JOURNAL OF
ARBORICULTURE

December 1981
Vol. 7, No. 12

MINIMIZING WINTER INJURY OF SHADE TREES[1]

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I find that discussions of cold hardiness of plants and how to minimize winter injury are usually of interest to people no matter where they reside. We who live in northern areas often think that we are the only ones who must worry about winter injury and sometimes find it hard to believe that people in Georgia, Florida, Texas or other southern states also frequently have winter injury problems. The frequency of our winter injury problems probably indicates that no matter where we live and how wide a diversity of plants that we have available that are well adapted, we are not satisfied. We persist in using too many plants that are marginally adapted to our particular climate.

For my discussion, I'll start by briefly reviewing what we currently know about cold acclimation of plants and what factors are involved. This background will provide a basis for discussing what we can do in our professional practices to minimize winter injury problems. For those desiring a more thorough understanding of cold hardiness and all its ramifications I'll refer you to the review articles by Weiser (1970) and Alden & Hermann (1971).

Plants differ widely in their tolerance to freezing temperatures at different stages of growth and development. A cold hardy plant such as red osier dogwood, *Cornus sericea* or paper birch, *Betula papyrifera* can be killed by temperatures only a few degrees below freezing in mid-summer when they are in active growth. The same plants have been shown to tolerate temperatures under laboratory conditions at least as low as −196°C (−320°F) without injury in midwinter when they are fully acclimated. Considerable research has been devoted to studying the biochemical changes that occur during these changes in hardiness levels. We know that there are many changes in amount of the various sugars, amino acids, etc., that accompany these changes but we still don't thoroughly understand any clearcut cause and effect relationships.

Research over the years by many scientists has given us a pretty good picture of the relationship of environmental conditions to initiation and development of cold hardiness by plants. We find that plants initially are triggered to begin the cold acclimation sequence as a result of decreasing daily photoperiods. This initial step in cold acquisition can occur under continuous warm temperatures and thus is not temperature dependent, although the rate of hardiness development during this phase is influenced by temperatures. The level of hardiness attained due to shortened photoperiod reaches a plateau after a few weeks and increases very slowly after that until colder freezing temperatures trigger the second stage of acclimation which then proceeds very rapidly. These stages are sequential. Cold temperatures prior to the development of photoperiod induced acclimation cannot trigger rapid acclimation responses.

We have also learned that different tissues in a plant have different hardiness potentials. Root tissues are much less capable of hardening than is stem tissue of the same plant (Pellett 1971) and flower buds are usually less hardy than vegetative buds. Xylem tissues are hardier than phloem tissues in early winter and less hardy in midwinter.

Thus one needs to be aware of the limiting factor when working with plants. For example, plants of forsythia or azaleas may be perfectly hardy but flower buds may be killed in some climates and thus the plants are not considered satisfactory for

[1]Presented at the annual conference of the International Society of Arboriculture in Boyne Falls, Michigan in August of 1981.

landscape use. Root hardiness can be the limiting factor when using plants in above ground landscape containers, in rooftop gardens, or in other situations where soil temperatures fluctuate widely. We also need to be aware of the time of year when injury occurs.

We are well aware that many plants aren't capable of hardening to withstand the minimum midwinter temperatures but timing of acclimation or deacclimation is just as critical. Many of our potential landscape plants are not hardy because they don't acclimate soon enough to withstand our first severe freezes even though they may have the potential to harden sufficiently to withstand the midwinter lows. Other plants deacclimate too early with warm periods and then are injured severely by subsequent freezes.

Other factors that we need to be aware of are the different types of injury and the different mechanisms that different plants have or even different tissues within the same plant have to tolerate freezing temperatures. Some tissues survive freezing temperatures because their cell sap does not freeze. Water in cells of overwintering flower tissue and in xylem ray parenchyma cells of some plants survive due to the ability to undercool and remain in a liquid state even at temperatures as low as −40 to −45°C. In other tissues water molecules migrate to ice centers between the cells and cells survive by tolerance to the dehydrated condition within the cell. In all cases under natural conditions freezing of water within the cell seems to be lethal.

Sun scald injury and winter browning of evergreens is thought to be due largely to intracellular freezing brought about by rapid drops in temperature over the freezing point. During bright winter days the tissue is thawed by the sun and exposed tissues may be 10-15°C higher than air temperature. When the sun goes down or is covered by scattered clouds the tissue temperature drops rapidly preventing water from migrating out of the cell and injury occurs as a result of intracellular freezing.

With this brief review of cold acclimation processes as a background I'd like to switch to a discussion of professional practices that we can use to minimize winter injury. Let's start with prevention of sun scald which can be quite serious with Norway maple, red maple, and many other thin barked species in some areas. To prevent or reduce incidence of sunscald injury we must look for ways to reduce the rapid temperature fluctuations of the tissues on the exposed side of the trunk. Let's evaluate current practices. Painting of the trunk with a white latex paint to reflect the sun's rays has been somewhat successful for orchardists but does distract from the natural appearance. Wrapping with Kraft tree wrap products is an old established practice but how effective is this practice? There doesn't seem to be much research literature to either show benefit or lack of benefit from use of this material. If anyone is aware of literature showing comparisons, I'd like to know about it.

In the last two winters we've compared various types of materials as possible trunk wrap materials. We monitored temperature levels of the cambium tissues on the exposed side of tree trunks to compare temperature levels when exposed and rates of temperature change that occurs following shading from the sun. Temperatures of trunks wrapped with standard Kraft tree wrap products did not differ greatly from non-wrapped trunks. The most promising material was a product called Foylon I which resulted in much less build up of temperature on sunny days. We had very little sunscald injury in the field and thus have no data on differences in injury using this material. Detailed results of this study will be written up for publication in the near future.

Another practice that I'd like to discuss is the practice of withholding water and/or fertilizer in late summer or early fall to slow growth, thus inducing earlier maturity and initiation of cold hardiness. This practice has some basis of merit but is over emphasized and is only valid for plants that are marginally adapted. As mentioned earlier under natural conditions, growth cessation and initiation of cold acclimation is triggered by declining daylength. With well adapted plants this happens sufficiently early to give plenty of margin for tolerance to the first freeze. For example, in Minnesota many of our native woody plants are hardy to below 0°F (−18°C) by early October when we normally encounter our first frost. With adapted plants the practice is not beneficial and if overdone can be detrimental to normal growth and development. If the plant doesn't harden soon enough due to daylength then the practice can help initiate some acclimation earlier but water and fertility levels are difficult to control in the field. I wouldn't recommend using marginally adapted plants and trying to compensate by withholding water and/or fertilizer. (For a detailed discussion of *Influence of Fertility on Cold Hardiness* see Pellett and Carter 1981.)

Another standard recommendation regarding watering practices and winter injury that I'd like to address briefly is that relating to evergreens and fall watering practices. We often hear the recommendation that one should make sure the soil is well watered prior to freezeup to reduce winter injury of conifers following dry autumn seasons. This gives the connotation that the critical time is late fall. Previous research of ours indicates that the critical stress occurs earlier in the fall and that one should not allow severe drought stress to occur (Pellett et al., 1980).

The last practice that I'll discuss is use of adapted clones and species. This is the area where we can do the most to reduce winter injury problems. Although we don't have a very good knowledge of the genetics of hardiness, we have long recognized the importance of source of stock on winter hardiness. Yet we have been quite careless in this regard in our production and planting practices and in evaluation of exotic plant species for potential use. We too often rely too much on hardiness zone ratings of plants without regard to geographic source. We try a plant once and if it fails we quickly label the species as not being hardy. There can be a tremendous difference in hardiness within a species due to source. Although little data are available I think that difference in hardiness due to source is due primarily to differences in timing of acclimation and not due to large differences in ability to acclimate to withstand minimum temperatures in midwinter.

There have been many studies that illustrate differences in initiation of acclimation. In general plants from southern latitudes or from low altitudes require longer periods of continuous darkness than do plants from northern areas or higher altitudes to initiate the cold acclimation processes. Thus when they are grown in a common site, plants from northern areas start acclimation much earlier in response to the declining photoperiod in late summer or fall.

To illustrate the extent of differences that can occur I'd like to cite the work of Pauley and Perry (1954). They obtained plants of *Populus trichocarpa* from throughout its native range and grew them all at Westin, Massachusetts, (42° latitude), and recorded cessation of growth. Plants from 60° N latitude ceased growth on June 20 while plants from 35° N latitude were still actively growing on October 28 when the growing shoot tips were killed by frost.

We have studied the midwinter hardiness capability of many species of woody plants and find that many are capable of tolerating minimum temperatures much lower than that associated with their hardiness zone ratings. (Pellett et al., 1981). Perhaps many species of plants native in other areas of the world are hardy to 1 or even 2 zones further north than we think if we obtain germplasm from different sources than we have previously tried.

With the improvement of relations with China hopefully we can explore this possibility for plants native in that country. China is the one area of the world that most closely approximates the U.S. in climate as the two countries have approximately equal borders in terms of latitude. We in Minnesota are interested in acquiring germplasm of woody plants from areas in Manchuria just north of the North Korean border as that area equals our latitude and has a climate somewhat comparable to ours. For most areas in the United States there is an area of China with comparable latitude and similar climate.

While I'm on the subject of source of plant material, I'd like to clear up one point that is commonly confused. We in northern areas often stress that plants should be obtained from northern nurseries. The important factor is not where the plant is grown but where the seed or clone originated. Thus, if seed of *Acer rubrum* collected in Minnesota is grown by a Florida nursery for sale in Minnesota there would be no problem unless the plant arrived in early spring in full growth and froze shortly after arrival. Plants from a northern seed source planted in a southern state would usually be much slower growing and also could be severely injured by spring freezes. Thus unless research has been conducted on seed sources for growth in your specific area you should use plants from a source as close to your location as possible. In cases of grafted plants, source of the rootstock is as important as is the geographic origin of the scion variety.

The current practice of introducing many new clones of various species of shade trees can be either very beneficial or can lead to more problems depending on how we react and how well we understand the implications in relationship to adaptation. If we use them properly and choose clones that are well adapted to our respective areas then the results can be beneficial. Adequate testing is needed to determine local adaptation of each new clone as it comes on the market. The fact that you have used the species successfully doesn't mean that all new clones will do well in your area.

To make my case I'll use *Acer rubrum* as an example. Red maple is native in much of the Eastern part of North America from Florida to Northern Minnesota and Southern Canada. However, within this broad native range the plants from any one source are not widely adapted due to differences in photoperiod required to trigger the cold acclimation process. Thus a clone selected from Florida or other southern or even mid latitude state are not likely to be well adapted to Northern areas or vice versa. Townsend (1977) conducted a thorough provenance study of various characteristics of red maple that illustrates some of the differences. Of the clones of red maple currently available in the trade none is well adapted for us in Minnesota. We have just released the clone Northwood to help fill the void in our area and are continuing our efforts to develop superior clones for Minnesota that may also be useful in other northern climates.

To summarize our best method of minimizing winter injury of shade trees is to develop, identify and use well adapted varieties. By understanding cold hardiness development and types of cold injury that occur we can modify our cultural practices to accentuate natural cold acclimation processes to aid the plant in tolerating winter stresses but cultural practices cannot adequately substitute for proper selection of plants. Use of marginally adapted plants will continue to result in frequent cold injury despite use of the best cultural practices.

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