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Determination of Salt Tolerance of Four American Grapevine Rootstocks 1103P, Kober 5BB, 140Ru and SO4 to Sodium Chloride Concentration in the Soil

LUSH SUSAJ[1*], ELIZABETA SUSAJ[2], FATBARDHA SHPATI[3]

[1]Agricultural University of Tirana, Faculty of Agriculture and Environment, Department of Horticulture and Landscape Architecture, Kodër Kamëz 1029, Tirana, Albania

[2]Polis University, Faculty of Urban Planning and Environmental Management (FUPEM), Department of Environment, Tirana, Albania

[3]University College "Qiriazi", Street "Taulantet", near Agricultural University of Tirana, Albania

*Corresponding author; E-mail: lsusaj63@hotmail.com

Abstract

Study for the tolerance of antiphylloxeric rootstocks to the high salt (sodium chloride) concentrations in the soil, was carried out during three consecutive years (2014-2016), at the greenhouse of the Experimental Base of Agricultural University of Tirana, in Valias. There were used four the most widely grown and used American antiphylloxeric rootstocks in Albanian nurseries and vineyards, such as 1103P (*Vitis Berlandieri x Vitis Rupestris*), 140Ru (*Vitis Berlandieri x Vitis Rupestris*), Kober5BB (*Vitis Berlandieri x Vitis Riparia*) dhe SO4 (*Vitis Berlandieri x Vitis Riparia*). Six NaCl concentrations (treatments) [control (normal tap water), 2000, 4000, 6000, 8000, and 10000 ppm] with five pots with 2 cuttings each for replication, for each rootstock, were used. There were accounted and evaluated the number of survived plants and the degree of shriveling and necrosis of leaves and shoots of all treatments for all rootstocks. The lowest number of survived plants was observed for SO4 and Kober 5BB treated with 10000 ppm NaCl, while the highest number was observed for control and 2000 ppm NaCl. The observed number of survived vines for all treatments was 94.4% for 1103P, 70% for 140Ru, 57.2% for Kober 5BB, and 47.2% for SO4. Observed differences between rootstocks come from specific rootstock's metabolism characters and genotypes. Based on the ampelographic assessment and evaluation levels resulting from Code 402 of OIV (2001), was found that rootstock 1103P was able to withstand the salinity level in the pot soil up to 0.87% NaCl (13.63 dS/m), 140Ru up to 0.75% NaCl (11.78 dS/m), Kober5BB, up to 0.53% NaCl (8.41 dS/m), while SO4 vines resisted up to 0.35% NaCl (4.82 dS/m). Based on the OIV Code 402 (evaluation levels 1-9), rootstock SO4 was shown to be more sensitive and less resistant to sodium chloride concentration compare to 1103P, 140Ru and Kober 5BB. The observed results were statistically confirmed by Anova ($p \leq 0.01$) (F = 33 > Fcrit = 4.5556 and P-value = 1.4E-07 = $1.4/10^7 < \alpha = 0.01$, while, for rootstocks, the value of statistical indicator F = 16.25 > Fcrit = 5.4169 and P-value = 0.0005768 < α = 0.01.

Keywords: 140Ru, Kober 5BB, SO4, concentration, rootstock, sodium chloride (NaCl), tolerance.

1. Introduction

Salinization of soil is a serious problem and is increasing steadily in many parts of the world, in particular in arid and semiarid areas [1, 11]. In 2000, saline soils occupied around 7% of the earth's land surface, in 2007 saline soils were out of 1.5 billion hectares of cultivated land around the world, about 77 million hectares [9], and increased salinization of arable land will result in up to 50% land loss by the middle of the 21st century. High levels of salinity (>4 dSm) or >0.1% soil content in soils is mainly due to the soluble salts in irrigation water and fertilizers used in agriculture, low precipitation and high temperature in these regions and over-exploitation of available water resources [4]. Salinization of soil via the slow accumulation of salts from irrigation water continues at a pace that often goes unnoticed. 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 [10] and production [12]. 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** [14]. The significance of soil salinity for grapevine yield is enormous [15] as it affects the establishment, growth and development of plants leading to huge losses in productivity [4, 8]. The direct effects of salt on plant growth may involve: (a) reduction in the osmotic potential of the soil solution; (b) toxicity of excessive Na^+ and Cl^- ions towards the cell – the toxic effects include disruption to the structure of enzymes and other macromolecules, disruption of cell organelles and their metabolism, damage to cell organelles and plasma membrane, disruption of photosynthesis, respiration and protein synthesis; (c) nutrient imbalance in the plant caused by nutrient uptake and/or transport to the shoot leading to ion deficiencies; (d) chlorosis and necrotic spots of leaves and shoots; (e) hormonal disorders, such us low synthesis of auxins, etc; and (f) decrease yield quality, leading to sudden dehydration, shriveling, withering and death of affected plants [10]. American grape rootstocks have also shown to have different tolerance levels to salt. Dardeniz *et al*. (2006) have shown 41 B was the most resistant rootstock, followed by 140 Ru and 1103 P, and the least resistant was 5 BB. The aim of this study was to determine the salt tolerance of two American grape rootstocks, 1103P and Kober 5BB, widely grown and used in sapling production in Albania. Rootstock 1103P was bred by crossing *Vitis Berlandieri x Vitis Rupestris*, while Kober 5BB was bred by crossing *Vitis Berlandieri x Vitis Riparia* [2]. Assessment of the grapevine characters must be carried out using codes and expression levels of the International Descriptors of Grapevine [5,7,16]. Assessment for the rootstock's resistance to chloride (salt) must be carried out using OIV Code 402, evaluation levels 1, 3, 5, 7, 9 [7, 13, 16] and IPGRI Code 8.6 [5, 13].

2. Material and Methods

Study for the tolerance and resistance of the antiphylloxeric rootstocks 1103P, 140Ru, Kober 5BB and SO4 to sodium chloride was carried out during 2014-2016, at the Experimental Base of the Agricultural University of Tirana in Valias. One year old cuttings of four rootstocks, 1103P, 140Ru, Kober 5BB and SO4, the most widely grown and used in sapling production in Albania, were collected from a private nursery. Cuttings were taken out in March and were kept in water for a day. Cuttings were cut with two buds, 7-8 mm under the first bud and 20-25 mm above the second bud. Then, two budded and 7-8 mm thick cuttings were placed for rooting in pots with a volume of 9.5 litres filled with soil and manure in proportion 3:1, on March 5-10.

Pots (vases) were kept for rooting and growth in the glass greenhouse of the Experimentale Base. A randomized block design with 4 replications, six concentrations of NaCl solution (0-10000 ppm), with 12 cuttings with standardized height and width for each treatment for replication, for each rootstock, was used. Cuttings were treated using common practices and were irrigated with normal tap water until to the start of salt applications. Cuttings developed 2-3 shoots one month after planting and they were subjected to six different salt (sodium chloride) concentrations after July 15, for 62 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 name, replication and NaCl solution. Starting for July 15, pots were irrigated using six different concentrations of NaCl solution, as was described above. There were treated 30 rooted cuttings for each rootstock. Observations and assessment for the resistance and tolerance of 1103P, 140Ru, Kober 5BB and SO4 rootstocks to NaCl concentration was carried out every week. The plants treated with highest salt concentrations started to show severe symptoms since July 30. Assessment for the resistance and tolerance of rootstocks was carried out in September 15 or 60 days after the first salt treatment, and was based on the number of survived rooted cuttings two months after the first treatment with NaCl solution and the degree of shriveling and necrosis of leaves and shoots, according to different treatments and rootstocks. 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 [5,7,12,16]. The observed results were statistically compared using Anova ($p \leq 0.05$) [6].

3. Results and Discussion

The number of survived rooted cuttings was accounted in September 15, 62 days after the first salt treatment with NaCl solution, and was carried out the assessment of the degree of shriveling and necrosis of leaves and shoots, according to different treatments and rootstocks. There was observed that four rootstocks, 1103 P, 140Ru, Kober 5BB and SO4, were affected with the increase of NaCl concentration. The degree of shriveling and necrotization of leaves and shoots was significantly increased and the number of survived saplings was decreased for all rootstocks, but the rate and response to salt treatments was different.

For control (normal tap water) there was observed a normal growth and development of saplings for both rootstocks, and were observed 100% healthy plants. For 1103P rootstock, although there was observed a surviving rate of 94.4% for all treatments, they differed significantly for the number of normaly grown plants. For the lowest NaCl concentration (V2 - 2000 ppm), there was observed a normal growth and development for 76.6% of the plants, while 23.4% of the plants showed small and shriveling leaves.

The highest degree of damage was observed for variants 5 and 6 (8000 and 10000 ppm NaCl), where for 83.3% of the survived plants (survived 50 from 60) and with necrotic shoots (died plants) 16.7% (necrotic shoots 10 from 60), followed by variant 4 (6000 ppm NaCl), where the number of the survived plants with lived shoots was 100% and 30% showed necrotic leaves (Table 1).

Table 1. Effects of different concentrations of sodium chloride on 1103 P grape rootstock viability

NaCl concentration	Number of cuttings (three years mean values)					
	Survived plants	Healthy	Shriveling leaves	Necrotic leaves	Dropped leaves	Necrotic shoots (died plants)
V1 - 0 ppm	30	30	0	0	0	0
V2 - 2000 ppm	30	23	7	0	0	0
V3 - 4000 ppm	30	0	30	0	0	0
V4 - 6000 ppm	30	0	0	9	21	0
V_5 - 8000 ppm	27	0	0	0	27	3
V_6 - 10000 ppm	23	0	0	0	23	7
Total	170	53	37	9	71	10

For 140Ru rootstock, was observed a surviving rate of 70% in total for all treatments (Table 2), they differed significantly for the number of normaly grown plants. The highest damage degree was observed for variants 5 and 6 (8000 and 10000 ppm NaCl).

Table 2. Effects of different concentrations of sodium chloride on 140 Ru grape rootstock viability

NaCl concentration	Number of cuttings (three years mean values)					
	Survived plants	Healthy	Shriveling leaves	Necrotic leaves	Dropped leaves	Necrotic shoots (died plants)
V1 - 0 ppm	30	30	0	0	0	0
V2 - 2000 ppm	30	12	18	0	0	0
V3 - 4000 ppm	30	0	9	21	0	0
V4 - 6000 ppm	25	0	0	0	25	5
V_5 - 8000 ppm	8	0	0	0	8	22
V_6 - 10000 ppm	3	0	0	0	3	27
Total	126	42	27	21	50	54

For Kober 5BB rootstock, the degree of plants damage (degree of shriveling and necrosis of leaves and shoots) of all treatments was higher compared to 1103P and 140Ru. Plant viability of rootstock Kober 5BB was 57.2%, with a difference of 37.2% and 12.8% compared to 1103P and 140Ru, respectively (Table 3).

Table 3. Effects of different concentrations of NaCl on Kober 5BB grape rootstock viability

NaCl concentration	Number of cuttings (three years mean values)					
	Survived plants	Healthy	Shriveling leaves	Necrotic leaves	Dropped leaves	Necrotic shoots (died plants)
V1 - 0 ppm	30	30	0	0	0	0
V2 - 2000 ppm	30	0	24	6	0	0
V3 - 4000 ppm	25	0	0	5	20	5
V4 - 6000 ppm	13	0	0	0	13	17
V_5 - 8000 ppm	4	0	0	0	4	26
V_6 - 10000 ppm	1	0	0	0	1	29
Total	103	30	24	11	38	77

For SO4 rootstock, the degree of plants damage (degree of shriveling and necrosis of leaves and shoots) of all treatments was higher compared to 1103P, 140Ru and Kober 5BB. Plant viability of rootstock SO4 was 47.2 %, with a difference of 47.2% compared to 1103P, with a difference of 22.8% compared to 140Ru and with a difference of 10% compared to Kober 5BB (Table 4). This difference between rootstocks comes mainly from differences of specific rootstock's metabolism characters and genotype.

Table 4. Effects of different concentrations of sodium chloride on SO4 grape rootstock viability

NaCl concentration	Number of cuttings (three years mean values)					
	Survived plants	Healthy	Shriveling leaves	Necrotic leaves	Dropped leaves	Necrotic shoots (died plants)
V1 - 0 ppm	30	30	0	0	0	0
V2 - 2000 ppm	30	0	18	12	0	0
V3 - 4000 ppm	19	0	0	0	19	11
V4 - 6000 ppm	6	0	0	0	6	24
V_5 - 8000 ppm	0	0	0	0	0	30
V_6 - 10000 ppm	0	0	0	0	0	30
Total	85	10	6	4	7	95

Assessment of the resistance of the rootstocks 1103 P and Kober 5BB to chlorides (salt) was carried out using OIV Code 402, based on the necrosis of leaves. There were evaluated all plants in all variants, and mean values are represented in Table 5.

Table 5. Ampelographic assessment of rootstocks (thee years mean values)

NaCl concentration	Rootstocks											
	1103P			SO4			140Ru			Kober 5BB		
	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
V1 - 0 ppm	9	9	9	9	9	9	9	9	9	9	9	9
V2 - 2000 ppm	9	9	9	7	7	5	9	7	7	5	5	5
V3 - 4000 ppm	9	7	9	3	1	1	5	5	5	1	3	3
V4 - 6000 ppm	7	5	5	1	1	1	3	3	3	1	1	1
V_5 - 8000 ppm	5	3	3	1	1	1	1	1	3	1	1	1
V_6 - 10000 ppm	3	1	1	1	1	1	1	1	1	1	1	1

Based on the dominant resistance/tolerance level through years, there was observed that:

Six different variants of rootstock 1003P were evaluated from 1 to 9, and only variant 6 (10000 ppm NaCl) was evaluated by 1, which means that 1103P was resistant to NaCl in the soil up to 8000 ppm. Two variants of rootstock 140Ru were evaluated by 1, and foru variants were evaluated by 3 to 5, which means that 140Ru was tolerant to NaCl in the irrigation solution up to 6000 ppm NaCl. Three variants of rootstock Kober 5BB (V4, V5 and V6) showed high degree of necrosis of leaves and shoots and were evaluated by 1 (marginal necrosis, comprising the total leaf blade, causing leaf drop; very high and very fast necrosis), and the only variant 2 (2000 ppm) was evaluated by 7 (high – sight necrosis of the margins of blade, necrosis is in dots up to 1 cm diameter). Four variants of rootstock SO4 (V3, V4, V5 and V6) showed high 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 6).

Table 6. Ampelographic assessment for the tolerance to sodium chloride of 1103 P, 140Ru, Kober5BB and SO4, according to different levels of sodium chloride

NaCl concentration	Rootstocks evaluation level			
	1103P	SO4	140Ru	Kober 5BB
V1 - 0 ppm	9	9	9	9
V2 - 2000 ppm	9	7	7	5
V3 - 4000 ppm	7	1	5	3
V4 - 6000 ppm	5	1	3	1
V_5 - 8000 ppm	3	1	1	1
V_6 - 10000 ppm	1	1	1	1

Differences between variants and rootstocks were statistically confirmed by Anova: Two-Factor Without Replication [6]. For variants (sodium chloride concentration), the value of statistical indicator F = 33 > Fcrit = 4.5556 and P-value = 1.4E-07 = $1.4/10^7 < \alpha = 0.01$, while, for rootstocks, the value of statistical indicator F = 16.25 > Fcrit = 5.4169 and P-value = 0.0005768 < α = 0.01. Observed results confirmed that there exist a significant relationship between sodium chloride concentration in the soil, rootstock, degree of necrosis of leaves and shoots (plant viability) (Table 7).

Table 7. Results of Anova: Two-Factor Without Replication for the relationship between sodium chloride concentration in the soil and rootstock

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Variants - % NaCl)	205.3333	5	41.0666	33	1.4E-07	4.5556
Columns (Rootstocks)	23.33333	3	7.7777	16.25	0.005768	5.4169
Error	18.66667	15	1.2444			
Total	247.3333	23				

4. Conclusions

Sodium chloride concentration in the soil has significantly affected the resistance and tolerance of 1103P, 140Ru, Kober 5BB and SO4 grape rootstocks. With the increase of NaCl concentration, the degree of shriveling and necrotization of leaves and shoots was significantly increased and the number of survived plants was decreased for both rootstocks. Rootstock 1103P was more resistant, while rootstock SO4 was more sensitive and less resistant to sodium chloride concentration. Taking into consideration the tolerance of studied rootstocks to sodium chloride, was recommended that in saline soils, where the content if NaCl is 0.3-0.8%, must be used the rootstock 1103P, which showed the highest tolerance degree.

5. References

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