

Investigations in to Cation Equilibrium in Grape (*Vitis Vinifera* L.)

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Abstract – Investigations were carried out in Thompson Seedless grape and its clones, grown on their own root and different rootstocks to study whether the cation equilibrium varies with rootstock, tissues and phenological stage. Cation equilibrium was constant among the clones of Thompson Seedless but not with rootstocks, phenological stages or tissues. Constancy in equilibrium was observed in Thompson seedless on Dog Ridge but not on Salt Creek and 110R rootstocks. Though Dog Ridge did not alter the equilibrium, it resulted in the increased proportion of K^+ and reduced Na^+ . Similarly, K^+ increased but Ca^{++} , Mg^{++} and Na^+ decreased, though the total cations did not vary in 2A on 1103 P. Increase in total cations in Thompson Seedless on Salt Creek was due to increase in the proportion of Na^+ , while on 110R due to increase in K^+ and Na^+ and reduction in Ca^{++} . Equilibrium also existed between petioles and laminae at fruit bud differentiation stage but not at full bloom. Stages differed in cation equilibrium in petioles. Variation in the proportion of individual cations in different plant tissues at a given phenological stage was attributed to the readjustment of ions between the tissues and that in the same tissue at different phenological stages can be attributed to the differential metabolic needs of cations. Cation equilibrium constancy between vines on their own root and on Dog Ridge indicated the scion directed absorption of cations, whereas the differences in the equilibrium on Salt Creek and 110 R indicated differential absorption by roots. This necessitates investigations in to the rootstock effect on organic acids metabolism in grapevines and to establish whether the increased cations in the foliar tissues is due to the absorption of cations by roots or the increased synthesis of organic anions in vines on these rootstocks.

Keywords – Cation Equilibrium, Grape, Varieties, Rootstocks, Tissues, Stages.

I. INTRODUCTION

It is a well-established fact that the summation of equivalents of cations in the plant tissue of a same genotype is constant (Bear and Prince, 1944; Itallie, 1948). This constancy was observed in all parts of tomato plants of a given variety at a given time (Kirkby and Mengel, 1967). But the information on the cation equilibrium at different phenological stages, in different plant tissues in a same genotype of perennial fruit tree on different rootstocks is missing. Hence investigations were carried out in Thompson Seedless grape and its clones, namely Tas-A-Ganesh and 2A, grown on their own root and different rootstocks to study whether the cation equilibrium is constant;

i) With rootstock, in light of the fact that composition of cations in leaf tissues varied with rootstock used (Cook and Lider, 1964; Downton, 1977; Fisarakis *et al.*, 2005),

ii) In petioles and laminae, as their cation composition was different (Shikhamany and Satyanarayana, 1971) and petioles are the index tissues of the nutrient status of vines and lamina is the site of all metabolic activities, particularly the synthesis of organic acids (Kliewer, 1966) and organic acids play a vital role in balancing the total electrical charge of cations in the plant tissues (Pierce and Appleman, 1943; Jacobson and Ordin, 1954) and

iii) At fruit bud differentiation and full bloom, which are distinctly at different stages in the tropics and have different metabolic activities.

Results of these investigations will also help understand the differential affinity of roots for cations, the metabolic needs of cations at different phenological stages and the readjustment of cations in the foliar tissues in addition to establishing the base equilibrium constancy in Thompson Seedless grape and its clones.

II. MATERIAL AND METHODS

Nutritional surveys conducted by the Petiole Analysis Advisory Services of the R&D Division of the Maharashtra State Grape Growers' Association were the source of data for these investigations. Eighty petioles, opposite to flower clusters were collected at random for each sample separately from 25 vineyards each of Thompson seedless, Tas-A-Ganesh and 2A Clone (2A) on Dog Ridge (DR) rootstock to study the variation in cation equilibrium in varieties. Tas-A-Ganesh is a bud sport of Thompson Seedless identified by a progressive grower in Maharashtra, while 2A clone was developed at Kearney Experimental Station, UC Davis, California, USA. Twenty four samples of Thompson Seedless each on their own root, on Dog Ridge, Salt Creek and 110 R were analysed to assess the influence of rootstocks, if any, on cation equilibrium in Thompson Seedless. Whereas, 20 samples of 2A clone each on own root, Dog Ridge and 1103 P were analyzed. Leaf samples from 25 vineyards of Thompson Seedless on Dog Ridge were collected at fruit bud differentiation stage (45 days after back pruning) and full bloom. Leaves at the fifth nodal position on the shoots above the condensed node were collected at fruit bud differentiation, while the leaves opposite to flower clusters at full bloom. The vineyards surveyed were in different locations in the state of Maharashtra, raised in soils with different levels available nutrients, pH, EC_e , $CaCO_3$ and ESP levels. Vines were in the age group of 5-7 years, uniformly spaced at 1.8m x 2.7m trained to extended Y trellis receiving varying forms and levels of nutrients. Leaves were separated for petioles and laminae. K, Ca, Mg and Na contents were estimated separately in petiole and

lamina contents by standard laboratory procedures. Their per cent contents were converted to me/100g. The significance of the differences in the means of individual and total cation contents among varieties and rootstocks, petioles vs. Laminas; differentiation vs. full bloom stages were tested by t-test assuming unequal variances using the Microsoft Excel data analysis package.

III. RESULTS AND DISCUSSION

Equilibrium among Varieties:

Total cation contents in the petioles of Thompson Seedless on Dog Ridge rootstock at full bloom was 179.1 ± 34.4 me/100g compared to 184.3 ± 28.5 me/100 g in Tas-A-Ganesh and 198.8 ± 36.4 me/100 g in 2A clone. Their means did not differ significantly. The proportions of total divalent cations, total monovalent cations or the individual cations did not differ significantly among Thompson Seedless and its clones (table 1). These results indicate that Tas-A-Ganesh and 2A clone being the Clonal selections from Thompson Seedless and propagated vegetatively, they are similar in demand for cation nutrients. Secondly, Dog Ridge did not differ in its absorption of cations under the influence of these varieties.

Equilibrium among Rootstocks:

The total cation content in petioles of Thompson Seedless on own root at full bloom was 186.5 ± 41.4 me/100g, while 179.3 ± 34.4 me/100g on Dog Ridge, 213.3 ± 45.4 me/100g on Salt Creek and 224.0 ± 70.3 me/100 g on 110 R. Rootstocks influenced the total cations significantly in Thompson seedless. While Dog Ridge did not influence, Salt Creek and 110R rootstocks had more total cations in the petioles of Thompson Seedless compared to own rooted vines (Table 2). Cations in the foliar tissues are balanced by anions. Anions include the inorganic ions (NO_3^- , H_2PO_4^- , SO_4^{2-} and Cl^-) absorbed from soil and the organic acids synthesized in the plant tissues (Kirkby and Mengel, 1967). In light of this, the higher cations content can be attributed to the increased anion absorption by the roots or increased synthesis of organic anions by Thompson Seedless under the influence of the rootstocks. If it is rootstock directed higher synthesis of organic ions, the cause is the synthesis of organic acids, result being cation absorption; and vice-versa. More weight needs to be given to the latter situation which points out higher affinity of the roots of Salt Creek and 110R for anions compared to Thompson seedless and Dog Ridge. Although Thompson Seedless vines on their own root and on Dog Ridge did not differ in total cation content, Thompson Seedless resulted in more proportion of K^+ ions compared to Dog Ridge. To maintain the equilibrium of cations, Na proportion increased on Dog Ridge (Table 2). Higher content of total cations was as a result of higher proportion of Na on Salt Creek, while higher proportions of both K and Na; and less proportion of Ca on 110R. Higher proportion of Na on rootstocks should not be linked to their preferential absorption of Na over K. It is only due to readjustment of ions in petioles to maintain the equilibrium. Total cation content at full bloom in the petioles of 2A clone on its own root was

205.8 ± 33.9 me/100g, whereas 199.4 ± 36.4 me/100g on Dog Ridge and 222.2 ± 35.0 me/100g on 1103 P. It did not vary significantly under the influence of either Dog Ridge or 1103 P rootstocks. While total cation content being constant, the proportion of divalent cations was less but of monovalent ones more on 1103 P compared to own rooted vines (Table 3). Own rooted vines had higher proportions of Ca, Mg and Na, while vines on 1103P had higher proportion of K. Thus the equilibrium in the cations of petioles of own rooted vines was maintained by the other three cations.

Equilibrium between Tissues:

The total cation content over stages in the petioles of Thompson Seedless on Dog Ridge was 211.4 ± 38.0 me/100g, whereas, 204.9 ± 43.2 me/100g in laminas. Cation equilibrium between petioles (P) and laminas (L) was constant in Thompson Seedless on Dog Ridge over the stages (fruit bud differentiation and full bloom). Equilibrium also existed between petioles and laminas at fruit bud differentiation stage but not at full bloom. Petiole had more cations than laminas at full bloom (Table 4). Although the equilibrium of total cations over the stages was constant between petioles and laminas, the total divalent cations were more in laminas while the monovalent cations in petioles. The individual divalent cations, namely Ca and Mg were also more in laminas and the individual monovalent ones were more in petioles. Proportion of individual and total divalent or monovalent cations at fruit bud differentiation in petioles (DP) and Laminas (DL) or at full bloom in petioles (BP) and laminas (BL) were similar to their mean values (P and L), except the proportion of Mg (Table 4). The proportion of Mg in laminas was more than petioles at full bloom, but not at differentiation. Less proportion of any ion in petioles is the indication of its movement in to laminas to participate in the metabolic functions or neutralize the organic anions synthesized in the laminas. Proportion of Ca in petioles being less at both the stages, it can be inferred that it moved in to laminas to neutralize the organic acids synthesized in laminas. Similarly, Mg moved from petioles to laminas at full bloom. Increased Mg content in lamina is the resultant of Mg role in nucleic acid synthesis and energy transfer, in addition to chlorophyll synthesis in laminas. On the other hand, less proportion of ions in laminas imply the movement of their compounds from laminas in to physiological sinks. Proportions of K and Na both at differentiation and full bloom stages were less in laminas. K has a role in fruit bud formation (Srinivasan and Mullins, 1981) and is implicated in the regulation of many enzymes associated with carbohydrate metabolism during flowering and berry set. Na substitutes K in its physiological functions in grapevines (Shikhamany and Sharma, 2008)

Equilibrium between Stages:

The mean content of total cations over the tissues in Thompson Seedless on Dog ridge was 203.6 ± 42.1 me/100g at fruit bud differentiation and 212.7 ± 39.4 me/100g at full bloom. Total cation contents did not differ significantly at fruit bud differentiation (D) compared to full bloom (B), nor the lamina contents differed, but petiole contents differed. Petioles at full bloom had more cations than at differentiation

(Table 5). Proportion of total or individual divalent cations; or total or individual monovalent cations did not differ significantly between stages either over the tissues or in petioles, but differed in laminas. Proportion of total divalent cations was more in laminas at full bloom, contributed by Mg alone, while that of monovalent cations more at differentiation, contributed by K and Na. Based on the significant increase in laminas, it can be inferred that, Ca has greater metabolic role at differentiation, while both Ca and Mg at full bloom. Laminas being the sites of all metabolic functions, particularly the synthesis of organic acids (Kliewer, 1966), the differences could be attributed to the differential translocation of cations from petioles into laminas as per the metabolic needs and substitution by other cations either by root absorption or from laminas to maintain cation equilibrium.

While the variation in the proportion of individual cations in different plant tissues at a given phenological stage was attributable to the readjustment of ions between the tissues as a result of metabolic demand for ions in the functional tissue, variation in the same tissue at different phenological stages can be attributed to the differential metabolic needs of cations. Cation equilibrium constancy between vines on their own root and on Dog Ridge in case of Thompson seedless and 2A clone hinted at scion directed absorption of cations, whereas the differences in the equilibrium on Salt Creek and 110 R indicated differential absorption by roots. This necessitates investigations in to the rootstock effect on organic acids metabolism in grapevines and to establish whether the increased cations in the foliar tissues is due to the absorption of cations by roots or the increased synthesis of organic anions in vines on these rootstocks.

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Table 1. Comparison cation contents (me/100g) in grape varieties on Dog Ridge rootstock at full bloom

Variety	Total cations	Proportion of ions (%)					
		K+	Ca ⁺⁺	Mg ⁺⁺	Na+	Total ⁺⁺	Total ⁺
TS	179.1	25.0	34.7	23.4	16.9	58.1	41.9
TAG	184.3	27.2	31.2	21.9	19.7	53.1	46.9
2A	198.8	24.1	33.5	24.1	18.3	57.6	42.4
t-TS vs TAG	-0.576 (NS)	-1.236(NS)	1.656 (NS)	1.009 (NS)	-1.184 (NS)	1.983 (NS)	-1.983 (NS)
t-TS vs 2A	-2.007 (NS)	0.426 (NS)	0.515 (NS)	-0.518 (NS)	-0.753 (NS)	0.178 (NS)	-0.178 (NS)
t-TAG vs 2A	-1.594 (NS)	1.394 (NS)	-1.026 (NS)	-1.676 (NS)	0.992 (NS)	-1.684 (NS)	1.684 (NS)

TS= Thompson Seedless; TAG= Tas-A-Ganesh; 2A= 2A Clone

++ = Divalent cations; + = Monovalent cations

NS= Not significant

Table 2. Comparison of cation contents (me/100g) in Thompson Seedless on rootstocks at full bloom

Rootstocks	Total cations	Proportion of ions (%)					
		K+	Ca ⁺⁺	Mg ⁺⁺	Na+	Total ⁺⁺	Total ⁺
Own root	186.5	28.5	34.2	23.9	13.3	58.2	41.8
Dog Ridge	179.3	24.8	34.5	23.4	17.3	57.8	42.2
Salt Creek	213.3	26.7	31.5	23.6	18.1	55.1	44.9
110 R	224.0	34.9	24.9	22.4	17.8	47.3	52.7
t- OR vs DR	0.647	2.350*	-0.116	0.357	-2.270*	0.141	-0.141
t- OR vs SC	-2.090*	0.902	1.302	0.223	-3.303**	1.343	-1.343
t- OR vs 110R	-2.202*	-3.346**	4.669**	1.118	-3.452**	5.035**	-5.035**

OR= Own Root; DR= Dog Ridge; SC= Salt Creek

++ = Divalent cations; + = Monovalent cations

*t-significant @ P=0.05; **t-significant @P=0.01

Table 3. Comparison of cation contents (me/100g) in 2A clone on rootstocks at full bloom

Rootstocks	Total cations	Proportion of ions (%)					
		K+	Ca ⁺⁺	Mg ⁺⁺	Na+	Total ⁺⁺	Total ⁺
Own root	205.8	25.4	30.7	25.2	18.7	55.9	44.1
Dog Ridge	199.4	24.3	32.7	23.9	19.0	56.6	43.4
1103 P	222.2	40.4	25.0	20.6	14.4	45.6	54.4
t- OR vs DR	0.574	0.457	-0.903	0.824	-0.153	-0.278	0.278
t- OR vs 1103 P	-1.509	-5.440**	2.354*	3.106**	2.744**	3.319**	-3.319**

OR= Own Root; DR = Dog Ridge; ++ = Divalent cations; + = Monovalent cations

*t-significant @ P= 0.05; **t-significant @P=0.01

Table 4. Comparison of cation contents (me/100g) in petioles and laminas at different stages in Thompson Seedless on Dog Ridge rootstock

Tissue/ Stage	Total cations	Proportion of K (%)	Proportion of Ca (%)	Proportion of Mg (%)	Proportion of Na (%)	Proportion of ++ (%)	Proportion of + (%)
P	211.4	24.9	32.1	23.7	19.3	55.8	44.2
L	204.9	16.7	43.3	26.8	13.2	70.1	29.9
t-Stat	0.793	6.344	-7.500	-2.742	5.962	-8.982	8.982
t-test	NS	**	**	**	**	**	**
DP	197.7	24.5	32.9	24.5	18.1	57.4	42.6
DL	209.6	18.2	42.3	24.7	14.7	67.0	33.0
t-Stat	-0.997	3.103	-4.822	-0.081	2.373	-4.243	4.243
t-test	NS	**	**	NS	*	**	**
BP	225.2	25.4	31.3	22.9	20.5	54.1	45.9
BL	200.3	15.1	44.3	29.0	11.7	73.2	26.8
t-Stat	2.311	6.320	-5.714	-4.845	6.327	-9.241	9.241
t-test	*	**	**	**	**	**	**

P = Petiole; L = Lamina; D= Fruit bud Differentiation; B= Full Bloom

P= Mean of cations over stages in petioles

L= Mean of cations over stages in laminas

++ = Divalent cations; + = Monovalent cations

*t-significant @ P=0.05; **t-significant @P=0.01; NS= Not significant

Table 5. Comparison of cation contents (me/100g) at different stages in petioles and laminas in Thompson Seedless on Dog Ridge rootstock

Tissue/ Stage	Total cations	Proportion of K (%)	Proportion of Ca (%)	Proportion of Mg (%)	Proportion of Na (%)	Proportion of ++ (%)	Proportion of + (%)
D	203.6	21.4	37.6	24.6	16.4	62.2	37.8
B	212.7	20.3	37.8	25.9	16.1	63.7	36.3
t-Stat	-1.111	0.719	-0.077	-1.121	0.292	-0.678	0.678
t-test	NS	NS	NS	NS	NS	NS	NS
DP	197.7	24.5	32.9	24.5	18.1	57.4	42.6
BP	225.2	25.4	31.3	22.9	20.5	54.1	45.9
t-Stat	-2.691	-0.396	0.733	1.169	-1.401	1.303	-1.303
t-test	*	NS	NS	NS	NS	NS	NS
DL	209.6	18.2	42.3	24.7	14.7	67.0	33.0
BL	200.3	15.1	44.3	29.0	11.7	73.2	26.8
t-Stat	0.749	2.453	-0.941	-2.546	3.033	-3.535	3.535
t-test	NS	*	NS	*	**	**	**

P= Petiole; L= Lamina; D= Fruit bud Differentiation; B= Full Bloom

D= Mean of cations over tissues at differentiation

B= Mean of cations over tissues at full bloom

++ = Divalent cations; + = Monovalent cations

*t-significant @ P=0.05; **t-significant @P=0.01; NS= Not significant

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