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The influence of rootstock on the cold-hardiness of Seyval grapevines

I. Primary and secondary effects on growth, canopy development, yield, fruit quality and cold hardiness

by

R. K. STRIEGLER and G. S. HOWELL

Michigan Agricultural Experiment Station, Department of Horticulture, Michigan State University, East Lansing, Michigan, USA

Einfluß der Unterlage auf die Kälteresistenz der Rebsorte Seyval

I. Primärer und sekundärer Einfluß auf Wuchsstärke, Dichte der Laubwand, Ertrag, Traubenqualität und Frosthärte

Zusammenfassung: Der Einfluß der Unterlage und der Wuchsleistung (kg Schnittholz je Rebe) auf die Kälteresistenz der Sorte Seyval wurden getrennt untersucht. In dem Unterlagenversuch wurden folgende Varianten geprüft: Wurzelechte Seyval-Reben (Sey/own), Seyval auf Seyval gepfropft (Sey/Sey), Kober 5 BB (Sey/5 BB), und Couderc 3309 (Sey/3309). Die Reben jeder Unterlagenvariante wurden in drei Wuchsklassen — stark, mittel und schwach — eingeteilt. Die Wirkung der Unterlage auf die Kälteresistenz wurde in Form der gesamten Knospenschädigung (Prozent tote Knospen) erfaßt. Als weiteres Merkmal für die Frosthärte diente die Qualität der Triebe innerhalb einer Rebe: mittlerer Triebdurchmesser und gute Exposition zur Sonne während der Vegetationsperiode.

Die verwendete Unterlage hatte keinen Einfluß auf das Wachstum der Reben und die Entwicklung der Laubwand. Der Traubenertrag wurde nur schwach, in erster Linie über das Traubengewicht, beeinflußt. Im Unterschied hierzu wirkte sich die Größe einer Rebe, unabhängig von der Unterlage, maßgeblich auf das Wachstum und den Ertrag aus.

Die Frosthärte hängt sowohl von Primär- wie Sekundäreinflüssen der Unterlage ab. Von allen Kombinationen wiesen die Sey/3309-Reben den geringsten Prozentsatz toter Knospen auf. Die Wuchsgröße beeinflußte den Ausfall von Knospen nicht signifikant, wenn Triebe gleicher Qualität beurteilt wurden. Die Unterlage beeinflußte ebenfalls nicht die Qualität der Triebe innerhalb einer Rebe.

Starkwüchsige Reben hatten sowohl eine größere Anzahl schlecht ausgereifter Triebe als auch mehr reife Triebe mit guter Frosthärte. Starke Reben scheinen nicht weniger kälteresistent zu sein als schwächer wachsende, sofern beim Rebschnitt eine sorgfältige Auswahl der Tragruten getroffen wird.

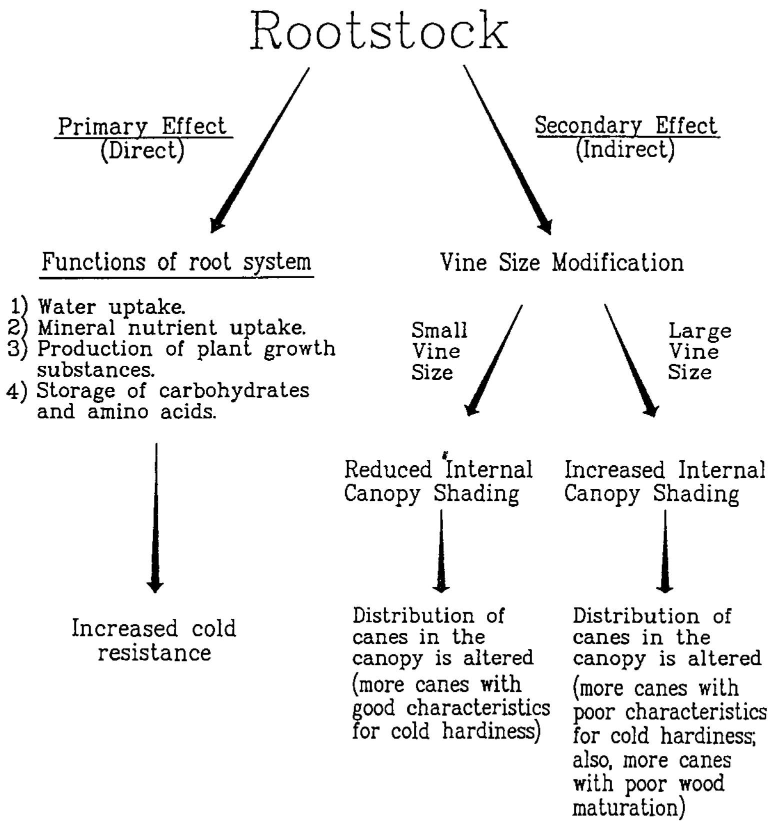
Key words: rootstock, growth, cold resistance, canopy, shading, shoot, bud, bunch, yield, must quality.

Introduction

Rootstock-scion relationships are complex and while efforts have been made to clarify that situation (RIVES 1971; LEFORT and LEGISLE 1977; HOWELL 1987), the subject remains difficult for a researcher desiring to measure rootstock contributions to scion characteristics. The rootstock may have direct or primary effects or it may produce indirect or secondary effects on the scion (Fig.).

The major functions of the grapevine root system are vine water relations, uptake and translocation of nutrients, synthesis and metabolism of plant growth substances, and storage of carbohydrates (RICHARDS 1983). Primary rootstock effects are likely mediated through one or a combination of these functions. Grapevine rootstocks have a primary effect on vine size (kg cane prunings/vine) (PONGRACZ 1983; CARBONNEAU and CASTERAN 1987; HOWELL 1987; POUGET 1987). Increases in vine size when canopy length is fixed result in crowding of shoots and internal canopy shading (SHAULIS 1982). The negative consequences of internal canopy shading on yield, fruit quality, and wine quality are well-documented (SHAULIS *et al.* 1966; SHAULIS 1982; SMART 1985; SMART and SMITH 1988; SMART *et al.* 1988). Most secondary effects of rootstock are mediated through rootstock influences on vine size and internal canopy shading.

There is considerable within-vine variation in cold hardiness (SHAULIS 1971; HOWELL and SHAULIS 1980; WOLPERT and HOWELL 1985; WOLF 1986). Differences in cold hardiness of primary buds and canes within the same vine varied by up to 12 °C depending on the presence of periderm, periderm color, cane diameter, persistent-lateral status, and leaf exposure to sunlight during the growing season (HOWELL and SHAULIS 1980; WOLPERT and HOWELL 1985; WOLF 1986).



Potential mechanisms of rootstock involvement in cold hardiness of grapevine primary buds and canes.

Mögliche Mechanismen des Unterlageneinflusses auf die Frosthärte der Primärknospen und Triebe der Rebe.

This information suggests the necessity of rational sampling procedures for grapevine cold hardiness studies. Current knowledge dictates that canes which are sampled should have similar diameter, sunlight exposure status, persistent-lateral status, and cropping stress. HOWELL (1987) used these criteria to sample comparable canes from vines of differing age and bearing status and found no hardiness differences. This provides strong evidence that non-treatment variation can be reduced substantially by using a critical sampling procedure. The detection of primary rootstock effects on cold hardiness of scion tissues depends on the use of such critical sampling, and primary cold hardiness influences by grape rootstocks have been demonstrated (MILLER *et al.* 1988).

Exposure of leaves to sunlight during the growing season and cane maturation, two factors which are associated with increased primary bud and cane cold hardiness, are not uniformly distributed in most grapevine canopies (SHAULIS 1971). Treatments which influence internal canopy shading can alter the distribution of canes which possess characteristics of maximum cold resistance and thereby affect vine cold hardiness.

Increases of vine size while canopy space is fixed provide a mechanism for secondary rootstock effects through alternation of the within-vine distribution of canes with maximum potential for cold hardiness. Of serious concern is the ease with which primary rootstock effects and those mediated by canopy capacity may be confounded, and this is viticulturally and scientifically important. Determination of separate rootstock and vine size effects would allow us to increase our understanding of primary and secondary rootstock effects on cold hardiness. This matter is of considerable practical importance (HOWELL 1987). If primary effects of rootstock are noted, genetic improvement can be undertaken to modify the characteristic of interest. Alternatively, if secondary effects are noted, the question becomes one of cultural management and not rootstock choice.

Therefore, the purpose of this research was to independently determine rootstock primary and secondary effects on vine cold hardiness. Canopy development, productivity, and fruit quality were also determined due to their interrelationship with cold hardiness.

Materials and methods

This experiment was conducted in a grafted Seyval vineyard at the Clarksville Horticulture Experiment Station, Clarksville, Michigan. Rootstock treatments included own-rooted Seyval and Seyval grafted to Seyval, Kober 5 BB (*Vitis berlandieri* PLANCHON × *V. riparia* MICHAUX), and Couderc 3309 (*V. riparia* MICHAUX × *V. rupestris* SCHEELE).

Vines were planted in 1983 in a uniform Kalamazoo sandy loam soil. Vineyard spacing was 2.4 m × 3.0 m (within row × between row) and row orientation was north to south. The training system employed was Hudson River Umbrella (a bilateral cordon at the top wire) with fruiting wood retained as 5-node canes. The trellis had two wires with one each, at 1 m and 1.8 m height. Vines were pruned to a 10 + 10 pruning severity (10 nodes retained/0.45 kg of cane prunings) on 18—19 April 1986. An upper limit of 50 nodes retained/vine was set to avoid overcropping.

Vines of small (0.45—0.91 kg cane prunings/vine), medium (1.14—1.59 kg cane prunings/vine), and large (1.82—2.27 kg cane prunings/vine) vine size were identified within each rootstock treatment after pruning. Six single vine replicates were randomly selected within each vine size class.

All vines were flower-cluster-thinned to 1 cluster/shoot with the basal cluster on each shoot being retained. Developing shoots were counted on 13 June 1986 when vines were at full bloom. Length of canopy per vine was measured after canopy development was complete on 13 September 1986. These data were used to calculate the percentage occupation by canopy of trellis space. This information was deemed important because failure to fill the allotted trellis space has been a problem for own-rooted Seyval vines in Michigan.

Individual vine yield and the number of clusters per vine were determined on 17 September 1986. Prior to harvest, samples of 5 apical berries from 20 randomly selected clusters were taken to give a 100 berry sample for each replicate, transported to the Viticulture and Enology Laboratory in the Department of Horticulture where they were weighed and then stored at 1 °C for later analysis. Sample analysis was completed within 2 d of sampling. Juice soluble solids, titratable acidity (as g tartaric/100 ml of juice) and acidity were measured as per AMERINE and OUGH (1980).

In previous work with Concord (HOWELL and SHAULIS 1980; WOLPERT and HOWELL 1985), Cabernet Sauvignon and Pinot noir (HOWELL and SHAULIS 1980) and Chardonnay (WOLF 1986), the differences in degree of periderm development (number of mature nodes) and periderm color (darker color within a particular genotype) were highly significantly correlated with the cold hardiness of bud and cane tissues. Further, HOWELL and SHAULIS (1980) showed that medium diameter canes showing moderate vigor (7—10 mm) were superior in hardiness.

The hardiness assessment was a rating based on these previous measurements. The rating was visual and subjective; three categories of shoots were used. These were: 1) medium diameter (7—10 mm), dark colored periderm and possessing 5 or more mature nodes; 2) all other canes (smaller or larger in diameter and/or light colored periderm) having 5 mature nodes; and 3) canes with fewer than 5 mature nodes. Persistent-lateral status was not considered a factor since all canes in categories 1) and 2) had persistent laterals and a large percentage of category 3) did also. A reference cane of 8 mm diameter and dark periderm color was used when categorizing a cane. The categorization was made at the internode between nodes 2 and 3.

The relative hardiness data collected were analyzed as both total number of each category per vine and as a percentage of the total per vine.

In late November, canes on the vines were rated according to the extent of maturation, diameter, and exposure to sunlight during the growing season. These characteristics were chosen because they have been associated with increased cold resistance (HOWELL and SHAULIS 1980). Our primary interest was to determine the influence of rootstock and vine size on the within-vine distribution of canes with superior cold resistance (category 1). Nodes 1 through 5 (base to apex) were rated since this was the bearing unit retained at pruning. The data are presented on a per vine and percentage basis. This was done so that methods of presenting this type of data could be compared.

Shootless nodes were counted after budburst in the spring of 1987. Shoots were allowed to grow approximately 15 cm before measurement. Data were analyzed as a 4 × 3 factorial with rootstock and vine size class serving as factors. Data were subjected to analysis of variance and mean separation was done by Duncan's new multiple range test. The arc-sine transformation was performed on percentage data prior to analysis of variance (STEEL and TORRIE 1980).

Results

Vine growth and development

Rootstock had little effect on growth and canopy development (Table 1). Sey/3309 vines were able to occupy more of their allotted canopy space than Sey/own, Sey/Sey,

Table 1

Effect of rootstock and vine size on growth and canopy development of Seyval grapevines · Clarksville, Michigan · 1986

Einfluß von Unterlage und Wuchsklasse auf das Rebenwachstum und die Entwicklung der Laubwand bei der Sorte Seyval · Clarksville, Michigan · 1986

Treatment	Vine size (kg/vine)	Nodes retained/ vine	Shoots/ vine	Shoot density of canopy (shoots/m)	Occupation of trellis space (%)
Rootstock					
Own-rooted	1.35	30	40	24.4	68
Seyval	1.32	28	38	24.5	65
Kober 5BB	1.41	31	44	27.0	67
Couderc 3309	1.43	31	43	22.1	79
	N.S.	N.S.	N.S.	N.S.	N.S.
Vine size (kg/vine)					
0.45—0.91	0.77 c[1]	17 c	29 c	20.1 c	60 b
1.14—1.59	1.39 b	30 b	40 b	23.3 b	74 a
1.82—2.27	1.98 a	43 a	55 a	30.1 a	76 a

[1]) Mean separation by Duncan's new multiple range test, $\alpha = 0.05$.

Table 2

Effect of rootstock and vine size on productivity of Seyval grapevines · Clarksville, Michigan · 1986

Einfluß von Unterlage und Wuchsklasse auf die Ertragskomponenten der Sorte Seyval · Clarksville, Michigan · 1986

Treatment	Yield (t/ha)	Clusters/ vine	Berries/ cluster	Berry weight (g)	Cluster weight (g)	Fruitfulness (kg fruit/ retained node)
Rootstock						
Own-rooted	17.8 ab[1])	36.7	199.0	1.89	376.1 a	0.46
Seyval	15.0 b	35.4	178.2	1.86	329.9 b	0.40
Kober 5BB	19.0 a	45.9	194.9	1.68	325.1 b	0.47
Couderc 3309	15.8 b	38.9	178.8	1.80	320.9 b	0.41
		N.S.	N.S.	N.S.		N.S.
Vine size (kg/vine)						
0.45—0.91	10.4 c	23.1 c	188.5	1.87 a	350.8	0.46
1.14—1.59	17.0 b	41.0 b	185.6	1.77 b	328.0	0.43
1.82—2.27	23.3 a	53.6 a	189.1	1.78 b	335.2	0.41
			N.S.		N.S.	N.S.

[1]) Mean separation by Duncan's new multiple range test, $\alpha = 0.05$.

or Sey/5 BB vines. Vine size had a greater effect on growth and canopy development than rootstock. Nodes retained/vine, shoots/vine, shoot density, and percentage of occupation of trellis space were directly related to vine size.

Yield and fruit quality

Productivity was only slightly affected by rootstock (Table 2). Sey/5 BB vines had the highest yield and the lowest berry weight. Clusters from Sey/own vines were larger than clusters from vines of the other rootstocks. Vine size had a greater impact on productivity than rootstock. Yield and the number of clusters per vine increased with increasing vine size. Small vines had slightly larger berries than vines in the medium or large vine size classes. Fruitfulness was not significantly reduced by large vine size, although a trend toward lower fruitfulness with higher vine size was evident.

Rootstock and vine size effects on fruit quality were limited to soluble solids (Table 3). The differences observed were inversely related to yield.

Distribution of hardy canes within the canopy

Rootstock did not affect the distribution of canes within the vine in relation to cold resistance (Table 4). The effect of vine size on the within-vine distribution of canes in relation to cold resistance varied according to the manner in which the data were reported. Increases in vine size resulted in a greater number of total canes, canes with superior cold resistance, and canes with less than 5 mature nodes when reported on a per vine basis. In contrast, presentation of the data as a percentage of total canes indicated that increasing vine size decreased the percentage of canes with superior cold resistance and canes with inferior cold resistance. The percentage of canes with less than 5 mature nodes increased with increasing vine size.

Rootstock effects were present in the percentage of shootless nodes data (Table 5). Sey/own vines had the highest and Sey/3309 vines the lowest percentage of shootless

Table 3

Effect of rootstock and vine size on fruit quality of Seyval grapevines · Clarksville, Michigan · 1986

Einfluß von Unterlage und Wuchsklasse auf die Beerenqualität der Sorte Seyval · Clarksville, Michigan · 1986

Treatment	Soluble solids (%)	Titratable acidity (g/100 ml)	pH
Rootstock			
Own-rooted	19.2 a[1]	1.06	3.15
Seyval	19.0 ab	1.05	3.14
Kober 5BB	18.2 b	1.08	3.16
Couderc 3309	19.4 a	1.07	3.19
		N.S.	N.S.
Vine size (kg/vine)			
0.45—0.91	20.2 a	1.09	3.16
1.14—1.59	19.0 b	1.05	3.17
1.82—2.27	17.6 c	1.06	3.16
		N.S.	N.S.

[1]) Mean separation by Duncan's new multiple range test, $\alpha = 0.05$.

Table 4

Effect of rootstock and vine size on the within-vine distribution of canes in relation to cold resistance · Clarksville, Michigan · 1986

Einfluß von Unterlage und Wuchsklasse auf die Verteilung der Triebe unterschiedlicher Kälteresistenz innerhalb der Rebe · Clarksville, Michigan · 1986

Treatment	Total canes/ vine	Superior cold resistance[1]		Inferior cold resistance[2]		Less than 5 mature nodes	
		Canes/ vine	%	Canes/ vine	%	Canes/ vine	%
Rootstock							
Own-rooted	35	10	28.6	8	22.9	17	48.6
Seyval	31	10	32.3	8	25.8	13	41.9
Kober 5BB	37	9	24.3	8	21.6	20	54.1
Couderc 3309	36	9	25.0	9	25.0	18	50.0
	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Vine size (kg/vine)							
0.45—0.91	22 c[3]	8 b	36.4 a	7	31.8 a	7 c	31.8 c
1.14—1.59	33 b	9 ab	27.3 b	9	27.3 b	15 b	45.4 b
1.82—2.27	48 a	11 a	22.9 c	8	16.7 c	29 a	60.4 a
				N.S.			

[1]) Cane characteristics = 7—10 mm in diameter and exposed to sunlight during the growing season.
[2]) Cane characteristics = canes having 5 or more mature nodes which were not 7—10 mm in diameter and/or exposed to sunlight during the growing season.
[3]) Mean separation by Duncan's new multiple range test, $\alpha = 0.05$.

Table 5

Effect of rootstock and vine size on the percentage of shootless nodes[1]) · Clarksville, Michigan · 1987

Einfluß von Unterlage und Wuchsklasse auf den Anteil nicht ausgetriebener Knoten · Clarksville, Michigan · 1987

Treatment	Shootless nodes[2]) (%)	Treatment	Shootless nodes[2]) (%)
Rootstock		Vine size (kg/vine)	
Own-rooted	58.3 a[3])	0.45—0.91	27.7
Seyval	31.2 b	1.14—1.59	24.5
Kober 5BB	15.2 bc	1.82—2.27	27.6
Couderc 3309	9.0 c		N.S.

[1]) Measurements were made on canes which were retained at pruning. Canes were 7—10 mm in diameter and had been exposed to sunlight during the growing season.
[2]) Arc-sine transformation was performed before AOV. Means represent detransformed data.
[3]) Mean separation by Duncan's new multiple range test, $\alpha = 0.05$.

nodes. There was also a significant graft union effect (Sey/own > Sey/Sey). Vine size did not significantly affect percentage of shootless nodes when comparable canes were evaluated.

Discussion

The number of shoots per vine increased with increasing vine size. This, coupled with a fixed canopy space allotted to each vine, resulted in an increase in shoot density as vine size increased. Increases in shoot density result in greater leaf area per unit row length and shade within the canopy (SHAULIS 1982; SMART 1985). Seyval vines with 6 shoots/30 cm of row had greater internal canopy shading than vines with 2 or 4 shoots/30 cm of row (REYNOLDS *et al.* 1986). Although occupation of trellis space increased with increasing vine size, it is doubtful that this is a practical method of solving the problem because of the greater internal canopy shading that would occur with increased vine size at a fixed canopy space. Improved training of cordons and medium vine size would likely yield a canopy with the desired characteristics.

The relationship between vine size and yield is not surprising in that node number per vine is based on vine size. A greater number of nodes per vine results in increased numbers of shoots and clusters. Cluster number and yield are directly related for thinned vines such as in this study. Sey/5 BB vines had the highest yield among rootstock treatments. The data are insufficient to declare this as a primary rootstock effect since Sey/own vines also displayed increased yield. However, synthesis and metabolism of cytokinins by grapevine roots and the involvement of cytokinins in the floral development and fruit set provide a possible avenue for primary rootstock effects on scion yield (RICHARDS 1983). Rootstock and vine size differences in soluble solids were related to yield. Competition between sinks for photosynthate and the resulting reduction in fruit or vegetative maturity are well-documented in the grapevine (WINKLER *et al.* 1974).

Rootstocks, vine size and vine hardiness

The lack of effect of rootstock and the considerable effect of vine size on the within-vine distribution of canes with superior cold resistance indicate that rootstock influences on vine cold hardiness through this mechanism were of a secondary nature. The problem then is not one of rootstock but of cultural management.

It is commonly believed that small vines are superior in cold hardiness to large vines due to their reduced internal canopy shading. Our data do not support this view. Large vines had a greater number of poorly matured canes but also had more canes with superior cold resistance. More importantly, large vines had a sufficient number of canes with superior cold resistance to easily meet the requirements of the training system and pruning severity used in this study. This suggests that with careful cane selection during pruning large vines would not be inferior to small vines in cold hardiness.

Methods of expressing cold hardiness data

Presentation of cane distribution data on a per vine basis had more viticultural utility than expressing the same data on a percentage basis since percentage data did not always denote viticulturally significant differences. As an example, the fact that small vines had a higher percentage of canes with superior cold resistance than large vines did is not viticulturally important as long as large vines had sufficient canes with superior cold resistance to meet the requirements of the training system and pruning severity. It appears that reporting within-vine cane distribution data on a percentage basis can result in inaccurate interpretation of the data (BYRNE and HOWELL 1978).

The shootless-node data provide further evidence against the concept of small vines having a greater degree of cold resistance than large vines. Vine size did not affect the percentage of shootless nodes when comparable canes (medium diameter, well-exposed canes retained at pruning) were evaluated. Primary rootstock effects were observed among the rootstock treatments. Sey/3309 vines had significantly lower percentage shootless nodes than Sey/own or Sey/Sey vines.

Summary

Primary (direct) and secondary (indirect) influences of rootstocks on vine cold hardiness were determined independently. Vine size (kg of cane prunings per vine) reflects the number of shoots produced per m of row and is closely associated with shoot crowding and internal canopy shading. This shading is a secondary rootstock influence.

Own-rooted Seyval (Sey/own), Seyval grafted to Seyval (Sey/Sey), Kober 5 BB (Sey/5 BB), and Couderc 3309 (Sey/3309) were the rootstock treatments used. Vine size classes were large (1.82—2.27 kg), medium (1.14—1.59 kg) and small (0.45—0.91 kg) and were established within each rootstock group.

Rootstock choice had no effect on vine growth and canopy development. Vine productivity was influenced slightly, primarily through differences in cluster weight. By contrast, vine size, regardless of rootstock chosen, had a great impact on both vine growth and yield.

Direct rootstock effects on cold hardiness were assessed via measurement of cumulative injury to buds and expressed as shootless nodes. Cane cold hardiness was based on the within-vine distribution of canes with differing characteristics associated with hardiness (diameter, exposure to sunlight during growth and the development of 5 or more mature nodes).

Both primary and secondary influences of rootstocks on cold hardiness were observed. Bud hardiness was best on scions grafted to Couderc 3309, and there was a significant graft union effect; Sey/own vines had more bud mortality than Sey/Sey vines. Vine size did not influence the percentage of shootless nodes when canes of comparable quality were evaluated. The within-vine distribution of cane quality was influenced, however, and large vines had a greater number of both poorly matured and canes with superior hardiness status. By contrast, rootstock did not influence the within-vine distribution of cane quality.

Large vines are not inferior to small vines in the number of best quality canes produced and should be equally hardy if careful cane selection is practiced at pruning.

Assessment of the within-vine distribution of canes with superior cold hardiness appears to be a useful method of determining secondary treatment effects on vine cold hardiness. This aspect of vine cold hardiness should receive greater attention by viticulture researchers.

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Correspondence to:

Dr. G. STANLEY HOWELL
Professor of Horticulture
Michigan Agricultural Experiment Station
Department of Horticulture
Michigan State University
East Lansing, MI 48824-1325
USA