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Performance of Landscape Plants from Northern Japan in the North Central United States[1]

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Abstract

In 1984 and 1985, 21 landscape plant introductions from northern Japan were distributed for testing in the NC-7 Regional Ornamental Plant Trials. Seventeen of these introductions were evaluated for 10 years at six to ten sites representing a cross-section of growing conditions in the north central United States. For these 17 introductions, first-year survival averaged 60%; however, by year 10, fewer than 20% of the original 425 plants were alive. Based on these evaluations, the populations could be divided into four groups. One population of *Rosa rugosa* was adapted to most trial sites; two populations (*Alnus hirsuta* and *Lonicera chrysantha*) were adapted to some sites; three populations were of poorly adapted dieback shrubs, and the remaining 11 populations included a diverse set of trees and shrubs unadapted to any, or nearly any, trial site. Temperature and moisture data from Japan and from trial sites were used to examine relationships between plant adaptation and climate. Statistically significant, multiple-regression models were calculated to describe the functional relationships between temperature and moisture conditions and plant adaptation at the various trial sites. Our models predict that plants from northern Japan are best adapted to sites in the northeastern United States where moisture surpluses exceed those typically found in the north central United States. These models also suggest criteria to evaluate sites throughout northeastern Asia for future exploration.

Index words: plant evaluation, introduction, climate.

Species used in this study: Manchurian alder (*Alnus hirsuta* (Spach.) Turcz. ex Rupr.); Erman's birch (*Betula ermanii* Cham.); Monarch birch (*Betula maximowicziana* Regel); Japanese beautyberry (*Callicarpa japonica* Thunb.); Harrington's plumyew (*Cephalotaxus harringtonia* (J. Knight ex Forbes) K. Koch var. *nana* (Nakai) Rehder); Climbing hydrangea (*Hydrangea anomala* D. Don subsp. *petiolaris* (Siebold & Zucc.) McClint.); Bigleaf hydrangea (*Hydrangea macrophylla* (Thunb.) Ser.); Coralline honeysuckle (*Lonicera chrysantha* Turcz. ex Ledeb. var. *crassipes* Nakai); Amur corktree (*Phellodendron amurense* Rupr.); Rugosa rose (*Rosa rugosa* Thunb.); and Gardeners' weigela (*Weigela hortensis* (Siebold & Zucc.) K. Koch).

Significance to the Nursery Industry

The climates and soils of the north central United States limit the diversity of woody plants that can be successfully produced and that are functional in the landscape. New plants from regions with climates resembling those in the north central region may expand the array of marketable species available to the trade, especially after they have undergone adequate testing. This study, which reports on a long-term evaluation of 21 seedling populations from northern Japan, produced three findings of significance to the nursery industry. First, our evaluation identified two populations of potential merit. *Rosa rugosa*, PI 479562, was well-adapted throughout the region, and individual plant selections with superior aesthetic qualities should be propagated for possible cultivar release. After further evaluation, selected plants of *Alnus hirsuta*, Ames 23190, may also prove worthy of commercial release. Second, we developed multiple-regression models that relate commonly available moisture and temperature data to plant survival in the north central region. Our models indicate that drought stress was a critical determinant of the survival of landscape plants from northern Japan. Finally, the results of these evaluations yielded criteria for identifying promising sites in northeastern Asia for future exploration and collection.

Introduction

In 1984 and 1985, the North Central Regional Plant Introduction Station, Ames, IA, distributed 21 new landscape plant

Table 1. Japanese plants evaluated and collection sites

Taxon	PI number	Collection site and elevation (in meters) when noted	Map code (Fig. 1)	No. planted (#)	Corrected no. alive after year 1 (see text) (#)	First-year survival (%)	Tenth-year survival (% of corrected no. alive)
Alnus hirsuta	479296ᶻ			23	12	52	58
Betula ermanii	479318	Teshio Forest, Teshio-gun, 125	2	20	7	35	0
Betula ermanii	479320	Rausu-cho, Menashi-gun, 675	5	18	13	72	15
Betula ermanii	479321	Akkeshi-machi, Akkeshi-gun	9	22	13	59	31
Betula ermanii	479322	Aomori-shi, Aomori-ken, 1324	14	23	14	61	14
Betula maximowicziana	479323	Teshio Forest, Teshio-gun	4	15	7	47	0
Betula maximowicziana	479324	Teshikaga-machi, Kawakami-gun	7	31	11	35	9
Betula maximowicziana	479325	Teshikaga-machi, Kawakami-gun	6	26	13	50	23
Callicarpa japonica	479331	Cultivated at the Hokkaido Pref. Forest Expt. Sta., Kikyo-machi	12	31	10	48	30
Cephalotaxus harringtonia var. *nana*	479344	Cultivated at the Furano Forest, Furano-shi	8	40	22	56	14
Hydrangea macrophylla	479425	Towada-shi, Aomori-ken	15	23	5	22	20
Hydrangea anomala subsp. *petiolaris*	479431	Towada-machi, Aomori-ken, 320	16	21	6	29	17
Lonicera chrysantha var. *crassipes*	479476	Hamanaka-machi, Akkeshi-gun	10	32	27	94	37
Phellodendron amurense	479512	Esashi-machi	3	19	14	74	29
Rosa rugosa	479562	Wakkanai-shi, Rebun Island, 31	1	33	28	91	96
Weigela hortensis	479649	Kayabe-gun, 390	11	23	19	83	26
Weigela hortensis	479650	Aomori-shi, Aomori-ken, 730	13	25	20	80	35

ᶻOriginally incorrectly distributed as *Alnus japonica* (Thunb.) Steudel, PI 479296, this population actually represented one of three populations of *A. hirsuta* collected from Hokkaido. This accession is now numbered Ames 23190.

introductions from northern Japan, as part of the NC-7 Regional Ornamental Trials, a long-term evaluation network conducted by cooperators at sites that represent the climatic and edaphic variation of the north central United States (25). These Japanese introductions were collected on a USDA-sponsored expedition by Kawase, Meyer, March, and Nielsen in September and October, 1982, and included a diverse assemblage of seeds of trees, shrubs, and vines (Table 1) from both natural populations and cultivated plantings of native Japanese plants.

At meetings in 1973 and 1978, the Ornamental Subcommittee of the NC-7 Regional Technical Advisory Committee recommended that high priority be placed on collection trips to northeastern Asia, including northern Japan, as a source of superior, hardy landscape plants (14). In response, Kawase (14) assembled a list of over 300 woody plant taxa native to Hokkaido, the largest island of northern Japan (Fig. 1), and stated that these plants would be 'potentially adaptable to the North Central region of the United States,' though no climatic comparisons were presented to substantiate that claim. As Spongberg (21) noted, Japan has long been a valuable source of attractive landscape plants, well adapted to conditions in the eastern United States. By exploring the northernmost parts of Japan, Kawase and his colleagues hoped to acquire plants with increased winter hardiness and better adaptation to the north central United States.

This report summarizes the performance of a subset of the Japanese introductions distributed in 1984 and 1985, in relation to climatic conditions at both collection and trial sites and to reports on the adaptation of other populations of these same species. These performance data should be valuable for planning future explorations to northeastern Asia and for examining climatic limitations to landscape plant adaptation in the north central United States.

Materials and Methods

Seventeen seedling populations of trees, shrubs, and vines from northern Japan were included in this study because they were thoroughly evaluated in at least six trial sites. The taxo-
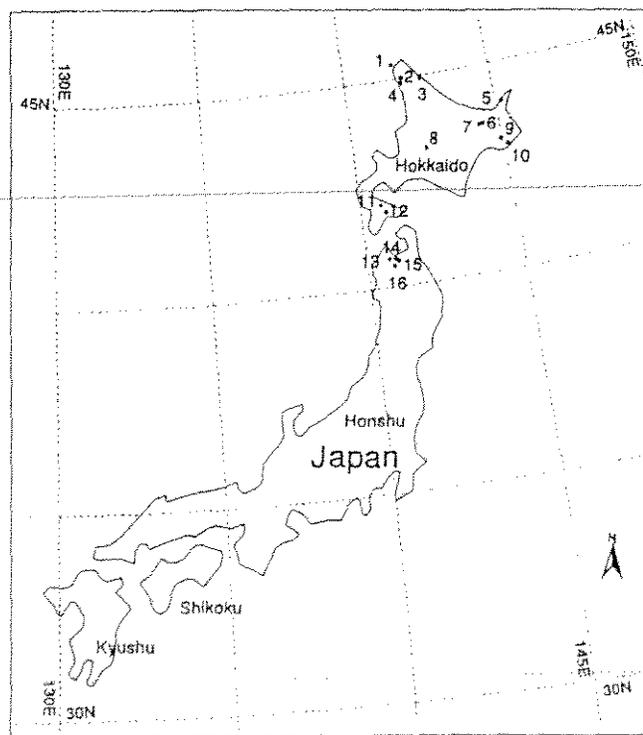

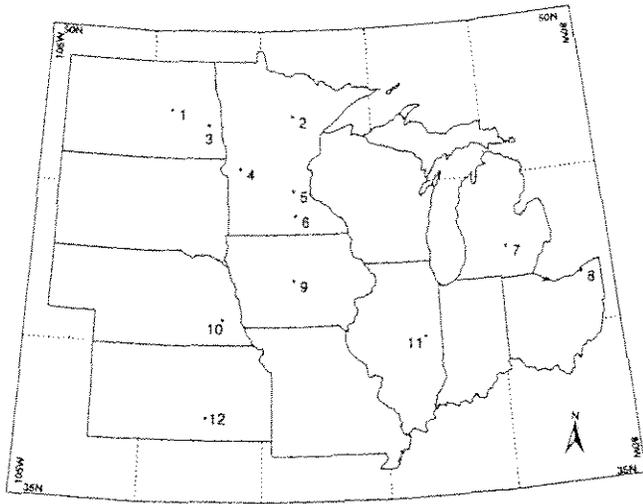Fig. 1. Map of collection sites in Japan. Legend: See Table 1.

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Fig. 2. Map of trial sites in the United States. Legend: 1. Foster County, ND: North Dakota State University Carrington Research Center; 2. Itasca County, MN: University of Minnesota North Central Experiment Station; 3. Cass County, ND: North Dakota State University Research Arboretum; 4. Stevens County, MN: University of Minnesota West Central Experiment Station; 5. Carver County, MN: University of Minnesota Landscape Arboretum; 6. Waseca County, MN: University of Minnesota Southern Experiment Station; 7. Ingham County, MI: Michigan State University; 8. Lake County, OH: The Holden Arboretum; 9. Story County, IA: Iowa State University Horticulture Research Station; 10. Lancaster County, NE: University of Nebraska at Lincoln; 11. Champaign County, IL: University of Illinois at Urbana-Champaign; 12. Sedgwick County, KS: Kansas State University Horticulture Research Center.

nomic identity and collection site of each population are listed in Table 1, with collection sites mapped on Fig. 1. Seed samples were collected in four regions: the northern tip of Hokkaido and nearby Rebun Island (sites 1–4), the eastern tip of Hokkaido (sites 5–7 and 9–10), central Hokkaido (site 8), and the southern tip of Hokkaido and Aomori Prefecture at the northern tip of Honshu (sites 11–16). Seedlings were initially grown at the Chicago Botanic Garden, Glencoe, IL, and were distributed to 27 sites for evaluation. Cooperators responsible for 12 sites (Fig. 2) reliably reported evaluation data for the duration of this study, therefore only data from those sites are reported herein.

One to 10 (usually three) seedlings of each test population were transplanted to the field in at least six of the 12 reporting sites. Plant survival, size, and performance were recorded by cooperators and reported to the senior author one, five, and ten years after planting. Cultural practices, such as methods of weed control and irrigation, were not uniform among the trial sites, but plants were usually irrigated at least during the establishment phase, and mowing, cultivation, or mulching employed to reduce competitive pressures. Records describing site-specific cultural practices can be obtained on request from the senior author.

For statistical analysis, survival data for each population at each trial site were converted to proportions. First-year survival was calculated as a percentage of the number planted. Tenth-year survival was calculated as a percentage of the number of plants alive in year one, following correction to account for those plants removed for administrative reasons

and not lost through natural causes. The preceding statistic summarizes survival during years two through ten, eliminating differences in initial establishment. Overall survival, a measure of survival for the complete duration of the test, was calculated by multiplying first-year survival by tenth-year survival.

Temperature, precipitation and snow cover data for sites in Japan were obtained from *Nihon no kikō* (24), *The Climatographic Atlas of Japan* (4), and the *Climatic Atlas of Asia* (23). Long-term climatic data for weather stations near test sites were obtained from *Climates of the States, 2nd ed.* (6). Estimates of potential evapotranspiration (PE) at trial sites were taken from a map by Thornthwaite (22) and PE estimates from Japan came from a map by Arai (1). To calculate the moisture index, I_m, we followed a formula developed by Mather and Yoshioka (16): $I_m = 100 [(\text{annual mean precipitation} / \text{PE}) - 1]$.

Hardiness zones for the United States were taken from the *USDA Plant Hardiness Zone Map* (3) and those for Japan estimated on the basis of January low-temperature data (4, 23, 24) compared with January low-temperature data in *Zhonggou Qihou Ziyuan Dituji* (5) and hardiness zones along the Pacific coast of China as mapped by Widrlechner (26). Regression analyses to test climatic models were based upon general designs described by Widrlechner et al. (27) and were conducted by using MSTAT-C statistical software (version 2.1) (17).

Results and Discussion

Initial establishment. Mean initial establishment was 60%, with 251 of 425 plants alive after one year (Table 1). Only six of 17 test populations had less than 50% survival: three *Betula* populations, two *Hydrangea* populations, and *Callicarpa japonica*. First-year reports indicated that three factors contributed to poor establishment. A majority of cooperators noted that drought and winter stresses were responsbile for losses, but in the instance of the three *Betula* populations, small size and/or poor quality of seedlings also contributed.

Tenth-year survival and plant performance. Of the 251 plants that survived the first year at the trial sites, 241 were evaluated and 80 survived for the duration of the study (Table 1). Ten plants were removed from test plantings between the first and tenth years because of administrative decisions, not lost directly through natural causes. Based on our analysis of performance data from trial sites and tenth-year survival, the 17 populations can be divided into four groups, discussed in the following four sections.

Widely adapted population. Only one population, *Rosa rugosa*, PI 479562, was well adapted throughout the north central region. It was collected from a sandy, well-drained beach about 30 m (100 ft) above the seashore. This population thrived at all sites, with good foliage quality, a long flowering period, and an excellent fruit display. Our results concur with other reports of this species' winter hardiness and broad adaptability (8, 10, 15, 28), suggesting that *R. rugosa* would most likely perform well throughout the north central United States. On well-drained sites, it makes an excellent ground cover, and individual plants with superior aesthetic qualities should be propagated for potential cultivar release, once compared to other cultivars of *R. rugosa* already in the

trade. The only concern noted by cooperators was the prevalence of mossy rose galls caused by the wasp, *Diplolepis rosae* (Linnaeus), at two sites in Minnesota.

Populations with limited adaptation. Although not as widely adapted as was *R. rugosa*, two populations showed patterns of survival that were promising enough to suggest that these plants might be successfully cultivated in certain parts of the north central region, or that superior selections could be made from these populations. The first, *Alnus hirsuta*, Ames 23190, initially incorrectly distributed as PI 479296, is a population of an alder rated as hardy to Zone IV (equivalent to USDA Hardiness Zone 5) by Rehder (19). This population has performed very well at the Lake County, OH, trial site (USDA Hardiness Zone 5b). Twelve years after planting, the trees measured 5.8 m (19 ft) tall, with good branching structure and no detectable winter injury; however, drought was noted as a factor leading to injury or death of this plant at many trial sites. It may be desirable to re-propagate the best trees of Ames 23190 for additional testing and possible commercial introduction, keeping in mind its probable intolerance to drought stress. The second is *Lonicera chrysantha*, PI 479476. All plants of this accession survived for the duration of the test at three sites: Stevens County, MN, and Cass and Foster Counties, ND. All three plants also were alive at the Carver County, MN site before they were removed in year seven because they lacked ornamental merit. At six other sites, all plants died of natural causes before year ten. In contrast to Hoag's comment (13) that this species 'does not appear to be sufficiently hardy or adapted to growing conditions in the northern Plains,' PI 479476 did survive with little winter injury in USDA Hardiness Zone 3b. Unfortunately, these shrubs have poor form and leaf quality; unsightly foliage from scorch or disease was noted at six sites. This lack of ornamental merit argues against its use, even where climatically adapted.

Poorly adapted dieback shrub populations. Three populations, *Callicarpa japonica*, PI 479331, and *Weigela hortensis*, PI 479649 and 479650, were poorly adapted to winter conditions in the north central region, surviving aboveground only after mild winters or when covered by snow. These populations showed no characteristics superior to commercially available selections of the same species. Our results are consistent with expectations based on winter hardiness ratings for these plants by Dirr (8) and Rehder (19), who reported *W. hortensis* hardy only to Zone VI (USDA Hardiness Zone 6b to 7a). Rehder (19) rated *C. japonica* not

fully hardy in Zone V (USDA Hardiness Zone 6a), and Dirr (8) noted that –20.6 to –23.3C (–5 to –10F) usually resulted in stem dieback. Observed intolerance to low temperatures is not surprising, given that these three populations were collected from sites 11, 12, and 13, which were among the mildest in terms of low winter temperatures (Table 2).

Unadapted populations. The remaining 11 populations include six different taxa. In general, the poor adaptation of these plants to growing conditions in the north central United States was expected. Rehder (19) rated *Betula ermanii, B. maximowicziana, Cephalotaxus harringtonia* (as *C. drupacea*), and *Hydrangea macrophylla* hardy only to Zone V (USDA Hardiness Zone 6a) at best. In contrast, he noted (19) that *H. anomala* subsp. *petiolaris* (as *H. petiolaris*) may be hardy to Zone IV (USDA Hardiness Zone 5), but Flint (11) remarked that this exceptionally attractive vine was 'very slow growing for the first few years.' Many of the young vines we evaluated were likely lost through drought and summer stresses before they had developed sufficient root systems. *Betula maximowicziana* was the object of an extensive, low-maintenance field trial conducted at the U.S. National Arboretum by Santamour (20), who concluded that, with only 28% survival after seven years, this species is 'generally inferior in juvenile survival and growth to most of the other birches used in landscape plantings.' *Cephalotaxus harringtonia* var. *nana*, PI 479344, was collected from site 8 in central Hokkaido, one of the coldest collection sites, suggesting that this population might be somewhat hardier than is typical. But variety *nana* is a low-growing, suckering shrub that may avoid damage in nature by being buried under snow during the coldest days of winter. The collectors' notes indicated that mean annual snowfall at the collection site was about 2.5 m (8.2 ft). In the north central United States, similar patterns of snow cover can only be found near the Great Lakes (6).

The only population that one might have expected to perform well *a priori* was *Phellodendron amurense*, PI 479512. In fact, first-year survival was above average for this test (Table 1); however, most of these plants died before completion of the trial. These results were surprising because this tree has been reported to grow rapidly and be well adapted to conditions in the upper Midwest, at least to USDA Hardiness Zone 3b or 4 (11, 18). And three trees of PI 479512 grown at the Lake County, OH, trial site, supplied by a source other than the NC-7 Regional Ornamental Plant Trials and, thus, not under evaluation for this experiment, have performed extremely well, with the largest tree measuring 6.1 m (20 ft)

Table 2. Climatic summaries for collection sites and trial sites.

Locations	$T_{Jan}(C)$	$T_{Jul}(C)$	I_m	Absolute min. temperature (C)[z]	USDA Hardiness zones
Japan (Fig. 1 sites):					
Northern Hokkaido (1–4)	–10 to –6	18	80 to 120	–30	5 to 6
Eastern Hokkaido (5–7, 9–10)	–12 to –6	16 to 18	50 to 130	–35 to –25	5 to 6
Central Hokkaido (8)	–10	18	110	–35	5
Southern Hokkaido and Northern Honshu (11–16)	–6 to –2	20 to 22	120 to 220	–25 to –20	6 to 7
North Central U.S. (Fig. 2 sites):					
Trial Sites (1–12)	–14.5 to –0.5	19.5 to 27	–30 to 40	–43 to –29	3b to 6a

[z]Absolute minimum temperatures over a 30 to 45-year period

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tall at age 13. In contrast, Dirr (8) noted a particularly slow-growing, unattractive population of *P. amurense* poorly adapted to summer conditions in Wichita, KS. Eight remnant trees of PI 479512 were planted at the North Central Regional Plant Introduction Station, Ames, IA, in 1985. After 12 years, six trees remain. Consistent with Dirr's note (8), the largest of these trees is only 3 m (10 ft) tall with a spread of 1.8 m (6 ft). Because of its inconsistent growth rates and poor survival in our trials, this population should be considered inferior to others already under cultivation.

Performance by test site and climatic comparisons. Measures of population survival differed widely among trial sites (Table 3). The most difficult sites were Waseca County, MN, where a single plant of *Rosa rugosa* survived from an original planting of 33 plants of ten different populations; Lancaster County, NE, where a single plant of *Betula ermanii* survived from an overall planting of 21; and Story County, IA, where a single plant of *Phellodendron amurense* survived from a total planting of 15. Note, however, that two plants of *Callicarpa japonica* were removed from the Lancaster County, NE, site after year five for lack of vigor although they were still alive. By contrast, the Lake County, OH, site reported an overall-survival rate of 70%.

The influences that temperature and moisture have on plant survival were tested by multiple-regression analysis. Similar analyses were valuable in elucidating geographic patterns of plant adaptation in the north central United States for plants from the former nation of Yugoslavia (27). Three climatic factors calculated for each trial site, January mean temperature (T_{Jan}), July mean temperature (T_{Jul}), the moisture index (I_m), and two-way multiplicative interactions among these three factors were regressed in all combinations to determine relative contributions of low and high temperatures and drought to plant loss among the trial sites.

For first-year survival (S_1), there are two models of similar explanatory power:

$$S_1 = 0.0052\ I_m + 0.579\ (R^2 = 0.319, P = 0.053),$$

and

$$S_1 = 0.00023\ (I_m \times T_{Jul}) + 0.579\ (R^2 = 0.326, P = 0.050).$$

These simple, linear-regression models explain less than 40% of the variation (as reflected in the R^2 values) in first-year survival, suggesting that other site-specific factors, such as post-transplant irrigation, weed competition, or soil characteristics, also were important determinants of initial plant establishment. Both models predict that survival would be lowest at the driest sites, but the second model further indicates that those sites with the warmest July mean temperatures and the greatest moisture deficits provide the greatest challenges to establishment, whereas survival rates are enhanced at the warmest, but wettest sites.

For tenth-year survival (S_{10}), the best regression model is:

$$S_{10} = 0.120\ I_m + 0.0020\ (I_m \times T_{Jan}) - 0.0045\ (I_m \times T_{Jul}) + 0.225\ (R^2 = .724, P = 0.013).$$

This statistically significant model explains over 70% of the site variation in tenth-year survival and includes the moisture index and two interaction factors, each involving the moisture index. However, a narrative description of this model is somewhat complex. In general, the temperature-by-moisture-index interactions temper the effects of the moisture index *per se*. For example, the driest trial sites have $I_m =$

Table 3. Plant survival at trial sites.

Trial site	First-year survival %	Tenth-year survival %[1]	Overall survival %
Illinois, Champaign County	60	33	20
Iowa, Story County	87	8	7
Kansas, Sedgwick County	57	35	20
Michigan, Ingham County	56	58	32
Minnesota, Carver County	73	18	13
Minnesota, Itasca County	94	21	20
Minnesota, Stevens County	48	43	21
Minnesota, Waseca County	52	6	3
Nebraska, Lancaster County	33	20	7
North Dakota, Cass County	48	31	15
North Dakota, Foster County	57	34	19
Ohio, Lake County	84	83	70

[1]Measured as a percentage of the corrected number of plants alive after year 1 (see Table 1).

–30 (Table 3); this value would lead to an 'impossible' reduction in tenth-year survival of 0.120 × –30, or –3.6. But that reduction is counteracted by the smaller, positive effects of the interaction factors. The opposite phenomenon occurs at the wettest sites, where the I_m factor can greatly increase predictions of tenth-year survival to values above 1, but the interaction factors reduce the degree of increase to more realistic levels. Although the effects of the interaction factors vary, given a positive I_m, the sites with the warmest winters and the coolest summers should have the greatest survival.

For overall survival (S_O), the best regression model is:

$$S_O = 0.097\ I_m + 0.0016\ (I_m \times T_{Jan}) - 0.0036\ (I_m \times T_{Jul}) + 0.113$$
$$(R^2 = .806, P = 0.003).$$

This equation includes the same variables as does the previously described S_{10} model, but it is slightly more powerful, explaining over 80% of the site variation. The primary differences between this model and the S_{10} model are that the magnitudes of all coefficients and the intercept are somewhat smaller. One would expect the intercept to be smaller, because S_O is always some fraction of S_{10}.

All regression models presented herein suggest that moisture index is the most important climatic determinant of plant survival when woody plants from northern Japan are cultivated in the north central United States. A direct comparison of climatic conditions at collection sites with those at trial sites (Table 2) lends heuristic support to this hypothesis. Mean January temperatures at collection sites in northern Japan fall within the range of those at the trial sites, and, at least for collection sites 1–10, extreme winter low temperatures also resemble those at trial sites. July mean temperatures at collection sites do tend to be somewhat cooler than those at the trial sites, but the most striking differences between the climatic conditions in these two regions are found in the moisture indices.

Even the driest collection sites have annual moisture surpluses exceeding the wettest trial site (Lake County, OH). Although small summer moisture deficits are common in northern Japan (1), Arakawa and Taga (2) reported that the most important climatic disasters, occurring during the growing season in northern Japan, result from cold, cloudy weather patterns and that summer drought is important only in regions considerably south of the collection sites. The northern Japanese climate thus more closely resembles that of

Allegheny State Park in southwestern New York or of Durham, NH ($T_{Jan} = -5C$ (23F), $T_{Jul} = 20$ to $21C$ (68 to 69.8F), $I_m = 80$ to 85) (6, 22) rather than those at the trial sites. This finding is supported by comparing soil maps for northern Japan and for North America (12), which indicate that general soil types in northern Japan are not closely analogous to those of the north central United States, but instead resemble those of New England and northern New York. Notably, the Lake County, OH, trial site is located closest to that region, and the overall survival rate reported there (70%) was more than twice that of the next most favorable trial site.

The central role that the moisture index plays in our models for predicting plant adaptation may, in part, have resulted from exceptionally dry growing seasons that occurred during this experiment throughout much of the north central United States. The most serious and widespread drought occurred in 1988, rather early in the evaluation period. As measured by the Palmer Drought Index, the spring and summer period of 1988 was the fourth driest on record in the United States. For a shorter period, April 1 to June 30, 1988, it was the worst drought on record. At the same time, lack of precipitation was combined with record high temperatures throughout much of the north central region (7, 9). Cooperators in North Dakota also reported serious drought conditions at trial sites during 1989, and the Lake County, OH, site experienced a severe drought in 1991.

In conclusion, 17 seedling populations representing a broad array of woody landscape plants from northern Japan were evaluated for adaptation at six to ten of 12 sites across the north central United States. After a ten-year evaluation, these populations could be divided into four groups. One population was widely adapted, two were adapted to some sites, three were poorly adapted dieback shrubs, and eleven were generally unadapted in the region. The most promising species in this trial was *Rosa rugosa*. Superior trees of *Alnus hirsuta* were also identified that may warrant re-propagation for further evaluation.

Temperature and moisture data were analyzed with multiple-regression models to elucidate statistical relationships between plant adaptation and climate. Significant regression models were identified that relate temperature and moisture conditions at trial sites with plant survival. A comparison of growing conditions at collection sites in northern Japan with those at trial sites indicated that northern Japanese climates are not analogous to those normally found in the north central United States, but may more closely resemble those of the northeastern United States.

Based on these evaluations and our predictive regression models, we suggest that it would be productive to make additional collections of landscape plants for testing in the north central United States from regions in northeastern Asia with January mean temperatures at or below $-6C$ (21.2F) , and July mean temperatures at or above $18C$ (64.4F). These temperature ranges resemble those found both in much of northern Japan and the north central United States. But most importantly, there should be moderate, annual moisture deficits, a condition rare in Japan, but more prevalent in continental northeastern Asia, especially in northern China.

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