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Differences in potassium uptake in grapevine varieties: Reasons and perspectives[1])

by

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Sortenunterschiede bei der Kaliumaufnahme der Weinrebe: Ursachen und Ausblicke

Zusammenfassung: Die Sortenunterschiede der Kaliumaufnahme bei den beiden *Vitis-vinifera*-Reben Leányka (Mädchentraube) und Ezerjó (Tausendgut) wurden durch Messungen des K-Influx unter Nahezugleichgewicht-Bedingungen bestimmt. Für die Untersuchungen wurden Einaugenstecklinge in Nährlösungen mit verschiedener K-Konzentration bewurzelt und aufgezogen. Die Ergebnisse der K-Aufnahme werden im Zusammenhang mit den K-, Na-, Mg- und Ca-Gehalten der Wurzeln, Blattstiele und Blätter diskutiert. Es zeigte sich, daß die Sorte Leányka, die K gut verwertet, über wirksame Aufnahme- und Transportmechanismen verfügt. Hingegen fehlen diese Aufnahme- und Transportsysteme bei der Sorte Ezerjó, die nicht in der Lage ist, Kalium wirksam zu nutzen. Die Ergebnisse stehen in guter Übereinstimmung mit den praktischen Erfahrungen über die Nutzung von K durch die beiden Sorten. Somit erscheint diese Methode für die Selektion von Rebsorten mit hohem K-Nutzungsvermögen geeignet.

Key words: potassium, sodium, magnesium, calcium, absorption, translocation, root, leaf, variety of vine, selection.

Introduction

Varietal differences in uptake and accumulation of minerals are well known from the practice of grapevine cultivation (DOWNTON 1977; EIFERT and KURUCZ 1978; DIÓFÁSI *et al.* 1981; SCHIMANSKY 1983). The genetically determined biochemical background of the efficient utilization of a certain element is, however, not known. Uptake in the root cells, translocation to the upper parts or compartmentalization within the cell may all be involved in the manifestation of varietal differences (CLARKSON and LÜTTGE 1984). This phenomenon is better understood for monocotyledonous than for dicotyledonous plants. For instance, among barley genotypes significant differences were found in short-term K influx (PETTERSON 1978; GLASS and PERLEY 1980; JENSÉN and PETTERSON 1980). For grapevine varieties, on the basis of K and Mg contents of leaf blades efficient and inefficient K-utilizer varieties were distinguished, these being the two extremes Leányka and Ezerjó, respectively. The former variety responded fast to K fertilization while Ezerjó gave a slower reaction and required higher doses than the efficient Leányka (DIÓFÁSI *et al.* 1981; EIFERT *et al.* 1982). These findings and experiences strongly suggest that possibly the primary uptake mechanism is involved in the varietal differences.

To check this possibility, K influx was determined in young roots of one-node cuttings of different K status. For the determination of influx rates the near-equilibrium

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technique was used (ERDEI *et al.* 1984) which was shown to provide information for the intensity of active and passive influxes as regulated by the K status of the root. In the interpretation of transport data the sodium, magnesium and calcium contents in the two varieties were also taken into consideration.

Materials and methods

Growth of plants

One-node cuttings of grapevines, *Vitis vinifera* L. cv. Leányka (Mädchentraube) and cv. Ezerjó (Tausendgut), were placed in plastic pots each containing 4 l of nutrient solution. Complete nutrient solution was used with different K supplies as follows in mM: $NaNO_3$ 0.5; $Ca(NO_3)_2$ 1.0; $MgSO_4$ 1.0; NaCl 0.5; NaH_2PO_4 and Na_2HPO_4 0.15 each and KCl ranging from 0.02 to 10.0. Micronutrients in µM were B 10.0; Fe 10.0; Mn 1.0; Mo 0.7; Zn, Cu and Si 0.5 each and Co and Al 0.1 each. The nutrient solution was renewed weekly before rooting (for 4 weeks) and twice a week after rooting (2 weeks) and continuously aerated. The cultivation took place in a conditioned glass-house with day/night temperature of 25/18 °C, under natural light conditions in May and June. Shoots were about 5 weeks old at the time of experiments.

Table 1

Average weight of roots, stems, petioles and leaf blades of the varieties Leányka (L) and Ezerjó (E) at the time of sampling (mg DW/plant)

Durchschnittsgewicht von Wurzeln, Sproßachsen, Blattstielen und Blattspreiten der Sorten Leányka (L) und Ezerjó (E) bei der Probenahme (mg T.G./Rebe)

[K] of growth medium (mmol/l)	Variety	Roots	Stems	Petioles	Leaf blades
0.005	L	9.5	75.4	13.1	154.9
	E	12.2	32.3	12.0	108.5
0.01	L	15.8	81.7	23.5	176.1
	E	18.0	42.8	9.3	123.2
0.02	L	16.8	140.6	30.6	295.4
	E	16.6	48.8	10.5	141.6
0.05	L	10.9	133.0	27.9	240.2
	E	16.3	62.3	19.2	227.5
0.1	L	17.7	95.4	31.5	182.0
	E	15.7	49.8	15.8	164.4
0.3	L	14.5	119.4	27.9	237.9
	E	16.1	53.0	11.5	145.9
1.0	L	13.3	102.9	26.3	243.2
	E	14.3	52.9	13.6	134.8
3.0	L	19.6	88.1	26.3	225.8
	E	15.1	38.8	7.9	105.8
10.0	L	17.3	104.4	21.2	219.1
	E	18.5	55.3	13.3	178.3

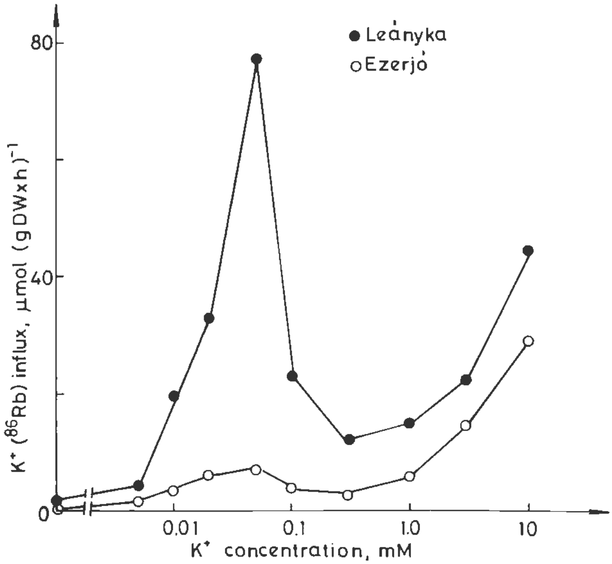

Fig. 1: Changes of K (^{86}Rb) influx into roots of intact *V. vinifera* plants as the function of K concentration in the growth and uptake solutions. Varieties Ezerjó (○) and Leányka (●).

Veränderung der K-(^{86}Rb-)Aufnahme durch die Wurzeln intakter *V.-vinifera*-Pflanzen in Abhängigkeit von der K-Konzentration der Wachstums- und Aufnahmelösungen. Rebsorten Ezerjó (○) und Leányka (●).

Uptake measurement and analysis

K (^{86}Rb) uptake experiments were carried out using freshly made growth solutions containing ^{86}Rb as tracer for K. The specific activity was constant throughout the solutions (37 kBq/100 µmol K). In order to ensure non-limiting conditions for K uptake below 0.2 mM concentration the amount af available K per plant was held constant by

Table 2

Uptake and translocation of K (^{42}K) and its distribution among leaf blades, petioles, stems, canes and roots · Experimental time was 5 h · Mean ±SD of data for 10 plants · Leaf blade dry weights were 82.0 ± 13.4 g for Leányka and 61.6 ± 14.2 g for Ezerjó

Aufnahme, Translokation und Verteilung von K (^{42}K) auf Blattspreiten, Blattstiele, Sproßachsen, Stecklingsholz und Wurzeln · Versuchsdauer 5 h · Mittelwerte ± Standardabweichung aus 10 Pflanzen · Blatttrockengewicht bei Leányka 82,0 ± 13,4 g, bei Ezerjó 61,6 ± 14,2 g

	K (^{42}K) — µmol (g DW × 5 h)$^{-1}$	
	Leányka	Ezerjó
Leaf blade	0.30 ± 0.3	0.010 ± 0.007
Petiole	0.97 ± 0.9	0.09 ± 0.1
Stem	1.18 ± 1.1	0.05 ± 0.06
Cane	0.38 ± 0.3	0.035 ± 0.06
Root	30.6 ± 19	17.6 ± 8.8

increasing the volume of the uptake solution. After an uptake period of 1 h at 25 °C the roots were rinsed in inactive uptake solution three times for 1 min. The roots and shoots were then separated and the ^{86}Rb taken up was assayed in a γ-spectrometer (Gamma, Budapest). Three cuttings were separately measured and their average is shown. Standard deviation was ± 15 %.

One experiment was conducted with ^{42}K as tracer for K with 10 plants of each variety grown on 0.05 mM K concentration. Experimental time was 5 h, other conditions were as described.

For the element analysis plant material from the same set of cuttings was separated for roots, stems, petioles and leaf blades (average weights see Table 1) and wet digested in a H_2SO_4/H_2O_2 mixture. K and Na were determined by atomic emission spectrometry and Mg and Ca by atomic absorption spectrometry as described earlier (Bérczi *et al.* 1982). Errors of determination did not exceed ± 10 %. Since the element contents in stems and petioles were practically the same in each sample data for stems are omitted.

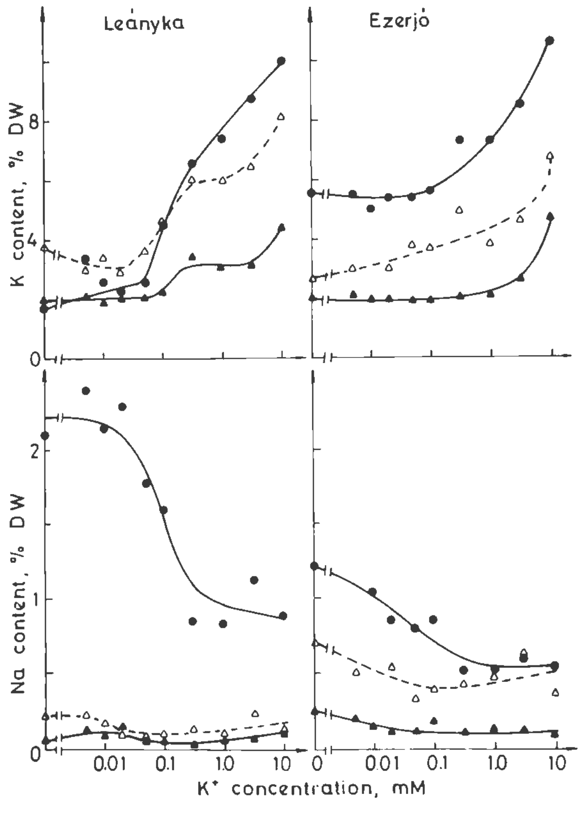

Fig. 2: Changes in the K and Na contents of roots (●), petioles (△) and leaf blades (▲) of the varieties Leányka and Ezerjó as the function of K supply.

Veränderung der K- und Na-Gehalte in den Wurzeln (●), Blattstielen (△) und Blättern (▲) der Rebsorten Leányka und Ezerjó in Abhängigkeit von der K-Versorgung.

Results

Fig. 1 shows the K (^{86}Rb) influx rates in the roots of Leányka and Ezerjó as the function of K concentration in the growth and uptake solutions. Leányka cuttings of low K status exhibit tenfold higher influx rate in comparison with Ezerjó giving maximum at the K concentration of 0.05 mM. Above 0.3 mM the patterns in the two varieties show smaller differences and are of similar character.

The difference in uptake and translocation between the two varieties is also shown by the results of a long term experiment using ^{42}K as tracer for K (Table 2). Although the difference between roots, due to the 5 h of uptake time, is less than in 1 h influx experiments, the translocated amount of K is about tenfold in Leányka in comparison with Ezerjó.

The changes in the K and Na contents in roots, petioles and leaf blades are shown in Fig. 2. For the changes in the K concentration in the growth medium the two varieties responded in different ways as follows: (1) at low K concentrations the K con-

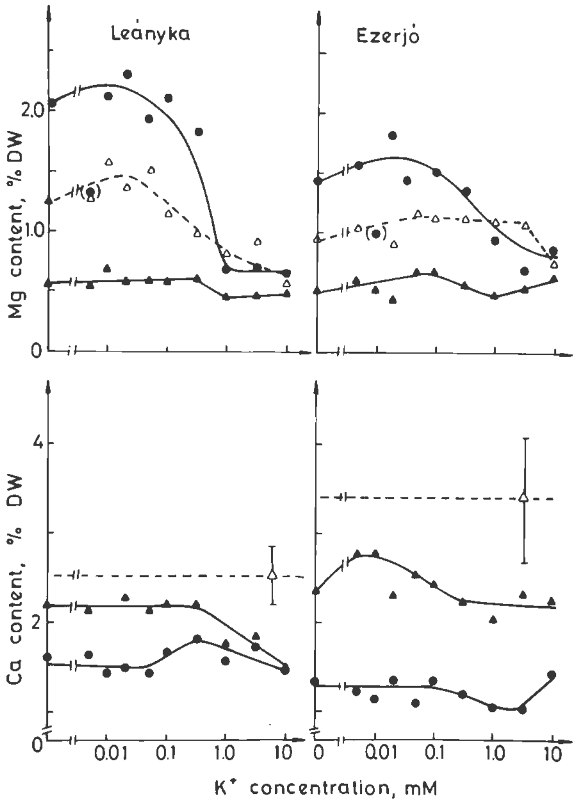

Fig. 3: Changes in the Mg and Ca contents of roots, petioles and leaf blades of the varieties Leányka und Ezerjó as the function of K supply. Symbols as in Fig. 2.

Veränderung der Mg- und Ca-Gehalte in den Wurzeln, Blattstielen und Blättern der Rebsorten Leányka und Ezerjó in Abhängigkeit von der K-Versorgung. Symbole wie in Abb. 2.

tent in the roots of Leányka was only the half of that in Ezerjó; (2) starting from K concentration of 0.05 mM Leányka intensively accumulated K in contrast to Ezerjó; (3) in Leányka K was translocated to the shoots whereas in Ezerjó translocation was very poor (petioles) or did not occur at all (leaf blades); (4) K content tended to saturate in Leányka but not in Ezerjó.

Na content decreased with increasing K content in both varieties. Leányka accumulated a considerable amount of Na in the roots for the replacement of K under low K supply. Na was, however, not translocated to the shoot in this case. For the other variety, Na was distributed among the different parts of the plant although a smaller amount of it was taken up.

Among the divalent cations, Mg content depended on the K supply (Fig. 3). In general, under K-deficient conditions the uptake of Mg seemed to be limited as well, and under high-K environment it decreased again owing to K-Mg competition. This phenomenon was more pronounced in Leányka than in Ezerjó. Changes in Mg content in petioles of Leányka showed a similar trend to that of roots, however, it appeared to be relatively independent of K supply in leaf blades of both cultivars and in the petioles of Ezerjó.

Ca content decreased at high K concentrations in Leányka. In most cases, however, it apparently fluctuated in an irregular way, especially in petioles. Therefore, for petioles the mean (± SD), instead of the actual values is shown in Fig. 3.

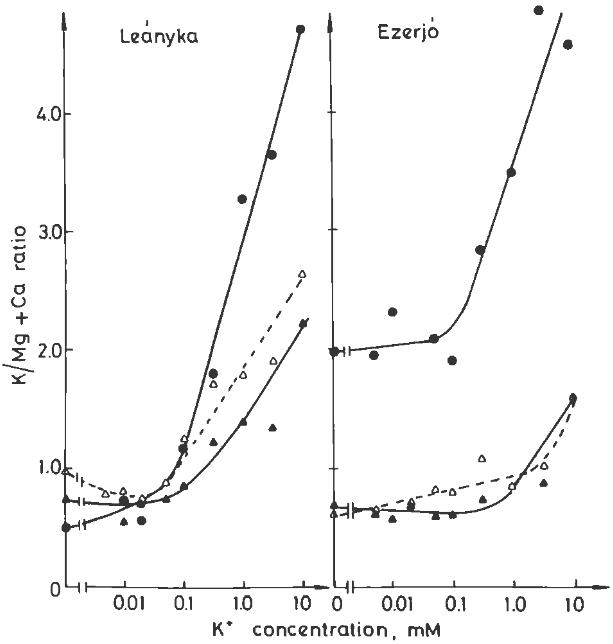

Fig. 4: K/Mg + Ca ratios in the roots, petioles and leaf blades of Leányka and Ezerjó as influenced by the K concentration in the growth solutions. Symbols as in Fig. 2.

K/Mg + Ca-Quotienten der Wurzeln, Blattstiele und Blätter von Leányka und Ezerjó unter dem Einfluß der K-Konzentration der Wachstumslösungen. Symbole wie in Abb. 2.

The K/Mg + Ca ratios in roots, petioles and leaf blades in the two varieties are shown in Fig. 4. It is seen that under high K conditions Leányka can be characterized by the higher K/Mg + Ca ratios. In its petioles the high K/Mg + Ca ratio is attributable to both the increased level of K and the decreased levels of Mg and Ca. In contrast, Ezerjó maintained Mg content at a constant value in the petioles and the level of Ca was also higher than in Leányka. Under low K conditions for roots the K/Mg + Ca ratios were very different in the two cultivars due to the diverse levels of K.

Discussion

The data presented suggest that the differences in the utilization of K in the two varieties can be attributed to the differences both in the rates of primary uptake and in the efficiency of the translocation to the shoot. The method used for the estimation of K uptake enabled us to distinguish between active and passive transport processes. In a previous paper (ERDEI *et al.* 1984) we have shown that the first part of the uptake pattern reflects the active uptake mechanism which probably can be induced by available K at low K supply and is inhibited by an excess of K according to a feedback control mechanism. The second part of the uptake pattern at high K contents represents passive processes, probably K/K exchange.

In the effective K utilizer Leányka, the active mechanism was well pronounced showing high affinity towards K in the low concentration region. After a maximal value of uptake rate it decreased again when the inner K content began to increase (negative feedback regulation). In the ineffective K-utilizer Ezerjó this kind of active transport mechanism was negligible, only the passive process was observed in the range of the high K supply. The magnitudes of the passive K influx rates were similar in both varieties. It is interesting to note that the roots of Ezerjó had a high (passive) adsorption ability under low K conditions since its K content was higher than that of Leányka, but this fraction was not available for translocation to the shoot.

The difference in upward translocation of K between the two varieties may be of similar nature to the difference in the uptake mechanisms, i.e. the failure of the mechanism operating at low concentrations. It is supposed that there is a second energy-dependent step in the plasmalemma of xylem parenchyma cells which actively secretes ions into xylem preceeding long distance transport (LÄUCHLI 1976). This suggestion has obtained experimental support by the inhibition of translocation but not of the primary uptake of K in the presence of 10^{-5} mol/l diethyl stilbestrol in wheat seedlings (OLÁH *et al.* 1982). These considerations may imply that the reason for the inefficient absorptive mechanism in Ezerjó is a defect in the K transport system in the plasmalemma of either the cortical or the xylem parenchyma cells.

It is seen from Table 1 that the leaf mass of Leányka was the higher one in comparison with that of Ezerjó. In the case of the samples grown at [K] = 0.05 and 0.1 mM, however, the difference was only about 20 %. In this way other factors than the possibly higher transpiration capacity of Leányka determinate its higher translocation of K. As is discussed above, the inefficient K transport system may be the rate limiting step in Ezerjó: this view was supported by the results of K uptake experiments with excised roots, where the difference in the influx rate between the two varieties was more than 10fold (8.8 and 0.6 μmol K $(g\ DW \times h)^{-1}$ for Leányka and Ezerjó, respectively, n = 5). The role of transpiration in K translocation in the scion, however, should be further investigated. These studies are in progress in our laboratory.

Data concerning changes in Na content call the attention to the role of Na in the substitution of K for a certain extent under low K conditions (MARSCHNER 1971). Here, of the two varieties, Leányka accumulated the greater amount of Na which was retained in the roots. In contrast, although less Na was taken up in the roots of Ezerjó, a considerable amount was translocated to the shoots. This might also be due to the failure of a selective secretion mechanism at the xylem.

Among the divalent cations, mainly the Mg content was affected by both the shortage in and the excess of K, reflecting the mutual dependency of these cations. Finally, it could be shown that the high K/Mg + Ca ratio in the petioles of Leányka, which is susceptible to 'stiellaehme' was the result of the increased K and decreased Mg content, in contrast to the 'stiellaehme' resistant Ezerjó where the K level increased but Mg content did not decrease in the petioles. The higher Ca content in the petioles and laminae of Ezerjó could also contribute to its 'stiellaehme' resistance.

In conclusion, it may be stated that measuring K influx under near-equilibrium conditions is a suitable method for the estimation of the efficiency of the K absorptive mechanism in grapevine varieties. It may also be a useful tool for breeders in the selection of the most efficient K-utilizer individuals. Further research is needed, however, for the elucidation of interaction between scion and rootstock. These investigations are currently in progress in our laboratories.

Summary

The varietal differences in potassium uptake in two grapevine cultivars (*Vitis vinifera* L. cvs Leányka and Ezerjó) were studied by measuring K (^{86}Rb) influx rates under near-equilibrium conditions. For this purpose, one-node cuttings were rooted and grown in nutrient solutions with different K supplies. The transport data are discussed along with K, Na, Mg and Ca contents of roots, petioles and leaf blades. It was found that the effective K-utilizer variety, Leányka, possesses efficient uptake and translocation mechanisms while these transport systems were lacking in the inefficient K-utilizer Ezerjó. Since the data presented are in good agreement with practical experiences for the utilization of K by the two cultivars, the method seems to be suitable for the selection of the most effective K-utilizer varieties.

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