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INFLUENCE OF ROOTSTOCKS ON NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT IN PETIOLES OF FOUR TABLE GRAPE VARIETIES

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ABSTRACT

Four field trials were conducted at Vicuña Experimental Center (30°02' S, 70°44' W) located in the Coquimbo Region, Chile, over four seasons, 2002-2003 to 2005-2006, to determine the influence of 10 rootstocks (Freedom, Harmony, Saint George, Salt Creek, SO4, 1613C, 1103P, 99R, 110R, 140Ru, as well as own roots vines) on nutrient content in petioles of vars. Flame Seedless, Thompson Seedless, Superior Seedless and Red Globe grapevines (*Vitis vinifera* L.). The trials took place at a site that had previously planted to vineyard. The experimental design was a randomized complete block with four replicates. Petioles opposite to clusters were taken at bloom as samples and analyzed for total N, P and K content. Significant differences in nutrient levels due to rootstocks were found in all varieties. Rootstocks increased the levels of petiole nutrients (except P) over the values usually reported in literature for table grapes. Vines grafted onto the rootstock 'Salt Creek' had significantly higher petiole N and P content than those on their own roots vines. Total N level increased 67% in 'Flame Seedless', 77% in 'Red Globe', 33% in 'Thompson Seedless' and 8.5% in 'Superior Seedless'. On the other hand, the petiole P level doubled in all varieties by using 'Salt Creek' as rootstock. Potassium status was also affected by rootstocks. 'Harmony' and '1613C' showed higher K levels by at least 60% in vars. Flame Seedless, Red Globe and Thompson Seedless as compared to plants grown on their own roots. The present investigation demonstrates that rootstocks may have a considerable effect on grapevine nutrition.

Key words: grapevine, mineral nutrition, rootstocks, petiole analysis, Chile.

INTRODUCTION

There is little information in Chile about the use of rootstocks. However, their commercial use is justified by the need to overcome soil limitations, especially in the arid northern region of the country, and because of the need to replace old or unproductive vineyards (Muñoz and Ruiz, 1998). Nevertheless, in order to select the type of rootstocks to be used in a specific edaphoclimatic condition, it is important to carry out local long-term studies, given the interactions that exist among the rootstock, the variety and the environment. This implies that the results obtained with a particular variety-rootstock combination in a specific environment cannot be extrapolated to other situations (Keller *et al*., 2001).

The use of rootstocks can have an important effect on the mineral nutrition of the grafted variety. Consequently, it is possible to reduce the application of nutrients by employing rootstocks that have a high absorption capacity (Keller *et al*., 2001). Although information is limited about the interactions among the variety, the rootstock and nutrient contents in grapevines (*Vitis vinifera* L.), several studies have shown that rootstocks differ in their effect on the level of nutrients in the grafted variety (Grant and Matthews, 1996; Muñoz and Ruiz, 1998; Nikolaou *et al*., 2000; García *et al*., 2001; Bavaresco *et al*., 2003; Fisarakis *et al*., 2004; Robinson, 2005). The differences are due to the inter-specific variation among rootstocks in terms of nutrient absorption and the transference of this property to the variety (Grant and Matthews, 1996). Little is known about the specific mechanisms used by grape rootstocks to absorb nutrients. Nikolaou *et al*. (2003) and Smart *et al*. (2005) point out that absorption is related to the increased density of root hairs as a response to the deficiency of a nutrient; or as Siminis and Stavrakakis (2008) report, absorption is related to the increased capacity of the roots to assimilate specific nutrients. In all cases, more study is required to understand the influence of the root system in mineral absorption (Nikolaou *et al*., 2000).

As well as influencing mineral absorption, grapevine rootstocks can affect fruit yield and quality (Grant and Matthews, 1996; Muñoz and Ruiz, 1998; Bavaresco *et al*., 2003; Nikolaou *et al*., 2003). The present study also

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measured parameters of vigor, yield and fruit quality. The results of these evaluations will be discussed in future articles.

The objective of this study was to evaluate the effect of 10 rootstocks on the content of total N, P and K in four varieties of table grapes.

MATERIALS AND METHODS

The study was carried out during the growing seasons of 2002-2003 and 2005-2006 at the Vicuña Experimental Center (30°02' S; 70°44' W) of the Instituto de Investigaciones Agropecuarias INIA, located in the city of Vicuña, Coquimbo Region. Research was carried out in a loamy Entisol soil of alluvial origin, with flat topography and moderate depth of over 100 cm. The assays included the vars. Flame Seedless, Thompson Seedless, Superior Seedless and Red Globe, grafted onto the rootstocks Freedom, Harmony, Saint George, Salt Creek, SO4, 1613C, 1103P, 99R, 110R and 140Ru, which were compared to plants grown on their own roots (control). The Red Globe trial had fewer rootstocks comparisons due to the failure of vines grafted onto 'SO4'. Vine loss with this rootstock occurred in the nursery and in the field during the growing season after planting; replant on the same rootstock combination also die.

The assay was established in the winter of 2001. Nematological analysis prior to planting showed the presence of the species *Pratylenchus*, *Meloidogyne*, *Criconemoides*, *Pratylenchus* and *Tylenchulus semipenetrans*. None of the populations had more than 18 individuals per 250 g of soil. The soil fertility analysis indicated values of 7.9 for pH, 2.4% of organic matter, 1.0 dS m^{-1} of electrical conductivity in saturated paste, and mineral N, P Olsen and exchangeable K, equivalent to 9, 12 and 237 mg kg^{-1}, respectively.

The plants were grafted using the Omega grafting technique, which consists of joining cuttings of the rootstock and the variety by means of a cut made by a grafting machine. The plants were developed in the Rinconada Chile nursery, located in the city of Ovalle, Coquimbo Region, and were then planted in an overhead trellis system at a distance of 3 x 3 m. Standard cultural practices were employed throughout the period of the study for all of the varieties. Drip irrigation was employed and the fertilization program consisted of applications of N, P_2O_5 and K_2O (90, 50, 70 kg ha^{-1}) by means of fertigation in the spring and early summer.

Considering the soil variation in the assay site, the treatments were arrayed in a randomized complete block design, with four replicates and three plants as the experimental unit.

Leaf petioles opposite to the clusters were collected in October at flowering stage (2002, 2003, 2004 and 2005). The samples consisted of approximately 60 petioles per treatment in each replicate. The samples were dried at 65 °C, then milled and sieved through a 1mm mesh. They were analyzed at the Foliar Analysis Laboratory of the Vicuña Experimental Center to determine concentrations of total N, P and K. Determination of total N was done using the Kjeldahl method (Nikolaou *et al*., 2000), P by the Olsen colorimetric method, using a Spectronic 21 spectrophotometer (Spectronic Instruments, Garforth, UK) at 440 nm and K by atomic absorption spectrophotometry (Unicam 929, Unicam Ltd., Cambridge, UK) (García *et al*., 2001). All the analyses are expressed in dry matter basis.

The data was submitted to a variance analysis to determine the average effect over the four years of evaluation (2002 to 2005) and the means of the treatments were separated using a Duncan Multiple Range Test ($P < 0.05$).

RESULTS AND DISCUSSION

Flame Seedless (Table 1)

The nutrient levels in petioles considered as normal in samples collected at flowering vary between 0.8% and 1.1% for total N, 0.2% and 0.5% for P, and 1.4% and 2.5% for K (adapted from Robinson, 2005). The highest total N content (1.22%) was reached in plants grafted onto 'Salt Creek'. In contrast, the plants without grafting showed the lowest values (0.73%). The two values were respectively above and below the range considered adequate for total N. The other combinations were within the normal range. 'Salt Creek' also had the highest P content, approximately

Table 1. Effect of rootstocks on nutrient levels in petioles of 'Flame Seedless' vines. Four-year average, 2002 to 2005.

Rootstock	N	P	K
	%		
Salt Creek	1.22a	0.43a	1.29cd
Harmony	1.04b	0.27bc	3.27a
Freedom	0.81fg	0.17d	1.52c
Saint George	1.00bc	0.28bc	1.51c
1103P	0.95bcd	0.25bc	1.02d
1613C	0.84f	0.21cd	2.24b
99R	0.95bcd	0.30b	1.27cd
110R	0.92cde	0.27bc	0.99d
140Ru	0.91cde	0.27bc	1.47c
SO4	0.90def	0.24bc	1.35cd
Control	0.73g	0.15d	1.60c
Significance	**	**	**

Means with the same letter in a column are not significantly different according to the Duncan multiple range test ($P < 0.05$).

three times that of the control plants. 'Freedom' and the plants without grafting registered P levels in the petioles that had statistically similar values and were the only treatments with values below the adequate range. The lowest K levels were with '110R' and '1103P', both values below the minimal value of 1.4%. 'Harmony' had the highest K content (3.27%).

Thompson Seedless (Table 2)

The higher N and P contents in the 'Thompson Seedless' plants were similar to the response of the var. Flame Seedless. Significantly higher N and P values were obtained with the rootstock Salt Creek compared to the other treatments. The combination with 'Freedom' was the only one that had a content level below the minimum. All the combinations presented normal K contents except '1613C', which was slightly above the adequate maximum at 2.55%.

Table 2. Effect of rootstocks on nutrient levels in petioles of 'Thompson Seedless' vines. Four-year average, 2002 to 2005.

Rootstock	N	P	K
	%		
Salt Creek	1.22a	0.38a	1.56cd
Harmony	0.99bc	0.21b	2.12b
Freedom	0.80e	0.13c	1.72c
Saint George	1.10b	0.24b	1.56cd
1103P	0.92cd	0.21b	1.13e
1613C	0.91cd	0.23b	2.55a
99R	0.92cd	0.20b	1.18e
110R	0.95cd	0.25b	1.37de
140Ru	1.01bc	0.24b	1.16e
SO4	0.87de	0.21b	1.33de
Control	0.92cd	0.20b	1.60cd
Significance	**	**	**

Means with the same letter in a column are not significantly different according to the Duncan multiple range test ($P < 0.05$).

Superior Seedless (Table 3)

Total N and P levels below the minimal level were registered in the petioles of plants of 'Superior' grafted onto 'Harmony'. The same occurred with 'SO4' for total N content. On the other hand, and coinciding with the vars. Flame Seedless and Thompson Seedless, the highest percentages of N and P were obtained in plants on 'Salt Creek', although '110R' also had a similar P content to that of 'Salt Creek'. In relation to K, none of the rootstocks used in the assay exceeded the value of the own roots plants, although all of them reached normal levels.

Table 3. Effect of rootstocks on nutrient levels in petioles of 'Superior Seedless' vines. Four-year average, 2002 to 2005.

Rootstock	N	P	K
	%		
Salt Creek	1.02a	0.41a	1.83d
Harmony	0.78fg	0.14e	2.23b
Freedom	0.89cd	0.28bc	2.36ab
Saint George	0.94bc	0.30bc	1.88cd
1103P	0.81ef	0.24cd	1.39e
1613C	0.82def	0.21d	2.15bc
99R	0.86de	0.29bc	1.59de
110R	0.97ab	0.39a	1.68de
140Ru	0.88cde	0.31b	1.87cd
SO4	0.72g	0.27bcd	1.63de
Control	0.94bc	0.22d	2.58a
Significance	**	**	**

Means with the same letter in a column are not significantly different according to the Duncan multiple range test ($P < 0.05$).

Red Globe (Table 4)

The vars. Red Globe and Flame Seedless, both with red fruit, had similar responses in relation to the effect of the rootstocks on nutrient content in the petioles. 'Red Globe' plants grafted onto 'Salt Creek' had the highest total N and P values. The highest K value was obtained with 'Harmony'. 'Salt Creek' and 'Harmony' doubled the percentages of P and K, respectively, in comparison to control plants.

This study showed that rootstocks exercise an important influence on nutrient levels in the studied varieties. The major part of the nutrient contents in the petioles was below or in the adequate range, in accordance with the information adapted from Robinson (2005). There were exceptions with the control plants without grafting, which had a N content below the minimum range in the vars. Flame Seedless and Red Globe. The same occurred with 'Harmony' and 'SO4' in Superior Seedless. Likewise, low P content was found with the rootstocks Freedom in the vars. Flame Seedless and Thompson Seedless, and the rootstock Harmony in the var. Superior. K values below the adequate limit were obtained only in the vars. Flame Seedless and Thompson Seedless, particularly with the group of rootstocks composed of 99R, 110R, 1103P and SO4.

The influence of the rootstocks on N content in the petioles was significant, especially when comparing plants on their own roots to those on the rootstocks. As well, differences were evident with respect to N content in the control plants. In the white grape varieties Thompson Seedless and Superior, the control plants showed levels

within the adequate range, while the red grape varieties Flame Seedless and Red Globe had levels below the range considered optimal. Thus, 'Flame Seedless' and 'Red Globe' were comparatively low in total N when grown on their own roots. However, the majority of the rootstocks significantly increased N content in these varieties.

Salt Creek clearly reached the highest total N values in the petioles of the four studied varieties, increasing the value by 67% in 'Flame Seedless', 77% in 'Red Globe', 33% in 'Thompson Seedless' and 8.5% in 'Superior Seedless', compared to control plants. In general, the N contents of the plants grafted onto 'Salt Creek' were slightly above the adequate level. In contrast, control plants and the combinations with 'Freedom', 'Harmony' and 'SO4' registered low levels of total N in petioles. Fisarakis *et al*. (2004) report differences in NO_3-N content in leaves of 'Thompson Seedless' plants grown in pots and watered with saline water. The highest value was found with '140Ru' and the lowest with plants growing on their own roots. On the other hand, Muñoz and Ruiz (1998) registered the highest level of NO_3-N in petioles of 'Red Globe' grafted onto 'Freedom'.

Excessive applications of N can have negative effects on the environment by contaminating ground water with nitrates. As well, high N content in grape vines can also increase the presence of pests, diseases and physiological disorders (Keller *et al*., 2001). Consequently, it is important to adjust the doses of N to make the most efficient use of fertilizers and avoid these problems. One way to use fertilizers efficiently is by employing appropriate rootstocks. Thus, the application of N can be reduced by using rootstocks that have a high capacity for N uptake and assimilation.

Table 4. Effect of rootstocks on nutrient levels in petioles of 'Red Globe' vines. Four-year average, 2002 to 2005.

Rootstock	N	P	K
		%	
Salt Creek	1.29a	0.42a	2.08c
Harmony	1.03bcd	0.25cd	3.37a
Freedom	0.86de	0.21d	1.74de
Saint George	1.21ab	0.30bc	2.12c
1103P	0.93cde	0.26bcd	1.49e
1613C	1.10abc	0.25cd	2.96b
99R	0.96cd	0.28bc	1.92cd
110R	1.00cd	0.30bc	1.47e
140Ru	1.01bcd	0.31b	2.02c
Control	0.73e	0.20d	1.66de
Significance	**	**	**

Means with the same letter in a column are not significantly different according to the Duncan multiple range test ($P < 0.05$).

There is no conclusive information regarding the relationship between N content in the petioles and the vigour of the plants. Keller *et al*. (2001) points out that generally the more vigorous rootstocks result in higher N levels on the grafted variety. In this investigation Salt Creek showed the highest pruning weights of the four studied varieties (information not shown). Likewise, Nikolaou *et al*. (2000) report an influence of rootstocks on the vigour of the var. Thompson Seedless. Higher pruning weights were reached with '99R' and '110R' compared to the other rootstocks. In both cases high cytokinin and N contents were registered in the xylem exudate and in the leaves. The authors indicate that the rootstock type influences shoot growth of the variety and that this is greater with those rootstocks that have high levels of cytokinins. As well, they suggest that high cytokinin values in the xylem are associated with high levels of total N in the plants. The differences among rootstocks could be due to the genetic factors affecting the root system. It is suggested that the various levels of cytokinin and N content among the studied rootstocks are due to different root size and density in superficial layers of the soil.

None of the variety-rootstock combinations increased P levels in petioles above the adequate range. However, 'Salt Creek' had twice the content of the control plants of all the varieties. The same occurred with '110R' in the var. Superior. Grant and Matthews (1996) showed that with a sufficient application of P in the soil, the vines grafted onto '110R' had higher contents of the element than plants grafted onto other rootstocks. The authors argue that the difference may be related to its *V. berlandieri* parentage, given that the metabolism of this American native species is better adapted for P absorption. Variations in P uptake have been reported by Troncoso *et al*. (1999), Bavaresco *et al*. (2003), Nikolaou *et al*. (2003) and Fisarakis *et al*. (2004), who suggest that the different rootstocks absorb unlike levels of P with concomitant effects on the growth of shoots and leaves.

Compared to the control plants, 'Harmony' doubled K content in the petioles of the vars. Flame Seedless and Red Globe. Likewise, '1613C'increased the K level by 1.6 times in 'Thompson Seedless' and 1.8 times in 'Red Globe'. In the three varieties, with the mentioned rootstocks, K levels were above the adequate range. On the other hand, in Superior Seedless variety the control plants and those grafted onto Freedom registered a K value statistically similar and above the range considered optimal. Muñoz and Ruiz (1998) report K values in petioles higher than those of control plants in the var. Red Globe grafted onto 'Freedom'. However, Nikolaou *et al*. (2000), García *et al*. (2001) and Fisarakis *et al*. (2004) indicate that the highest K contents were obtained

with the rootstocks 99R, 110R and SO4. In the present study, these rootstocks registered K levels lower than the adequate range in the vars. Flame Seedless and Thompson Seedless.

It has been demonstrated that the uptake of K differs among rootstocks. This in turn will affect the K status of the grafted variety. These variations could be caused by differences in the absorption capacity of the roots and/or differences in the incorporation of K ions into the xylem and their translocation from the roots to shoots (Mpelasoka, 2003). Differences among rootstocks in the morphology and density of the roots in the soil profile could also explain the variations in the K absorption capacity of the roots. In this respect, Rühl (1993) points out those rootstocks that provide low quantities of K to the variety retain the majority of absorbed cations in the vacuole of root cells.

CONCLUSIONS

This study demonstrated the large influence that rootstocks can have on the nutritional composition of table grape varieties. In particular, 'Salt Creek' showed a potential to increase N and P levels. Likewise, 'Harmony' and '1613C' had higher K content in petioles. However, the present study also showed the importance of studying individual varieties because Superior Seedless was able to accumulate a high quantity of K in petioles, regardless of rootstocks.

Before recommending a specific variety-rootstock combination, it is necessary to evaluate the effect that rootstocks can have on vigour, production and fruit quality. Some of the rootstocks that did not show extreme nutrient content in this study could be selected for some particular agricultural characteristic. As well, it is important to emphasize that the results obtained are only valid for edaphoclimatic condition in which the assays were carried out.

RESUMEN

Influencia de portainjertos sobre el contenido peciolar de nitrógeno, fósforo y potasio en cuatro variedades de uva de mesa. Se realizaron cuatro ensayos en Vicuña (30°02' S, 70°44' O), Región de Coquimbo, Chile, durante cuatro temporadas, 2002-2003 a 2005-2006 para determinar la influencia de 10 portainjertos de vid (*Vitis vinifera* L.) (Freedom, Harmony, Saint George, Salt Creek, SO4, 1613C, 1103P, 99R, 110R, 140Ru, además de plantas sobre sus propias raíces) sobre el contenido de nutrientes en pecíolos de las vars. Flame Seedless, Thompson Seedless, Superior Seedless y Red Globe. Los ensayos se establecieron en un terreno previamente plantado con vides y el diseño experimental fue de bloques completos al azar con cuatro repeticiones. Se colectaron muestras de pecíolos opuestos al racimo en el estado fenológico de floración, para determinar los contenidos de N total, P y K. En las cuatro variedades se encontraron diferencias significativas en los niveles de nutrientes debido al uso de portainjertos. Los portainjertos incrementaron los niveles de nutrientes en pecíolos (excepto P) por sobre los valores reportados generalmente en la literatura para vides de mesa. Las plantas injertadas sobre el portainjerto 'Salt Creek' tuvieron contenidos de N y P en pecíolos significativamente más altos que las plantas sobre sus propias raíces. El nivel de N total aumentó 67% en 'Flame Seedless', 77% en 'Red Globe', 33% en 'Thompson Seedless' y 8,5% en 'Superior Seedless'. Por otro lado, el nivel de P en los pecíolos se duplicó en todas las variedades con el portainjerto 'Salt Creek'. El contenido de K también fue influenciado por los portainjertos. 'Harmony' y '1613C' mostraron valores de K al menos 60% mayores en las vars. Flame Seedless, Red Globe y Thompson Seedless en comparación con las plantas sobre sus propias raíces. La presente investigación demuestra que los portainjertos pueden tener un efecto considerable en la nutrición de las vides.

Palabras clave: vid, nutrición mineral, portainjertos, análisis de pecíolos, Chile.

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