Journal of the American Pomological Society 59(4):182-191 2005

Cane and Leaf Growth and Leaf Mineral Nutrients in Various Cultivars of Wine Grapes

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Abstract

Cane growth, leaf size, and leaf lamina and petiole mineral nutrients of 15 grape cultivars under climatic conditions of southwest Idaho (Intermountain West region) were evaluated from 1999-2001. They were: 'Cabernet Franc 01', 'Cabernet Sauvignon 11', 'Carignane 06', 'Dolcetto 01', 'Grenache 03', 'Limberger 02', 'Malbec 06', 'Merlot 08', 'Meunier 01', 'Nebbiolo 01', 'Petite Verdot 01', 'Petite Sirah 03', 'Pinot Noir 18', 'Valdepenase 03', and 'Viognier 01'. 'Valdapenase 03' had longer canes, larger lamina, and heavier leaves while 'Limberger 02' and 'Dolcetto 01' had shorter canes than several other cultivars. 'Limberger 02' had lower concentrations of lamina N, and 'Nebbiolo 01' had lower petiole nitrate-N than other cultivars. 'Valdepenase 03' and 'Petite Verdot 01' had higher lamina N than most other cultivars. 'Valdepenase 03' also had higher lamina K but lower lamina and petiole Ca and Mg than most other cultivars. 'Merlot 08' had higher concentrations of lamina and petiole K as well as petiole Ca than most other cultivars. 'Grenache 03' had lower concentrations of lamina and petiole Zn than other cultivars examined. 'Limberger 02' had lower lamina Mn, and 'Valdapenase 01' had lower petiole Mn than other cultivars.

Introduction

Interest in production of wine grapes has increased throughout the world, and this interest is partially due to the medical reports implying certain health benefits associated with wine consumption. California is the major producer of wine grapes in the U.S., and thus, numerous research projects are conducted in that state on various viticultural aspects of wine grapes, including breeding and cultivar evaluations. Vine adaptability, fruit quality attributes, and status of leaf mineral nutrients of wine grape cultivars in a geographical region need to be evaluated before they are widely planted on a commercial scale. Adaptability and quality of wine grapes in different regions of the United States have been reported (1, 2, 7, 8, 11, 14, 15, 18, 21, 26).

The leaf is the major metabolic organ on the grape vine, and thus foliar mineral analysis has been used as a diagnostic tool to evaluate vine performance and grape quality for several decades. Vine mineral nutrients in wine grapes not only influence yield and cane growth (10, 19, 24, 25) but also affect wine quality (22). Developmental stage, type of tissue (lamina vs. petiole), and position of leaf for mineral analysis, to represent optimum growth and fruit quality of the vine, has been a controversial issue among viticulturists for many years (4, 19). Currently, both lamina and petiole from the basal portions of shoots are sampled at full bloom and/or at veraison for analysis of mineral status in grapes (18). Following the early works by Maume and Dulac (16,

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Acknowledgement: We wish to thank the Idaho Grape Growers and Wine Commission, Northwest Center for Small Fruit Research, Growers Supplies, Fruitland, Idaho, and Quiedan Co., Carmel, California for providing financial support and supplies for this project.

17), the French Diagnostic Foliar laboratory at Montpellier relied upon leaf stalk (lamina and petiole), sampled twice from each vineyard, one at bloom time and the other at veraison. Average mineral compositions for these two samples were compared with standards. However, following an early report by Ulrich (23), petiole tissue alone, sampled at bloom time, is often used for mineral nutrients in California. Also, for determination of nitrate-N, a petiole sampling at anthesis is recommended in the Australian grape industry (20).

Wine grapes have been grown in southwest Idaho since the early 1960's. In 1999, there were 266 ha of wine grapes in southwest Idaho (12), which has increased to approximately 445 ha in 2005 (personal knowledge). Long warm days during spring and summer and cool nights in September and October, combined with well-drained sandy-loam soil provide excellent conditions for production of high quality wine grapes in southwest Idaho. In spite of these favorable conditions, wine grapes in the region are subjected to the risk of severe winter injury in some years. However, since phylloxera (P*hylloxera daktulospharia* vitifolia) has not been found in Idaho, most wine grape vines are established on their own roots. Thus, when severe winter injury damages the upper portions of the vines, they may re-grow and a new canopy can be established.

A well-established root system and canopy during early years of planting is essential for better winter survival in cold regions. Uptake of nutrients, particularly N and K, play an extremely important role in canopy establishment. A substantial volume of information is available on the effects of fertilizer applications (4, 19), irrigation, and canopy development (19) and rootstock (5, 6) on leaf mineral concentrations. However, in spite of the considerable commercial wine grape production and potential for expansion in the Intermountain Western region, there is limited information on adaptability and fruit quality (7, 8, 11) and no information on the canopy growth, leaf size, and leaf mineral status of cultivars in the region. Therefore, the objective of this research was to study cane growth, leaf size, and leaf lamina and petiole mineral nutrients in 15 wine grape cultivars grown under climatic conditions of southwest Idaho (Intermountain West region).

Materials and Methods

The experiment was arranged as a randomized complete block design with four replications (blocks) of eight vines per block. Six central vines in each block were selected for cane growth measurements and leaf sampling. The experimental vineyard, consisting of 15 of cultivars of wine grapes, was established at the University of Idaho Parma Research and Extension Center in southwestern Idaho in the spring of 1997. The cultivars were: 'Cabernet Franc 01', 'Cabernet Sauvignon 11', 'Carignane 06', 'Dolcetto 01', 'Grenache 03', 'Limberger 02', 'Malbec 06', 'Merlot 08', 'Meunier 01', 'Nebbiolo 01', 'Petite Verdot 01', 'Petite Sirah 03', 'Pinot Noir 18', 'Valdepenase 03', and 'Viognier 01'. All plant materials were obtained as certified non-grafted dormant cuttings of 0.63 to1.9 cm diameter and 35.5 cm length from Foundation Plant Materials Services (FPMS) at the University of California-Davis, and were rooted in March of 1997.

The vines were planted at 2.1 m x 2.4 m spacing. The vineyard soil was sandy loam with a pH of about 7.5. Pressure-treated wooden posts, 2.4 m long, were installed at 4.9 m spacing, with 1.8 m above the ground. One 2.3-m galvanized metal post (U shape) was pounded next to each vine with 46 cm in the ground. Twelve-gauge galvanized wires were installed at 41, 107, and 127 cm from the ground as drip irrigation line wire, cordon wire, and catch wire, respectively. A 15-cm cross-arm was installed horizontally on each metal post at 168 cm from the ground. Two parallel wires were installed, one on each side of the cross-arm, to keep the shoots in an upright position.

The vines were not pruned (remained uncut as bush) during the first growing season. During the following dormant season (early March), two trunks per vine were selected and trained as a cordon system, and the rest were removed. Other than these two trunks, any new growth below the cordon arms was removed during each subsequent growing or dormant season. Each cordon arm was spur-pruned to leave 6 to 8 spurs of 2 buds (for red wine grapes) and 3 buds (for the white wine grapes), not counting the basal buds, during the dormant season (early March) of each year. During May of each year, new shoots were thinned out to leave a space of approximately 8-10 cm between shoots of each arm for better light penetration and air movement, and all down-ward growing shoots were also removed. Some of the shoots were positioned upward between the two wires on the cross-arms during each growing season.

A drip line was installed on the lowest wire with two 3.78-L/hr emitters per vine to deliver total of 7.56 L/hr water per vine. Each emitter was placed 17.8 cm away from the vine trunk. Soil moisture was monitored with WaterMark Sensors and/or a neutron probes and vines were irrigated twice a week. During summer months, each vine received approximately 30 to 45 L/week in 1997 and 1998, 60 L/week in 1999, and 76 L/week in 2000 and 106 L/week in 2001. Each vine received actual N at rates of 0.6 g, 2.6 g, 6.7 g, 11.6 g, 28.0 g in 1997, 1998, 1999, 2000, and 2001, respectively. Each vine received actual amounts of 9.7 g P in 2000, 23.4 g P in 2001 and 11.7 g of K in 2000 and 28.0 g of K in 2001.

Weeds were controlled mechanically by hand during the first two years of planting, and after that they were controlled by application of glyphosate (Roundup) twice a year. The vineyard floor was disked three times a year and kept clean. No insecticide was applied to this vineyard during the period of the experiment as no insect damage was observed. Vines were sprayed with sulfur once or twice a year to control powdery mildew.

Length of one average-size cane in the middle of each cordon arm (total of two risers per vine and 12 risers per 6 central vines for each of the four blocks) was measured at the end of each growing season in 1999-2001.

Ten leaves per vine were sampled randomly from the opposite side of basal clusters during full bloom of each cultivar between June 6 and June 21 in 1999 through 2001. Leaves of 6 central vines in each block were combined to make a composite sample of 60 leaves for each of the four blocks. Petioles were separated from laminas, and fresh weights of these tissues were measured. Leaf lamina area was measured with a Li-3100 Area Meter (Li-Cor, Inc., Lincoln, NE). Leaf laminas and petioles were washed with a mild solution of Ligui-Nox detergent (Alocnox, Inc., New York, NY), rinsed in deionized water, dried at 65°C, and ground (Cyclotec 1093,Teactor, Inc., Hoganas, Sweden) to pass through a 40-mesh screen. Nitrogen concentration of each sample was measured with a LECO Nitrogen-Protein Determinator (FP-528, LECO Corp., St. Joseph, MI). The concentration of potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) were measured by atomic absorption spectrophotometry (Perkin-Elmer 1100 B, Norwalk, Connecticut) as described by Chaplin and Dixon (3) and Jones (13).

Assumption of normality was evaluated by conducting a univariate analysis for all vine responses in this study. Analyses of variance were conducted by using SAS (SAS Institute, Cary, NC, USA), and means were compared by Fisher's least significant difference (LSD) at $P \leq 0.05$. Since no interactions were found between cultivars and years of evaluation, the over-all averages for 3 years of 1999-2001 are reported here. Pearson's correlation coefficients among yield and fruit quality attributes, which were previously reported by Fallahi et al. (7), and leaf lamina and petiole minerals for the 3-year averages were computed.

Results and Discussion

Cane and Leaf Growth:

'Valdapenase 03' had longer canes, larger lamina area, and higher lamina and petiole fresh and dry weights than any other cultivar (Table 1). Also, 'Carignane 06' had significantly larger and heavier leaf laminas and relatively heavier petioles than all cultivars other than 'Valdapenase 03' (Table 1). Wine produced from 'Valdepenase 03' was among the most favored ones in this evaluation (7). If the root development is proportional to the cane and leaf growth, a more vigorous cane and larger leaf of 'Valdapenase 03' could be advantageous as the vine can get established in shorter time and perhaps avoid potential of frost damage in southwest Idaho. 'Dolcetto 01' and 'Limberger 02' had shorter canes than all other cultivars and differences were often significant (Table 1). 'Dolcetto 01', 'Petite Verdot 01', and 'Viognier 01' often had smaller laminas with lower fresh and dry weights than many other cultivars (Table 1). It is noteworthy that wines of 'Petite Verdot 01' and 'Viognier 01' received high rankings in our taste evaluation (7). However, 'Petitie Verdot 01' had very low yield and thus is not recommended for planting under conditions of southwest Idaho (7).

'Meunier 01' and 'Dolcetto 01' had relatively lower petiole fresh and dry weights than those of other cultivars (Table 1). Lamina and petiole percent dry weights of 'Nebbiolo 01' were higher while those of 'Dolcetto 01' were lower than several other cultivars (Table 1).

Berry weight was positively correlated with lamina area (r=0.53) and lamina fresh weight (r=0.54). Cane growth had no significant correlation with petiole nitrate-N concentrations.

Lamina and Petiole Mineral Concentrations

Nitrogen. 'Limberger 02' had significantly lower concentrations of lamina N than all other cultivars (Table 2). 'Valdepenase 03' and 'Petite Verdot 01' had higher lamina N concentrations than most other cultivars. It seems that length of canes in some of these cultivars is proportional to their lamina N concentration, as 'Valdepenase 03' had larger and 'Limberger 02' had shorter canes than other cultivars (Table 1).

'Nebbiolo 01', 'Cabernet Sauvignon 11', and 'Limberger 02' had lower petiole nitrate-N than most other cultivars (Table 2).

The relationship between lamina N and petiole nitrate-N was variable. For example 'Limberger 02' had the lowest lamina N concentration and was among the cultivars with lower petiole nitrate-N (Table 3). In contrast, 'Malbec 06' was among the cultivars with lower lamina N concentrations, but had relatively higher petiole nitrate-N than all other cultivars. Laminas rarely had any measurable nitrate-N. Pooling values of all cultivars together showed insignificant correlations between lamina N concentrations and petiole nitrate-N. Petiole nitrate-N did not have strong correlations with berry soluble solids concentrations, cluster weight or cluster weight (data not shown).

Robinson (19) has compiled data from various researchers and has reported threshold levels for grape petioles and lamina mineral concentrations. In that report, petiole tissues with less than 340 $\mu g.g^{-1}$ nitrate-N are considered to be deficient and those with more than 2000 $\mu g.g^{-1}$ are in excess ranges in California. In 1999, petioles nitrate-N concentrations in only four cultivars ('Cabernet Sauvignon 11', 'Limberger 02', 'Nebbiolo 01', and 'Valdepe-

Table 1. Cane growth, leaf lamina area, and lamina and petiole fresh, dry, and percent dry weights in 15 wine grape cultivars grown under environmental conditions of the Intermountain West region, in southwest Idaho, USA

Cultivar	Cane length (cm)	Leaf lamina area (cm^2/leaf)	Lamina fresh weight (g/leaf)	Lamina dry weight (g/leaf)	Lamina percent dry weight	Petiole fresh weight (mg/petiole)	Petiole dry weight (mg/ petiole)	Petiole percent dry weight
Cabernet Franc 01	61 defg[z]	109 def	2.06 ef	0.60 efg	29.5 abc	482 ef	70 ef	15.18 abc
C. Sauvignon 11	60 defg	102 def	2.08 ef	0.62 efg	30.5 ab	480 ef	67 ef	15.15 abc
Carignane 06	67 cdef	201 b	4.11 b	1.01 b	24.4 f	903 b	130 b	14.71 bcd
Dolcetto 01	46 fg	90 f	1.86 f	0.44 h	24.2 f	463 f	57 f	13.20 ef
Grenache 03	56 efg	120 cd	2.57 cde	0.72 de	28.1 cde	560 def	68 f	12.48 f
Limberger 02	42 g	139 c	3.08 c	0.87 c	28.4 bcde	807 bc	119 bc	15.00 abc
Malbec 06	81 abcd	110 def	2.13 ef	0.57 fgh	26.9 e	514 ef	65 f	13.28 ef
Merlot 08	72 bcde	138 c	2.85 cd	0.80 cd	28.4 bcde	708 cd	103 cd	14.88 bc
Meunier 01	77 bcde	102 def	1.95 f	0.57 fgh	29.4 abc	414 f	60 f	15.44 ab
Nebbiolo 01	86 abc	112 cdef	2.27 ef	0.67 def	30.6 a	488 ef	74 ef	16.13 a
Petite Sirah 03	68 bcde	114 cde	2.32 def	0.66 ef	28.6 abcde	639 de	87 de	14.17 cde
Petite Verdot 01	76 bcde	97 def	1.94 f	0.55 fgh	28.5 abcde	493 ef	69 ef	14.54 bcd
Pinot Noir 18	90 ab	102 def	1.90 f	0.55 fgh	29.2 abcd	530 ef	76 ef	15.17 abc
Valdepenase 03	103 a	247 a	5.56 a	1.48 a	26.8 e	1600 a	223 a	14.21 cde
Viognier 01	57 efg	92 ef	1.91 f	0.52 gh	27.2 de	515 ef	67 ef	13.70 de

[z] Mean separation within columns using Fisher's LSD, $p \leq 0.05$. Each value is the average of 3 years of 1999-2001, each year with four blocks, and each block with 6 vines.

Table 2. Leaf lamina and petiole nitrogen (N), potassium (K), calcium (Ca) and magnesium (Mg) concentrations in 15 wine grape cultivars grown under conditions of the Intermountain West Region, in southwest Idaho, USA[z] .

Cultivar	N (% dry wt)	Nitrate – N (μg.g⁻¹)	K (% dry wt)		Ca (% dry wt)		Mg (% dry wt)	
	Lamina	Petiole	Lamina	Petiole	Lamina	Petiole	Lamina	Petiole
Cabernet Franc 01	3.41 ab[2]	1287 c	1.34 cde	4.25 cde	2.04 cd	1.97 bcd	0.36 de	0.81 de
C. Sauvignon 11	3.23 def	999 cd	1.18 efg	4.47 bcd	2.08 cd	2.02 bc	0.42 abc	0.94 c
Carignane 06	3.14 f	1496 bc	1.36 bcd	4.72 bc	2.15 bc	1.62 d	0.43 abc	0.66 f
Dolcetto 01	3.25 cdef	2583 a	1.52 b	5.09 ab	2.58 a	1.98 bc	0.45 a	0.67 f
Grenache 03	3.14 f	2455 a	1.37 bc	4.22 cde	2.23 abc	1.76 cd	0.42 abc	1.08 ab
Limberger 02	2.96 g	1119 cd	1.13 fg	4.45 bcd	2.15 bc	1.89 bcd	0.38 cd	0.74 ef
Malbec 06	3.18 ef	2967 a	1.39 bc	3.67 ef	2.46 ab	2.04 bc	0.44 ab	0.88 cd
Merlot 08	3.41 ab	2793 a	1.72 a	5.56 a	2.17 bc	2.42 a	0.45 ab	0.97 bc
Meunier 01	3.34 abcd	2220 a	1.20 defg	2.63 g	2.11 c	2.09 abc	0.40 bcd	1.11 a
Nebbiolo 01	3.12 f	412 d	1.29 cdef	3.99 cde	2.12 c	1.97 bc	0.42 abc	0.72 ef
Petite Sirah 03	3.40 abc	2656 a	1.13 g	3.91 de	2.20 bc	1.93 bcd	0.46 a	0.72 ef
Petite Verdot 01	3.47 a	2063 ab	1.16 fg	4.06 cde	2.47 ab	2.09 abc	0.43 abc	0.77 def
Pinot Noir 18	3.21 def	2330 a	1.18 efg	2.95 fg	2.32 abc	2.19 ab	0.45 ab	0.95 c
Valdepenase 03	3.47 a	1410 bc	1.70 a	4.72 bc	1.75 d	1.24 e	0.33 e	0.52 g
Viognier 01	3.31 bcde	1436 bc	1.10 g	4.14 cde	2.46 ab	1.92 bcd	0.44 ab	0.87 cd

[z] Mean separation within columns using Fisher's LSD, $p \leq 0.05$. Each value is the average of 3 years of 1999-2001, each year with four blocks, and each block with 6 vines.

Table 3. Leaf lamina and petiole iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) concentrations in 15 wine grape cultivars grown under conditions of the Intermountain West Region, in southwest Idaho, USA[z].

Cultivar	Fe ($\mu g.g^{-1}$)		Zn ($\mu g.g^{-1}$)		Cu ($\mu g.g^{-1}$)		Mn ($\mu g.g^{-1}$)	
	Lamina	Petiole	Lamina	Petiole	Lamina	Petiole	Lamina	Petiole
Cabernet Franc 01	109.3 ab	23.7 bc	18.02 a	22.80 ab	8.32 bc	7.72 abcd	184.4 a	142.12 a
C. Sauvignon 11	95.3 cde	18.6 f	13.36 cd	14.13 cd	7.54 cd	6.45 de	121.3 cde	73.37 cde
Carignane 06	96.4 bcd	17.9 f	14.82 bcd	14.30 cd	7.54 cd	6.87 bcde	161.3 abc	72.10 cde
Dolcetto 01	92.0 de	20.0 ef	15.25 abcd	18.32 abcd	7.32 cd	6.05 e	135.6 bcd	77.85 bcde
Grenache 03	92.1 de	23.5 bc	12.59 d	12.47 d	6.32 d	6.49 cde	145.1 abcd	94.87 bc
Limberger 02	83.2 def	24.0 bc	16.09 abc	26.16 a	8.21 bc	8.37 ab	89.0 e	73.91 cde
Malbec 06	78.7 f	20.2 ef	15.26 abcd	16.52 bcd	7.87 c	7.98 abc	117.3 de	85.56 bcd
Merlot 08	116.3 a	24.1 b	17.03 ab	19.07 abcd	7.49 cd	8.76 a	167.5 ab	134.17 a
Meunier 01	107.6 abc	27.5 a	15.82 abc	25.24 a	9.27 ab	8.94 a	119.4 de	98.81 bc
Nebbiolo 01	85.7 def	21.1 de	17.09 ab	24.61 a	9.70 a	8.33 ab	154.8 abcd	104.14 b
Petite Sirah 03	82.8 ef	22.8 bcd	15.22 abcd	14.86 cd	6.33 d	7.10 bcde	149.9 abcd	60.07 de
Petite Verdot 01	84.4 def	21.8 cde	15.21 abcd	15.14 bcd	7.10 cd	7.49 abcde	131.2 bcd	84.41 bcd
Pinot Noir 18	91.6 def	27.9 a	15.42 abcd	21.97 abc	7.75 c	6.71 cde	119.6 de	86.72 bcd
Valdepenase 03	84.8 def	15.3 g	15.18 abcd	16.69 bcd	8.31 bc	6.22 de	109.5 de	49.36 e
Viognier 01	89.9 def	21.1 de	14.86 bcd	15.52 bcd	7.98 c	7.43 abcde	135.2 bcd	97.40 bc

[z] Mean separation within columns using Fisher's LSD, $p \leq 0.05$. Each value is the average of 3 years, each year with four blocks, and each block with 6 vines.

nase 03') were in the deficiency range (data not shown) according to Robinson's standards (19). Results during 2000 and 2001 seasons (not shown) and 3-year averages over 1999-2001 (Table 2) revealed that none of the cultivars was deficient in petiole nitrate-N according to those standards (19). Furthermore, none of the cultivars had lamina N concentrations in deficiency range and no N deficiency symptoms were ever observed in any of the tested grapes during 1999-2001. Also, we did not see any symptoms of leaf burning (toxicity) in any cultivar including those with petiole nitrate-N exceeding 2000 $\mu g.g^{-1}$ during any time of this study. Therefore, we do not believe that 2000 $\mu g.g^{-1}$ is necessarily a correct threshold for high petiole-N limit as reported in California (4, 19), and our conclusion is consistent with those from Western Australia (10, 19) and South Australia (19, 20),

Potassium, Calcium, and Magnesium. Potassium and Mg concentrations in laminas were lower than those in petioles in all cultivars (Table 2). 'Valdepenase 03' and 'Merlot 08' had higher concentrations of lamina K than other cultivars. 'Merlot 08' also had higher concentrations of petiole K and Ca than other cultivars (Table 2). The higher concentration of K in these cultivars could lead to their earlier cane maturity, as reported for grapes in general by Cook (4). A well-expanded root system and early cane maturity could lead to a better winter survival in the early years of planting under the climatic conditions of southwest Idaho. Survival of a red wine grape, such as 'Valdapenase 03', in the region is extremely important, as many of the red wine cultivars were severely damaged during December of 1990 when temperatures plunged to -28 °C (personal knowledge).

Averaging values over 3 years, significant correlations were found between leaf lamina area and lamina K (r=0.54) and lamina K and lamina fresh weight (r=0.53). Pooling values of all cultivars showed positive correlations between lamina K and petiole K in 1999 (r=0.52), 2000 (r=0.55), and 2001 (r=0.66). Also, positive correlations existed between lamina Ca and petiole Ca in 1999 (r=0.47), 2000 (r=0.65), and 2001 (r=0.48).

'Valdepenase 03' had lower Ca and Mg concentrations in both lamina and petiole tissues in spite of its relatively higher lamina N and K than most other cultivars (Table 2). Petioles in 'Meunier 01' had the highest Mg but the lowest K concentrations among all cultivars (Table 2). Antagonism between foliar K and Mg has been previously reported for other fruits (9) and could be the reason for lower lamina Mg in 'Valdepenase 03' and higher petiole Mg in 'Meunier 01' than other cultivars. 'Dolcetto 01 had higher lamina Ca than many other cultivars (Table 2). A significantly positive correlation existed between lamina Ca and lamina Mg (r=0.55).

In apples, fruit tissues compete with leaves for absorption of K (9). In this experiment, a positive correlation existed between lamina K and leaf area (r=0.53) but a negative correlation was found between leaf area and lamina Ca (-0.44), when values of all grape cultivars were pooled over 3 years. If the relationship between leaf and fruit minerals in grapes is similar to apples, grape cultivars with larger leaf laminas may have less K in their fruit tissues than those with smaller leaf laminas, as larger leaves could demand more K. Fruit K status may affect wine quality, and thus this area deserves further investigation.

Lamina and Petiole Micronutrients. Iron and Mn concentrations in laminas were higher than those in petioles in all cultivars (Table 3). In some cultivars in 1999, Cu and Zn concentrations of laminas and petioles were marginal or deficient based on Robinson standards (19) but the concentrations were in sufficient ranges in 2000 and 2001 (data not shown) without additional application of these elements, perhaps due to better root establishment and more efficient uptake. 'Merlot 08' and 'Cabernet Franc 01' had higher lamina Fe, Zn, and Mn and higher petiole Mn than other cultivars, although differences were not always significant (Table 3). 'Grenache 03' had relatively lower levels of lamina and petiole Zn than other cultivars. Ability to absorb higher levels of Fe and Zn is an important factor as deficiency of these elements is a common problem in the high soil pH conditions of the southwest Idaho.

'Nebbiolo 01' and 'Meunier 01' had relatively higher lamina and petiole Cu than several other cultivars (Table 3). 'Limberger 02' had relatively higher petiole Zn and lower lamina Mn, while 'Valdapenase 03' had lower petiole Mn than other cultivars (Table 3).

A positive correlation existed between lamina Fe and lamina Mn (r=0.56). Positive correlations existed between concentration of a micronutrient in lamina with the same element in the petiole tissue and the values were often significant (data not shown).

General Comments

The results in this report underscore the need for developing foliar standards for each commercially important cultivar in each geographical region. General standards developed by averaging values for several regions and cultivars, can be used as a guideline, but they may not be very precise for making ultimate quality wine, as vine nutrition can directly influence musk nutrient content and thus wine quality.

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