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Original Research Paper

Variation in the Interactions among soil K$^+$, Ca^{++}, Mg^{++} and Na$^+$ ions as influenced by the variety and rootstock in grape

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ABSRACT

A nutritional survey was conducted to study the influence of variety and rootstock on interaction among K$^+$, Ca^{++}, Mg^{++}and Na$^+$ ions in grape during 2012-14. Soil cation contents did not correlate with their respective contents in petioles indicating a strong antagonism among them. Quadratic relationship of soil cations with the absorption (ratio of petiole content to soil content) of other ions revealed that the antagonism among cations was observed in case of soil K$^+$ with Ca^{++} and Na$^+$ absorption on 110R and Dog Ridge rootstocks, soil Ca$^+$ with K$^+$ and Mg^{++} and Na$^+$ in Sonaka variety and Na$^+$ in own rooted vines, soil Mg^{++} with Ca^{++} and Na$^+$ also in own rooted vines; and Na^{++} with Ca^{++} and Mg^{++} respectively in 2A clone and Dog Ridge. Contrarily, increased absorption of K$^+$ by soil Ca^{++} on 110R, Na$^+$ and K$^+$ by soil Mg^{++} respectively in Sonaka and 110R, and Ca^{++} by soil Na$^+$ on Dog Ridge was also observed. All the soil cations together influenced K$^+$ absorption most in Sonaka followed by Mg^{++} absorption in 2A clone, but Ca^{++} absorption on Dog Ridge followed by K$^+$ on 110R.

Keywords: Cations, interactions, grape, variety, rootstock

INTRODUCTION

Antagonism among K, Na, Ca and Mg ions is well established (Robson and Pitman, 1983; Shikhamany *et al*., 1988; Wilkinson *et al*., 1999; Fageria, 2001). Cation content in the plant tissue is dependent on the physico-chemical characteristics of the soil (Abrol *et al*., 1988; Sumner and Yamada, 2002; Fisarakis *et al*., 2005; Shikhamany and Sharma, 2008; Shikhamany *et al*., 2017), both the availability of a particular cation and the presence and absence of other cations (Emmert, 1959; Bergman et al., 1960) and their relative abundance in the growth medium (Epstein, 1972). Generally an excess of one cation in the medium reduces the uptake of other cations to maintain the cation equilibrium in the soil-plant system (Dibb and Thompson, 1985). Further, the cation composition of the plant tissue was found to vary with the variety, based on its physiological need (Jacobson and Ordin, 1954; Barbar and Russell, 1961) and the rootstock due to affinity of their roots to particular ion (Downton, 1977; Anna and Lajos, 2008; Antonio and Carlos, 2009; Marco *et al*., 2011). The vineyard soils of Maharashtra, where more than 80 per cent of the area under grapes in India exists, are saline alkali with wide variation in soil physico-chemical characteristics and available nutrient status. Thompson Seedless and its clones, namely 2A and Sonaka are grown on their own roots as well as on Dog Ridge and 110R rootstocks. In this background, these investigations were aimed at bring out the variation in the influence of dominant cations in the absorption of other cations in a given stionic combination and guide in fertilizer practices.

MATERIAL AND METHODS

A survey was conducted to study the variation in bloom time petiole nutrient contents of Thompson Seedless and its clones namely, 2A and Sonaka grown on their own roots, Dog Ridge or 110Richter rootstocks in Pune and Sangli districts of Maharashtra during 2012-14 fruiting seasons. Six vineyards in each stionic combination (three varieties x three roots) were selected for the study. All the vineyards were in the age group of 4-6 years and received varying levels of nutrients.

The soils of the vineyards surveyed belonged to the order 'Vertisols' with the following characteristics.

All the vines selected for the study were planted at 2.7 x 1.8 m, trained to extended Y trellis and pruned

General Characteristics of the vineyard soils (Mean of 54 samples)

	OM	pH	EC (dsm^{-1})	$CaCO_3$ (%)	ESP (%)	Available K (mg/kg)	Available Ca (mg/kg)	Available Mg (mg/kg)	Available Na (mg/kg)
Mean	2.57	7.76	0.604	15.79	7.7	110.8	456.0	141.4	70.4
SD	1.08	0.52	0.428	4.21	1.82	54.2	118.8	29.5	17.4
CV(%)	27.8	14.9	70.9	26.7	32.6	48.9	26.1	20.9	24.7

to have 30±2 canes/vine. One hundred petioles of leaves opposite to flower clusters were collected at full bloom in November 2013 from each vineyard and soil samples from 15-30 cm depth at 60 cm away from the vine stem at back pruning before the application of fertilizers. Cations from soil samples were extracted using 1.0 N neutral ammonium acetate in 1:5 (w/v) ratio. Oven dried petiole samples were wet digested with HNO_3: $HClO_4$ (9:4 v/v). Potassium and sodium contents in soil as well as petiole samples were determined by flame photometer, while calcium and magnesium contents by atomic absorption spectrophotometer. All the contents were expressed as me/100 g dry weight.

Linear, quadratic and multiple regression equations were fitted to elucidate the variation in the interaction of soil cation contents (independent variable) with petiole contents (dependent variable) among the varieties and rootstocks. Threshold levels of soil cations were determined by the formula -b/2c in the quadratic equation $Y= a + bx + cx^2$ in negative correlations. It is the level of x at which the negative relationship between x and y parameters turns positive. It is inverse to the x-optimum in a positive correlation.

RESULTS AND DISCUSSION

Interaction among cations: Correlations among the major cation nutrients in the petioles revealed positive relationship of Mg with Ca and Na across all the varieties and rootstocks (**Table 1**). On the other hand, in contrast to the observations of Bayers (1951), Emmert (1959) and Bergman *et al*. (1960), no significant relationship between the soil and petiole contents of any ion was observed except the negative relationship between K^+ contents (**Table 2**). Since the uptake of nutrient ions is directed by the variety (Jacobson and Ordin, 1954; Barbar and Russell, 1961) and rootstock (Smith and Wallace, 1956; Cook and Lider, 1964; Downton, 1977); and different varieties and rootstocks were involved in these correlations, variety-wise and rootstock-wise regression analysis could reveal better picture of the interactions among the cations in different varieties and rootstocks. Simple correlations revealed that soil contents of K, Ca or Na were not correlated with their respective contents in the petioles of any variety or rootstock, but Mg content alone was correlated in the variety Sonaka. Petiole K and Na contents were also influenced by the soil Ca in this variety. Among the rootstocks, soil Na influenced the petiole Ca on Dog Ridge, while soil Ca influenced the petiole K on 110R (**Table 3**).

Table 1. Correlation matrix among petiole nutrient contents

	K	Ca	Mg	Na
K	1.000			
Ca	-0.0029	1.000		
Mg	0.0019	0.2989*	1.000	
Na	0.0409	0.1638	0.3475*	1.000

Table 2. Correlations between soil and petiole cation contents

X parameter	Y parameter	r
Soil K	Petiole K	-0.291*
Soil Ca	Petiole Ca	-0.004
Soil Mg	Petiole Mg	-0.083
Soil Na	Petiole Na	-0.118

Interaction among cations was also dependent on their relative abundance in the root medium (Bayers,

Table 3. Linear relationship of soil nutrients with petiole contents in grape varieties and rootstocks

		Correlation coefficients (r)					
		Varieties			Rootstocks		
Soil nutrient	Petiole content	Thompson Seedless	2A Clone	Sonaka	Own root	Dog Ridge	110 R
K	K	0.045	-0.382	-0.359	-0.283	-0.285	-0.399
	Ca	0.077	-0.330	-0.089	0.313	-0.077	-0.443
	Mg	0.032	0.319	-0.089	0.054	0.063	-0.235
	Na	0.032	0.000	-0.095	0.376	-0.366	-0.352
Ca	Ca	-0.095	-0.032	0.288	-0.316	-0.044	0.418
	K	0.045	0.055	0.588*	-0.333	0.095	0.567*
	Mg	-0.167	-0.167	0.195	-0.212	0.138	0.173
	Na	0.326	0.055	-0.515*	0.359	0.089	0.333
Mg	Mg	-0.182	-0.504*	0.288	-0.207	0.045	0.134
	K	0.045	0.170	0.431	-0.363	0.465	0.435
	Ca	-0.239	-0.184	0.167	-0.385	0.237	0.071
	Na	0.167	0.000	-0.032	0.279	0.212	0.416
Na	Na	-0.167	-0.032	-0.406	0.373	-0.352	-0.418
	K	-0.032	-0.173	-0.032	0.122	-0.247	-0.348
	Ca	-0.084	0.452	0.210	0.000	0.510*	0.170
	Mg	0.179	0.361	-0.214	0.000	0.439	0.341

*Significant at P=0.0

1951; Emmert, 1959; Bergman *et al*., 1960) and was found to be synergistic under low levels but antagonistic under high levels (Fageria, 1983). Hence interactions were assessed in a quadratic relationship. Quadratic functions reflected the interactions among cations better than the linear functions with higher determination coefficients (**Table 4**). Regression equations for the significant quadratic relationship among soil and petiole contents of cations with their determination co-efficient and the threshold levels of soil cations associated with the lowest contents of other ions in petioles, are presented in Table-4 and the graphical presentation of the variation in the petiole contents in relation to the increasing levels of soil cation contents in **Figure 1.** Interaction among cations was complex in this study. A soil cation was found to influence more than one ion in the petiole; differently in different varieties and rootstocks.

Interaction of soil K^+: Increasing levels of soil K up to 1.59 me/100 g were associated with its increased contents in petioles in Sonaka and reduced on Dog Ridge rootstock up to 3.95 me/100 g. The threshold levels of soil K, beyond which the Ca content in the petiole on 110R rootstock and Na contents on Dog Ridge rootstock increased, were respectively 6.3 and 4.38 me/100 g. Soil K accounted for 22.9 per cent variation in the petiole K in Sonaka while for 39.6 per cent on Dog Ridge rootstock. It also accounted for 31.0 per cent variation in petiole Ca on 110R rootstock and 24.5 per cent in petiole Na on Dog Ridge rootstock.

Absorption of K by Sonaka was independent of other cation contents in the soil. Physiological demand for K seems to be more in Sonaka, irrespective of the root affinity for any cation in any rootstock. Optimum level of soil K seemed to be 1.59 me/100 g for this variety. Negative relationship of soil K with petiole K and Na on Dog Ridge rootstock suggests its higher affinity for other cations than K and dominant antagonism between Na and K on this rootstock.

Table 4: Quadratic relationship of the significant correlations of soil cations with petiole contents in grape varieties and rootstocks

Variety/ rootstock	Soil ion (X)	PetioleIon (Y)	Regression equation	R^2	Threshold level (me/100 g)
Sonaka	K	K	$35.4+33.5x-10.56x^2$	0.229*	1.59
Dog Ridge	K	K	$131.25-50.52x+6.39x^2$	0.396**	3.95
110R	K	Ca	$115.47-23.17x+1.84x^2$	0.310*	6.30
Dog Ridge	K	Na	$74.39-23.41x+2.67x^2$	0.245*	4.38
Sonaka	Ca	K	$120.98-8.12x+0.233x^2$	0.429**	17.42
110R	Ca	K	$22.68+1.52x+0.002x^2$	0.322*	-608.3
2A Clone	Ca	Ca	$449.73-27.29x+0.47x^2$	0.403**	29.03
Sonaka	Ca	Mg	$142.42x-9.79x+0.231x^2$	0.263*	21.19
Sonaka	Ca	Na	$59.39-1.7x+0.015x^2$	0.266*	56.67
Own root	Ca	Na	$110.36-6.51x+0.146x^2$	0.365**	22.29
110R	Mg	K	$-29.89+11.37x-0.32x^2$	0.222*	17.76
Own root	Mg	Ca	$242.69-26.53+0.99x^2$	0.223*	13.40
Sonaka	Mg	Mg	$93.41-10.19x+0.47x^2$	0.340*	10.84
Sonaka	Mg	Na	$-25.64+10.17x+0.436x^2$	0.272*	-11.66
Own root	Mg	Na	$113.78-15.13x+0.75x^2$	0.253*	10.09
2A Clone	Na	Ca	$169.3-82.44x+15.87x^2$	0.368**	2.60
Dog Ridge	Na	Ca	$-27.91+34.86x-1.53x^2$	0.260*	11.39
Dog Ridge	Na	Mg	$260.6-145.18x+23.8x^2$	0.300*	3.05

*Significant @P=0.05 **Significant @P=0.01

Interaction of soil Ca^{++}: Increasing levels of soil Ca were not associated with increase in petiole Ca in any variety or on any rootstock, but contrarily resulted in its quadratic reduction in 2A clone. The threshold level of soil Ca, beyond which its content increased was 29.03 me/100 g. Increasing levels of Ca in soil up to 17.42 me/100 g resulted in reduced contents of K in petioles in Sonaka but in steadily increasing K contents in a linear fashion on 110R. They were also found to reduce the petiole Na contents in Sonaka and in all varieties on their own roots. The threshold levels of soil Ca above which it was associated with increasing levels in petiole Na were 56.67 and 22.29 me/100 g respectively for Sonaka and own rooted vines of other varieties. Increasing levels of Ca in soil up to 21.19me/100 g were associated with reduced content of Mg in the petioles of Sonaka, above which, Mg contents increased. Soil Ca was found to determine its content in petiole by 40.3 per cent in 2A Clone. It accounted for variation in petiole K by 42.9 per cent in Sonaka, and 32.2 per cent on 110R rootstock. It also accounted for 26.3 per cent variation in petiole Mg. Soil Ca was also found to determine the petiole Na contents by 26.6 and 36.5 per cent respectively in Sonaka and own rooted vines.

Reduction in petiole Ca with increasing levels of soil Ca was due to either less physiological need by 2A clone or strong antagonism of other cations in the soil. Soil Ca at higher levels was synergistic to K in Sonaka and on 110R and to Mg in Sonaka. It was antagonistic to Na in Sonaka but synergistic at higher levels on own root. Thus, Sonaka proved to be a better bet for the utilization of available soil K and Mg; and restricting the sodium absorption in soils with high available Ca (> than 20 me/100 g). Higher absorption of Na by own rooted vines of all variety suggests the

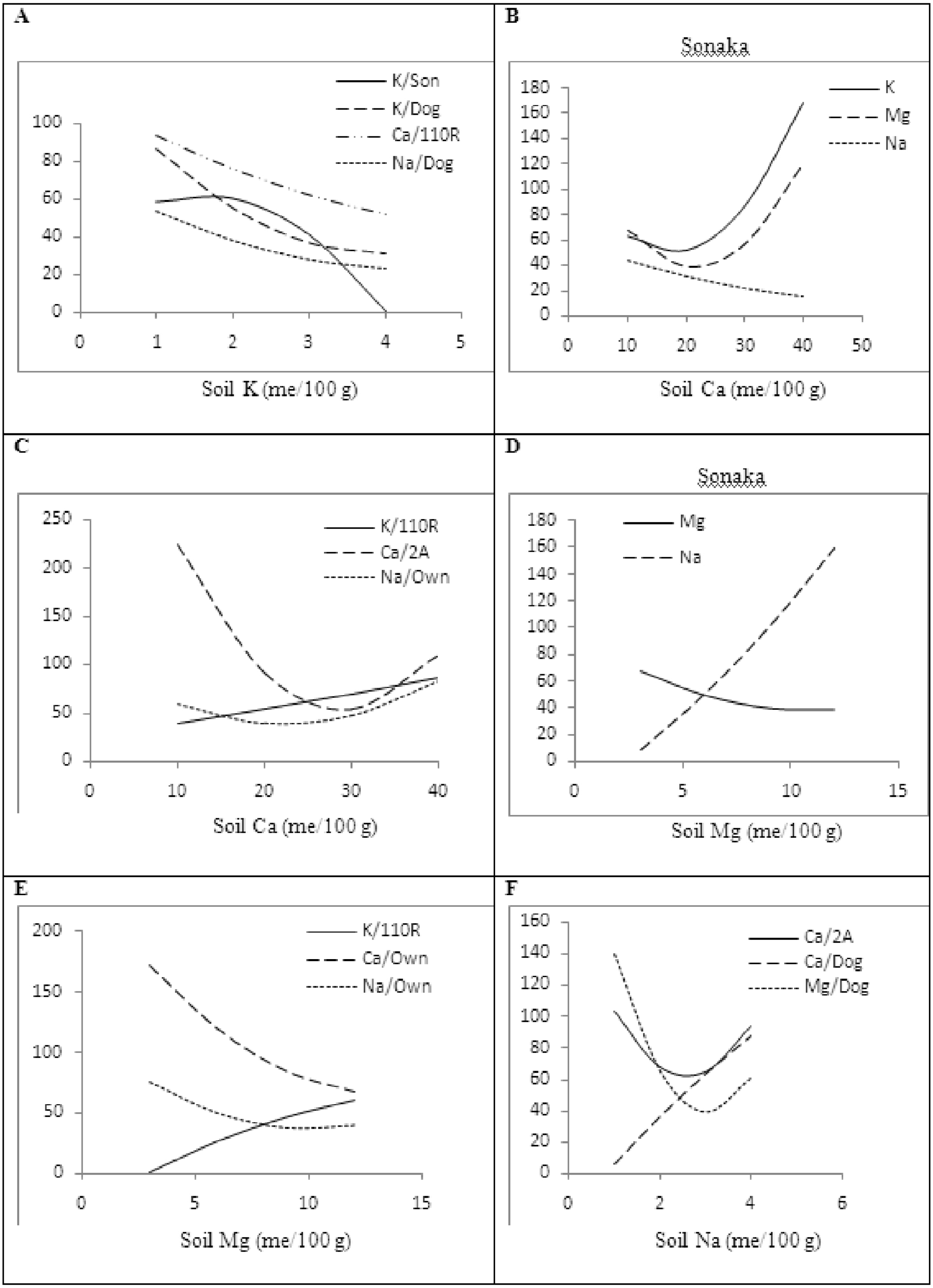

Fig.1: Relationship of soil cations with petiole contents (Y- axis) in me/100 g in grape varieties /rootstocks

use of either Dog Ridge or 110R rootstock; particularly 110R for better utilization of K in such soils.

Interaction of soil Mg^{++}: Increasing levels of Soil Mg up to 10.84 me/100 g were found to reduce its contents in Sonaka but not in any other variety or on any root stock. Higher levels of soil Mg up to 17.76 me/100 g were associated with higher petiole contents of K on 110R rootstock. Increasing levels of soil Mg up to 13.4 me/100 g reduced the petiole Ca in vines on their own roots. They increased the petiole Na steadily in a linear fashion in Sonaka. Increasing levels of soil Mg up to 10.09 me/100 g were associated with reduced contents of Na in the petioles of vines on their own roots. Soil Mg was found to determine the petiole Mg by 34.0 per cent in Sonaka only but not in other varieties or on any rootstock. It also accounted for 22.2 per cent variation in petiole K on 110R rootstock and 22.3 per cent in the petiole Ca in own rooted vines. Soil Mg determined the petiole Na content by 27.2 per cent in Sonaka and 25.3 per cent in vines on their own roots.

Reduction in petiole Mg with its increasing soil levels; and strong synergism of soil Mg with petiole Na in Sonaka imply that either the physiological needs are less or its roots have less affinity for Mg and more affinity for Na. Synergism of soil Mg with petiole K on 110R rootstock can be attributed to its root affinity. Positive relationship between two cations is possible, when a third dominating one simultaneously suppresses their absorption. Such phenomenon was observed by Shikhamany and Satyanarayana(1972) in grape. Strong antagonism of soil Mg with petiole Ca and Na points out that management of available soil Mg is crucial in balancing the absorption of Ca and Na in vines of any variety on their own roots.

Interaction of soil Na^{+}: Higher levels of Soil Na up to 2.6me/100 g were associated with reduced petiole Ca content in 2A clone. Soil Na up to 11.39/100 g increased the Ca contents steadily, but reduced the Mg contents up to its level of 3.05me/100 g on Dog Ridge. Soil Na accounted for variation in the petiole Ca by 36.8 per cent in 2A Clone and 26.0 per cent on Dog Ridge rootstock. It also accounted for30.0 per cent variation in petiole Mg on Dog Ridge.

The negative relationship of soil Na with petiole Mg but positive one with petiole Ca on Dog Ridge rootstock indicates the greater affinity of its roots for Ca than Mg in soils with high available Na content. Soil Na at its lower levels although reduced the absorption of Ca, increased it at higher levels in 2A clone.

Interaction with petiole contents: Individual cation contents in the petioles were influenced by many soil cations; differently in different varieties and rootstocks. Their co-efficient of determination by all the four soil cations together in different varieties and rootstocks is presented in **Table 5**. Individual effects of soil cations (**Table 4**) were masked by their mutual interactions in their combined effect. The normalized petiole contents in relation to their respective soil contents in varieties on different rootstocks are presented in **Table 6.**

Interaction with K: Petiole K was influenced by soil K as well as ca in Sonaka with their respective determinations of 22.9 and 42.9 per cent as against 57.2 per cent by all the soil cations together. Soil Ca was found to influence the petiole K more than soil K. Soil Ca and Mg had synergistic effect, whereas Na had strong antagonism on the absorption of K. Thus soil Na reduced the absorption of K by antagonizing with soil K, Ca and Mg in Sonaka.

Petiole K contents were also influenced by soil Ca and Mg on 110R rootstock. They respectively accounted for 32.2 and 22.2 per cent variation in the petiole K content as against 44.0 per cent by all the soil cations together. Antagonistic effect of soil Na on reducing the synergistic effect of soil Ca and Mg on K was evident on 110R rootstock also. Petiole K content was also found to be determined by 39.6 per cent by soil K on Dog Ridge rootstock, as against 28.5 per cent by all the soil cations together. In addition to antagonizing K, soil Na suppressed the synergistic effect of soil Mg in K absorption. This was how, the relatively higher absorption of K by Sonaka and on 110R rootstock; and less absorption on Dog Ridge rootstock (Table-6).

Interaction with Ca: Petiole Ca varied differently with soil Ca and Na levels in 2A Clone. They respectively accounted for 40.3 and 36.8 per cent variation in petiole Ca, as against 32.4 per cent by all the soil cations together. Soil K and Mg antagonized

Table 5. Multiple Regression equations for the relationship of nutrient ion contents (me/100 g) of petioles(Y) and soil (X) in grape varieties and root stocks.

VARIETY	Y parameter	Regression equation	R^2
Thompson Seedless	Petiole K	$Y= 42.25 +0.409K +0.079Ca +0.193Mg -0.615Na$	0.005
	Petiole Ca	$Y= 98.05 +2.844K +0.976Ca -5.767Mg -0.509Na$	0.083
	Petiole Mg	$Y= 28.69 +1.96K -0.258Ca -1.341Mg +8.026Na$	0.108
	Petiole Na	$Y= 42.2 -0.596K +1.075Ca -0.722Mg -6.426Na$	0.179
2A Clone	Petiole K	$Y=105.11 -17.84K -0.174Ca +0.798Mg -5.545Na$	0.223*
	Petiole Ca	$Y=103.99 -19.08K +0.702Ca -3.56Mg +11.55Na$	0.324*
	Petiole Mg	$Y= 58.22 +2.78K +0.78Ca -4.02Mg +5.77Na$	0.431**
	Petiole Na	$Y= 34.55 +0.97K +0.29Ca -0.37Mg -0.32Na$	0.006
Sonaka	Petiole K	$Y=5.13 -1.75K +2.55Ca +1.84Mg -6.96Na$	0.572**
	Petiole Ca	$Y=60.49 -13.76K -0.23Ca +1.0Mg +11.41Na$	0.154
	Petiole Mg	$Y= 30.78 -2.79K +0.53Ca +1.25Mg -3.09Na$	0.291*
	Petiole Na	$Y= 46.15 +2.1K -0.93Ca +0.81Mg -3.48Na$	0.379**
ROOTSTOCK			
Own root	Petiole K	$Y=66.95 -2.87K -0.36Ca -1.53Mg +7.25Na$	0.463**
	Petiole Ca	$Y=119.2 +8.8K -1.42Ca -3.77Mg +2.4Na$	0.368**
	Petiole Mg	$Y=58.72 +0.64K -0.38Ca -0.61Mg +1.8Na$	0.087
	Petiole Na	$Y= 20.4 -2.11K +0.42Ca +0.18Mg +2.17Na$	0.209
Dog Ridge	Petiole K	$Y=30.84 -2.27K -0.66Ca +4.1Mg -3.33Na$	0.285*
	Petiole Ca	$Y=-73.25 -0.25K -2.26Ca +7.65Mg +32.48Na$	0.507**
	Petiole Mg	$Y=-19.52 +0.75K +0.11Ca +1.22Mg +14.82Na$	0.220*
	Petiole Na	$Y= 60.08 -3.71K +0.25Ca -0.02Mg -7.07Na$	0.239*
110 R	Petiole K	$Y=65.32 -2.03K +1.27Ca -0.18Mg -8.41Na$	0.440**
	Petiole Ca	$Y=70.47-4.59K +2.16Ca -4.0Mg +3.8Na$	0.374**
	Petiole Mg	$Y=19.08 -0.62K +0.13Ca +0.29Mg +4.74Na$	0.175
	Petiole Na	$Y= 37.02 -1.18K -0.002Ca +0.56Mg -4.268Na$	0.360**

Ca and Na in reducing their synergistic effect on Ca absorption.

Petiole Ca contents were also influenced by soil Mg on own roots; soil K on 110R and Soil Na on Dog Ridge. While soil Mg explained the variation in petiole Ca by 22.3 per cent, all the soil cations together did 36.8 per cent. Ca absorption was antagonized by Mg, but soil K and Na increased it in own rooted vines. Soil K accounted for 31.0 per cent variation in petiole Ca on 110R rootstock, as against 37.4 per cent by all the soil cations together. While soil K and Mg antagonized, Na increased the absorption of Ca on this rootstock. Soil Na was found to explain the variation in petiole Ca by 26.0 per cent on Dog Ridge rootstock as against 50.7 per cent by all the soil cations together. Soil Mg enhanced the favourable effect of Na in Ca absorption. Thus these cation interactions contributed for less absorption of Ca by 2A Clone and 110R rootstock; and further less in 2A Clone on Dog Ridge rootstock, but more in own rooted vines of Sonaka and Thompson Seedless (Table-6).

Interaction with Mg: Petiole Mg was influenced by Ca and Mg levels in soil accounting respectively for 26.3 and 34.0 per cent variability in petiole Mg

Table 6: Cation composition of soil and petioles (me/100 g) of vineyards

Variety/ rootstock	Petiole contents (mean of 6 samples)				Soil contents (mean of 6 samples)				Ratio of petiole/ soil contents			
	K$^+$	Na$^+$	Ca^{++}	Mg^{++}	K$^+$	Na$^+$	Ca^{++}	Mg^{++}	K$^+$	Na$^+$	Ca^{++}	Mg^{++}
Thompson Seedless/ Own root	30.6	50.4	88.0	48.6	4.81	3.39	24.4	11.2	6.36	14.9	3.61	4.33
Thompson Seedless/ Dog Ridge	39.2	28.3	64.9	48.5	3.88	3.31	21.5	11.0	10.1	8.55	3.03	4.43
Thompson Seedless/ 110R	48.1	22.2	51.8	35.9	5.07	3.33	19.5	10.3	9.48	6.65	2.65	3.49
2A Clone/ Own root	58.7	44.5	70.8	54.6	2.26	3.06	25.5	12.1	26.0	14.5	2.78	4.53
2A Clone/ Dog Ridge	53.5	41.2	66.1	53.4	2.0	3.0	26.2	12.7	26.8	13.9	2.52	4.21
2A Clone/ 110R	63.1	29.6	82.6	40.6	1.7	3.1	27.4	14.3	36.3	9.60	3.02	2.84
Sonaka/ Own root	52.3	36.0	70.7	47.1	1.4	1.8	17.6	10.2	38.4	20.0	4.02	4.60
Sonaka/ Dog Ridge	46.7	28.0	70.9	37.2	2.6	3.3	19.7	11.1	18.1	8.56	3.58	3.36
Sonaka/ 110R	68.3	28.3	75.9	41.7	1.9	3.3	23.7	13.3	35.9	8.51	2.21	3.14
Mean	51.2	34.3	71.3	45.3	2.8	3.1	22.8	11.8	23.1	11.7	3.05	3.88
SD±	11.7	9.30	10.5	6.75	1.4	0.8	5.94	2.46	12.5	4.35	0.59	0.67
CV%	22.9	27.2	14.7	14.9	48.7	24.7	26.0	20.2	54.3	37.3	19.3	17.3

content, while all the soil cations together for 29.1 per cent in Sonaka. This was due to the suppression of Mg absorption by soil K and Na. Petiole Mg was also influenced by soil Na on Dog Ridge. While all the soil cations together accounted for 22.0 per cent variation in petiole Mg, soil Na alone for 30.0 per cent. Soil Na contributed more than soil Mg in the absorption of Mg by this rootstock. Absorption of cations, including Na, was highest in Sonaka on its own roots. Na absorption was reduced by the rootstocks in this variety (Table-6). Since absorption of Mg was favoured by soil Na on Dog Ridge, this rootstock is better for the management of Mg nutrition in Sonaka in soils with high levels of available Na.

Interaction with Na: Absorption of Na was influenced by soil Ca and Mg in Sonaka. They were found to determine the petiole Na by 26.6 and 27.2 per cent respectively as against 37.9 per cent by all soil cations together. Soil K had synergistic effect on Soil Na in the absorption of Na in this variety. Soil Ca and Mg also influenced the absorption of Na by vines on their own roots. They accounted respectively for 36.5 and 25.3 per cent variation in the petiole Na contents, while all the soil cations together accounted for 20.9 per cent only. Favourable effect of Ca and Mg on the absorption of Na was suppressed by soil K in own rooted vines. Soil K influenced Na absorption on Dog Ridge rootstock with a determination of 24.5 per cent as against 23.9 per cent by all the soil cations together. Soil Ca reduced the suppressing effect of soil K in the absorption of Na by Dog Ridge rootstock. These interactions suggested the use of rootstocks for Sonaka and application of higher doses of potash to vines on their own roots or Dog Ridge rootstock to limit the absorption of Na.

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