Potassium partitioning between leaves and clusters: Role of rootstock

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Summary: Different scion/rootstock combinations in grapevine (*Vitis vinifera/Vitis* spp.) were tested for nutritional properties and juice composition. Chardonnay and Cabernet Sauvignon each grafted on 22 rootstock varieties (10 new crosses and 12 already used in viticulture) were grown in outdoor pots containing very poor nutritional substrate.

Crop load had a strong effect on juice composition and potassium nutrition. Results indicate that under our experimental conditions rootstock can have an effect on potassium partitioning between leaves and cluster: 9 out of 22 rootstocks that we tried were able to improve leaf potassium content without inducing a significant increase in juice potassium content.

Key words: potassium, nutrition, translocation, rootstock, scion, leaf, bunch, growth, yield, must quality, biometry.

Introduction

Excessive or deficient mineral content in fruits can impair fruit quality in many horticultural crops. Frequently, optimal fruit mineral nutrition does not correspond with optimal leaf mineral nutrition, but optimal leaf mineral nutrition is important for high yield and high plant efficiency (Faust 1980). Thus, regulation of mineral partitioning between leaves and fruits is an important factor in regulating plant productivity and crop quality.

In grapevines, high yield can be obtained with high leaf potassium nutrition (Champagnol 1988), but frequently high leaf potassium nutrition corresponds to excessive potassium accumulation and high pH values in berry juice, and particularly to insufficient wine quality (Mattick *et al.* 1972; Hale 1977; Munyon and Nagel 1977; Boulton 1980; Morris and Cawthon 1982; Morris *et al.* 1980, 1983, 1987; Champagnol 1986; Ryser *et al.* 1989).

Potassium partitioning between leaves and clusters depends on grape variety, crop load of the vines, harvest date, potassium and water soil availability. Data of Morris *et al.* (1987) indicate that in Arkansas Gewurztraminer had higher potassium petiole content and lower potassium juice concentration than Cynthiana, and that the application of potassium fertilizer to Gewurztraminer did not cause an increase in potassium in petioles or juice, whereas fertilization caused an increase in petiole potassium with De Chaunac and an increase in both petiole and juice potassium with Cabernet Sauvignon.

Data from Hepner and Bravdo (1985) indicate that in Carignan and Cabernet Sauvignon a: high crop load was able to reduce potassium levels in leaves and juice and that in Cabernet S. high soil water availability increased the leaf and juice potassium, but that both the effects were more consistent in leaves than in juice.

Morris and Cawthon (1982) were able to indicate an effect of crop load and irrigation on juice potassium but not on petiole potassium with Concord. Similarly, Freeman and Kliewer (1983) noted a more consistent effect of irrigation on juice potassium than on petiole potassium.

Morris *et al.* (1983) in a pot trial showed that with Concord, when the potassium supply ranged from 0 to 12 g/plant, the leaf potassium content passed from 1.25 to 3.5 % dw and the juice potassium concentration raised only from 2.7 to 3.3 g/l.

Table 1: Rootstock varieties and new crosses tested for nutritional behaviour grafted with Chardonnay and Cabernet Sauvignon

Rootstock	Parents
Used varieties	
KOBER 5BB (K5BB)	Vitis Berlandieri x V. riparia
3309 C	V. riparia x V. rupestris
1103 P	V. Berlandieri x V. rupestris
420 A	V. Berlandieri x V. riparia
110 R	V. Berlandieri x V. rupestris
140 Ru	V. Berlandieri x V. rupestris
41 B	V. vinifera (cv. Chasselas) x V. Berlandieri
SO4	V. Berlandieri x V. riparia
GOLIA	Castel 15.612 x Vitis rupestris du Lot
SCHWARZMANN	Vitis riparia x V. rupestris
FERCAL	BCI (V. Berlandieri x V. vinif. cv. Colombard) N. 1 x 333 EM (V. vinifera cv. Cabernet S. x V. Berlandieri)
New crosses	
USMI 1	V. Berlandieri self pollinated
USMI 2	V. Berlandieri self pollinated
USMI 3	V. Berlandieri x V. riparia
USMI 4	V. riparia x V. rupestris
USMI 5	V. Berlandieri x V. vinifera
USMI 6	V. Berlandieri self pollinated
USMI 7	V. riparia x V. rupestris
USMI 8	V. Berlandieri x V. riparia
USMI 9	V. Berlandieri x V. riparia
USMI 10	V. riparia x V. rupestris

Delas *et al.* (1989) indicated that potassium fertilization had greater effect on petiole potassium than on juice potassium and that at low potassium availability the petiole potassium content decreased with greater extent than juice potassium.

Also, rootstocks seem to be effective on potassium partitioning. Delas *et al.* (1989) found that the correlation coefficients between petiole and juice potassium content were affected by rootstock. They also showed some different behaviours of Cabernet S. grafted on different rootstocks: Riparia at the same petiole potassium levels as SO 4 and Fercal induced lower juice potassium concentration.

Our hypothesis is that rootstock could have a significant role in potassium partitioning between leaves and clusters. It should assure an adequate leaf potassium content for adequate productivity (source activity, bud differentiation and assimilate translocation) but should not favour high potassium accumulation in grape juice.

Different physiological patterns are possible to explain the rootstock effect on potassium partitioning: e. g. rates in potassium uptake during the vegetative season, intensity and persistency of shoot apex growth that can compete with cluster for potassium, and regulation of leaf senescence and thus of potassium translocation from leaves to clusters.

Data from screening of new rootstocks for nutritional efficiency verify the possible role of rootstock in potassium partitioning between leaves and clusters.

Materials and method

Different scion/rootstock combinations in grapevine (*Vitis vinifera/Vitis* spp.) were tested for nutritional properties and juice composition and characteristics in 1988 at the experimental farm of the University of Milano in Montanaso Lombardo (Po Valley).

4-year-old vines were grown in outdoor pots (30 l) containing very poor nutritional substrate, constituted of 50 % peat (in volume), with the following characteristics: pH in water 7.6; total Ca carbonate (De Astis method) 8.2 %; soluble Ca carbonate (Drouineau-Galet method) 0.50 %; total nitrogen (Kjeldhal method) 0.46 %; available P (Olsen method) traces; exchangeable K ($AcNH_4$ method) 30 μg/g in K_2O. Pots were kept at field capacity during the entire season by means of trickle irrigation, water loss was replaced daily. To measure the mineral efficiency under these poor soil nutrition conditions, every pot was only slightly fertilized. Each pot was supplied with nitrogen (0.28 g as NH_4NO_3), potassium (0.75 g as K_2SO_4), phosphorus (2.4 g as $Ca(H_2PO_4)_2$), magnesium (0.5 g as $MgSO_4 \cdot 7\,H_2O$) and micronutrients (Mn, Cu, Zn, B, Mo and Fe).

Two cultivars, Chardonnay and Cabernet Sauvignon, each grafted on 22 rootstocks, were chosen. 10 new crosses (USMI series) from the Milano Pomology Institute were compared to rootstocks already used in viticulture (Table 1). Vines were arranged in one randomized block with two replications. To standardize the plants at the beginning of the season, 4 shoots with 2 flower clusters each per vine were retained. Flowering was the 1st week of June in Chardonnay and the 2nd in Cabernet S., while veraison was the 1st and the 2nd week of August, respectively.

When ripe (Chardonnay 30th August, Cabernet S. 4th October), all the grape clusters were collected and weighed. The juice obtained with a manual wine press was analysed for soluble solids (refractometric method), titratable acidity (with NaOH N/10, end pH 8.2), pH, malic acid (enzymatic method), tartaric acid (colorimetric method) and potassium (spectrophotometric method). A sample of basal (4-6 node) and apical (last 3-4 fully expanded) leaves were collected. Potassium was determined by plasma emission spectrometer in the leaf samples. The total shoot length was also measured.

Relations between nutrition and juice characteristics were analysed by correlation. The effects of rootstock and scion on nutrition and juice characteristics were tested by variance and covariance analyses. Differences between the average values were verified by Tukey (1956) test ($P = 0.05$).

Results

The scion/rootstock interaction was never significant, therefore results will be presented and discussed only as scion and rootstock main effects.

Relationships between crop load and juice composition (Table 2)

Both in Chardonnay and Cabernet S. grape yield per vine was negatively related with soluble solids, pH and K content of juice, whereas tartaric acid and titratable acidity were negatively associated with crop load.

Relationships between crop load and potassium leaf content (Table 3)

Crop load decreased the potassium content both in basal and apical leaves.

Table 2: Regression coefficients of the relations between vine crop load and juice composition. CH = Chardonnay, CS = Cabernet Sauvignon. NS: non-significant, *, **, ***: P ≤ 0.05, 0.01, 0.001

JUICE COMP.	CV	SOLUBLE SOLIDS	pH	TITRAT. ACIDITY	MALIC ACID	TARTARIC ACID	K
CROP	CH	-0.58***	-0.57***	0.34**	NS	0.48***	-0.42***
LOAD	CS	-0.44***	-0.57***	0.31**	0.35***	0.30**	-0.51***

Table 3: Regression coefficients of the relations between vine crop load and leaf potassium content at harvest time. CH = Chardonnay, CS = Cabernet Sauvignon. NS: non-significant, *, **, ***: P ≤ 0.05, 0.01, 0.001

LEAF K	CV	BASAL LEAVES	APICAL LEAVES
CROP	CH	-0.45***	-0.31***
LOAD	CS	-0.31***	-0.29**

Table 4: Regression coefficients of the relations between juice K and juice composition. CH = Chardonnay, CS = Cabernet Sauvignon. NS: non-significant, *, **, ***: P ≤ 0.05, 0.01, 0.001

JUICE COMP.	CV	SOLUBLE SOLIDS	pH	TITRAT. ACIDITY	MALIC ACID	TARTARIC ACID
JUICE	CH	0.46***	0.48***	NS	NS	NS
K	CS	0.42***	0.22*	-0.24*	NS	-0.22*

Relationships between juice potassium content and juice composition (Table 4)

Both in Chardonnay and Cabernet S. potassium content of the juice correlated with its soluble solids concentration and with its pH levels.

Relationships between leaf potassium content and juice composition (Table 5)

Potassium content of leaves correlated with potassium in the juice in both the cultivars. The other juice characteristics correlated with leaf potassium only in Chardonnay, where soluble solids, pH and malic acid values were positively associated with leaf potassium.

Table 5: Regression coefficients of the relations between leaf K content and juice composition. CH = Chardonnay, CS = Cabernet Sauvignon. NS: non-significant, *, **, ***: P ≲ 0.05, 0.01, 0.001

JUICE COMP.	CV	SOLUBLE SOLIDS	pH	TITRAT. ACIDITY	MALIC ACID	TARTARIC ACID	K
BASAL	CH	0.32*	0.43***	NS	0.34**	-0.23*	0.58***
LEAF K	CS	NS	NS	NS	NS	NS	NS
APICAL	CH	0.27*	0.22*	NS	0.35**	NS	0.52*
LEAF K	CS	NS	NS	NS	NS	NS	NS

Table 6: Scion effect on juice composition; means adjusted by crop load effect. Means followed by the same letter are not different (P = 0.05)

	SOLUBLE SOLIDS g/l	pH	TITRAT. ACIDITY meq/l	MALIC ACID meq/l	TARTARIC ACID meq/l	K meq/l
CHARDONNAY	155a	3.06a	108a	50a	85a	15.8a
CABERNET S.	169b	3.02b	121b	72b	84a	18.1b

Table 7: Rootstock effect on juice composition evaluated by variance and covariance analyses with vine crop load as covariate variable. F = Fisher's F, P = Fisher's F probability

		SOLUBLE SOLIDS	pH	TITRAT. ACIDITY	MALIC ACID	TARTARIC ACID	K
VARIANCE	F	1.945	1.905	2.011	1.661	1.370	2.391
ANALYSIS	P	**0.022**	**0.026**	**0.017**	0.063	0.169	**0.040**
COVARIANCE	F	1.394	1.575	1.797	1.666	1.072	1.905
ANALYSIS	P	0.157	0.086	**0.039**	0.062	0.399	**0.026**

Scion and rootstock effects on vine vigour and crop load (Fig. 1)

Total shoot length did not correlate with yield per vine. Average number of shoots per vine was 3.8. It was not influenced by scion and rootstock due to experimental standardization of the plants. Total shoot length was slightly controlled by rootstock, Golia induced a high shoot growth, while USMI 7 was characterized for inducing low shoot growth in the scion.

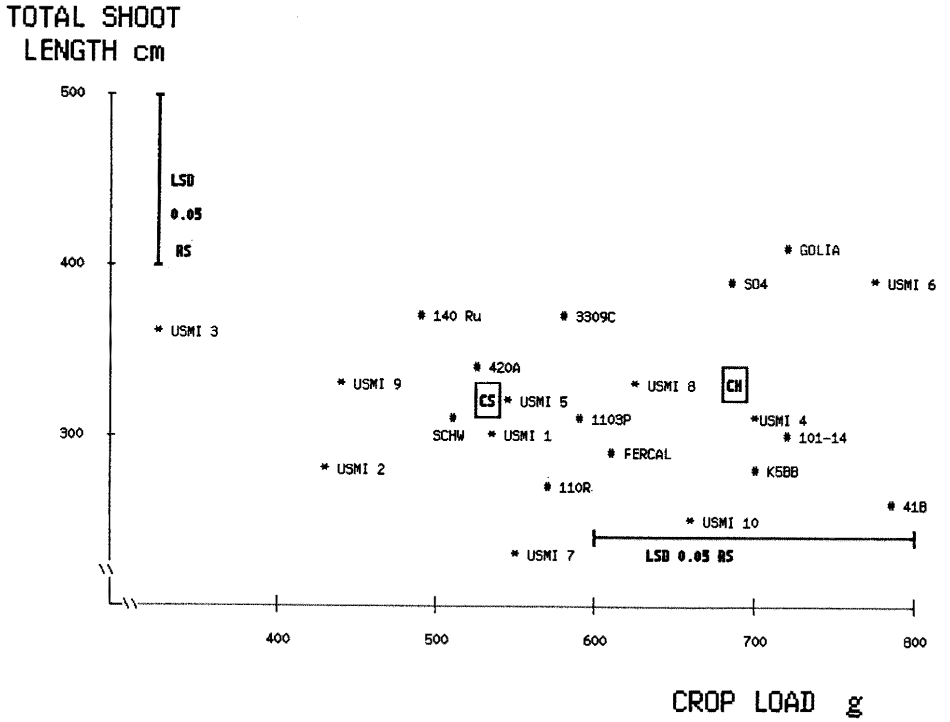

Fig. 1: Scion and rootstock effect on vine vigour and crop load.

In spite of the initial plant standardization, the number of grape clusters per vine was influenced both by scion and rootstock, whereas average weight of grape cluster was influenced only by scion. Consequently, crop load per vine was controlled both by scion and rootstock. Chardonnay had a higher grape production than Cabernet S.; USMI 6 and 41 B induced high grape yield; USMI 2 , USMI 3 and USMI 9 induced low grape yield.

Scion and rootstock effect on juice characteristics (Tables 6 and 7)

Due to the correlation between juice characteristics and crop load, scion and rootstock effects on juice composition were studied by variance and covariance analyses.

Table 8: Scion effect on leaf potassium content at harvest time; means adjusted by crop load effect. Means followed by the same letter are not different (P = 0.05). CH = Chardonnay, CS = Cabernet Sauvignon

LEAVES	CH	CS
BASAL	0.41a	0.32b
APICAL	0.40a	0.36b

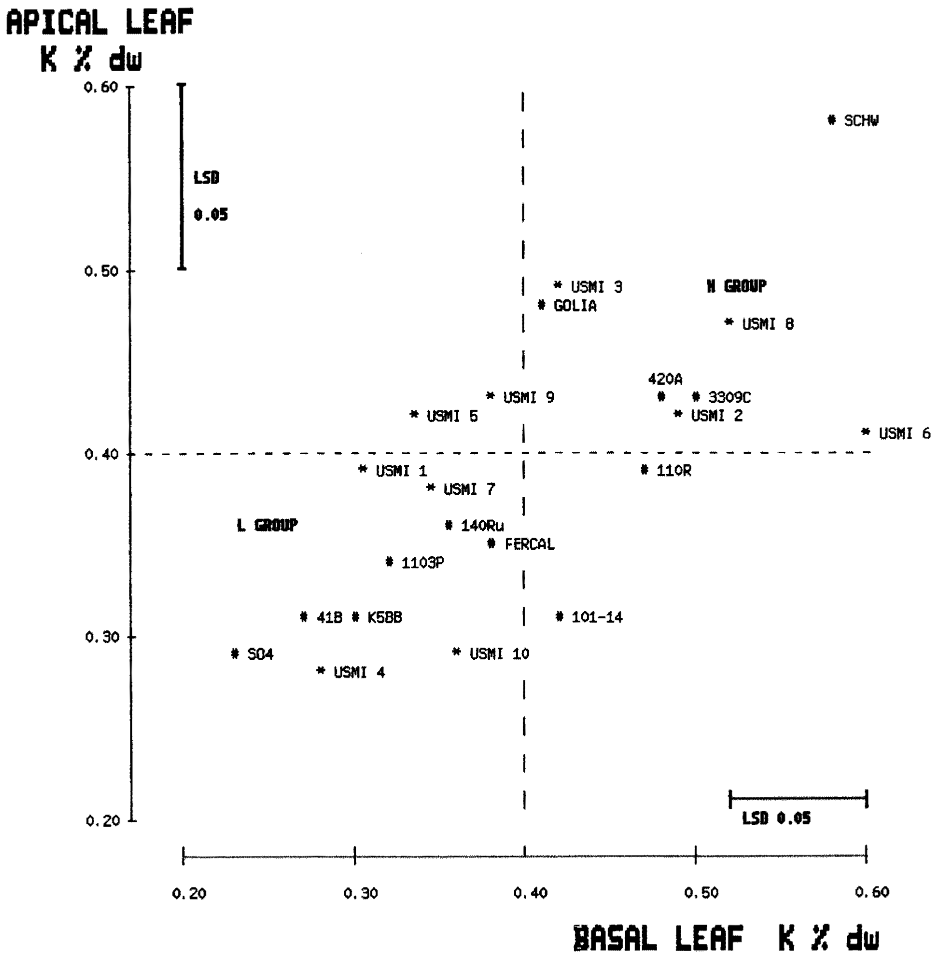

Fig. 2: Scion and rootstock effect on basal and apical leaf potassium content. Means adjusted by the crop load effect.

Scion varieties were different in juice characteristics with the exception of tartaric acid content.

Rootstock had an effect on soluble solids and pH but these effects were related with the different crop load induced by the rootstock itself, in fact its effect was still not significant when evaluated with covariance analysis with crop load as covariate variable.

Titratable acidity and potassium content of the juice were affected by rootstock. This effect was reduced, but still significant when adjusted by crop load. Malic and tartaric acid contents of the juice were not affected by rootstock.

Scion and rootstock effect on potassium nutrition in leaves (Table 8, Fig. 2)

Both scion and rootstock had an effect on leaf potassium content.

Cabernet S. had a lower leaf potassium content than Chardonnay.

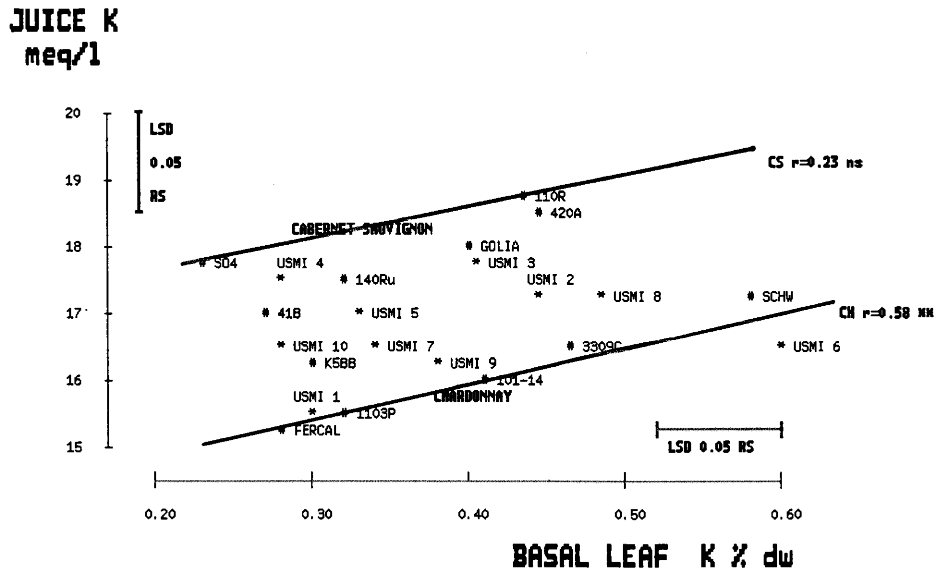

Fig. 3: Scion and rootstock effect on potassium partitioning between basal leaves and berry juice. Means adjusted by crop load effect.

Two rootstock groups were detected: the first group (L group) with potassium level below approximately 0.4 % dw both in basal and apical leaves; the second group (H group) with potassium level above approximately 0.4 % dw both in basal and apical leaves.

Scion and rootstock effect on potassium partitioning between leaves and berry juice (Fig. 3)

Cabernet S. had higher juice potassium and lower leaf potassium content than Chardonnay.

Rootstock had a greater effect on potassium leaf content in respect of potassium juice content. With the exception of USMI 1, Fercal and 1103 P which induced a juice potassium content lower than 16 meq/l, all the other rootstocks induced an average juice potassium content ranging from 16 to 18.5 meq/l with 'high' or 'low' leaf potassium content.

Discussion

Under our experimental conditions, potassium nutrition and juice characteristics were strongly related to crop load of the vines. it reduced sugar and potassium accumulation in the berry, increased their acidity and reduced leaf potassium content. For this reason, result interpretation has to take in consideration the crop load effect.

In Chardonnay the similar effect of crop load on potassium content of leaves and juice, and on soluble solids in juice, determined the correlation among these parameters. Therefore, the positive relation between potassium nutrition and sugar content of juice does not seem due to a greater leaf efficiency but to a different 'source-sink' relation.

In Cabernet S. the lack of relation of leaf potassium with soluble solids and potassium in juice seems to be related to the late leaf sampling date. At sampling time leaves were senescent due to nutrient shortage and were not at a proper nutritional index.

When adjusted by crop load effect, the scion effect was significant on juice composition (Table 6). The differences in juice composition between the two cultivars seem to be related with their different length and period of the ripening phase. In fact, the higher soluble solid and potassium content of Cabernet S. could be related with its longer ripening period, and the lower malic acid content of Chardonnay with the higher temperature that occurred during its ripening.

Similarly, the scion effect on potassium leaf content seems to be related with the different sampling dates and the different states of leaf senescence. Cabernet S. leaves were sampled 1 month after Chardonnay leaves.

For what concerns the rootstock effect when it was adjusted by the crop load effect, it was only significant on vigour, titratable acidity and potassium content of the juice, and on leaf potassium levels.

The small effect of the rootstock on plant vigour seems to be related to the pot condition. The pot volume limiting root growth also limited shoot growth.

The great effect of rootstock on vine crop load has to be related to the young age of the vines, during which rootstock has generally a higher effect on flower initiation.

Rootstocks had an effect on potassium partitioning between leaves and berry juice, indeed they induced similar juice potassium contents, with different levels of leaf potassium.

Rootstocks could be divided into two groups in relation to their capability of controlling leaf potassium nutrition. The first group (H group) was able to assure higher leaf potassium nutrition, in the second group (L group) leaf potassium nutrition was low.

These results confirm the variability among rootstocks in potassium nutrition and suggest that, at least in poor soil conditions, an adequate rootstock can raise the leaf potassium nutrition without increasing the juice potassium content.

From our data, choice of rootstock seems to be a mild method in regulation of potassium partitioning within the vine.

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