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EFFECT OF POTASSIUM FERTILIZATION ON ITS AVAILABLE AND FIXED CONTENT IN VINEYARD SOIL

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Abstract: The experiment was conducted on brown forest soil in the vineyard with Sauvignon blanc variety on Kober 5BB rootstock. During a three-year experiment (1994-1996), potassium fertilizer was added in a dose of 0 kg K_2O/ha, 50 kg K_2O/ha, 100 kg K_2O/ha, 150 K_2O/ha respectively. After the determination of soil potassium content (1870-1920 mg K_2O/100 g), its available form was monitored by using two different extraction methods (AL method and 1N ammonium-acetate extraction). The amount of extracted available K was not significant between the used methods, while the effect of fertilization was visible only at 150 kg/ha potassium rate during the first year in soil layers (30-60 cm, 60-90 cm). Also, another examined soil K fraction (fixed K^+) was not affected by K fertilizer application.

Key words: potassium, vineyard soil, available potassium, fixed potassium, AL method, 1N ammonium-acetate extraction.

Introduction

Potassium plays one of the most important roles in grape nutrition, and the high rates of potassium fertilizer application are usually a regular practice in grape production. Concerning that some important soil conditions influence K nutrition (soil type, clay content, water regime, ect.), the amount of applied K usually differs from country to country. It can be found that a recommended dose of K ranges between 60 kg K_2O/ha in France (Delas et al. 1990), 100-200 kg K_2O/ha in Italy (Fregoni, 1985), to 200 kg for light and 360 kg K_2O/ha for heavy vineyard soils in Germany (Platz et al.1980). A new trend with low potassium fertilization comes as a consequence that high K content in must and wine reduce free acids level, pronouncing a wine clarification problem. A usual dose of K in our vineyards is about 100 kg/ha (Milosavljević, 1985), but it

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should be lower concerning that our soils are mostly well supplied with K (around 20 mg K_2O/100 g) (Ličina et al. 1992).

The K doses are usually calculated upon its uptake by grape yield, where the applied K fertilizer must balance a lost from soil. Added K from fertilizer increases its available content in soil, but its utilization is controlled by different soil factors, where a certain amount of applied K is left. The fate of applied potassium is similar to that of other cations in soil: it can be adsorbed by soil colloids, or K^+ remains in soil solution. A selective penetration of K^+ in clay interlayer (2:1 clay minerals) is what distinguishes it from other cations, thus making it a potential source of K for plants. With an intensive K fertilization in vineyard during the tree years, we tried to estimate the efficiency of this measure on soil available K reserves. Two different methods for evaluation of available K were used (standard AL method and 1N ammonium-acetate extraction), and, also, the K fixing processes after fertilization monitored.

Material and Methods

A three-year experiment (1994-1996) was conducted on brown forest soil of the Faculty experimental station - Radmilovac. In a young vineyard planted with cv. Sauvignon blanc, grafted on Kober 5BB, each experimental variant of 54 m^2, as 6 x 3 x 3 m, had three repetitions. The potassium fertilizer was applied in doses of 0 kg K_2O/ha, 50 kg K_2O/ha, 100 kg K_2O/ha, 150 K_2O/ha, respectively. The usual soil agrochemical properties were determined by standard methods (Jakovljević et al.1992). In addition, an initial content of total potassium in soil was estimated by using HF (48%) and conc.H_2SO_4 for destroying clay minerals lettuce. Potassium fertilizer KCl (50% K_2O) was added to soil in late winter as a starting fertilizer together with NP fertilizers (80 kg N/ha KAN and 50 kg P/ha of superphosphate). The soil samples were collected at the end of vegetative period, and the soil testing for available K was done with standard AL method. Another method for the extraction of exchangeable K was conducted by using 1N ammonium-acetate. The change in another soil K fraction was measured too: potassium in a fixed form (Knudsen et al.1989). In this procedure a released K^+ was estimated by using KCl in 24h extraction procedure by 1N ammonium-acetate. All measures were done by flame photometry and AAS use.

Results and Discussion

Typical agrochemical values for the vineyard brown forest soils of our country were obtained by standard soil analyses (Table1). However, prior to starting the experiment, a total K was estimated in soil profile: 1870 mg K_2O/100 g (0-30 cm), 1870 mg K_2O/100 g (30-60 cm), 1910 mg K_2O/100 g (60-90 cm) and 1920 mg K_2O/100 g (90-120 cm). By destroying a soil K bearing lettuce, K

content was obtained that was up to hundred times higher than its available form in the soil.

T a b. 1. - The vineyard soil agrochemical characteristics with the amount of total potassium in profile (1994)

Depth cm	pH H_2O	pH KCl	Humus %	N %	NH_4 µg/g	NO_3 µg/g	K_2O mg/ 100	P_2O_5 mg/ 100	Ca mg/ 100	Mg mg/ 100	Tot.K_2O mg/ 100
0-30	7.4	6.5	3.31	0.21	10.5	3.5	15.9	11.7	564	23.2	1870
30-60	7.4	6.5	2.11	0.19	10.5	5.2	14.1	14.0	494	20.2	1870
60-90	6.7	5.4	1.88	0.16	10.0	5.2	12.7	9.0	350	22.1	1910
90-120	6.9	5.7	1.64	0.16	11.2	7.0	12.5	8.0	399	23.1	1920

The main source of K^+ for plants growing in natural conditions comes from the weathering of K containing minerals. This fraction of soil K is usually predominant, but the rate of this K utilized by plants concerning their demand is usually of minor importance. Other three K fractions play a more important role in grape nutrition: K adsorbed in exchangeable form to the soil colloids and K in soil solution. Also, a potential K source for plants in soils belongs to fixed K. Added K with fertilizer enrich some of these soil K fractions, but the way of its distribution depends to a great extent on soil type and its 2 :1 clay minerals. In this investigation, AL method (Egner-Rhiem) was applied as a standard method in our country for the estimation of available soil K (K in soil solution and adsorbed K). The results of this extraction method are presented in Table 2.

T a b . 2. - The effect of K fertilization on its available content in vineyard soil (AL - extraction method) in 1994,1995 and 1996

Treatment	Depth	1994 mg/100g	1995 mg/100g	1996 mg/100g	Average mg/100g
Control	0 - 30	13.9	18.5	17.8	16.7
	30 - 60	14.6	18.4	16.5	16.5
	60 - 90	13.9	16.7	14.2	14.9
	90 - 120	13.0	15.4	17.7	15.3
50 kg K/ha	0 - 30	13.5	20.7	16.9	17.0
	30 - 60	14.9	19.5	16.8	17.0
	60 - 90	15.3	17.1	17.6	16.6
	90 - 120	14.3	17.7	19.3	17.1
100 kg K/ha	0 - 30	15.0	20.8	17.5	17.6
	30 - 60	14.6	18.1	19.8	17.5
	60 - 90	15.8	20.3	16.2	17.4
	90 - 120	14.6	19.6	16.7	17.0
150 kg K/ha	0 - 30	16.6	26.0	18.5	20.3
	30 - 60	17.9**	18.3	18.0	18.1
	60 - 90	16.5**	18.1*	13.3	16.0
	90 - 120	13.7	15.8	14.6	14.7
				Average in depths:	16.5

For 30-60 cm (1994) $LSD_{0.05}$ = 2.0412 $LSD_{0.01}$ = 3.0920
For 60-90 cm (1994) $LSD_{0.05}$ = 2.0703 $LSD_{0.01}$ = 3.1364
For 60-90 cm (1995) $LSD_{0.05}$ = 3.4728 $LSD_{0.01}$ = 5.2611

The used AL method did not show any fertilization effects of the lower K doses. The average value over the experimental years has a significant K increase only where the highest rate of K was applied (150 kg K_2O/ha in 1994,1995). In addition, potassium fertilization, in general, did not show a vigorous increase of available soils K during the experiment. For instance, in the first layer (0-30 cm), the application of 150 kg/ha changed available K concentration only by 3.6 mg K_2O/100 g. Such kind of slight differences between the treatments could be covered by the inadequate collection of soil samples or by the small number of analyzed samples. The results of analyses were also weather dependent, where 1995 varied significantly compared to the other two years of the experiment.

Another method (1N am. acetate extraction) for the evaluation of soil available K, estimated very similar amounts of extracted potassium like AL method (Table 3). Both analyses brought about 16.5 mg K_2O/100 g (AL method)

Tab. 3. - The effect of K fertilization on its available content in vineyard soil (1N ammonium acetate extraction) in 1994,1995 and 1996

Treatments	Depth	1994 mg/100g	1995 mg/100g	1996 mg/100g	Average mg/100g
Control	0-30	11.9	20.0	15.0	15.6
	30-60	14.1	19.7	14.7	16.2
	60-90	12.7	17.7	12.8	14.4
	90-120	12.2	17.8	15.8	15.2
50 kg/ha	0-30	12.8	22.5	15.0	16.7
	30-60	13.6	21.4	14.7	16.5
	60-90	14.7	20.6	15.8	17.0
	90-120	13.6	20.8	16.1	16.8
100 kg/ha	0-30	13.8	21.1*	17.2	17.4
	30-60	13.6	20.5*	17.2	17.1
	60-90	14.1	23.8	14.7	17.5
	90-120	13.3	21.6	15.3	16.7
150 kg/ha	0-30	15.0*	23.3*	16.7	18.3
	30-60	16.1	21.7*	16.6	18.3
	60-90	14.7	20.5	11.1	15.4
	90-120	12.2	19.4	13.0	14.8
				Average in depths:	16.4

For 0-30 cm (1994) $LSD_{0.05}$ = 2.1507 $LSD_{0.01}$ = 3.2582
For 0-30 cm (1995) $LSD_{0.05}$ = 3.7744 $LSD_{0.01}$ = 5.7179
For 30-60 cm (1995) $LSD_{0.05}$ = 2.8916 $LSD_{0.01}$ = 3.1180

and 16.4 mg K_2O/100 g (1N am. acetate extraction), on average, in treatments during the experiment. Also, tested variations confirmed a significant increase of potassium at the highest dose (150 kg/ha), but the latter method (1N am. acetate

extraction) proved to be a more sensitive, detecting the fertilizing effect of 100 kg K_2O/ha application. All these effective variants determined by this extraction refer to the top soil layers (0-30 cm and 30-60 cm), as expected. Generally, recommended doses for potassium fertilizer for high grapevine yield are very low compared to the K bulk soil available reserves. If the total available quantity of potassium is calculated based on its content of 15.6 mg/100 g (0-30 cm), a considerable amount of this element is available to the plants (702 kg/ha). The deeper soil layers (30-60 cm, 60-90 cm), where grape roots mainly take up their nutrients, are even with higher K saturation. In such nutrient, medium it comes out that small K fertilizer rate can not induce any fertilization effects. Some data (Burkart, 1975) indicate that in some cases rates as high as 300 kg K_2O/ha gave only slight responses to the soil potassium level.

K applied from fertilizers saturates mostly a soil solution, partly adsorbed by soil colloids, but a certain amount undergoes fixation in clay minerals. Concerning that content of clay in our soils range from 12.7% (0-30 cm) to 23.9% (30-60 cm), this process was of importance for K status in soil. According to some investigations, a large sum of K from fertilizer can be fixed (>50%), especially if the 2:1 clays are present (Arifin et al. 1973). The K fertilization effect on K fixed content in soil during 1994,1995 and 1996 is presented in Table 4.

Tab. 4. - The K fertilization effect on its fixed content in soil in 1994,1995 and 1996

Treatment	Depth	1994 mg/100g	1995 mg/100g	1996 mg/100g	Average mg/100g
Control	0 - 30	88.0	93.0	99.0	93.5
	30 - 60	91.0	92.2	109.3	97.5
	60 - 90	93.2	88.2	105.2	95.5
	90 - 120	90.6	89.2	113.1	97.6
50 kg/ha	0 - 30	94.2	99.5	105.0	99.5
	30 - 60	95.4	98.6	105.3	99.7
	60 - 90	97.3	97.4	110.1	101.6
	90 - 120	100.4	98.1	108.5	102.3
100 kg/ha	0 - 30	94.1	101.8	101.8	99.2
	30 - 60	88.4	101.4	106.8	98.8
	60 - 90	97.8	100.2	105.3	101.1
	90 - 120	94.6	97.3	96.7	96.2
150 kg/ha	0 - 30	111.0*	96.6	101.3	102.9
	30 - 60	112.9*	98.3	101.3	104.1
	60 - 90	105.3*	94.4	78.9	99.2
	90 - 120	91.8	88.5	92.9*	91.7
				Average in depths:	98.77

For 30-60 cm (1994) $LSD_{0.05}$ = 9.0620 $LSD_{0.01}$ = 8.7122
For 60-90 cm (1994) $LSD_{0.05}$ = 10.2323 $LSD_{0.01}$ =15.5011
For 90-120 cm (1996) $LSD_{0.05}$ = 7.2081 $LSD_{0.01}$ =10.9197

Although the significant values were determined in treatments with 150 kg K_2O/ha (1994), the difference of fixed K^+ in this variant and control exceeds the amount of potassium applied with fertilization. According to calculations for only one soil layer (30-60 cm), the estimated differences of fixed K^+ in a control (91.0 mg K_2O/100 g) and the treatment with 150 kg/ha (112.9 mg K_2O/100 g) is 21.9 mg/100 g. Practically, it means that this soil layer with added 150 kg K_2O/ha was enriched with 985 kg/ha of potassium (21.9 mg/100 g x 10.000 m^2 x 30cm x 1.5 g/cm^3). So, this K content in a fixed form was not achieved by fertilization, and the results presented in Tab. 4, which pointed the changes in a fixed form of potassium were not dependent on fertilization effect. Such results could be affected by the absence of the homogenized soil profile, which derives from soil cultivation up to the 120 cm depth. Also, the collected soil samples for analyses could have a great variation in soil fixed K. This is also confirmed by significant variation of fixed K^+ estimated in the deepest layer (Tab.4. Year 1996), which could be hardly affected with added potassium without similar changes in the upper layers. The obtained results also point to the detection problems of fixed K in field conditions, which has been usually avoided, especially in the investigations on cultivated soils. It should be also mentioned that the applied method for the determination of fixed potassium content is much more efficient in pot experiments and in the experiments where the structure and soil profile layers with clay were not disturbed for a long period. However, the fact is that the portion of fixed K depends extremely on applied potassium, but this increase can reach only certain limits (Pantović,1962). Hence, plant producers tend to saturate soils as much as possible with K (or with some other element) by fertilizer application, in order to increase its available content. In the past, this was a common practice in grape growing, where potassium was applied in extremely high quantities on soils rich in clay (Platz,1980). In our experiment, the applied quantities of potassium during the observed period could not affect the similar process.

Conclusion

According to the used AL method, in the first experimental year the fertilization of vineyard soil with potassium resulted in a significant increase of its available content at 30-60 cm and 60-90 cm depth with 150 kg/ha dose. Similar results were obtained with another used method for the extraction of available K (extraction with 1N ammonium-acetate), where significant variations were observed too in 1995 with the application of 100 kg/ha K_2O dose. Besides that these two analyses extracted similar amounts of available K, in general, they did not point out that the soil was enriched with potassium by fertilization. Even the highest dose (150 kg/ha) of added K was diluted in K present in the soil, having

only a slight effect on its available form in soil. The measuring of fixed K^+ was not dependent on potassium fertilization, and did not give reliable and repeatable results. With a significant effect only in the first year of the experiment (1994), it was calculated that the fixed K^+ quantity exceeds the amount of applied soil in investigated soil layers.

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UTICAJ DJUBRENJA KALIJUMOM NA NJEGOV PRISTUPAČNI I FIKSIRANI SADRŽAJ U VINOGRADARSKOM ZEMLJIŠTU

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Kalijum igra jednu od najvažnijih uloga u ishrani vinove loze, pa je redovna primena visokih doza kalijumovih djubriva praksa u proizvodnji groždja. Imajući u vidu da mnogi uslovi u zemljištu utiču na ishranu loze kalijumom (tip zemljišta, sadržaj gline, vodni režim itd), u trogodišnjem periodu (1994-1996) je praćena

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primena kalijumovog djubriva u rastućim dozama: 0 kg K_2O/ha, 50 kg K_2O/ha, 100 kg K_2O/ha i 150 K_2O/ha. Ogled je izveden na gajnjači u vinogradu sa sortom Sovinjon blank, kalemljenoj na podlozi Kober 5BB. Posle utvrdjivanja ukupnog sadržaja kalijuma u zemljištu (1870-1920 mg K_2O/100 g), odredjen je i njegov pristupačni sadržaj i to primenom dve različite ekstrakcione metode: AL-metoda i ekstrakcija sa 1 N amonijum acetatom. Količine pristupačnog K koje su ovim metodama ekstrahovane su bile vrlo slične, bez signifikantnih razlika. Na osnovu rezultata primenjene AL metode efekat djubrenja kalijumom je bio vrlo signifikantan samo pri dozi od 150 kg/ha u prvoj godini ogleda u srednjim slojevima (30-60 cm, 60-90 cm). Druga ekstrakciona metoda kojom je odredjivan pristupačni K takodje je utvrdila efekat djubrenja kalijumom u 1994. i 1995. godini pri dozi od 150 kg/ha, ali sa nižim stepenom signifikantnosti. Fiksirani K^+ u zemljištu nije bio zavisan od djubrenja, medjutim, rezultati analiza ukazuju na teškoće pri odredjivanju ove frakcije K u zemljištu. Količine koje su odredjene kao fiksirane količine prevazilaze količine dodatog kalijuma djubrivima.

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