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# Feature

## Horticultural Applications of a Newly Revised USDA Plant Hardiness Zone Map

Mark P. Widrlechner[1,5], Christopher Daly[2], Markus Keller[3], and Kim Kaplan[4]

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Summary. **The accurate prediction of winter injury caused by low-temperature events is a key component of the effective cultivation of woody and herbaceous perennial plants. A common method employed to visualize geographic patterns in the severity of low-temperature events is to map a climatological variable that closely correlates with plant survival. The U.S. Department of Agriculture Plant Hardiness Zone Map (PHZM) is constructed for that purpose. We present a short history of PHZM development, culminating in the recent production of a new, high-resolution version of the PHZM, and discuss how such maps relate to winter-hardiness per se and to other climatic factors that affect hardiness. The new PHZM is based on extreme minimum-temperature data logged annually from 1976 to 2005 at 7983 weather stations in the United States, Puerto Rico, and adjacent regions in Canada and Mexico. The PHZM is accessible via an interactive website, which facilitates a wide range of horticultural applications. For example, we highlight how the PHZM can be used as a tool for site evaluation for vineyards in the Pacific northwestern United States and as a data layer in conjunction with moisture-balance data to predict the survival of Yugoslavian woody plants in South Dakota. In addition, the new map includes a zip code finder, and we describe how it may be used by governmental agencies for risk management and development of recommended plant lists, by horticultural firms to schedule plant shipments, and by other commercial interests that market products seasonally.**

Horticulturists have long recognized that the accurate prediction of winter injury is a key component of the effective cultivation of long-lived woody and herbaceous perennial plants in many climates. Winter injury can limit long-term plant survival and vigor and can reduce production of valuable horticultural products, including flowers, foliage, fruit, and seeds. As noted by Skinner (1962), "frost dates, length of the growing season, and minimum winter temperatures are among the least readily controlled of the major factors governing the geographic adaptability of plants," so the ability to forecast the risks associated with such factors is extremely valuable.

Freeze injury to various plant tissues and organs typically occurs at three stages in the annual cycle (Larcher, 2005; Raulston and Tripp, 1994): 1) During the autumn, when plants cease growth (Kalcsits et al., 2009) and begin to harden or acclimate to winter conditions (often signaled by decreasing photoperiod and temperature), early, low-temperature events can exceed a plant's (or a specific tissue's) ability to withstand the event. 2) During the lowest temperatures of midwinter, when plant tissues optimally achieve a maximal degree of cold acclimation, extreme low-temperature events may still overwhelm adaptive survival mechanisms. 3) And finally, during the late winter and early spring, plants may deharden when exposed to temperatures above freezing, having satisfied physiological rest requirements (Litzow and Pellett, 1980), and can then suffer damage from subsequent low-temperature events.

Studies that thoroughly document the seasonal progression of acclimation and provide graphical representations of the timing of actual or potential injury from low-temperature events at all three stages in the annual cycle include those by McNamara et al. (2002), McNamara and Pellett (1993), Mills et al. (2006), Scheiber et al. (2002), Schrader and Graves (2003), Szalay et al. (2010), and Väinölä et al. (1997).

### Hardiness-zone basics

Of the three stages when injury often occurs, the frequency and severity of midwinter, low-temperature events have historically received considerable attention by plant scientists. Specific weather events causing plant injury on a case-by-case basis may yield insights on factors influencing adaptation [see Bachtell and Green (1985) for an example from the Chicago region and Gu et al. (2008) for a detailed discussion of the Spring 2007 freeze in the eastern and central United States], but such weather events are not repeatable and do not lend themselves to experimentation and hypothesis testing. However, further insights can be gained by shifting emphasis away from individual weather events (or even seasons) to longer time frames that document multiple, extreme events on a climatic scale. Heinze and Schreiber (1984) presented a comprehensive review of this topic, detailing the history and application of long-term climatological data to relate patterns of woody-plant adaptation to low-temperature injury.

**A brief history of hardiness zones and zone maps.** A relatively simple method used to visualize geographic patterns of the biological severity of low-temperature events is to map a climatological variable that closely correlates with patterns of plant survival. Rehder (1927) developed the first such map for the United States, with a mapped zonation system that