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# Cultural Practices Affect Cold Hardiness and Peach Tree Short Life[1]

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*Abstract.* **To determine whether cold hardiness of peach [*Prunus persica* (L.) Batsch] is affected by cultural practices, 2-year-old 'Coronet' trees growing in a peach tree short-life site were treated by soil fumigation with 1,2-dibromo-3-chloropropane (DBCP) late fall application of nitrogen, combination of fumigation and fall applied nitrogen, fall pruning (November), or usual grower practices (control). Cold hardiness was measured by determining the leakage of electrolytes from dormant terminal twig sections exposed to low temperatures, and visually by oxidative browning and ease of phloem-xylem separation. Fall-pruned trees were lower in cold hardiness and survival than controls. Nitrogen applied alone or in combination with fumigation reduced cold hardiness in early winter but increased vigor and survival. Trees grown in fumigated soil and winter-pruned were hardier than control trees and fall-pruned trees in nonfumigated soil. Differences in hardiness were greatest near bloom time. Cultural practices strongly affected cold hardiness of xylem, phloem, and cambium of treated trees, and cold hardiness was associated with tree longevity.**

Cold injury usually occurs in late winter after the chilling requirement has been met. Trees often die suddenly, during or shortly after bloom, or undergo a gradual decline (4), or the peach replant problem (13). Cold injury has been recognized as one of the major factors involved in PTSL. Other associated factors include bacterial canker, nematodes, soil fungi, nutrition, and cultural practices (27).

Cold injury usually occurs in late winter after the chilling requirement has been met. Trees often die suddenly, during or shortly after bloom, or undergo a gradual decline during summer (20). Other symptoms include separation of the bark from the wood and browning of the cambium, xylem, and phloem. Trunk, crotch, and major scaffold branches are most frequently affected, with more severe damage on the sunward side of these plant parts (25). It has been shown that some of the most severe tree losses occurred when temperatures in late winter reached 22°C or more for several days in succession followed by a rapid drop to −6° or below (5, 21, 25). Visual symptoms of injury may be observed a few days after environmental changes.

PTSL is most frequently associated with old peach land and soil fumigation has alleviated severe tree losses on problem sites (2, 6, 11, 18, 19, 27). In New York, control of the nematode, *Pratylenchus penetrans* Cobb, by soil fumigation resulted in increased cold hardiness and survival of cherry (10). Fall pruning is frequently associated with large numbers of tree deaths (4, 19, 22, 25, 27). Research has indicated that late fall nitrogen applications (near leaf fall) might improve tree longevity (25, 26, 30). Several workers have measured cold hardiness in trees during dormancy (1, 10, 14-16, 23, 29), but few studies have related the association of cultural practices to cold hardiness and PTSL.

## Materials and Methods

Cultural treatments were applied to 2-yr-old 'Coronet' peach trees propagated on cannery seedling rootstocks growing in a commercial orchard. The orchard was located on an old peach site where ca. 10% of the trees died the previous year with symptoms of cold injury, and others were severely weakened as shown by yellow leaves and stunted growth. Soil assays recovered an average of 1,120 *Criconemoides xenoplax* Raski and 640 *Scutellonema* sp. per 100 cc of soil. The root systems were necrotic under both apparently healthy and unhealthy trees, and few feeder roots were present.

In June 1972, 100 apparently healthy trees of moderate vigor were selected. Five treatments were applied to 20 trees each: a) fumigation of the soil surrounding each tree with DBCP[3] (Nemagon, 1.45 kg/liter, at 46.7–65.5 liters/ha) applied on Oct. 6, 1972 and May 10, 1973 (18); b) fall application of 900 g of $NaNO_3$ (16% N) per tree applied on Nov. 6, 1972 and Nov. 15, 1973, by broadcasting around the tree and left on top; c) a combination of fall N application and soil fumigation; d) fall (November) pruning; e) control (grower's standard practices) consisting of 560 kg/ha of 0N–6.4P–24.9K applied in Nov. of 1972 and 1973 and 280 kg/ha of $NaNO_3$ (16% N) applied in March of 1972 and 1973. Fall pruned trees were pruned Nov. of 1972 and 1973, other trees were pruned in Feb. Clean cultivation was maintained through discing. The experiment consisted of 20 single-tree replicates in a completely random design.

Cold hardiness assays were conducted on Jan. 23, Feb. 7, Feb. 22, and March 12 during winter I (1972-73) and on Dec. 4, Dec. 17, Jan. 7, Jan. 23, and Feb. 19 for winter II (1973-74). The electrolytic conductance assay for cold hardiness was conducted as described by Ketchie et al. (15) except for the following modifications. Terminal twig internodes were cut into

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1-cm segments using a sharp knife mounted on a cutting board to resemble a paper cutter. The use of this device provided uniform twig segments with minimal mechanical damage. The artificial freezing tests were conducted by placing 5 g of twig segments in metal-capped test tubes, submerging in a circulating ethylene glycol bath at room temperature, and lowering the temperature at $1^{o}$ to $2^{o}$C/hr. A conventional home freezer was used during winter I and a Forma Scientific circulating bath (Model 2154) for winter II. Samples were removed at −6, −12, −18, and $-23^{o}$ and thawed 2 hr at $25^{o}$. One control was maintained at 4 to $7^{o}$ during the exposure period and was moved to the thawing chamber along with the first samples removed from the freezing unit. All samples were assayed in duplicate. Conductance readings were expressed as the index of cold injury ($I_t$) as described by Flint et al. (12).

Cold damage was also evaluated visually. Dormant terminal twigs were collected and handled similarly to the previous assay. Terminal 6- to 10-cm segments were removed and placed 2 per metal-capped test tube; then exposed to the same temperature regimen as above. Four twigs per tree were used. Once desired temperatures were reached, the samples were removed and held for 1 to 5 days at $25^{o}$C. The viability of stem tissues was rated during that time using oxidative browning as an indication of xylem or phloem damage and ease of phloem-xylem separation for cambium injury (23). Differences in tissue damage were generally distinct except where saprophytic fungi damaged the tissues, and such samples were not indexed. This test was used to correlate visual symptoms with results of conductance tests and to observe the type of symptoms expected in the field.

Climatological data were obtained from National Oceanic and Atmospheric Administration, National Weather Service Officer/Agriculture. A weather station located 9.6 km from the site was used. Weather was considered near normal during the test periods except for unusually mild temperatures in Jan. 1974.

Nematode data collected at frequent intervals indicated the population of nematodes was reduced by only about 50% during winter I; but following a second fumigation nematode control was achieved. High ring nematode populations (500–1000/100 cc soil) were detected in soil surrounding trees not fumigated except during hot dry weather of August to October of each year. Detailed nematode studies are given elsewhere (18).

## Results

In March 1973 typical wilting and collapse characteristic of PTSL occurred in some trees. Other trees were weakened and declined slowly during the summer with loss of one or more scaffold limbs. By August, 40% of the fall-pruned trees had died compared with 15% of the controls, 5% of the trees in fumigation and combination treatments, and none in the late N treatment. Trees in the fumigation treatment grew rapidly, and increases in cross sectional area (Table 1) were significantly greater in fumigated trees without additional N than in trees in any other treatment. Fall-pruned trees grew least.

Table 1. Increase in trunk cross sectional area of 'Coronet' peach trees associated with 5 cultural treatments.

| Treatment | % increase in area June–Nov. 1972 | % increase in area May–Nov. 1973 |
|---|---|---|
| Check | 244a[z] | 54c |
| Fall-pruned | 269a | 36d |
| Late fall nitrogen | 249a | 64b |
| Soil fumigation (DBCP) | 223a | 78a |
| Fumigation plus nitrogen | 247a | 55c |

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

*Effects of cultural treatments on cold hardiness.* Cold hardiness, as determined by indices of cold injury ($I_t$ values), was significantly affected by cultural treatments, but the type of response differed in the two winters tested (Tables 2 and 3). Variability in hardiness was observed, but trees in fumigated soil were generally hardier than those in other treatments, while fall-pruned and control trees were least hardy. Trees receiving the N or combination treatments were intermediate in hardiness. The cold hardiness of fall-pruned and control trees tended to decrease more rapidly than that of other treatments once the chilling requirement was met.

Table 2. Index of cold injury for terminal twigs of 'Coronet' peach as influenced by 5 cultural treatments, winter 1972-73.

| Treatment | Index of cold injury[z] Sampling date Jan. 23 | Feb. 7 | Feb. 22 | Mar. 12 |
|---|---|---|---|---|
| *at $-12^{o}C$* | | | | |
| Check | 1.1a[y] | 8.9c | 2.6a | 22a |
| Fall-pruned | 1.3a | 8.1c | .9a | 32b |
| Late fall nitrogen | – | 6.3bc | .8a | 22a |
| Soil fumigation (DBCP) | 2.9a | 4.6a | 1.8a | 16a |
| Fumigation plus nitrogen | – | 5.8ab | 1.0a | 18a |
| *at $-18^{o}C$* | | | | |
| Check | – | – | 11.2a | 56b |
| Fall-pruned | – | – | 8.8a | 59b |
| Late fall nitrogen | – | – | 7.9a | 59b |
| Soil fumigation (DBCP) | – | – | 9.8a | 47a |
| Fumigation plus nitrogen | – | – | 9.1a | 53b |
| *at $-23^{o}C$* | | | | |
| Check | 18b | 36b | 22a | 87b |
| Fall-pruned | 20b | 35ab | 19a | 88b |
| Late fall nitrogen | – | 34ab | 18a | 90b |
| Soil fumigation (DBCP) | 14a | 29a | 18a | 81a |
| Fumigation plus nitrogen | – | 32a | 20a | 82a |

[z]Index calculated according to Flint et al. (12). Higher values indicate greater cold injury.

[y]Mean separation in columns within temp by LSD, 5% level.

*Association of cold hardiness with air temperature.* Changes in cold hardiness during dormancy occurred frequently and were apparently influenced by temperature trends (Tables 2 and 3, Fig. 1). Trees gained hardiness during cold periods but lost hardiness during warm periods. During winter I, first measurements on Jan. 23 indicated that trees were very hardy. After chilling requirements were completed (approx Jan. 15), the trees appeared to lose or gain hardiness rapidly in response to short periods of warm or cold weather. However, in winter II the chilling requirement was not completed until Feb. 15, and similar warm periods prior to that time resulted in more gradual loss of hardiness. Once sufficient chilling hours were accumulated and temperatures increased, the trees rapidly lost the hardiness of late Jan. and early Feb.

*Cold hardiness of twig tissue.* Visual observations of injury to twigs exposed to varying degrees of cold indicated that phloem was the most hardy tissue from Dec. to Feb. (Fig. 2). Xylem changed little in hardiness until Feb. when it lost hardiness. Cambium was least hardy in early fall but rapidly gained hardiness until it was intermediate between phloem and xylem in early Jan. In late Jan., following a lengthy warming trend, the cambial tissue rapidly lost hardiness and was damaged severely when exposed to $-6^{o}$C.

The sensitivity of xylem, phloem, and cambium tissue varied to some extent with treatment as well as time of year. In Dec., the cambium was damaged at $-6^{o}$C in trees of all treatments except those of the fumigation treatment. With phloem, trees in the fall-pruned and N treatments were damaged at $-18^{o}$, while no phloem damage was observed in trees of other treatments. At bloomtime (Feb. 19) the cambium and xylem of all trees except

Table 3. Index of cold injury for terminal twigs of 'Coronet' peach as influenced by 5 cultural treatments, winter 1973-1974.

| Treatment | Index of cold injury[z] | | | | |
|---|---|---|---|---|---|
| | Sampling date | | | | |
| | Dec. 4 | Dec. 17 | Jan. 7 | Jan. 23 | Feb. 19 |
| *at −6°C* | | | | | |
| Check | 5.9b[y] | 1.0a | – | 5.0b | 17.6ab |
| Fall-pruned | 7.6b | 1.0a | – | 3.0a | 24.1c |
| Late fall nitrogen | 5.1b | 2.9b | – | 4.5b | 15.3a |
| Soil fumigation (DBCP) | 2.2a | .6a | – | 2.1a | 14.8a |
| Fumigation plus nitrogen | 6.4b | 1.8b | – | 4.2b | 18.5b |
| *at −12°C* | | | | | |
| Check | 16.9a | 7.8ab | 6.1a | 14.0a | 39.1b |
| Fall-pruned | 19.4a | 7.2ab | 6.6a | 12.6a | 44.1c |
| Late fall nitrogen | 19.4a | 10.0b | 7.2a | 15.4a | 35.8b |
| Soil fumigation (DBCP) | 15.4a | 5.9a | 7.2a | 12.0a | 24.2a |
| Fumigation plus nitrogen | 15.2a | 9.5b | 7.5a | 12.0a | 36.8b |
| *at −18°C* | | | | | |
| Check | 32b | 9.2a | 28.9a | 44a | 75b |
| Fall-pruned | 31ab | 10.1a | 28.9a | 41a | 75b |
| Late fall nitrogen | 33b | 14.0b | 29.5a | 43a | 67a |
| Soil fumigation (DBCP) | 24a | 9.0a | 26.4a | 40a | 67a |
| Fumigation plus nitrogen | 36b | 12.6b | 27.8a | 42a | 67a |

[z]Index calculated according to Flint et al. (12). Higher values indicate greater cold injury.

[y]Mean separation in columns within temp by LSD, 5% level.

those in the fumigation treatment were severely damaged at −6°. The phloem was not damaged until −18° in trees receiving either N, fumigation, or the combination, but was damaged at −6° in fall-pruned and −12° in the control trees.

## Discussion

Cultural practices influence cold hardiness of peach on a PTSL site. Fall-pruning, which is known to be detrimental (4, 8, 22), reduces cold hardiness of trees. Fumigation, which is beneficial (2, 6, 11, 27), promotes increased cold hardiness while controlling nematodes. Additional N appears to increase vigor of trees, but decreases cold hardiness. Combination of fumigation and additional N was not superior to either practice alone.

The results of our study and others (1, 7, 9, 29) show that maximum cold hardiness is attained following periods of cold weather but cold hardiness is lost with warm temperatures. Temperature, more than any other factor, governs changes in cold hardiness from fall through winter (1). Our observations showed that trees lose hardiness more rapidly once the chilling requirement is complete. Our study confirms reports (14) that maximum hardiness can be attained after the chilling requirement has been completed.

Phloem tissue is more hardy than xylem or cambium. The xylem gains hardiness, then remains at a constant level until the chilling requirement is met, when it loses hardiness rapidly. The cambium gains hardiness rapidly with low temperatures but loses hardiness rapidly with the advent of warm temperatures. Damage to twigs during controlled freezing tests was similar to the cold damage to peach reported in the literature (1, 4, 5, 9, 21, 29) and to that observed in the test orchard during the spring of 1973.

The sudden death of peach trees often associated with cold injury and PTSL was observed in the test site during spring, 1973. Symptoms observed in March 1973 were typical of cold injury symptoms described by Daniell (4, 5) and those observed in the laboratory when twigs were exposed to freezing temperatures. These symptoms of collapse resemble symptoms of water deficiency. The injury of xylem we observed and injury reported by Daniell (5) could impede the flow of water sufficiently to result in wilting when water needs of the plant

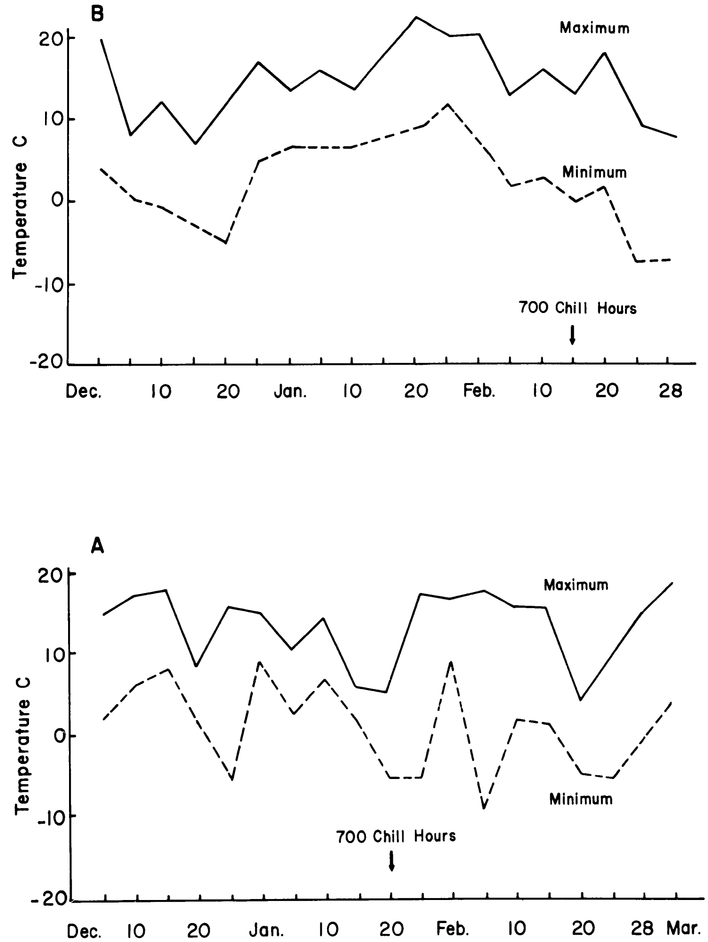


Fig. 1. Maximum and minimum temperature during 2 winters at Trenton, SC. A: Winter I (1972-73); B: Winter II (1973-74).

increase sharply following leaf emergence in spring. Thus, the sudden wilt and collapse observed follows logically from the type of anatomical injury we found in tissue exposed to cold. Trunk and crotch are usually several degrees less hardy than terminal twigs (1, 16, 25). Temperatures below −6°C were frequently recorded during both winters and on one occasion (Feb. 1973) a low of −12° occurred. We suspect, therefore, that temperatures sufficient to damage xylem and cambium did occur in the field. We conclude that cold hardiness and cold injury are associated with tree survival on a PTSL site and that the observed symptoms could logically be expected from cold injury.

Regardless of treatment, trees were usually of equal hardiness following several days of cold weather. Thus, it appears that differences in hardiness relate to a) rate of development of cold hardiness; b) ability to retain the hardiness during periods of warm weather; c) rate of dehardening or loss of hardiness; d) the rate with which hardiness can be regained. Fall-pruning is damaging because it results in decreased cold hardiness, decreased vigor, and increased mortality. These trees are usually less hardy following periods of warm weather, especially after the chilling requirement has been met, indicating that fall-pruned trees may frequently be damaged at higher temperatures than are trees in other treatments.

The mechanism involved in reduction of cold hardiness of fall-pruned trees is not understood. However, the pruning wounds partially healed in midwinter indicating cambial activity (24). When cambial activity occurs, peach trees are very susceptible to cold injury (1).

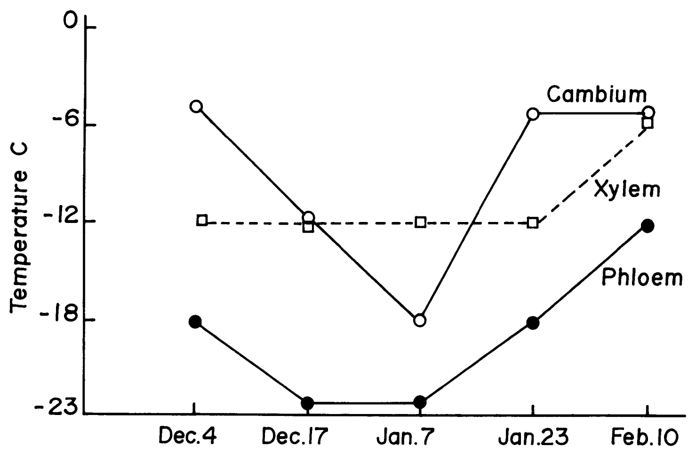


Fig. 2. Cold hardiness of xylem, phloem, and cambium of 'Coronet' peach twigs during the winter of 1973-74 as indicated by the highest temperature at which damage was observed.

Nitrogen, when applied near leaf fall, usually reduces the cold hardiness of trees. These trees in our test were especially susceptible to cold in early winter. These findings support other evidence (1, 3, 9) that late fall N amendment decreases cold hardiness. Levitt (17) suggests that addition of N causes the tree to remain vegetative and not acclimate properly. Our study did not indicate that late fall N treated trees remained vegetative any later than other trees. Since the N was added about leaf fall, Levitt's hypothesis may not explain the lack of hardiness observed. The xylem and phloem, but not the cambium, of late fall N treated trees appeared more sensitive to cold than those of control trees in midwinter. Thus, the mechanism of decreasing cold hardiness by adding late fall N is not clear.

Although cold hardiness of trees receiving the N amendment was generally reduced, vigor and tree survival were improved. That finding supports the hypothesis of Taylor et al. (26) that trees with an inadequate supply of stored N may not be able to resist cold. When fall N applications were made to fumigated soil, much of the improved cold hardiness associated with fumigation was lost. Therefore, this combination treatment, as applied in our study, should be discouraged because it appears to have potential for reducing cold hardiness and tree vigor.

While temperature probably plays the major role in cold hardiness of peach, selected cultural practices may strongly influence sensitivity of specific tissues to cold. Cold hardiness on any one date is the result of many factors.

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