

Nutrient Utilization during Fruiting Season in Thompson Seedless Grape (*Vitis vinifera* L.) on Dogridge in the Tropics

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Abstract – Variation in periodical changes in the petiole and lamina nutrient contents at 15-day intervals starting from 45 days after fruit pruning (full bloom) to 150 days (Berry ripe) contents of nutrients in the petioles and lamina was used as an indicator of their need and utilization in various metabolic activities during fruiting season in Thompson Seedless vines grafted on Dogridge rootstock under tropical conditions. Increase in petiole nutrients reflected their need. While decrease in petiole nutrient contents with concurrent increase in lamina was indicative of their utilization in the synthesis of organic compounds in lamina, decrease in lamina contents, irrespective of the concurrent change in petioles indicated their movement in to berries to form the berry components. Reduction in lamina NO₃-N during 45-60, 105-135 days indicated its utilization in the synthesis of organic N compounds. Petiole Na reduced during 60-75 days when K increased, contrarily, it increased during 75-90 days when K decreased indicating the substitution of K by Na and preferential absorption of K during 60-75 days and of Na during 75-90 days. Stages of peaks followed by reduction in petiole nutrient contents were identified as the indicators of their need and utilization. Peaks corresponding to 60 days after pruning were of N and Mg, while 75 days for NO₃-N, K, Ca and Zn; 90 days for Fe, Mn, Cu and Na. The second peak was at 105 days for NO₃-N, N and Zn; at 120 days for K, Ca and Mg; at 135 days for Fe, Mn and Cu and 150 days for Na. There was also a third peak at 120 days for NO₃-N and 135 days for N and Zn. In light of these peaks the time and method of nutrient application need to be standardized to ensure the higher nutrient use efficiency.

Keywords – Fruiting season, Nutrient utilization, Petiole and Lamina contents, Thompson Seedless, Tropics.

I. INTRODUCTION

Periodical change in the nutrient status of petioles reflects their availability and of lamina their demand in grapevines at a given point of time. Concurrent decrease of a nutrient in the petioles and increase in the lamina is the indication of the depletion of petiole nutrient for the synthesis of its organic compounds in lamina. On the other hand, increase in petioles and non-significant change in lamina of a nutrient element at any stage is indicative of its luxury consumption. Either increase or non-significant change in petioles associated with a reduction in lamina or simultaneous reduction in a nutrient content in both the tissues indicate its depletion from leaves to berries. Seasonal variation in petiole nutrient composition documented earlier (1, 2, 3, 5) is limited to the indication of need in the temperate conditions; and depends on the available nutrients in the growing media at a given stage.

Petiole nutrient status indicates the availability but not its utilization at a given phenological stage, particularly in the tropics. While fruit bud formation for the next crop and the growth and development of clusters for the current crop take place in one season in temperate region, only cluster growth and development in fruiting season in the tropics. Cluster cane ratio in Thompson Seedless is approximately 2.0 in the tropics as against 8.0 in temperate regions. In the backdrop of the role of nutrients in various metabolic activities, absorption and utilization of nutrients will be different in the tropics. Hence the present studies were conducted to identify the role and need of different nutrients at different phenological stages of growth and development. Information generated by this study can help evolve precise fertigation schedule for Thompson Seedless grape on Dogridge rootstock in tropical viticulture.

II. MATERIAL AND METHODS

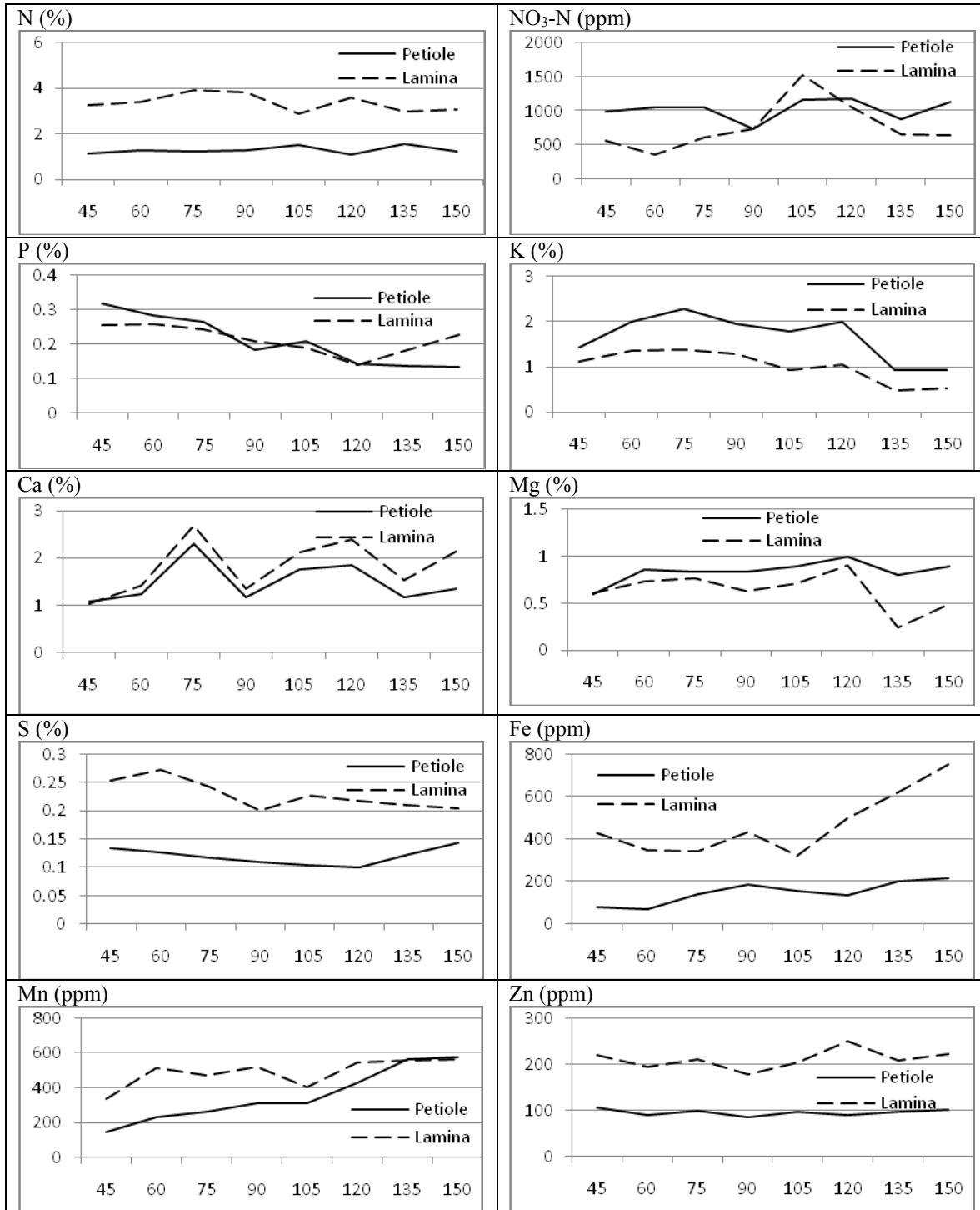
Leaf samples consisting of 100 youngest mature leaves (Fifth unfolded leaf from the shoot tip) were collected at random from three plots of Thompson Seedless on Dogridge rootstock at 15-day intervals starting from 45 days after fruit pruning (full bloom) to 150 days (Berry ripe) from the Research Station of Maharashtra Grape Growers' Association, Pune, India. All the vines selected for the study were planted at 2.7 x 1.8 m, trained to extended Y trellis and pruned to have 30±2 canes/vine. Collected leaves were separated for petioles and lamina. Total N, P, K, Ca, Mg, S, Na, Fe, Mn, Zn and Cu contents in petiole and lamina samples were estimated following the standard analytical methods suggested by the AOAC. Difference in the contents of petioles and lamina at every stage and also between two successive intervals separately in petioles and lamina were worked out for each nutrient. Significance of the difference was assessed by the standard error of means.

III. RESULTS AND DISCUSSION

Nutrient content of petioles was considered as its status in the vine as suggested by Cook (4). It is the potential of the nutrient to participate in various metabolic functions. A periodical change in it reflects the demand by the vines and its availability at the given time. The youngest mature leaf being the site of many metabolic functions and maintains balance in mobile and immobile nutrients, its nutrient content is considered as its need and utilization at that point of time. Concurrent decrease of a nutrient in the

petioles and increase in the lamina is the indication of the depletion of petiole nutrient for the synthesis of its organic compounds in lamina. On the other hand, either concurrent increase in petioles and decrease in lamina or simultaneous decrease of a nutrient in both the tissues indicates its depletion from leaves to berries. Hence the changes in the demand and utilization of each nutrient at

15-day intervals during the fruiting season are presented in the following paragraphs. Differences in nutrient contents in successive stages in respect of petioles and lamina are presented in Table 1, those between petiole and lamina contents at different stages in Table 2 and the graphical presentation of the petiole and lamina contents in Fig. 1.



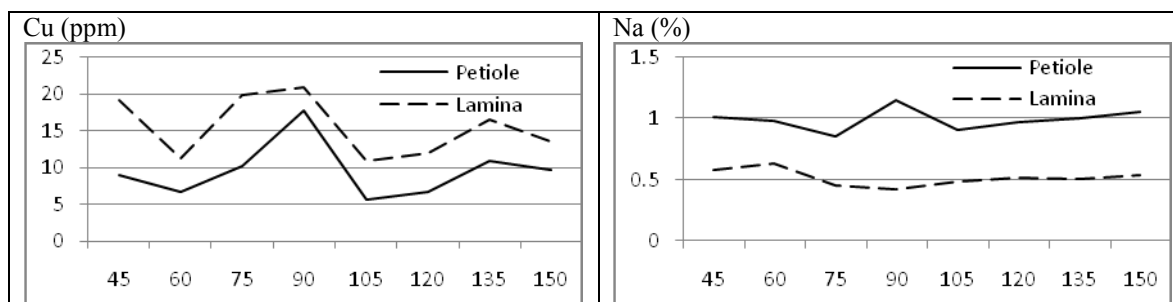


Fig. 1. Variation in nutrient contents of leaf tissues in Thompson Seedless grape
 Figures on X-axis represent the days after fruit pruning (____ Petiole contents; _ _ _ _ Lamina contents)

Table 1. Periodical changes in leaf nutrient contents

Nutrient	Leaf Tissue	Period of change (days after Fruit Pruning)							S Em±
		45to 60	60 to75	75 to90	90 to 105	105to120	120to135	135to150	
N(%)	Petiole	0.150*	-0.060*	0.036	0.244*	-0.427*	0.47*	-0.317*	0.058
	Lamina	0.13	0.527*	-0.094	-0.953*	0.693**	-0.616*	0.133	0.138
NO ₃ -N (ppm)	Petiole	60*	-4.3	-316.7*	-731*	13	-302*	251.3*	54.4
	Lamina	-216.5*	254.3*	132.4*	782.3*	-472.3*	-391*	-28.4	128
P(%)	Petiole	-0.034*	-0.02	-0.08*	0.024	-0.064*	-0.006	-0.004	0.025
	Lamina	0.004	-0.014	-0.036*	-0.017*	-0.05*	0.043*	0.044*	0.014
K(%)	Petiole	0.566*	0.284*	-0.334*	-0.166	0.216*	-1.066*	0	0.181
	Lamina	0.22*	0.034*	-0.1	-0.334*	0.117	-0.567*	0.05	0.121
Ca(%)	Petiole	0.153	1.077*	-1.15*	0.593*	0.107	-1.86*	0.177*	0.154
	Lamina	0.374*	1.276*	-1.336*	0.77*	0.283*	-0.87*	0.617*	0.206
Mg(%)	Petiole	0.264*	-0.027	0	0.06*	0.1*	-0.197*	0.094*	0.04
	Lamina	0.127*	0.037	-0.14*	0.083*	0.19*	-0.653*	0.246*	0.07
S(%)	Petiole	-0.006*	-0.01*	-0.008*	-0.006*	-0.003	0.023*	0.02*	0.005
	Lamina	0.02*	-0.03*	-0.043*	0.027*	-0.01*	-0.007	-0.007	0.009
Fe(ppm)	Petiole	-10.3	68.3*	46.7*	-29*	-21*	63.3*	16	18.56
	Lamina	-79.3*	-5.7	91.7*	-113.7*	176.7*	119.6*	134*	53.06
Mn(ppm)	Petiole	83.7*	36	48.3	-4	121*	132.7*	12.3	54.98
	Lamina	173.7*	-39.7*	51*	-119.3*	138.3*	15.4	5.3	28.34
Zn(ppm)	Petiole	-16*	8.7*	-14.4*	11*	-7*	8*	4.7*	2.52
	Lamina	-25.6*	15.3*	-31*	25.3*	45.4*	-40*	13*	7.39
Cu(ppm)	Petiole	-2.3*	3.6*	7.4*	-12*	1	4.3*	-1.3	1.34
	Lamina	-8*	8.7*	1	-10*	1	4.7*	-3*	1.46
Na(%)	Petiole	-0.03	-0.133*	0.3*	-0.25*	0.067*	0.033*	0.05*	0.032
	Lamina	0.053*	-0.183*	-0.033*	0.066*	0.034*	-0.017	0.033*	0.024

Table 2. Periodical changes in the difference in the nutrient contents of leaf tissues

Nutrient	Periodical Difference between tissue contents (petiole-lamina)								S Em±
	Days after fruit pruning								
	30	45	60	75	90	105	120	135	
N	-2.123*	-2.103*	-2.69*	-2.56*	-1.363*	-2.483*	-1.397*	-1.847*	0.179
NO ₃ -N	420.5*	697*	438.4*	-10.7	-356*	129.3*	218.3*	498*	117.8
P	0.064*	0.026*	0.02*	-0.024*	0.017	0.003	-0.046*	-0.094*	0.017
K	0.304	0.65	0.9	0.667	0.834	0.933	0.434	0.384	0.086
Ca	0.057	-0.164	-0.363	-0.177	-0.354	-0.53	-0.34	-0.78	0.089
Mg	-0.01	0.127	0.063	0.203	0.18	0.09	0.546	0.394	0.065
S	-0.12	-0.146	-0.126	-0.091	-0.124	-0.117	-0.087	-0.06	0.01
Fe	-346.7	-277.7	-203.7	-248.7	-164	-361.7	-418	-536	42.98
Mn	-190	-280	-204.3	-207	-91.7	-109	8.3	15.3	37.72
Zn	-113.3	-103.7	-110.3	-93.7	-108	-160.4	-112.4	-120.7	7.01
Cu	-10.3	-4.6	-9.7	-3.3	-5.3	-5.3	-5.7	-4	0.911
Na	0.433	0.35	0.4	0.733	0.417	0.45	0.5	0.517	0.041

Total Nitrogen

Demand for nitrogen changed in a cyclic rhythm with alternate increases and decreases at fortnightly intervals from the 45th day after pruning during fruiting season. N content in petiole decreased with concurrent increase in lamina during 60-75, 105-120 and 120-135 days after pruning. Increase in lamina N during 135-150 days was not significant. Increase of N in the lamina during 60-75 is the indication of the depletion of petiole N for the synthesis of chlorophyll and proteins in the lamina, since this period corresponds to the grand growth of shoots. During the period between 105 to 120 days berries grow by translocation of metabolites, mainly carbohydrates, organic acids and proteins. Hence the demand for N increased in the lamina for their synthesis. On the other hand, petiole N increased with concurrent decrease in lamina N during 90-105 and 120-135 days after pruning. Period between 90-105 days corresponds to post lag phase of berry growth. Organic nitrogenous compounds present in lamina translocate in to actively growing berries. Similarly, the period between 120-135 days is the period of berry ripening, during which biochemical changes, mainly degradation of acids and conversion of polysaccharides to monosaccharides take place, wherein many enzymes are involved. Enzymes basically being proteins and synthesized in lamina, move in to ripening berries, resulting in the depletion of total N content in lamina.

Nitrate Nitrogen

Petiole nitrate nitrogen content holds significance in grape nutrition because, N is absorbed as NO_3^- ion by grape roots and petiole nitrate-N content was shown as an indicator of N status of vines (9). As in total nitrogen, decrease in petiole nitrate N was associated with increase in lamina nitrate N and vice versa. Lamina nitrate N increased significantly during 60-75, 75-90 and 90-105 days, when its content in petioles decreased significantly, except during 60-75 days. Petiole nitrate is reduced to amides, amino acids and proteins in the lamina, which is reflected as its total nitrogen content. Thus the reduction in lamina nitrate N is the indication of its utilization in the nitrogen metabolism. Hence the pattern of variation of nitrate N in petioles and that of total nitrogen in the lamina was almost same, except between 75-90 and 90-105 days. Simultaneous reduction of nitrate N and total N in lamina during 120-135 days and increase during 60-75 days indicates the hindrance in the reduction of nitrate N.

Phosphorus

Reduction in petiole P was not associated with significant increase in lamina P during 45-60 days, but with significant reduction during 75-90 and 105-120 days after pruning. Similarly, significant increase in lamina P during 120-135 and 135-150 was not associated with significant reduction in petiole P. Thus the reduction as well as increase in petiole P was parallel in lamina. However there was significant reduction in lamina P during 75 days through 120 days, the period of berry growth and ripening. The inorganic P translocated in to lamina from petiole seems to have been utilized in the synthesis of nucleic acids, ATP and other organic

phosphorus compounds. Energy transfer is the main metabolic activity with which P is associated for berry growth and ripening. Simultaneous increase during 45-60 days and reduction during 75-90 days in lamina P with lamina contents of K, Ca and Mg indicates the movement of phosphate ions (PO_4^-) in to leaves and berries to balance the ionic charges during their respective stages of active growth.

Potassium

Unlike nitrogen, reduction in petiole K was not associated with increase in lamina K at different stages. It is because K exists in elemental form in both the tissues and it is involved in its physiological functions in the leaves remaining in elemental form only. Increase in petiole K contents was significant during 45-60, 60-75, 105-120 days after pruning, whereas only during 45-60 days in lamina K. While the reduction in petiole K was significant during 75-90 and 120-135 days, it was during 90-105 and 120-135 days in lamina K. Period between 90-105 days corresponds to post lag phase of berry growth, when K moves in to berries for osmoregulation. So also during 120-135 days to activate enzymes associated with carbohydrate metabolism.

Calcium

As in potassium, Ca content of petiole varied similar to lamina content. Both petiole and lamina Ca increased significantly during 60-75, 90-105, and 135-150 days after pruning, but lamina Ca only increased significantly during 45-60 and 105-120 days. Its reduction was significant in both the tissues during 75-90 and 120-135 days. Pattern of change in Ca contents of petioles and lamina was also similar to the change in K contents, except 90-105 days after pruning, when calcium increased but potassium decreased. Berry growth is by cell proliferation during 75-90 days, when Ca from leaves is utilized for cell wall formation. Period between 120-135 days is the initial stage of berry ripening when berry starts softening. Calcium moves in to the cells of berry skin to increase cell wall turgidity.

Magnesium

The pattern of change in the Mg contents of petioles and lamina was similar to that of calcium throughout all stages from 45 - 135 days after pruning, except during 60 - 75 days. Petiole Mg increased simultaneously with lamina Mg during 45-60, 90-105, 105-120 and 135-150 days, but was associated with concurrent reduction in lamina Mg during 75-90 and 120-135 days. Period between 45-60 days corresponds to active shoot growth period. Mg, being more mobile and a constituent of chlorophyll moves in to the newly emerging leaves for the synthesis of chlorophyll. Increased Mg content in lamina during 90-120 days is the resultant of Mg role in nucleic acid synthesis and energy transfer in the leaves. Reduction in lamina Mg during 75-90 days signifies its movement into berries in their post lag phase of growth to play a key role in the synthesis of chlorophyll in their skin, translocation of metabolites and energy transfer, as it is essential in the functioning of several enzymes associated with these activities.

Sulphur

Sulphur content in petioles decreased steadily from 45-120 days after pruning and increased thereafter until 150 days, whereas it increased during 45-60 and 90-105 days but reduced during 60-90 and 105-150 days. Concurrent increase in S content of lamina and decrease in petiole indicates its movement from petiole to lamina for balancing the cations and for the synthesis of proteins during these stages which are required for berry growth during its post lag phase corresponding to 60-95 days and ripening during 105-150 days.

Iron

Pattern of change in Fe content of petioles was similar to that of lamina. Lamina content increased during 75-90, 105-120 and 120-150 days after pruning. Its increase can be attributed to its role in the chlorophyll synthesis. Lamina Fe decreased significantly during 45-75 and 90-105 days. Decrease could be due to its translocation in to berries for the synthesis of chlorophyll in the pericarp of newly formed berries during 45-75 days and participate in the translocation of metabolites in to berries during 90-105 days.

Manganese

Manganese content of lamina increased simultaneously with petiole content during 45-60, 75-90, 105-120 and 120-135 days and reduced during 60-75 and 90-105 days after pruning. The main functions of Mn in grapevine being enzyme activation, chlorophyll synthesis and a component of mineral content in grape berries, its increase in lamina can be attributed to its increased role in metabolic activities in lamina and depletion to its translocation into berries for enzyme activation.

Zinc

Pattern of change in Petiole Zn was similar to that in lamina Zn throughout the fruiting season, except during 105-135 days after pruning. Zn content increased in lamina during 105-120 days while it decreased in petioles. Contrarily petiole Zn increased but lamina Zn decreased during 120-135 days. Decrease in lamina Zn during 45-60 days, the period of pre-lag phase of berry growth can be attributed to its movement in to berries for the activation of synthesis of tryptophan, the precursor of IAA, which promotes berry growth by cell multiplication. Similarly, its reduction in lamina during 75-90 and 120-135 days could be due to its movement in to berries respectively for protein synthesis as tryptophan is also implicated in protein synthesis; and activation of enzymes associated with ripening.

Copper

Pattern of change in copper content of petioles was similar to that of lamina content. Both increased significantly during 60-75 and 120-135 days after pruning and reduced during 45-60, 90-105 and 130-135 days. Depletion from leaves could be attributed to its movement in to berries, since copper is a natural constituent of grapes in trace amounts (10).

Sodium

Although sodium is not an essential plant nutrient, but shown to be a substitute to potassium in its physiological functions and excess absorption by vines, in soils with

high sodium content, can result in its toxicity (8). Hence changes in sodium content were also studied. Sodium content in lamina increased during 45-60, 90-120 and 135-150 days after pruning, but reduced significantly during 60-90 days. Simultaneous increase in Na and K contents in lamina during 75-90 and 120-135 indicates the greater requirement of monovalent cations in berries for osmoregulation. Further monobasic (Na and K) tartarates were found to increase at the later stage of berry ripening corresponding to 120-135 days after pruning (6). On the other hand the simultaneous increase in their lamina contents during 45-60 and 105-120 could be due to supplementation of K needs by Na in its physiological functions in the leaves. Reduction in K and increase in Na content in lamina during 90-105 days indicates the movement of K in to berries to play its specific role in berries; probably the activation of enzymes associated with carbohydrate metabolism, which Na cannot perform; and Na moved in to lamina from petiole to balance the ionic charges as evidenced by the significant reduction in its petiole content during this period.

A perusal of fig. 1 would reveal that $\text{NO}_3\text{-N}$, P, K, Mg, and Na contents in petioles were more compared to lamina throughout the fruiting season, except $\text{NO}_3\text{-N}$ contents during 90-120 days and P contents during 120-150 days. This indicates that, i) These nutrient status of the vines is adequate enough to meet their requirements, ii) $\text{NO}_3\text{-N}$ needs are more during 90-120 days after pruning for the synthesis of amino acids and proteins in the lamina from where they move to berries as evidenced by the decrease in total N content in the lamina, iii) P needs are more during 120-150 days as seen by the significant reduction in petiole P with simultaneous significant increase in lamina P. On the other hand lamina contents of total N, S, Fe, Mn, Zn and Cu were more compared to petiole contents. This could be attributed to the role of N, Fe, Mn, Zn in chlorophyll synthesis. Although higher contents of Mg but less contents of Ca in lamina compared to petioles in normal leaves and vice-versa in Mg deficient leaves were observed in Anab-e-Shahi (7), all the leaf samples of Thompson Seedless on Dogridge rootstock were devoid of Mg deficiency. This could be due to one or more of the following reasons; i) less requirement of Mg for Thompson Seedless than Anab-e-Shahi, ii) Difference in the preference in nutrient absorption by Dogridge roots and iii) Relative abundance of Ca in the soil. Reasons for higher concentration of S and Cu in lamina than petiole could be the sprays of copper and sulphur fungicides. Yet another reason for S being more in lamina could be its role in neutralizing the charges of cations.

In the pattern of periodical changes in the petiole nutrient contents, a peak followed by reduction indicates the utilization of the nutrient in the synthesis of organic compounds or physiological functions in the lamina. Hence the peak indicates the stage at which nutrient build up is essential. Peaks corresponding to 60 days after pruning were of N and Mg, while 75 days for $\text{NO}_3\text{-N}$, K, Ca and Zn; 90 days for Fe, Mn, Cu and Na. The second peak was at 105 days for $\text{NO}_3\text{-N}$, N and Zn; at 120 days for K, Ca and Mg; at 135 days for Fe, Mn and Cu and 150

days for Na. There was also third peak at 120 days for NO₃-N and 135 days for N and Zn. In light of these peaks the time and method of nutrient application need to be standardized to ensure the availability at higher quantities of nutrients at their corresponding peaks. Particularly of K, Ca and Mg, since i) their period of requirement is the same, ii) antagonism exists among them in absorption from soil solution and iii) Sodium interferes with their absorption.

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