Cornell University
College of Agriculture and Life Sciences
Cornell Cooperative Extension

Assessing Winter Cold Injury of Grape Canes and Trunks

By Robert Pool, Cornell University, © Copyright 2000
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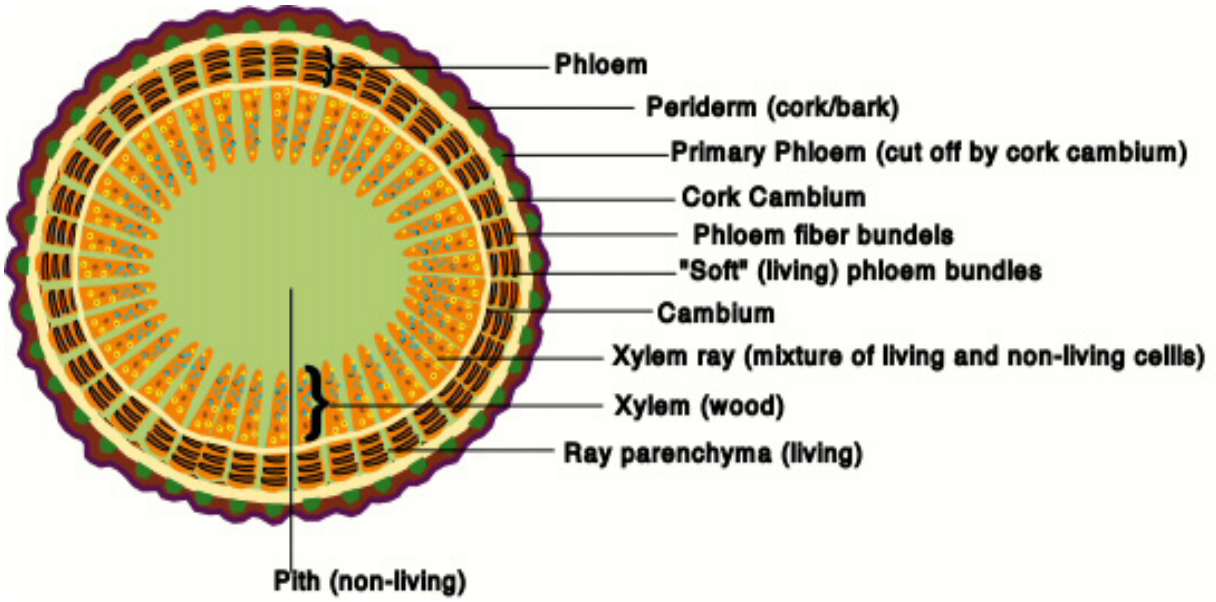
Cane and Trunk Anatomy in Relation to Cold Injury

A grape cane is a shoot that has matured (has formed visible periderm or "bark") and has lost its leaves. Buds on canes produce shoots, leaves and clusters during the subsequent crop year. Canes retained beyond the second season become trunks. Older wood can be distinguished from canes by bark which shreds. Sequential, annual production cork cambium in older wood results in bark which does not adhere tightly and which shreds. Shoots have greenbark, canes brownish bark which adheres tightly, and trunks have brown bark which shreds. Horizontal trunks are called cordons, and short trunk extensions on which canes or spurs are retained are called arms. In terms of cold injury, arms and cordons behave like trunks.



Diagrammatic cross section of a cane.

Grape **phloem** is made up of alternate bands of fiber cells and bands of so-called soft phloem. Cells of the soft phloem conduct sugars and other nutrients through the plant. Functional grape phloem is living and is active for more than one season. The last band of phloem created by the vascular cambium in a season is always soft phloem. In the fall the conducting cells of the phloem produce a

carbohydrate called callose which plugs the conducting cells, ending movement of sugars for the year. In the spring the callose disappears and the phloem cells become reactivated.

The **vascular cambium** is made up of undifferentiated cells which retain the ability to divide. It is quite distinct when shoots, canes or trunks are actively growing, but becomes indistinct when growth slows. The residual cells in the vascular cambium resume division early in the season and form additional bands of phloem and xylem. Yearly bands of xylem are retained and buried within the trunk as it increases in circumference, but the new bands of phloem are cut off by successive cork cambia.

The **xylem** is a complex tissue made up of dead water conducting cells, living companion cells (parenchyma) and living wood fibers, which have great strength. The large conducting cells in the xylem are connected end to end to create conduits for water and nutrient movement. At maturity these vascular elements are not living and yet still function. Sometimes in response to stress and often in the fall, companion cells generate matter which balloons into and otherwise plug the conduction cells. Older bands of xylem are encased in a matrix and form visually distinct heartwood.

In the one-year-old cane the **pith** is distinct, but it is usually more difficult to distinguish in older trunks. Canes which develop properly will have a small diameter pith and relatively large diameter xylem. Thus relative pith diameter is also an indication of cane quality.

All the vascular tissues inside the cork cambium are arranged in pie-shaped segments alternating with **vascular rays** made up of living, relatively undifferentiated parenchyma cells. Ray cells live for more than one year, and are thought to be important for radial flow of nutrients.

Role of Bud Survival

In studies that Charlotte Pratt and I made, we noticed that shoot development and trunk cambial activity are interrelated. When few buds survive the winter, trunk growth suffers. When we excised all buds above, there was no phloem reactivation or vascular cambial activity. If we let buds develop and then later excised the shoots, cambial activity which had started would cease.

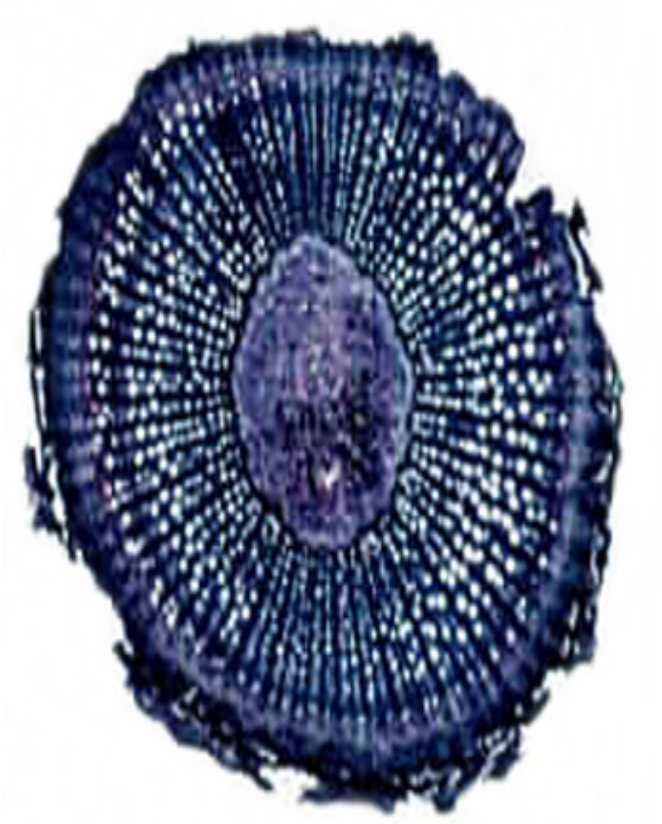
We simulated winter injury to trunks by applying a stream of liquid nitrogen to freeze portions of canes. When we excised the buds above the frozen tissue, there was no new cambial activity. When shoots were allowed to develop, only non-frozen vascular cambium resumed growth in the spring. However, provided shoot growth continued, eventually undifferentiated cells in the rays cells of the frozen canes would begin to divide and a new vascular cambium would form at these sites. A portion of non-differentiated parenchyma would remain buried in new xylem.

Developing shoots produced a substance which stimulated unorganized callus growth similar to that produced by crown gall. A continued flow of these substances allowed the creation of a new vascular cambium. We found that we could replace the growing shoot with a paste of the plant hormone, auxin. We believe that vascular cambium is reactivated in response to a flow of auxin produced by the developing shoots. In uninjured trunks the "old cambium" is regenerated in response to auxin flowing down the reactivated phloem in the last formed phloem bundle. The last soft phloem is always produced adjacent to the cambium of the previous year.

This interrelationship between bud survival, shoot growth and cambial reactivation helps to understand the nature of trunk cold injury and the appropriate response to it.

Types of Recovery

Chardonnay vines were planted in Geneva in 1974. Following the growing season of 1976, canes were selected to become trunks. In January, 1977 many of these canes became injured just above the snow line. Most injury was restricted to a few inches. Ms. Pratt and I were able to follow the development of these injured canes in their second year of life. The figures below show what we found.



Normal undamaged cane after two months of growth in year 2

Note complete resumption of cambial activity in yr. 2 around the circumference of the cane.

Tissues in order (starting at center)

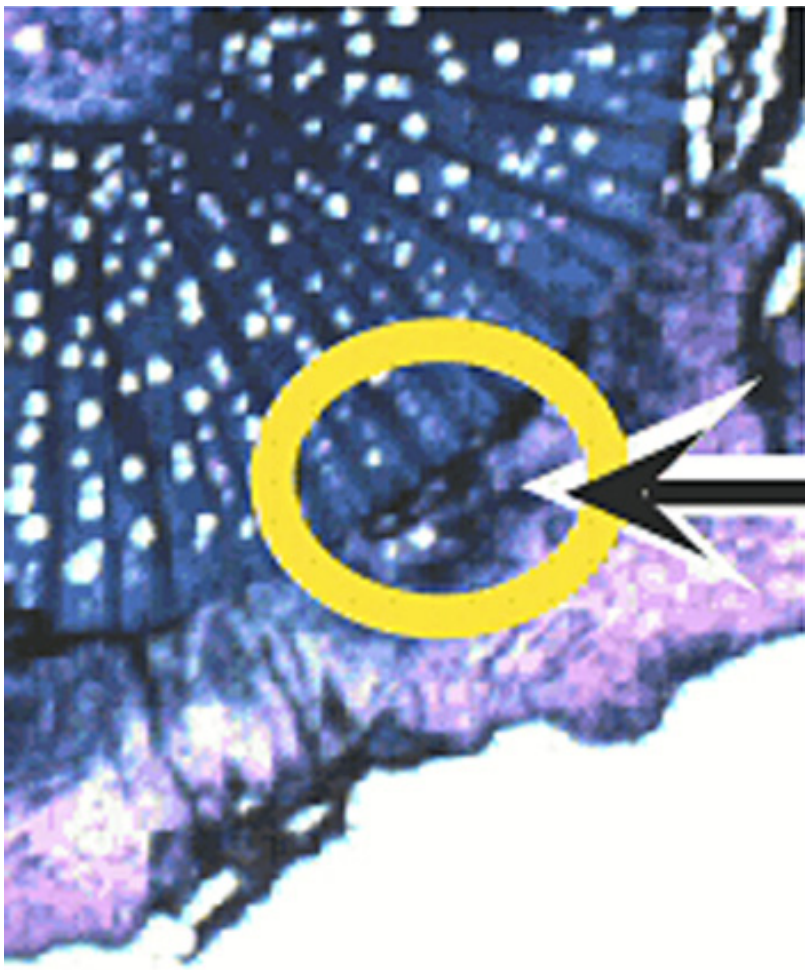
- Pith
- 1 year old xylem
- Site where previous year vascular cambium ended activity
- This year's xylem
- Vascular cambium
- This year's phloem, cork cambium
- Last year's phloem

Partially winter injured cane following 2 months of year 2 growth

Year 1 pith, xylem and vascular cambium are distinct. Most year 1 phloem was not dislodged by new cambial activity. In lower left there has been callus growth originating in the phloem ray cells. A new vascular cambium has formed there and is producing xylem and phloem

Cane in year 2 following complete cambial death in winter following year 1

All that is visible is pith and year 1 xylem.



Detail of extensively cold damaged but recovering cane

In the lower section pinkish, undifferentiated callus has proliferated. Such growth generally begins in the phloem region, if phloem survives, or in xylem ray tissue if the phloem sector is dead.

Near the lower center at the margin of last year's vascular cambium, new xylem and phloem cells have been produced by a new vascular cambium. This tissue formed inside the callus growth in response to a supply of plant hormones produced by growing shoots above the cold damaged area and translocated down to the wound.

Deciding What to do When Trunks are Injured

Here is the sequence of actions to take when trunk injury occurs in your vineyard.

First, retain a full complement of buds on the vine, and make sure any low growing spurs, canes or buds which might be used to form needed replacement trunks are retained.

In June, around the time of grape bloom, the vascular cambium of sound trunks will be fully reactivated (reactivation starts near the developing buds, and proceeds down the trunk; the base of the trunk is not usually reactivated until just about bloom). At that time go through the vineyard and make decisions about trunks. If you come to a suspicious vine (irregular shoot growth, unusually strong sucker growth, trunk cracking and callusing) make a small cut into the trunk at the effective winter ground height (snow on the ground may have raised the effective height). You will find one of three conditions:

1. No injury and bark which slips Bark slips (separates at the xylem/phloem juncture) because the vascular cambium is active. The new, undifferentiated, thin walled cells of the cambium have much less physical strength than those of the phloem or xylem).
2. Discolored phloem and bark which slips.

3. Discolored phloem and bark which does not slip.

The appropriate action for these three situations are:

1. **No discoloration/bark slips** the trunk is probably not injured, use your normal viticultural practice.
2. **Discoloration/bark slips** the phloem was injured, but a vascular cambium has reformed. This trunk will not fully recover. It should be flagged and replacement trunk(s) trained. The flagged trunks should be removed during winter or the following spring.
3. **Discoloration/bark does not slip** the phloem and perhaps the xylem were damaged, and the vascular cambium has not regenerated. This vine may well collapse during the growing season. If possible, two or more shoots should be trained up as replacements. If the old top dies, the extra shoots will help prevent excessive shoot growth. The old trunk should be flagged and removed as with example two.

You can see the critical decision regarding winter injured vine trunks is not made in winter, but in summer when the extent of injury may be better evaluated.

Strategies for Living with Cold Damage Injury to Canes and Trunks

Sooner or later most vineyards in cool climates will suffer cold injury. Spring freeze is the most common, but I have seen cane and trunk cold injury in California and Australia, certainly not places associated with cold winters. In northern Europe growers in such historic areas as Champagne, Chianti and the Rhinegau can expect to have vines killed to the ground by winter cold injury at least once or twice a generation. Thus every grower might consider how he should treat vines which have been cold damaged.

The big difference between **cold** climates and **cool** climates is that grape growers in cold climates can assume that cold damage may be the rule rather than the exception. The cold climate grape grower should be prepared to not only grow vines that tolerate cold stress, he/she should practice a viticulture which tolerates cold injury to vines.

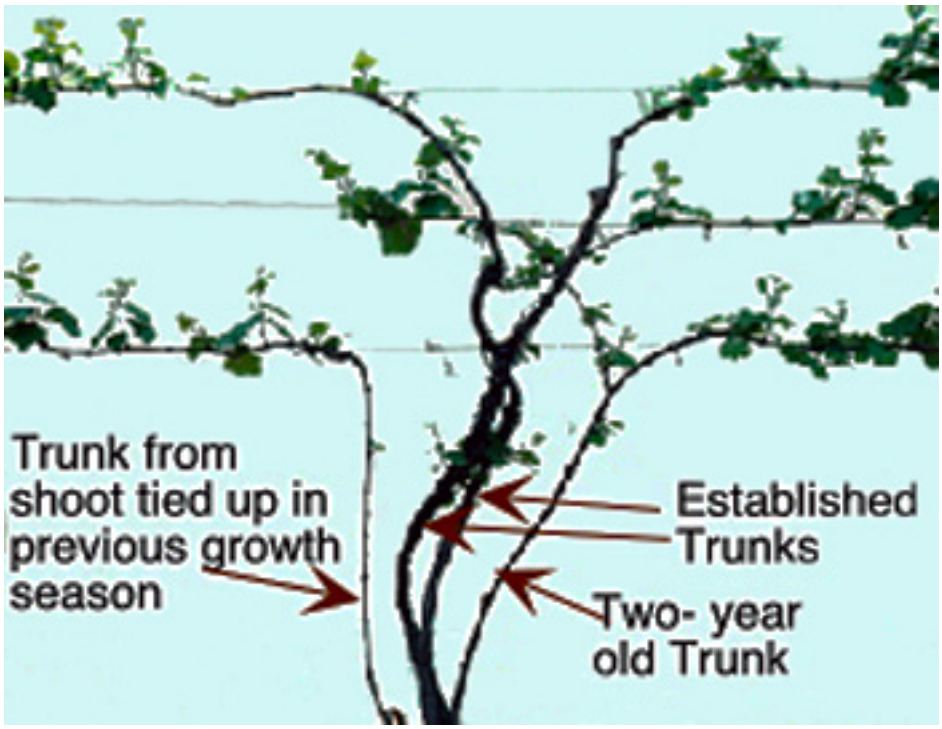
Grower Endurance

By far the most common strategy to deal with cold injury is grower tolerance, not vine tolerance. Even in the coolest European grape growing regions the expected frequency of cold damage is small enough that growers do not resort to special treatments which complicate management and certainly increase the annual expense of grape growing. The growers are prepared to endure the damage. When their vines are injured they have the choice of retraining new vines from sucker growth or replacing the injured vines.

Keeping a Cold Injured Vineyard Productive

Multiple trunks are one part a system for surviving cold injury sometimes referred to as 'Spare Parts Viticulture'. In areas where one must be prepared to endure cold **damage** as well as **cold stress,** it seems wise to have extra plant parts in place. One hopes that some of the parts will escape

injury even when others do not. The figure below shows a vine with multiple trunks. There are four trunks of at least three different ages. The two large trunks are more than 3 years old. Another trunk was formed by tying up a sucker originating near the graft union two summers previous to the winter the picture was taken. The youngest trunk is a cane which developed from a sucker shoot tied up in the previous growing season. When (if) some of the older trunks show signs of winter cold injury, they can be removed and the remaining trunks can bear a full crop.



A Chardonnay vine trained to endure winter cold injury.

Note multiple trunks of various ages and the high number of retained canes and buds. At this stage of development the number of canes and/or growing shoots can be adjusted to a "normal" target number. Even though there has been some cold bud injury (note buds which did not produce shoots), sufficient buds did survive to produce a normal crop.

The figure also shows some of the complications of this approach. First the large number of canes and trunks require a large amount of space. As a result, otherwise desirable training systems such as cordon or vertically shoot positioned training become difficult. The many trunks can interfere with machine harvesters. The collecting plates remain open too long and some fruit may be lost to the ground. Finally there is a matter of labor and materials expense. The multiple trunks slow pruning, and the shoots required to develop new trunks must be trained in the summer.

Suckering is also made more complicated by the need to retain growth at the base of the vine. When growers are meticulous about removing unwanted shoot growth from the base of the vine for the first 2-3 years of vineyard life, the tendency for sucker development in future years is minimized. In the long run suckering cost is minimized. However, this approach will not work for multiple trunked vines. The grower needs a continuous supply of suckers to form new shoots. This also means he/she has a more expensive yearly task of removing suckers not wanted for trunks. The need to retain green

shoot growth at the base of the trunk also makes weed control by post-emergent herbicides, such as round-up (glyphosate), more difficult.

Training Multiple Trunks

If a multiple trunk vine is desired, then little shoot pruning is done at planting, and 4-8 shoots are encouraged to grow. Usually they are trained to a low wire. Many shoots are retained because regions with cold winters also usually have short summers. The goal is to get maximum early season leaf area development, and to avoid excessively vigorous shoot growth which might not mature in a short season. For the second season the longest, best placed cane is tied up, and 4-8 shoots arising high on the cane are allowed to develop. During that second growing season one or two shoots arising near the ground (make sure they are not shoots of the rootstock variety) are retained and tied up. During the following winter, canes appropriate for the training system are retained from the older trunk, and the new trunk is shortened to an appropriate head height. Often a spur is left near the ground to produce new shoots, although this isn't really necessary so long as the vine bases are not kept completely free of shoots in future years.

When grow tubes are used, retaining many shoots in the first year may not be feasible, but new trunks can usually be formed after the grow tubes are removed.

Summary

Cold season grape growers have to expect cold injury to buds, canes and trunks. Buds develop as individuals and there are usually a surplus produced in any one year. However, trunks and canes have to support major portions of the vine, and injury is more serious. Understanding which tissues become injured and the impact of the injury can provide growers with information needed to make good decisions about cold injured grapevines. When injury is expected even when vine growth is optimized, then an approach which ensures that spare parts are available to replace injured vines parts may be an economic approach.

This White Riesling vine grew for almost 30 years in our experimental planting at Geneva, New York, before the vineyard was removed. Note that some trunks had obviously lived for many years, that at least four trunks have been formed so that spares would be available should the oldest trunks become injured.