

# Four Cultivars of Japanese Barberry Demonstrate Differential Reproductive Potential under Landscape Conditions

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**Abstract.** While Japanese barberry (*Berberis thunbergii* DC.) is an acknowledged invasive plant naturalized throughout the eastern and northern U.S., the danger posed by its popular horticultural forms is unknown and controversial. This work analyzed the reproductive potential and seedling growth of four ornamental genotypes important to the nursery industry. Fruit and seed production was quantified in 2001, 2002, and 2003 for multiple landscape plants of *B.t.* var. *atropurpurea*, ‘Aurea’, ‘Crimson Pygmy’, and ‘Rose Glow’. The average number of seeds produced per landscape specimen ranged from lows of 75 and 90 for ‘Aurea’ and ‘Crimson Pygmy’ to 2968 for var. *atropurpurea* and 762 for ‘Rose Glow’. Seed production relative to canopy surface area for ‘Rose Glow’ was similar to ‘Aurea’ and ‘Crimson Pygmy’ and all three cultivars were less prolific than var. *atropurpurea* in this regard. Cleaned and stratified seeds from var. *atropurpurea*, ‘Crimson Pygmy’ and ‘Rose Glow’ showed an average greenhouse germination rate of 70% to 75%, while ‘Aurea’ yielded 46% germination. A subpopulation of seedlings from each genotype accession was grown further outdoors in containers for a full season to ascertain seedling vigor and development. The vigor of 1-year-old seedlings, as measured by dry weight of canopy growth, for progeny derived from ‘Aurea’ (0.70 g) and ‘Crimson Pygmy’ (0.93 g) was significantly less than var. *atropurpurea* (1.20 g) and ‘Rose Glow’ (1.33 g). These results demonstrate that popular Japanese barberry cultivars express disparate reproductive potential that, after further study, may be correlated with invasive potential. Some popular commercial cultivars may pose significantly less ecological risk than others.

Nonnative invasive species imperil natural ecosystems and rank second only to habitat destruction as a threat to biodiversity (Wilcove et al., 1998). Invasive exotic plants establish self-sustaining populations in natural landscapes which may perturb the composition of native plant communities through physical displacement and other means (Webb et al., 2000; Woods, 1993). Additionally, invasive plants can have detrimental effects on native herbivores (Tallamy, 2001), alter the physical and chemical properties of soil (Ehrenfeld et al., 2001; Heneghan et al., 2002), modify ecosystem processes such as hydrology regimes and nutrient cycling (Gordon, 1998; Vitousek et al., 1996) and incur substantial economic costs related to their management and control (Pimentel et al., 2000).

According to Reichard and White (2001), >80% of the 235 woody plants considered invasive across the U.S. were introduced primarily for horticultural purposes. This group includes Japanese barberry (*Berberis thunbergii* DC.), a shrub grown in the U.S. as a landscape ornamental since 1875 that in the decades following its introduction began spreading from cultivation to establish populations in unmanaged areas

(Silander and Klepeis, 1999). This plant is currently considered naturalized in >30 central and eastern states (USDA, 2005) where it may form vast thickets that threaten native plant communities and interfere with human activities in forests, woodlands, pastures, waste places and other areas (Silander and Klepeis, 1999). Rising concern over these destructive habits has prompted state legislatures across the U.S. to consider banning this and other commercial plants with invasive traits (Harrington et al., 2003; Mezitt and Regelbrugge, 2002).

Japanese barberry is represented chiefly in garden cultivation by >40 cultivars which possess unique traits related mainly to foliage color and growth habit (Dirr, 1998). These ornamental clones currently constitute a \$5 million crop for Connecticut’s nursery industry (Heffernan, 2005) and hold tremendous market share across the nation, as well (Steffey, 1985). Although little is known regarding the potential for cultivars of Japanese barberry and other invasive ornamental plants to contribute to invasive populations (Mezitt and Regelbrugge, 2002), much of the legislation considered by lawmakers across the country banning these crops makes no distinction between a species and its garden cultivars (Harrington et al., 2003; American Nurseryman, 1999). Given the economic stakes of such prohibitions and the paucity of knowledge available regarding the invasion biology of horticultural plants, the invasive potential of Japanese barberry cultivars is a compelling area for study.

Since barberry migrates to new environments primarily through bird- and animal-mediated dispersal of the seeds contained within its red berries (Silander and Klepeis, 1999), quantifying the reproductive potential of *B. thunbergii* cultivars is a logical method of estimating the invasive potential of these forms. Similar methods have been previously employed to study cultivars of other invasive plants including the ‘Compactus’ clone of *Euonymus alatus* (winged euonymus) (Ellis and Manley, 2003), the cultivars ‘Asplenifolia’ and ‘Columnaris’ of *Rhamnus frangula* (glossy buckthorn) (Wheeler and Starrett, 2001), a wide variety of *Buddleia* spp. (butterfly bush) forms (Anisko and Im, 2001) and a limited number of barberry species and cultivars (Lovinger and Anisko, 2004). These investigations, which primarily utilized seed production and germination potential as predictors of invasive capacity, found differences among cultivated genotypes.

Our research analyzed the reproductive potential of four popular garden forms of Japanese barberry using multiple parameters. Studies were undertaken to measure the fruit and seed production of cultivar specimens, the viability of these seeds and the vigor of the resultant seedling progeny. Most previous research on the invasive dynamics of Japanese barberry, such as that conducted by Silander and Klepeis (1999), Ehrenfeld et al. (1999, 2001) and Kourtev et al. (1999, 2003), has focused exclusively on the green-leaf, large-growing wild type plants that comprise the vast majority of invasive populations. These plants differ starkly, however, from the dwarf and/or colored-leaf genotypes that constitute most of the contemporary barberry nursery crop. Lovinger and Anisko (2004) estimated the invasive potential of a limited number of *B. thunbergii* cultivars by measuring fruit production per unit stem length and seed germination potential. While germination rates differed little, widely varying levels of fruit production per unit stem length were found (Lovinger and Anisko, 2004). This estimate of fruit production was correlated to presumed invasive potential despite the observations of Arena and Vater (2003), Ehrenfeld (1999) and others that fruit production among shoots within an individual barberry plant varies widely. Our research, which examined multiple reproduction and growth parameters and employed total fruit harvest, provides a more complete understanding of the reproductive potential of important horticultural genotypes.

## Materials and Methods

*Cultivar fruit and seed production.* In Fall 2001, 2002, and 2003, ripe fruits were collected from four popular Japanese barberry genotypes of verifiable nomenclature located in botanical institutions, commercial nurseries and landscapes throughout the northeastern U.S. (Table 1). The use of established landscape specimens for quantification of fruiting is a prudent strategy since this approach elucidates a clear picture of the reproductive potential of each genotype under typical real world

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landscape situations. Material was sampled from 15 replications of *B. t.* var. *atropurpurea*, 13 'Aurea', 39 'Crimson Pygmy' (syn. 'Atropurpurea Nana') and 17 'Rose Glow' during the research period to resolve overall trends between cultivars and account for variables such as plant age and cultural conditions (Table 1). Both var. *atropurpurea* and 'Rose Glow' are large-growing (1.8 to 2.4 m tall and wide) upright plants with purple foliage that is variegated in the case of 'Rose Glow' (Dirr, 1998). By contrast, the most popular commercial cultivar (Mark Sellow, Prides Corner Farms, Conn., personal communication), 'Crimson Pygmy' is a low mounded plant with purple leaves that seldom exceeds 1 m in height and spread while 'Aurea' forms a rounded, medium-sized shrub (1.2 to 1.8 m tall and wide) bearing yellow foliage (Dirr, 1998).

Most study plants were harvested com-

pletely by manually stripping fruit to accurately measure reproductive potential and resultant seedling vigor. It was impossible to completely harvest the fruit of some shrub specimens; therefore only seed germination and seedling vigor data were collected for these accessions (Table 1). Some plants were sampled in more than one year during the study period. Study specimens were generally growing under conditions deemed optimal for *B. thunbergii* (Table 1), an adaptable plant that requires only high light and well-drained soil to reach its full potential (Dirr, 1998).

At the time of collection, the canopy of each individual mother plant was measured (height, width and depth) to facilitate assessment of fruit and seed production relative to canopy surface area via geometric calculation [formula:  $S_a = \pi (h^2 + r^2)$ ] (South, 2003). Each plant was considered a spherical dome for these calcula-

tions and the radius parameter was deduced by averaging width and depth measurements and dividing by two. Assessment of relative propagule production between cultivars using canopy dome surface area estimation is an appropriate strategy given the typical mature shape of Japanese barberry specimens and their fruit production which is located primarily on the exterior of the plant canopy. Furthermore, Arena and Vater (2003) noted that the fruit production of *Berberis buxifolia* (Magellan barberry) was greatest on 1-year-old shoots which are generally located on the plant periphery. Fruit accessions were counted and cleaned by maceration to extract seeds which were then subjected to a two month period of cold stratification in moist sterilized sand to facilitate germination according to Dirr and Heuser (1987).

*Cultivar seed germination and seedling*

Table 1. Background information for Japanese barberry (*Berberis thunbergii*) ornamental genotype accessions examined during the study period.

Accession ID	Year <sup>z</sup>	Data use <sup>y</sup>	Source <sup>x</sup>	Plant age (y) <sup>w</sup>	Exposure <sup>v</sup>	Canopy dimensions (cm) <sup>u</sup>		
						Ht	Width	Depth
<i>var. atropurpurea</i>								
01-BR01	1,2,3	1,2	CT1	15	FS	193	224	183
01-PF04	1	2	NY1	45	FS	157	142	104
01-PF09	1	2	NY1	45	FS	152	165	152
01-SCH01	1	2	MA1	NA	NA	NA	NA	NA
02-7	1	2	NY1	45	FS	NA	NA	NA
02-10	1	2	NY1	45	FS	NA	NA	NA
02-25	2	1,2	MA2	12	FS	132	183	163
02-27	2	1,2	MA2	12	FS	183	183	152
02-28	2	1,2	MA2	12	FS	160	160	102
02-59	2,3	1,2	CT2	10	FS	114	152	137
02-70	2	2	NY2	NA	NA	NA	NA	NA
03-57	3	1	MA2	12	FS	147	163	114
03-58	3	1	MA2	12	FS	163	127	114
03-62	3	1	MA2	12	FS	152	172	114
03-63	3	1	CT3	35	FS	208	279	279
'Aurea'								
01-NYBG23	1	2	NY3	5	FS	NA	NA	NA
02-14	2	1,2	CT4	15	LS	147	152	137
02-15	2	1,2	CT4	15	LS	135	127	122
02-16	2	1,2	CT4	15	LS	102	127	112
02-17	2	1,2	CT4	15	LS	122	127	102
02-18	2	1,2	CT4	15	LS	137	142	132
02-66	2	1,2	CT2	10	FS	41	56	41
02-67	2	2	CT2	10	FS	NA	NA	NA
02-72	2	2	NY4	NA	NA	NA	NA	NA
03-41	3	1	CT2	12	LS	74	94	89
03-53	3	1	NY1	5	FS	58	61	53
03-54	3	1	NY1	5	FS	53	46	46
03-55	3	1	NY5	12	FS	112	117	102
'Crimson Pygmy'								
01-AA03	1,2	1,2	MA3	50	LS	64	114	89
01-BR03	1,2	1,2	CT1	15	FS	20	43	33
01-NYBG1	1	1,2	NY3	10	LS	84	104	79
01-NYBG7	1	1,2	NY3	10	LS	69	76	61
01-PF08	1,3	1,2	NY1	40	FS	91	114	107
01-PF02	1,3	1,2	NY1	40	FS	81	86	84
02-5	2	1,2	NY2	40	FS	97	152	132
02-20	2	1,2	MA2	10	FS	56	79	76
02-21	2	1,2	MA2	10	FS	64	71	51
02-22	2	1,2	MA2	10	FS	64	89	71
02-51	2	2	OH1	NA	NA	NA	NA	NA
02-63	2	1,2	CT2	20	LS	84	114	102
02-73	2	2	CT5	NA	NA	NA	NA	NA
03-13	3	1	CT2	20	LS	71	107	102
03-27	3	1	CT2	10	FS	46	61	56
03-28	3	1	CT2	10	FS	43	61	61
03-29	3	1	CT2	10	FS	48	66	64
03-30	3	1	CT2	10	FS	48	76	66
03-31	3	1	CT2	10	FS	53	71	69
03-32	3	1	CT2	10	FS	46	71	66

vigor. Following stratification in 2001, 2002, and 2003, up to 200 seeds from each accession (some seed lots comprised fewer than 200 seeds) were sown on May 1 in rows in heavy plastic flats (Kadon Corp., Dayton, Ohio) using Metro Mix 360 Growing Medium (Scotts Co., Marysville, Ohio). Individual seed accessions derived from the same cultivar were randomized within multiple seed flats. The flats were placed in a greenhouse with set points of 21 °C day and 17 °C night and natural lighting. The flats were irrigated and weeded as needed and monitored weekly for germination rate and seedling survival.

After 6 weeks, 15 (in 2002) or 30 seedlings (in 2001) were randomly selected from each accession and potted into 1040-mL black plastic square pots (Belden Plastics, Roseville, Minn.) using Metro Mix 510 Growing Medium (Scotts, Co., Marysville, Ohio). Seedlings

were not grown further in 2003. Potted plants were randomized in outdoor cold frames and grown for a full season (June to November) at 100% ambient sunlight. The plants were hand-weeded, irrigated as needed and provided a soluble 20N-8.74P-116.6K fertilizer (Peters 20-10-20 Fertilizer, Scotts Co., Marysville, Ohio) at 150 ppm N every 2 weeks during active growth. Following leaf abscission, these plants were harvested by unpotting them, dislodging loose media and thoroughly washing the roots to remove all remaining substrate. The root mass was severed from the top growth at the soil line and the dimensions (height and width) of the crown and its number of branches were determined. All tissue was placed in a drying oven at 70 °C for 2 weeks before dry weight measurements were recorded.

*Statistical analysis.* Studies measuring fruit/seed production and germination for

cultivars were repeated for 3 years, while measurements of seedling vigor were repeated twice. Data were combined by variable for statistical analysis. A completely randomized design was utilized for all studies and analyses of variance (ANOVA) and mean separation using Fisher's least significant difference ( $P \leq 0.05$ ) were performed on data using SAS for Windows Version 8.0 (SAS Institute, Cary, N.C.) and PROC GLM.

## Results and Discussion

*Cultivar fruit and seed production.* A fairly consistent trend emerges when comparing measures of reproductive potential among the four ornamental study genotypes. The large-growing purple-leaf forms var. *atropurpurea* and 'Rose Glow' produced more fruit and seeds than the smaller growing 'Aurea' and

Table 1 (continued). Background information for Japanese barberry (*Berberis thunbergii*) ornamental genotype accessions examined during the study period.

Accession ID	Year <sup>a</sup>	Data use <sup>b</sup>	Source <sup>c</sup>	Plant age (y) <sup>w</sup>	Exposure <sup>v</sup>	Canopy dimensions (cm) <sup>u</sup>		
						Ht	Width	Depth
<b>'Crimson Pygmy'</b>								
03-39	3	1	CT2	20	LS	56	107	84
03-42	3	1	CT2	20	LS	53	84	84
03-43	3	1	CT2	20	LS	69	107	81
03-44	3	1	CT2	20	LS	58	114	112
03-45	3	1	CT2	20	LS	71	137	102
03-69	3	1	CT6	12	FS	94	142	122
03-70	3	1	CT6	12	FS	91	127	81
03-71	3	1	CT6	12	FS	102	132	112
03-72	3	1	CT7	15	FS	64	122	86
03-73	3	1	CT7	15	FS	56	122	107
03-74	3	1	CT7	15	FS	64	117	107
03-75	3	1	CT7	15	FS	64	99	91
03-76	3	1	CT7	15	FS	61	122	117
03-77	3	1	CT7	15	FS	58	107	91
03-78	3	1	CT8	15	FS	64	127	122
03-79	3	1	CT8	15	FS	58	127	97
03-80	3	1	CT9	20	FS	64	127	122
03-130	3	1	NY6	20	FS	76	152	132
03-132	3	1	NY6	10	LS	58	91	91
<b>'Rose Glow'</b>								
01-AA01	1,2,3	1,2	MA3	30	FS	152	163	107
01-AA02	1,2,3	1,2	MA3	30	FS	157	137	132
01-BR02	1,2,3	1,2	CT1	15	FS	142	142	112
01-NYBG6	1	2	NY3	10	FS	89	71	66
01-NYBG8	1	2	NY3	10	FS	152	157	157
02-1	2,3	1,2	CT10	15	LS	179	191	163
02-12	2	1,2	NY1	15	FS	107	132	122
02-26	2,3	1,2	MA2	15	LS	203	193	173
02-62	2	2	CT2	10	FS	NA	NA	NA
03-33	3	1	CT2	10	FS	102	112	112
03-34	3	1	CT2	10	FS	86	96	91
03-35	3	1	CT2	10	FS	97	102	94
03-36	3	1	CT2	10	FS	89	107	97
03-37	3	1	CT2	10	FS	76	96	81
03-38	3	1	CT2	10	FS	86	102	99
03-40	3	1	CT2	10	LS	107	94	89
03-61	3	1	MA2	15	HS	140	137	122

<sup>a</sup>Year codes: 1 = 2001; 2 = 2002; and 3 = 2003.

<sup>b</sup>Data use codes: 1 = accession used to measure number/density of propagules and number of seeds per fruit; and 2 = accession used to measure seed germination and growth habit/dry weight of seedling progeny.

<sup>c</sup>Source codes: CT1 = residence, North Willington, Conn.; CT2 = Prides Corner Farms, Lebanon, Conn.; CT3 = residence, South Willington, Conn.; CT4 = restaurant, Mansfield, Conn.; CT5 = Bartlett Arboretum, Stamford, Conn.; CT6 = filling station, Tolland, Conn.; CT7 = shopping center, Tolland, Conn.; CT8 = shopping center, Storrs, Conn.; CT9 = shopping center, Mansfield, Conn.; CT10 = Variegated Foliage Nursery, Eastford, Conn.; MA1 = F.W. Schumacher Co., Inc., Sandwich, Mass.; MA2 = Smith College, Northampton, Mass.; MA3 = Arnold Arboretum, Jamaica Plain, Mass.; NY1 = Planting Fields Arboretum, Oyster Bay, N.Y.; NY2 = Sheffield's Seed Co., Inc., Locke, N.Y.; NY3 = New York Botanical Gardens, Bronx, N.Y.; NY4 = Cornell Plantations, Ithaca, N.Y.; NY5 = residence, Valley Stream, N.Y.; NY6 = Atlantic Nurseries, Freeport, N.Y.; and OH1 = Holden Arboretum, Kirtland, Ohio.

<sup>w</sup>Approximate age of plant at time of first fruit collection. NA indicates that the age is unknown.

<sup>v</sup>Exposure codes are: FS = full sun; LS = light shade; and HS = half shade. NA indicates that the exposure is unknown.

<sup>u</sup>Canopy dimensions of plant at time of first fruit collection. NA indicates that the canopy dimensions are unknown and/or propagule density measurements were not calculated due to incomplete fruit harvest.

'Crimson Pygmy'. Although 'Rose Glow' was prolific relative to the two smaller cultivars, it produced significantly less fruit and seeds than var. *atropurpurea*. The var. *atropurpurea* specimens included in our study produced on average about 2500 fruit and 3000 seeds, while 'Rose Glow' yielded about 900 fruit and 800 seeds (Fig. 1a). By contrast, 'Aurea' produced 90 fruit and 75 seeds and 'Crimson Pygmy' developed 75 fruit and 90 seeds (Fig. 1a). This trend parallels the findings of Lovinger and Anisko (2004) who also observed a difference between the fruit set of 'Atropurpurea Nana' (syn. 'Crimson Pygmy') and 'Aurea' as compared to 'Rose Glow' (var. *atropurpurea* was not included in their study).

When fruit and seed data are expressed as production per unit surface area of plant canopy (to compensate for differences in growth habit between the study genotypes), the reproductive output of 'Rose Glow' is statistically similar to 'Aurea' and 'Crimson Pygmy' and all three cultivars are less prolific than var. *atropurpurea* (Fig. 1b). The surface area parameter takes into account the relatively large size of 'Rose Glow' and this cultivar's more moderate per plant production of fruit and seeds compared to var. *atropurpurea* (Fig. 1a).

The data presented thus far indicate significant differences in reproductive potential between the study genotypes. The slower growth rate and small stature of 'Crimson Pygmy' may

contribute to reduced fruit and seed production. After observing close to 40 'Crimson Pygmy' specimens it appears that optimal fruit production only occurs on plants of advanced age (as estimated by qualitative observation of relative plant size and stem caliper), a trait not observed with var. *atropurpurea* and 'Rose Glow'. The reproductive potential of 'Aurea' may be compromised due to altered chlorophyll levels and resultant reduced vigor. The existence of differential reproductive potential among cultivated genotypes of invasive species is not without precedent. After testing 35 cultivars of *Buddleia davidii* (butterfly bush), a popular invasive ornamental shrub, Anisko and Im (2001) found two genotypes with seed production <10% that of the highest producing cultivar. The cultivar 'Potter's Purple' produced 1.25g of seed per infructescence while 'Orchid Beauty' and 'Summer Rose' yielded <0.1g of seed per fruiting structure (Anisko and Im, 2001).

**Cultivar seed germination and seedling vigor.** Although 'Crimson Pygmy' demonstrated significantly reduced gross yield of fruit and seeds relative to larger growing genotypes, the number of seeds per fruit it produced was comparable to var. *atropurpurea* (Fig. 2a). 'Aurea' and 'Rose Glow' yielded fewer seeds per fruit than the other genotypes studied (Fig. 2a). These findings are supported by observations during the fruit cleaning process that many 'Aurea' and 'Rose Glow' berries contained either one seed or no seeds, as opposed to the other cultivars whose fruit mostly held one or two seeds. The origin of reduced yield of seeds per fruit for 'Aurea' and 'Rose Glow' is unknown and may be due to reproductive defects, poor pollination dynamics or other genetic factors.

Germination rates for genotype seed lots varied and seldom exceeded 80% success for any accession. While 'Crimson Pygmy' produced the highest average germination rate among cultivars at 75%, 'Rose Glow' and var. *atropurpurea* seeds germinated at statistically similar levels (Fig. 2b). Seeds from 'Aurea' exhibited poorer germination success than the other genotypes tested, producing a mean germination rate of only 46% (Fig. 2b). It is not uncommon to observe such differences in seed germination among cultivars of invasive species. Seeds from the cultivar 'Columnaris' of *Rhamnus frangula* (glossy buckthorn), for example, showed a mean germination of 65% while seeds from 'Asplenifolia' germinated at only 2.4% (Wheeler and Starrett, 2001).

Comparison of progeny vigor among barberry genotypes revealed that seedlings derived from the two large-growing purple forms outperformed seedlings from 'Aurea' and 'Crimson Pygmy'. For example, seedlings from var. *atropurpurea* and 'Rose Glow' attained greater height and width and produced more branches than progeny from 'Aurea' and 'Crimson Pygmy' (Table 2). Furthermore, comparison of shoot dry weights revealed that seedling populations derived from var. *atropurpurea* and 'Rose Glow' produced significantly heavier canopy growth than 'Aurea' and 'Crimson Pygmy' progeny over the course of a

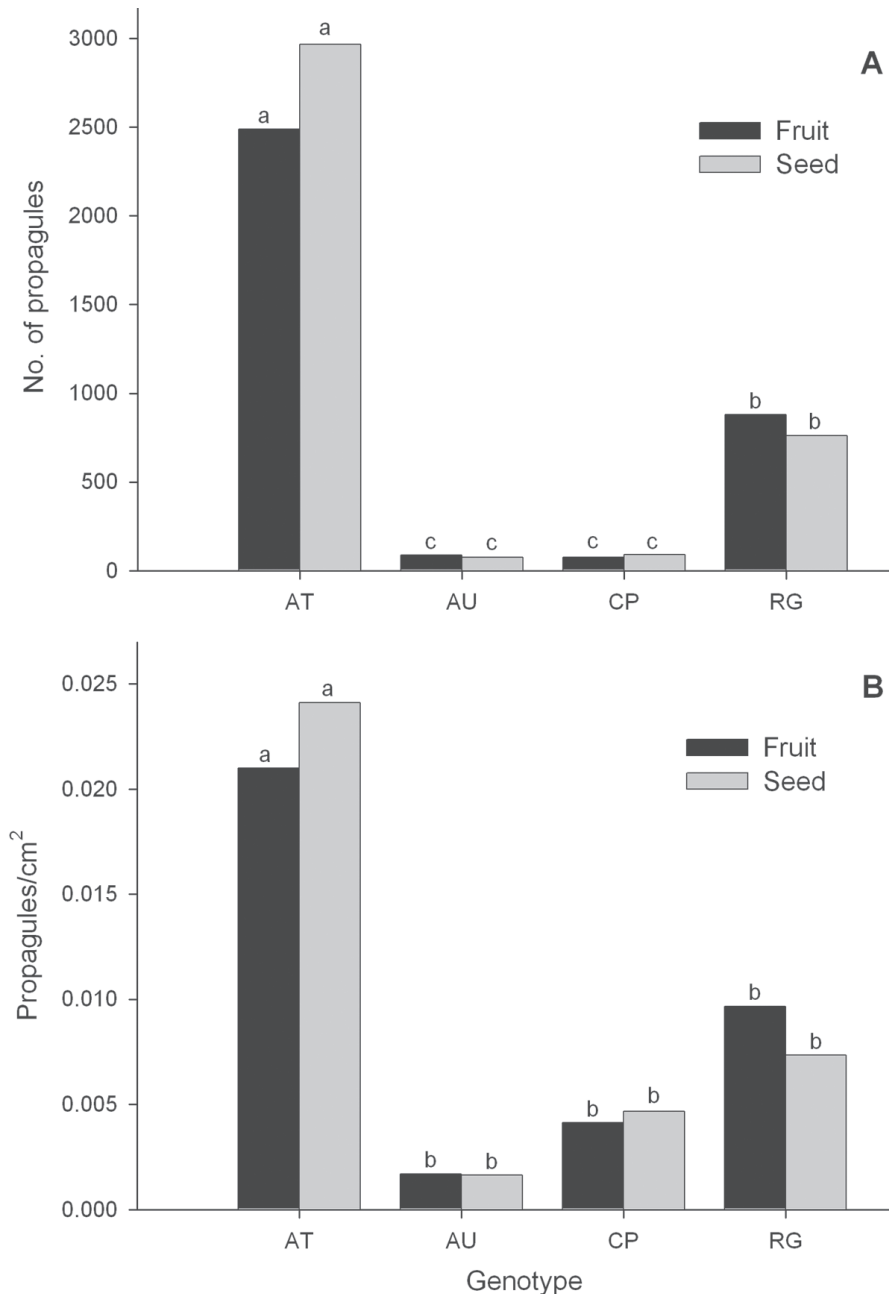


Fig. 1. Japanese barberry (*Berberis thunbergii*) genotype (AT = var. *atropurpurea*, AU = 'Aurea', CP = 'Crimson Pygmy', RG = 'Rose Glow') comparison of (A) number of fruit and seeds produced and (B) fruit and seed production per unit surface area of plant canopy. Means with different letters indicate significant differences ( $P \leq 0.05$ ) by Fisher's least significant difference test.

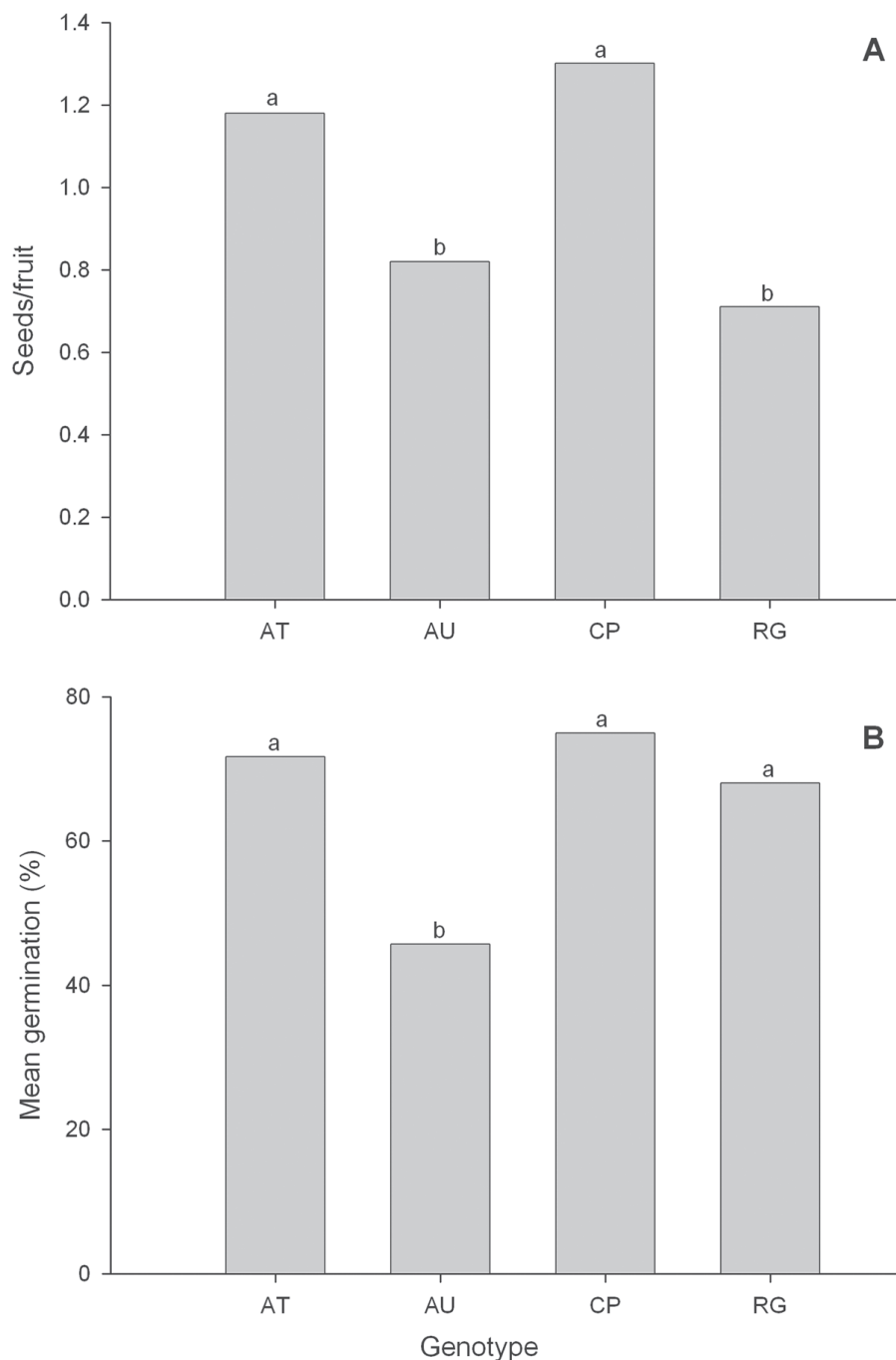


Fig. 2. Japanese barberry (*Berberis thunbergii*) genotype (AT = var. *atropurpurea*, AU = 'Aurea', CP = 'Crimson Pygmy', RG = 'Rose Glow') comparison of (A) number of seeds per fruit and (B) germination of seeds. Means with different letters indicate significant differences ( $P \leq 0.05$ ) by Fisher's least significant difference test.

Table 2. Growth and tissue dry weight of seedlings derived from four ornamental Japanese barberry (*Berberis thunbergii*) genotypes.

Genotype	n	Ht (cm)	Width (cm)	No. branches	Dry wt (g)	
					Shoots	Roots
var. <i>atropurpurea</i>	230	200.1 a <sup>2</sup>	111.2 b	5.2 b	1.2 b	2.5 a
'Aurea'	124	178.0 b	64.3 d	3.2 d	0.7 d	1.5 c
'Crimson Pygmy'	255	161.4 c	93.4 c	4.5 c	0.9 c	2.0 b
'Rose Glow'	187	197.2 a	145.6 a	5.6 a	1.3 a	2.5 a

<sup>2</sup>Mean separation within columns by Fisher's least significant difference test,  $P \leq 0.05$ .

growing season (Table 2). This trend suggests that the genetic tendencies of seedlings can be expected to correspond to the parent genotype

as they relate to top growth. A similar pattern was observed for root dry weights of cultivar seedlings, though relative differences were not

as great (Table 2). While the initial growth of cultivar seedlings in containers provides insight concerning establishment success under field conditions, the differences observed between forms may not be substantial enough to reduce the relative success in situ of offspring derived from one cultivar in comparison to another.

### Summary and Conclusions

Comparative analyses of several reproductive and seedling growth parameters reveal differential levels of performance among the four popular Japanese barberry cultivars studied. The genotypes segregate into two general groups: 1) the large-growing purple-leaf forms var. *atropurpurea* and 'Rose Glow,' which produced high levels of fruit/seed production and seedling vigor; and 2) the smaller, less vigorous cultivars 'Aurea' and 'Crimson Pygmy,' which exhibited fruit/seed production and seedling vigor that were significantly reduced. Although these results alone cannot be used to assess the culpability of individual cultivars in contributing progeny to invasive populations, they do serve as clear evidence that not all barberry genotypes possess the same baseline reproductive and progeny growth potential. This conclusion mirrors the findings of studies which analyzed ornamental genotypes of invasive *Rhamnus* (Wheeler and Starrett, 2001) and *Buddleia* (Anisko and Im, 2001). Some Japanese barberry cultivars, such as 'Aurea' and 'Crimson Pygmy,' could be deemed to pose significantly less ecological risk and therefore be considered safe enough to justify their continued commercial production and sale. These choices will ultimately be made by various interest groups with stake in the invasive plant issue.

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