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Effect of grafting on grapevine chlorosis and hydraulic conductivity

L. Bavaresco[1)] and C. Lovisolo[2)]

[1)] Istituto di Frutti-Viticoltura, Cattedra di Viticoltura, Università Cattolica S. Cuore, Piacenza, Italia
[2)] Dipartimento di Colture arboree, Università di Torino, CVT-CNR, Grugliasco, Italia

Summary

In a pot experiment the following grapevines were grown in a calcareous soil: Pinot blanc own-rooted and self-grafted, grafted on SO 4 and on 3309 C; SO 4 own-rooted, self-grafted and grafted on Pinot blanc; 3309 C own-rooted, self-grafted and grafted on Pinot blanc. The occurrence of chlorosis was strongly affected by graft combinations. In self-grafted 3309 C plants the specific conductivity was significantly reduced as compared to own-rooted ones. Own-rooted SO 4 plants showed the highest specific conductivity, associated with the highest rate of shoot growth and leaf chlorophyll content.

K e y w o r d s : grafting, hydraulic conductivity, specific conductivity, chlorosis.

Introduction

Soil lime can induce iron chlorosis (leaf yellowing) and, under severe stress conditions, leaf drop and coulure. Breeding efforts for lime-tolerant rootstocks have been successful (140 Ru, 41 B, Fercal), even though the «ideal» rootstock variety has not yet been obtained. While the physiology of lime-induced chlorosis in grafted grapevines has been investigated (Pouget and Juste 1972; Pouget and Ottenwaelter 1973; Murisier and Briguet 1988; Bavaresco *et al.* 1992, 1993; Fregoni and Bavaresco 1997) the role of grafting itself seems to be crucial too, under the same soil and cultural conditions. According to Giorgessi *et al.* (1996) grafting seems to have a negative effect on vine vigour. Hydraulic conductivity (Tyree and Ewers 1991) has already been studied in grapevine shoots by Salleo *et al.* (1982; 1985), Schultz and Matthews (1988, 1993), Schubert *et al.* (1995, 1999) and Lovisolo and Schubert (1998, 2000). However, up to now direct evidence for the role of grafting on hydraulic conductivity of grapevines is still lacking. Peterlunger and co-workers (1990) measured root hydraulic conductivity of own-rooted rootstocks. Analogous studies have been carried out with citrus (Syvertsen and Graham 1985; Rieger and Motisi 1990), apple (Olien and Lakso 1984) and peach (Marangoni *et al.* 1989) rootstocks. The present experiments were undertaken to investigate the effect of grafting on mineral uptake, the occurrence of chlorosis and hydraulic conductivity.

Material and Methods

P l a n t m a t e r i a l : The experiments were carried out using own-rooted and self-grafted cv. Pinot blanc (*V. vinifera* L.), SO 4 (*V. berlandieri* Planch. x *V. riparia* Michx.), 3309 C (*V. riparia* Michx. x *V. rupestris* Scheele); In addition, SO 4 and 3309 C were grafted on Pinot blanc and Pinot blanc was grafted on SO 4 and 3309 C. Own-rooted plants were obtained from two-node cuttings (about 15 cm long) rooted in a sandy substrate in a greenhouse in early spring, while grafted plants were obtained by "omega" grafting. In the middle of June, 5 plants per treatment were potted (pot volume 45 l) in a natural calcareous soil collected in the field and utilized immediately. The pots were placed outdoors under a hail protection net and the soil was kept near field capacity by drip irrigation. The main soil characteristics were: texture silty sand, pH 8.7, total carbonates 75 %, active lime 18 %, P_2O_5 (Olsen) 6 mg kg^{-1}, iron (extracted by 5 mM DTPA + 10 mM $CaCl_2$+ 100 mM triethanolamine) 37 mg kg^{-1}. In the second year each plant was trained to three shoots, shoot growth was recorded every 15 d.

L e a f s a m p l i n g a n d a n a l y s e s : About 80 d after bud-burst (middle of June) the 3rd and 4th leaf (from shoot tip) of each shoot was sampled and chlorophyll (Chl) and mineral element concentrations were determined. Leaf Chl concentration was analysed by a portable Chlorophyll Meter SPAD 502 (Minolta). SPAD units were transformed into Chl values (mg 100 g^{-1} DW) according to Bavaresco (1995). After wet digestion of the dry matter P, K, Ca, Mg and Fe were analysed by flame photometry (K and Ca), atomic absorption spectrometry (Mg and Fe) and colorimetry (P).

H y d r a u l i c c o n d u c t i v i t y o f t h e v i n e : After the leaves had dropped, three plants per group were prepared as shown in Fig. 1, where the numbers represent the position of the recorded diameters. The average node number of the canes was: Pinot blanc: 16; Pinot blanc self-grafted: 10; SO 4 grafted on Pinot blanc: 7; 3309 C grafted on Pinot blanc: 9; SO 4: 8; SO 4 self-grafted: 6; Pinot blanc grafted on SO 4: 9; 3309 C: 14; 3309 C self-grafted: 9; Pinot blanc grafted on 3309 C: 12. A cane length of 40 cm was chosen to include entire vessels of *Vitis* spp (Sperry *et al.* 1987). Conductivity was measured immediatly after cutting according to a modified method described for root hydraulic conductivity (Graham and Syvertsen 1984), as reported by Schubert *et al.* (1995) and Lovisolo and Schubert (1998). The portion of the plant to be tested was

Correspondence to: Prof. Dr. L Bavaresco, Istituto di Frutti-Viticoltura, Cattedra di Viticoltura, Università Cattolica S. Cuore, Via Emilia Parmense, 84, 29100 Piacenza. Fax: +39-0523-599268. E-mail: lbavares@pc.unicatt.it

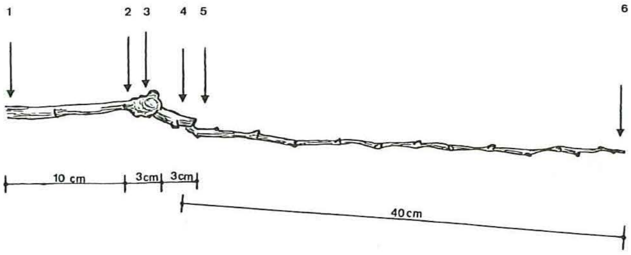


Fig. 1: Test plants (schematic). Numbers indicate the position where diameters were measured.

inserted into a pressure chamber half filled with distilled water, with its base immersed in the water. In the chamber a pressure of 0.15 MPa was imposed for 10 min to force water through the xylem. Water spilling at the apical end of the cane was collected and weighed. Hydraulic conductivity (K_h) was calculated from pressure gradient and flow measurements. Specific conductivity (K_s) was calculated by dividing K_h by the average transectional area recorded at the position indicated in Fig. 1.

Results

The chlorophyll concentration of leaves was strongly affected by the graft combination (Tab. 1). Values ranged from 72 mg 100 g^{-1} DW (3309 C/Pinot blanc, chlorotic leaves) to 296 mg 100 g^{-1} DW (SO 4 own-rooted, non-chlorotic leaves). Graft combinations significantly affected the concentration of mineral elements in the leaves. P concentrations ranged from 0.29 % (Pinot blanc self-grafted) to 0.81 % (3309 C self-grafted), K levels ranged from 1.01 % (SO 4 self-grafted) to 2.07 % (3309 C self-grafted), Ca varied from 1.21 % (SO 4 self-grafted) to 1.97 % (3309 C own-rooted), Mg varied from 0.25 % (SO 4 self-grafted) to 0.38 % (3309 C/Pinot blanc), and Fe varied from 66 mg kg^{-1} (Pinot blanc own-rooted) to 175 mg kg^{-1} (SO 4/Pinot blanc).

Hydraulic (K_h) and specific (K_s) conductivity were significantly affected by grafting (Tab. 2). 3309 C self-grafted had the lowest K_h and K_s values (0.043 kg $s^{-1}\cdot MPa^{-1}$ m 10^{-4} and 0.090 kg $s^{-1} MPa^{-1}$ m^{-1}, respectively), while SO 4 self-grafted showed the highest K_h value (0.581 kg $s^{-1}\cdot MPa^{-1}$

Table 1

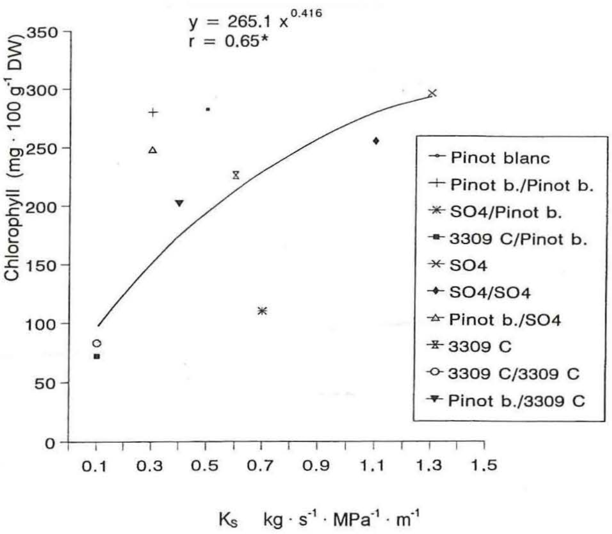
Chlorophyll and mineral elements in leaves of various graftings

	Chlorophyll (mg · 100 g^{-1} DW)	P (%)	K (%)	Ca (%)	Mg (%)	Fe ($mg\cdot kg^{-1}$)
Pinot blanc	282	0.39	1.81	1.79	0.29	66
Pinot blanc / Pinot blanc	280	0.29	1.13	1.53	0.30	91
SO 4 / Pinot blanc	110	0.40	1.83	1.60	0.31	175
3309 C / Pinot blanc	72	0.42	1.91	1.39	0.38	153
SO 4	296	0.38	1.31	1.51	0.27	74
SO 4 / SO 4	255	0.32	1.01	1.21	0.25	96
Pinot blanc / SO 4	248	0.37	1.18	1.68	0.26	78
3309 C	226	0.49	1.36	1.97	0.30	76
3309 C / 3309 C	83	0.81	2.07	1.75	0.35	134
Pinot blanc / 3309 C	202	0.31	1.15	1.45	0.26	97
$LSD_{0.05}$	100	0.15	0.43	0.34	0.045	53

Table 2

Hydraulic (K_h) and specific (K_s) conductivity, final shoot length and root dry matter of the graft combinations

	K_h $kg\cdot s^{-1}\cdot MPa^{-1}\cdot m\cdot 10^{-4}$	K_s $kg\cdot s^{-1}\cdot MPa^{-1}\cdot m^{-1}$	Shoot length (m)	Root dry matter ($g\cdot plant^{-1}$)
Pinot blanc	0.199	0.533	1.50	20.8
Pinot blanc / Pinot blanc	0.176	0.269	0.98	44.1
SO 4 / Pinot blanc	0.474	0.719	1.06	40.2
3309 C / Pinot blanc	0.137	0.154	0.57	8.2
SO 4	0.538	1.303	1.59	55.3
SO 4 / SO 4	0.581	1.086	1.31	85.7
Pinot blanc / SO 4	0.345	0.314	1.49	41.7
3309 C	0.199	0.584	0.98	45.2
3309 C / 3309 C	0.043	0.090	0.94	54.9
Pinot blanc / 3309 C	0.275	0.383	1.13	78.0
$LSD_{0.05}$	0.244	0.421	0.47	14.4



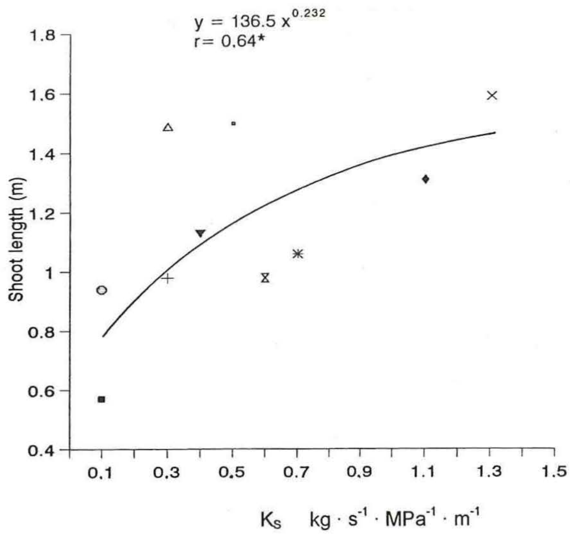


Fig. 2 (left): Regression between leaf chlorophyll content and specific conductivity.
Fig. 3 (right): Regression between final shoot length and specific conductivity.

m 10^{-4}) and SO 4 own-rooted showed the highest K_s value (1.303 kg s^{-1}·MPa^{-1} m^{-1}). Average shoot length was also affected by the graft combinations (Tab. 2). Growth of 3309 C self-grafted was very poor (0.94 m), while SO 4 own-rooted reached the highest value (1.59 m). Root dry matter was dramatically reduced for 3309 C / Pinot blanc (8.2 g $plant^{-1}$), while SO 4 self-grafted showed the largest root system (85.7 g $plant^{-1}$).

By plotting leaf Chl versus K_s (Fig. 2) a significant and positive correlation occurred (r = 0.65*). Other significant correlations were calculated, as follows: leaf Chl versus leaf K (r = -0.78**); leaf Chl versus leaf Mg (r = -0.89**); leaf Chl versus leaf Fe (r = -0.89**); shoot length versus K_s (r = 0.64*, Fig. 3).

Discussion

The occurrence of chlorosis was affected by grafting in different ways. When comparing own-rooted and self-grafted genotypes, only the Chl level of 3309 C varied dramatically, being chlorotic when grafted and non-chlorotic when ungrafted. On the other hand the Chl level of Pinot blanc and SO 4 did not vary significantly when grafted and were always non-chlorotic. In spite of the different chlorosis levels between self-grafted and ungrafted 3309 C vines, no significant differences were observed as regarding shoot and root growth. These latter parameters were however affected by grafting in the case of Pinot blanc and SO 4, shoot growth being reduced and root development being increased by grafting. The more intense root growth of grafted plants as compared to the ungrafted ones, which was significant for Pinot blanc and SO 4 but not for 3309 C, was related to a poor shoot growth; thus grafting had induced a better soil exploration. Chlorosis symptoms of self-grafted 3309 C plants as compared to ungrafted ones were also related to higher leaf P, K, Mg and Fe concentrations. Evidence for high K levels in chlorotic leaves has already been shown earlier (Bavaresco *et al.* 1992), moreover high Fe levels have sometimes been detected (Bavaresco *et al.* 1994, 1999). Comparing the Chl levels of the three ungrafted genotypes, no significant differences were found. All were non-chlorotic, even the lime-susceptible rootstock 3309 C. Pinot blanc as a rootstock behaved differently depending on the scion, therefore the occurrence of chlorosis is the result of an interaction between scion and rootstock and not just a feature of the rootstock. When comparing reciprocal graftings like SO 4/Pinot blanc and Pinot blanc/SO 4, a different plant behaviour can be observed: leaves were chlorotic in the first case and non-chlorotic in the second case; moreover specific conductivity was higher with SO 4 as scion. It can be speculated that the grafting point itself is not crucial in this case, however the morphological structure of the scion (SO 4) vessels may be more important since with SO 4 as scion, K_s was always high. In the case of reciprocal graftings of 3309 C/Pinot blanc and Pinot blanc/3309 C similar relationships were observed with regard to the specific conductivity, while all other tested parameters were very different. The chlorophyll content and shoot growth were correlated with the specific conductivity. However, with Pinot blanc as scion, other adaptive factors superimposed water conductivity resulting in well developed vines with a high chlorophyll content, although the specific conductivity was low.

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