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Influence of Substrate pH on Root Growth, Biomass and Leaf Mineral Contents of Grapevine Rootstocks Grown in Pots

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ABSTRACT

The present study was carried out in order to test the effect of grapevine rootstocks root growth on biomass and leaf nutrition status in extreme soil conditions. Own rooted cuttings of rootstocks Fercal, Teleki Kober 5BB, Georgikon 28 and four new rootstock hybrids from the breeding program of Georgikon Faculty, Hungary (FB01, JB01, Zamor 17 and SZF10) were grown 3 months in pots. The 5 L pots were filled with a layer of gravel, high lime content Rendzina soil (pH 8.54) topped with a layer of peat-soil mixture (pH 4.94). The biomass production, shoot, leaf and root development largely depended on the rootstocks genotype. The differences among studied rootstocks were significant under low pH. Correlation was found between the root dry weight and the aboveground parts. The ratio between them was strongly influenced by rootstocks genotype. Rootstocks had strong influence on leaf nutrient status.

Keywords: Root pot experiment, Soil pH, Vine rootstock.

INTRODUCTION

The root system characteristics of grape rootstocks are determined by geographic origin and genetic background (Galet, 1990; Morlat and Jacquet, 1993; Smart, *et al.*, 2002). From that point of view, the root system is the key of site adaptability (Gruben and Kosegarten, 2002; Patil *et al.*, 2005; Pire *et al.*, 2007; Marguerit *et al.*, 2012; Vršič *et al.*, 2015). Soil properties are usually very variable in viticulture and may involve extreme pH (Pavloušek, 2009; 2011) and drought due to the climate changes (Pellegrino, *et al.*, 2005; Vršič *et al.*, 2014). The selection of right varieties and rootstocks is extremely important for a successful production (Ghaderi *et al.*, 2011; Pulko *et al.*, 2012). Low or high soil pHs are limiting factors for the development of plant. Soil conditions strongly affect shoot growth (Bavaresco *et al.*, 1993). The iron-efficient rootstocks do not induce chlorosis under lime-stress condition and take up more iron (Bavaresco *et al.*, 2003). Morlat and Jaquet (1993) were able to demonstrate that in vine-stocks there was a high correlation between the developments of the underground and aboveground parts. Individual cultivars of grapevine assimilate large quantities of K in leaves, regardless of rootstock, but the absorption of this element was also related to the rootstock cultivar used (Garcia, *et al.*, 2001). Rootstock genotype significantly influenced the nutrient concentrations of different vine organs (Fisarakis, *et al.,* 2005). The objective of this study was to determine whether the rootstock genotypes showed different performances under two different pH levels and structure of soils, and how deep could roots penetrate into the soil. We also studied how the biomass production and leaf nutrition status

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depended on the rootstocks genotypes in correlation with their root performance.

MATERIALS AND METHODS

Seven rootstock genotypes were included in the trial: Fercal, the most lime tolerant rootstock (Pouget and Ottenwaelter, 1978), Teleki Kober 5BB, the most common rootstock in central Europe in the last 100 years (Poczai *et al*., 2013), Georgikon 28 (Kocsis *at al*., 1999) and four new rootstock hybrids from the breeding program of Georgikon Faculty, Hungary; FB01 (Fercal×Börner), JB01 (Juhfark×Börner), Zamor 17 (5BB×Rup. metallica), and SZF10 (Georgikon 28×Börner).

The experiment was set up under glasshouse conditions and was based on random groups with five replications for each of the rootstocks. The 5 L plastic pots were filled with a layer of gravel, a layer of high lime content Rendzina soil (pH 8.54) topped a layer of peat-soil mixture (pH 4.94). Plants i.e. cuttings, were approximately 25 cm long and own–rooted (with 3 to 5 roots). After the root system emergence in stone sponge, they were transferred to pots, placing the emerging roots on the boundary of lime soil and peat (Figure 1). Each pot contained 1 kg of gravel, 1 kg of lime soil and 0.5 kg of peat. After 3 months, the biomass production was determined on the basis of length of the main and lateral shoots, length of internodes and shoots, leaf and root development (based on their dry weight at 65°C). The roots weights were separately determined in each layer of soil (lime, peat). Beside the biomass production, the leaf nutrient content was determined in all plants. The nutrients in basal leaves (Rühl, 1989) were analyzed in each plant following the standard methods used for determination of macro- and micro-elements in leaf blades. The analyses were performed according to the protocol written in the Hungarian Standard (MSZ-08-1783-15:1984). Preparation of the leaf samples after drying was done by block destructor (OE-718/H type), the analysis were done by flame photometer (OE-851 type) and by solar photometer AAS (Solar 969-OL-741; OL-743).

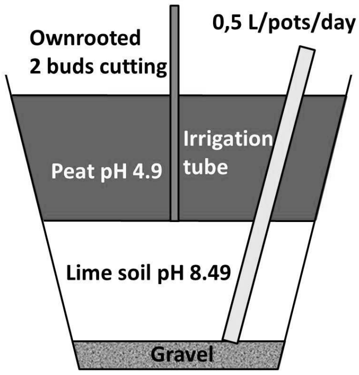

Figure 1. Own-rooted cutting of grapevine rootstock planted into the pot, placing the emerging roots on the boundary of the different type of soil (schematically).

The differences between rootstocks were detected using one-way analysis of variance (ANOVA). The statistical evaluation of data was performed by the SPSS 19.0 programme ($P \leq 0.05$).

RESULTS AND DISCUSSION

Biomass Production

The biomass production varied depending on the rootstock genotypes. The number of leaves per shoot, length of the main and lateral shoots, and length of internodes exhibited significant differences (Table 1). Similar results have been observed by Bavaresco *et al*. (2003); high-carbonate content in the soil decreased the leaf and shoot growth, and the total dry matter production. The main shoots were the most developed in the Fercal and FB01 rootstocks. Regarding the length of lateral shoots, the rootstock FB01 was quite above the average. Highly developed lateral shoots were also found on the SZF10 rootstock. The rootstocks with highly developed lateral shoots are considered to be less suitable for the production of cuttings with the currently used cultivation methods.

The biomass production of the rootstocks is presented in the Table 2. The dry weight

Table 1. Length of shoots and internodes and number of leaves per shoot [(±Standard error)– (±SE), P≤ 0.05] of different grapevine rootstocks in pots trial with divided soil layers in 2013.

Rootstock	Length of shoot (cm)		Number of leaves		Length of internode (cm)
	Main shoot	Lateral shoot	Main shoot	Lateral shoot	
Fercal	179.0ab±15.778	103.9bc±17.586	23.50a±1.853	12.27bc±1.917	7.68ab±0.388
FB 01	196.1a±32.677	411.6a±45.790	20.50ab±2.994	41.75a±4.620	9.27a±0.453
G28	143.0abc± 6.288	53.4c±8.298	18.67ab±3.442	7.00c±0.949	6.51b±0.232
5BB	142.3 abc± 6.467	110.8bc±25.480	19.83ab±0.796	11.44bc±2.304	7.18b±0.163
JB 01	104.5bc ±12.966	91.8bc±20.211	14.50ab±1.668	10.17bc±1.641	7.21b±0.350
Zamor	91.4c ±16.126	144.4bc±21.082	13.20b ±1.685	15.20bc±2.311	6.82b±0.620
SZF 10	113.6bc ± 6.030	200.0b±29.818	17.00ab±0.707	22.20b±3.040	6.71b±0.398

Table 2. Shoots, leaves and roots dry weight in soil with low pH (root above) and high pH level (roots below) in g plant^{-1}, and ratio of roots to aboveground parts of plants (main and lateral shoots with leaves) of different grapevine rootstocks in pots trial in 2013 (±SE, P≤ 0.05).

Rootstock	Shoot	Lateral shoots	Leaves	Roots above	Roots below	Roots	Ratio (roots/shoots with leaves)
Fercal	4.33a±0.417	1,02bc±0,224	5.91a±0.409	1.58a±0.128	0.47a±0.081	2.06a±0.180	0.203a±0.011
FB 01	4.51a±0.523	2,69a±0,244	5.01ab±0.521	0.46b±0.037	0.40a±0.068	0.85b±0.096	0.092bc±0.011
G28	3.85a±0.217	0,46c±0,074	5.29ab±0.329	0.49b±0.088	0.54a±0.058	1.03b±0.141	0.111bc±0.011
5BB	3.56a±0.490	1,19bc±0,355	4.35ab±0.544	0.34b±0.047	0.39a±0.051	0.73b±0.088	0.096bc±0.008
JB 01	2.55a±0.372	0,90bc±0,236	3.49b±0.342	0.37b±0.060	0.38a±0.051	0.75b±0.083	0.138b±0.032
Zamor	2.96a±0.417	1,56abc±0,422	3.12b±0.335	0.40b±0.061	0.38a±0.075	0.78b±0.131	0.128bc±0.013
SZF 10	3.54a±0.421	1,90ab±0,378	4.09ab±0.449	0.29b±0.043	0.21a±0.038	0.50b±0.055	0.066c±0.004

(g plant^{-1}) of the main shoots was the highest in Fercal, FB01 and Georgikon 28 rootstocks. It was slightly higher than in standard 5BB rootstock. The dry weight of lateral shoots was closely associated with their lengths (R^2= 0.777, the value is not reported in this paper). FB01 rootstock exhibited the highest dry weight of lateral shoots and can be considered as less suitable for the rootstock-cuttings production. The lowest dry weight of leaves was determined in JB01 and Zamor 17 rootstocks, while Fercal had the highest. The dry weight of roots in soil with low pH level (root above) showed significant differences among rootstocks. Dry weight of roots in soil with high pH level (root in lime (see fig 1)) did not differ in different rootstock genotypes. Fercal developed the highest amount of roots in low pH soil, and dry weight of roots was significantly different from the others.

We determined the correlations between the root dry weight and the shoot, and the leaves dry weight, similar to Morlat and Jaquet (1993). The highest correlation (R^2= 0.3239, P= 0.05) was observed between roots and leaves dry weight (Figure 2). The ratio of the dry weight of roots to aboveground parts of plants (0.203±0.011) was significantly different ($P\leq 0.05$) among the different rootstocks and was the highest in Fercal rootstock (Table 2). The roots of the examined genotypes, except the Fercal, did not differ significantly in pots under low or high level of pH. Regarding the biomass production, three rootstocks, namely, Fercal, FB01, and Georgikon 28 surpassed the others (Figure 3); these rootstocks probably had better adaptability to extreme soil pH conditions. The biomass of 5BB rootstock used as the control, was close to the overall average of the trial.

Nutrient Content in Leaves

The differences in nutrient content in leaves among the rootstocks were significant ($P\leq 0.05$) (Table 3). The leaves of the Fercal rootstock had the highest content of Ca, Na and Mn; 18, 24 and 61 % higher than the experimental averages, respectively. The content of Ca in leaves of Zamor 17 and SZF10 was at the same level as in Fercal. Mn in leaves of FB01 was also significantly different from the others. The lowest content of N in leaves was determined in Fercal,

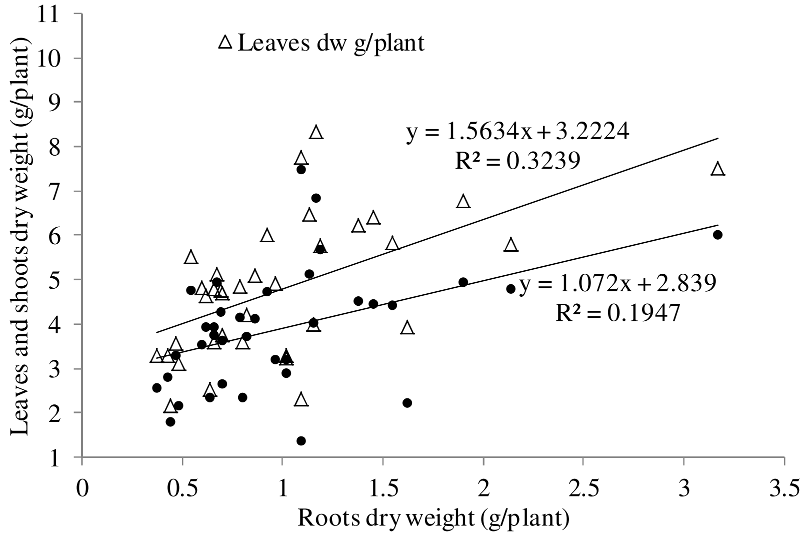

Figure 2. Correlation between the root dry weight and the shoots, the leaves dry weight of seven different rootstocks in pots trial in 2013.

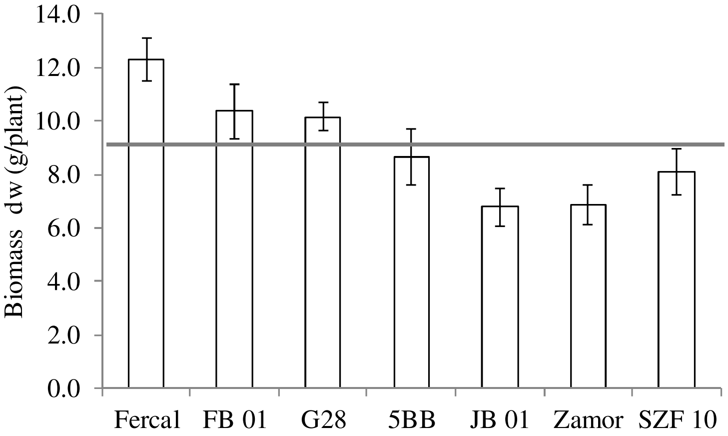

Figure 3. Biomass dry weight (dw) in g plant^{-1} (±SE) production varied depending on rootstocks in pots trial with different soil properties in 2013 (the horizontal line is the overall experimental average).

Table 3. Nutrient content in dry weight of leaves (±SE, $P \leq 0.05$) of seven different grapevine rootstocks in pots trial with divided soil layers in 2013.

Rootstock	N (%)	P (%)	K (%)	Na (%)
Fercal	2.998b±0.094	0.863a±0.060	0.806bc±0.042	0.082a±0.005
FB 01	3.393ab±0.099	0.878a±0.128	1.018ab±0.049	0.061bc±0.005
G28	3.580a±0.079	0.418b±0.022	1.055ab±0.077	0.073ab±0.003
5BB	3.453ab±0.130	0.753ab±0.030	1.082a±0.052	0.061bc±0.003
JB 01	3.440ab±0.097	0.512b±0.094	0.737c±0.082	0.065abc±0.004
Zamor	3.448ab±0.114	0.426b±0.031	0.710c±0.034	0.052c±0.004
SZF 10	3.564a±0.100	0.586ab±0.063	0.866abc±0.045	0.050c±0.003
Rootstock	Ca (%)	Mg (%)	Zn (mg kg^{-1})	Mn (mg kg^{-1})
Fercal	2.347a ±0.138	0.623ab±0.049	36.717ab±1.739	218.833a±189.381
FB 01	1.928ab±0.103	0.629ab±0.018	35.188ab±2.371	177.500a±154.019
G28	1.468b±0.034	0.498b±0.017	28.967ab±2.126	98.717b±73.047
5BB	1.785ab±0.113	0.558ab±0.018	28.675b±1.670	106.650b±92.081
JB 01	1.997ab±0.165	0.602ab±0.029	30.183ab±2.422	80.133b±65.489
Zamor	2.132a±0.090	0.628ab±0.021	42.360a±9.016	83.160b±77.424
SZF 10	2.084a±0.081	0.722a±0.051	31.680ab±1.459	103.560b±84.192

while SZF10 and G28 rootstocks had the highest. The results demonstrated that there were differences between rootstocks regarding the accumulation of K$^+$ in leaves. Kober 5BB had the highest content of K, which was 47 to 52% higher than in the leaves of JB01 and Zamor 17. The extent of K$^+$ accumulation measured in basal leaves, can be considered as a reliable screening method for the evaluation of rootstocks which restrict K$^+$ accumulation, as reported by Rühl (1989). Rootstocks had high impact on leaf nutrient content (Brancadoro *et al.*, 1994; Paranychianakis *et al.*, 2006). The content of P and Mn was the highest in the rootstocks with the Feracal pedigree. The lime stress-conditions affected mineral nutrition uptake, especially P and K, as reported by Bavaresco *et al.* (2003). The content of Mg was the highest in SZF10 rootstock, 45% higher than in G28. The rootstock genotypes significantly influenced the magnesium concentrations in leaves. Similar situation was also observed by Garcia, *et al.* (2001) and Fisarakis, *et al.* (2005). High correlation was determined between the roots dry weight and the content of some mineral nutrients in leaves. The content of N decreased with increase in root dry weight (R^2= 0.801), while the content of Mn (R^2= 0.611) and Ca (R^2= 0.735) increased ($P \leq 0.05$).

CONCLUSIONS

The effect of the root growth of grapevine rootstocks on the biomass production was investigated in a pot experiment. The horizontally divided root zones with two different pH levels and soil types resulted in significant differences in biomass production of different plant organs, depending on the rootstocks. Assuming that biomass production could be an indicator of adaptability, our results show that Fercal is one of the best rootstock genotypes, followed by FB01 and Georgikon 28. These three rootstocks have better adaptability to high soil pH conditions. The absorption of some elements and, consequently, leaf mineral composition were also related to the rootstocks genotype and significantly influenced the nutrient concentrations of different vine organs. These results are of great importance in the selection of suitable rootstocks of grapevine, especially those with better adaptability to calcareous soils.

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تاثیر واکنش (اسیدیته) بسترشد روی رشد ریشه، زیست توده، و عناصر غذایی موجود در برگ پایه های انگور کشت شده در گلدان

س. ورسیک، ل. کوسیس، و ب. پولکو

چکیده

هدف پژوهش حاضر بررسی اثر رشد ریشه پایه های انگور در شرایط غیر عادی خا ک روی زیست توده و موقعیت تغذیه برگ ها بود. به این منظور، قلمه های خود-ریشه(own rooted) پایه هایی به نام های Fercal، Teleki Kober 5BB، Georgikon 28و چهار پایه هیبرید از برنامه بهنژادی دانشکده Georgikonمجارستان شامل (Zamor , JB01, FB01، و SZF10) به مدت سه ماه

در گلدان کاشته وپرورش داده شدند. گلدان های مزبور ۵ لیتری بودند و با لایه ای ازقلوه سنگ و خاک رندزینا (**R**endzina) حاوی آهک زیاد پرشدند و در قسمت های بالای آن لایه ای شامل مخلوط خاک وپیت(pH 4.94) اضافه شد. مشاهدات نشان داد که تولید زیست توده و نیز رشد ساقه و برگ و ریشه وابستگی زیادی به ژنوتیپ پایه انگور داشت و در شرایط pH کم پایه های مطالعه شده تفاوت های معنا دار با هم داشتند. همچنین، بین وزن خشک ریشه وبخش های هوایی همبستگی وجود داشت و نسبت بین آن ها شدیدا تحت تاثیر ژنوتیپ پایه بود. نیز، پایه های انگور قویا روی محتوای عناصر غذایی در برگ تاثیر داشت.