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Lower Petiole Potassium Concentration at Bloom in Rootstocks with *Vitis berlandieri* Genetic Backgrounds

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Abstract: The effect of rootstock on seasonal vine nutrition was monitored at three trials in Northern California: two in the Sacramento Delta with Chardonnay and Cabernet Sauvignon as the scions and one in Amador County with Zinfandel as the scion. Each site was planted with identical sets of 14 rootstocks. Leaf petioles were sampled at the three phenological stages of bloom, veraison, and harvest and analyzed for potassium (K) content. Rootstocks differed significantly in petiole K concentration at bloom, 44-53 had the highest K status at all three phenological sampling times, and Freedom also had high K status. Total K levels generally declined significantly between bloom and harvest for all varieties, although the amount and pattern of decline differed among rootstocks. Leaf lamina K concentrations were much lower than those of petioles. The ranges between the high and low values were much narrower, but trends were consistent with petiole samples. Rootstocks with *Vitis berlandieri* genetic backgrounds contained lower levels of petiole K at bloom, but these differences were not apparent at veraison and harvest. It is possible that water deprivation because of drip-irrigation or deficit-irrigation practices contributed to this result, as it has not been consistently observed in previous investigations.

Key words: grapevine, rootstocks, potassium, petiole, *Vitis*

The failure of ungrafted vineyards in California (Wildman 1986) and the collapse of AXR#1 rootstock to type B phylloxera (De Benedictis and Granett 1993) resulted in extensive planting of alternative phylloxera-resistant rootstocks throughout California's coastal regions. Concurrent with the replacement of AXR#1 as a rootstock, irrigation practices also changed. Replanted vineyards were established with microirrigation systems (drip), and a deficit irrigation strategy was widely adopted. Both of these changes are recent with respect to viticulture practice in California. Grapevines are long-lived perennials when they are not confronted with environmental stressors such as severe mineral nutrient deficiencies or pests and diseases. As a result, the development and testing of rootstocks under new management regimes is a slow process.

It is well accepted that a rootstock can affect foliar nutrient levels (May 1994), but the complex interactions of rootstock, rootstock-scion combination, soil type, climate, and management practice have made it challenging to acquire sufficient and consistent information on rootstock mineral nutrition. In addition, great variation generally exists in nutrient concentrations in the plant tissues used for grapevine nutrient analysis. In the example of potassium (K), the subject of this investigation, petiole concentration of K can range from less than 1% to greater than 5% (Delas and Pouget 1979, Ruhl 1989, Robinson 1990, Christensen et al. 1994, Brancadoro et al. 1994) (Figure 1). Potassium content is further dependent on phenological stage of development (results presented here).

Australia's viticulturists were among the first to undertake extensive trials to evaluate mineral nutrition in different regions and on diverse soils (Ruhl 1989, May 1994). A primary focal point of the Australian effort was K nutrition. However, the objective of their investigations was somewhat different in relation to California viticulture because Australian soils, as noted by May (1994), are K sufficient. It was felt that high K levels diminished wine quality because of the known positive correlation that exists between berry K content and must pH (Boulton 1980, Ruhl 1989). Higher pH is generally associated with wines of reduced color quality, lack of acidity in flavor, and poor wine stability. These and other efforts to understand rootstock influence on vine mineral nutrition have been commonly conducted under flood and furrow irrigation systems (Ruhl 1989), in climates where there is summer rainfall (Delas et al. 1987), or in soils with excessive K (May 1994). Other studies have focused on K content of leaf lamina at fruit set and veraison; since these values were lower and less reliable than those in petioles, they have

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not been widely adopted in nutrient programs in comparison with petioles (Brancadoro et al. 1994).

Here we report on petiole K concentrations in order to understand rootstock nitrogen (N) and K relations in California's diverse soils and climatic conditions. (Results from this trial for other nutrients, primarily N and P, crop levels, and leaf areas at each site will appear in forthcoming publications.) California soils are not particularly deficient in available K. Nonetheless, K deficiencies have been the focus of attention in this viticulture region (Christensen et al. 1984). The results we report are from the first comprehensive rootstock trials to our knowledge to monitor K nutrition in the petiole for a wide range of rootstocks growing in the same soil under drip irrigation in a climate with severe summer drought.

Materials and Methods

Three California rootstock trials are reported in this preliminary analysis. Two vineyard sites were located in the Sacramento River Delta, near the town of Hood. The scions were Cabernet Sauvignon grown in a Tinnin loamy sand and Chardonnay grown in a sandy loam variant of an Egbert clay (Anamosa 1998). A third site was located in Amador County's Shenandoah Valley and the soil was Sierra sandy loam, with Zinfandel as the scion. None of the sites were deficient in nitrogen. These three vineyards were established with a randomized block design and evaluated an identical set of 14 rootstocks: 5C, 5BB, 3309C, 101-14, 110R, 1103P, 420A, 1616C, St. George, 44-53, Ramsey, Harmony, Freedom, and O39-16. Genetic origins and full names of these rootstocks are given in Table 1.

Petiole and blade tissues were collected from rootstock treatments at each of three phenological stages: bloom, veraison, and harvest. Bloom samples were leaves opposite the basal-most cluster, while veraison and harvest samples were the most recently fully expanded leaves. Samples were collected over three years (1995 to 1997) at all three sites. At each sampling date, 20 petioles and blades were collected per treatment-replicate. The petioles and blades were separated, oven-dried, and sent to the Division of Agriculture and Natural Resources analytical laboratory at the University of California, Davis, for processing and analysis. All samples were analyzed for K using a nitric acid/hydrogen peroxide microwave digestion and determination by atomic absorption spectrometry. Potassium was expressed as a percentage of the total dry mass (%K).

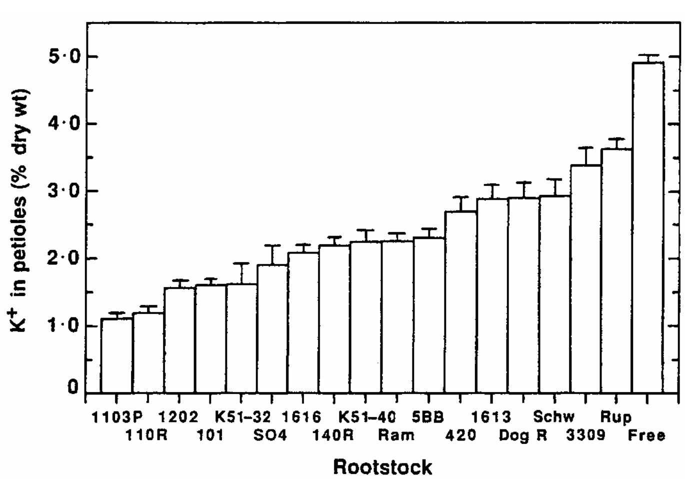

Figure 1 Petiole potassium concentrations for rootstocks growing in the germplasm collection in Merbein (Ruhl 1989). Error bars are standard errors (n = 6). Reproduced with permission of CSIRO Publishing, Collingwood, Victoria, Australia (http://www.publish.csiro.au/journals/ajea).

Results

Leaf petiole and blade total K levels were relatively consistent among years for all rootstocks and sites. Thus, the results presented in this report represent the average for all three years at each site. Irrigation practices differed slightly between sites because different strategies for water delivery and slightly different objectives existed among growers for achieving what was perceived as an appropriate level of vine water status. For example, Chardonnay received more seasonal water and was allowed a shorter fruit ripening period than the red varieties. In general, each variety at each site received less irrigation water than would be indicated by estimates of crop evapotranspiration (California Irrigation Management and Information System; www.cimis.water.ca.gov).

Chardonnay, Sacramento Delta. Petiole K levels (Table 2, Chardonnay) were higher at bloom (2.81%) and veraison (2.73%), while much lower at harvest (1.59%). The

Table 1 Genetic origin of 14 rootstocks in this investigation: rootstock name, abbreviation, and species or species crosses used to derive each rootstock.

Rootstock	Genetic origin
Rupestris St. George (St. George)	*Vitis rupestris*
1103 Paulson (1103P)	*V. berlandieri* x *V. rupestris*
110 Richter (110R)	*V. berlandieri* x *V. rupestris*
5BB Kober (5BB)	*V. berlandieri* x *V. riparia*
420A Millardet et de Grasset (420A)	*V. berlandieri* x *V. riparia*
5C Teleki (5C)	*V. berlandieri* x *V. riparia*
101-14 Millardet et de Grasset (101-14)	*V. riparia* x *V. rupestris*
3309 Couderc (3309C)	*V. riparia* x *V. rupestris*
1616 Couderc (1616C)	*V. solonis* x *V. riparia*
Salt Creek (Ramsey)	*V. champinii*
Freedom	*V. champinii* x 1613C[a]
Harmony	*V. champinii* x 1613C[a]
44-53 Malegue (44-53)	*V. riparia* x (*V. cordifolia* x *V. rupestris*)
O39-16	*V. vinifera* x *Muscadinia rotundifolia*

[a]1613C (*V. labruscana* X *V. riparia* x *V. vinifera*).

highest petiole K contents at bloom included the rootstocks 44-53 (4.47%) and 1616C (3.98%), while the group showing low bloom K included 110R (1.54%), 1103P (1.56%), and 420A (1.66%). At harvest, the highest petiole K concentration occurred in Harmony (2.45%) and 1616C (2.43%) rather than in 44-53. The rootstock 420A had the lowest harvest petiole K concentration at 0.70%. Rootstocks showing low harvest petiole K levels included Ramsey (1.07%), 110R (1.16%), and 3309C (1.23%).

Potassium concentrations in leaf lamina (Table 3, Chardonnay) were also highest at bloom (1.16%), decreasing significantly by veraison (1.00%), and significantly again by harvest (0.88%). The rootstock with the highest blade K at bloom was also 44-53 at 1.72%. Other rootstocks with high blade bloom K included 1616C (1.44%), Harmony (1.33%), and O39-16 (1.28%), while rootstocks with low bloom blade K values included 1103P (0.79%), 110R (0.92%), and 420A (0.93%). The range of blade K values at bloom was almost a full percentage (1.72 to 0.79%), but by harvest, the range had decreased to 0.4% (1.04 to 0.63%). Between bloom and harvest the rootstock with the greatest decline in K was 44-53, a 0.76% loss (1.72 to 0.96%), although it was still among the rootstocks with highest K concentration at harvest. Most rootstocks by comparison lost only 0.2 to 0.4% K. The rootstock 1103P actually increased slightly in K between bloom and harvest, resulting in its rank increasing from the lowest bloom K to among the highest.

Cabernet Sauvignon, Delta. The three-year average petiole K levels (Table 2, Cabernet) showed a steep decline from bloom (2.33%) to veraison (1.21%) and from veraison to harvest (0.38%). The highest levels at bloom were once again found in 44-53 (3.54%) and Freedom (3.26%), while the lowest levels at bloom were seen in 420A (1.36%) and 110R (1.67%). Among the rootstocks with a relatively good petiole K status at harvest were 110R (0.51%), 5BB (0.49%), and 44-53 (0.64%).

Leaf blade K concentration (Table 3, Cabernet) did not change from bloom (0.89%) to veraison (0.90%) but declined substantially by harvest (0.42%). The rootstocks with the highest leaf blade K values (Table 2) at harvest were 44-53 (0.52%), 110R (0.49%), and 5BB (0.48%), while the lowest values were seen in Ramsey (0.34%), O39-16 (0.37%), and 3309C (0.37%).

Zinfandel, Amador County. Petiole K concentration (Table 2, Zinfandel) generally remained constant from bloom (2.06%) to veraison (2.00%), but declined significantly from veraison to harvest (0.87%). Rootstocks with the highest petiole K concentrations at bloom were Freedom (2.74%) and 44-53 (2.66%). The rootstock with the lowest level of K in the petiole at bloom was 420A (1.19%), while others with a low bloom K concentration included 5BB, 110R, 1103P, and Ramsey. Five rootstocks showed an increase in petiole K levels between bloom and veraison, three showed no change, and the remainder decreased. The concentration of K in petioles decreased dramatically in all rootstocks between veraison and harvest. Average leaf blade K concentration did not change between bloom (0.91%) and veraison (0.96%), but showed a sharp decline from verasion to harvest (0.54%).

Rootstocks with high leaf blade K concentrations at bloom (Table 3, Zinfandel) included 44-53 (1.17%), St. George (1.01%), and 1616 (1.00%). Four rootstocks, 420A (0.74%), 1103P (0.79%), 110R (0.80%), and 5BB (0.81%), had lower leaf blade K concentration at bloom.

Rootstocks. Rootstocks with *Vitis berlandieri* genetic backgrounds generally showed deviations in petiole K concentration in comparison with the site means (Figure 2, page 168). At bloom, when *Vitis vinifera* cv. Chardonnay was the scion (Figure 2A), the petioles from rootstocks 5C, 420A, 110R, and 1103P (*V. berlandieri* origin, Table 1) all had statistically significantly lower petiole K concentrations ($p < 0.05$, ANOVA) than those of Freedom, Harmony, O39-16, 1616C, and 44-53. The rootstocks 3309C, 101-14 Mgt, and St. George were intermediate (the K concentration in petioles was not statistically significantly different from either the *V. berlandieri* genotypes or other rootstocks with higher K concentrations). The rootstocks 5C, 5BB, 420A, 110R, 1103P, 3309C, St. George, and Ramsey showed statistically significantly lower petiole K concentrations ($p < 0.05$) than petioles of 44-53, 1616C, Harmony, and Freedom (Table 2) when *V. vinifera* cv. Cabernet Sauvignon was the scion. The rootstocks 101-14 Mgt and O39-16 were intermediate when Cabernet Sauvignon was the scion. Finally, when Zinfandel was the scion, the rootstocks 5C, 5BB, 420A, 110R, 1103P, 3309C, and Ramsey had statistically significantly lower petiole K concentrations ($p < 0.05$) than the rootstocks 101-14 Mgt, St. George, 44-53, 1616C, O39-16, Harmony, and Freedom. For Zinfandel, no rootstocks were found to have intermediate K concentrations between these two groups.

Discussion

There was a distinct seasonal pattern of change in K concentration in the petiole (Table 2). At bloom distinct and genetically discernible differences among rootstocks were detectable, and the concentrations of K were relatively high, ranging from 1.19% (Zinfandel on 420A) to 4.47% (Chardonnay on 44-53). But petiole K concentration declined sharply during the period between veraison and harvest, ranging from 0.19% (Cabernet Sauvignon on Ramsey) to 1.10% (Zinfandel on 44-53) for the red varieties and from 0.7% (420A) to 2.45% (Harmony) for Chardonnay (Table 2). The differences among rootstock scion combinations had generally disappeared by harvest (Table 2). This finding suggested that absorption of K in spring, from budbreak to bloom, may be a more critical period for K acquisition, while retranslocation from existing tissues to ripening fruit may represent the primary source for K during the ripening period. Root growth does not commence for the autumn root flush (Van Huyssteen 1988) until after harvest and when water is available (D.R. Smart, unpublished data 2002). If root absorption of K were able

Table 2 Effect of rootstock on potassium (K) concentration in leaf petioles of Chardonnay (Sacramento Delta), Cabernet Sauvignon (Sacramento Delta), and Zinfandel (Amador County) grapes at bloom (B), veraison (V), and harvest (H). Shown are the means of observations covering 1995 to 1997.

	Leaf petiole potassium (% dry wt)[a]					
	Season					
Rootstock	**B**	**V**	**H**	**Bloom**	**Veraison**	**Harvest**
Cabernet						
5C	a	b	c	2.23 e	1.23 bc	0.40 bc
5BB	a	b	c	1.84 f	1.37 abc	0.49 b
420A	a	a	b	1.36 g	1.15 c	0.34 cde
110R	a	a	b	1.67 f	1.31 abc	0.51 ab
1103P	a	b	c	2.21 e	1.25 abc	0.30 cde
101-14	a	b	c	2.72 c	1.42 ab	0.39 bcd
3309C	a	b	c	2.21 e	1.21 bc	0.25 de
St. George	a	b	c	2.52 d	1.24 abc	0.29 cde
44-53	a	b	c	3.54 a	1.40 ab	0.64 a
1616C	a	b	c	2.59 cd	1.48 a	0.38 bcd
O39-16	a	b	c	2.07 e	0.79 d	0.31 cde
Harmony	a	b	c	2.49 d	1.20 bc	0.31 cde
Freedom	a	b	c	3.26 b	1.19 bc	0.45 bc
Ramsey	a	b	c	1.87 f	0.73 d	0.19 e
All stocks	a	b	c	2.33	1.21	0.38
Zinfandel						
5C	b	a	c	1.91 c	2.25 a	0.92 abcd
5BB	b	a	c	1.66 d	2.06 abc	0.91 abcd
420A	b	a	c	1.19 e	1.53 e	0.74 de
110R	b	a	c	1.48 d	2.21 ab	1.00 ab
1103P	b	a	c	1.57 d	2.10 abc	0.94 abc
101-14	a	b	c	2.24 b	1.92 cd	0.76 cdec
3309C	a	a	b	1.98 c	1.99 bcd	0.66 ef
St. George	a	b	c	2.39 b	2.08 abc	1.04 a
44-53	a	b	c	2.66 a	2.19 ab	1.10 a
1616C	a	a	b	2.41 b	2.28 a	0.97 ab
O39-16	a	b	c	2.66 a	1.96 cd	1.02 a
Harmony	a	a	b	2.30 b	2.26 a	0.82 bcde
Freedom	a	b	c	2.74 a	1.82 d	0.81 bcde
Ramsey	a	b	c	1.62 d	1.33 f	0.51 f
All stocks	a	b	c	2.06	2.00	0.87
Chardonnay						
5C	a	a	b	2.40 f	2.56 cde	1.52 de
5BB	a	a	b	2.69 ef	2.81 bc	1.70 bcd
420A	b	a	c	1.66 g	2.13 f	0.70 g
110R	b	a	c	1.54 g	2.45 def	1.16 f
1103P	b	a	b	1.56 g	2.30 ef	1.58 cd
101-14	a	a	b	2.86 def	2.74 bcd	1.49 de
3309C	a	a	b	2.89 def	2.53 cde	1.23 ef
St. George	a	a	b	2.80 ef	2.35 ef	1.47 de
44-53	a	b	c	4.47 a	3.54 a	1.92 b
1616C	a	a	b	3.98 ab	3.64 a	2.43 a
O39-16	a	b	c	3.39 cd	2.92 b	1.69 bcd
Harmony	a	a	b	3.59 bc	3.50 a	2.45 a
Freedom	a	b	c	3.17 cde	2.62 bcde	1.83 bc
Ramsey	a	a	b	2.41 f	2.12 f	1.07 f
All stocks	a	a	b	2.81	2.73	1.59

[a]Means of K concentration followed by the same lowercase letter or season (phenological stage) assigned the same lowercase letter do not differ significantly as determined by Duncan's multiple range test ($p < 0.05$).

Table 3 Effect of rootstock on potassium (K) concentration in leaf lamina of Chardonnay (Sacramento Delta), Cabernet Sauvignon (Sacramento Delta), and Zinfandel (Amador County) grapes at bloom (B), veraison (V), and harvest (H). Shown are the means of observations covering 1995 to 1997.

	Leaf lamina potassium (% dry wt)[a]					
	Season			Bloom	Veraison	Harvest
Rootstock	**B**	**V**	**H**			
Cabernet						
5C	a	a	b	0.81 cd	0.88 cdef	0.40 def
5BB	b	a	c	0.80 cd	0.90 cde	0.48 abc
420A	b	a	c	0.73 e	0.83 def	0.42 cde
110R	a	a	b	0.84 c	0.91 bcd	0.49 ab
1103P	b	a	c	0.80 cd	0.86 cdef	0.39 def
101-14	a	a	b	0.99 b	0.93 bc	0.41 cde
3309C	a	a	b	0.94 b	0.87 cdef	0.37 ef
St. George	a	b	c	0.95 b	0.88 cdef	0.41 cde
44-53	a	b	c	1.17 a	0.98 ab	0.52 a
1616C	a	a	b	0.97 b	1.04 a	0.45 bcd
O39-16	a	a	b	0.76 de	0.82 ef	0.37 ef
Harmony	a	a	b	0.95 b	1.01 a	0.44 bcde
Freedom	a	b	c	0.94 b	0.86 cdef	0.46 bcd
Ramsey	a	a	b	0.77de	0.79 f	0.34 f
All stocks	a	a	b	0.89	0.90	0.42
Chardonnay						
5C	a	ab	b	1.03 fg	0.99 cd	0.84 def
5BB	a	a	b	1.08 ef	1.04 bc	0.85 def
420A	a	a	b	0.93 g	0.83 f	0.63 g
110R	a	a	b	0.92 g	0.98 cd	0.80 ef
1103P	b	a	a	0.79 h	0.95 cd	0.97 abc
101-14	a	b	b	1.19 de	1.04 bc	0.93 bcd
3309C	a	b	c	1.21 de	0.94 de	0.78 ef
St. George	a	b	b	1.19 de	0.94 de	0.87 cde
44-53	a	b	b	1.72 a	1.10 ab	0.96 abc
1616C	a	b	c	1.44 b	1.18 a	1.02 ab
O39-16	a	b	b	1.28 cd	0.98 cd	0.90 cd
Harmony	a	b	b	1.33 bc	1.11 ab	1.04 a
Freedom	a	b	b	1.16 de	1.00 cd	0.97 abc
Ramsey	a	b	b	1.01 fg	0.86 ef	0.76 f
All stocks	a	b	c	1.16	1.00	0.88
Zinfandel						
5C	b	a	c	0.86 d	0.97 bcd	0.52 cde
5BB	b	a	c	0.81 de	0.94 cde	0.49 de
420A	b	a	c	0.74 e	0.87 f	0.51 cde
110R	b	a	c	0.80 de	1.02 ab	0.61 a
1103P	b	a	c	0.79 de	0.98 bcd	0.55 bc
101-14	a	a	b	0.95 bc	1.00 abc	0.54 cde
3309	a	a	b	0.93 c	0.97 bcd	0.49 e
St. George	a	a	b	1.01 b	1.01 ab	0.60 ab
44-53	a	b	c	1.17 a	1.06 a	0.64 a
1616C	b	a	c	1.00 b	1.06 a	0.55 cd
O39-16	a	a	b	0.96 bc	0.89 ef	0.52 cde
Harmony	a	a	b	0.92 c	0.99 abc	0.54 cde
Freedom	a	a	b	0.94 bc	0.92 def	0.53 cde
Ramsey	a	a	b	0.82 d	0.81 g	0.43 f
All stocks	a	a	b	0.91	0.96	0.54

[a]Means of K concentration followed by the same lowercase letter or season (phenological stage) assigned the same lowercase letter do not differ significantly as determined by Duncan's multiple range test ($p < 0.05$).

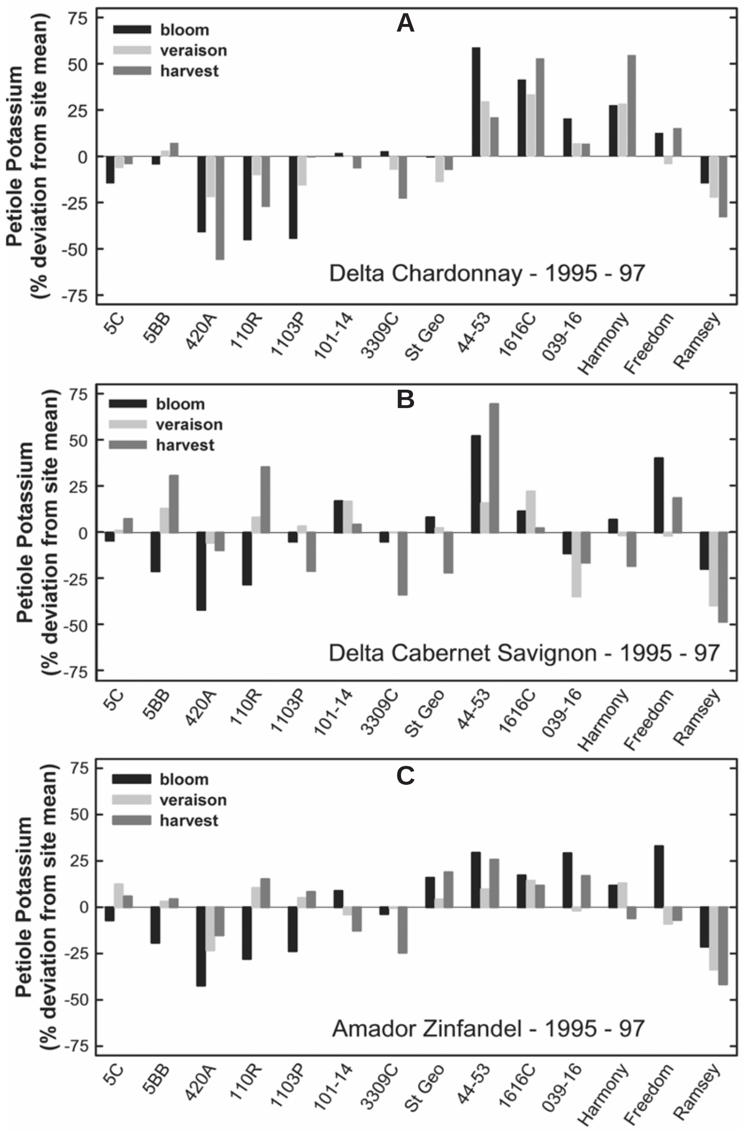

Figure 2 Deviation in petiole potassium concentration expressed as a percent deviation from the site mean for the 1996 to 1997 study: (**A**) Chardonnay, Sacramento Delta; (**B**) Cabernet Sauvignon, Sacramento Delta; (**C**) Zinfandel, Amador County.

to meet demands at this time, then it is more likely that K concentration would not decline in new leaves and petioles if K were available in soils with enough moisture for its absorption and translocation. This view was supported by the fact that Chardonnay, harvested earlier and at a lower Brix, had higher petiole K contents at harvest than did either of the red varieties.

In California (Cook and Kishaba 1956, Christensen et al. 1978) and in other regions (Robinson 1990), K nutrition of grapevines is monitored primarily by analysis of nutrients in petiole tissue at bloomtime and comparing it against historical records or with apparent “critical” levels (Christensen 1978, 1984). In this investigation, it was clear that rootstock scion combinations have widely differing concentrations of K at bloom and that retranslocation of K played a substantial role in K nutrition (Table 2). This suggests that different sampling strategies, and levels of K that might be considered sufficient at bloom, should be considered for each individual rootstock-scion combination. Other recent reports that scion genotype affects rootstock response (Virgona et al. 2003) support this interpretation.

Conclusion

One consistent result that emerged in this study regardless of scion was that rootstocks with *Vitis berlandieri* genetic backgrounds consistently showed negative deviations in petiole K concentration at bloom with respect to the site means. In general, the absolute concentrations of K in petioles at bloom were statistically significantly lower if the rootstock contained *V. berlandieri* genetic background. *Vitis champinii* rootstocks are known for enhanced K uptake, but higher petiole K concentrations were also observed from other non-*champinii* rootstocks such as 1616C, 44-53, and O39-16 that do not have *V. champinii* backgrounds. Exceptions to this trend were the rootstocks 101-14 Mgt and 3309C. These two *Vitis riparia x V. rupestris* hybrids were consistently intermediate between the *Vitis berlandieri* and *V. champinii* crosses. Our results therefore suggest that levels of K concentration might be more broadly classified according to genetic origin of the rootstock, and we are currently pursuing this possibility.

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