Factors Affecting Cold Hardiness in Grapevines

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Thanks to Deke Arndt for supplying the weather data.

Introduction

Cold hardiness is a major limitation to growing the highest quality European grape cultivars in Oklahoma. Mid-winter low temperatures coupled with wildly fluctuating temperatures in the fall and spring can cause significant injury. In order to maximize conditions to give grapevines the best opportunity to survive, prudent decision making is a necessity. Several factors go into maximizing cold hardiness in grapes.

Stages of Dormancy in Grapes

Three main physiological stages exist related to dormancy and cold hardiness in grapes. The first stage in the dormancy process is acclimation, which is the ability to adjust to climate change. This begins after the vine has ripened its crop and shoot growth has ceased (Rombough, 2002), which is usually late summer into early fall. In order to reach full acclimation a period of cool weather is required before the first freeze. Acclimation occurs mainly during the fall months of October and November, although it begins in August. The weather during October and November can be difficult in some areas of Oklahoma because damaging temperatures may occur prior to full acclimation. Areas in the northern regions of Oklahoma (Table 1) are much more likely to experience harmful temperatures than those in southern Oklahoma.

The second stage, mid-winter hardiness, is the ability to survive particular climatic adversities, especially freezing temperatures during dormancy. This occurs in Oklahoma from December through February. There is a limit as to how cold hardy a particular cultivar can be based on its genetic background. Exposure to temperatures below 20 °F over a period of several days ensure maximum hardiness (Rombough, 2002). Mid-winter temperatures below 0 °F are considered to be potentially damaging to *V. vinifera* grapes (Fennell, 2004). These temperatures are prevalent only in northern areas of Oklahoma where the average occurrence is more than once per year (Table 2). However, damaging freeze events are common enough throughout the state to warrant caution when growing *V. vinifera* grapes.

The third stage is called deacclimation. It is the process of breaking dormancy and readjusting to warmer temperature conditions. This process is caused by periods with temperatures above 32 °F and it occurs fairly quickly (Rombough, 2002). It usually occurs in the spring, but warm temperatures in winter can cause deacclimation leading to severe damage when cold weather returns. Timing of deacclimation is likely the most worrisome for Oklahoma grape growers. This is particularly true for cultivars with early budbreak, such as 'Chardonnay'. Northern regions of Oklahoma average many potentially damaging weather events during the normal deacclimation period of March through May (Table 3). Even areas in the southern part of the state will experience a handful of freeze events during spring. At best, minimal bud and/or green shoot damage is experienced. At worst, trunk splitting and permanent trunk and cordon damage can occur.

Genetic Factors Affecting Cold Hardiness

Grapevine genetics play an important role in the level of cold hardiness a particular cultivar can achieve. Species have different abilities to withstand cold temperatures and that ability is determined by evolutionary factors such as its area of origin. The lineage of a particular cultivar, especially a hybrid, can give clues as to its potential cold hardiness. Many grape species have been used in breeding of winegrapes. Most of the cold hardiness genes come through American grape species such as *Vitis labrusca*, *V. aestivalis*, and *V. riparia* (Fennell, 2004). Other American species (*V. rotundifolia*, for example) are not cold hardy at all. *Vitis vinifera* is the most common winegrape species and originated in the Mediterranean areas of Europe. Its ability to withstand cold mid-winter weather is not great. Also, it is highly susceptible to fluctuating fall, winter, and spring temperatures that lead to deacclimation. Therefore, knowledge of the genetic background of a cultivar is a key component to choosing genotypes that are adapted to a particular climate.

Environmental Factors Affecting Cold Hardiness

Several environmental factors are involved in determining the eventual mid-winter hardiness of grapevines, including: elevation, temperatures, light levels, daylength, soil conditions, and disease pressure (Fennell, 2004). Elevation is important because height and slope are needed for proper air and water drainage. Drainage of cold air should not be impeded by trees or other obstacles. Northern slopes will shorten the growing season whereas south slopes with lengthen the growing season. Therefore, early ripening cultivars should be planted on north slopes and late ripening cultivars on south slopes. Ambient temperatures interact with the genetic background of a cultivar to determine its ultimate cold hardiness. Fluctuating temperatures can delay the vine from reaching full cold hardiness. Light exposure is essential for maximum cold hardiness. Shade during the growing season leads to reproductively unproductive vines (unbalanced vine growth – too much vegetative and not enough reproductive) that do not harden off as well as those exposed to full sunlight. American species are responsive to changes in daylength, and coupled with decreasing temperatures, promote more rapid acclimation response than found in *V. vinifera* that responds primarily to decreasing temperatures (Fennell, 2004). Highly fertile soils can lead to excess vigor and poor soils can stress vines due to lack of essential nutrients and water availability. Rootstock selection can compensate for some of these deficiencies. Diseased vines are weak and cannot develop enough carbohydrates through photosynthesis during the growing season to harden wood thoroughly.

Management Factors Affecting Cold Hardiness

Many decisions made by a would-be grape growers can significantly impact cold hardiness. One should choose an optimal site, match cultivars to the climatic conditions, select an appropriate training and trellis system, choose rootstocks wisely, fertilize and irrigate prudently, and also manage the cropping levels of the vine (Howell, 2003). Training and trellis systems should ensure maximum sunlight exposure while balancing vegetative and reproductive growth. Cultivar growth habit needs to be matched with appropriate trellis system. Rootstock selection has a direct influence on scion biochemistry and it may have a direct or indirect impact on cold hardiness levels (Fennell, 2004). The main impacts are due to the rootstock influence on vine size, canopy shading, and cane maturity. Fertilization, when done correctly, has little impact on eventual winter hardiness. However, late season N fertilization can induce vigorous growth that will not harden off in time for cold weather. High levels of irrigation during the growing season can delay acclimation of vines and mild water stress at the end of the season may affect secondary and tertiary bud cold hardiness. Cropping levels are extremely important to maintain vine health. Excessive crop loads can delay acclimation whereas low crop loads have greater cold tolerance during the fall acclimation period.

Ramifications of Cold Injury

Grapevines can experience three types of injury: bud injury, trunk injury, and vine death. Bud injury can usually be corrected with compensatory pruning. Trunk injury is more severe. There are three levels of trunk damage (Amberg, 1994). The first is not severe with only a browning of the phloem in early spring and full recovery. The second level is more severe and is a permanent injury, with death of phloem tissue that leads to some trunk die-back (Fig. 1) and potential entry for crown gall. The most severe injury is cambium death followed by vine collapse to the ground level. The vine will need to be regrown from the root system. The impact of vine death is obvious as the vine needs to be replaced altogether. Sometimes trunk damage and vine death is not immediately noticeable when pruning is done in the late winter or early spring. The vine may appear normal at pruning, but fail once normal growth is initiated. This could be due to root injury from severe cold or, more likely, from cambial damage. The essence of the problem is that the vine cannot pump water and nutrients from the storage system (roots) to the growing portion of the vine (cordons, trunk, etc.). The inhibition of water and nutrient movement up the trunk due to damaged cambial tissues result in vines being unable to sustain cordon and trunk well-being.

Crown Gall

Many strains of *Agrobacterium* exist, but only one is responsible for tumor development (Amberg, 1994). While inactive in healthy tissue, the bacteria proliferate when associated with winter injury and mechanical damage (Fig. 2). Frequent development of crown galls is the result of trunk injury and not the cause of it. There are a few tools for managing crown gall. The best and most effective is to use appropriate cultivars and rootstocks that have resistance to the bacteria and are well adapted to the region where they are grown. Also, make sure nursery stock is disease free and try to eradicate infected vines if possible. Chances are grapevines grown in Oklahoma will get crown gall at some point because of the harshness of the environment. However, attentive vine management, especially sanitation and eradication, can minimize the detrimental effects.

Concluding Statements

Good site and cultivar selection along with sound vine management are keys to having success in growing grapevines. Protection of the graft union in grafted vines can provide some insurance against winter injury as well. The use of multiple trunks may help in areas where very cold temperatures are common because research has shown that both trunks will not have the same level of hardiness (Fennell, 2004; Howell, 2003). And most of all, healthy vines are happy vines. Sound management will create the best environment for establishing full winter hardiness in grapevines.

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Table 1. Number of freeze events below 28 °F at nine locations within Oklahoma for the months October and November from 1950-2005 when fall acclimation occurs.

Location	Total Freeze Events	Average/Year
Boise City	875	16
Buffalo	558	10
Pawhuska	470	9
Webbers Falls	346	6
Hobart	274	5
Enid	268	5
Chandler	254	5
Durant	197	4
Ardmore	112	2

Table 2. Number of freeze events below 0 °F at nine locations within Oklahoma for the months December-February from 1950-2005 when mid-winter hardiness occurs.

Location	Total Freeze Events	Average/Year
Boise City	157	3
Buffalo	115	2
Pawhuska	89	2
Chandler	38	<1
Webbers Falls	35	<1
Enid	34	<1
Hobart	23	<1
Durant	13	<1
Ardmore	5	<1

Table 3. Number of freeze events below 28 °F at nine locations within Oklahoma for the months March-May from 1950-2005 when deacclimation occurs.

Location	Total Freeze Events	Average/Year
Boise City	969	18
Buffalo	597	11
Pawhuska	483	9
Enid	375	7
Hobart	323	6
Webbers Falls	308	6
Chandler	269	5
Durant	162	3
Ardmore	125	2

Fig. 1 Symptoms of winter injury on ‘Sangiovese’. Cordons have been killed back to the trunk where re-growth has been initiated.

Fig. 2 Severe crown gall symptoms at the base of a grapevine.