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American Pomological Society U. P. Hedrick Award
Second Place Award 1992

Cold Hardiness of Peach Stem Tissue Over Two Dormant Seasons

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Abstract

Cold hardiness of one nectarine and five peach cultivars was evaluated using electrical conductivity from January to March 1991 and from December 1991 to February 1992. Differences in cold hardiness were observed among cultivars. In both years 'Redhaven' and 'Harbrite' were the hardiest cultivars and 'Salem' was most susceptible to cold injury. For the other cultivars the results were not consistent over the two years. Training system and crop load had no influence on cold injury.

Additional index words. Cold injury, electrical conductivity.

Low temperatures during the dormant season limit the production of peaches and nectarines [*Prunus persica* (L.) Batsch] in the northern United States and Canada. Severe losses in yield have been attributed to late spring frosts, which damage the flower buds. During winter, low temperatures can cause injury to stem tissue, which weakens the tree and allows wound parasites to enter through dead and dying tissue (4). This has led to the assumption that cold injury is one of the main causes for peach tree short life (15). Differences in cold hardiness among diverse peach genotypes have been observed (3, 4, 14) and several attempts have been made to explain the physiological processes involved (5, 6, 28, 31). It has been shown that peach bud and stem tissue deep supercool to avoid freezing injury (1, 18, 19, 20, 21). During low temperature exposure, cell water does not freeze until temperatures came close to the homogeneous nucleation point. Ice formation starts spontaneously, and the freezing water releases heat, which can be measured by differential thermal analysis (DTA). Cold injury in *Prunus* species occurs mainly during this process commonly known as the low temperature (LT) exotherm. In early winter and spring the initial temperature for the LT exotherm is higher and occurs over a smaller temperature range.

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Dexter et al. (7) developed the electrical conductivity method to determine cold hardiness in herbaceous plants. It is based on the assumption that the quantity of electrolytes released by the cell is correlated to the amount of injury caused by a given treatment. The greater the electrical conductivity of the sample, the greater is the injury to the tissue. Later it was shown to be valid for apple stem and root tissue (12, 24, 25, 26, 27) and for peach trees (32). The method permits a quick and accurate evaluation of cold injury and has been successfully employed in several studies (13, 15, 22, 29, 30).

Greene et al. (9) determined that the primary cause of peach decline in the mid-Atlantic region was due to winter injury, and there were indications that susceptibility varied between cultivars. Therefore, the purpose of this study was to evaluate cold hardiness of different peach cultivars commonly grown in the region, as well as determine the influence of training system on cold hardiness.

Materials and Methods

Five peach cultivars, 'Jerseydawn,' 'Redhaven,' 'Newhaven,' 'Harbrite' and 'Salem' and one nectarine cultivar 'Earliscarlet,' all on Lovell rootstock, were sampled from an orchard planted in 1989 at the Russell E. Larson Agricultural Research Center. The training system for half of the trees was open center and for the other half modified central leader. Eight to ten one year old, nonbranched shoots were cut from each of the trees of every cultivar with each tree representing a replication. The shoots were kept on ice until the laboratory preparation. The first four nodes were removed from the terminal end of the shoots in order to minimize variation caused by different twig sections (2). The remainder of each shoot was cut in 1 cm long internodal segments. The segments of each group of the shoots were mixed and ten segments were placed in each of three 30 ml Nalgene Polypropylene bottles (Thomas Scientific), representing three temperatures. The tissue weight in gram of each bottle was recorded and the bottles were placed in wire cages and stored in refrigerated cooler (5C) until the beginning of the freezing treatment. Sampling dates were 14 January, 11 February, 26 March in 1991 and 19 November, 16 December, 21 January and 17 February in the winter 1991/92. The sampling procedure was identical in both years. However, the number of replicates was increased from six in 1991 to ten in the winter 1991/92. Also in 1991/92 the same trees were used for each sampling, so that the influence of other variables on cold hardiness, such as training treatment, could be analyzed.

A Tenney JR programmable temperature chamber (Tenney Engineering Inc.) was used for the freezing treatment. The samples were frozen at 3C/h to -24, -30 and -36C. In November 1991 the freezing temperatures were -9C, -15C and -21C because it was expected that cold injury occurs at warmer temperatures than in midwinter. When the designated temperature was reached, the samples were held at this temperature for 15 minutes, then removed to the cooler where they were allowed to thaw for at least 2 hours. Twenty ml of deionized water was added to each sample and the samples agitated for 22 +/- 2 hours at 120 cycles/min at room temperature.

Electrical Conductivity (EC) was measured using a calibrated Conductance-Resistance-Meter (YSI, Model 34) with a Beckman Conductivity Cell (Beckman Instruments Inc.). After the samples were measured and the readings were recorded, the tissue was killed by placing the samples in a water bath at 99 +/- 1 C for 7 minutes. The samples were then agitated for another 22 +/- 2 hours and the EC measured. The percentage of electrolytes released was calculated for each sample by the following formula:

% EC = 100 x (EC_t/EC_{th})

% EC = percentage electrolytes released from the cells

EC_t = electrical conductivity of the sample frozen at temperature (t)

EC_{th} = electrical conductivity of the sample frozen at temperature (t) and then heat killed

No transformations of the percentage data were necessary, because variances had a normal distribution. The data were analyzed by analysis of variance by the SAS ANOVA Program (SAS Institute Inc.). The means were compared separately by Duncan's multiple range test at the 5% level for each temperature and each month.

Results

1991

The results from the experiment conducted at different sampling dates from January to March 1991 are shown in Table 1. The % EC values increased with decreasing temperatures. At -24C, the ratings were between 17.2% and 18.6% and significant differences could be observed between 'Jerseydawn' with the highest % EC value, and 'Redhaven,' which had the lowest % EC value.

For the -30C treatment values were between 24.6% for 'Salem' and 26.6% for 'Harbrite,' but no significant differences occurred among cultivars. At -36C % EC values ranged between 33.1% for 'Redhaven' and 44.3% for 'Jerseydawn.' 'Jerseydawn' was significantly different from all other cultivars. 'Salem' had the second highest % EC value and was significantly different from 'Harbrite,' 'Newhaven' and 'Redhaven.' No significant differences were observed among 'Earliscarlet,' 'Harbrite,' 'Newhaven' and 'Redhaven.'

The data for February 1991 results similar to those obtained in January, but significant differences were only for the samples frozen down to -30C. At this temperature, 'Earliscarlet,' 'Jerseydawn' and 'Salem' had significantly higher % EC values than the other three cultivars. In March % EC values were much higher for all cultivars for each temperature treatment. The % EC values increased to values between 40% and 48% at -30C and over 67% for -36C. Significant differences among cultivars again were only observed for the temperature treatment at -30C. 'Earliscarlet' had the highest % EC value and was significantly different from all other cultivars. No differences were found among the other cultivars.

1991-92

An experiment was started in November 1991 to observe the reaction of cultivars in the early dormant season. The % EC values were very low for all temperature treatments in No-

Table 1. Mean %EC values[z] of 6 peach cultivars for 3 temperature treatments on different dates in winter 1991.

		Temperature/C[z]		
Date	Cultivar	-24	-30	-36
1-14-91	Earliscarlet	17.5 ab	24.7 a	36.1 bc
	Harbrite	17.2 ab	26.6 a	34.6 c
	Jerseydawn	18.6 a	25.6 a	44.3 a
	Newhaven	17.4 ab	24.7 a	33.3 c
	Redhaven	16.4 b	25.5 a	33.1 c
	Salem	17.9 ab	24.6 a	39.6 b
2-11-91	Earliscarlet	20.1 a	28.6 a	40.7 a
	Harbrite	18.8 a	24.4 b	38.0 a
	Jerseydawn	20.1 a	27.2 a	41.9 a
	Newhaven	18.8 a	23.8 b	36.8 a
	Redhaven	19.5 a	24.4 b	40.3 a
	Salem	19.6 a	27.5 a	40.0 a
3-26-91	Earliscarlet	28.2 a	47.9 a	75.1 a
	Harbrite	27.1 a	41.3 b	67.0 a
	Jerseydawn	28.3 a	40.4 b	69.0 a
	Newhaven	27.4 a	41.6 b	69.9 a
	Redhaven	27.9 a	40.5 b	70.5 a
	Salem	28.0 a	40.5 b	68.1 a

[x]Values calculated after the following formula: % EC = 100 x (EC_t/EC_{th}).

[y]Mean separation in columns by date by Duncan's multiple range test, P = 0.05.

vember 1991 (data not shown), and no differences among cultivars were observed.

Table 2 presents mean % EC values for the experiments conducted from December 1991 to February 1992. The means were calculated from 10 replications of each cultivar for each temperature treatment. In December % EC values at -24C were between 16.7% and 18.7%. For the samples cooled down to -30C, % EC values between 21.6% and 25.5% could be observed. For the temperature treatment at -36C, values ranged between 32.2% and 37.4%.

Significant differences among cultivars were observed for all temperature treatments. At -24C, 'Jerseydawn' had the lowest % EC value and was significantly different from 'Earliscarlet.' There were no significant differences among the other cultivars. In shoots frozen to -30C, 'Earliscarlet' and 'Salem' had the highest % EC values and were significantly different from 'Redhaven.' No other differences among cultivars were observed. At -36C, 'Salem' still had the highest % EC value and was significantly different from 'Harbrite,' 'Jerseydawn' and 'Redhaven.'

Table 2. Mean %EC values[x] of 6 peach cultivars for 3 temperature treatments on different dates during winter 1991/92.

Date	Cultivar	Temperature/C[y] -24	-30	-36
12-16-91	Earliscarlet	18.7 a	25.5 a	34.6 ab
	Harbrite	17.8 ab	23.3 ab	32.2 b
	Jerseydawn	16.7 b	23.5 ab	32.9 b
	Newhaven	17.6 ab	23.1 ab	34.7 ab
	Redhaven	17.3 ab	21.6 b	32.5 b
	Salem	17.7 ab	24.5 a	37.4 a
1-21-92	Earliscarlet	21.2 a	26.2 a	36.5 bc
	Harbrite	21.0 a	25.3 a	37.1 ab
	Jerseydawn	20.2 a	24.7 a	34.4 c
	Newhaven	21.6 a	26.8 a	37.4 ab
	Redhaven	20.6 a	25.8 a	36.3 bc
	Salem	20.5 a	25.1 a	38.8 a
2-17-92	Earliscarlet	36.4 a	45.3 a	60.5 b
	Harbrite	37.2 a	45.6 a	59.1 b
	Jerseydawn	35.3 a	44.8 a	62.4 ab
	Newhaven	36.6 a	43.5 a	60.2 b
	Redhaven	37.1 a	47.3 a	60.7 b
	Salem	37.0 a	45.4 a	66.2 a

[x]Values calculated after the following formula: % EC = 100 x (EC_t/EC_{th}).
[y]Mean separation in columns by date by Duncan's multiple range test, P = 0.05.

In January 1992 % EC values were slightly higher than in December 1991. No significant differences were found among cultivars at -24C and -30C. As in December 1991, 'Salem' had the highest % EC value at -36C and was significantly different from 'Earliscarlet,' 'Redhaven' and 'Jerseydawn.' 'Newhaven' and 'Harbrite' formed a second group, which was significantly different from 'Jerseydawn,' the cultivar with the lowest % EC.

The data from February show an increase of % EC values and most differences among cultivars disappeared. At -24C, the highest value was 37.2% and the lowest 35.3%. For -30C % EC values ranged between 43.5% and 47.3%. For the -36C temperature treatment values were between 59.1% and 66.2%. No significant differences among cultivars were observed, except for the temperature treatment at -36C. At this temperature, 'Salem' again had the highest % EC value and was significantly different from all cultivars except 'Jerseydawn.' No other differences among cultivars were observed.

Discussion

The measurement of electrical conductivity in both years show differences in % EC values among cultivars for the different temperature treatments and also changes over the course of the dormant season. It is suggested, that higher % EC values indicate more cold injury. Therefore it is postulated, that cultivars that have higher % EC values at a given temperature are less cold hardy than cultivars with lower % EC values at the same temperature.

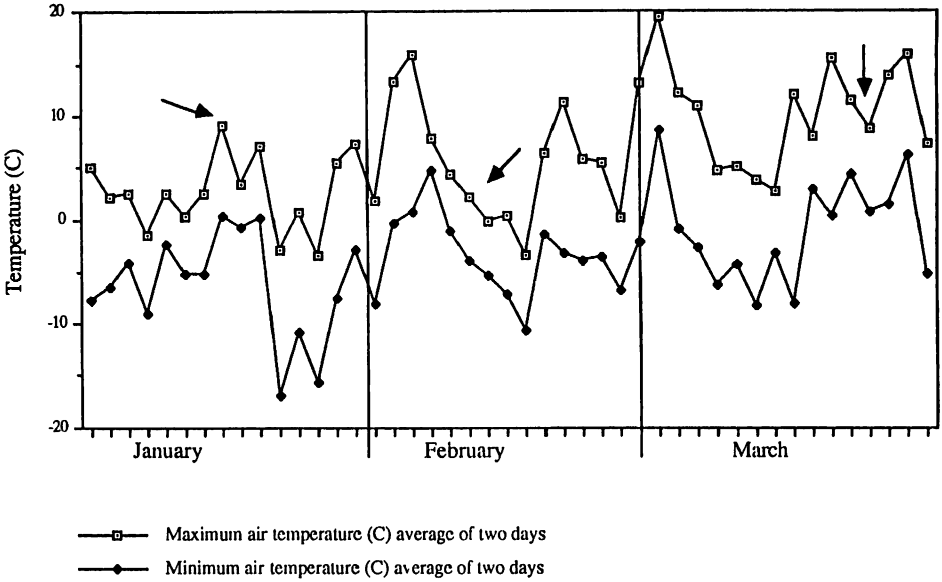

Figure 1. Maximum and minimum air temperatures (C) during Winter 1991 (arrows indicate sampling dates).

However, the statistical design of the experiment only allows to observation of differences in cold hardiness at specific points in time. It is not possible to decide if those differences are economically relevant or not.

It has been previously described that the low temperature exotherm occurs between -24C and -40C in peach stem tissue in midwinter (1, 19, 20). The temperatures chosen in the experiment were within the LT exotherm, suggesting that the differences observed among cultivars in this experiment could represent the temperatures of the LT exotherm.

From January to March 1991 two different groups can be distinguished (Table 1). The first group is formed by the cultivars with generally higher injury; 'Earliscarlet,' 'Jerseydawn' and 'Salem.' 'Jerseydawn' had the highest % EC values in January and February 1991, but in March it was not less hardy than the other cultivars. However, 'Earliscarlet' was the cultivar with the highest % EC value in March. This seems to indicate, that the susceptibility to cold injury of a cultivar can change during the dormant season. It is probable that this observation is related to the ability of the cultivar to acclimate to cold temperatures. It has been reported by Cain and Andersen (3) that some cultivars are able to acclimate earlier and to stay longer in this physiological stage.

The second general group consisted of 'Redhaven,' 'Newhaven' and 'Harbrite.' These cultivars have, in most of the cases lower % EC values than those of the first group. This suggests, that these cultivars may be hardier than the other cultivars tested in the experiment.

In January 1991 % EC values were lowest among the three sampling dates of the experiment. It seems probable that the cultivars reached their maximum hardiness level in December or January as has been reported previously (1, 31) and then started to deacclimate. Since % EC values in March 1991 were much higher than in the

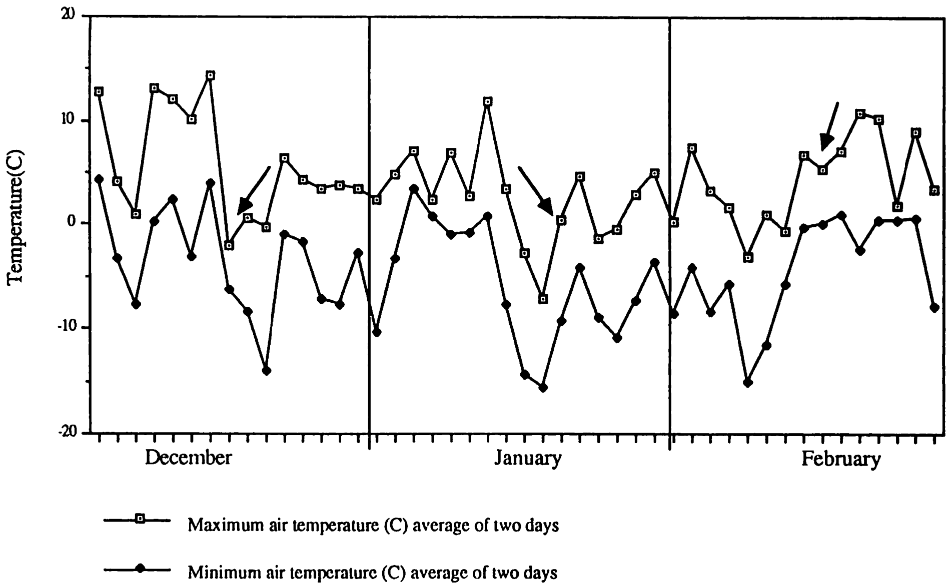

Figure 2. Maximum and minimum air temperatures (C) during Winter 1991-92 (arrows indicate sampling dates).

previous months, it is probable that at this time the stage of deacclimation was nearly finished. It also was observed that differences among cultivars nearly disappeared in March. This indicated that cold injury occurs at a higher temperature level and that the same temperatures cause more injury in late winter or early spring than in midwinter for all the cultivars.

In the second experiment in Winter 1991-92, the observations differ in some cases from the first experiment. Results from this experiment showed 'Salem' to be one of the most susceptible cultivars to cold injury. It had the highest % EC values for two temperature treatments in December 1991 and for one temperature treatment for each of the other months. Also 'Earliscarlet' and 'Newhaven' had high % EC values for some temperature treatments, but their position compared to the other cultivars changed over the months. 'Earliscarlet' seemed to be more hardy in January and February 1992 than in December 1991 for the lower temperature treatments. Also % EC value for 'Newhaven' at -36C in February 1992 was significantly lower than % EC value for 'Salem.' However, in the previous months, 'Newhaven' could be classified in the same group as 'Salem.' This supports the results from the first year that a cultivar can be more susceptible to cold injury compared to other cultivars at different times of the dormant season.

Changes in % EC level were observed over the months. The lowest % EC values were obtained in December 1991. The values from January 1992 were slightly higher than those of December 1991 and were nearly the same as in January 1991, except for 'Jerseydawn.' However, in February values increased substantially and were nearly twice as high for some temperature treatments. They were also much higher than the values obtained in February 1991. It is possible that the trees reached a physiological stage where they are more susceptible to cold injury earlier than in the previous year.

It has been reported that deacclimation can be increased by high air temperatures after the plants have reached their maximum hardiness level (8, 10, 11, 12, 16, 17, 23). Proebsting (17) reported that the average temperature of the last two days before the sampling date influences cold hardiness of peach flower buds. Figures 1 and 2 show the two-day average minimum and maximum temperatures over the period of time of the two experiments. In February 1992 air temperatures rose shortly before the sampling date. It is possible that the trees deacclimated during this period and for this reason % EC values were much higher than in January 1992 or in February 1991.

It was suggested that the training system may influence cold hardiness. Results from the experiment from December 1991 to January 1992 (data not shown) indicate no differences between trees pruned as open center and those pruned as modified central leader. It appeared that the training system had no major effect on cold hardiness in this experiment.

In addition effect on yield per tree was evaluated (data not shown) because it was assumed, that since the trees bore their first crop in 1991, it might account for some differences between the two experiments. However, no correlation was found between yield and % EC values in this experiment.

In summary, 'Salem' was more susceptible to cold injury than the other cultivars in both years. 'Redhaven' and 'Harbrite' had low % EC values in both years which may indicate that these two cultivars could be, in general, hardier than the other cultivars tested in the experiment. However, 'Jerseydawn,' 'Earliscarlet' and 'Newhaven' changed their relative position in the second year. This may indicate, that for these cultivars non-genetic factors have more influence than genetic factors.

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Influence of a Single Heading Pruning Treatment

A recent study summarized the effects of dormant heading back of terminal extension shoots on the scaffold limbs of 1-year-old 'Empire'/M.26. The single treatment was made in 1985 and resulted in increased shoot growth from 1-and 2-year old limb sections. Annual trunk enlargement was reduced in 1985 and 1986 by the 1985 heading back treatment. Yields were decreased in 1986 through 1989 by the heading back treatments applied in 1985. These results are due to 7 to 9 cuts/tree and show clearly the adverse effect on fruiting due to heading back pruning of young trees.

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