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Influence of Peach Seedling Rootstocks on Defoliation and Cold Hardiness of Peach Cultivars[1]

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Abstract. **Bearing trees of 'Loring', 'Redhaven' and 'Babygold 5' peach trees (*Prunus persica* (L.) Batsch) on Siberian C seedlings defoliated earlier than those on the other seedling rootstocks. Early cold acclimation of scions in the fall and scion cold hardiness in mid-winter were enhanced more by Siberian C seedlings than by those of the other seedling rootstocks. Bud survival and fruit set of 'Redhaven' and 'Bablygold 5' scions were greater on Siberian C seedlings than on any of the other seedling rootstocks following an outdoor cold stress at −23.4°C in January. The cold hardiness of phloem, cambium, and xylem stem tissues were closely correlated with each other in the fall, but were not correlated with cold hardiness of flower buds on the same shoots. Seedlings of Siberian C appeared to enhance early scion dormancy and they increased scion bud hardiness by as much as 4.7° in the fall, and 1.3° in mid-February, compared with those of other rootstocks tested.**

Peach seedlings are used almost exclusively as rootstocks for peach in North America and are also widely used elsewhere (8, 17). Commercial cultivars used in the canning and drying industries, such as 'Lovell', 'Elberta' and 'Halford', are the major source of seeds for rootstocks (8). Other sources include selected parental clones that are used only as rootstock seed sources, such as Rutgers Red Leaf, Siberian C, Harrow Blood and Bailey (9). Peach seedlings usually resemble their seed parent because of self-pollination (4). While seedlings are more variable genetically than clonal propagules of the same maternal seed parents, they are easier and less expensive to produce and, therefore, in wide commercial use as rootstocks.

Cold injury is an important limitation to peach production especially in the Northern United States and Canada (8). It may also be more important than formerly thought in the Southern U. S., because of its association with the peach tree short life problem (12). Recently, differences in hardiness of peach seedling rootstocks were reported in which Siberian C seedlings were the hardiest of those studied, followed in descending order by seedlings of Harrow Blood, Rutgers Red Leaf, 'Halford', 'Elberta', and Nemaguard (8, 9). It was also reported that some peach seedling rootstocks enhanced early scion defoliation (9, 10), and increased cold hardiness of nursery (2) and 2-year-old potted trees (13). Early defoliation may be an indication of early dormancy. Early dormancy is associated with early cold acclimation (19, 20). We undertook these studies, therefore, to determine whether there were rootstock-scion effects on defoliation and cold hardiness of bearing trees in the orchard, and whether early defoliation influenced early cold acclimation.

Materials and Methods

Three experimental orchards were planted in 1968 on a Fox sandy loam soil which had been fumigated the previous fall with Telone (1,3-dichloropropene and other related C_3 hydrocarbons, Dow Chemical Co.) at 333 liters/ha. 'Loring', 'Redhaven' and 'Babygold 5' were the test cultivars, each of which was planted in a separate but adjacent orchard experiment designated Expt. 1, Expt. 2 and Expt. 3, respectively. Seedlings of Siberian C, Harrow Blood, Rutgers Red Leaf and 'Veteran' were the rootstocks common to each experiment. Seedlings of Bailey and 'Halford', were included as rootstocks with the 'Babygold 5' experiment only. Each orchard was planted in a randomized block design with 5 replications in which rootstocks were the treatments. Experimental units consisted of 3-tree sub-plots and replications consisted of rows of trees planted 4.2 m within and 6.0 m between rows. Trees were trained to an open center and pruned annually in the spring after bloom. In each orchard the same cultural practices were followed which included annual cultivation between the rows from April to July, then the planting of a cover crop of oats (*Avena sativa* L.) or Italian rye grass (*Lolium multiflorum* Lam.) to slow growth in the fall, prevent soil erosion, and trap snow during the winter.

Unless otherwise stated, the data for each scion cultivar were analyzed separately by analysis of variance (ANOV) and the rootstock means were compared by Duncan's multiple range test (DMR).

Rootstock influence on defoliation. In the fall of each year from 1970 to 1975 inclusive, a visual estimate of percent foliation was made for each scion-rootstock combination in each orchard experiment. Defoliation estimates were usually made on the date when 50% or more of the leaves had fallen. The data on annual defoliation for each scion cultivar were analyzed separately. The data were then analyzed using years as replications and rootstocks as treatments and the 6-year means were compared using DMR.

Rootstock influence on bud hardiness in mid-winter 1971. Terminal shoots of the previous season's growth were collected from each rootstock sub-plot in each replication on Feb. 16 and subjected to controlled freezing tests the same day. A liquid nitrogen apparatus (18), adjusted to provide a cooling rate of 5°C per hr, was used. Shoots were removed at −20°, −23° and −26°, thawed and incubated at about 4°, then assessed for injury to the flower bud primordia (16). The temp required to kill 50% of the flower buds (T_{50}) was determined graphically (15).

Rootstock influence on bud survival and fruit set in 1972. On Jan. 16, a natural cold stress of −23°C occurred outdoors that caused severe injury to peach flower buds (16). Terminal shoots of 'Redhaven', 'Loring' and 'Babygold 5' were collected from each rootstock sub-plot in every replication on Jan. 24, incubated as before, then examined for injury to the flower bud primordia. In the summer, yields were determined on a per tree basis for each cultivar when the fruits were at optimum maturity. In the case of the bud survival data, the square root transformation ($\sqrt{x + 0.5}$) of the percent survival data was made before ANOV and DMR analyses were conducted.

Rootstock influence on hardiness of flower buds and stem tissue in the fall of 1973. Terminal shoots of the 3 scion cultivars were collected during the defoliation period and immediately subjected to controlled freezing tests in the laboratory. 'Redhaven' shoots were collected on Oct. 24, 'Loring' on Oct. 30, and 'Babygold 5' on Nov. 7. The test temp for 'Redhaven' and 'Babygold 5' were −6°, −8°, −10° and −12°C, respectively; while those for 'Loring' were −4°, −6°, −8°,

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and -10°. The same assessment procedures and data analyses were used as described for the 1971 freezing tests. Injury to the stem tissue was assessed on the shoots that were used to determine bud mortality. In preliminary tests we found that there was a gradient in tissue hardiness from the apex to the base of terminal shoots and that the terminal 15 cm were more cold sensitive than the basal portions. We also found that cambium, phloem, and xylem tissues were more cold sensitive than the cortex. Accordingly, ratings of tissue injury were based on the terminal 15 cm portion of each shoot, and individual assessments of injury were made for the phloem, cambium and xylem regions as viewed longitudinally at 2x magnification. Injury was assessed by the intensity and continuity of tissue browning. Oxidative browning of tissues is a reliable index of injury for peach stems (12, 13). Injury ratings were as follows: 1 = absence of browning; 2 = light to moderate browning in the apical region with discontinuous browning in the median and basal portions; 3 = moderate but continuous browning in the apical and median portion with discontinuous browning in the basal portion; 4 = moderate to severe and continuous browning of tissues from the apex to the base. Survival tests were not made but tissues with ratings of 4 were thoughtto be incapable of recovery, those with a rating of 3 or 2 were thought to be capable of partial or full recovery, respectively, while those with ratings of 1 were apparently uninjured. ANOV was conducted on tissue injury ratings at each test temp for each cultivar, then the temp that gave the highest F values for rootstock effects were further analyzed as follows. First, ANOV was performed on the injury ratings to the phloem, cambium, and xylem, and the appropriate means were compared by DMR. Next, the data were pooled over rootstocks and ANOV was performed on the pooled data in which the ratings of individual tissues were considered as the treatments, and the treatment means were compared by DMR. Finanly, a multiple correlation analysis was performed on the ratings of tissue injury and the T_{50}'s for flower buds by pooling the data for all cultivars and rootstocks.

Results

Rootstock influence on scion defoliation. On the basis of 6 years of data, Siberian C seedlings caused earlier defoliation of 'Redhaven' and 'Babygold 5' than did any of the other seedling rootstocks (Table 1). Defoliation of 'Loring' occurred earlier on seedlings of Siberian C and Rutgers Red Leaf than on those of Harrow Blood. In some years early defoliation caused by bacterial spot infection (*Xanthomonas pruni* (E. F. Sm.) Dows.) had a masking effect on natural defoliation, sometimes resulting in nonsignificant rootstock effects, but the average response for the 6 years showed that defoliation was significantly affected by rootstocks.

Rootstock influence on bud hardiness in mid-winter 1971. Seedlings of Siberian C promoted greater cold hardiness in mid-winter (Feb. 16) of 'Redhaven' flower buds than did those of the other three rootstocks. The T_{50}'s for 'Redhaven' flower buds were 1.3°C lower on Siberian C than on Harrow Blood seedlings for example.

Rootstock influence on bud survival and fruit set in 1972. The cold stress of -23.4°C that occurred outdoors on Jan. 16 caused complete kill of 'Loring' flower buds; therefore, the data are not presented. Some bud survival of 'Redhaven' and 'Babygold 5' flower buds occurred, however, and bud survival was influenced by rootstocks (Table 2). Seedlings of Siberian C enhanced bud survival of 'Babygold 5' more than those of any of the other 5 rootstocks. They also enhanced bud survival of 'Redhaven' to a greater degree than did those of any of the other three rootstocks. Harrow Blood seedlings had more of an effect on hardiness of 'Redhaven than did those of 'Veteran'. In 1972, 'Redhaven' and 'Babygold 5' also had higher yields on Siberian C seedling roots than on those of any of the other rootstocks as a direct result of enhanced bud hardiness. Yields of 'Redhaven' were highest on Siberian C and lowest on 'Veteran' seedlings but were, nevertheless, too low to be commercially significant. Yields of 'Babygold 5' on Siberian C seedlings were similar to those on Bailey, but were greater than those on 'Halford', Rutgers Red Leaf, 'Veteran' and Harrow Blood seedlings. The lowest yields were from trees on Harrow Blood and 'Veteran' seedling roots. Differences in yield of 'Babygold 5'

Table 1. Peach seedling rootstock influence on average defoliation of 'Loring', 'Redhaven' and 'Babygold 5' in separate experiments (1970 to 1975).

	Avg % scion defoliation		
Rootstocks	Expt. 1 Loring	Expt. 2 Redhaven	Expt. 3 Babygold 5
Siberian C	68.2c[z]	80.5b	86.7b
Veteran	57.7ab	74.8a	78.8a
Rutgers Red Leaf	61.7bc	73.7a	77.2a
Harrow Blood	53.8a	72.0a	75.0a
Bailey			75.3a
Halford			73.3a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 2. Peach seedling rootstock influence on flower bud survival and fruit set of 'Rehaven' and 'Babygold 5' in separate experiments in 1972.

	Expt. 2 Redhaven		Expt. 3 Babygold 5	
Rootstocks	Bud survival[z] (%)	Fruit yield (kg/tree)	Bud survival[z] (%)	Fruit yield (kg/tree)
Siberian C	4.1c[y]	3.7b	13.0b	37.7c
Harrow Blood	1.9b	2.0ab	5.2a	19.4a
Rutgers Red Leaf	1.1ab	1.9ab	5.2a	25.8ab
Veteran	0.6a	0.8a	5.1a	22.9a
Bailey			5.1a	31.7bc
Halford			5.0a	30.2b

[z]Scions collected from outdoors on Jan. 24 following exposure to -23.4°C on Jan. 16, and assessed for bud survival.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 3. Influence of peach seedling rootstocks on cold hardiness of peach flower buds of 'Loring', 'Redhaven' and 'Babygold 5' in separate experiments in the fall of 1973.

	Temp required to kill 50% of the flower buds (T_{50})		
Rootstocks	Expt. 1 Loring[z]	Expt. 2 Redhaven[y]	Expt. 3 Babygold 5[w]
Siberian C	−8.9c[x]	−8.8b	−10.7a
Rutgers Red Leaf	−8.5bc	−7.9ab	−9.9a
Harrow Blood	−6.8b	−7.3a	−10.5a
Veteran	−4.2a	−7.4a	−10.6a
Bailey			−10.8a
Halford			−10.5a

[z]Terminal shoots collected from outdoors and frozen artificially on Oct. 30.
[y]Terminal shoots collected from outdoors and frozen artificially on Oct. 24.
[w]Terminal shoots collected from outdoors and frozen artificially on Nov. 7.
[x]Mean separation within columns by Duncan's multiple range test, 5% level.

on rootstocks other than Siberian C were greater than their differences in percent bud survival. Some of this could be attributed to differences in tree size which was also affected by rootstocks (11). In any case, yields were sufficiently high, especially on Siberian C and Bailey seedlings, to be commercially significant.

Rootstock influence on scion hardiness in the fall of 1973. Seedlings of Siberian C rootstock increased flower bud hardiness of 'Loring' and 'Redhaven' more than did those of Harrow Blood or 'Veteran' (Table 3). However, none of the seedling rootstocks significantly altered the bud hardiness of 'Babygold 5'. Flower buds of 'Loring' on Siberian C were 4.7°C more hardy than those on 'Veteran' seedlings, and 2.1° more hardy on Siberian C than on Harrow Blood seedlings. 'Redhaven' flower buds, on the other hand, were only 1.4° more hardy on Siberian C seedling stocks than on 'Veteran' seedlings and 1.5 more hardy on Siberian C than on Harrow Blood seedlings.

Siberian C seedling stocks promoted more tissue hardiness of 'Redhaven' than did any of the other 3 seedling rootstocks (Table 4). Phloem, xylem and cambium injury of 'Redhaven' was less on Siberian C than on Harrow Blood stocks. Average tissue injury of 'Babygold 5' was less on Siberian C, 'Veteran' and Harrow Blood than on the other three seedling rootstocks. Phloem, cambium and xylem injury of 'Babygold 5' was also less on Siberian C than on Rutgers Red Leaf, Bailey and 'Halford' but was similar to that on 'Veteran' and Harrow Blood seedling stocks.

Relative hardiness of peach stem tissue in the fall of 1973. Regardless of the rootstock influence on the hardiness of phloem, cambium, and xylem, these tissues also differed from each other in relative hardiness when they were considered as the treatments and the rootstock values were pooled (Table 5). Thus, xylem tissue of 'Loring' was hardier than phloem or cambium on Oct. 30, and the same relationship was obtained for 'Babygold 5' on Nov. 7. Phloem tissue of 'Redhaven', on the other hand, was hardier than xylem when tested on Oct. 24. Although the stem tissues differed in their relative hardiness, injury to xylem was closely correlated with injury to cambium ($r = 0.912^{**}$), as was phloem with cambium ($r = 0.991^{**}$) and phloem with xylem ($r = 0.902^{**}$). Cold hardiness of peach flower buds in the fall was not correlated with phloem, cambium or xylem injury, however.

Discussion

Trees on Siberian C seedling rootstock defoliated earlier than those on the other seedling roostocks (Table 1). No other peach seedling rootstock has been reported to consistently induce early scion defoliation. If the early defoliation induced by Siberian C seedlings was an indication of early scion dormancy, then this seedling stock would be expected to enhance early cold acclimation of peach scions as well (14, 19). Seedling of Siberian C did indeed increase the cold hardiness of peach scions in the fall (Tables 2 and 3), and enhanced scion cold hardiness more than any of the other seedling rootstocks studied. It appeared, therefore, that the effect of Siberian C seedlings on early defoliation was a rootstock effect on early scion dormancy. Enhancement of scion hardiness by Siberian C seedling stocks was not restricted to the fall, however, since scion hardiness was also enhanced in Jan. and Feb.

In another study on nursery trees (2), rootstock seedlings of Harrow Blood were found to enhance more scion tissue hardiness than those of Siberian C or Rutgers Red Leaf. Studies on 2-year-old potted trees (13) in controlled environments, on the other hand, showed that under short days (9 hr) and cool temp (10°/4°C), seedling stocks of Siberian C had a greater effect than did those of Harrow Blood in enhancing cold hardiness of scion flower buds, but neither stock appeared to differ in its effect on leaf bud or stem tissue hardiness of the same shoots.

Many factors, including climate, genotype and cultural practices, affect the cold hardiness of peach cultivars (12, 13, 14, 15, 16). The factors that affect cold hardiness of peach roots are less well known, although the parental source of the seedling rootstocks (8, 9, 10, 11), soil moisture, soil type and

Table 5. Relative hardiness of peach stem tissue averaged over rootstocks in the fall of 1973.

	Avg tissue injury ratings[z]		
Tissues	Expt. 1 Loring[y] −10°C	Expt. 2 Redhaven[x] −8°C	Expt. 3 Babygold 5[w] −10°C
Phloem	3.6b[v]	2.5a	3.1b
Cambium	3.5b	2.6ab	3.1b
Xylem	3.3a	2.7b	2.8a

[z]Injury ratings based on intensity and continuity of tissue browning where 1 = no browning; 2 = light and discontinuous browning; 3 = moderate and discontinuous browning; and 4 = moderate to severe and continuous browning.

[y]Terminal shoots collected from outdoors and frozen artificially on Oct. 30.

[x]Terminal shoots collected from outdoors and frozen artificially on Oct. 24.

[w]Terminal shoots collected from outdoors and frozen artificially on Nov. 7.

[v]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 4. Influence of peach seedling rootstocks on mean ratings of tissue injury of 'Redhaven' and 'Babygold 5' in separate experiments in the fall of 1973.

	Avg tissue injury ratings[z]							
	Expt. 2 Redhaven (−8°C)[y]				Expt. 3 Babygold 5 (−10°C)[x]			
Rootstocks	Phloem	Cambium	Xylem	Mean	Phloem	Cambium	Xylem	Mean
Siberian C	1.7a[w]	1.8a	2.0a	1.8a	2.5a	2.5a	2.2a	2.4a
Veteran	2.7b	2.7b	2.7ab	2.7b	2.9ab	2.9ab	2.4ab	2.7a
Harrow Blood	3.0b	3.0b	3.0b	3.0b	2.9abc	2.9abc	2.4ab	2.8a
Rutgers Red Leaf	2.6b	2.6b	2.6ab	2.6b	3.7d	3.6c	3.4c	3.6d
Bailey					3.3bcd	3.3bc	3.1bc	3.2bcd
Halford					3.6cd	3.5bc	3.1bc	3.4cd

[z]Injury ratings based on intensity and continuity of tissue browning where 1 = no browning; 2 = light and discontinuous browning; 3 = moderate and discontinuous browning; and 4 = moderate to severe and continuous browning.

[y]Terminal shoots collected from outdoors and frozen artificially on Oct. 24.

[x]Terminal shoots collected from outdoors and frozen artificially on Nov. 7

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

root age (Layne, unpublished data) have been found to be important. The external and internal factors that affect the rootstock influence on scion hardiness are unknown, however, and should be studied. Tree age appears to be important, since different results were obtained with young non-bearing trees (2, 13) than with bearing trees reported here. Presumably other environmental and physiological factors are involved as well.

Peach seedling rootstocks are known to differ in their level and activity of cytokinins (6). Cytokinins are produced in plant roots and translocated in the xylem sap to the shoots where they are required for normal shoot development (3). Processes of senescence seem to be associated with lower levels of cytokinin activity (3). The onset of dormancy in willow (*Salix viminalis* L.) was found to be associated with low levels of cytokinins and high levels of abscisic acid (1). Peach seedling rootstocks have been found to differ in their effects on growth and development (5, 7, 10, 11), defoliation and dormancy reported here, and cold hardiness of peach scion cultivars (2, 10, 13). The physiological bases for the rootstock effects on these factors are not known. It is possible that rootstock effects on scion dormancy and cold hardiness may be related to effects they may have on the level and activity of growth regulators that accumulate in the shoots during the fall and winter, such as cytokinins (1, 6), abscisic acid (1), and phytochrome (20). Further research is needed to determine if this is the case.

Because of the unusual cold hardiness of the roots of Siberian C seedlings (8, 9), as well as their ability to enhance early dormancy and cold hardiness of scion cultivars, at least in northern climates, this rootstock should be tested further in regions where cold injury to peach scions and/or rootstocks is a problem. However, rootstock seedlings of Siberian C appear to be susceptible to root lesion (*Pratylenchus penetrans* (Cobb) Filip & Stekh.) and root knot (*Meloidogyne incognita* Kofoid & White) nematodes (9); therefore, they should be tested on fumigated soils.

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