Cold Tolerance of Shade Tree Species and Cultivars in the Upper Midwest[1]

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Abstract

Evaluation of shade tree species and cultivars for adaptability to Minnesota climatic conditions was initiated in 1978. Evaluation includes cultivars of *Acer platanoides, Acer rubrum, Acer saccharinum, Acer saccharum, Fraxinus americana, Fraxinus pennsylvanica, Ginkgo biloba, Gleditsia triacanthos inermis, Tilia americana, Tilia cordata,* and other shade tree species. Plantings were established at the University of Minnesota Landscape Arboretum, Chanhassen, MN. The severe winter of 1983-84 was especially damaging to clones of *Acer platanoides.* Survival data are given for plants under evaluation.

Index words: winter hardiness, acclimation

Introduction

Many species of woody plants are native over a wide geographic area, which sometimes leads to the mistaken impression that, since a species is native in the area, any new clone of that species will be well-adapted. This is usually far from the truth. Through many thousands of years of natural selection, plants in a given area have evolved that are well-adapted to the local environmental conditions, but may not be adapted to conditions in other areas within the range of the species. Many morphological differences might also exist between plants from two different ecotypes. Townsend (2) discusses some of the differences that exist in the growth and morphological characteristics in *Acer rubrum* collected from different locations throughout its native range. Similar differences occur in other species.

Low winter temperature is the most limiting environmental factor for success of landscape plants in Minnesota and other northern areas; thus, our greatest concern is for cold hardiness. Plant cold acclimation and tolerance is complex and the greater understanding we have of it, the better we can evaluate and predict the potential of any plant to withstand winter conditions. We need be concerned not only about the ability of a plant to withstand the absolute minimum temperatures that occur in midwinter, but we must also understand the acclimation and deacclimation processes. Many plants are quite capable of acclimating to withstand the midwinter low temperatures, but they do not acclimate soon enough and/or fast enough to escape early winter cold or they may deacclimate too soon and be damaged by late winter and early spring drops in temperature.

The acclimation process in temperate perennials is triggered by photoperiod (3), but different species or even ecotypes of the same species respond to different critical photoperiods to trigger cessation of growth and initiation of the cold acclimation process. Data of Pauley and Perry (1) provide an excellent illustration of the magnitude of the difference in growth cessation due to source. They acquired *Populus trichocarpa* from throughout its native range and grew populations of each source at Weston, Massachusetts (40° N latitude). Plants native to 60° N latitude had ceased growth and formed terminal buds by June 20, while plants from 35° N latitude were still actively growing when the shoot tips were killed by freezing on October 28. Plants native to a given area begin the acclimation process well in advance of early freezing conditions and have an ample margin of safety between acquired hardiness levels and low temperatures that might occur. From tests of woody species native to our area we find acclimation usually begins by late July and by mid to late September native plants are capable of surviving temperatures as low as -18°C (0°F). In general, native woody plants by early fall are capable of tolerating temperatures of approximately 16°C (30°F) lower than normal minimum air temperatures for that time of the year. Plants native in other regions would not have this margin of safety and can often be severely injured by unseasonal early winter cold.

When any new woody plant cultivar is introduced it should be tested on a limited scale for several years under local conditions before it is widely planted. This is especially true for shade trees since they are much slower to reach their landscape effectiveness and should be considered more of a permanent fixture in the landscape than shrubs.

Materials and Methods

In 1978, we increased our emphasis on evaluation of adaptability of shade tree clones to our climatic conditions. Our goal was to acquire and evaluate all new clones of tree species that we felt might have potential for use in our area. Five trees of each shade tree cultivar were acquired, planted in a completely random design, and evaluated at the University of Minnesota Landscape Arboretum. Chanhassen, MN.

Results and Discussion

Table 1 gives a listing of shade tree clones, year

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Table 1. Winter injury ratings of shade trees under evaluation at the University of Minnesota Landscape Arboretum.

Cultivar	Source	Year					
		1979	1980	1981	1982	1983	1984
Acer platanoides	Cole	0000-[z,y]	0000-	0000-	0000-	0000-	3403-
A.p. 'Almira'	Scanlon		04000	0D000	0D000	0D000	3D400
A.p. 'Cavalier'	Scanlon		20000	00004	0000D	0000D	0403D
A.p. 'Cleveland'	Cole	00000	00000	00000	00000	00000	31444
A.p. 'Cleveland Two'	Scanlon		00000	34203	0D000	0D000	4D030
A.p. 'Deborah'	Holmlund			00000	00000	00000	00000
A.p. 'Emerald Lustre'	Bailey			00000	00000	00000	00000
A.p. 'Emerald Queen'	Cole	00000	00000	00000	00000	00000	34342
A.p. 'Greenlace'	Schmidt		0000-	0000-	0000-	0000-	4004-
A.p. 'Oregon Pride'	Pacific Coast				00000	00000	40004
A.p. 'Scanlon Gold'	Scanlon		00000	00000	00000	0000*	4040-
A.p. 'Schwedleri'	Cole	00000	00000	00000	00000	00000	04040
A.p. 'Summershade'	Cole	100--	D00--	D00--	D00--	D00--	D33--
A.p. 'Summershade'	Sherman	10*00	D0-00	D0-00	D0-00	D0-00	D4-44
A.p. 'Superform'	Cole	00000	00000	00000	00000	00000	34244
Acer rubrum	Cole	2440-	0DD°-	0DD0-	0DD0-	0DD0-	4DD0-
A.r. 'Armstrong Two'	Scanlon	42200	D0000	D0000	D0000	D0000	D4000
A.r. 'Autumn Flame'	Cole	00000	00000	01000	01000	00000	00000
A.r. 'Bowhall'	Cole	04000	0D000	0D400	0DD12	0DD00	0DD41
A.r. 'Curtis'	Pacific Coast				11111	DDD00	DDD00
A.r. 'Drake'	Schmidt		10000	00000	00000	00000	00000
A.r. 'Doric'	Scanlon	44400	DDD20	DDD00	DDD00	DDD00	DDD00
A.r. 'Embers'	Holmlund				33211	DD00D	DD00D
A.r. 'Gerling'	Cole	43002	D4000	DD000	DD004	DD00D	DD00D
A.r. 'Karpick'	Schichtel				44441	DDDD0	DDDD0
A.r. 'Morgan' (Indian Summer)	Sheridan	0000-	0000-	0000-	0000-	0000-	4030-
A.r. 'Northwood'	Bailey					00000	00000
A.r. 'October Glory'	Cole		00440	00DD0	00DD1	00DD0	00DD2
A.r. 'October Glory'	Sherman	44444	DDDDD				
A.r. 'Redskin'	Schichtel						
A.r. 'Red Sunset'	Cole		04000	2D224	0D00D	0D00D	0D00D
A.r. 'Red Sunset'	Sherman	04404	0DD0D	0DD0D	4DD1D	DDDDD	
A.r. 'Scanlon'	Scanlon	14020	2D000	0D000	0D000	4D000	DD400
A.r. 'Scarlet Sentinel'	Pacific Coast					00000	00000
A.r. 'Schlesinger'	Scanlon	00402	00D00	00D00	00D00	00D00	00D00
A.r. 'Tilford'	Cole	04001	0D000	0D000	0D000	0D000	0D000
Acer saccharinum aurea	Jewell			010--	000--	000--	010--
A.s. 'Lees Red'	Sheridan					00000	00000
A.s. 'Sheridan'	Sheridan			00010	00100	00000	00003
Acer saccharum 'Bonfire'	Princeton	00004	0000D	0000D	0000D	0*00D	0-00D
A.s. 'Commemoration'	Moller						4----
A.s. 'Commemoration'	Wandell				1----	0----	0----
A.s. 'Fairview'	McGill		0000-	0000-	0000-	0000-	0000-
A.s. 'Green Mountain'	Sherman	00000	01000	00000	00000	00000	00000
A.s. 'Green Mountain'	Princeton	00000	00000	00000	00000	00000	00000
A.s. 'Green Mountain'	Bailey					00000	40014
A.s. 'Greenspire'	Moller						40014
A.s. 'HRI-1' (Endowment™)	Siebenthaler					000--	100--
A.s. 'Legacy'	Wandell				03---	00---	20---
A.s. 'Legacy'	Moller						33344
A.s. 'Moraine'	Siebenthaler					000--	000--
A.s. nigrum	Cole	00000	00000	00000	00000	00000	00000
A.s. 'Temple's Upright'	Cole		0000-	0000-	0000-	0000-	0000-
Betula nigra 'Heritage'	Holmlund						00000
Corylus colurna	Bailey			0444-	3DDD-	DDDD-	
Celtis laevigata 'All Seasons'	Wandell					4----	
Celtis occidentalis 'Prairie Pride'	Wandell				00---	00---	00---
Celtis occidentalis	Jewell					00000	00000
Fraxinus americana 'Autumn Applause'	Holmlund			0000-	0230-	0440-	4DD4-
F.a. 'Autumn Applause'	Wandell				40---	D0---	D4---
F.a. 'Autumn Purple'	Cole	00000	00004	0000D	0000D	0000D	0000D
F.a. 'Champaign County'	Holmlund			00000	33333	40444	D0DDD
F.a. 'Champaign County'	Wandell					40---	D4---
F.a. 'Kleinburg'	Sheridan		00000	00000	00000	00000	00000
F.a. 'Manitou'	Sheridan		00000	00000	00000	00000	00000
F.a. 'Rosehill'	Sheridan	00000	02000	00000	00000	00000	44004
F.a. 'Skyline'	Cole				00---	00---	*0---
F.a. 'Wilson'	Iowa Arb.					00000	41044

Table 1. Winter injury ratings of shade trees under evaluation at the University of Minnesota Landscape Arboretum (continued).

Cultivar	Source	Year 1979	1980	1981	1982	1983	1984
Fraxinus excelsior 'Kimberly Blue'	Sherman	00403	00D04	00D0D	00D0D	00D0D	44D4D
Fraxinus mandshurica	Sheridan	00000	40400	D0D00	D0D00	D0D00	D0D00
Fraxinus nigra	Sheridan	00000	40400	D0D00	D0D00	D0D00	D4D00
F.n. 'Fallgold'	Aubin				0000*	0000-	0010-
F.n. 'Fallgold'	Aubin						00000
Fraxinus pennsylvanica	Bailey	00000	00000	00000	00000	00000	00000
F.p. 'Bergeson'	Bergeson	00000	00000	00000	00000	00000	00000
F.p. 'Emerald'	Neosho	44444	DDDDD				
F.p. (golden)	Bailey		000--	000--	000--	000--	000--
F.p. (golden)	Bailey						00000
F.p. 'Jewell'	Jewell	00000	00000	00000	00000	00000	00000
F.p. 'Kindred'	Cross			00000	00000	00000	00000
F.p. 'Marshalls Seedless'	Cole	00000	00000	00000	00000	00000	00000
F.p. 'Marshalls Seedless'	Cole						00000
F.p. 'Newport'	Bailey	00000	00000	00000	000*0	000*0	000*0
F.p. 'Patmore'	Aubin				000--	000--	000--
F.p. 'Patmore'	Bailey						00000
F.p. 'Patmore'	Holmlund						
F.p. 'Summit'	Sheridan	00000	00000	00000	00000	00000	00000
F.p. 'Summit'	Bailey				0000-	0000-	0000-
Ginkgo biloba	Cole		00000	00030	00040	000D0	000D0
G.b. (male)	Cole			00000	00000	00000	00000
G.b. 'Saratoga'	Monrovia					00000	02111
G.b. 'Sentry'	Cole			00000	00000	00000	00000
Gleditsia triacanthos inermis 'Arrowhead'	Umapine					00000	00000
G.t.i. 'Continental'	Princeton						11022
G.t.i. 'Fairview'	McGill				10122	00000	000*0
G.t.i. 'Golden Halo'	Umapine					00000	11114
G.t.i. 'Green Glory'	Holmlund						11333
G.t.i. 'Halka'	Moller			00000	01000	00000	01100
G.t.i. 'Skyline'	Bailey					00000	11111
G.t.i. 'Trueshade'	Pacific Coast				33033	00004	0000D
Liquidamber styraciflua 'Moraine'	Siebenthaler				D00--	D00--	D44--
Populus alba 'Raket'	Sheridan		00000	00000	00000	00000	00000
Populus canescens 'Tower'	Aubin				0----	0----	0----
Populus jackii 'Northwest'	Aubin				0----	0----	0----
Quercus rubra	Sherman	00000	02002	00000	00000	00000	10000
Q. palustris 'Sovereign'	Cole					00000	00000
Tilia americana	Cross					00000	00000
Tilia americana	Bailey		00000	00000	00000	00000	00000
Tilia americana fastigiata	Bailey		00000	0000*	0000-	0000-	00D0-
Tilia cordata	Bailey		000--	000--	000--	000--	000--
Tilia cordata	Bailey					00000	00000
T.c. 'Bicentennial'	Scanlon		00---	00---	00---	00---	00---
T.c. 'Chancellor'	Cole		04444	0DDDD	0DDDD	0DDDD	0DDDD
T.c. 'Chancellor'	Schmidt					04-00	
T.c. 'De Groot'	Sheridan	00000	00004	0000D	0000D	0000D	0000D
T.c. 'Fairview'	McGill		00000	00000	00000	00000	00000
T.c. 'Glenleven'	Sheridan		00000	00000	00000	00000	00000
T.c. 'Greenspire'	Bailey						0*000
T.c. 'June Bride'	McGill		00000	00000	00000	00000	00000
T.c. 'Morden'	Sheridan		00040	000D4	000DD	040DD	0D0DD
T.c. 'Olympic'	Schmidt		00000	00000	00000	00000	00000
T.c. 'Rancho'	Scanlon		00000	00004	0000D	0000D	0000D
T.c. 'Sheridan Hybrids'	Sheridan		00000	00000	00000	00*00	00-00
Tilia x *euchlora* 'Redmond'	Bailey		00000	00000	00000	00000	00000
Tilia europaea 'Pallida'	Sheridan		00000	00000	00000	00000	00000
T.e. wratislavensis	Scanlon		00040	000D0	000D0	000D0	000D0

Table 1. Winter injury ratings of shade trees under evaluation at the University of Minnesota Landscape Arboretum (continued).

		Year					
Cultivar	Source	1979	1980	1981	1982	1983	1984
T. flavescens 'Dropmore'	Aubin				00100	00000	00000
T. heterophylla 'Prestige'	Wandell				00---	00---	00---
T. platyphyllos 'Laciniata'		0000-	0000-	0000-	0000-	0000-	0400-
T. platyphyllos 'Rubra'	Sheridan			44000	DD031	DDDD4	DDDD1

[z]Each digit refers to an individual tree. When less than five trees are evaluated, these absences are designated by a dash (-). A "D" is used to designate those individuals which were previously removed due to insufficient winter hardiness. A "*" indicates injury due to reasons other than cold hardiness such as breakage, graft failure, herbicide injury, or tractor blight.

[y]Numerical rating scale: 0 = no winter injury; 1 = winter injury of first year growth; 2 = winter injury extending to second year growth; 3 = winter injury extending to main trunk; and 4 = extreme winter injury, resulting in complete loss of landscape value, or death.

planted and amount of injury recorded for accessions added to our trials since 1978. Although concrete recommendations cannot be made yet, the data do indicate that many clones are definitely not adapted to our Minnesota conditions and should be avoided. The winter of 1983-84 provided a severe test for early cold and minimum temperature tolerance, as we recorded -38 °C (-32 °F) on December 19, 1983 at the University of Minnesota Arboretum shattering all previous December records. Other winters, for example 1982-83, were mild and did not provide very severe tests of tolerance to low temperatures (Table 2).

The extreme cold in mid-December 1983 followed autumn conditions that were less than ideal for normal cold acclimation. A review of the temperature records shows only one night prior to November 23 (23 °F on November 12) during which freezing of woody plant tissues could have occurred. After that time temperatures dropped below that required to freeze stems of trees and shrubs and stayed below freezing temperatures except for two days in the week of November 23-30 when temperatures rose to -1 to 0 °C (31 to 32 °F) which may have thawed plant tissues. Thus, we did not have any significant period of freezing at night and thawing during the day that normally occurs. In a normal hardening sequence, shortening day length will trigger the initiation of acclimation and when proper day length is reached (specific for each plant taxon), plants will develop some hardiness but the metabolic activities that result in this acclimation take place much faster at temperatures above freezing(3). Thus, a period of fluctuating freezing and thawing conditions allows the second stage of hardiness to develop normally. Since this fluctuating condition did not occur this past fall the hardening sequence of many plants probably did not proceed fast enough to permit them to tolerate the extreme cold they experienced in early winter.

This past winter was especially hard on young Norway Maple trees (Table 1). Trees approximately 7.5-10 cm (3-4 in) in diameter proved to be the most vulnerable, while both older and younger trees showed less injury. Thus, a high percentage of trees of all clones of Norway Maple planted in our trials in 1978 and 1979 were killed. In many cases the lethal injury to the tree was bark injury. Vegetative buds survived and the trees leafed out normally, but the bark which had been killed dried out or split as the trunk began to swell (Figs. 1 and 2). This unusual type of injury can be explained by the unseasonal cold early in the winter. In mid-winter phloem (bark) tissues are hardier than living cells in the xylem, but phloem cells acclimate later than xylem cells. Norway Maple is one of the later woody plants to cease growth and begin the acclimation process. The early sub-zero temperatures in mid-winter no doubt occurred at a time when the cambium and phloem cells of the trunk had not reached sufficient hardiness to withstand

Table 2. Minimum temperature °C (°F) recorded and date of occurrence in the following calendar periods during winters of 1978-84, at the University of Minnesota Landscape Arboretum, Chanhassen, MN.

Year	Nov. 15-30	Dec. 1-15	Dec. 16-31	Jan. 1-31	Feb. 1-28	Mar. 1-15
1978-79	——	——	——	-31 (-23) Jan. 3	-32 (-25) Feb. 5	-21 (-5) Mar. 10-11
1979-80	-11 (+12) Nov. 30	-19 (-2) Dec. 13	-23 (-9) Dec. 16	-29 (-20) Jan. 9	-24 (-11) Feb. 29	-23 (-10) Mar. 1
1980-81	-9 (+15) Nov. 25	-18 (0) Dec. 2 & 11	-22 (-8) Dec. 22	-24 (-12) Jan. 5	-24 (-12) Feb. 3	-10 (+14) Mar. 2
1981-82	-13 (+9) Nov. 22	-20 (-4) Dec. 15	-24 (-12) Dec. 20	-34 (-29) Jan. 10	-31 (-23) Feb. 3	-21 (-6) Mar. 7
1982-83	-16 (+3) Nov. 24	-19 (-2) Dec. 12	-19 (-3) Dec. 29	-24 (-12) Jan. 27	-22 (-8) Feb. 7	-9 (+15) Mar. 10
1983-84	-13 (+8) Nov. 30	-21 (-6) Dec. 3	-36 (-32) Dec. 19	-33 (-27) Jan. 20	-25 (-13) Feb. 6	-24 (-11) Mar. 9

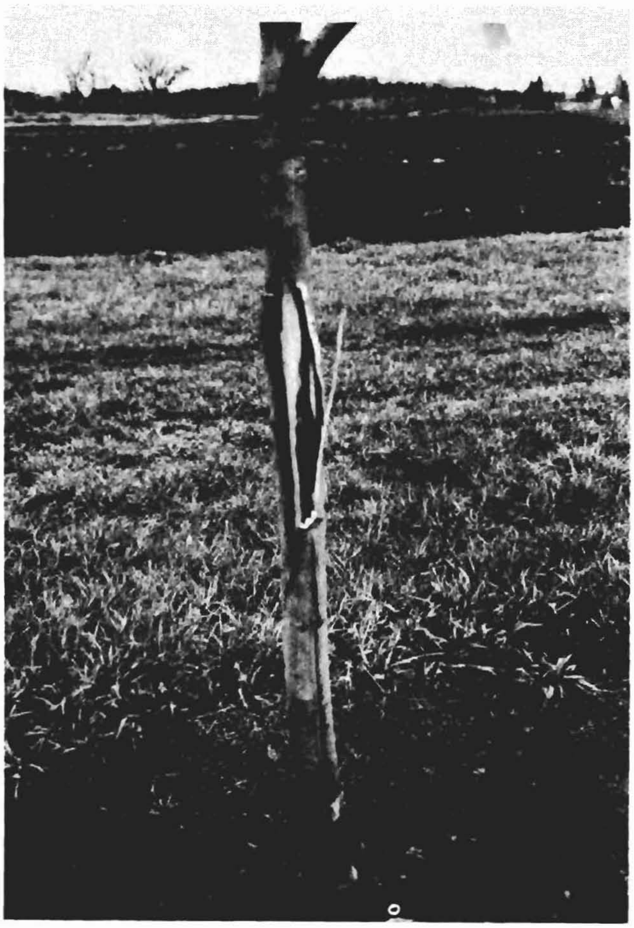

Fig. 1. **Typical trunk injury of *Acer platanoides* cultivars following the 1983-84 winter. The injury first showed up as vertical splitting of the bark.**

Fig. 2. **Peeling away of the bark of *Acer platanoides* revealed the entire bark and cambium tissues had been winter killed above the snow line.**

the low temperatures encountered, while vegetative buds and xylem cells had developed sufficient hardiness. Trees 7.5-10 cm (3-4 in) in caliper are probably at a stage of most rapid trunk growth and thus at a stage of greatest vulnerability to the conditions encountered this past winter.

We plan to continue this evaluation effort to include observations on aesthetic qualities, relative rate of growth, etc., as these trees grow and develop. We intend to continue adding new clones as they become available.

Significance to the Nursery Industry

It is important for the nursery industry to know which shade tree cultivars are adapted to their area. To provide this information, new cultivars must be evaluated on a regional basis, as the different day lengths and minimum winter temperatures encountered may not be suitable for all cultivars. This article presents the initial results of a shade tree cultivar evaluation in the upper midwest.

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