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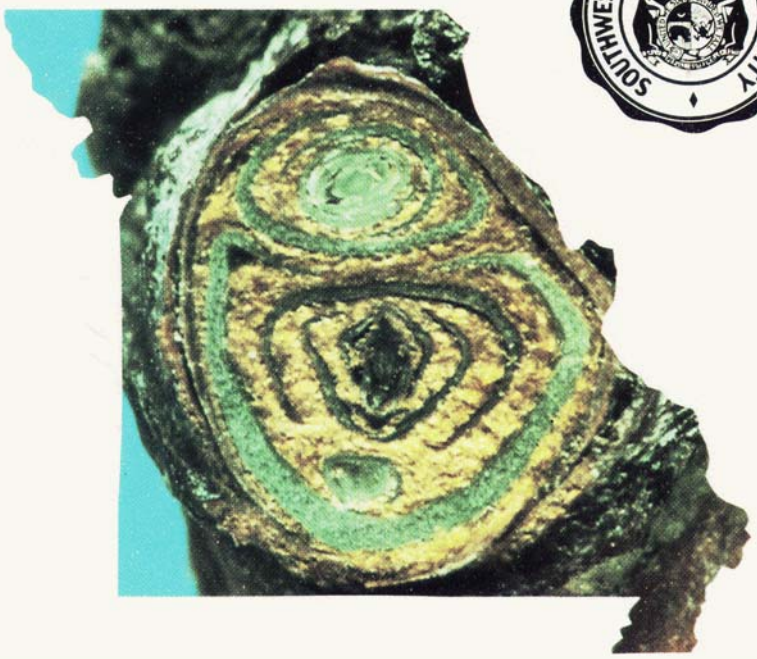
COLD HARDINESS OF GRAPES
A Guide for Missouri Growers



STATE FRUIT EXPERIMENT STATION

COLLEGE OF HEALTH AND APPLIED SCIENCES

MISSOURI STATE UNIVERSITY

MOUNTAIN GROVE, MISSOURI

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COLD HARDINESS OF GRAPES
(A Guide for Missouri Growers)

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Cover photo shows cross section of 'Dutchess' compound grape bud with killed primary bud and live secondary and tertiary.

(cover photo courtesy of Dr. T. Zabadal
New York Cooperative Extension Service)

COLD HARDINESS OF GRAPES

Grapevine hardiness is a major factor in the selection of species and varieties for production in a particular area. Cultivated grapevines are often grown in areas not entirely suited to their optimum growth and development. The grower must choose cultivars, sites, and cultural techniques that will maximize profit as well as produce a quality product from season to season. Cold injury is, at times, a problem in Missouri and must be considered in order to maintain consistent, high quality production. This bulletin is organized to introduce the problem of cold injury to grapevine, to list cultural techniques that minimize or prevent injury, and to present winter bud hardiness data from the State Fruit Experiment Station at Mountain Grove.

DEFINITION OF TERMS

Cold hardiness is the ability to resist injury during exposure to low temperature.

Cold tenderness is the opposite of cold hardiness.

Cold injury is the killing by low temperature of some part of the vine.

Seriousness of cold injury is indicated by the amount of decrease in fruit production and/or quality resulting from cold injury.

Dehardening is the process after the chilling requirement (rest) is satisfied whereby the plant or tissue loses hardiness and is ready to resume growth.

Dormancy is the condition of a bud or seed characterized by the lack of outwardly visible growth.

Double pruning is the cultural practice whereby twice the number of buds dictated by the balanced pruning formula are retained after an initial pruning in early to mid winter. A second pruning is done after bud damage can be assessed and/or the threat of spring frost injury is minimal.

Hardening is the process by which a plant or tissue is made more resistant to any environmental extreme such as low temperature.

Rest is a state of suspended growth due to internal physiological blocks. Rest is fulfilled by exposure to temperatures of 45°F (7°C) or less for an extended period (chilling requirement). After the rest period is satisfied, a plant may either break dormancy and begin to grow if conditions allow, or may remain dormant if conditions do not favor growth.

HARDINESS

The hardiness of grape wood and bud varies with species and variety. European (vinifera) type vines are the least hardy and require warm to hot summers and mild winters. American (labrusca) and French American hybrid vines will withstand humid summers and cold winters and these are the types grown extensively in Missouri.

A grapevine must undergo many changes in order to survive the winter and grow the following spring. The vine must mature properly at the end of the growing season and must harden to be able to withstand the cold winter temperatures. This hardiness must be maintained throughout the dormant season. In late winter or early spring, the vine will lose hardiness and resume growth when conditions are favorable.

The vine hardens in fall to a certain level that is maintained during the winter. Once a variety has reached its particular hardiness level, it will remain inactive and will not resume growth if the weather warms. This is because the plant needs to fulfill its rest period (a certain number of hours of chilling temperatures) before it will begin to grow. Once the vine satisfies its rest, it will then start to grow and lose hardiness if the weather is favorable. This is why a plant will not resume active growth during a warm spell in January but will lose hardiness and begin to grow under favorable conditions in March.

At any given time during this seasonal cycle, different plant parts will vary in hardiness. The primary bud is more susceptible to cold injury than the secondary which is in turn less hardy than the tertiary bud (Figure 2). The wood of the grape is more resistant to injury than are the buds.

FACTORS THAT INFLUENCE VINE HARDINESS

Many factors other than species and cultivar influence grapevine hardiness. In one study, winter hardiness varied up to 22°F (12°C) on different canes of the same vine(5). The presence of the woody covering on a mature cane, cane color, leaf exposure to the sky, and cane diameter influenced cold hardiness for 'Concord'. Dark colored canes of medium diameter exposed to the sun were hardier. Canes with deciduous laterals (side shoots) or small persistent laterals had the best mixture of cane and primary bud hardiness when the cane diameter was in the medium range. These observations should be kept in mind when pruning or sampling for evaluation of winter injury.

Heavy fruit load and excessive shoot growth that continues into the fall are the factors that enhance the probability and severity of cold injury. The Missouri Cooperative Extension Service presently recommends shoot thinning for selected cultivars to avoid overcropping. 'Chelois', for example, is subject to winter injury and Gloor stated that most of the problems with this variety can probably be attributed to overcropping (4).

Site selection is extremely important when considering cold injury. A site with both adequate air and water drainage is recommended. In general, cold air pockets and excessive moisture can be associated with low areas. When judging the air drainage situation, note the area surrounding the site as well as the site itself. A dense wooded area above the planting can divert cold air away from the site, thus keeping it warmer. A wooded area below the site may impede cold air drainage away from the site, thus increasing the danger of cold injury. Drainageways can be cut through wooded areas in order to allow the cold air to drain through.

Internal water drainage should be assessed prior to planting. To do this, dig holes a foot or so deep in representative areas on the site, fill them with water and note the amount of time they take to drain. If a substantial amount of water (about 4-6 inches) remains for more than a day, a drainage problem is indicated. If the hole is dug in dry soil, keep the hole filled with water a day before testing in order to saturate the surrounding soil. Grapevines on poorly drained soils do not harden as well as vines on well drained soils in most cases. Hardy tissue is more dehydrated than tender tissue.

Basically, cultural practices that promote healthy vines that bear a consistent crop will promote winter hardiness as well. Additional Cultural modifications are discussed with the treatment of specific types of cold injury and are summarized below (2,6,11,12).

(1) Select a site that has adequate air drainage.
(2) Practice delayed pruning or double pruning.
(3) Multiple trunk training will allow the grower to replace winter injured trunks of tender varieties.
(4) If replacement trunks are not available, allow suckers to grow and replace injured trunks.
(5) Promote development of a deep, healthy root system by adequate soil preparation.
(6) Maintain adequate vine size via sound consistent cultural practices.
(7) Avoid late harvest.
(8) Maintain healthy foliage.
(9) Assure proper exposure of leaves to the sun via a suitable training system.

(10) Manage to promote early and complete vine maturity. Do this by allowing undervine cover to grow at the end of the growing season. Also, avoid cultivation, nitrogen fertilization, excessive irrigation, and pruning late in the season.
(11) Keep cover crop height low, especially in areas where cold air tends to settle.
(12) Avoid overcropping and undercropping.
(13) Avoid defoliation of vines.

TYPES OF COLD INJURY

I. Early fall frost or cold temperature may injure vines before they are fully hardened. This is more of a problem with late maturing Cultivars. Choosing a site with adequate air drainage is important in avoiding this type of injury. Cultural practices that minimize early fall injury by promoting early maturation should be followed. Do not allow the cluster to remain on the vine for any longer than necessary. Do not overcrop or undercrop. Avoid pruning, nitrogen fertilization, excessive irrigation, and cultivation late in the season. Defoliation due to combing, harvesting, or pests should be minimized. Allowing the ground cover to grow later in the season will promote maturation which is essential for the vine to harden properly.

II. Winter cold injury occurs after the plant has hardened and may affect buds, canes, trunks, and even roots. Winter temperatures between -10° and -17°F (-23° and -27°C) are generally critical for canes of American and French hybrid vines (1). Generally, when temperatures drop lower than -5°F (-20.4°C), winter bud injury should be assessed for American and French hybrid vines.

To assess winter bud injury for vines trained to the 4-cane Kniffen system, ten 10-node canes of pencil thickness should be collected per variety per vineyard (100 buds). These canes should be healthy and suitable to be retained for the new season's crop. If the vines are trained to the single or double cordon (curtain) training system, then collect buds from the area that would ordinarily be left after spur pruning. Select 20 to 30 spurs, each with 3 to 5 nodes (100 buds). Sampling should be done after injury is suspected. The canes should be allowed to stand at room temperature for 48 hours before evaluation. If the canes are collected several days after the low temperatures occurred and have been exposed to above freezing temperatures for at least 2 days, then the sample can be evaluated immediately after collection.

Familiarity with the compound bud of grape is necessary to evaluate the buds for winter injury. This compound bud actually consists of 3 single buds; the primary bud in the center, the secondary bud nearest the leaf scar, and the tertiary or smallest bud (Figure 1).

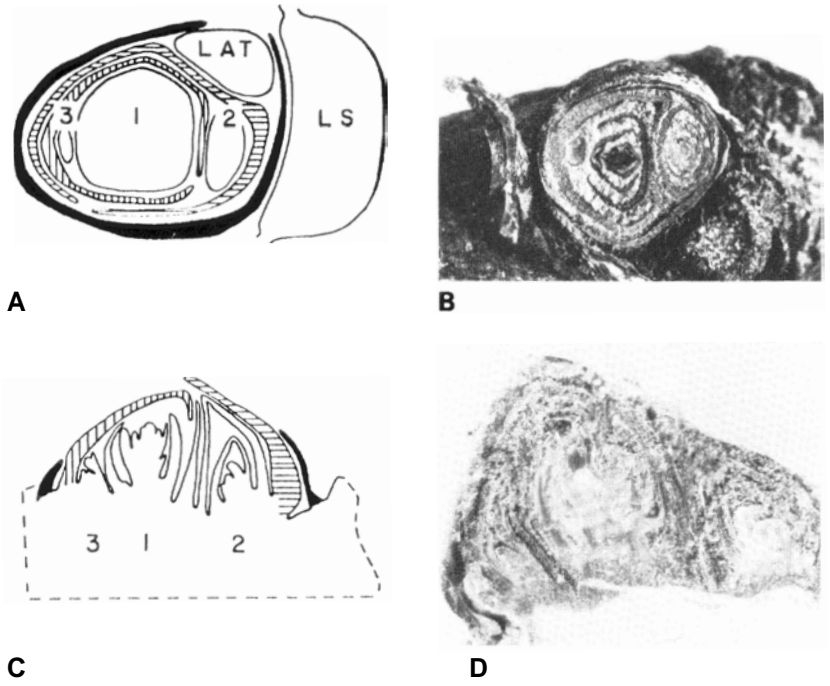

Figure 1. A. Diagrammatic cross section through a compound bud of 'Concord' showing relative positions of the leaf scar **(LS),** lateral shoot **(LAT)** and three dormant buds. B. Cross section of 'Dutchess' showing the three dormant buds and a killed primary bud. C. Diagrammatic longitudinal section in the plane of the cane axis showing the compound bud of 'Concord'. Leaf scar indicated by broken line at right of bud. D. Longitudinal section of the compound bud of 'Baco Noir'. Diagrams magnified 18 times (10). Photos courtesy of Dr. T. Zabadal, New York Cooperative Extension Service.

The primary bud is the least hardy and the most fruitful. To evaluate for injury, look down at the pointed top or apex of the compound bud and slice off the top quarter with a razor parallel to the base of the bud. If the primary is alive it will be bright green in the center. It will be brown or black in the center if it is dead. If you are unfamiliar with this technique, begin at the tip of the compound bud and slice it until the three single buds are seen. Slice below these buds in the cambial region of the cane to learn to distinguish the more olive green smooth textured cambium of the cane from the brighter green bud center with concentric rings of tissue (Figure 2).

The primary bud is of greatest interest to the grower. The New York Cooperative Extension Service recommends that if less than 20 percent of the primaries are killed, then follow the balanced pruning formula for the specific variety. If 20 to 50 percent of the primaries are killed, then leave anywhere from 1 to 2 extra canes (4 to 5 extra spurs) to twice as many buds as dictated by the balanced pruning formula. If more than 50 percent of the primaries are killed, then leave everything for evaluation after bud break. Double pruning is the two-step method in which extra buds are left on the vines when first pruned. The second and final pruning is performed after bud break when bud loss can be estimated. Delayed pruning of tender cultivars until bud break or until the danger of killing winter temperature is diminished, is another option. The fruitfulness of the secondary bud varies with species and cultivar. Some French hybrids with less than 50 percent primary bud survival can bear a full crop. Winter injury may in fact eliminate some of the need for shoot or cluster thinning on cultivars such as 'Seyval Blanc', 'Vidal Blanc', or 'Chelois'.

If more than 50 percent of the primaries are killed, then cane and trunk damage is likely. This is difficult to assess in the dormant season. After growth starts, a small section of bark can be cut out with a knife in order to observe the phloem and cambium tissue underneath (Figure 3). Healthy tissue is nearly white or green. Tissue that has suffered some damage is gray to light brown and severely damaged tissue is almost black. One sympton of trunk injury is sap exudation in droplets in March or April. Later in the season as weather warms, longitudinal splits may occur when injured phloem tissue is unable to control surface evaporation. Winter injured trunks may develop crown gall on the injured sections (Figure 4).

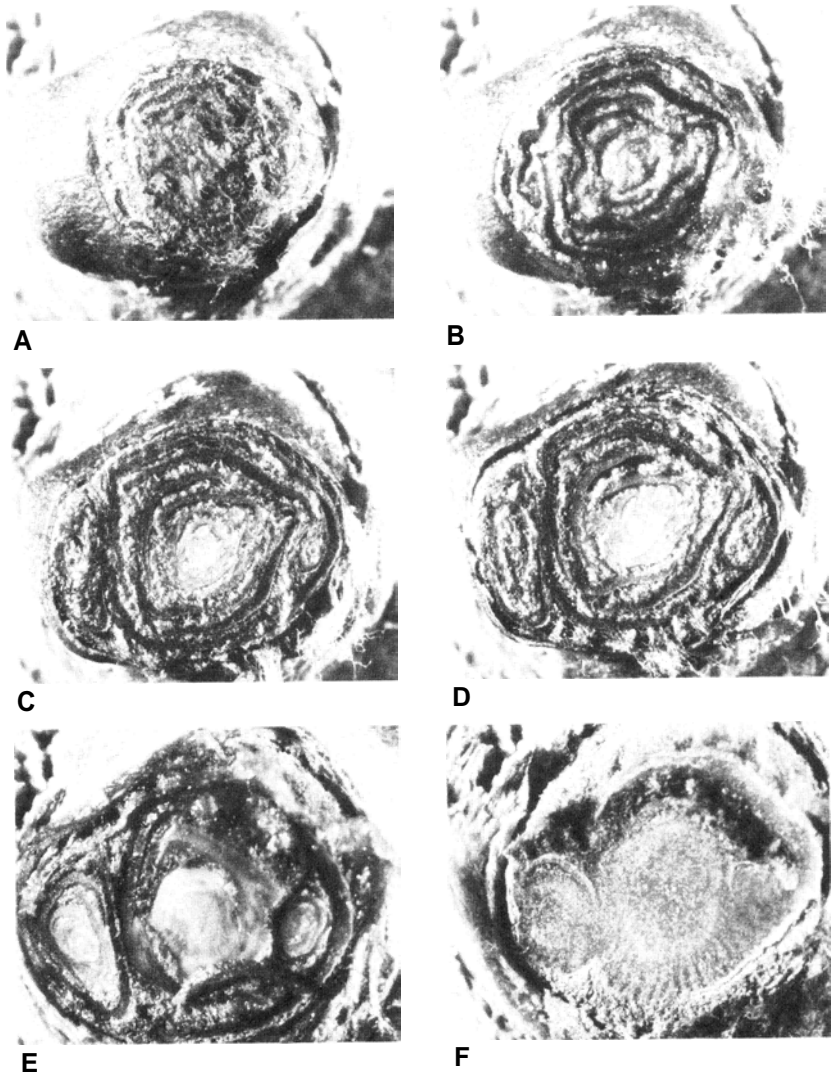

Figure 2. Series of slices off the compound bud of 'Baco Noir' beginning near the apex (A) and progressing through the 3 buds within to the base (F). A and B are cut too shallow for evaluation of the primary bud; C and D are properly cut for evaluation of the primary bud; and E and F are cut too deep for evaluation of the primary bud. Photos courtesy of Dr. T. Zabadal, New York Cooperative Extension Service.

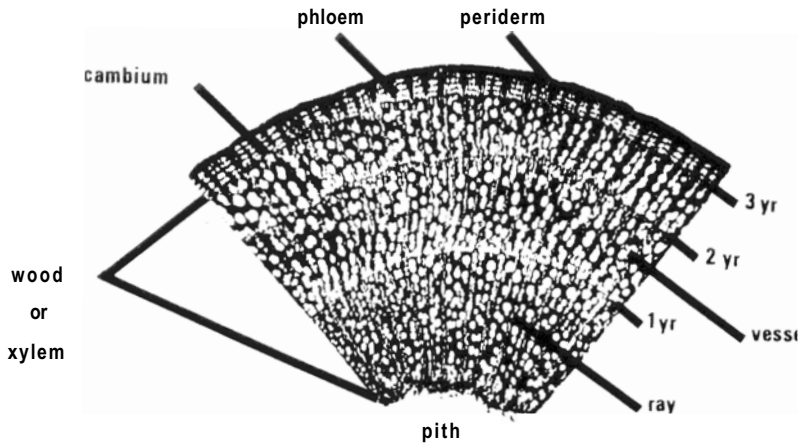

Figure 3. A cross section of a three year old grape stem (trunk) showing the periderm and phloem of the bark, the cambium at the juncture of the bark and wood, and the wood or xylem with vascular rays and vessel elements. Magnified 8 times (3).

Figure 4. Photograph of crown gall infection on trunk of 'Chelois'. Photo courtesy of Dr. James F. Moore Jr., Missouri State Fruit Experiment Station.

When growing winter tender varieties, 3 to 6 trunks of different ages can be maintained. In the first year, the new shoot is tied to the wire and in the second year, it is trained to the height of the old trunk. The oldest or most damaged trunk is removed when the renewal trunk is 2 to 3 years old. Another method for protection of tender vines is to lay the vine down in the row and cover it with friable soil, straw, or other insulating material.

Ill. Spring frost injury is another type of cold injury. After the vine has remained dormant throughout its rest period, warm weather in late February or March will cause the plant to begin developing. The more developed a bud or shoot becomes, the less hardy it is. Cultivar identity determines both the rate of shoot development as well as the actual hardiness at any given stage. Spring frost injury is the most common form of injury suffered by the more winter hardy cultivars. Leon Millot, for example, is quite winter hardy, but breaks bud early, thus creating a spring frost hazard.

Prevention of spring frost injury primarily rests in site selection, that is, choosing a site that allows cold air to drain away from it. If a low area must be planted, it should be occupied by cultivars that are hardier and break bud later in the season. Note that cold air settles at the tips of a continuous cover crop or ground cover; therefore, a very high cover will hold cold air nearer to the canes and buds. Delayed pruning or double pruning will also help minimize the hazard. Leaving canes or spurs that are longer than necessary not only aids in pruning adjustment for winter injury, but also causes buds closest to the old wood to break later. The apical or end buds develop first and surpress the development of the buds nearer the trunk or arm. The less developed a bud, the hardier it is, so the more developed end buds can be removed after the threat of spring frost injury has diminished. Mechanical, physical, and chemical methods of frost protection have not been demonstrated to be economically feasible as yet and there are no current recommendations on this.

MISSOURI BUD HARDINESS STUDY

Experimental setup: Mature dessert and wine grape cultivars and selections at the Southwest Missouri State University State Fruit Experiment Station were classified into hardiness groups according to percentage of primary and secondary bud mortality. Tertiary bud mortality was recorded, but not used to determine hardiness grouping. The bud mortality was caused by critical temperatures of -16°F (-27°C) and -14°F (-25°C) that occurred in mid January 1982. The buds were collected from two sample sites. Vineyard F, established in 1973, is a nonirrigated mixture of wine and dessert grape cultivars and selections. The vines are trained to the 4 cane Kniffen system and are spaced 8 feet within and 10 feet between rows, respectively. The rows run north and south along a 3.5% eastern slope. Vineyard T was established in 1976 of primarily seedless dessert grapes. This trickle irrigated vineyard has a 4.5% southern slope and the rows are oriented north and south in the same spacing as vineyard F. The vines are trained to the bilateral cordon/single curtain training system but were not combed in 1981. Both vineyards received the same pesticide-fertilizer program.

Three 10-bud cane sections were randomly collected from mature vines of each cultivar or selection in late January and early February of 1982. The cane sections were of live wood of uniform size suitable to be retained after pruning for the next season's crop. Of the 30 buds collected, 25 were cut and a count of the primary, secondary, and tertiary bud mortality was recorded. Mortality was recorded if the tissue in the bud center was brown or black. All samples were taken from vineyard F or T except for 'Concord' which was collected from a nearby, unirrigated site.

Results and Discussion: 'Concord Seedless', 'Ives', 'Steuben', 'Baco Noir', 'Foch', 'Catawba', 'DeChaunac', 'Golden Muscat', 'Bath', 'Totmur', 'Leon Millot', 'Concord', 'Delaware', 'Cascade', 'Venus' and 'Chancellor' were among the most bud hardy cultivars sampled. 'Reliance' was the hardiest seedless dessert grape. The most tender vines in the trial were 'Seneca', 'Seyval Blanc,' 'Glenora', 'Romulus', 'Dutchess', 'Chambourcin', 'Lakemont', and 'Suffolk Red' (Table 1).

Table 1. Wine and dessert grape winter bud hardiness data following the test winter 1981-82.

Cultivar or numbered selection	Percent winter bud mortality[z] Primary	Secondary	Tertiary	Rank[v]
Group 1: Very hardy cultivars or selections				
Concord Seedless	4	0	0	2.64
GR-7	4	0	0	2.64
Ives	4	0	0	2.64
Steuben	4	0	0	2.64
Baco Noir	8	0	0	5.28
Foch	8	0	0	5.28
Golden Muscat[x]	8	0	0	5.28
BS 2862	12	0	0	7.92
Catawba	12	0	0	7.92
DeChaunac	12	0	0	7.92
Golden Muscat[x]	8	8	0	7.92
GW-5	12	4	0	9.24
Reliance[x]	16	0	0	10.56
Bath	16	0	0	10.56
Castel 19637	16	0	0	10.56
GW-7	16	0	0	10.56
Humbert #3	16	0	0	10.56
JS 23-416	16	0	0	10.56
Totmur	12	8	0	10.56
Leon Millot	16	4	0	11.88
Concord[w]	20	0	0	13.20
GW-8	20	0	0	13.20
JS 26-627	20	0	0	13.20
Neva Munson[v]	10	20	0	13.20
Delaware	20	12	0	17.16
Cascade	28	4	0	19.80
Venus[v]	30	0	0	19.80

Group 2: Hardy cultivars or selections

S 7136	32	8	0	23.76
Chancellor	40	0	0	26.40
SV 18-307	36	8	0	26.40
BS 2846	40	4	4	27.72
Veeport	36	12	4	27.72
S 23047	44	9	9	29.04
Rosette	40	16	4	31.68
Reliance[x]	44	12	8	33.00
Canada Muscat	40	20	0	33.00
GW-10	48	4	0	33.00
SV 23-512	48	4	0	33.00
Captivator	48	8	0	34.32
NY Muscat	48	8	4	34.32

Group 3: Moderately hardy cultivars or selections

Vignoles	56	8	0	39.60
Isabella	56	12	0	40.92
Ravat 578	56	16	0	42.24
Canadice	56	24	16	44.88
Elvira	60	16	0	44.88
Himrod[x]	52	32	4	44.88
Vincent	60	16	4	44.88
Aurore	68	8	0	47.52
Interlaken[x]	48	48	40	47.52
Alden	72	8	4	50.16
SV 23-410	56	40	36	50.16
Cayuga White	64	28	8	51.48
A 1041	80	0	0	52.80
GW-2	76	8	4	52.80
Rougeon	72	28	4	56.76
S 2986	68	36	12	56.76
Vinered	68	36	12	56.76
A 1026	72	32	0	58.08
Vidal Blanc	72	32	0	58.08
Canadice	84	12	8	59.40
NY 36661	68	52	24	62.04
Villard Blanc	64	60	36	62.04
GR-3	68	68	12	67.32
A 1105	100	8	0	68.64
Himrod[x]	84	44	10	69.96

Group 4: Cold tender cultivars or selections

S 10868	96	24	18	71.28
Chelois	84	52	24	72.60
GW-4	88	48	4	73.92
GW-9	100	36	12	77.88
Landal	96	56	40	81.84
JS 12-428	100	51	16	82.83
Colobel	100	52	36	83.16
Interlaken[x]	92	72	44	84.48

Group 5: Very cold tender cultivars or selections

Seneca	100	68	64	88.44
Seyval Blanc	96	80	28	89.76
Glenora	95	84	60	90.42
Romulus[x]	95	84	60	90.42
Dutchess	100	76	36	91.08
Romulus[x]	96	84	76	91.08
Chambourcin	100	80	4	92.40
S 7136	100	84	32	93.72
Lakemont	100	88	84	95.04
Suffolk Red[x]	100	92	88	96.36
SV 12-303	100	92	72	96.36
GR-8	100	96	64	97.68
Landot 4511	100	96	72	97.68
S 14117	100	100	72	99.00
Suffolk Red[x]	100	100	96	99.00

[z]Mortality is based on a 25 bud sample.

[v]Cultivars were ranked by giving 66% value to the primary mortality percentage, 33% value to the secondary mortality percentage, and no value to the tertiary mortality percentage (Zabadal, personal communication). Hardiness classes are based on the ranking as follows: Group 1 (0-20), Group 2 (20-35), Group 3 (36-70), Group 4 (71-85), and Group 5 (86-100).

[x]These cultivars were represented in both vineyards sampled; therefore, two samples were taken of them.

[w]The 'Concord' sample was taken from a vineyard other than the two sampled in order to be used as a standard for comparison.

[v]Only one plant remained for these cultivars.

Several cultivars, indicated in Table 1, were represented in both sample sites and there were hardiness differences between them. The differences between vineyards F and T which may have contributed to the hardiness differences within the same variety are site, irrigated vs. nonirrigated condition, severity of anthracnose infection, and vine age difference. The extent to which these factors affected the results are not known. However, the hardiness differences between the same variety illustrate several points, one being that many other factors beside cultivar identity influence the hardiness of the vine. Another is that within this particular test temperature range, there is a great deal of variation in hardiness response between individual vines of the same cultivar. This implies that for these borderline instances, good cultural practices may be the decisive factor between severe or mild cold injury. There was enough difference in cold injury sustained by 'Reliance' and 'Interlaken' sample pairs to place them in two different classifications, while the sample pair 'Himrod' placed in opposite extremes of the same hardiness group. There was not much difference between the F or T Vineyard sample of the very cold tender 'Romulus' and 'Suffolk Red'.

A comparison between the Mountain Grove hardiness evaluation, based solely on winter bud mortality in a test year, and general evaluations from other sources is detailed in Table 2. Factors to consider when comparing the 2 sets of information include differences in location, climate, length of growing season, the parameters considered in the classification and whether the classification is based on one or several seasons data. The cultural system which prevails in the area should also be considered. In Table 2, note that 'Catawba' is classified hardier in the Mountain Grove trial than in a general classification from New York. The growing season is longer in Missouri than in New York and since 'Catawba' is late in maturing, it is better able to harden properly in Missouri. 'Seyval Blanc' is classified as less hardy in Missouri than in New York. One factor that possibly influenced this outcome is that in our particular trial, the vines in our study were not regularly cluster or shoot thinned, and overcropping may have been a problem.

Table 2. Hardiness rank of important[z] grape cultivars in Missouri.

Type	Cultivar	1981-82 bud mortality based classification-Mtn. Grove[y]	General classification based on other sources[x]
American	Catawba	1	2
	Concord	1	1
	CynthianaiNorton		1[w]
	Delaware	1	2
	Elvira	3	1
	Missouri Riesling		2[v]
	Niagara		2
Red hybrids	Baco Noir	1	4
	Chambourcin	5	4
	Chancellor	2	2
	Chelois	4	3
	Couderc Noir	-	1[u]
	DeChaunac	1	2
	Foch	1	1
	Leon Millot	1	2
	Villard Noir		3[w]
White hybrids	Aurore	3	3
	Cayuga White	3	3
	Seyval Blanc	5	3
	Vidal Blanc	3	3
	Vignoles	3	3
	Villard Blanc	3	3
Dessert	Reliance	1	1
	Canadice	3	1
	Himrod	3	4
	Lakemont	5	4
	Interlaken	4	5
	Glenora	5	5
	Suffolk Red	5	5

[z]Important grape cultivars in Missouri as listed by Meagher, et al. (8) not including dessert grape section.

[y]The numbers in this column correspond to the hardiness grouping based on winter bud hardiness data recorded in 1982 at the State Fruit Experiment Station at Mountain Grove, Missouri. Number 1 denotes the hardiest and 5 denotes the most tender.

[x]Classification according to Gloor (4) unless otherwise noted. Gloor's classification 2-6 is changed to 1-5 in Table 2 in order to offer a somewhat relative comparison between the Mountain Grove column and the general column.

[w]Classification derived from hardiness information by Lockshin (7).

[v]Classification according to Pool, et al. (9).

[u]Lucien Dressel (Augusta, Missouri), personal communication.

Grapes are considered to be deep rooted plants. The soils at the State Fruit Experiment Station are shallow, droughty, and are underlain by a dense and acid layer called a fragipan. The fragipan can restrict rooting depth to between 15 and 35 inches (41-89 cm) deep. 'Baco Noir' is classified hardier in Missouri than in New York (Table 2). One possible explanation is that our soil restricts the root system of this extremely vigorous grower, and perhaps the vine will more effectively harden in the restrictive soil at the end of the growing season. Recall that excessive vegetation growth at the end of the season may interfere with adequate hardening.

Weather conditions, cultural practices, site, maturing of wood, vigor of vine, overcropping, and undercropping can affect the hardiness of any vine. The hardiness of tissues on the same plant vary also. The general classification in Table 1 is a preliminary guide as it is based on one sample trial and one parameter (winter bud hardiness). Although the classification is not definitive, it is information that can be assimilated into grapevine hardiness recommendations for the state.

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