Cold Hardiness of Flowering Crabapple Cultivars[1]

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Abstract

Stem cold hardiness of 38 crabapple taxa (*Malus* L.) was evaluated on 6 dates throughout the dormant period of 1992–93. Differences in cold hardiness among taxa were detected on all sampling dates, with no single cultivar being consistently most hardy. Midwinter hardiness levels ranged from –32C (–26F) for 'Jewelberry' to –44C (–47F) for *M. baccata* 'Jackii'. 'Dolgo', 'Red Jade', 'Red Splendor', 'Selkirk', and *M. baccata* 'Jackii' were all hardy to at least –40C (–40F) in midwinter and also exhibited excellent early- and late-season hardiness. Large differences in hardiness among crabapple taxa were observed on November 9 and April 26 sampling dates [14C (25F) and 17C (31F), respectively], indicating that taxa vary substantially in timing and/or rates of acclimation and deacclimation. Although most cultivars demonstrated adequate hardiness for use in USDA hardiness zone 4a, the acclimation and deacclimation characteristics of some taxa may predispose them to injury from extreme low temperatures in the fall and early spring.

Index words: *Malus*, crabapple, freeze tolerance, acclimation, deacclimation.

Significance to the Nursery Industry

Limited information is available on cold tolerance of flowering crabapples and, as a consequence, relative hardiness of cultivars is rarely considered when selecting varieties for production and sale in northern climates. In this study, laboratory freezing tests detected substantial differences in midwinter hardiness and timing of acclimation and deacclimation among taxa. Use of varieties with superior cold hardiness will enable northern growers to avoid losses associated with winter freezing injury. The range of cold tolerance observed among taxa also suggests that hardiness characteristics are important criteria for evaluating new crabapple introductions prior to promotion of their use in areas with severe winters.

Introduction

Flowering crabapples are valued for their attractive floral displays, colorful fruit, small stature, diversity of form, and environmental adaptability (4, 5). Recent introductions that combine improved disease resistance with superior aesthetic traits are certain to enhance the popularity of these versatile landscape plants.

Although crabapples are commonly grown in the northern United States, little is known about the cold hardiness characteristics of most cultivars. Prediction of cold tolerance based upon parental hardiness is difficult since many cultivars originate as chance seedlings from open-pollinated maternal parents. Long-term survival of plants under natural conditions is the best indicator of adaptability to cold, but extensive field-trialing of cultivars is impractical for most growers. Laboratory determinations of cold hardiness performed on a range of woody plant species have correlated well with observations of field performance (10, 11, 12, 13) and provide a simple means of predicting a cultivar's adaptability to regional conditions. Comparisons of hardiness among taxa should be based upon multiple evaluations performed throughout the dormant period because relative hardiness rankings frequently vary with sampling date (1, 9, 12, 13).

The objective of this work was to characterize the cold hardiness of 38 flowering crabapple taxa in order to assess their suitability for use in northern climates.

Materials and Methods

Plants used in this study were field-grown at the University of Minnesota Landscape Arboretum located in Chanhassen, MN (44° 50' N latitude). Three trees of each cultivar were grown in rows on a 4 m (12 ft) spacing with 5 m (16 ft) sod aisles. The trees were well established and ranged from 9 to 11 years in age.

Each tree received an applicaton of 34N–0P–0K [2 kg/100 m^2 (4 lbs/1000 ft^2)] fertilizer the first 3 springs following planting and were not fertilized thereafter. The sod strips were mowed 3–4 times per growing season and a 15 cm (6 in) layer of wood-chips was applied in the rows each spring to suppress weed growth. No supplemental irrigation was provided beyond the year of establishment. The trees were not pruned for several years prior to initiation of this study.

On the morning of each sampling date, shoots consisting of current year's growth were collected from all 3 trees of each cultivar and placed in polyethylene bags for transport to the laboratory. Extremely vigorous shoots (water sprouts) were avoided. Stem sections 4 cm (1.6 in) in length were prepared after discarding the terminal 10 cm (3.9 in) of the shoot. Leaves still attached to the shoots on the earlier sampling dates were excised at the base of the petiole with a razor blade. All material was prepared within 2 hours of collection and was not exposed to laboratory temperature for longer than 5 minutes. Five stem sections of each cultivar were placed in polyethylene bags in contact with an ice nucleating agent (moist paper toweling). A copper-constantan thermocouple was inserted into the pith of a single stem section in each bag and the bags were placed into a programmable, ultralow-temperature freezer. The samples were held overnight at a temperature approximating the previous night's minimum temperature. An additional 5 stem sections of each cultivar were placed in polyethelene bags with moist paper towels and held overnight under refrigeration at 2C (3.6F) to serve as controls. The following day the temperature in the freezer was lowered at a rate of 3C (5F) per hr. Sample temperatures were monitored on a strip-chart

[1]Received for publication December 18, 1995; in revised form March 22, 1996. Journal Series Paper number 22,219 of the Minnesota Agricultural Experiment Station.

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recorder. The range of exposure temperatures used was varied by season to bracket the estimated lethal temperature. Five samples of each cultivar were removed from the freezer at 2C (3.6F) intervals and allowed to thaw under refrigeration at 2C (36F) for 24 hr. Samples were then incubated at ambient room temperature (22 ± 2C; 72 ± 4F) for 7 days. Stem sections were cut longitudinally and visually evaluated for injury with the aid of a dissecting microscope (2, 7, 15, 16). Brown discoloration of the xylem or cambium was considered fatal.

Variability in injury between samples was observed in some taxa as treatment temperatures reached lethal levels. The lowest survival temperature (LST) was determined as the temperature at which no more than 40% of the replicates exhibited injury.

Results and Discussion

Significant differences in cold hardiness among taxa were detected on all sampling dates (Table 1), with no individual taxon consistently most hardy on all dates. 'Dolgo', 'Red Jade', 'Red Splendor', 'Selkirk', and *M. baccata* 'Jackii' exhibited the greatest hardiness overall, withstanding –40C (–40F) or colder in the 19 January test and also possessing good hardiness in the fall and early spring. *M. baccata* 'Jackii' had the maximum midwinter hardiness level detected at –44C (–47F). Midwinter low temperature tolerance is a critical factor affecting the geographic distribution of woody plants (3). Our results indicate that these five taxa possess sufficient midwinter hardiness for use in USDA hardiness zone 3b (17) [average annual minimum temperature of –34 to –37C (–30 to –35F)]. Herman (8) reported that these taxa survived without injury in Fargo, North Dakota (USDA zone 3b). 'Dolgo', 'Red Splendor', and 'Selkirk' have also performed well at the University of Minnesota Agricultural Experiment Station in Grand Rapids, MN (USDA zone 3b) [Dr. David Wildung, personal communication].

'Jewelberry' and *M. floribunda* were the least hardy taxa tested on most sampling dates. A comparison of the hardiness profiles of these taxa with that of 'Red Splendor' and local temperature data (Fig. 1) illustrates the relative vulnerability of these taxa to cold injury. Both 'Jewelberry' and *M. floribunda* lack sufficient hardiness to avoid injury in

Table 1. Lowest survival temperatures [C (F)] of shoots of crabapple taxa as determined by laboratory freezing tests in 1992–93.

	Sampling date					
Taxa	11–09	12–15	01–19	02–16	03–17	04–26
Adams	–24 (–11)	–34 (–29)	–38 (–36)	–34 (–29)	–32 (–26)	–23 (–9)
Beverly	–32 (–26)	–38 (–36)	–38 (–36)	–38 (–36)	–36 (–33)	–21 (–6)
Bob White	–24 (–11)	–34 (–29)	–38 (–36)	–34 (–29)	–30 (–22)	–17 (1)
Cascole[z]	–22 (–8)	–36 (–33)	–36 (–33)	–32 (–26)	–28 (–18)	–17 (1)
Centzam[z]	–24 (–11)	–34 (–29)	–38 (–36)	–36 (–33)	–32 (–26)	–19 (–2)
Chrishozam[z]	–22 (–8)	–36 (–33)	–38 (–36)	–36 (–33)	–30 (–22)	–21 (–6)
David	–28 (–18)	–38 (–36)	–38 (–36)	–36 (–33)	–36 (–33)	–15 (5)
Dolgo	–36 (–33)	–40 (–40)	–40 (–40)	–40 (–40)	–38 (–36)	–26 (–15)
Donald Wyman	–22 (–8)	–36 (–33)	–38 (–36)	–36 (–33)	–32 (–26)	–17 (1)
Hargozam[z]	–24 (–11)	–36 (–33)	–36 (–33)	–34 (–29)	–34 (–29)	–19 (–2)
Indian Magic	–26 (–15)	–38 (–36)	–38 (–36)	–36 (–33)	–34 (–29)	–23 (–9)
Indian Summer	–24 (–11)	–38 (–36)	–38 (–36)	–36 (–33)	–32 (–26)	–21 (–6)
Jewelberry	–22 (–8)	–32 (–26)	–32 (–26)	–32 (–26)	–26 (–15)	–12 (10)
Liset	–24 (–11)	–38 (–36)	–38 (–36)	–38 (–36)	–36 (–33)	–26 (–15)
Mary Potter	–24 (–11)	–36 (–33)	–36 (–33)	–34 (–29)	–32 (–26)	–15 (5)
Molazam[z]	–24 (–11)	–38 (–36)	–38 (–36)	–36 (–33)	–34 (–29)	–15 (5)
Ormiston Roy	–32 (–26)	–36 (–33)	–36 (–33)	–36 (–33)	–32 (–26)	–23 (–9)
Prairifire	–26 (–15)	–38 (–36)	–38 (–36)	–38 (–36)	–36 (–33)	–19 (–2)
Professor Sprenger	–24 (–11)	–38 (–36)	–38 (–36)	–38 (–36)	–34 (–29)	–21 (–6)
Profusion	–22 (–8)	–34 (–29)	–38 (–36)	–36 (–33)	–34 (–29)	–23 (–9)
Ralph Shay	–24 (–11)	–36 (–33)	–36 (–33)	–36 (–33)	–32 (–26)	–17 (1)
Red Baron	–26 (–15)	–38 (–36)	–36 (–33)	–34 (–29)	–32 (–26)	–21 (–6)
Red Jade	–36 (–33)	–38 (–36)	–40 (–40)	–36 (–33)	–30 (–22)	–23 (–9)
Red Splendor	–36 (–33)	–40 (–40)	–42 (–44)	–40 (–40)	–36 (–33)	–23 (–9)
Robinson	–24 (–11)	–32 (–26)	–38 (–36)	–34 (–29)	–32 (–26)	–23 (–9)
Ruby Lustre	–26 (–15)	–36 (–33)	–36 (–33)	–36 (–33)	–34 (–29)	–23 (–9)
Selkirk	–36 (–33)	–38 (–36)	–42 (–44)	–40 (–40)	–36 (–33)	–21 (–6)
Sentinel	–22 (–8)	–36 (–33)	–38 (–36)	–34 (–29)	–28 (–18)	–17 (1)
Snowdrift	–26 (–15)	–38 (–36)	–38 (–36)	–36 (–33)	–34 (–29)	–21 (–6)
Sutyzam[z]	–24 (–11)	–36 (–33)	–38 (–36)	–36 (–33)	–34 (–29)	–19 (–2)
Velvetcole[z]	–30 (–22)	–36 (–33)	–38 (–36)	–36 (–33)	–34 (–29)	–23 (–9)
Weepcanzam[z]	–24 (–11)	–36 (–33)	–38 (–36)	–36 (–33)	–32 (–26)	–17 (1)
Winter Gold	–24 (–11)	–36 (–33)	–38 (–36)	–36 (–33)	–34 (–29)	–21 (–6)
Zumarang	–26 (–15)	–38 (–36)	–38 (–36)	–38 (–36)	–32 (–26)	–15 (5)
M. baccata 'Jackii'	–32 (–26)	–42 (–44)	–44 (–47)	–38 (–36)	–32 (–26)	–19 (–2)
M. floribunda	–22 (–8)	–34 (–29)	–34 (–29)	–32 (–26)	–28 (–18)	–17 (1)
M. sargentii	–22 (–8)	–34 (–29)	–36 (–33)	–36 (–33)	–32 (–26)	–17 (1)
M. x zumi calocarpa	–22 (–8)	–30 (–22)	–36 (–33)	–36 (–33)	–34 (–29)	–9 (16)

[z]Cascole = White Cascade®; Centzam = Centurion®; Chrishozam = Christmas Holly®; Hargozam = Harvest Gold®; Molazam = Molten Lava®; Sutyzam = Sugar Tyme®; Velvetcole = Velvet Pillar®; Weepcanzam = Weeping Candied Apple®.

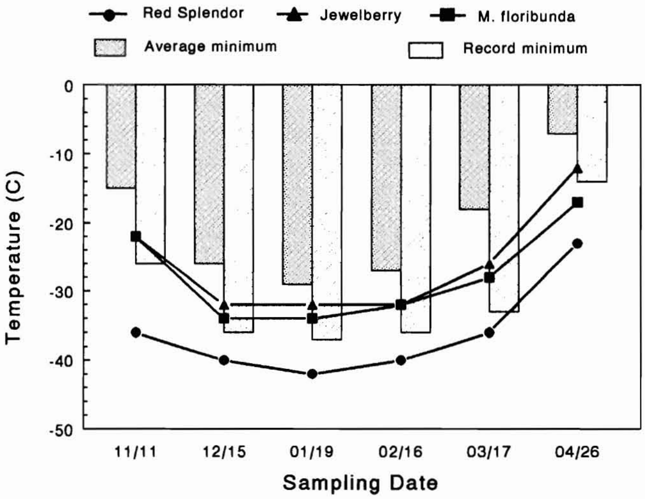

Fig. 1. **Hardiness profiles of *Malus* taxa 'Jewelberry', 'Red Splendor', and *M. floribunda* determined from laboratory freezing tests during 1992–93. Vertical bars represent the average monthly minimum temperatures and the coldest monthly minimum temperatures on record at the Horticultural Research Center, Excelsior, MN.**

years with below-average minimum temperatures in USDA zone 4a [average annual minimum temperature of –32 to –34C (–25 to –30F)]. These two taxa have exhibited winter injury in multiple years at the Minnesota Landscape Arboretum and were among the most severely damaged taxa in North Dakota trials (8).

Taxa differed in hardiness by as much as 14C (25F) on November 9, 1992, indicating that crabapple genotypes vary considerably in timing and/or rates of cold acclimation, and as a consequence, vulnerability to early season freezing events. 'Cascole', 'Chrishozam', 'Donald Wyman', 'Jewelberry', 'Profusion', 'Sentinel', *M. floribunda, M. sargentii,* and *M.* x *zumi calocarpa* were the least hardy [–22C (–8F)] taxa on November 9. These taxa along with 'Mary Potter', 'Prairifire', and 'Professor Sprenger' were severely injured in the field at the Minnesota Landscape Arboretum in the spring of 1986, while little or no damage was noted on the other taxa (14). The injury observed was speculatively attributed to severe cold (–26C (–14F) that occurred in the fall (November 29) of 1985. Our laboratory results support this hypothesis.

Timing and/or rates of deacclimation also varied greatly among crabapple taxa as evidenced by the large differences

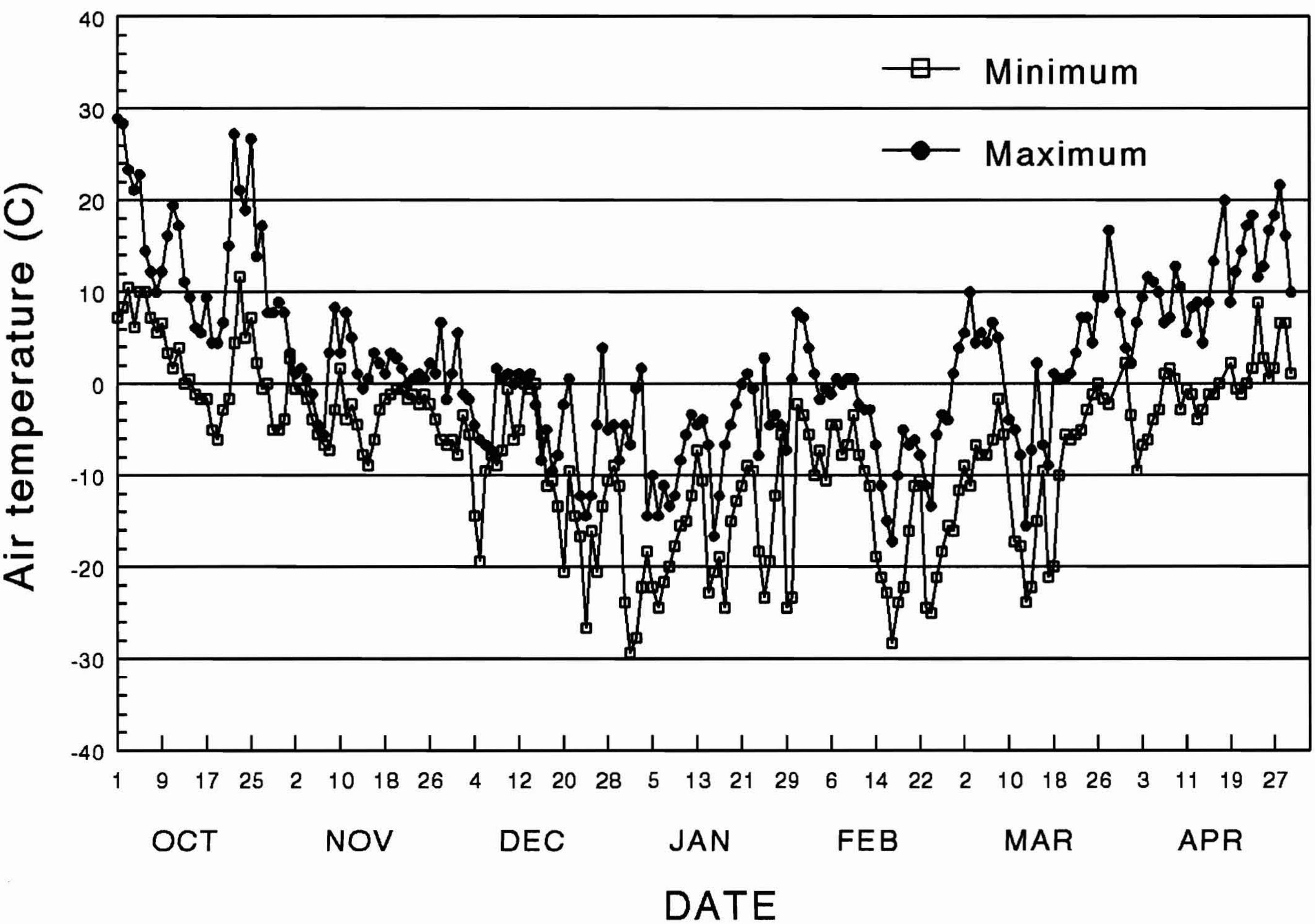

Fig. 2. **Daily maximum and minimum air temperatures (C) recorded at the Horticultural Research Center, Excelsior, MN during the winter of 1992–1993.**

in hardiness [up to 17C (31F)] measured on April 26, 1993. The results also indicate that crabapple taxa which initiate growth earliest in the spring aren't necessarily more vulnerable to late-winter cold snaps than late-breaking varieties. 'Dolgo', 'Selkirk', and *M. baccata* typically break bud from several days to a week earlier in spring than many of the less hardy taxa. Holubowicz et al. (6) reported similar results for a group of fruiting apple cultivars.

'Jewelberry' and *M.* x *zumi calocarpa* exhibited the greatest loss of hardiness by April 26 and may be susceptible to cold-injury at this time of year. However, under the temperature conditions occurring in the winter of 1992–93 (Fig. 2), most taxa maintained sufficient hardiness to avoid late-season freezing injury in central Minnesota. Further work is needed to determine how taxa with a propensity for early or rapid deacclimation perform in regions where broad temperature fluctuations in winter or early spring are more common.

The five crabapple taxa having the greatest mid-winter hardiness ('Dolgo', 'Red Jade', 'Red Splendor', 'Selkirk', and *M. baccata* 'Jackii') were also among the hardiest on the earliest and latest sampling dates. However, as reported for other species (9, 11, 12, 13), no consistent relationship existed between hardening and dehardening characteristics of crabapple taxa and their maximum midwinter hardiness levels. For example, 'Donald Wyman' and 'Velvetcole' exhibited similar hardiness on December 15, January 19, and February 16, but 'Donald Wyman' acclimated later in the fall and deacclimated earlier in the spring than 'Velvetcole'. These findings underscore the importance of developing full-season profiles when characterizing plant cold hardiness.

The geographic location of Chanhassen is conducive to expression of the maximum hardiness potential of many temperate-zone woody plant species by midwinter (typically the second to fourth week of January). Thus, hardiness determinations performed at that time can provide information on both the relative hardiness of taxa and their absolute maximum hardiness capabilities. However, because annual variation in meteorological conditions can substantially affect timing and rates of acclimation and deaclimation, determinations made at times other than midwinter are less useful as predictors of absolute cold tolerance. The least hardy cultivars in this study were killed in freezing tests between –22 and –24C (–8 and –11F) on November 9, 1992. However, the same plants survived –24C (–12F) in the field on November 7 of the previous year without injury. This disparity is likely a result of annual variations in hardiness caused by differing environmental conditions from one year to the next.

The immense popularity of flowering crabapples is certain to promote development and introduction of new cultivars. Our results show that sufficient hardiness exists within the genus *Malus* for development of varieties with excellent cold tolerance characteristics. Cold hardiness should be included among criteria used for evaluation of new crabapple selections.

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