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9. Dirr, M.A., E. Friedhoff, and T. Smith. 1978. Plant hardiness evaluations. Amer. Nurserymen. 148(5):12–72.

10. Dirr, M.A., G.E. Smith, D. Ehrlinger, T. Smith, and L. Thomas. 1984. Casualties and survivors of 1983–1984 freeze. Amer. Nurseryman 160(12):33–35.

11. Fuchigami, L.H., C.J. Weiser, and D.R. Evert. 1971. Induction of cold acclimation in *Cornus stolonifera* Michx. Plant Physiol. 47:98–103.

12. Hummel, R.L., P.D. Ascher, and H.M. Pellet. 1982. Inheritance of the photoperiodically induced cold acclimation response in *Cornus sericea* L., red-osier dogwood. Theor. Appl. Genet. 62:385–394.

13. Godfrey, R.K. 1988. Trees, shrubs, and woody vines of northern Florida and adjacent Georgia and Alabama. The University of Georgia Press, Athens, GA.

14. Lewandowski, R. 1989. New plant forum: *Fothergilla* 'Blue Mist.' Proc. Intern. Plant Prop. Soc. 39:556.

15. Lindstrom, O.M. and M.A. Dirr. 1989. Acclimation and low temperature tolerance of eight woody taxa. HortScience 24:818–820.

16. Lindstrom, O.M. and M.A. Dirr. 1991. Cold hardiness of six cultivars of Chinese elm. HortScience 26:290–292.

17. Lindstrom, O.M., Jr. and M.A. Dirr. 1991. Cold hardiness of *Magnolia grandiflora* L. cultivars. J. Environ. Hort. 9:116–118.

18. Lindstrom, O.M. and W.L. Corley. 1992. Leaf and stem cold hardiness of four selections of *Raphiolepis umbellata* Makino. J. Environ. Hort. 10:1–3.

19. Lindstrom, O.M. and K. Del Hierro. 1992. Leaf and stem cold hardiness estimates of six selections of Chinese evergreen oak over two winter seasons. J. Environ. Hort. 10:11–13.

20. Neumann, E.A. 1992. Landscape plants for the twenty-first century. Friends of US National Arboretum, Washington, D.C. 73 pp.

21. Sakai, A., L. Fuchigami, and C.J. Weiser. 1986. Cold hardiness in the genus Rhododendron. J. Amer. Soc. Hort. Sci. 111:273–280.

22. Smithberg, M.H. and C.J. Weiser. 1968. Patterns of variation among climatic races of red-osier dogwood. Ecology 49:495–505.

23. Stergios, B.G. and G.G. Howell, Jr. 1973. Evaluation of viability tests for cold stressed plants. J. Amer. Soc. Hort. Sci. 98:325–330.

24. U.S. Department of Agriculture. 1990. USDA plant hardiness zone map. Misc. Publ. No. 1475, Agr. Res. Serv.

25. Van Huystee, R.B., C.J. Weiser, and P.H. Li. 1967. Cold acclimation in *Cornus stolonifera* under natural and controlled photoperiod and temperature. Bot. Gaz. 128:2002–2005.

Cold Hardiness Estimates of *Acer* L. Taxa[1]

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Abstract

The cold hardiness of eleven *Acer taxa* was determined by laboratory techniques. The red leaf cultivars of *A. platanoides* were less cold hardy than the green leaf 'Emerald Queen.' 'Crimson Sentry,' a branch sport of 'Crimson King,' exhibited similar cold hardiness to that of its parent. Among *A. saccharum* cultivars, 'Legacy' was the most cold hardy followed by 'Green Mountain,' 'Commemoration' and 'Bonfire.' 'Green Column,' a selection of black maple from a native Iowa population, developed –30°C (–22°F) midwinter cold hardiness but lost all cold hardiness [killed at –3°C (27°F)] by March. All sugar maple cultivars survived at least –9°C (16°F) on the March date. Of the hybrids of *Acer platanoides* and *A. truncatum*, Pacific Sunset™ was significantly more cold hardy than Norwegian Sunset™ and should be rated USDA Zone 4 and 5, respectively.

Index words: Maple, new introductions, hardiness evaluations, cold hardiness.

Species used in this study: Norway maple (*Acer platanoides* L.); black maple (*Acer saccharum* Marsh. subsp. *nigrum* (Michx. f.) Desmarais [*A. nigrum* Michx. f.]; sugar maple (*Acer saccharum* Marsh.); hybrid purple blow maple × Norway maple (*Acer truncatum* Bunge × *Acer platanoides* L.).

Significance to the Nursery Industry

Laboratory cold hardiness determinations permit early assessment of a new cultivar's low temperature adaptability. Previous work with a wide range of woody plants has shown positive correlations between laboratory and observed field cold hardiness. In this study, minimal cold hardiness differences were detected among *A. platanoides* 'Crimson King,' 'Crimson Sentry,' and 'Royal Red' although the literature reports 'Royal Red' as the most cold hardy. 'Legacy' proved the most cold hardy of the newer sugar maples and Pacific Sunset™, a hybrid of *A. platanoides* and *A. truncatum*, was at least one zone more cold hardy than its sibling Norwegian Sunset™. The data provide an early barometer of geographic adaptability, a factor that coupled with growth data, will allow nurserymen and retailers to make intelligent choices relative to the best *Acer* cultivars to grow and market.

Introduction

New *Acer* introductions appear yearly and often without adequate evaluation for cold hardiness and cultural adaptability. Previous field work (6) has shown remarkable cold hardiness differences among cultivars within *Acer platanoides, A. rubrum* L. or *A. saccharum*. This type of

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evaluation is expensive and long term, and unless significant low temperatures occur during the experimental period, low temperature tolerances may not be adequately determined.

With *Acer platanoides*, the provenance is unknown and it is impossible to estimate low temperature tolerances of new seedling selections. Several *A. platanoides* selections are chimeras of known selections (1, 14) and their cold hardiness should be similar to the mother plants. Studies with *A. rubrum* have shown remarkable congruities between cold hardiness and seed source (11). Unfortunately, the seed sources from which most new cultivars are selected are seldom known. Thus, the ability to predict cold hardiness potential is lost.

In earlier work, a close relationship between laboratory cold hardiness determinations and observed field cold hardiness of species and cultivars has been demonstrated (5). This study, in cooperation with Schmidt Nursery, Boring, Oregon, determined the cold hardiness of 11 *Acer taxa*. The purpose was to compare the cold hardiness of several newer introductions with that of established clones. Also, we wanted to differentiate the cold hardiness of 3 *Acer platanoides* red leaf cultivars.

Materials and Methods

The *Acer* taxa were collected on October 14, November 12, December 18, 1991, and January 14, February 11, March 17, and April 14, 1992 at Schmidt Nursery, Boring, Oregon, and sent by overnight mail to Griffin, Georgia. Thirty-six, uniform, 10 cm (4 in) long stem tips were removed from multiple plants of each clone. Within 2 hours of receiving the stems, they were prepared for the freezing test. The terminal 7 cm (2.8 in) of each stem was removed. Leaves, if present, were removed from the stems. Stems were wrapped in moist cheesecloth and placed into a test tube (25 × 200 mm). The tubes were then submerged in ethylene glycol-water solution (1:1) in a temperature bath (Forma Scientific, Model 2425, Marietta, Ohio) precooled to –2 ± 0.5°C (28° ± 1°F).

Stem temperatures were measured by thermocouples placed next to the samples and recorded by a datalogger (Campbell Scientific, Model CR7, Logan, Utah). Crushed ice crystals were applied to the wet cheesecloth to insure that samples did not undercool. The temperature of the samples was held constant at –2 ± 0.5°C (28 ± 1°F) for approximately 14 hours. Samples were then cooled at a rate of 4°C (7°F) per hour. Four stems of each taxon were removed from the bath at progressively lower 3°C (5°F) temperature intervals as soon as that temperature was reached. Controls were prepared and kept at 4°C (39°F) for the duration of the freezing test.

After thawing at 4°C (39°F) overnight, the samples were removed from the tubes and placed in disposable, round, 100 × 15 mm (3.9 × 0.6 in) petri dishes containing filter paper saturated with water to maintain 100 percent relative humidity. The petri dishes were placed on their sides at room temperature in the dark (22 ± 2°C) (72 ± 4°F) for 10–14d, and samples were visually evaluated for injury (3, 4, 9, 10, 13). Stems showing brown discoloration and break down of cells in the cambium and phloem were rated as dead. The controls and samples not injured by the freezing treatments remained green and showed no discoloration in the cambium or phloem. The number of stems killed at each temperature was recorded and from these data the lowest survival temperature (LST) was determined. The LST is the lowest temperature at which little or no injury is observed, as described by Sakai et al. (7). There was no variability between replicates when determining the LST for a specific cold hardiness determination. The lack of variation between replicates can be explained by the use of clonal material, and that the cold hardiness was also determined only within a 3°C (5°F) range.

Results and Discussion

Among *Acer platanoides* cultivars, 'Emerald Queen' is considered one of the most cold hardy (1). The laboratory tests indicate cold hardiness to –30°C (–22°F) in January and February (Table 1). Pellett et al. (6) evaluated this cultivar over a 6-year period in Minnesota with no injury occurring at lows of –29°C (–20°F) on January 9, 1980 or –34°C (–29°F) on January 10, 1982 during the first 5-years. However, a low of –36°C (–32°F) on December 19, 1983 resulted in lateral branch kill to the main trunk. In this study, by December 18, 1991 'Emerald Queen' did not acclimate to the level re-

Table 1. The lowest survival temperatures in °C (°F) of eleven *Acer taxa*

Taxa	October	November	December	January	February	March	April
	°C (°F)						
Acer platanoides							
'Crimson King'	–12 (10)	–21 (–6)	–21 (–6)	–21 (–6)	–30 (–22)[z]	–15 (5)	ck[y]
'Crimson Sentry'	–12 (10)	–21 (–6)	–21 (–6)	–21 (–6)	–30 (–22)[z]	–9 (16)	ck[y]
'Emerald Queen'	–12 (10)	–24 (–11)	–21 (–6)	–30 (–22)[z]	–30 (–22)[z]	–15 (5)	ck[y]
'Royal Red'	–12 (10)	–18 (0)	–18 (0)	–27 (–17)	–24 (–10)	–18 (0)	ck[y]
Acer saccharum subsp. *nigrum*							
'Green Column'	–6 (21)	–12 (10)	–30 (–22)[z]	–30 (–22)[z]	–30 (–22)[z]	ck[y]	ck[y]
Acer saccharum							
'Bonfire'	–6 (21)	–21 (–6)	–24 (–11)	–24 (–11)	–24 (–11)	–9 (16)	ck[y]
'Commemoration'	–6 (21)	–15 (5)	–12 (10)	–30 (–22)[z]	–30 (–22)[z]	–9 (16)	ck[y]
'Green Mountain'	–6 (21)	–9 (16)	–27 (–17)	–30 (–22)[z]	–30 (–22)[z]	–9 (16)	–6 (21)
'Legacy'	–6 (21)	–18 (0)	–30 (–22)[z]	–30 (–22)[z]	–27 (–17)	–15 (5)	–6 (21)
Acer truncatum × *Acer platanoides*							
Norwegian Sunset™	–12 (10)	–12 (10)	–15 (5)	–27 (–17)	–27 (–17)	ck[y]	ck[y]
Pacific Sunset™	–9 (16)	–12 (10)	–30 (–22)[z]	–30 (–22)[z]	–30 (–22)[z]	–9 (16)	ck[y]

[z]Was not killed at the lowest temperature tested –30° (–22°F), the limit of the freezing bath.

[y]Survived 4°C (39°F), but not the next lowest temperature increment –3°C (27°F).

quired to survive –36°C (–32°F). Based on Pellett et al's (6) temperature data, the December 19 low as –12°C (–20°F) lower than the next lowest temperature for the December testing periods. Ideally, plant hardiness evaluations should include acclimation, midwinter hardiness and deacclimation to fully assess the adaptability of a particular cultivar to a given geographic region (5, 6).

The reddish-purple leaf Norway maples are less cold hardy than the green leaf forms under Minnesota field conditions (Pellett, personal communication, 1993). 'Crimson King' is the oldest and most popular red leaf cultivar (14) in the United States. 'Royal Red' is considered a synonym of 'Crimson King' although the literature (1, 14) ascribes a different origin and greater cold hardiness. In this study, 'Crimson King' was more cold hardy than 'Royal Red' in November, December, and February. Neither was consistently as cold hardy as 'Emerald Queen,' a fact that corroborates Pellett's observations.

'Crimson Sentry' is a branch of sport of 'Crimson King' that was introduced in 1972 by A. McGill & Son Nursery, Fairview, Oregon. It is broadly columnar in habit with reddish purple leaves. The cold hardiness should be comparable to 'Crimson King' and the data, except for the March date, corroborate this supposition. Based on the data and Pellett et al's. (6) work, the red leaf forms are adaptable to Zone 5 and 'Emerald Queen' to Zone 4 (12).

The sugar and black maple introductions with the exception of 'Bonfire' were cold hardy to –30°C (–22°F) on two or more of the sampling dates in December, January, and February. 'Bonfire' only acclimated to –24°C (–11°F) suggesting use in Zone 6b. 'Bonfire' was introduced in 1975 by Princeton Nursery, Princeton, New Jersey for superior orange-red fall color. The authors have not observed anything but yellow fall color. Possibly the original introduction has been lost in the production process. 'Green Mountain' is one of the more cold hardy sugar maple selections (6) and the midwinter data reflect this observation.

'Green Column' is a columnar form selected from the native range of black maple in central Iowa. It developed –30°C (–22°F) in the December, January, and February cold hardiness tests, but had deacclimated completely by March and April (Table 1). This is surprising considering the Iowa provenance. Where late spring freezes are problematic, this cultivar could be injured.

Two of the best adapted sugar maple taxa, particularly to the heat of zones 7 and 8, are 'Commemoration' and 'Legacy' (2). They were introduced in 1983 by Willet Wandell, Discov-tree, Oquawka, Illinois. Their leaf shape and texture indicate a western, possibly Missouri, provenance. 'Legacy' was the most cold hardy, acclimated faster, and deacclimated slower than the other cultivars. 'Commemoration' and 'Legacy' develop excellent yellow to yellowish orange fall coloration in zones 7 and 8, peaking in early to mid November in 7b. 'Legacy' is listed as cold hardy to zone 5, 'Commemoration' to zone 4 (14). Our data suggest the reverse.

Norwegian Sunset™ and Pacific Sunset™ are hybrids between *Acer truncatum* and *Acer platanoides* (8). *Acer truncatum* has prospered in Orono, Maine and Ames, Iowa and has survived at least –34°C (–30°F). These two introductions are chance seedlings and the lineage of the parental species is unknown. Pacific Sunset™ was consistently more cold hardy than Norwegian Sunset™ which also was slower to acclimate. Since –30°C (–22°F) represents the limits of the equipment, Pacific Sunset™ could be more cold hardy. These cultivars offer small habit [9 meters (30 ft)], yellow flowers before the leaves, lustrous dark green foliage that changes orange and red in fall. In field tests at Spartanburg, South Carolina, they have displayed excellent heat tolerance and orange-red fall color in November. Although listed as zone 4b adaptable, Pacific Sunset™ should be designated zone 4, Norwegian Sunset™—zone 5.

This study corroborates the known cold hardiness of selected *Acer* taxa and provides additional data for establishing potential zones of adaptability for newer introductions. The data are also useful for comparing the taxonomic/genetic relationship of one clone to another. Although the literature often notes that 'Crimson King' and 'Royal Red' are the same clone, the data indicate otherwise. Also, the similarity of cold hardiness between 'Crimson Sentry' and 'Crimson King' further validates the usefulness of laboratory freezing tests as a predictive tool.

Literature Cited

1. Dirr, M.A. 1990. Manual of Woody Landscape Plants. Stipes Publ. Co. Champaign, IL.

2. Dirr, M.A. 1992. *Acer saccharum*, the sugar maple. Some newer cultivars are developing a southern drawl. Nursery Manager 8(3):27–28.

3. Fuchigami, L.H., C.J. Weiser, and D.R. Evert. 1971. Induction of cold acclimation in *Cornus stolonifera* Michx. Plant Physiol. 47:98–103.

4. Hummell, R.L., P.D. Ascher, and H.M. Pellett. 1982. Inheritance of the photoperiodically induced cold acclimation response in *Cornus sericea* L., red-osier dogwood. Theor. Appl. Genet. 62:385–394.

5. Lindstrom, O.M. and M.A. Dirr. 1989. Acclimation and low-temperature tolerance of eight woody taxa. HortScience 24:818–820.

6. Pellett, H.M., S. Moe, and K. Vogel. 1985. Cold tolerance of shade tree species and cultivars in the upper midwest. J. Environ. Hort. 3:58–62.

7. Sakai, A., L. Fuchigami, and C.J. Weiser. 1986. Cold hardiness in the genus *Rhododendron*. J. Amer. Soc. Hort. Sci. 111:273–280.

8. Schmidt, J. Frank, and Co. 1991–1992. Nursery catalog. Boring, OR.

9. Smithberg, M.H. and C.J. Weiser. 1968. Patterns of variation among climatic races of red-osier dogwood. Ecology 49:495–505.

10. Stergios, B.G. and G.G. Howell, Jr. 1973. Evaluation of viability tests for cold stressed plants. J. Amer. Soc. Hort. Sci. 98:325–330.

11. Townsend, A.M., J.W. Wright, W. Beneke, R.P. Guries, and C.A. Mohn. 1982. Early patterns of flowering, winter injury, and flushing of red maple progenies grown in five locations. Canadian. J. Hort. Res. 12:814–821.

12. U.S. Department of Agriculture. 1990. USDA Plant Hardiness Zone Map. Misc. Publ. No. 1475, Agr. Res. Serv.

13. Van Huystee, R.B., C.J. Weiser, and P.H. Li. 1967. Cold acclimation in *Cornus stolonifera* under natural and controlled photoperiod and temperature. Bot. Gaz. 128:2002–2005.

14. Wandell, W.N. 1989. Handbook of Landscape Tree Cultivars. East Prairie Publ. Co., Gladstone, IL.