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RESEARCH ARTICLE (Open Access)

Relationship between Nacl Concentration of the Irrigation Water and the Plants Moisture Content of Four Antiphylloxeric Rootstocks of Grapevine

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Abstract

Study for the relationship between whole plant moisture content and the shoot hardwood cuttings and NaCl concentration of four antiphylloxeric rootstocks of grapevine was conducted during 2014 -2015 at the Experimental Base of the Agricultural University of Tirana. Rooted rootstock's cuttings were irrigated using normal tap water up to July 20, and, after that, for 45 days, were irrigated using sodium chloride solucion in six different concentrations [control (normal tap water), 2000, 4000, 6000, 8000, and 10000 ppm]. Obtained results showed that with the increase of NaCl concentration, the whole plant moisture content and the hardwood cuttings, was decreased for all rootstocks under study. For the same NaCl concentration, the moisture content of the entire plants and shoot hardwood cuttings were different for different rootstocks. Ranking of rootstocks, according to the plant moisture content, was 1103P (83.2-83.6%), followed by 140Ru (79.5-79.8%), SO4 (79.3-79.5%) and Kober 5BB (79.03-79.2%). The moisture content of shoot hardwood cuttings was lower than moisture content of the whole plant. Ranking of the rootstocks, according to the moisture content of hardwood cuttings, was 1103P (58.2-58.4%), 140Ru (59.8-59.9%), Kober 5BB (55.6-55.9%) and SO4 (54.9-55%). Ampelographic assessment of the resistance of the rootstocks to chlorides (salt) was carried out using OIV Code 402. Rootstock SO4 was more sensitive and less resistant to sodium chloride concentration compare to 1103 P, 140Ru and Kober 5BB. There were significant differences ($p \leq 0.01$) in plant moisture content between NaCl treatments and tested rootstocks.

Keywords: plant; shoot; hardwood cutting; rootstock; moisture content; sodium chloride.

1. Introduction

The main grapevine rootstocks used in the Albanian nurseries and vineyards are hybrid-origin rootstocks such 1103 Paulsen (Berlandieri x Rupestris), Kober 5BB (Berlandieri x Riparia), SO4 (Berlandieri x Riparia), 140 Ruggeri (140 Ru) (Berlandieri x Rupestris) and Du Lot (Berlandieri x Rupestris) [17; 1]. Salinization of soil is a serious problem and is increasing steadily in many parts of the world. In 2000, saline soils occupied around 7% of the earth's land surface [13], in 2007 saline soils were out of about 77 million hectares of cultivated land around the world [19], and increased salinization of arable land will result in up to 50% land loss by the middle of the 21st century [25]. Salinization of soil via the slow accumulation of salts from irrigation water continues at a pace that often goes unnoticed. After each successive irrigation, pure water is transpired by crop plants and evaporates from the soil surface, leaving behind a little more salt than was there before irrigation. Grape growers will need to regularly monitor the salinity of their soil, especially when rainfall is low over multiple years. By the time leaf symptoms are observed ("salt burn", necrotic tissue on leaf margins); soil salinity is often at serious levels that can negatively impact vine growth and production [16; 6].

Grapevine is a relatively resistant and tolerant to salt concentration in the soil and irrigation water, but it is seriously threatened in the soils with high concentration of iron, chlorides and sodium sulphate [18]. Most of the commercial rootstocks appear to have

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an intermediate capacity for salt exclusion, though some are clearly weak chloride excluders. Rootstocks with good chloride excluding ability can have a significant positive impact on yields in moderately stressful years and can keep severe damage from occurring in extremely stressful arid years. The significance of soil salinity for grapevine yield is enormous [23] as it affects the establishment, growth and development of plants leading to huge losses in productivity [16; 4].

The direct effects of salt on plant growth may involve: reduction in the osmotic potential of the soil solution that reduces the amount of water available to the plant causing physiological drought [5]; toxicity of excessive Na^+ and Cl^- ions towards the cell [15], disruption of cell organelles and their metabolism, damage to cell organelles and plasma membrane, disruption of photosynthesis, respiration and protein synthesis [8; 5]; nutrient imbalance in the plant caused by nutrient uptake and/or transport to the shoot leading to ion deficiencies; chlorosis and necrotic spots of leaves and shoots [20, 21, 22]; hormonal disorders, such us low synthesis of auxins, etc [11]; and decrease yield and quality, leading to sudden dehydration, shriveling, withering and death of affected plants [16; 7]. American grape rootstocks have also shown to have different tolerance levels to salt. Dardeniz *et al*. [3] have shown that 41 B was the most resistant rootstock, followed by 140 Ru and 1103 P, and the least resistant was 5 BB.

Environmental stresses have a negatively effect on the crop production. To overcome this issue and to complete their normal biological cycle, plants have adopted different protection mechanisms, which stop their growth and development until the environmental stresses will be overcome [14]. Plants can be normally grown when the osmotic potential of the soil is not more than few bars, except halophyte plants which can be normally grown in saline soils. Dissolved salts play osmotic role in water movement, while the specific ions have second effects [8]. Microscopic water content on plant material depends on the plants type and plants parts. Drying temperature must be around 105°C because above this temperature occur the carbonization of plant material [2].

The aim of this study was to determine the effects of sodium chloride concentration on moisture content of overall plant and shoot hardwood cuttings of four antiphylloxeric grapevine rootstocks, 1103P, Kober 5BB, SO4, and 140 Ru.

2. Material and Methods

2.1. Experimental design

Study for the effects of sodium chloride (NaCl) concentration on moisture content of the whole plant and moisture content of shoot hardwood cuttings of four antiphylloxeric rootstocks of grapevine, 1103P, Kober 5BB, 140Ru, and SO4, was conducted during 2014-2015, at the Experimental Base of the Agricultural University of Tirana.

2.2. Plant material

Rootstock cuttings were kept in sand, in darkness conditions, for three months at 1-4ºC and abaut 90% relative humidity, after being treated with a fungicide. Cuttings were cut with two buds, 7-10 mm under the first bud and abaut 20 mm above the second bud. Two budded and 8-12 mm thick cuttings were placed for rooting directly in pots with a volume of 9.5 litres, filled with loam + peat mixture (3:1), on March 15. Pots (vases) were kept for rooting and growth in the greenhouse with controlled temperature conditions (18-20°C).

2.3. Treatments

Four rootstocks, treated with six NaCl concentrations solution (treatments) (0-10000 ppm), with 5 pots by 2 rooted cuttings (plants) or 10 cuttings with standardized height and width for each variant, were used. In total, there were monitored 120 pots (30 pots/rootstock) and 240 plants (60 plants for each rootstock). Rootstocks cuttings were treated using common practices and were irrigated with normal tap water until to the start of salt applications, July 15, and, after that, were subject to six different sodium chloride concentrations, for 45 days. Treatments were as below:

V1 – control (irrigation with normal tap water)
V2 – irrigation with 2000 ppm NaCl solution
V3 – irrigation with 4000 ppm NaCl solution
V4 – irrigation with 6000 ppm NaCl solution
V5 – irrigation with 8000 ppm NaCl solution
V6 – irrigation with 10000 ppm NaCl solution

Treatments were identified using unmoved plastic labels, named with rootstock’s name, replication and NaCl solution. Starting for July 20, pots were irrigated using six different concentrations of NaCl solution, as were described above. Irrigation with different NaCl solution was repeated every two weeks.

2.4. Measurements and observations

Weights and measurements for moisture content of the whole plant and moisture content of hardwood cuttings was conducted in September 5, using a sample of four randomly selected plants for each variant, 24 plants per rootstock. Plants were cleaned from dust and other debris, were packaged, labeled, placed in plastic bags, and were sent to the Lab of Horticulture Department for the whole plant moisture content and hardwood cuttings moisture content. Hardwood cuttings were taken from shoots at 3-5 internodes. Whole plants and hardwood cuttings were weighted using an electronic balance and were dried on the thermostat until when there were no differences between successive weights. Calculation of whole plant moisture content and hardwood cuttings moisture content was carried out using standard methods, as were described by Dabulla *et al.* [2] and at using the formula:

$$W (\%) = \frac{A - B}{B} \times 100, \text{ where:}$$

W = moisture content in the sample (%)
A = weight of wet sample (g)
B = weight of dry sample (g)

Assessment of the necrosis (resistance of the rootstocks to chlorides - salt) was carried out using OIV Code 402, with expression levels: 1 (very low - marginal necrosis, comprising the total leaf blade, causing leaf drop; very high and very fast necrosis), 3 (low – partially high and fast necrosis of leaves), 5 (medium – ends of veins are necrotic), 7 (high – sight necrosis of the margins of blade, necrosis is in dots up to 1 cm diameter), 9 (very high - leaf totally green, without necrosis at all) and IPGRI Code 8.6 (17; 24; 12; 9].

2.5. Statistical analyses

In order to statistically confirm differences between rootstocks and treatments, the obtained data were subject of ANOVA: Two-Factor Without Replication ($p \leq 0.01$) [10].

3. Results and Discussion

3.1. Whole plant moisture content (%)

Whole plant moisture content (%) was measured for each rootstock and each treatment of the study, based on wet and dry weight of samples, according to standard methods. Obtained results showed that with the increase of NaCl concentration, the whole plant moisture content was significantly decreased for all rootstocks under study. For the same NaCl concentration, different rootstocks showed to have different whole plant moisture content. The highest mean values of the whole plant moisture content, as well as for all the treatments (NaCl concentration), was observed for 1103P (83.23-83.6%), followed by 140Ru (79.55-79.8%), SO4 (79.36-79.5%), and Kober 5BB (79.03-79.2%) (Table 1).

Table 1. Whole plant moisture content (%), according to different rootstocks, years and treatments

Treatments	1103P		140Ru		SO4		Kober5BB	
(NaCl concentration)	2014	2015	2014	2015	2014	2015	2014	2015
V1 (control – 0 ppm NaCl)	87.6	88	85.9	86.1	83.9	83.7	82	82.3
V2 (2000 ppm NaCl)	87.2	87.6	84.1	84.4	82.5	82.5	81.7	81.5
V3 (4000 ppm NaCl)	86.2	86	81	81.3	79.6	79.8	78.4	78.6
V4 (6000 ppm NaCl)	81.7	83	78.2	78.4	77.7	78	77.6	77.9
V5 (8000 ppm NaCl)	79.8	80	75.3	75.4	77.3	77.5	77.4	77.7
V6 (10000 ppm NaCl)	76.9	77.1	72.8	73.1	75.2	75.4	77.1	77.3
Mean	83.23	83.6	79.55	79.8	79.36	79.5	79.03	79.2

Tolerance to high salt content in the soil substrate have a strong relationship with the water content in the plant. This is because the water content in plant cells and tissues depends on the specific suction force of rootstocks, in terms of high osmotic potential of the soil substrate. With the increase of NaCl concentration in the irrigation water, there was observed a significant decrease of the whole plants moisture content for all the rootstocks, because of the increase of the negativity degree of the soil osmotic potential and the decrease of the absorption intensity of water from the plant. As was mentioned above, dissolved salts play osmotic role in water movement, while the specific ions have second effects [8].

3.2. Shoot hardwood cuttings moisture content (internodes 3-6) (%)

Shoot hardwood cuttings moisture content (internodes 3-6) (%) was measured for each rootstock and each treatment of the study, based on wet and dry weight of samples, according to standard methods. Obtained results showed that with the increase of NaCl concentration, the shoot hardwood cuttings moisture content was significantly decreased for all rootstocks under study. For instance, the shoot hardwood cuttings moisture content of 1103P was decreased from 59.2-59.5% (V1-control) to 56.8-56.9% (V6 – NaCl 10000 ppm). There was observed that the shoot hardwood cuttings moisture content was lower than the whole plant moisture content for four rootstocks under study. For the same NaCl concentration, different rootstocks contained different shoot hardwood cuttings moisture content. Mean value of the shoot hardwood cuttings moisture content varied from 54.9-55% (SO4) to 59.8-59.9% (140 Ru) (Table 2).

Table 2. Shoot hardwood cuttings moisture content (internodes 3-6) (%), according to different rootstocks, years and treatments

Treatments (NaCl concentration)	1103P 2014	1103P 2015	140Ru 2014	140Ru 2015	SO4 2014	SO4 2015	Kober5BB 2014	Kober5BB 2015
V1 (control – 0 ppm NaCl)	59.2	59.5	61.3	61.5	55.3	55.6	56.4	56.8
V2 (2000 ppm NaCl)	59.1	59.2	61.1	61.3	55.3	55.4	56.2	56.4
V3 (4000 ppm NaCl)	58.6	58.7	60.7	60.8	55.1	55.3	55.8	56
V4 (6000 ppm NaCl)	58.2	58.3	59.5	59.6	54.8	54.9	55.5	55.7
V5 (8000 ppm NaCl)	57.6	57.8	58.4	58.8	54.6	54.7	55.2	55.4
V6 (10000 ppm NaCl)	56.8	56.9	57.8	57.9	54.3	54.4	54.8	54.9
Mean	*58.25*	*58.4*	*59.8*	*59.9*	*54.9*	*55*	*55.65*	*55.9*

Results confirmed that there exists a significant relationship between sodium chloride concentration of the irrigation water, rootstock, and the whole plants moisture content and for the shoot hardwood cuttings moisture content.

Figure 1. View of the experiment at the beginning and at the end of treatments

Assessment of the resistance of the rootstocks to chlorides (salt) was carried out using OIV Code 402, based on the necrosis of leaves, with expression levels: 1 (very low - marginal necrosis, comprising the total leaf blade, causing leaf drop; very high and very fast necrosis), 3 (low – partially high and fast necrosis of leaves), 5 (medium – ends of veins are necrotic), 7 (high – sight necrosis of the margins of blade, necrosis is in dots up to 1 cm diameter), 9 (very high - leaf totally green, without necrosis at all) and IPGRI Code 8.6 (17; UPOV, 2008; OIV, 2001; IPGRI, 1997). For 1003 P rootstock, different variants were evaluated from 1 to 9. The only variant 6 (10000 ppm NaCl) was evaluated by 1. Rootstocks 140Ru in variant 5 was evaluated by 1. Three variants of Kober5BB (V4, V5 and V6), which showed a higher degree of necrosis of leaves and shoots, were evaluated by 1 (marginal necrosis, comprising the total leaf blade, causing leaf drop; very high and very fast necrosis). Four variants of rootstock SO4 (V3, V4, V5 and V6), which showed a higher degree of necrosis of leaves and shoots, were evaluated by 1. Rootstock SO4 was more sensitive and less resistant to sodium chloride concentration compare to 1103 P, 140Ru and Kober 5BB (Table 3).

Table 3. Ampelographic assessment for the tolerance to sodium chloride (evaluation level) of 1103 P, 140Ru, Kober5BB and SO4, according to different levels of sodium chloride

Treatments (NaCl concentration)	1103 P	140 Ru	Kober5 BB	SO4
V1 (control – 0 ppm NaCl)	9	9	9	9
V2 (2000 ppm NaCl)	7	7	5	3
V3 (4000 ppm NaCl)	7	5	3	1
V4 (6000 ppm NaCl)	5	3	1	1
V5 (8000 ppm NaCl)	3	1	1	1
V6 (10000 ppm NaCl)	**1**	**1**	**1**	**1**

Differences between treatments (sodium chloride concentration of the irrigation water) and rootstocks were significant and statistically confirmed (ANOVA: Two-Factor Without Replication) (Lekaj *et al*., 2014) for both moisture indicators: the whole plants moisture content and for the shoot hardwood cuttings moisture content. ANOVA data showed that, for treatments (NaCl concentration), $F = 15.9891 > F_{crit} = 4.5556$ and *P-value* = $1.52E\text{-}05 = 1.52/10^5 < \alpha = 0.01$, while for rootstocks $F = 158.8658 > F_{crit} = 5.4169$ and P-value = $1.38E\text{-}11 = 1.3/10^{11} < \alpha = 0.01$ (Table 4).

Table 4. Results of ANOVA for the relationship between sodium chloride concentration of the irrigation water, rootstock and moisture content

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (NaCl concentration)	15.625	5	3.125	15.9891	1.52E-05	4.5556
Columns (rootstocks)	93.1483	3	31.0494	158.8658	1.38E-11	5.4169
Error	2.9316	15	0.1954			
Total	111.705	23				

Based on the previous results of the assessment and comparison of the observed morphological indicators and the degree of shriveling and necrotization of leaves and shoots [6; 20; 21; 3], there was concluded that the tolerance of the grapevine rootstocks to salinity was significantly related to the moisture content of the whole plant and the moisture content of shoot hardwood cuttings [20; 22], and to the ability of plants to absorb and accumulate water in their cells and woody tissues.

4. Conclusions

Sodium chloride concentration in the irrigation water significantly affetcs the whole plant moisture content and the shoot hardwood cuttings moisture content of grapevine rootstocks. For the same sodium chloride concentration, the whole plant moisture content and the shoot hardwood cuttings moisture content were significantly different.

With the increase of NaCl concentration, the whole plant moisture content and the shoot hardwood cuttings moisture content were significantly decreased for all rootstocks.

Relationship between whole plant moisture content and the shoot hardwood cuttings, NaCl concentration, and rootstock was significant and differences between treatments and rootstocks were statistically confirmed by ANOVA ($p \leq 0.01$).

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