Growth and Nutritional Responses of Nine Grape Cultivars to Low Soil pH

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Abstract. Nine grape cultivars (*Vitis vinifera* L., *V. labruscana* Bailey, and French-American hybrids) were evaluated in pot culture for their tolerance to strongly acid (pH 4.8) and slightly acid (pH 6.7) soil. Differences in cultivar tolerance to the strongly acid soil included a reduction in shoot and root dry weights and root volume. Based on root development, the most tolerant cultivars to the strongly acid soil were the *V. labruscana* cultivars Concord and Catawba and the *V. riparia* × *V. berlandieri* rootstock cultivar SO 4. The least tolerant vines were the two *V. vinifera* cultivars White Riesling and Chardonnay and the interspecific hybrid 'Aurore'. No consistent treatment effects were found in foliar N, K, or B levels, but P and Ca were higher and Mg, Fe, Cu, and Zn lower in plants grown in the very acid soil.

The potential for adverse effects of acid soils on growth, productivity, and nutritional status of grapevines has been observed in diverse geographical regions, such as Italy (Fregoni and Bavaresco, 1984), Portugal (Coutinho et al., 1984), France (Delas and Juste, 1975; Marcelin, 1974), Germany (Booss et al., 1982; Meidinger, 1984; Pearson and Goheen, 1988), South Africa (Conradie, 1983), and the United States (Cummings and Lilly, 1984).

Field observations (unpublished data) of grapevines growing in the Great Lakes region of western New York have suggested that there may be pronounced differences in the tolerance of grape cultivars to strongly acidic soils. *Vitis labruscana* cultivars, which have traditionally been grown in this area, appear to be quite tolerant of the acidic vineyard soils, which may reach pH values of 4.5 or lower. Plantings of *V. vinifera* cultivars in the area have developed nutritional disorders on low-pH soils, suggesting that this species may be less tolerant of acidic conditions.

The name "Säureschäden" is used in Germany to describe leaf symptoms on vines growing in extremely acid (pH 3.4-4.5) soils low in Ca and Mg (Meidinger, 1984). Foliar symptoms are associated with deficiencies of Ca, Mg, and P. Excess K, Al, and especially Mn may also be involved (Pearson and Goheen, 1988). Mn levels toxic to grapevines have been reported at pH levels below 5.0. Copper may also be toxic under these conditions, while deficiencies of Mg and, to a lesser extent, K and B are common (Fregoni, 1980; Fregoni and Bavaresco, 1984; Marcelin, 1974).

Hiroyasu (1961) found no significant differences in the growth and yield of 'Black Queen' (*V. vinifera*) vines grown in sand

culture at pH values ranging from 4 to 8. However, growth of vines in solution culture using ammonium sulfate as the source of N was normal at pH values of 6, 7, and 8, but was very poor at pH 4 and 5, when yellow spots developed on the leaves. Soil pH below 5.5 limited yield of muscadine grapes (*V. rotundifolia*), but higher pH levels did not influence yield (Cummings and Lilly, 1984). Maximum yields for vines grown at pH 5.0 were 47 kg/vine, while those grown at 6.5 averaged 59 kg/vine.

Field observations (unpublished data) in western New York suggested that *V. labruscana* cultivars might be much more tolerant to very acid vineyard soils than the *V. vinifera* cultivars. The acid soil tolerance of French-American hybrids is unknown. This study was conducted to determine if cultivar or species differences in tolerance to low-pH soils exist among six major wine and juice grape cultivars and three common grape rootstock. If such differences exist, divergent cultural requirements for liming and fertilizer applications may need to be taken into account for optimum vineyard management.

Dormant cuttings (30 cm long) from nine grape cultivars, including the *V. labruscana* cultivars Concord and Catawba; two French-American hybrids (*Vitis* × *species*), 'Seyval' and 'Aurore'; two *V. vinifera* cultivars, 'White Riesling' and 'Chardonnay'; and three rootstock cultivars, 'SO 4', '5 BB', and '3309 C', were made on 16 Mar. 1986 and were subsequently rooted in a 1 peat : 1 perlite (v/v) propagating bed in a heated greenhouse. Vines were transplanted into 12-liter plastic pots containing soil from adjacent field plots that had not been previously planted with grapevines and whose acidity had been adjusted with calcitic lime. Two shoots were allowed to develop on each vine.

The experimental design was a split-plot, with main plots consisting of two soil acidity levels and subplots consisting of nine cultivars. Twelve vines of each cultivar were grown in a Pompton gravelly silt loam (coarse-

loamy, mixed, Mesic Aquic Dystrochrepts) in Chautauqua County, N. Y., a soil having an aqueous pH of 4.8 in 1 soil : 1 water (CaCl₂, pH = 4.2) and an exchange acidity of 11 meq/100 g. Twelve additional vines were grown in the same soil that had previously been adjusted in the field to pH 6.7 [CaCl₂, pH = 6.2] (Table 1). Soil analyses were performed by the Agronomy Soil Testing Service, Cornell Univ., Ithaca, N. Y., using previously described methods (Greweling and Peech, 1965).

Vines were potted on 2 May 1986 and allowed to grow outdoors under field conditions until the plants were harvested on 12 Oct. 1986. Each pot received 20 g of slow-release fertilizer (18N-2.6P-10K) at planting and was kept well-watered throughout the experiment. Appropriate fungicide and insecticide sprays were applied throughout the growing season as needed. At termination, the plants were divided into shoots and roots, with the original cane being discarded. Root volume was measured in a graduated cylinder by a water displacement method. Foliar samples were washed in water containing detergent, rinsed three times with distilled water, and dried at 80C (Bertoni and Morard, 1982). Dried samples were weighed and foliar samples (lamina plus petiole) were ground, dry-ashed, and analyzed for elemental concentrations using a Jarrell-Ash 975 Atomcomp plasma emission spectrophotometer (Jarrell-Ash, Chicago). Samples were analyzed for ammonia-based N by the micro-Kjeldahl procedure. Foliar analysis was performed at the Pomology Analytical Laboratory, Cornell Univ.

Significant differences in the tolerance of the grape cultivars to strongly acidic soils were noted in shoot and root dry weights and root volume differences between those grown in high-pH (6.7) and low-pH (4.8) soil (Table 2). Low pH reduced shoot dry weight of all cultivars, except for the two *V. vinifera* representatives. An increase in shoot dry weight of 8% for 'White Riesling' and 87% for 'Chardonnay' occurred in the plants grown in the low-pH soil.

Low-pH soil reduced root dry weight in 'Aurore', 'Chardonnay', 'White Riesling', and '5 BB', and root volume in 'Concord', 'Seyval', 'Aurore', 'White Riesling', 'Chardonnay', '5 BB', and '3309 C'.

In South Africa (Conradie, 1983), rootstock '140 Ru', 'USVIT 8-7', '110 R', '99 R', and 'USVIT 2-1' were best suited for use on acid soils. Cultivars least suited for acid soils included 'SO 4', which was a top performer in the present study. Other poorly suited rootstock included '101-14 Mgt', '44-53 M', 'SO 4', 'Rupestris du Lot', and 'USVIT 3-6', while the other tested cultivars ('779 P', '1103 P', '1447 P', 'Ramsey', and '3306 C') performed moderately well. Branas (1974) reported that soil acidity has been revealed as a limiting factor in France for the successful use of some rootstock, such as '99 R' and 'Rupestris du Lot', while '196-17 Cl' thrived on acid soils.

The toxic effect of high Al and Mn concentrations at soil pH levels below 5.5 have

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Table 1. Analyses of high- and low-pH soil used in experiment.

Soil pH	pH (aqueous)	pH (CaCl ₂)	Exchange acidity (meq/100 g)	Element (ppm)					
				P	K	Mg	Ca	Al	Mn
High	6.7	6.2	---	19	170	120	1900	19	4
Low	4.8	4.2	11	2	90	80	70	321	9

Table 2. Effects of high (6.7) and low (4.8) soil pH on shoot and root dry weights and root volume.

Cultivar	Shoot dry wt (g)		Root dry wt (g)		Root volume (cm ³)	
			pH			
	High	Low	High	Low	High	Low
Concord	9.3	8.2 ^{NS}	13.6	12.6 ^{NS}	61	45*
Catawba	12.7	10.4*	15.0	15.9 ^{NS}	54	59 ^{NS}
Seyval	15.0	13.7*	6.0	5.9 ^{NS}	32	28 ^{NS}
Aurore	12.7	9.5*	6.6	4.6*	28	13*
White Riesling	6.3	6.8 ^{NS}	5.0	2.6*	19	15*
Chardonnay	4.5	5.8*	7.0	3.5*	35	19*
SO 4	9.9	7.4*	11.3	11.9 ^{NS}	40	46 ^{NS}
5 BB	22.2	11.6*	9.8	5.2*	45	24*
C 3309	11.8	9.5*	7.0	6.7 ^{NS}	35	28*

*. ^{NS}Paired means separated within rows by *t* test at *P* = 0.05 or not significant, respectively.

Table 3. Elemental concentrations (dry-weight basis) in foliar tissue of grapevines grown in high-pH (6.7) and low-pH (4.8) soil.

Element and pH	Cultivar								
	Concord	Catawba	Seyval	Aurore	White Riesling	Chardonnay	SO 4	5 BB	3309 C
<i>Percent</i>									
N—high	2.11 bc ^z	1.91 cd	2.53 a	2.58 a	2.42 ab	2.49 a	2.21 b	2.43 ab	2.64 a
N—low	2.04 c	2.05 c	2.64 a	2.66 a	2.55 ab	2.40 b	1.94 cd	2.21 b	2.30 b
Significance	NS ^y	*	*	NS	*	NS	*	*	*
K—high	1.84 a	1.37 c	1.75 a	1.67 ab	2.14 a	2.01 a	1.35 c	1.42 c	1.22 cd
K—low	1.39 b	1.23 bc	1.82 a	1.80 a	1.76 a	1.88 a	1.14 cd	1.40 b	1.46 b
Significance	*	*	NS	*	*	NS	*	*	*
P—high	0.20 c	0.20 c	0.26 b	0.29 ab	0.24 bc	0.26 b	0.31 a	0.27 b	0.26 b
P—low	0.17 c	0.15 c	0.21 ab	0.23 a	0.23 a	0.22 ab	0.16 c	0.22 a	0.20 bc
Significance	NS	*	*	*	NS	NS	*	*	*
Ca—high	1.33 b	1.24 bc	1.35 b	1.21 c	1.27 b	1.34 b	1.53 a	1.24 bc	1.19 c
Ca—low	1.03 b	1.09 b	1.04 b	0.76 cd	0.90 bc	1.01 b	1.24 a	0.97 bc	0.86 c
Significance	*	*	*	*	*	*	*	*	*
Mg—high	0.12 bc	0.11 c	0.14 ab	0.11 c	0.16 a	0.15 ab	0.15 ab	0.17 a	0.17 a
Mg—low	0.13 bc	0.12 bc	0.21 a	0.14 b	0.21 a	0.22 a	0.22 a	0.20 a	0.21 a
Significance	NS	NS	*	NS	*	*	*	NS	NS
<i>PPM</i>									
Mn—high	211 a	127 bc	114 c	122 bc	153 b	150 b	159 b	143 b	104 cd
Mn—low	752 a	771 a	493 cd	459 cd	556 bc	541 bc	639 b	558 bc	562 b
Significance	*	*	*	*	*	*	*	*	*
Fe—high	579 c	1032 b	312 d	1110 b	1313 a	996 b	801 b	592 c	679 c
Fe—low	1168 a	1430 a	750 cd	1280 a	1131 a	1013 b	1053 ab	1515 a	978 bc
Significance	*	*	*	*	*	NS	*	*	*
Cu—high	5.8 c	6.1 c	6.1 c	7.4 b	9.9 a	8.1 b	5.9 c	6.9 bc	6.1 c
Cu—low	7.4 c	7.0 cd	11.8 b	10.5 b	14.9 a	10.2 b	7.5 c	8.4 c	7.8 c
Significance	NS	*	*	*	*	*	NS	*	*
B—high	34.4 a	26.4 bc	24.6 c	26.2 bc	31.5 ab	29.6 ab	23.7 c	19.2 d	22.1 cd
B—low	25.4 bc	20.4 d	26.1 b	26.3 b	27.5 ab	28.1 a	27.6 ab	23.0 c	28.6 a
Significance	*	*	NS	NS	*	NS	*	NS	*
Zn—high	30.0 bc	34.4 b	22.5 cd	32.1 b	49.3 a	39.6 b	30.3 bc	28.2 bc	25.4 c
Zn—low	37.1 cd	39.0 cd	36.7 d	48.5 b	56.9 a	45.2 a	49.0 b	41.0 bc	41.2 bc
Significance	*	NS	*	*	*	*	*	*	*
Al—high	406 c	743 b	194 d	689 b	937 a	859 ab	529 b	357 c	475 c
Al—low	783 c	1062 a	473 d	867 b	862 b	946 a	780 c	1100 a	729 cd
Significance	*	*	*	*	*	*	*	*	*

^zMean separation within rows by Duncan's new multiple range test at *P* = 0.05.

^yPaired means separated within columns by *t* test at *P* = 0.05 (*) or not significant (NS).

been well documented (Fey et al., 1978; Taylor, 1988). This toxicity would be expected to most greatly affect root growth and development. In the present study, a negative trend was established in the low-pH soils, as evidenced by the reduced shoot weight in seven cultivars, reduced root weight in four, and reduced root volume in six of the nine

cultivars. No clear species tolerance grouping appeared in the data.

In this experiment, the 4.8-pH soil reduced shoot weight on average by 27%, root weight by 13%, and root volume by 21% below values obtained of 6.7-pH soil. In a similar experiment in South Africa (Conradie, 1983), 15 rootstock cultivars were tested

in soils with pH (KCl) values of 4.1, 5.0, and 6.0. Shoot masses of vines were increased over the 4.1 treatment by 27% and 87% in the 5.0 and 6.0 treatments, respectively. Root masses were similarly increased by 11% and 32%.

The different treatments had no consistent effect on the foliar N, K, or B levels, while

P and Ca levels were always higher in the plants grown in the higher pH soil; Mg, Fe, Cu, and Zn levels showed an opposite trend (Table 3). Plants grown under low pH contained 416% more Mn and 147% more Al than those grown under high-pH conditions. Highest foliar Mn levels were recorded for 'Catawba', 'Concord', and 'SO 4', while the lowest levels were found in '3309 C', 'Seyval', and 'Aurore'. Despite the elevated Mn in the foliar samples from low-pH soils, the levels did not exceed the toxic norms of 750 ppm for leaf blades and 1500 ppm for petioles suggested by Conradie (1986). Highest foliar Al was found in '5 BB', 'Catawba', and 'Chardonnay', while the lowest levels were recorded in 'Seyval', '5 BB', and '3309 C'. Delas and Juste (1975) found that the *V. vinifera* cultivars Maccabeo and Carignan were much more sensitive to excessive Mn levels found in acid soils than was 'Grenache'.

Similar differences in the elemental concentrations in vines grown on '420 A', '5 BB', 'Rupestris du Lot', 'Riparia', '101-14', and '8 B' were noted in France by Fregoni and Bavaresco (1984), as well as in 15 rootstock examined by Conradie (1983).

In summary, based on plant growth, the cultivars most tolerant to strongly acid soils appeared to be the two *V. labruscana* cultivars Concord and Catawba, along with the *V. riparia* × *V. berlandieri* rootstock cultivar SO 4, while 'Seyval' and 'C 3309' also performed well. The cultivars most intolerant to acid soil appeared to be the two *V. vinifera* cultivars White Riesling and Chardonnay and the interspecific hybrid 'Aurore'. The three best adapted cultivars, 'Catawba', 'Concord', and 'SO 4', were also shown to accumulate the highest Mn levels in their foliage under the low soil pH condition. The two most poorly adapted cultivars, 'White Riesling' and 'Chardonnay', had the highest foliar Al concentrations under the high soil pH condition.

The results of this study would suggest that grape cultivars vary in their tolerance to very acid soils. These differences should be considered when choosing cultivars and adjusting vineyard soil pH levels for new plantings or in soil testing and liming schedules for established vineyards. Although *V. vinifera* vines are rarely grown on their own roots, a choice of an acid-tolerant rootstock, such as 'SO 4' or 'C 3309', should be considered.

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