How Woody Plants Survive Extreme Cold

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The ability of a tree or shrub to survive an Iowa winter depends on the seasonal change in its metabolism to a quiescent or dormant state known as acclimation. The first stages of acclimation are induced in early autumn by exposure to short days and nonfreezing chilling temperatures, both of which combine to stop growth. But to survive the kind of low midwinter temperatures recently experienced in Iowa, woody plants must be exposed to temperatures at or below freezing for some time before they become fully acclimated. Once acclimated, many of our landscape plants are quite capable of tolerating midwinter temperatures near -40 to -50 F!

It is important to remember that plants are composed primarily of water, and that freezing of water inside living cells is fatal to individual cells and potentially deadly for the entire plant. Therefore, living tissues survive low temperatures by suppressing ice formation, or by allowing water to freeze, but only in areas of the plant that won't be injured by ice crystal formation.
Many trees and shrubs commonly found in the hardwood forests of southeastern Canada and the eastern United States have the ability to suppress ice crystal formation in their cells, even at temperatures far below the freezing point. This "deep supercooling" is seen in species such as oak, elm, maple, beech, ash, walnut, hickory, rose, rhododendron, apple, pear, peach, and plum. However, cellular water can supercool only to about -40 F, at which temperature ice formation occurs spontaneously resulting in the death of the cell. This -40 F limit explains the existence of timberlines at high elevations, and also why low-elevation timberlines exist in Alaska (3,750 feet) and increasingly higher timberlines occur as you travel south to Montana (7,500), Wyoming (9,750 feet), Colorado (10,500 feet) and Arizona (11,250 feet).

Very hardy woody species such as paper birch, redtwig dogwood, willow, and quaking aspen growing in northern Canada and Alaska are subject to average annual minimum temperatures well below -40 F. Instead of depending on deep supercooling to survive, these plants prevent water from freezing within their cells using a dehydration mechanism. Here water moves out of the cells in response to freezing temperatures, freezing in areas between the cell walls where ice formation is not destructive. This slow dehydration concentrates solutes (sugars and other compounds) in the remaining cell sap which lowers its freezing point (similar to antifreeze in a car radiator). In midwinter, many hardy woody plants survive extreme dehydration that results when all of their freezable water crystallizes in the spaces between the cells. Generally the hardier the plant the greater the capacity of cells to tolerate dehydration. This may explain why some woody species that are resistant to freezing are also resistant to water deficit during the growing season.
Plants appropriately adapted to the local climate, and those that have fully acclimated will usually survive even the coldest temperatures (see winter 1996). But injury can occur when: (1) temperatures fall below a plant's maximum low temperature limit even after normal acclimation has occurred, (2) when premature freezing occurs before the plant has acclimated in the fall, (3) when unusually late freezes occur in the spring after the plant has deacclimated, and (4) when

there are dramatic swings in temperature during the winter that cause a plant to deacclimate before the threat of severe freezing is over.

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