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Effect of different grape rootstocks on the growth, yield and quality of Superior grape under salt stress

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ABSTRACT

Grape rootstocks recently have taken special attention for grape cultivation to cover soil salinity. This work aimed to clarify the performance of Superior seedless under soil salinity using grape rootstocks. Four treatments, each had five replicates and arranged in a complete randomize block design. Treatments were Superior seedless on own roots (control), Superior grafted on Couderc, Dog Ridge and on Salt Creek. Bud burst and fertility were recorded. Shoot length and width, number of leaves per shoot, number of shoots per vine and leaf area as vegetative growth parameters were measured. Leaf chlorophyll and cane carbohydrate contents were also determined. Numbers of cluster per vine and cluster weight were used to calculate yield per vine. The parameter of quality attributes, *i.e.*, cluster length and width, volume of 100 berries, berry length and width, total soluble solids (TSS), Titratable acidity and finally total sugars were measured. Results revealed that performance of Superior seedless grafted on all grape rootstocks under investigation showed significantly better results in most measured parameters compared to those grown on their roots. Salt Creek showed the highest value in that respect followed by Dog Ridge and then Couderc. The study recommends Salt Creek as the best rootstock for gape cv. Superior seedless under soil salinity condition.

Keywords: Superior seedless, Salt Creek, Dog Ridge, Couderc, Soil salinity, Yield, Quality

Introduction

Invention in agriculture is true deal and grapevines (*Vitis vinifera* L) have special interest in that deal, therefore their cultivations are widespread everyday worldwide. However, salinity stress is one of the main challenges in growing cultivation especially that grapes were considered moderately sensitive to soil salinity (Paranychianakis *et al.*, 2008). Ayers and Westcot (1985) found that grape production was decreased 10 % at soil with EC of 1.5-2.5 dS m^{-1}, between 10-15% at the EC 2.5-4.0 dS m^{-1} and reached 20-25% at EC 4.7 dS m^{-1}. Moreover, other parameter such growth, fruit production and quality were found to be seriously affected by soil salinity in grapes (Stevens and Walker, 2002; Zhang *et al.*, 2002). Interestingly, Dog Ridge and Salt Creek under NaCl salinity showed similar tolerance at EC of 6.5 dS m^{-1}(Tambe, 1999). Moreover, Dog Ridge and Salt Creek under Na_2SO_4 salinity showed tolerance at EC of 9.27 and 8.34 dS m^{-1}, respectively (Tambe, 1999). Moreover, Dog Ridge and Salt Creek rootstocks showed drought tolerant as well (Kadam, 2001). Superior seedless is sugarcane table grape variety as classified by United States and European Union. Superior grapes are sweet with slight Muscat flavor, low acidity, crisp, firm and ripen early in the season (last week of May) and this make it occupies advanced order in exportation to foreign markets. The rootstocks are the most important tools in spreading vineyards at all conditions. However, the most of vineyards are growing on own roots that coming from cuttings which well known for grape multiplications with minor problems. Little knowledge about the grape rootstocks is available. Selection of the rootstock is depends on its benefits. The importance of grape rootstocks characteristics were previously reported in several studies such as adaptation to high and low pH soils and saline soils (Walker *et al.*, 2007) excess of water or drought stress (De Herralde *et al.*, 2006; Serra *et al.*, 2014) nematode resistance (Ferris *et al.*, 2012) and fungal diseases (Brown *et al.*, 2013; Wallis *et al.*, 2013). This variable takes place direct or indirect manner and subsequently affects all physiology process in grape rootstocks and scions. For instance, previous studies found that rootstocks affect growth, yield and fruit quality of the vines (Virgona *et al.*, 2003; Cookson *et al.*, 2012; Keller *et al.*, 2012). Furthermore, the content of leaf petiole mineral were revealed significant

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differences between scions grafted on different rootstocks compared to grown on own rooted (Miele *et al.*, 2009; Kodur *et al.*, 2011). The aim of this work was firstly to study the effects of Couderc, Dog Ridge and Salt Creek as rootstocks on growth, yield and quality of superior grape vines under salt stress condition and secondly to recommend the most proper and suitable rootstock for superior grape vines under this condition.

Material and methods

Experimental design

Field experiments was performed during 2016 and 2017 seasons in a 5-years-old vineyard of *Vitis vinifera* 'Superior seedless' on own roots and on Dog Ridge, Salt Creek and Couderc as rootstocks with planting space of 3 m between rows and 2 m within rows resulting density of 700 vines/ feddan in sandy soil under drip irrigation system in a private farm located at Al Mansouria, Giza governorate, Egypt. Before the start of the experiment, soil characteristics were figure out as shown in Table (1).

Table 1: Orchard soil characteristics of Superior seedless cultivar vineyard experiment.

Soil depth (cm)	Particle size distribution (%)			pH 1:2.5	EC dS m^{-1}	O.M g Kg^{-1}	Available NPK mg Kg^{-1}		
	Fine sand %	Course sand %	Silt + Clay %				N	P	K
0-30	47.11	50..17	2.72	8.47	5.87	0.56	33.19	2.35	174.14
30-60	55.18	32.35	12.47	8.55	5.95	0.37	30.26	2.15	170.84
60-90	60.28	35.44	4.28	8.86	6.13	0.21	28.71	1.85	168.23

Vines were grown on supported Barron system and pruned to 120 buds per vine (12 canes X 10 buds/ vine). When cluster reached around 10 cm length, the crop load was normalized to 36 bunches per plant. Normal agriculture practices inclusive fertilization, pests and diseases control were similarly applied on all treatments. There were four treatments arranged in randomize complete block design each had five replicates inclusive three vines for each as follow: T1: Superior seedless on own roots (control), T2: Superior grafted on Couderc rootstocks, T3: Superior grafted on Dog Ridge rootstocks, T4: Superior grafted on Salt Creek rootstocks.

Studied parameters:

Bud behavior:-

Bud burst % was calculated when 5 % of buds were bursted according to EL-Shahat (1992). One month later of bud burst the number of bursted buds and cluster per vine were counted to calculate fertility % (Omran, 2000) as follow:

$$\text{Bud Burst \%} = \frac{\text{Number of brusted buds/vine}}{\text{Total number of buds left/vine(40)}} \times 100$$

$$\text{Bud fertility \%} = \frac{\text{Number of clusters/vine}}{\text{Total number of buds left/vine(40)}} \times 100$$

Vegetative traits:-

- At full bloom stage, shoot length and width were measured.
- Matured single leaf counted as the sixth leaf from the top of the shoot was used for leaf area determination using digital planimeter.
- Number of leaves/shoot and then multiplied by number of shoots/vine that have been counted as well.

Total carbohydrate and chlorophyll:-

- Total carbohydrates in the canes (%) were measured as described by Hedge and Hofreiter (1962).
- The determination method of leaf total chlorophyll (mg g FW^{-1}) according to Von- Wettstein (1957) was followed.

Yield and fruit quality:-

According to Hamza (2013) at the level of TSS of 16-17% the harvest was done and the following measurements were taken:-

- Cluster weight was estimated then multiplied by the number of cluster/vine to calculate the yield/vine (Kg).
- The cluster length and width.
- Berry length and width.
- Volume juice of 100 berries was determined.
- Total sugars and acidity in juice were determined (A.O.A.C., 2000).
- Total soluble solids (TSS) as Brix using Hand refractometer was determine.

Petiole mineral contents

Micro-kjeldehl method as described by page (1982) was used for nitrogen (N). Cotteine *et al.* (1982) were followed for phosphorus measurement. Flame photometer was used for potassium (K) and sodium (Na) determination according Jackson (1967). Perkin Elmer-3300 method according Chapman and Pratt (1961) was used for calcium measurement using atomic absorption spectrophotometer. The method of Wilde *et al.*, (1985) was used for magnesium (Mg) determination. According to Mohr's titration method (Rhoades, 1982) chloride was determined using silver nitrate (0.025 M) and potassium chloride (0.1 M).

Statistical analysis

Data were analyzed by Statistical Graphics Corporation, STATGRAPHICS Plus (St. Louis, MO, USA) for one way analysis of variance and employing Duncan's multiple range tests (Duncan, 1955) at the 0.05 confidence level and for principle component analysis (PCA).

Results and Discussion

The effect of rootstocks on bud behavior

Results in Table (2) reveal that Salt Creek rootstock significantly promoted Superior seedless to the highest bud burst and fertility compared to its own roots and the other rootstocks (73.43%, 65.25%). Dog Ridge rootstock followed Salt Creek in this concern and then Couderc. Superior seedless showed the lowest value of bud burst and fertility (63.15 %, 53.55%). These results are in agreements with those found by El Morsi *et al*. (2006); Gaser (2007) and El-Banna *et al*. (2008) who found that Superior seedless showed the lowest value of bud burst and fertility when grown on own roots compared to all other rootstocks under their studies since Salt Creek and Dog Ridge were among them as well.

Table 2: The effect of rootstocks on bud burst and fertility of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	Year	Control	Couderc	Dog Ridge	Salt Creek
Bud burst %	2016	63.17 **d**	65.25 **c**	68.14**b**	73.44 **a**
	2017	63. 13 **d**	65.27 **c**	68.15 **b**	73.43 **a**
Average		63.15 **D**	65.26 **C**	68.14 **B**	73.43 **A**
Bud fertility %	2016	53.54 **d**	56.28 **c**	60. 18 **b**	65.28 **a**
	2017	53.57 **d**	56.29 **c**	60.21 **b**	65.22 **a**
Average		53.55 **D**	56.28 **C**	60.20 **B**	65.25 **A**

In this table and the following, means followed by the same letter are not statistically different by Duncan at 0.05 levels.

The effect of rootstocks on vegetative parameters

Results in Table (3) show that Salt Creek, Dog Ridge and Couderc rootstocks significantly improved all vegetative parameters under investigation, *i.e.*, shoot length and diameter, number of leaves per shoot, number of shoots per vine and leaf area compared to Superior seedless on own roots. The highest values were obtained by Salt Creek followed by Dog Ridge and then Couderc. These findings were in the same line with the previous studies by Stevens and Walker (2002); Zhang *et al.* (2002); Virgona *et al.* (2003); Cookson *et al.* (2012); Keller *et al.* (2012) who found a clear superiority concerning vegetative growth of different grape varieties grafted on different rootstocks compared to their own roots.

The effect of rootstocks on total chlorophyll and carbohydrate

Chlorophyll content is consider as a parameter that reflects leaves injury due to salt stress which maybe not showing visible symptoms such as chlorosis or necrosis. Carbohydrate content as an indicator for salt stress as well which is associating with bud burst and fertility. Results in Table (4) show that Salt Creek, Dog Ridge and Couderc rootstocks significantly increased leaf chlorophyll content and total carbohydrates in cans compared to Superior seedless on own roots. The highest value was obtained by Salt Creek followed by Dog Ridge and then Couderc. These results came in line with those Sourial *et al.*, (2004) and Kilany *et al.* (2006) who found that salinity reduced the content of chlorophyll in leaves and carbohydrates in cans of grape cultivars on their own roots more than those grown on grape rootstocks.

The effect of rootstocks on the yield and quality parameters

Results in Table (5) show the effect of grape rootstocks on yield parameters. Salt Creek, Dog Ridge and Couderc rootstocks significantly increased number of cluster per vine, average cluster weight and subsequently average yield per vine compared to Superior seedless on own roots.

Table (6 and 7) show the effects of Salt Creek, Dog Ridge and Couderc rootstocks on the quality attributes, *i.e.* cluster length and width, volume of 100 berries, berry length and width, total soluble solids (TSS), Titratable acidity and finally total sugars. Similarly, all rootstocks under investigation improved all quality attributes compered to un-grafted grapes (Superior seedless). In this respect, Salt Creek showed the highest value followed by Dog Ridge and then Couderc, whereas Superior seedless showed the lowest value. These results reflect the potential role of the rootstocks in decreasing the effect of salt stress on yield and fruit quality. Similar studies were previously reported by Stevens and Walker (2002); Zhang *et al.* (2002); Virgona *et al.* (2003); Cookson *et al.* (2012); Keller *et al.* (2012). Ruhl (1989) found that Dog Ridge and Ramsey increased scion grape juice of potassium concentration and pH. However, higher levels of total N were found with lower yields in the Dog Ridge rootstocks (Reddy *et al.*, 1992).

The effect of rootstocks on petiole mineral contents

Results in Table (8) show the effect of grape rootstocks on petiole mineral content. Salt Creek, Dog Ridge and Couderc rootstocks, respectively, showed significant increase of the uptake of N, P, K, Ca and Mg, whereas they showed significant decrease of the uptake of Cl and Na compared to Superior seedless on own roots. The role of grape rootstocks was previously reported through several studies Cirami *et al.* (1984); Bhargava *et al*. (1982) who found that higher potassium and nitrogen levels were observed in grape cv.Shiraz or Anab-e-Shahi grafted onto Dog Ridge. Generally, diverse uptake by grape rootstocks under salinity stress were previously reported by Ahmed, (2007) and Wasim (2011).

Table 3: The effect of rootstocks on shoot length, shoot width, No. leaves/shoot, No. shoots/vine and leaf area of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	Shoot length (cm)		AV.	Shoot diameter (mm)		AV.	No. Leaves/shoot		AV.	No. shoots/vine		AV.	Leaf area (cm)		AV.
Seasons	**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**	
Control	211.24**d**	212.11**d**	211.67**D**	5.81**c**	6.85**c**	5.83**D**	30.14**c**	29.13**c**	29.63**D**	55.65**d**	55.57**d**	55.61**D**	155.14**d**	155.11**d**	155.13**D**
Couderc	251.62**c**	252.35**c**	251.98**C**	5.92**c**	5.80**c**	5.86**C**	31.70**bc**	31.73**bc**	31.72**C**	58.41**c**	58.51**c**	58.46**C**	176.36**c**	176.29**c**	176.33**C**
Dog Ridge	282.14**b**	282.31**b**	282.23**B**	6.90**b**	6.95**b**	6.93**B**	32.11**b**	32.19**b**	32.15**B**	62.31**b**	62.36**b**	62.34**B**	187.45**b**	187.39**b**	187.42**B**
Salt Creek	315.29**a**	315.25**a**	315.27**A**	7.46**a**	7.40**a**	7.43**A**	34.17**a**	34.19a	34.18**A**	71.74**a**	71.59**a**	71.67**A**	195.78**a**	195.79**a**	195.78**A**

AV. Refers to the Average

Table 4: The effect of rootstocks on Superior seedless leaf chlorophyll content and cane carbohydrate content grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	Year	Control	Couderc	Dog Ridge	Salt Creek
Total chlorophyll mg g FW^{-1}	**2016**	25.13 **d**	28.47 **c**	31.31 **b**	36.43 **a**
	2017	26. 21 **d**	28.39 **c**	31.74 **b**	36.47 **a**
Average		25.67	28.43	31.53	36.45
Total carbohydrate %	**2016**	15.54 **d**	18.17 **c**	22.41 **b**	26.36 **a**
	2017	16.11 **d**	18.41 **c**	22.35 **b**	26.31 **a**
Average		15.83	18.29	22.38	26.34

Table 5: The effect of rootstocks on No. clusters/vine, average cluster weight and average yield/vine of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	**Year**	**Control**	**Couderc**	**Dog Ridge**	**Salt Creek**
No. clusters/vine	**2016**	26.14 **d**	29.35 **c**	31.32 **b**	35.40 **a**
	2017	26.13 **d**	29.33 **c**	31.30 **b**	35.36 **a**
Average		26.13 **D**	29.34 **C**	31.31 **B**	35.38 **A**
Cluster weight (Kg)	**2016**	512.15**d**	524.21 **c**	531.41 **b**	563.65**a**
	2017	513.01 **d**	524.36 **c**	531.53 **b**	563.35 **a**
Average		512.58 **D**	524.29 **C**	531.47 **B**	563.50 **A**
Yield/vine (Kg)	**2016**	13.39 **d**	15.38 **c**	16.64 **b**	19.95 **a**
	2017	13.40 **d**	15.37 **c**	16.63 **b**	19.92 **a**
Average		13.39 **D**	15.37	16.63 **B**	19.94 **A**

Table 6: The effect of rootstocks on cluster length, cluster width, volume of 100 berries, berry length and berry width of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	Cluster length (cm)		Av.	Cluster width (cm)		Av.	volume of 100 berries (cm3)		Av.	Berry length (cm)		Av.	Berry width (cm)		Av.
Seasons	**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**	
Control	18.35**d**	18.33**d**	18.34**D**	14.13**d**	14.15**d**	14.14**D**	273.54**d**	274.11**d**	273.83**D**	21.47**d**	21.43**d**	21.45**D**	15.56**d**	15.58**d**	15.57**D**
Couderc	22.41**c**	22.43**c**	22.42**C**	16.53**c**	16.57**c**	16.55**C**	280.41**c**	280.43**c**	280.42**C**	23.54**c**	23.56**c**	23.55**C**	17.74**c**	17.75**c**	17.74**C**
Dog Ridge	24.69**b**	24.72**b**	24.71**B**	18.87**b**	18.89**b**	18.88**B**	286.32**b**	286.35**b**	286.33**B**	25.39**b**	25.38**b**	25.37**B**	19.83**b**	19.88**b**	19.85B
Salt Creek	27.45**a**	27.47**a**	27.46**A**	21.25**a**	21.23**a**	21.24**A**	293.21**a**	293.25**a**	293.23**A**	27.89**a**	27.88**a**	27.88**A**	22.64**a**	22.66**a**	22.65**A**

Table 7: The effect of rootstocks on TSS, acidity and total sugars of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	Year	Control	Couderc	Dog Ridge	Salt Creek
TSS (°Birx)	**2016**	16.13 **d**	16.23 **c**	16.59 **b**	17.10 **a**
	2017	16.11 **d**	16.25 **c**	16.58 **b**	17.13 **a**
Average		16.12 **D**	16.24 **C**	16.58 **B**	17.12 **A**
Titratable acidity (g L^{-1})	**2016**	0.73 **d**	0.68 **c**	0.64 **b**	0.55 **a**
	2017	0.74 **d**	0.69 **c**	0.63 **b**	0.54 **a**
Average		0.73 **D**	0.68 **C**	0.64 **B**	0.54 **A**
Total sugars %	**2016**	12.35 **d**	12.50 **c**	13.31 **b**	14.22 **a**
	2017	12.31 **d**	12.51 **c**	13.33 **b**	14.21 **a**
Average		12.33 **D**	12.50 **C**	13.32 **B**	14.21 **A**

Table 8: The effect of rootstocks on petiole contents of N, P, K, Ca, Mg, Cl and Na of Superior seedless grown in soil that affected by salt during 2016 and 2017 seasons.

Parameters	N %		Av.	P %		Av.	K %		Av.	Ca %		Av.	Mg %		Av.	Cl %		Av.	Na %		Av.
Seasons	**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**		**2016**	**2017**	
Control	2.61**c**	2.62**c**	2.61**C**	0.18**c**	0.17**c**	0.17**C**	1.67**c**	1.66**c**	1.66**C**	2.33**c**	2.34**c**	2.33**C**	0.51**c**	0.50**a**	0.50**A**	1.33**a**	1.32**a**	1.32**A**	0.51**a**	0.50**a**	0.50**A**
Couderc	2.65**c**	2.66**c**	2.65**C**	0.20**c**	0.21**c**	0.20**C**	1.72**c**	1.71**c**	1.71**C**	2.41**c**	2.43**c**	2.42**C**	0.55**c**	0.56**a**	0.55**A**	1.29**a**	1.28**a**	1.28**A**	0.48**a**	0.47**a**	0.47**A**
Dog Ridge	2.71**b**	2.72**b**	2.71**B**	0.24**b**	0.24**b**	0.24**B**	1.78**b**	1.77**b**	1.77**B**	2.50**b**	2.51**b**	2.50**B**	0.66**b**	0.67**b**	0.66**B**	1.23**b**	1.22**b**	1.22**B**	0.40**b**	0.39**b**	0.39**B**
Salt Creek	2.87**a**	2.86**a**	2.86**A**	0.27**a**	0.28**a**	0.27**A**	1.88**a**	1.89**a**	1.88**A**	2.63**a**	2.62**a**	2.62**A**	0.76**a**	0.77**c**	0.76**C**	1.18**c**	1.17**c**	1.17**C**	0.29**c**	0.28**c**	0.28**C**

Conclusion

The demand for new agriculture technics that copping salinity are always of interest. The results highlighted the effect of Salt Creek, Dog Ridge and Couderc as grape rootstocks for Superior seedless cultivated in saline soil. These rootstocks revealed superiority in improving growth, yield and quality of Superior seedless compared to that grown on its own roots. Salt Creek showed the best results in this concern, consequently the authors strongly recommend such rootstock for wide cultivation of Superior seedless in soil affected by salinity.

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Conflicts of interest

The authors declare that there are no conflicts of interest related to the publication of this work.

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