

## Effect of K supply and relative humidity on ion uptake and distribution on two grapevine rootstock varieties

by

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### Der Einfluß von K-Versorgung und relativer Luftfeuchtigkeit auf die Ionenaufnahme und -verteilung in zwei Unterlagsrebsorten

**Zusammenfassung:** An zwei Unterlagsrebsorten (Freedom, 140 Ruggeri) wurde der Einfluß unterschiedlicher K-Versorgung und Luftfeuchtigkeit auf die K-Aufnahme untersucht, um den Mechanismus, der für die unterschiedliche K-Aufnahme dieser Sorten verantwortlich ist, näher zu charakterisieren. Bei niedrigem K-Angebot (0.5 mmol/l) waren die K-Gehalte in den Blattspreiten und -stielen der beiden Sorten ähnlich, doch bei hoher K-Versorgung (5 mmol/l) überstiegen die K-Gehalte in den Blattspreiten und -stielen von Freedom deutlich diejenigen von 140R. Die Gesamt-K-Aufnahme während des Versuchs bestätigte dieses Ergebnis mit signifikant höherer K-Aufnahme von Freedom-Reben im Falle hoher K-Versorgung. Bei niedriger K-Versorgung ließen sich 30—60 % der Gesamt-K-Aufnahme mit dem theoretischen Eintrag von K im Transpirationsstrom erklären. Bei hoher K-Versorgung dagegen überstieg der theoretische K-Transport im Transpirationsstrom die tatsächliche K-Aufnahme um 232—479 %. Die sortentypische K-Aufnahme könnte durch einen zweiphasigen K-Aufnahmemechanismus erklärt werden: System I, welches von 0 bis etwa 0.5 mmol/l K arbeitet, scheint auf aktivem Transport zu beruhen, System II, welches ab etwa 1 mmol einsetzt, scheint dagegen passiv zu sein und könnte an die Wasserbewegung des Transpirationsstroms gebunden sein. System I dürfte in beiden Sorten identisch sein, nicht dagegen System II. Die Existenz eines solchen zweiphasigen K-Aufnahmemechanismus mit zwei voneinander unabhängigen Systemen würde die Züchtung und Auslese von Unterlagsorten erlauben, die die K-Aufnahme im Falle hohen K-Angebots begrenzen, ohne dabei ihre Effizienz im niedrigen K-Versorgungsbereich einzubüßen.

**Key words:** rootstock, nutrition, potassium, cation, anion, water, absorption, translocation, transpiration, growth, dual uptake mechanism.

### Introduction

One of the major factors affecting the perception of grape juice or wine quality is pH. It not only determines the acid taste, but also affects the microbial stability and hue of red wines (BOULTON 1980). The pH is controlled by the balance of cations and anions, with K the major cation and malate and tartrate the major anions (WEJNAR 1971; SOMERS 1975; BOULTON 1980; ILAND 1987). It has been shown that rootstock varieties affect grape juice pH by affecting grape juice K concentrations (HALE 1977; CIRAMI *et al.* 1984; RÜHL *et al.* 1988). There is increasing evidence that this rootstock effect on grape juice K concentration can be attributed to genetically based differences in K uptake and/or root-to-shoot transport rates. In particular, the variety Freedom, a complex hybrid with the species *Vitis champinii* as the major component in its pedigree, has demonstrated a high K accumulation rate in the shoot, while *V. berlandieri* × *V. rupestris* hybrids (1103 Paulsen and 140 Ruggeri) showed low K accumulation (RÜHL 1989 b, 1991).

The mechanism involved in these genetically different K uptake rates is not clear. Nutrient uptake and distribution not only depends on the actual ion absorption, but

also on ion movement to the site of uptake and on the translocation from the root to the shoot. To identify the mechanism which regulates K uptake in rootstocks a knowledge of the most important pathway of K movement to the site of uptake is therefore essential as well. BARBER (1962) proposed three principle ways of ion transport: root interception, diffusion and massflow. Root interception and diffusion are dependent on root growth and root surface area (MARSCHNER 1986), thus varietal differences in uptake of ions, which depend predominantly on either interception or diffusion as the major means of arriving at the root surface, may largely be the result of differences in root growth or root surface area. If in contrast mass flow, which is driven by transpiration, is the major form of transport, the uptake differences may depend less on root growth or root surface area and more on unrestricted water and ion flow. Mass flow is commonly regarded as less important for K movement (BARBER 1974), but may be the major pathway in cases of high K supply (SCHACHTSCHABEL *et al.* 1976).

EPSTEIN *et al.* (1963) proposed a dual mechanism for the absorption of K by roots. The first part (system I) operates from 0 to 0.5 mmol/l K and follows Michaelis-Menten kinetics with a steep increase initially, but only a marginal increase in K absorption from 0.1 to 0.5 mmol/l K supply. At a K supply of approximately 1 mmol/l K a second mechanism, called system II, becomes operative, resulting in a strong increase in K absorption. This dualism in ion absorption has been confirmed in a number of publications (cf. EPSTEIN 1972), but the K absorption by system II could in contrast to system I not be described in terms of Michaelis-Menten kinetics (EPSTEIN and RAINS 1965). While system I is generally regarded as being located in the plasma membrane, discussion concerning the site of system II is still ongoing (cf. EPSTEIN 1972; NISSEN *et al.* 1980; BORSTLAP 1983). Potassium uptake studies on a range of grapevine rootstock varieties revealed different K uptake rates when K supply was 1 mmol/l or higher, but not when K supply was 0.1 mmol/l (RÜHL 1989 b). This indicates that differences between these varieties might only occur in the range of system II.

In the present study the effects of different transpiration rates and K supply on ion uptake and distribution of two rootstock varieties were investigated in an attempt to characterize the mechanism(s) involved in varietal based differences in K uptake rates.

### Materials and methods

Cuttings of the rootstock varieties Freedom and 140 Ruggeri (140R) were rooted in sand in a misthouse, transplanted into 1.5 l<sup>1</sup> pots, containing a sand/peat mixture (4:1 v/v) and kept in a glasshouse at ca. 25/20 °C. When the shoots were approximately 25 cm long the trial commenced. Five vines of each genotype were harvested before the commencement of the trial and the dry weight and mineral contents of the various parts determined. The remaining 20 plants of each genotype were transferred to one of two identical growth cabinets (10 vines each), set at 25 °C for 16 h (day) and 20 °C for 8 h (night). The relative humidity in the cabinets was set at 90 and 30 %, respectively. The photon flux density during the light period at plant level was 250  $\mu\text{mol}/\text{m}^2/\text{s}$  (400–700 nm).

The plants were watered daily to excess with 400 ml of a complete nutrient solution (MARSCHNER and SCHROPP 1977), with K levels modified in the various treatments. Five plants of each genotype in each cabinet were supplied with a total concentration of 0.5 mmol/l K in the solution, the other five with nutrient solution containing a total concentration of 5.0 mmol/l K (as  $\text{K}_2\text{SO}_4$ ). After growing for 21 d under these conditions, all plants were harvested. Leaf area was measured with an image analysing system or in the case of intact plants (at the beginning of the trial) from leaf width and a

polynomial regression, describing the relationship between leaf area and width of the various rootstock varieties ( $r \geq 0.98$ ). Apical (developed during experiment) and basal laminae, petioles, stems and roots were dried at 65 °C and ground in a hammermill to pass a mesh size of 0.2 mm. For K, Mg, Ca and Cl analyses samples were ashed at 550 °C for 14 h, and the ashes dissolved in HNO<sub>3</sub> and analysed by flame emission or silver-ion titration, respectively, as described earlier (RUHL 1989 a). Soluble nitrate was extracted from 100 mg dried, ground material in 1 ml water at 35 °C for 1 h using an ultrasonic waterbath. After centrifugation of the extracts, nitrate was determined by HPLC, using a Perkin Elmer series 400 pump, an ICI-Kortec K65B autosampler and a Varian CM-2 conductivity monitor, which was interfaced to an IBM-AT compatible computer with DAPA Chromatography Software (Kalamunda, W.A.) installed. The column used was a Hamilton PRP-X100 column kept at 35 °C and the mobile phase was 4 mmol/l potassium hydrogen phthalate at pH 4.8 (flow rate 1 ml/min).

One day before the end of the trial, transpiration was measured gravimetrically as the total water consumption of intact plants over a 24 h period. This was regarded as sufficiently accurate as previous experience had shown that even one transpiration measurement on a single leaf could sufficiently predict the water consumption of glasshouse grown vines over a 4 week period (RUHL 1981). The total water consumption of each vine was estimated as the product of the transpiration per leaf area unit (dm<sup>2</sup>) and per day, the average leaf area between day 1 and day 21 of the experiment and the number of days (21). The total average mineral content of each vine was calculated as the sum of the products of mineral concentration in the dry matter and the dry weights of the various plant parts. The total average mineral contents of plants harvested prior to the commencement of the trial were subtracted from the total mineral contents of plants at the end of the experiment to estimate their total mineral uptake during the trial period. From these data the theoretical contribution of mass flow to the uptake of the various cations was estimated as the ratio between the product of the total water consumption per vine during the trial period and the mineral concentration in the soil solution (i.e. the nutrient solution) and the total mineral uptake.

Data were analysed as a completely randomised factorial design using GENSTAT. For the analysis of the relative contribution of mass flow to mineral uptake a logarithmic transformation of the data prior to computation was required to achieve a normal distribution. The means ( $n = 5$ ) of the various rootstock/humidity/K supply interactions are presented in the tables. Means of main effects (rootstock, humidity and K supply) are not shown in the tables, but are referred to in the text as 'averages' to distinguish them from interactive means.

## Results

### Dry weight production and transpiration

Freedom vines had higher dry weight than 140R in both root and shoot (Table 1). This was most likely due to the use of more developed plants at the start of the experiment. (Dry weights of shoot parts are not presented separately.) First order interactions between K supply, rootstocks and humidity were never significant: it was therefore concluded that treatment effects on plant growth and the growth differences between the genotypes at the commencement of the trial did not affect the mineral concentrations in the various plant parts. Low relative humidity clearly enhanced the average transpiration: at 90 % relative humidity transpiration was 14.7 g water/dm<sup>2</sup>/d compared to 20.5 g water/dm<sup>2</sup>/d at 30 % relative humidity (Table 1). On average, 140R

showed a higher transpiration rate (18.7 g/dm<sup>2</sup>/d) than Freedom (16.5 g/dm<sup>2</sup>/d), but total transpiration of Freedom vines was generally higher due to their larger plant size.

Table 1

Effect of different K supply and relative humidity on dry weight and transpiration of two different grapevine rootstock varieties · Data are means of five replicates each · Different letters indicate significant differences (P = 0.05) between treatments

Einfluß unterschiedlicher K-Versorgung und relativer Luftfeuchtigkeit auf Trockengewicht und Transpiration von zwei verschiedenen Unterlagsrebsorten · Die Zahlen stellen Mittelwerte von je fünf Wiederholungen dar, wobei unterschiedliche Indizes signifikante Unterschiede (P = 0.05) zwischen den Behandlungen bezeichnen

Plant part	K supply mmol/l	Dry weights (g/plant)			
		30 % RH		90 % RH	
		Freedom	140R	Freedom	140R
Shoot	0.5	7.00 d	3.62 ab	5.33 c	4.39 a
	5.0	4.84 bc	3.83 ab	5.38 c	3.17 ab
Root	0.5	1.96 bc	0.72 a	2.40 cd	1.12 a
	5.0	1.77 b	0.71 a	2.61 d	1.12 a
	K supply mmol/l	Transpiration			
		30 % RH		90 % RH	
		Freedom	140R	Freedom	140R
Transpiration (g water/dm <sup>2</sup> /h)	0.5	18.4 bc	22.2 d	14.1 a	15.4 ab
	5.0	19.7 cd	21.8 d	13.7 a	15.7 ab
Total transpiration (g water/plant/21 d)	0.5	3407 e	2484 cd	1853 ab	1829 ab
	5.0	2821 d	2628 cd	2280 bc	1640 a

### Cation contents

On average, higher K supply (5 mmol/l) increased K and reduced Mg contents in all plant parts significantly, while a significant reduction of the average Ca contents could only be found in laminae and petioles and not in stems and roots (Table 2). At low K supply K contents in laminae and petioles were not affected by rootstocks or humidity but with higher K supply differences appeared with higher K contents in laminae and petioles of Freedom vines than in those of 140R vines. While Mg concentrations in laminae of Freedom were significantly reduced when K supply was increased, no significant changes occurred in laminae of 140R. Calcium contents in laminae showed a similar trend. While lower relative humidity increased K, Mg and Ca contents in roots, and K in stems, it only increased Ca in apical laminae (developed during total period) significantly, but did not affect K or Mg in laminae or petioles. This indicates that relative humidity and transpiration are less important for K and Mg transport than for Ca transport. However, only in laminae produced during the trial period did Ca levels show significant differences.

Table 2

Effect of different K supply and relative humidity on cation contents in plant parts of two different grapevine rootstock varieties · Data are means of five replicates each and expressed in % dry weight · Different letters indicate significant differences ( $P = 0.05$ ) between treatments

Einfluß unterschiedlicher K-Versorgung und relativer Luftfeuchtigkeit auf die Kationengehalte in den Pflanzenteilen von zwei verschiedenen Unterlagsrebsorten · Die Zahlen (% des Trockengewichts) stellen Mittelwerte von je fünf Wiederholungen dar, wobei unterschiedliche Indizes signifikante Unterschiede ( $P = 0.05$ ) zwischen den Behandlungen bezeichnen

Plant part	K supply mmol/l	K				Mg				Ca			
		30 % RH		90 % RH		30 % RH		90 % RH		30 % RH		90 % RH	
		Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R
Apical laminae	0.5	1.38 a	1.56 a	1.53 a	1.37 a	0.52 c	0.45 b	0.52 c	0.40 ab	1.60 c	1.51 c	1.67 c	1.16 ab
	5.0	2.74 c	2.23 b	3.14 d	2.45 bc	0.37 a	0.41 ab	0.38 a	0.38 a	1.28 b	1.18 ab	1.29 b	1.05 a
Basal laminae	0.5	1.07 a	1.40 ab	1.74 abc	1.72 abc	0.61 c	0.49 abc	0.56 bc	0.46 ab	2.47 b	1.71 a	2.49 b	1.74 a
	5.0	3.24 e	2.07 bcd	2.78 de	2.45 cd	0.40 a	0.45 ab	0.37 a	0.37 a	1.55 a	1.44 a	1.59 a	1.38 a
Petioles	0.5	4.24 a	4.82 a	5.09 ab	4.34 a	0.73 c	0.49 b	0.82 c	0.74 c	1.40 abc	1.46 abc	1.54 c	1.48 bc
	5.0	6.77 d	6.05 bcd	6.54 cd	5.80 bc	0.27 a	0.39 ab	0.40 ab	0.42 ab	1.21 a	1.22 ab	1.46 abc	1.28 abc
Stem	0.5	1.49 a	3.24 e	1.74 ab	2.22 bc	0.25 b	0.31 c	0.32 c	0.32 c	0.64 a	0.77 c	0.69 ab	0.73 bc
	5.0	3.08 de	2.92 de	2.63 cd	2.83 de	0.19 a	0.26 b	0.20 a	0.27 b	0.67 ab	0.68 ab	0.71 bc	0.72 bc
Roots	0.5	0.65 b	0.70 b	0.30 a	0.76 bc	0.43 d	0.34 c	0.38 c	0.33 bc	1.54 c	1.83 de	1.35 ab	1.70 d
	5.0	0.99 cde	1.22 e	0.86 bcd	1.08 de	0.29 ab	0.28 a	0.26 a	0.25 a	1.46 bc	1.92 e	1.31 a	1.71 d

Table 3

Effect of different K supply and relative humidity on anion contents of two different grapevine rootstock varieties · Data are means of five replicates each and expressed in % dry weight · Different letters indicate significant differences ( $P = 0.05$ ) between treatments · (In apical and basal laminae only traces of Cl could be detected)

Einfluß unterschiedlicher K-Versorgung und relativer Luftfeuchtigkeit auf die Anionengehalte in zwei verschiedenen Unterlagsrebsorten · Die Zahlen (% des Trockengewichts) stellen Mittelwerte von je fünf Wiederholungen dar, wobei unterschiedliche Indizes signifikante Unterschiede ( $P = 0.05$ ) zwischen den Behandlungen bezeichnen · (In apikalen und basalen Blattspreiten konnten nur Spuren von Cl gefunden werden)

Plant part	K supply mmol/l	Cl				NO <sub>3</sub>			
		30 % RH		90 % RH		30 % RH		90 % RH	
		Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R
Apical laminae	0.5	0.00	0.00	0.00	0.00	2.04 bcd	2.05 bcd	1.93 abc	1.27 ab
	5.0	0.00	0.00	0.00	0.00	2.89 d	1.14 a	2.20 cd	1.58 abc
Basal laminae	0.5	0.00	0.00	0.00	0.00	1.06 a	1.10 a	2.11 ab	1.43 a
	5.0	0.00	0.00	0.00	0.00	2.89 bc	1.36 a	1.41 a	3.29 c
Roots	0.5	0.28 b	0.55 d	0.17 a	0.46 cd	1.66 abc	2.26 c	1.12 a	1.80 bc
	5.0	0.26 ab	0.52 d	0.23 ab	0.38 c	1.44 ab	1.21 ab	1.12 a	1.66 abc

### Anion contents

While only traces of Cl could be detected in apical and basal laminae, Cl contents in roots were between 0.17 and 0.55 % in the dry weight (Table 3). As no Cl was added, this Cl must have originated from trace levels in nutrient salts and demineralized water. Because of the identical treatment of the varieties, it can be assumed that both had similar Cl supplies. Despite this presumably similar Cl supply, on average roots of 140R contained twice as much Cl (0.48 %) as those of Freedom (0.24 %). While K supply did not affect Cl content in the roots, plants grown in low humidity had significantly higher Cl contents (0.40 %) in their roots than those grown in high humidity (0.31 %). On average,  $\text{NO}_3$  levels were higher in apical laminae of Freedom than in those of 140R, but in roots the reverse situation applied with higher levels in 140R.

### Total mineral uptake and relative contribution of nutrient flow in the transpiration stream (mass flow) to total uptake

During the trial period Freedom vines took up more K, Mg and Ca than 140R vines (Table 4), a result which is at least partly due to a higher dry matter production of Freedom (Table 1). However, K supply did not significantly affect dry matter production, and therefore its effects on total uptake of K, Mg and Ca are not artefacts of differences in plant growth: Higher K supply significantly increased total K uptake and reduced that of Ca and particularly Mg. The effect of higher K supply on total K and Mg uptake was more pronounced in Freedom than in 140R vines.

Calculations of the theoretical contribution of nutrient flow in the transpiration stream (mass flow) to the actual uptake of various cations (Table 4) indicate that mass flow could have accounted for the entire uptake of Mg and Ca in any of the treatment  $\times$  genotype combinations. In contrast, mass flow could only account for the entire K uptake, if plants were supplied with 5 mmol/l K in the nutrient solution. With 0.5 mmol/l K supply only about half of the K uptake could be contributed by mass flow and the other half must be attributed to diffusion and interception. All values in the 5 mmol/l K treatments were well above 100 %, indicating that the actual uptake was well below the theoretical contribution of mass flow. The plants apparently have restricted K uptake. This uptake restriction was more pronounced in 140R vines, with contributions by mass flow to K uptake of 471 and 371 %, respectively, compared to Freedom vines (311 and 232 %, respectively).

As lower relative humidity increased transpiration (Table 1), it also increased the theoretical contribution by mass flow to uptake of K, Mg and Ca significantly, but no interaction with K supply or genotype was significant.

### Discussion

The aim of this study was to investigate the effect of different transpiration rates and K supply on the K uptake and distribution of two different rootstock varieties, in an attempt to characterize the mechanism(s) responsible for the different K uptake of these genotypes. The results presented confirm previous reports of varietal differences in K accumulation rates of grapevine rootstocks in general, and of the two varieties in this study (Freedom and 140R) in particular (RUHL 1989 b, 1991). Differences in K uptake could not be observed when K supply was 0.5 mmol/l, while at a K supply of 5 mmol/l Freedom vines had significantly higher K concentrations in their laminae and petioles than 140R vines. This study also confirms earlier results (RUHL 1989 b)

Table 4

Effect of different K supply and relative humidity on total mineral uptake during trial period and relative contribution of nutrient flow in transpiration stream (mass flow) to mineral uptake · Different letters indicate significant differences ( $P = 0.05$ ) between treatments

Einfluß unterschiedlicher K-Versorgung und relativer Luftfeuchtigkeit auf die Aufnahme verschiedener Nährstoffe während der Versuchsperiode und den relativen Beitrag des Nährstofftransports im Transpirationsstrom (Massenfluß) auf die Nährstoffaufnahme · Unterschiedliche Indizes bezeichnen signifikante Unterschiede ( $P = 0.05$ ) zwischen den Behandlungen

	K supply mmol/l	K				Mg				Ca			
		30 % RH		90 % RH		30 % RH		90 % RH		30 % RH		90 % RH	
		Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R	Freedom	140R
Total mineral uptake (mg/vine)	0.5	117 a	79 a	104 a	82 a	31 c	13 a	24 bc	18 ab	93 d	40 ab	76 cd	56 abc
	5.0	183 b	110 a	193 b	95 a	8 a	11 a	12 a	8 a	43 ab	37 a	65 bc	33 a
Relative contrib. of mass flow (%)	0.5	58 bc	65 c	35 a	44 ab	197 abc	468 de	126 a	178 ab	313 ab	553 c	198 a	268 a
	5.0	311 d	479 f	232 de	371 e	712 e	397 cde	299 bcd	420 cde	545 c	598 c	284 a	505 bc

which showed virtually identical K contents in laminae or petioles of Freedom and 140R when grown in nutrient solution containing 0.1 mmol/l K. However, if vines were grown in 1, 2 or 10 mmol/l K solutions, significantly higher K contents were measured in Freedom vines (RUHL 1989 b). This indicates that different K uptake between these varieties only occurred in the range of system II (from 1 mmol/l upwards), but not in the range of system I. Most models of a dual carrier system (cf. EPSTEIN 1972) imply an active transport across the membrane for both system I and II, a precondition which is not necessarily required (MARSCHNER 1986). Solute passage through a membrane may also be passive, particularly in a situation of high external concentration (CLARKSON 1977). As system II is operational in the high K supply range, does not follow Michaelis-Menten kinetics and has so far not been localized, the question arises, whether uptake in system II is an active or in fact a passive process as proposed by CHEESEMAN and HANSON (1979) and KOCHIAN *et al.* (1985) for corn roots.

Further evidence for a passive K transport in case of high K supply (5 mmol/l) may be the fact that the theoretical contribution of nutrient flow in the transpiration stream (mass flow) to K transport in this study was always higher than the actual K uptake, i.e. the amount of K carried by the transpiration stream to the root surface was higher than the actual amount of K taken up. If only a proportion (approximately 21–43 %) of this K had been carried with the transpiration stream through the plasma membrane, this amount would have accounted for the total K uptake of these plants. On the other hand, when K supply was 0.5 mmol/l, only about half of the K uptake could be attributed to mass flow. The amount of K carried with the transpiration stream to the roots and possibly through the plasma membrane should not have fully accounted for K uptake. As root interception is regarded as only being of minor importance in K movement to the root (BARBER 1974), the most likely pathway of K movement in this case was diffusion. Ion movement via diffusion is driven by a gradient difference between soil and root free space, it can therefore be assumed that this gradient was created by an active K carrier system in the plasma membrane. Thus the data presented here indicate that a dual K uptake mechanism can be found in grapevine roots, which is similar to that described in corn roots (CHEESEMAN and HANSON 1979; KOCHIAN *et al.* 1985). The two components are system I, an active carrier system, which operates up to about 0.5 mmol/l K supply and system II, which operates from about 1 mmol/l K upwards, is passive, may use K<sup>+</sup> channels (KOCHIAN *et al.* 1985) and might be driven by the water movement of the transpiration stream.

The fact that when K supply was high the theoretical mass flow exceeded K uptake between 2.3 and 4.8 fold not only supports this model of passive, transpiration driven K transport through the plasma membrane, but indicates that, at least under the conditions of this experiment, a mechanism exists in grapevine roots, which restricts passage of K in case of high supply. The fact that relative humidity (transpiration rate) did not affect K contents in laminae or petioles significantly, illustrates the effectiveness of this mechanism in regulating K uptake. The ratio between mass flow and uptake was higher in 140R than in Freedom, indicating a more efficient mechanism for the restriction of K uptake in 140R than in Freedom. This model might explain the observed differences in K accumulation in these genotypes, when K supply was 1 mmol/l or more (RUHL 1989 b, 1991). As no differences in the K uptake could be found when K supply was 0.5 mmol/l or less, system I seems to be identical in the varieties Freedom and 140R.

As a consequence of this distinct different behaviour with respect to K uptake it appears to be possible to breed and evaluate rootstock genotypes, which restrict K uptake in the high K supply range, and thereby reduce K accumulation in the grape berries with its accompanying quality related side effects, but are still as K efficient as

other rootstock varieties in the low K supply range. Such rootstock varieties would therefore be more adaptable to a wide range of K supply conditions, avoiding both K deficiency in the low supply range and excessive uptake in the high supply range.

### Summary

The effect of K supply and relative humidity on K uptake was studied in two grapevine rootstock varieties (Freedom, 140 Ruggeri) in an attempt to characterize the mechanism(s) responsible for the different K uptake of these varieties. When K supply was low (0.5 mmol/l), K contents in laminae and petioles of both varieties were similar, but with high K supply (5 mmol/l) K contents in laminae and petioles of Freedom exceeded those of 140R. The total K uptake per vine during the trial period confirmed these results, with significantly higher K uptake in Freedom vines only when K supply was high (5 mmol/l). When K supply was low, the potential relative contribution of nutrient flow in the transpiration stream to total K uptake ranged from 30 to 60 %, but when K supply was high nutrient flow in the transpiration stream exceeded K uptake by 232—479 %. A dual uptake mechanism is proposed for these grapevine rootstocks with system I, operating up to about 0.5 mmol/l K and based on an active carrier system, and system II, operating from about 1 mmol/l K upwards, which may be passive and possibly driven by the water movement of the transpiration stream. System I seems to be identical in the two varieties, but not system II. The existence of such a dual uptake mechanism with two independent systems should permit the breeding and evaluation of rootstock varieties, which restrict K uptake in the high K supply range without losing K efficiency in the low K supply range.

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