SCIENTIFIC NOTE

POTASSIUM AND PHOSPHORUS IN MUSCAT ROSADA GRAPE YIELD IN ELQUI VALLEY SOIL

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ABSTRACT

The effects of P and K on grapevines (*Vitis vinifera* L.) var. Muscat Rosada were evaluated four years, considering the same levels of N. The experiment was conducted at the Vicuña Experimental Station (30° S; 70°44´ W) of the Instituto de Investigaciones Agropecuarias (INIA). The soil is alluvial antropic miscellaneous (Entisols). Three fertilization treatments were established: 1) N 160 + P_2O_5 200 + K_2O 300; 2) N 160 + P_2O_5 0 + K_2O 300; and 3) N 160 + P_2O_5 200 + K_2O 0. At the beginning of the experiment, grape vines received all the phosphate fertilizers, 200 kg ha^{-1} of P_2O_5 as triple superphosphate in Treatments 1 and 3. Nitrogen was applied as urea for four years. The applications were initiated when the vine buds measured 20 cm. The K was applied to the soils of Treatments 1 and 2, at a dosage of 200 kg ha^{-1} K_2O, using potassium sulphate. Between berry set and 30 d before harvest, 100 kg ha^{-1} K_2O were applied as potassium sulphate by fertigation. Significant effects of the P fertilization were observed by the second year, with increased cluster numbers per plant. K also increased grape fruit yield by the third year. This response was obtained with less than 5 mg kg^{-1} of P available in the soil and less than 145 mg kg^{-1} of exchangeable K in the soil. The initially low content of available K and P suggests a high probability of response to the application of both elements.

Key words: grapes, fertilization, phosphorus, potassium.

INTRODUCTION

Grapes growing for the production of “pisco” are important economically and socially for the Northern zone of Chile where many medium and small scale farmers cultivate vineyards for the production of this alcoholic beverage. There are approximately 9000 ha in the area dedicated to the cultivation of pisco grapes. Many of these vineyards are located from the middle toward the interior of the transversal valleys, owing to the better conditions of summer temperatures for the maturation and of winter cold, which favor budding. The soils in the area, more in the interior of the valleys, have an appreciable spatial variability in terms of their physical characteristics, owing to their geomorphological origin. These are alluvial or coluvial-alluvial developed in small areas of narrow valleys (Contreras and Sierra, 2004).

Nutrition with P and K is important for growth and production of the vine (Skinner and Matthews, 1989; Ruiz and Sadzawka, 2005). Both nutrients can generate a positive interaction in the productivity of vineyards, even when other agronomic factors, such as irrigation and N management can equally affect the expression of the yield potential of pisco vineyards.

The objective of the present work was to study the effect of the application of P and K in the production of pisco grapes cv. Moscatel Rosada, under the soil and arid climatic conditions of the Northern area of the country.

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MATERIALS AND METHODS

The experimental work was conducted at the Vicuña Experimental Center of the Instituto de Investigaciones Agropecuarias (INIA) (30° S; 70°44´ W). The climate of the area is defined as Ovalle Agro-climate (Novoa and Villaseca, 1989), which is defined as sub-tropical semi-arid Mediterranean. The average temperature of the hottest month (January) is 28.5 ºC and of the coldest (July) is 6.3 ºC. The average annual temperature is 16.6 ºC. The hydric regime is characterized by an average precipitation of 126 mm, which is concentrated between May and August. The dry season lasts for 10 months. The soil where the experiment was conducted is colluvial-alluvial formations, originating from the action of the Elqui River and adjacent creeks. The soil profile presents little development, owing to the dominant conditions of aridity. The edaphic condition of the area where the experiment was developed is defined as "Miscellaneous alluvial anthropic" (Agrolog Chile Ltda., Comisión Nacional de Riego, 1979) corresponding to an Entisol, with a loamy sandy texture up to 50 cm and thick sand below this depth, with clasts in the substrate at a moderate depth (60-70 cm) and a moderate slope.

The trial was conducted on an 18-yr-old vineyard var. Moscatel Rosada (Pink Muscat), overhead trellis system, with 4 x 4 m spacing. Plots were 20 x 12 m, with three rows of plants and five plants per row, covering an area of 240 m^2 per experimental unit. For experimental evaluation, three plants from the central row of each plot were harvested. Phosphate fertilizers had not been applied for 18 yr and K had not been applied for 3 yr. Only N fertilizer had been applied annually.

The concentration of nutrients absorbed by leaves and petiole during full flowering was evaluated. The number of clusters and fruit weight per plant were evaluated at harvest. The vines were managed each season with 120 buds. The experiment began in August 1994 and was evaluated over four seasons (until 1998).

Irrigation was conducted considering 100% of evapotranspiration (ET), adjusted according to the crop coefficient (kc) of vine, using daily records obtained using a class A pan evaporimeter of the Agrometeorological Station of the Vicuña Experimental Center.

The experiment began in August 1994, with application of differentiated base fertilization treatments to the soil, in lateral furrows 40 cm from the foot of the plants. The following treatments were established: 1) N160 + P_2O_5 200 + K_2O 300; 2) N160 + P_2O_5 0 + K_2O 300; and 3) N160 + P_2O_5 200 + K_2O 0.

Treatments 1 and 3 received all the P, 200 kg ha^{-1} of P_2O_5 as triple superphosphate (SFT), at the beginning of the experiment in August, 1994. Treatments 1 and 2 received K in dosages of 300 units of K_2O using potassium sulphate as a source, incorporating 200 units in the soil in August, 1994 and 100 additional units via fertirrigation, applied annually, from when buds measured 20 cm until the beginning of veraison. As well, all of the treatments received 30 kg ha^{-1} Zn sulphate, applied once to the soil at the beginning of the trial. The three treatments received the same N dosage annually, incorporating it as urea via fertigation, beginning the application at 20 cm plant bud length. The fertilization applied to the soil was located a 25 cm from the row at 25 cm depth in furrows parallel to both sides of plants. This work was done in winter, a recess period for vines. In the second season of the trial, during winter 1995, semi-composted goat manure was applied to all treatments in dosages of 25 kg $plant^{-1}$, soil incorporated in furrows next to the plants. Goat manure applied contained 322 mg kg^{-1} available N, 1331 mg kg^{-1} available P and 915 mg kg^{-1} interchangeable K, dry matter basis. In October of same year fenamiphos (dosage 2.88 kg i.a. ha^{-1}) (Nemacur, Bayer, 12 L ha^{-1}) was applied through drip irrigation to control nematodes.

Before starting the fertigation treatment, soil samples were taken from the experimental site with four rhizotrons and at three depths for chemical analysis. The soil analysis methodology used is described by Sadzawka (1990). Soil was characterized by a very low content of mineral N and available Olsen-P and a average content of interchangeable K in whole profile (Table 1). Total C and N content was equally low. The pH was moderately alkaline.

The experiment used a randomized complete block design that included three treatments and four replicates. Information was statistically analyzed using SAS computer program (SAS Institute, 1989).

RESULTS AND DISCUSSION

In the first two years of the experiment, yields from the treatments with three macro-nutrients applied reached levels close to 36 kg $plant^{-1}$, equivalent to 22.5 t ha^{-1} of fruit (Table 2). In the third season yields

Table 1. Initial soil chemical analysis in the experimental site. Vicuña Experimental Center.

Depth	Mineral N	P-Olsen	K	pH in suspension	OM
cm		$mg\ kg^{-1}$			%
0-15	15	5	144	7.8	1.3
15-30	6	1	100	7.7	0.8
30-60	6	1	100	7.4	1.0

Average of four replicates.
OM: organic matter.

Table 2. Phosphorus fertilization effects on the yields of table grape cv. Muscat Rosada, over four growing seasons. Vicuña Experimental Center.

Treatments	1994-1995	1995-1996	1996-1997	1997-1998	Average of three seasons
			$kg\ plant^{-1}$		%
N 160 + P 200 + K 300	36.16a	36.0a	50.4a	51.2a	100.0
N 160 + P 0 + K 300	33.0a	25.12b	37.12b	42.72b	76.28
Difference among treatments	3.16	10.88	13.28	8.48	23.72

Different letters in the same column indicate significant differences according to Duncan test ($P \leq 0.05$).

increased to 50.4 kg plant^{-1}, and in the fourth year a yield of 51.2 kg plant^{-1}, equivalent to 31.2 t ha^{-1} of fruit was achieved. Production greater than 60 kg plant^{-1} should be considered high for this variety, despite the important yield increase obtained, Moscatel Rosada can achieve even higher yields. On the other hand, this cultivar has a lower yield potential than var. Pedro Jiménez, which can easily reach 85 kg plant^{-1}. Consequently, yields of 51 kg plant^{-1} achieved in the trial can be considered adequate for the variety. As well, 4 x 4 m spacing implies a lower yield potential, given that it represents a population of only 625 plants ha^{-1} considering poor fertility conditions of soil.

It is important to note that productivity increases were produced the season after having applied organic amendment, such as goat manure and nematicide to the soil. The response of plants to inorganic fertilization was conditioned to the soil management with organic amendments and control of nematodes. This effect was even clearly evident in the treatment without application of P, which increased its yield from 25.12 to 37.12 kg plant^{-1}. This could suggest an improvement of the vine radical system, which, on the one hand, allowed for taking better advantage of the scarce P content present in the soil, and as well, the P contribution from goat manure. Goat manure has moderate content of available Olsen P, which reaches 1331 mg kg^{-1} DM basis. That is, application of 25 kg plant^{-1} of manure meant incorporating 24.9 g available P per plant, assuming 25% of humidity of the manure; an important quantity, which can explain the improvement of control treatment without P, along with improved agronomic management.

On the other hand, improvement of the radical system should be considered a result of the control of nematodes, achieved by the nematicide and also because of the effect of the organic amendment. Both factors are determinants to achieve a better root development (Sierra, 2001). It should be noted that P is one of the nutrients whose absorption is most affected in the context of a limited radical system. Barber (1995) indicates that there is a strong correlation between length of corn plant roots (*Zea mays* L.) and P absorption. This is due to the low mobility of P in the soil, which is generally absorbed in solid or precipitated phase.

Table 2 presents the effect on fruit production per plant with and without P applied during four seasons, with the same level of N, K and an organic amendment. No significant effect was observed in the first season on yields by the addition of phosphate fertilizer. This explains why in the first season of phosphate fertilization, vine yield was already predetermined, given that bud differentiation is produced during the previous season. Nevertheless, from the second season onward a significant effect was produced, with increases higher than 10 kg plant^{-1}. The P treatments increased production per plant from 36.16 kg plant^{-1} for the first season to 51.2 kg plant^{-1} in the last season. The clear effect of P on fruit production is explained by the low content of available Olsen-P, detected by chemical soil analysis prior to beginning the experiment, which reached 5, 1 and 1 mg kg^{-1} P in the three strata of soil profile, respectively (Table 1).

It is important to note the low content of available P between 16 and 60 cm depth, area from which vines can extract important quantities of nutrients, especially from the first 30 cm of soil. Likewise, a low content of available P, only 5 mg kg^{-1}, was present in the first stratum. Carrasco *et al.* (1992), studying the P availability in soils of the Northern area, indicates that in arid zones an important fraction of P is found in organic matter (OM). The OM content of soil is very low and reaches 1.3 and 0.8% in the first and second soil stratum, respectively (Table 1). It should be noted that the soil of the experimental site had not been fertilized with P in 18 years, which explains the low content of available P.

The increased yield produced in the last three seasons and expressed as a percentage of the P treatment indicates that the low content of this nutrient in the soil allowed for achieving only 76.28% of potential yield with this element (Table 2). In the complete treatment yields remained high, while in the treatment without phosphates yields showed more variation over the years; this is explained by P deficiency in the plants, which possible does not allow the accumulation of adequate reserves in each season of the study.

The effect of K was significantly evident in the third season of the trial, when plants achieved a greater potential of production, more than 50 kg $plant^{-1}$ (Table 3). This was achieved after overcoming P deficiency in the second season of the trial. In the last two seasons, the increase in yield over the control without K reached 14.1 and 12.5 kg $plant^{-1}$, respectively.

The increase of yields produced in the last two seasons and expressed as a percentage of the treatment with K, allowed for reaching only 73.85% of the yield without this element. This suggests that a content of interchangeable K of 144; 100 and 100 mg kg^{-1} in the soil profile does not allow for sustaining a level of production of 50 kg $plant^{-1}$, equivalent to 31.2 t ha^{-1} fruit. More than soil K content, it is highly probable that the limited radical system of plants explains the response to the nutrient applied; nevertheless, root measurements were not made and consequently this is presented as a probable hypothesis that could explain this response. Ruiz and Sadzawka (2005) indicated that responses to K have been observed in table grape vineyards in soils in the central zone with K levels lower than 109 mg kg^{-1} between 30 and 60 cm depth.

The treatment that included the three macro-nutrients had an evolution of 74.8 to 114.4 clusters per plant in the second and fourth season of the trial, respectively (Table 4). It should be noted that in the first and second season of the trial, soil was tilled again to apply fertilizer in the first year and then the goat manure and nematicide; it is probable that the tilling contributed to reducing the number of clusters by the effect of root destroying. The treatment without P applied in the fourth season had fewer clusters per plant compared to treatments with K and the three macro-nutrients applied. This suggests that the lack of P in the plants had an important influence in the number of clusters. It is widely recognized in the literature that this element significantly affects vine fruiting (Skinner and Matthews, 1989). The applied K did not significantly increase fruiting of cv. Moscatel Rosada. The lack of K is not relevant in defining fruiting; K is more important for increasing the size of berries (Ruiz and Sadzawka, 2005).

The absorption of nutrients by the vines, in leaves and pedicels in full flowering, is presented in Table 5. Nitrogen content fluctuated between 2.16 and 2.55% for the second and first season, respectively. In the last season, foliar N content was 2.21%, the minimum

Table 3. Potassium fertilization effects on fruit yields of table grape cv. Rosada Muscat over four growing seasons. Vicuña Experimental Center.

Treatments	1994-1995	1995-1996	1996-1997	1997-1998	Average the last two seasons
	kg $plant^{-1}$				%
N 160 + P 200 + K 300	36.16a	36.0a	50.4a	51.2a	100.00
N 160 + P 200 + K 0	33.40a	34.72a	36.32b	38.72b	73.85
Diff. among treatments	2.76	1.28	14.1	12.5	26.15

Different letters in the same column indicate significant differences according to the Duncan test ($P \leq 0.055$).

adequate level, which is explained by the greater yield achieved by plants in the last year. Values greater than 2.5% of N in vine leaves are considered adequate (Velemis *et al.,* 1997). It is important to note that N levels in petiole are very distinct from values reported for leaves. Levels between 0.8 and 0.9% of total N are considered adequate (Goldspink, 1998a). So total N content in leaves tended to decrease slightly from the beginning of the experiment.

The P content in leaf and petiole was very similar. A total P content of 0.20% should be considered as a minimum (Reuter and Robinson, 1997; Goldspink, 1998b). In accordance with this, the level detected in the first season was marginal, as low as 0.17% in the treatment with complete fertilization. Nevertheless, P content increased steadily in the following seasons until reaching 0.23%. This is explained by the fertilization with P applied to the treatment, as well as the application of manure and nematicide, that certainly allowed for a greater P absorption. In the treatment without P applied, P concentration remained at clearly deficit levels, 0.16 and 0.18% in the second and third seasons of the trial, respectively. Nevertheless, in the last season of the trial, the treatment with complete fertilization reached 0.23% foliar P contents.

In the treatment without K, plants had a low K concentration, close to 1.1%. It should be noted that contents of less than 1% in leaves is considered as critical (Velemis *et al*., 1997). The plants treated with N, P and K reached higher content levels in the last season (1.51%). The plants without P had contents greater than 2.0%. In this case, the lack of P did not allow greater plant growth, which promoted more accumulation of K in leaves.

The experimental results clearly suggest that contents of available Olsen-P lower than 5, 1 and 1 mg kg^{-1} in the soil profile should be considered as very low for vines, and should be applied to increase yields. In accordance with these results, soil analysis as a diagnostic tool is a good indicator of available P and is related to absorption by plants.

In the case of K, it can be inferred that contents less than 150 mg kg^{-1} in the profile of loamy sandy soil of medium depth, are restrictive for achieving a yield equal to or greater than 50 kg $plant^{-1}$ in Moscatel Rosada. Potassium increases sugar content of berries (Ruiz and Sadzawka, 2005) and consequently allows for a better alcohol yield.

Table 4. Cluster number per plant cv. Muscat Rosada in three fertilization treatments, over four growing seasons. Vicuña Experimental Center.

Treatment	1994-1995	1995-1996	1996-1997	1997-1998	Average of the last two seasons
					%
N 160 + P 200 + K 300	111.1a	74.8a	113.0a	114.4a	100.0
N 160 + P 200 + K 0	98.0a	65.1a	106.7a	98.0a	90.0
N 160 + P 0 + K 300	75.0a	47.0b	74.4b	91.0b	72.7

Different letters in the same column indicate significant differences according to the Duncan test (value of P ≤ 0.05).

Table 5. Evolution of macronutrient content in Muscat Rosada leaves, over four growing seasons, according to three fertilization treatments. Vicuña Experimental Center.

Treatment	1994-1995			1995-1996			1996-1997			1997-1998		
	N	P	K	N	P	K	N	P	K	N	P	K
	%											
N 160 + P 200 + K 300	2.55	0.17	1.11	2.16a	0.19a	0.96a	2.52a	0.22a	1.18a	2.21a	0.23a	1.51a
N 160 + P 200 + K 0	-	-	-	2.13a	0.16a	1.06a	1.94a	0.18b	1.10a	2.28a	0.20a	1.1c
N 160 + P 0 + K 300	-	-	-	1.94a	0.14b	1.04a	1.80a	0.14b	1.20a	2.32a	0.14b	2.1b

Different letters in the same column indicate significant differences according to the Duncan test (P ≤ 0.05).

CONCLUSIONS

In the conditions of the present experiment, the P_2O_5 application of 200 kg ha^{-1} allowed for increasing fruit production by 10.88 kg $plant^{-1}$, in the second season of the study. This response is mainly explained by the increase in the number of clusters per plant.

The response to K was significant by the third year of application, increasing production by 14.1 kg $plant^{-1}$ over the treatment without K.

The treatment with both nutrients allowed for increasing yield by 15.04 kg $plant^{-1}$, in comparison to the initial control, after 4 yr treatment. This implies an increase in yield of 9.4 t ha^{-1}.

R E S U M E N

Fósforo y potasio en la producción de vid moscatel rosada en suelo del Valle de Elqui. Carlos Sierra B.[1*], y Rubén Alfaro P.[1]. En el Campo Experimental del Instituto de Investigaciones Agropecuarias (INIA), ubicado en la localidad de Vicuña (30° S; 70°44′ O), se evaluó durante cuatro años el efecto de la aplicación de P y K, considerando un mismo nivel de aplicación de N en vid (*Vitis vinifera* L.) var. Moscatel Rosada. El suelo corresponde al tipo misceláneo antrópico coluvial (Entisols). Se establecieron tres tratamientos de fertilización: 1) N 160 + P_2O_5 200 + K_2O 300; 2) N 160 + P_2O_5 0 + K_2O 300; y 3) N 160 + P_2O_5 200 + K_2O 0. El parrón recibió toda la fertilización fosfatada aplicada al suelo al inicio del experimento, 200 kg ha^{-1} P_2O_5, como superfosfato triple en los Tratamientos 1 y 3. La fertilización nitrogenada se aplicó como urea, durante las cuatro temporadas, y se inició cuando las plantas alcanzaron un largo de brote de 20 cm. El K se aplicó a los Tratamientos 1 y 2 en dosis de 200 unidades de K_2O al suelo, usando como fuente sulfato de K, y durante el crecimiento del parrón, desde cuaja y hasta 30 días antes de cosecha, se aplicaron 100 kg ha^{-1} adicionales de K_2O, como sulfato de K vía fertirrigación. Al segundo año de evaluación se observó un efecto significativo de la fertilización con P, el cual incrementó el número de racimos por planta. El K igualmente incrementó el rendimiento de fruta al tercer año. Esta respuesta se logró con niveles menores a 5 mg kg^{-1} de P disponible en el perfil del suelo y menos de 145 mg kg^{-1} de K de intercambio. Bajos contenidos iniciales de P y K disponibles en el suelo sugieren una alta probabilidad de respuesta a la aplicación de ambos elementos.

Palabras clave: vides, fertilización, fósforo, potasio.

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