Duncan k-ratio test and the 1996 birch evaluations were analyzed using the General Linear Models and Duncan's New Multiple Range Test.

Results and Discussion

Insect evaluations. Dogwood Borer (*Synanthedon scitula*)—1998 and 2000 (Table 1). Nearly all the replicates of the *C. florida* cultivars had relatively low borer activity. The *C. kousa* cultivars and the *C. f.* x *k.* crosses experienced higher mortality, with the most severe borer activity on *C. k.* 'National' and *C. f.* x *k.* 'Constellation' in 1998 and on all the *C. f.* x *k.* crosses in 2000. These results contradict reports that *C. kousa* is resistant to the dogwood borer (10). Lowest borer activity was on *C. mas* 'Gold Glory' (Cornelian Cherry), which has characteristics quite different from the other dogwoods.

Bronze Birch Borer (*Agrilus anxius*)—1998 and 2000 (Table 2). In 1998, cultivars which had no borer emergence holes included *Betula jacquemontii* (Whitebarked Himalayan), *B. papyrifera* (Paper), *B. populifolia* 'Whitespire', and *B. nigra* (River). In 2000, cultivars for which surviving trees had no borer emergence holes included *B. papyrifera* (Paper), *B. populifolia* 'Whitespire', *B. nigra* (River) and *B. n.* 'Heritage.' *B. platyphylla szechuanica* 'Purpurea' was extremely susceptible, averaging ca. 33 and 30 exit holes per tree in 1998 and 2000 respectively. Only five dead trees remained standing for evaluation in 2000. Other cultivars that experienced high mortality from borers were *B. pendula* and *B. platyphylla szechuanica*. Exit holes on most cultivars were predominantly on the south/southwest side of trees. In 1998, borers in *B. nigra* 'Heritage' created larger exit holes and may have been flatheaded appletree borers, *Chrysobothris femorata* (Olivier). Birches reported to be resistant to or tolerant of bronze birch borer attack include *B. platyphylla japonica* and *B. nigra* (10). Our study supports *B. nigra* as being resistant, however, the *B. platyphylla* subspecies was highly susceptible.

Aphids (*Hamamelistes spinosus*)—1996 and 1998 (Table 3). During both years, aphid numbers were generally low on all cultivars except *Betula nigra* and *B. n.* 'Heritage.' The ratings were noticeably lower in 1998, probably because the evaluation was done at a later date than in 1996, resulting in lesser observed pest activity. Johnson and Lyon (10) state that at least in New York, most activity of *H. spinosus* on birch is completed by the end of June. Characteristic damage is corrugation of leaves with eventual leaf death and drop. This aphid utilizes witch-hazel, *Hamamelis* spp., as an alternate host, although none were observed near the plots. Several species of lady beetles (Coccinelidae) were attracted to infested leaves.

Table 2. Reactions of birch (*Betula* sp.) to bronze birch borer (*Agrilus anxius*), 1998 and 2000.

	1998		2000	
Species/cultivar	Avg ratings[z]	% infested	Avg ratings[z]	% infested
Betula pendula (European White)	0.3b[y]	10	3.0a[y]	100
B. jacquemontii (Whitebarked Himalayan)	0.0b	0	—	0
B. platyphylla szechuanica (Asian White)	0.1b	11	3.0a	100
B. platyphylla szechuanica 'Purpurea'	3.0a	100	3.0a	100
B. populifolia 'Whitespire'	0.0b	0	0.0b	0
B. papyrifera (Paper)	0.0b	0	0.0b	0
B. nigra (River)	0.0b	0	0.0b	0
B. nigra 'Heritage'	0.3b	11	0.0b	0

[z]Rating system: 0 = No pest activity (0 borers); 1 = Low pest activity (1 borer); 2 = Moderate pest activity (2 borers); 3 = Severe pest activity (≥ 3 borers)

[y]Means followed by the same letter do not differ significantly (Tukey (HSD), P = 0,05)

Table 3. **Reactions of birch (*Betula* sp.) to aphids (*Hamamelistes spinosus*), 1996 and 1998.**

	1996		1998	
Species/cultivar	**Avg ratings[z]**	**% infested**	**Avg ratings[z]**	**% infested**
Betula pendula (European White)	0.4bc[y]	40	0.0b[y]	0
B. jacquemontii (Whitebarked Himalayan)	0.1bc	10	0.0b	0
B. platyphylla szechuanica (Asian White)	0.2bc	22	0.0b	0
B. platyphylla szechuanica 'Purpurea'	0.6b	60	0.0b	0
B. populifolia 'Whitespire'	0.2bc	20	0.0b	0
B. papyrifera (Paper)	0.0c	0	0.0b	0
B. nigra (River)	2.0a	100	1.0a	100
B. nigra 'Heritage'	2.3a	100	1.0a	100

[z]Rating system: 0 = No pest present (0% damage); 1 = Low pest numbers (1–33% damage); 2 = Moderate pest numbers (34–66% damage); 3 = High pest numbers (67–100% damage)

[y]Within columns, means followed by the same letter do not differ significantly (Tukey (HSD), P = 0.05)

Japanese Beetle (*Popillia japonica*)—1996 and 1998 (Table 4). *Betula jacquemontii* (Whitebarked Himalayan) received the most damage from adult Japanese beetle feeding during both years. By 1998, these trees remained quite small at 1.5–1.8 m (5–6 ft) tall compared to all other cultivars that were typically 3.7–6.2 m (12–20 ft) tall. By 2000, all of the *B. jacquemontii* had died. Similarly, Ranney and Walgenback (14) found that *B. jacquemontii* was the most susceptible of the nine birch taxa they evaluated for resistance to Japanese beetle feeding in North Carolina. *B. papyrifera* also sustained significant damage in our study in 1998. *B. pendula* (European White) showed the most resistance to beetle feeding in 1996 with only one plant out of 10 with low level damage.

Birch Leafminer (*Fenusa pusilla*)—1996 and 1998. Birch leafminers never became a serious problem in the test plots. A few mined leaves were noted on all cultivars except *Betula platyphylla szechuanica* 'Purpurea' in 1996. In 1998, *B. papyrifera* (Paper) was the only cultivar on which any mines were observed.

Disease evaluations. Reactions of Dogwood Cultivars to Diseases and Cold Temperature Injury—1994 (Table 5). The trees were exposed to extremely low temperatures (–29C on January 18) and also a local frost on May 2. Tree leaves and shoots showed dieback, discolored phloem and cambium, and tree death from the combined effects of cold temperature and frost. *Botryosphaeria* canker/dieback disease pressure was very low and was recognized by the brown color of infected areas and identification of fungal fruiting structures in the cankers. Powdery mildew disease pressure was moderate and the location of mildew signs on young and mature leaves and shoots was variable; spot anthracnose pressure was low. Significant differences in cold injury symptoms were observed among the dogwoods with hybrids tending to show the least injury. Powdery mildew and spot anthracnose incidence varied among the dogwood cultivars. Levels of *Botryosphaeria* canker were not significantly different among the four dogwood species represented.

Reactions of Dogwood Cultivars to Powdery Mildew—1997 (Table 5). The first signs of powdery mildew were detected on May 30 on *C. florida*. Powdery mildew incidence increased, especially in early July, reaching 100% on susceptible trees. Disease pressure in the plots was high, and susceptible *C. florida* trees were severely affected with scorched, curled, mildewed, and discolored leaves. All *C. florida* cultivars, with the exception of 'Cherokee Brave' were susceptible to powdery mildew. Of the others, *C. mas* and *C. kousa* are resistant, and the *C. florida* x *C. kousa* hybrids, along with *C. florida* 'Cherokee Brave' are intermediate. A progressive increase in the disease index, reflecting both incidence and severity, occurred from early June to early September.

Reactions of Birch Cultivars to Birch Leaf-spot—1996 (Table 6). Leaf-spot symptoms typical of those caused by *Cryptocline betularum* developed in early May on *Betula pendula* and *B. platyphylla szechuanica* but no significant differences in disease index were detected until July 10.

Table 4. **Reactions of birch (*Betula* sp.) to Japanese beetle (*Popillia japonica)* defoliation, 1996 and 1998.**

	1996		1998	
Species/cultivar	**Avg ratings[z]**	**% infested**	**Avg ratings[z]**	**% infested**
Betula pendula (European White)	0.1c[y]	10	0.3d[y]	33
B. jacquemontii (Whitebarked Himalayan)	1.9a	100	2.8a	100
B. platyphylla szechuanica (Asian White)	0.9b	89	0.3d	33
B. platyphylla szechuanica 'Purpurea'	0.9b	90	0.4cd	40
B. populifolia 'Whitespire'	1.0b	100	1.0c	100
B. papyrifera (Paper)	1.0b	100	1.7b	100
B. nigra (River)	1.0b	100	0.2d	20
B. nigra 'Heritage'	1.0b	100	0.4cd	38

[z]Rating system: 0 = No pest present (0% damage); 1 = Low pest numbers (1–33% damage); 2 = Moderate pest numbers (34–66% damage); 3 = High pest numbers (67–100% damage)

[y]Within columns, means followed by the same letter do not differ significantly (Tukey (HSD), P = 0.05)

Table 5. Reactions of dogwoods (*Cornus* sp.) to diseases and cold temperature injury, 1994 and 1997.

Species/cultivar	1994 Percent cold injury[z]	1994 Powdery mildew[y]	1994 Spot anthracnose[x]	1997 Powdery mildew index[w] June 10	July 3	August 3	Sept 4
Cornus mas 'Golden Glory'	0.1d[v]	0.1c	0.2b	0.00a[u]	0.00a	0.00a	0.00a
C. kousa 'Milkyway'	0.4cd	0.2c	0.1b	0.00a	0.00a	0.10a	0.01a
C. kousa 'National'	2.3bc	0.6bc	0.2b	0.00a	0.00a	0.02ab	0.02ab
C. florida x *kousa* 'Galaxy'	0.0d	0.4c	0.2b	0.01a	0.01a	0.21abc	0.20abc
C. florida x *kousa* 'Stardust'	0.1d	0.7bc	0.1b	0.03a	0.12ab	0.50cd	0.40abcd
C. florida x *kousa* 'Constellation'	0.0d	0.2c	0.2b	0.01a	0.12ab	0.24abc	0.40abcd
C. florida 'Cherokee Brave'	NA	NA	NA	0.00a	0.00a	0.31bc	0.49bcde
C. florida wild type	6.2a	2.3a	0.9a	0.09a	0.34bc	0.51cd	0.65cde
C. florida 'Barton White'	2.1bc	1.5ab	0.3b	0.03a	0.32bc	0.51cd	0.71de
C. florida 'Cloud Nine'	1.0cd	1.5ab	0.3b	0.03a	0.43c	0.49cd	0.78de
C. florida 'Cherokee Chief'	4.2ab	1.8a	0.8a	0.03a	0.49c	0.66d	0.90e

[z]Percent foliage and shoots showing symptoms related to cold temperature injury.

[y]Powdery mildew disease rating: 0 = none, 1 = trace, 2 = 1–5% leaves with fungal signs, 3 = 6–10%.

[x]Spot anthracnose rating: 0 = none, 1 = trace to 5% leaves with spots.

[w]Powdery mildew index is derived from incidence and severity estimates recorded as 0 to 10 with 10 = 100%; The index is calculated by arcsine square root transformation of [incidence times (severity / 100)]. If all parts of all leaves had symptoms, the index would be 1.57; where no disease symptoms are recorded, the index would be 0.

[v]Means for 1994 data in a column followed by the same letter are not significantly different by DNMRT, P = 0.05.

[u]Means for 1997 data in a column followed by the same letter are not significantly different by Waller-Duncan k-ratio test (k = 100, P = 0.05).

Table 6. Reactions of birch (*Betula* sp.) to birch leaf-spot, 1996.

Species/cultivar	Leaf-spot index[z] July 10[y]	August 13	August 21	October 8	Percent defoliation October 8
Betula pendula (European White)	0.31a	0.57a	0.56a	0.29a	54a
B. nigra (River)	0.31a	0.36b	0.47ab	0.27a	29b
B. nigra 'Heritage'	0.20b	0.33b	0.46ab	0.16a	29b
B. platyphylla szechuanica (Asian White)	0.16b	0.25bc	0.33b	0.24a	16c
B. platyphylla szechuanica 'Purpurea'	0.04c	0.15cd	0.12c	0.11a	3cd
B. populifolia 'Whitespire'	0.04c	0.08d	0.06c	0.15a	1d
B. papyrifera (Paper)	0.01c	0.03d	0.08c	0.17a	1d
B. jacquemontii (Whitebarked Himalayan)	0.00c	0.01d	0.02c	0.31a	16c

[z]A general index of leaf-spot disease was calculated as follows: arcsine square root transformation of [incidence times (severity / 100)].

[y]Within columns, means followed by the same letter do not differ significantly (DNMRT, P = 0.05)

Symptoms continued to increase throughout the season. Although there were no significant block effects detected, there was a much larger than anticipated level of variability of symptom expression within each cultivar. *B. platyphylla szechuanica* was the most variable; an individual tree had a disease index of 0.01 to 0.10 across the season, and a second individual ranged from 0.50 to 0.80 across the season. The cultivars *B. pendula*, *B. nigra* and *B. nigra* 'Heritage' appeared most susceptible whereas *B. jacquemontii* and *B. papyrifera* appeared the least susceptible. Leaf spot incidence and severity differences were masked by October because disease leaves dropped. Defoliation ratings made at the same time confirmed relative disease susceptibility.

Literature Cited

1. Doney, J., J. Hartman, M. Johnson, W. Fountain, and R. McNiel. 1995. Reactions of dogwoods to diseases and cold temperature injury, 1994. Biological and Cultural Tests 10:66.

2. Doney, J., J. Hartman, M. Johnson, W. Fountain, and R. McNiel. 1998. Reactions of dogwood cultivars to powdery mildew, 1997. Biological and Cultural Tests 13:53.

3. Hartman, J.R., J.L. Gerstle, M. Timmons, and H.G. Raney. 1986. Urban integrated pest management in Kentucky—A case study. J. Environ. Hort. 4:120–124.

4. Hartman, J.R., B. Clinton, and R.E. McNiel. 1988. Reactions of flowering crabapple cultivars to foliar diseases, 1987. Biological and Cultural Tests 3:81.

5. Hartman, J.R., B. Clinton, and R.E. McNiel. 1989. Reactions of flowering crabapple cultivars to foliar diseases, 1988. Biological and Cultural Tests 4:79.

6. Hartman, J.R., B.S. Kennedy, and R.E. McNiel. 1990. Reactions of flowering crabapple cultivars to foliar diseases, 1989. Biological and Cultural Tests 5:91.

7. Hartman, J., J. Doney, M. Johnson, and W. Fountain. 1994. Evaluation of juniper cultivars for susceptibility to Phomopsis and Kabatina blights, 1993. Biological and Cultural Tests 9:161.

8. Hartman, J., J. Doney, M. Johnson, W. Fountain, and R. McNiel. 1995. Evaluation of juniper cultivars for susceptibility to Kabatina blight, 1994. Biological and Cultural Tests 10:68.

9. Johnson, M.P., D.A. Potter, and G.S. Gilmore. 1993. Suitability of juniper cultivars for survival and growth of the bagworm. J. Environ. Hort. 11:167–170.

10. Johnson, W.T. and H.H. Lyon. 1988. Insects that Feed on Trees and Shrubs, 2nd edition. Cornell University Press, Ithaca, NY, 556 pp.

11. Morgan, D.L., G.W. Frankie, and M.J. Gaylor. 1978. Potential for developing insect-resistant plant materials for use in urban environments. *In*: Perspectives in Urban Entomology, G.W. Frankie and C.S. Koehler (eds.), Academic Press, New York, pp. 267–294.

12. Potter, D.A. 1986. Urban landscape pest management. *In*: Advances in Urban Pest Management, G.W. Bennett and J.M. Owens (eds.). Van Nostrand Reinhold Co., New York, pp. 219–252.

13. Potter, D.A., P.G. Spicer, D. Held, and R.E. McNiel. 1998. Relative susceptibility of cultivars of flowering crabapples, lindens, and roses to defoliation by Japanese beetles. J. Environ. Hort. 16:105–110.

14. Ranney, T.G. and J.F. Walgenbach. 1992. Feeding preferences of Japanese beetles for taxa of birch, cherry and crabapple. J. Environ. Hort. 10:177–180.

15. Smith-Fiola, D. 1995. Pest resistant ornamental plants. Rutgers University Cooperative Extension Service, Ocean County, NJ. 23 pp.

16. Walker, J.T. 1982. Disease resistance among woody ornamentals. *In*: Diseases of Woody Ornamental Plants and Their Control in Nurseries, R.K. Jones and R.C. Lambe (eds.). North Carolina Agricultural Extension Service, pp. 112–114.