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Low-Temperature Susceptibility of 'Redhaven' Peach Floral Buds on Various Rootstocks in the 1994 NC-140 Trial

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Abstract

'Redhaven' budwood was collected from Missouri, Ohio, and South Carolina from January 1997 through March 1999 and subjected to controlled freezing tests to evaluate the relative cold tolerance of peach floral buds on rootstocks included in the 1994 NC-140 trial. Floral bud hardiness was not affected by rootstock at any site when samples were collected in early November 1997 and 1998. However, in January 1997 and 1999, the T50 values of floral buds on Ta Tao 5 interstem/Lovell rootstock were consistently low ($\leq$ -19.1°C) in Missouri, whereas those of buds on BY520-8 and S.2729 trees were high. At the Ohio site, which had fewer rootstocks in the trial, floral buds on Tennessee Natural 281-1 trees were more cold tolerant than those on other trees in March 1998 and 1999, while floral buds on BY520-9 were less tolerant. In South Carolina, none of the rootstocks conferred greater floral bud hardiness than Lovell at any sampling date. However, buds on H7338013 and Ta Tao 5 interstem/Lovell trees had lower T_{50} values than those on Tennessee Natural 281-1, Myran, and Nemaguard in January 1997 and late February 1999. Thus, at the two sites that had Ta Tao 5 interstem/Lovell, floral bud hardiness was similar to, or better than that of Lovell trees.

Introduction

Low-temperature injury is often a limiting factor in peach production. Loss of floral buds due to cold temperatures reduces annual yield and root injury affects tree survival and longevity (10). To enhance yield stability, researchers have attempted to identify cold-hardy germplasm that avoids low temperature injury (5, 6, 7, 12, 15, 20, 21). However, strict 'hardiness' classifications are difficult to construct because low-temperature susceptibility of scion reproductive and vegetative tissues varies during dormancy (11, 13, 21, 22). Moreover, when peaches are grown on sandy soils, roots are relatively more susceptible to low-temperature injury than above-ground portions of the tree in midwinter (8). Root injury occurs at soil temperatures of -5°C and can be severe on seedling rootstocks such as Nemaguard, Yunnan, Halford, and Rutgers Red Leaf at -13°C (8, 9). Based on controlled freezing tests of root tissue, Layne (8) categorized the root systems of Tzim Pee Tao and Siberian C as more cold resistant than Bailey.

On sites with non-sandy soils where root damage is uncommon, low-temperature injury of floral buds and shoots may be of greater importance than that of roots (8, 11). Under these conditions, research efforts have focused on the influence of rootstocks on scion survival (2, 4, 5, 6, 21). Three studies used germplasm from the 1984 NC-140 peach rootstock trial, which included Bailey, Damas 1869, GF 655-2, GF 677, Halford, Lovell, Siberian C, and own-rooted 'Redhaven' trees (2, 5, 21). Following a mid-February freeze (-2°C) in New York, Brown and Cummins (2) reported that Redhaven on GF 655-2 and GF 677 generally had the lowest floral bud survival, while buds on Citation and Damas 1869 had the greatest survival. In New Jersey, after low temperatures ($\leq$ -23°C) were recorded in mid- and late January in two consecutive years in the field, floral bud survival of 'Redhaven' was consistently greater on Siberian C than on GF 677 (5).

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In contrast, results from artificial freezing tests conducted in early March in Missouri revealed that floral buds on Lovell were hardier than those of all other rootstocks except Damas 1869 (21).

In recent reports (18, 19), rootstocks such as H7338013, H7338019, and Chui Lum Tao and interstems such as Tzim Pee Tao, and Ta Tao 5 were classified as more cold tolerant than Lovell. Thus, the purpose of this study was to evaluate the relative cold tolerance of 'Redhaven' floral buds on rootstocks included in the 1994 NC-140 trial at three times during dormancy over a three-year period at three locations.

Materials and Methods

Peach rootstock trials were established in1994 with 'Redhaven' as the scion cultivar budded onto various Prunus rootstocks (Table 1) according to guidelines established by the NC140 committee (19). Budwood was collected from plantings maintained at New Franklin, Missouri; Wooster, Ohio; and Clemson, South Carolina. Due to a shortage of plant material, plantings at these three sites had 11 rootstocks in common, while Missouri and South Carolina plantings included additional rootstocks (Table 1).

Tissue for the freezing tests was collected the first week of January in 1997, 1998, and 1999 at all three locations to assess floral bud hardiness in mid-winter. To evaluate low- temperature susceptibility at bud swell, tissue was sampled from trees at the South Carolina site the last week of February in 1997, 1998, and 1999, while buds at the same phenological stage were sampled from Ohio and Missouri sites in early March of the same years. Floral bud acclimation was also evaluated at all sites the first week of November in 1997 and 1998. At all locations, budwood was collected from six replications of the field trial. On each sampling date, six 4-node cuttings were collected from the middle portion of one-year-old wood at equidistant positions around the trunk of each tree at approximately 1.5 m above the soil surface. Tissue was then placed in sealed polyethylene bags, packed on ice, and transported to the laboratory. Samples from Ohio were sent by overnight mail to the University of Missouri-Columbia, where freezing tests were conducted, along with samples collected from New Franklin. South Carolina samples were subjected to freezing tests at Clemson University. Immediately after the receipt of the tissue from Ohio or collection from the field (Missouri and Ohio), a 4-node twig sample from each rootstock treatment was placed in moist cheesecloth and wrapped in aluminum foil for each of six test temperatures. A 0.0l-mm-diameter (30-gauge) copper constantan thermocouple was placed in contact with a bud of a sample enclosed in aluminum foil to monitor tissue temperature. Thermocouple output was read with a digital thermometer (Omega Engineering, Inc., Stamford, Conn.). Samples were then placed in a programmable freezer at -2°C and held at this temperature for one hour. The cheesecloth froze and seeded the tissue with ice at about -1°C. Samples were removed from the freezer at 3° intervals at tissue temperatures that were estimated to result in bud injury, and thawed at 2°C for 24 hr. After thawing, tissue was incubated at 100% relative humidity at 25°C for 5 days, sectioned with a razor blade, and examined for oxidative browning under a dissecting microscope at ≤40×. The number of injured and uninjured floral primordia were recorded and the modified Spearman-Karber equation (1) was used to calculate T50 values for buds at each sampling date. Data from each state were subjected to an analysis of variance by each sampling date using the GLM procedure of SAS (SAS Institute, Cary, N.C.). Next, data from *all* three states were pooled and analyzed by each sampling date to determine if the eleven rootstocks grown at all three sites influenced the low-temperature susceptibility of floral buds. Means were separated by Fisher's protected least significant difference (LSD) test, $P \leq 0.05$.

Results and Discussion

The Missouri and Ohio NC-140 trial sites are categorized by the USDA as hardiness zones 5b in which the average an-

Table 1. Rootstocks included at the NC-140 sites.

Rootstock	Type and origin of rootstock	NC-140 sites MO	OH	SC
Bailey	peach seedling originally found in Iowa in 1890 (14)	+[z]	+	+
BY520-8	peach seelding from a seedling x Nemaguard cross in 1954	+	+	+
BT520-9[Y]	peach seedling from a seedling X Nemaguard cross in 1954 (15)	+	-	+
Chui Lum Tao	peach seedling from Harbin, China (11)	+	+	+
GF 305	peach seedling selected in France in 1945 (Jean-Luc Poëssel, personal communication)	+	+	+
H7338013	peach seedling from a Bailey x Siberian C cross made in Canada in 1973	+	-	+
H7338019	peach seedling from a Bailey x Siberian C cross made in Canada in 1973	+	-	+
Higama	peach seelding introduced from Japan to France in 1960 and released in 1981 (Jean-Luc Poëssel, personal communication)	+	+	+
Ishtara	clonal rootstock froma 'Belsiana' plum and a plum x peach made in France in 1950 and released in 1986 (Jean-Luc Poëssel, personal communication)	+	+	+
Lovell	peach seedling originally found in California in 1882	+	+	+
Montclar	peach seedling selected at Massif Central, France in 1960 and released in 1982 (Jean-Luc Poëssel, personal communication)	+	+	+
Myran	clonal rootstock from a 'Belsiana' plum and 'Unnan' peach cross made in France in 1950 and released in 1982 (jean-Luc Poëssel, personal communication (7)	-	-	+
Nemaguard	peach seedling selected in Georgia from a seedlot labeled *Prunus davidiana* in 1949	-	-	+
Rubira	peach seedling originally from USA but selected in France in 1960 and released in 1980 (Jena-Luc Poëssel, personal communication)	+	+	+
S.2729	clonal rootstock probably from a myrobalan plum x peach cross made in France (Jean-Luc Poëssel, personal communication)	+	-	+
Starks' Redleaf	open pollinated peach seedling of Tennessee Natural selected by Stark Bro's nursery around 1955 (Elmer Kidd, personal communication)	+	+	+
Ta Tao 5[X]	peach seedling selected in China in 1933	+	-	+
Tennessee Natural . 281-1	peach seedling selected from Tennessee	+	+	+
Tzim Pee Tao	peach seedling selected from Harbin, China as early as 1957	+	-	+

[Z]+ indicates that this rootstsock was included in the trial at a specific location whereas - indicates that it was not sampled from that site. There were 11 rootstocks common to the MO, OH, and SC locations.
[Y]Rootstock was trademarked Guradian™ Brand 'BY520-9' after the inception of the trial.
[X]Ta Tao was budded onto Lovell rooststock in this study.

nual minimum temperatures range from -10 to -15°C (3). However, temperatures recorded in Missouri during the test periods were generally lower than those in Ohio (Table 2). January was particularly cold in Missouri in 1997 and 1999, with temperatures ≤ -25°C. As a result of these severe temperatures on 17 Jan.1997 in Missouri, all floral buds sampled in March 1997 exhibited oxidative browning injury in the field so freezing tests could not be performed nor T_{50} values determined from this tissue. The Ohio site recorded its lowest temperature (-16°C) in January 1997, but had relatively mild winter conditions during this study. Low temperatures did not eliminate crops in either Ohio or South Carolina during this study. The South Car-

Table 2. Minimum single day temperatuares (°C) at Missouri, Ohio, and South Carolina NC-140 peach trial sites from November 1996 through March 1999.

Month	Year	MO	OH	SC
November	1996	-9	-5	-2
December	1996	-17	-9	-8
January	1997	-28	-3	-8
February	1997	-7	-7	-5
March	1997	-7	-16	-1
November	1997	-8	-9	--1
December	1997	-7	-13	-4
January	1998	-12	-12	-8
February	1998	-6	-7	1
March	1998	-17	-10	-5
November	1998	-3	-3	2
December	1998	-17	-11	-2
January	1999	-25	-16	-10
February	1999	-7	-9	-5
March	1999	-6	-11	-2

olina NC-140 trial site has been categorized as a hardiness zone 7b, with average annual minimum temperatures of 5° to 0°C. However, in December 1996 and in January 1997, 1998, and 1999, temperatures ≤ -8°C were recorded (Table 2).

Data analysis by location revealed differences in floral bud hardiness among rootstocks. In Missouri, T50 values of floral buds among rootstocks were significantly different at the January 1997 and 1999 sampling dates (Table 3). Floral buds on all rootstocks except Lovell had lower T_{50} values in January 1997 than in 1999. In January 1997, 'Redhaven' floral buds on Ta Tao interstem/Lovell rootstock, H7338019, and Bailey had lower T50 values than those on Stark's Redleaf, Ishtara, BY520-8, H7338013, S.2729, and Lovell rootstocks. However, in January 1999, buds on Lovell and Ta Tao interstem/Lovell trees were more cold tolerant than those on Higama, S.2729, GF 305, Chui Lum Tao, and BY-520-8. At other sampling dates, differences in T_{50} values were not detected (data not shown). The reason that floral buds of Lovell trees had the poorest cold tolerance in January 1997 but the greatest cold resistance in January 1999 is unknown. In other studies, floral buds of 'Redhaven' on Lovell trees tend to be relatively cold tolerant when compared to those on other rootstocks (Warmund, unpublished data). Unfortunately, yield could not be correlated with hardiness because the severe winter temperatures eliminated the crop in 1997. In spite of this inconsistency in the ranking of Lovell, discrimination of floral bud hardiness among rootstocks occurred in January 1997 and 1999. Ta Tao 5 interstem/Lovell rootstock consistently conferred cold resistance to the floral buds in January 1997 and 1999 when temperatures were relatively low. These results support Layne's findings (11) that genetic differentiation of scion hardiness is generally best in midwinter when cultivars are near maximum hardiness levels and when wide fluctuations in temperature are less frequent.

Table 3. Mean T_{50} values of 'Redhaven' peach floral buds on various rootstocks sampled from Missouri in January 1997 and 1999.

	T_{50} value (°C)[z]	
Rootstock	January 1997	January 1999
Bailey	-20.7	-18.3
BY520-8	-19.3	-16.7
BY520-9	-20.5	-18.3
Chui Lum Tao	-20.5	-17.2
GF 305	-20.0	-17.2
H7338013	-19.3	-17.5
H7338019	-20.9	-17.7
Higama	-19.8	-17.3
Ishtara	-19.5	-18.0
Lovell	-18.6	-19.3
Montclar	-20.0	-18.1
Rubira	-20.0	-17.9
S.2729	-18.9	-17.3
Stark's Redleaf	-19.8	-18.3
Ta Tao 5 interstem/Lovell	-21.2	-19.1
Tennessee Natural 281-1	-19.9	-18.5
Tzim Pee Tao	-20.1	-18.5
$LSD_{0.05}$	1.1	1.7

[z]Mean separation within column by Fisher's protected LSD test, $P \leq 0.05$.

Table 4. Mean T_{50} values of 'Redhaven' peach floral buds on various rootstocks sampled from Ohio in March 1998 and 1999.

Rootstock	T_{50} value (°C)[z] March 1998	March 1999
Bailey	-16.2	-15.2
BY520-8	-17.0	-15.8
BY520-9	-15.3	-13.4
GF 305	-15.9	-16.0
Higama	-15.4	-14.9
Ishtara	-15.8	-16.2
Lovell	-16.0	-13.5
Montclar	-16.0	-14.3
Rubira	-16.0	-14.9
Stark's Redleaf	-14.9	-15.8
Tennessee Natural 281-1	-18.3	-16.2
$LSD_{0.05}$	1.3	2.0

[z]Mean separation within columns by Fisher's protected LSD test, $P \leq 0.05$.

In other studies, (16, 17), Ta Tao 5 buds have been identified as high chilling. The Ta Tao 5 interstem/Lovell rootstock combination delayed full bloom of scion cultivars as much as 13 days later than similar cultivars on Lovell rootstock alone (16, 17). However, when two low temperature freezing episodes occurred in South Carolina in March 1996, Ta Tao 5 interstem/Lovell rootstock delayed bloom but apparently did not enhance flower survival (17). Results from the current study revealed that Ta Tao5/Lovell rootstock, as well as Lovell rootstock alone can confer low-temperature resistance to 'Redhaven' floral buds in mid-winter. Thus, these findings may indicate that increased floral bud hardiness cannot be attributed solely to the high-chilling requirement of Ta Tao 5, (i.e., prolonging dormancy), but rather to another, unidentified factor(s).

In Ohio, differences among T_{50} values were detected at the March 1998 and 1999 sampling dates (Table 4). In March 1998, floral buds on Tennessee Natural 281-1 and BY520-8 were less susceptible to low temperatures than those on Higama, BY520-9, and Stark's Redleaf. In March 1999, buds on Tennessee Natural 281-1 and Ishtara were hardier than those on Lovell and BY520-9. Again, the reason for the relatively high T_{50} value of floral buds on Lovell rootstock in March 1999, but not in March 1988, is unknown. However, floral bud hardiness of Tennessee Natural 281-1 trees was consistently greater than that of BY520-9 when differences among rootstocks were detected.

In South Carolina, January 1997 and late February 1999 were the only two sampling dates when differences among floral bud hardiness were detected (Table 5). In January 1997, floral buds on H7338013, Ishtara, Lovell and Ta Tao 5 interstem/Lovell trees had lower T_{50} values than those on Tennessee Natural 281-1, Myran, and Nemaguard trees. In late February 1999, floral buds of H7338013,

Table 5. Mean T_{50} values of 'Redhaven' peach floral buds on various rootstocks sampled from South Carolina in January 1997 and late February 1999.

Rootstock	T_{50} value (°C) January 1997	February 1999
Bailey	-20.2	-18.3
BY520-8	-19.8	-17.4
BY520-9	-21.0	-16.3
Chui Lum Tao	-21.2	-18.0
GF305	-19.8	-17.3
H7338013	-21.9	-18.7
H7338019	-21.1	-16.8
Higama	-20.7	-17.7
Ishtara	-21.7	-17.3
Lovell	-21.3	-17.9
Montclar	-19.9	-17.4
Myran	-17.5	-16.3
Nemaguard	-17.5	-16.3
Rubira	-20.7	-17.5
S.2729	-20.4	-17.4
Stark's Redleaf	-20.1	-17.1
Ta Tao 5 interstem/Lovell	-21.3	-18.5
Tennessee Natural 281-1	-19.6	-15.4
Tzim Pee Tao	-20.9	-18.0
$LSD_{0.05}$	1.6	1.4

[z]Mean separation within columns by Fisher's protected LSD test, $P \leq 0.05$.

Table 6. Mean T_{50} values of 'Redhaven' peach floral buds on various rootstocks sampled from Missouri, Ohio, and South Carolina in January 1997.

Rootstock	T_{50} value (°C)[z]
Bailey	-20.1
BY520-8	-19.1
BY520-9	-20.0
Higama	-19.5
Ishtara	-20.1
Lovell	-19.3
Montclar	-19.2
Rubira	-19.8
Stark's Redleaf	-19.3
Tennessee Natural 281-1	-19.3
$LSD_{0.05}$	0.8

[z]Data from all three states were pooled for statistical analysis. Mean separation by Fisher's protected LSD test $P \leq 0.05$.

Ta Tao 5 interstem/Lovell and Bailey trees were hardier than those of H7338019, BY520-9, Nemaguard and Tennessee Natural 281-1. However, none of the rootstocks had significantly greater floral bud hardiness than Lovell at any sampling date. Other studies have found that Nemaguard not only delays the hardening of scion tissue, but is also more susceptible to root injury than other rootstocks grown in sandy soils (8, 9, 12). This study also revealed the susceptibility of floral tissues just before bud break on trees grown in hardiness zone 7b.

When data were pooled to compare the scion floral bud T_{50} values of the 11 rootstocks common to all three locations, three dates of collection (January 1997 and late February/March 1998 and 1999) had statistically significant differences in T_{50} values among rootstocks. However, January 1997 was the only sampling date for which the differences in T_{50} values of rootstocks were significant, without a site x rootstock interaction (Table 6). In January 1997, floral buds of Ishtara and Bailey trees were hardier than those of Montclar and BY520-8. The low-temperature tolerance of floral buds of Lovell was similar to that of all other rootstocks. Because the Ohio trial included only 11 rootstocks, results derived from the pooled data are limited in scope.

In conclusion, data from individual sites revealed the most important information on the influence of rootstock on floral bud hardiness. Under relatively cold climatic conditions (temperatures ≤-25°C) in midwinter, Ta Tao 5 interstem/Lovell rootstock conferred hardiness to floral buds of the scion. In contrast, Tennessee Natural 281-1 and Nemaguard rootstocks adversely affected the cold tolerance of floral buds of the scion under relatively mild winter conditions experienced in hardiness zone 7b. The difference in floral bud susceptibility on various rootstocks at the three locations was likely affected by temperature minima at each site, differing dates of rest completion due to climatic conditions, rates and extent of deacclimation during mild, above-freezing weather, and possible reacclimation of reproductive tissues in late winter (11).

Acknowledgments

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Chilling Period and Bud Dormancy

Shoots of apple and pear were cut at different times and stored at a range of temperatures. Storage period was the most important factor influencing the progression of dormancy, while in some cases the effects of both storage temperature and the freeze treatment were significant, the contribution to the differences in the progression of dormancy was negligible. A model indicated that temperatures between -1 to 13 ° C were over-emphasized relative to the period of exposure to these chilling temperatures. From Jacobs et al 2002. J. Hort. Sci. & Biotech 77(3):333-339.

'Mutsu' Performance on Rootstocks

Trees on M.9 produced more and yellower fruit compared to J.9, M.26, and B.9. Generally the lowest starch degradation pattern and highest fruit firmness were found in fruits from trees on M.26 and B.9. Highest TA was from fruits on M.26 and J.9 and highest SSC on trees on J.9 and B.9. High correlations to SSC for green fruit and TA for medium and yellow fruit and some correlation to yield and number of fruits per tree. From Daugaard and Callerson 220. J. Hort. Sci and Biotech. 77(2):248-251.