

Cold Hardiness of New Apple Cultivars of Commercial Importance in Canada

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Abstract

Six new apple cultivars were evaluated for cold hardiness in early December and February for two consecutive winters, relative to traditional cultivars 'Golden Delicious', 'Mutsu' (winter tender) and 'McIntosh' (hardy). Pieces of dormant current season's shoots were frozen in a series of test temperatures from -20°C to -40°C in a programmable freezer. Ratings of tissue browning in the xylem were used to assess injury after thawing. The temperature of incipient damage (TID), the warmest temperature at which a cultivar began to show injury, was obtained from survival curves by non-linear regression. TID varied significantly among cultivars, but generally not with the time of the dormant period. Overall, the cultivars could be placed in groups based on relative winter hardiness as follows: 'Aurora Golden Gala' (very tender) < 'Mutsu', 'Jonagold', (tender) < 'Ambrosia', 'Golden Delicious' and 'Gala' (intermediate) < 'Northern Spy', 'McIntosh' (hardy), and 'Honeycrisp' (very hardy). These data indicate nearly a 10°C range in winter hardiness amongst the nine cultivars studied, depending on the sampling date. The cultivars, 'Ambrosia' and 'Aurora Golden Gala' appear to be particular winter tender; 'Aurora Golden Gala' appears more tender than 'Mutsu' and 'Jonagold' while 'Ambrosia' is similar to 'Golden Delicious'— all of which are considered relatively tender in Ontario and British Columbia. 'Honeycrisp' demonstrated the greatest winter hardiness. Based on these findings, it would be prudent to consult long-term climate normals and to take into account the frequency of extreme weather events for potential susceptibility to winter injury particularly prior to establishing the new tender cultivars 'Aurora Golden Gala', 'Ambrosia', and 'Gala'.

Apples (*Malus x domestica* Borkh) are grown in a wide range of environments both within and among the provinces of British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia, which range in hardiness from zone 8a to 5b (1) in Canada. Winter injury is a major constraint restricting fruit production (13, 23) and consequently orchards are typically established in close proximity to the moderating influence of large water bodies such as Lake Okanagan, or the Great Lakes. Winter injury sufficient to cause damage to apple trees occurs once every five to seven years (20) in western Canada, and perhaps more frequently in eastern Canada (5). In the Okanagan Valley of British Columbia, increasingly, the most vulnerable period is November when outbreaks of Arctic air flow southward and damage trees before they have fully acclimated (3, 25). In Ontario and eastern

Canada, the most vulnerable period is mid-to late winter, after unseasonably warm temperatures have caused early de-hardening followed by very cold temperatures (27). Late winter freezes cause injury to apple trees in climates where freeze-thaw cycles are frequent or in regions where apples are grown in extreme cold conditions (5).

In an attempt to avoid winter injury, one strategy is to grow cultivars that are more resistant to cold (24). Apple producers are continually searching for new cultivars in response to market demands and to improve orchard profitability. Cold hardiness is not a selection criterion that many breeding programs are focused on. Consequently, considerable risk is taken when establishing new cultivars that have not been fully assessed for their horticultural attributes, regional adaptability, and more specifically, cold/winter hardiness. Furthermore, new restricted-

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access cultivars, such as 'Minneiska', 'Red Prince' and 'Cripps Pink' for example, are not readily available for regional testing by researchers prior to commercial release.

'Honeycrisp' (15, 26), 'Ambrosia' (18), and 'Aurora Golden Gala' (9) are examples of cultivars in Canada that have been established in regions where they may be limited by either summer growing conditions (heat units) or extreme minimum winter temperatures. In Ontario, 'Gala', 'Ambrosia', 'Honeycrisp', 'McIntosh', 'Northern Spy', 'Golden Delicious', 'Mutsu', and 'Aurora Golden Gala' represent 21%, 16%, 13%, 13%, 6%, 6%, 4%, and 2% of the newly planted cultivars, respectively since 2003 (19). In British Columbia, 'Ambrosia', 'Gala', and 'Sunrise' represent 29%, 19%, and 6% of the overall orchard acreage as of 2010 (J. Campbell, personal communication). Understanding the winter hardiness

limitations of these cultivars, when growing regions differ widely with respect to minimum winter temperatures, is important for long term tree survival and orchard sustainability.

The objective of this study was to determine the winter hardiness of new, promising apple cultivars and to determine minimum temperatures at which winter injury can be anticipated.

Materials and Methods

Wood from nine apple cultivars including some with a range of known winter hardiness (Table 1) were sampled from research orchards at the Horticultural Experiment Station, Simcoe (lat. 42°51'40" N, long., long. 80°16'8" W) on 2 Feb. 2010, 6 Dec. 2010, 7 Feb. 2011, and 12 Dec. 2011 from mature fruiting trees on M.9 rootstock. The selected trees were healthy and free of

Table 1. Cultivars evaluated or proposed for wood hardiness.

Cultivar	Parents	Status	Hardiness ^z
1 Ambrosia	Unknown - (possibly Starking Delicious × Golden Delicious)	New	Unknown
2 Aurora Golden Gala	Splendour and Gala	New	Unknown. Preliminary reports indicate similar to Golden Delicious (10)
3 Gala	Kidd's Orange Red × Golden Delicious. Kidd's Orange Red = Cox's Orange Pippin × Delicious	Newer	Reportedly similar to Golden Delicious (14)
4 Golden Delicious	Unknown; circumstantial evidence suggests Grimes Golden × Golden Reinette	Reference cultivar	Tender (13, 24)
5 Honeycrisp	Keepsake × unknown	New	Unknown in Canada, Hardy in USA (15,16)
6 Jonagold	Golden Delicious × Jonathan	Reference cultivar	Tender (6)
7 McIntosh	Unknown. Fameuse type, possibly Fall St. Lawrence - Emperor Alexander	Reference cultivar	Hardy (17)
8 Mutsu/Crispin	Golden Delicious × Indo	Reference cultivar	Tender (13)
9 Northern Spy	Chance Seedling	Reference cultivar	Moderate (29)

^z - hardiness is based on previous reports in the literature as cited

disease and displayed typical growth and size representative of the cultivar. The early December sampling date was chosen for greater propensity to damage following an early cold period when trees would not be fully acclimated. The early February date was selected to represent a period when trees were most likely at their maximum hardness. Wood hardness and derivation of the "temperature of incipient damage" (TID) was determined using the protocol described previously (24).

Ten 1-yr-old extension shoots that were at least 30 cm in length were sampled from each of seven individual tree replicates of each cultivar. Shoots were approximately 8-12 mm in diameter and sampled from all parts of the canopy at least 1 m from the ground. All samples were collected from trees within 200 m of each other, and thus exposed to similar environmental conditions. Shoots of each cultivar were cut into lengths of about 4 cm. Shoot segments smaller than 8 mm diameter were discarded. Each segment included at least one vegetative bud (node). The wood segments were mixed in a plastic tub and five to six pieces were sealed into each of ten polyethylene zip lock bags pre-labeled with a sample code number and target temperature. The cultivar name was not included on the label in order to prevent bias later during injury ratings.

In 2010, the preparation of the shoot segments was completed in Summerland whereas in 2011, it was completed in Simcoe. Shoots (2010) or shoot segments (2011) were sealed in plastic bags and placed in a styrofoam cooler over crushed ice and shipped by air courier to Summerland, British Columbia for delivery within 24 hr.

A portable electronic data logger (Model HOBO® U12-011 Temperature Data Logger, Onset Computer Corp, Pocasset, MA) was placed in the container to record and verify temperature conditions every 60 sec during transport. Minimum and maximum temperatures during transit were -0.4/4.5°C

(2 Feb. 2010), -3.3/-0.5°C (6 Dec. 2010), 2.8/3.8°C (7 Feb. 2011), and -1.1/0.5°C (12 Dec 2011).

The bags were then transferred to a -3°C freezer chamber and stored overnight. The following morning, a T-type thermocouple was attached to the surface of one of the wood pieces in each bag, using an elastic band to ensure close contact.

Samples were then placed in a custom-built Conviron (Winnipeg, Manitoba) walk-in programmable freezer (2.5 m x 2.5 m) equipped with circulating fans, a custom-built cold pre-chamber anteroom, and a Conviron CMP3244 firmware controller. Tissues were exposed to a series of test temperatures between -20 and -40°C, with a temperature ramp of -1°C/hr. Samples were removed at 2.5°C intervals, beginning at -20°C. Once the measured temperature on the sample reached the target, the samples were removed from the freezing chamber, and transferred to a cooler with crushed ice (-3°C, dark) and then held at 1°C for 24 hours. Samples were then kept at 22°C for 24 hr at 100% relative humidity to allow tissue browning to occur, then stored on ice at 0°C in the dark to prevent decay over the 1-4 weeks required to complete sample scoring.

Tissue browning was rated on a scale of 0 to 10 (Fig. 1), modified from the original 0-5 scale described by Quamme (21). Each shoot piece was re-cut and viewed in cross-section with a stereomicroscope (Zeiss STEMI SV8, Carl Zeiss Canada, Don Mills, ON). Ratings for browning of xylem tissue consisted of estimating the percent area affected, where 0 = no visible damage, 1 = 10% damage, 2 = 20% damage, etc.

The shape of a typical freeze-tissue injury curve followed a sigmoidal pattern with the high rating scores (most injury) corresponding with the lowest temperatures. Mean scores for each cultivar were regressed against temperature using Equation 1 and graphing analysis software (Sigma Plot, version 11, Systat Software, Chicago, IL).

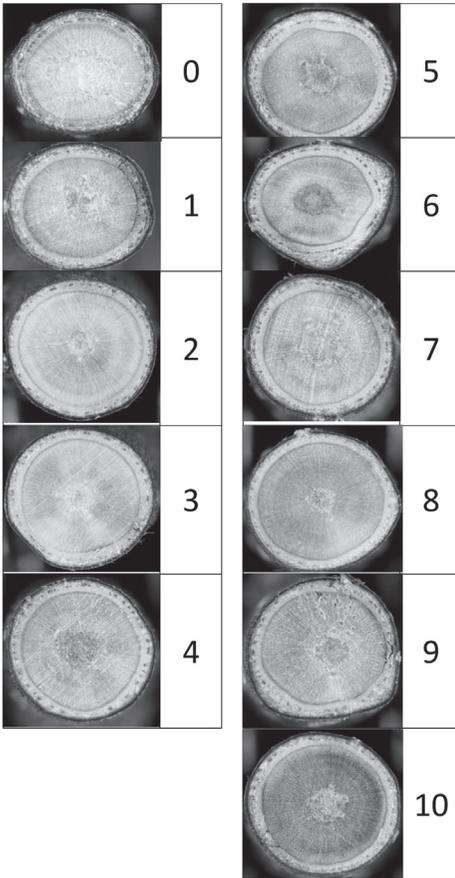


Fig. 1. Tissue browning was rated on a scale of 0 to 10, based on an estimate of percent area affected, where 0 = no visible damage, 1 = 10% damage, 2 = 20% damage, etc. No tissue browning of the phloem tissue was generally observed, even at the coldest temperatures. Modified after Quamme (24).

$$r = \frac{a}{1 + e^{-\left(\frac{x-x_0}{b}\right)}} \quad (1)$$

Equation 1 is a sigmoidal function used to determine the relationship between temperature and damage rating, where r = damage rating, a and x_0 are coefficients, and x = temperature in °C.

The temperature corresponding to a score of 1 (trace amount of injury) was interpolated from each curve and was designated as the “temperature of incipient damage”

(TID), also sometimes called the minimum survival temperature (4, 24). A rating of 1, while somewhat arbitrary, would likely result in xylem damage in the orchard and manifest itself through typical cold injury symptoms such as shoot top dieback (H. Quamme, personal communication). Mean rating scores for each cultivar and exposure temperature were also analyzed using PROC GLM (SAS version 9.2; SAS Institute, Cary, NC) with cultivar means separated using Duncan’s Multiple Range Test at $P=0.05$.

Results and Discussion

Significant cultivar differences in winter cold hardiness were observed during all four sampling dates (Table 2). The temperatures at which injury was observed were consistent with those published previously for data from British Columbia (24). Xylem injury was not observed in any of the untreated control values (data not shown) or exposure temperatures warmer than -22.5°C (e.g., -20 °C), with the exception of samples collected on 12 Dec. 2011. Xylem injury became evident at temperatures of -27.5°C on 2 Feb., 2010, -22.5°C on 6 Dec. 2010, -30.0°C on 7 Feb. 2011, and -22.5°C on 12 Dec. 2011 and increased in a sigmoidal fashion with decreasing temperatures (Table 2). It is at these temperatures that damage to xylem ray parenchyma cells occurs (8, 28). No injury to the phloem tissue was detected and therefore all ratings were based upon xylem scores of injury.

Another approach to determine injury under field conditions is to estimate the temperature at which the first detectable injury can be observed, referred to as the temperature of incipient damage (TID) (7, 22). These values, calculated using Equation 1, varied markedly among cultivars and appear in Table 3.

Overall, in Table 4 and Fig. 2, the winter hardiness of cultivars summarized in order of increasing winter hardiness, are: ‘Aurora Golden Gala’ < ‘Mutsu’, ‘Jonagold’, < ‘Ambrosia’, ‘Golden Delicious’ and

Table 2. Mean shoot xylem injury rating of several apple cultivars sampled on Feb 4, 2010 from the Simcoe Research Station and exposed to temperatures ranging from -22.5 to -40°C

Cultivar	-22.5 °C	-25 °C	-27.5 °C	-30 °C	-32.5 °C	-35 °C	-37.5 °C	-40 °C	Overall Average
04 Feb 2010									
Aurora Golden Gala	0.00	0.00	0.0	0.1	2.6	4.5	7.8	9.6	4.1
Golden Delicious	0.00	0.00	0.0	0.3	4.0	3.9	6.7	9.6	4.1
Jonagold	0.00	0.00	0.0	0.3	2.3	3.7	7.1	9.8	3.9
Mutsu	0.00	0.00	0.1	0.0	1.7	3.3	5.7	10.0	3.5
Ambrosia	0.00	0.00	0.0	0.4	2.1	3.6	5.9	6.7	3.1
McIntosh	0.00	0.00	0.2	0.0	0.8	1.1	3.1	6.7	2.0
Honeycrisp	0.00	0.00	0.0	0.0	0.9	1.9	3.3	5.7	2.0
Gala	0.00	0.00	0.1	0.0	0.3	1.2	3.7	6.5	1.9
Northern Spy	0.00	0.00	0.0	0.0	0.1	0.5	1.4	7.2	1.5
Statistical significance ^z	NA	NA	ns	*	***	***	***	***	***
P Value			0.077	0.02	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
06 Dec 2010									
Ambrosia	0.00	0.04	0.04	0.69	2.29	5.53	5.90	5.90	2.9
Aurora Golden Gala	0.00	0.06	0.60	2.66	3.64	7.60	8.74	8.74	4.6
Gala	0.00	0.04	0.49	1.57	3.34	4.49	7.03	7.03	3.4
Golden Delicious	0.00	0.01	0.16	0.60	2.66	6.44	7.07	7.07	3.4
Honeycrisp	0.00	0.00	0.00	0.13	0.76	1.17	1.24	1.24	0.6
Jonagold	0.01	0.00	0.84	1.47	3.10	5.07	6.54	6.54	3.4
McIntosh	0.01	0.01	0.00	0.67	1.94	4.41	5.87	5.87	2.7
Mutsu	0.00	0.10	2.34	4.36	7.43	8.10	8.06	8.06	5.5
Northern Spy	0.00	0.00	0.17	0.27	2.80	5.26	6.80	6.80	3.2
Statistical significance ^z	ns	ns	***	***	***	***	***	**	***
P Value	0.4797	0.838	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0013	<0.0001
07 Feb 2011									
Ambrosia	0.00	0.00	0.00	0.06	0.90	2.56	5.47	9.61	3.7
Aurora Golden Gala	0.00	0.00	0.00	2.07	4.36	8.40	9.36	10.00	6.8
Gala	0.00	0.00	0.00	0.04	0.47	3.40	4.61	6.54	3.0
Golden Delicious	0.00	0.00	0.00	0.09	0.33	1.91	6.29	9.47	3.6
Honeycrisp	0.00	0.00	0.00	0.00	0.26	1.81	2.57	5.31	2.0
Jonagold	0.00	0.00	0.00	0.19	0.80	3.77	5.03	9.54	3.9
McIntosh	0.00	0.00	0.00	0.01	0.00	1.53	2.51	6.84	2.2
Mutsu	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northern Spy	0.00	0.00	0.00	0.11	0.60	3.83	5.29	8.76	3.7
Statistical significance ^z				***	***	***	***	***	***
P Value				<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
12 Dec 2011									
Ambrosia	0.13	0.01	0.16	0.11	0.73	4.81	6.21	9.86	2.8
Aurora Golden Gala	0.00	0.00	0.00	0.07	0.43	5.10	6.83	10.00	2.8
Gala	0.17	0.41	0.44	0.93	1.70	4.81	7.60	10.00	3.3
Golden Delicious	0.09	0.23	0.73	1.14	2.71	6.41	8.44	10.00	3.7
Honeycrisp	0.24	0.69	1.21	1.57	4.36	8.13	9.60	10.00	4.5

Jonagold	0.85	0.75	2.67	2.50	5.05	8.63	9.92	10.00	5.0
McIntosh	0.54	0.97	1.77	4.00	5.70	8.84	10.00	10.00	5.2
Mutsu	0.00	0.07	0.13	0.43	2.96	7.60	9.90	10.00	3.9
Northern Spy	0.00	0.21	0.47	1.99	3.11	5.49	8.73	10.00	3.8
Statistical significance ^z	***	***	***	***	***	***	***	ns	***
P Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.47	<0.0001

^z ns, *, **, ***, indicates not significant, and significant differences at P= 0.05, P=0.10, and P=0.01 respectively

‘Gala’ < ‘Northern Spy’, ‘McIntosh’, and ‘Honeycrisp’. ‘Golden Delicious’, ‘Jonagold’ and ‘Mutsu’ are all considered “winter sensitive”, while ‘McIntosh’ is considered to be winter hardy in British Columbia (4). ‘Northern Spy’ in the past has been reported to have moderate winter hardiness in New York (2) while ‘Gala’ has been reported to be closer in hardiness to ‘Golden Delicious’ in Minnesota (16). The results for ‘Honeycrisp’ with an average TID of -35°C are consistent with the reported winter hardiness of this Minnesota cultivar (15). These data also reveal that the ranking of hardiness remains relatively unchanged between sampling dates, with the exception of 2 Feb. 2010. Apart from ‘Honeycrisp’, all cultivars demonstrated a range of 2 to 4°C

greater hardiness on the February versus December sampling. ‘Honeycrisp’, in contrast was equally hardy on these sampling dates. In addition, considering the sampling dates collectively, the data indicate that ‘Honeycrisp’ may acclimate earlier in the season than the other cultivars in the study.

In order to understand the short-term climatic effects on acclimation and deacclimation processes and how these may have influenced the hardiness values, hourly temperatures ten days prior to each sampling date were investigated (Table 5). Immediately prior to the two February 2010 and 2011 sampling dates, relatively low minimum temperatures were experienced. However, a maximum air temperature of 6.4°C eight days prior to the 2 Feb. 2010

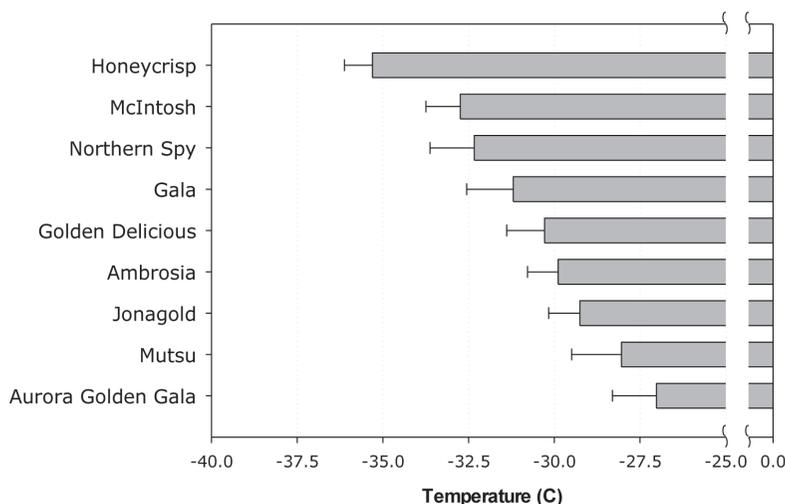


Fig. 2. Estimate of temperatures at which xylem injury rating equated to a value of 1 for nine apple cultivars, determined across four sampling dates (2 Feb. 2010, 6 Dec. 2010, 7 Feb. 2011, 12 Dec. 2011). Error bars represent the standard deviation of the four means (sampling dates) divided by two.

Table 3. Regression parameters, coefficient of variation, and predicted temperatures when assessment of tissue browning reached a value of 1 (temperature of incipient damage) for several apple cultivars sampled on four dates. University of Guelph Research Station, Simcoe

Cultivar	parameter a ^y	parameter x0 ^z	parameter b ^z	R ²	Estimated temp. (°C) at which TID was associated with a rating of 1
02 Feb 2010					
Ambrosia	7.2	-34.8	-1.99	0.99	-30.9
Aurora Golden Gala	10.5	-35.4	-2.02	0.99	-30.7
Gala	8.2	-37.8	-1.59	1.00	-34.5
Golden Delicious	13.5	-37.3	-3.13	0.96	-29.2
Honeycrisp	10.0	-39.2	-2.71	0.99	-33.0
Jonagold	12.3	-36.8	-2.39	0.99	-30.8
McIntosh	29.2	-43.2	-2.68	0.99	-34.2
Mutsu	18.8	-39.7	-2.83	0.99	-31.4
Northern Spy	7.9	-37.7	-1.01	1.00	-35.6
06 Dec 2010					
Ambrosia	11.1	-36.0	-2.68	0.97	-29.6
Aurora Golden Gala	9.0	-30.0	-1.91	0.98	-25.8
Gala	15.0	-37.8	-3.56	0.98	-28.2
Golden Delicious	9.7	-34.3	-1.92	0.94	-29.9
Honeycrisp	-8.4	-113.4	-2.23	0.98	-36.3
Jonagold	15.9	-38.3	-3.77	0.99	-27.9
McIntosh	15.9	-38.7	-3.10	0.99	-30.1
Mutsu	10.5	-33.3	-2.30	0.99	-27.9
Northern Spy	11.7	-36.0	-2.55	1.00	-29.7
07 Feb 2011					
Ambrosia	14.8	-38.6	-2.22	1.00	-32.6
Aurora Golden Gala	10.1	-32.7	-1.62	1.00	-29.0
Gala	6.7	-35.5	-1.64	0.98	-32.4
Golden Delicious	10.4	-36.9	-1.31	1.00	-33.9
Honeycrisp	12.5	-40.9	-2.71	0.98	-36.3
Jonagold	18.2	-39.8	-2.80	0.98	-31.7
McIntosh	8.2	-37.5	-1.55	1.00	-34.3
Mutsu	-	-	-	-	-
Northern Spy	11.2	-37.3	-2.24	0.98	-31.9
12 Dec 2011					
Ambrosia	11.8	-35.1	-2.68	1.00	-28.5
Aurora Golden Gala	10.8	-31.6	-2.66	0.99	-25.3
Gala	11.8	-36.1	-2.31	1.00	-30.4
Golden Delicious	10.6	-34.4	-2.07	1.00	-29.5
Honeycrisp	11.5	-36.6	-2.12	0.98	-36.3
Jonagold	10.4	-32.9	-1.89	0.99	-28.5
McIntosh	10.3	-35.7	-1.67	0.98	-31.8
Mutsu	11.3	-32.5	-2.87	0.98	-25.6
Northern Spy	10.2	-33.6	-1.23	1.00	-30.8

^z Ratings approximated a decay model, where rating, $r = a \cdot e^{-b \cdot x}$, x = temperature (°C)

Table 4. Predicted temperatures when assessment of tissue browning reached a value of 1 (TID) for nine apple cultivars sampled over several dates. University of Guelph Research Station, Simcoe.

Cultivar ^z	02 Feb 2010	Rank ^x	06 Dec 2010	Rank ^x	07 Feb 2011	Rank ^x	12 Dec 2011	Rank ^x	Overall mean		Rank ^x	Hardiness
Aurora Golden Gala	-30.7 ^y	2	-25.8	1	-29.0	1	-25.3	1	-26.7	a ^w	1	V. Tender
Mutsu	-34.2	7	-27.9	3	-	-	-25.6	2	-29.2	ab	2	} Tender
Jonagold	-30.8	3	-27.9	2	-31.7	2	-28.5	4	-29.7	abc	3	
Ambrosia	-30.9	4	-29.6	5	-32.6	5	-28.5	3	-30.4	bcd	4	} Inter- mediate
Golden Delicious	-29.2	1	-29.9	7	-33.9	6	-29.5	5	-30.6	bcd	5	
Gala	-34.5	8	-28.2	4	-32.4	4	-30.4	6	-31.4	cd	6	} Hardy
Northern Spy	-35.6	9	-29.7	6	-31.9	3	-30.8	7	-32.0	cd	7	
McIntosh	-34.2	6	-30.1	8	-34.9	7	-31.8	8	-32.8	d	8	} V. Hardy
Honeycrisp	-33.0	5	-36.3	9	-36.3	8	-36.3	9	-35.4	e	9	

^z cultivars ranked in order of least to most winter hardy

^y ratings approximated a sigmoidal model, where rating, $r = a/(1+\exp(-(x-x_0)/b))$, x = temperature (°C)

^x ranking from least (1) to most winter hardy (9).

^w average values with the same letter within a given column are not significantly different according to Duncan's multiple range test at $P = 0.05$.

sampling date was experienced indicating some potential for deacclimation. This may explain some why 'Golden Delicious' and 'Honeycrisp' appeared less hardy on 2 Feb. 2010 in comparison with the other sampling date. Air temperatures were considerably warmer prior to the December 2010 and 2011 sampling dates, as indicated by higher minimum temperatures, maximum temperatures and degree hours above 0°C. As observed, acclimation temperatures (hardiness) were lower for the warmer late autumn sample dates, which is consistent with other studies (12). Based on several studies reviewed by Kalberer (12), deacclimation occurs more rapidly (days to weeks) than acclimation (weeks to months). In one study on apple in Michigan, a deacclimation loss of 15°C in hardiness occurring over one day

required three cold days to reverse (11). The acclimation and deacclimation processes in the present study were clearly influenced by both air temperature and the apple cultivars assessed (12), but further comments on these effects are beyond the scope of this study.

Collectively, these data indicate nearly a 6 to 10°C range in winter hardiness amongst the nine cultivars studied, depending on the sampling date. The newer cultivars, 'Ambrosia' and 'Aurora Golden Gala' appear to have less winter resistance than 'Golden Delicious' and 'Mutsu', respectively – cultivars which are considered tender in Ontario and British Columbia. Further data are required to substantiate these results, however growers might be cautioned to avoid planting these cultivars in the colder apple producing regions of Ontario and British Columbia.

Table 5. Air temperatures (°C) the previous seven days prior to the sampling dates University of Guelph Research Station, Simcoe

Cultivar	02 Feb 2010	06 Dec 2010	07 Feb 2011	12 Dec 2011
Minimum	-18.3	-5.5	-24.6	-7.9
Maximum	-0.2	12.4	-0.5	9.3
Mean	-9.0	0.5	-8.7	0.8

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