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The Effects of Sewage Sludge Applications on Growth, Yield and Flower Quality of *Limonium sinuatum* (Statice) under Salinity Conditions

Tuzlu Koşullar Altında Arıtma Çamur Uygulamasının *Limonium sinuatum* (Statice)'un Bitki Gelişimi, Verim ve Çiçek Kalitesine Etkileri

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Tuzluluk, Arıtma Çamuru, Toprak Islahı, *Limonium sinuatum*

ABSTRACT

Objective: In this study conducted in greenhouse conditions, the effects of sewage sludge application on plant growth, yield and flower quality of *Limonium sinuatum* (Statice) under salinity conditions were investigated.

Material and Methods: For this purpose, application of 0%, 25%, 50% and 75% sewage sludge doses and 50 mM and 100 mM salt treatment was preferred. Research was conducted as 3 replicates and according to two factor random plots experimental design and in such a way as to have 5 plants in each plot. During in the study, the number of the leaves, the number of flowers harvested per plant, flower peduncle length and thickness were determined. At the end of this study, the root length, the fresh and dry weight of upper parts of plant, the root fresh and dry weight were examined.

Results: As expected, while increasing salt application no statistical affected the vegetative growth parameters of the plant, yield and flower quality, the increasing sewage sludge doses affected all parameters examined during the research positively. When compared to SS0 (without sewage sludge condition), SS3 dose (75%) increased the number of the leaves by 39 %, fresh weight of upper parts by 87 %, dried weight of upper parts by 73 %, root length by 93 %, root fresh weight by 93 %, root dry weight by 111 %, the number of the flowers harvested per plant by 70 %, the length of flower peduncle by 14 % and the thickness of flower peduncle by 23 %

Conclusion: In light of the findings of the current research, it has been determined that in the salty conditions the increasing sewage sludge application doses affected plant growth, yield and flower quality positively by removing the negative effect of salt.

ÖZ

Amaç: Sera koşullarında yapılan bu çalışmada, Gökova-Akkaya atık su arıtma tesis arıtma çamuru uygulamasının tuzlu koşullar altındaki *Limonium sinuatum* (Statice) bitkisinin bitki gelişimi, verim ve çiçek kalitesi üzerine etkileri araştırılmıştır.

Materyal ve Metot: Bu amaçla, %0, % 25, % 50 ve % 75 arıtma çamuru ve 50 mM ile 100 mM tuz dozlarının uygulanması tercih edilmiştir. Deneme 3 tekerrürlü ve her parselde 5 bitki olacak şekilde iki faktörlü tesadüf parselleri deneme desenine göre kurulmuştur. Deneme süresince bitki başına yaprak sayısı, bitki başına hasat edilen çiçek sayısı, çiçek sapı uzunluğu ve kalınlığı belirlenmiştir. Çalışmanın sonunda, kök uzunluğu, üst aksam yaş ve kuru ağırlığı, kök yaş ve kuru ağırlığı incelenmiştir.

Bulgular: Tuz uygulaması bitkinin gelişimini, verimini ve çiçek kalitesini istatistiksel olarak olumsuz etkilemezken, artan arıtma çamuru dozları incelenen tüm parametreleri olumlu etkilemiştir. Arıtma çamuru uygulanmamış SS0 dozu ile karşılaştırıldığında, % 75 arıtma çamuru içeren SS3 dozunda yaprak sayısı % 39, üst aksam yaş ağırlığı % 87, üst aksam kuru ağırlığı % 73, kök uzunluğu % 93, kök yaş ağırlığı % 93, kök kuru ağırlığı % 111, bitki başına hasat edilen çiçek sayısı % 70, çiçek sapı uzunluğu % 14 ve çiçek sapı kalınlığı % 23 oranında artmıştır.

Sonuç: Mevcut araştırma bulguları ışığında, tuzlu koşullarda artan arıtma çamur uygulama dozlarının, tuzun olumsuz etkilerini kaldırarak, bitki büyümesini, verimini ve çiçek kalitesini olumlu yönde etkilediği tespit edilmiştir.

INTRODUCTION

As the standard of living increases, the amount of domestic and Municipal waste and sewage sludges generated increases steadily. And environmental pollution arises as a result. Disposal of this waste emerges as a serious problem. During the next decade, the urban waste water treatment will being produced more sludge and sludge disposal could become increasingly difficult. The current methods for disposal include land filling, incineration, dumping in sea and field application for agricultural use. Sludge disposal in the case of sea will be illegal. Sludges use in agriculture are the supply organic fertilizer, at low cost. Because of its high organic matter and nutrient content, sewage sludge can develop physical, chemical, and biological properties of soil (Angın and Yağanoğlu, 2009; Angın and Yağanoğlu, 2011). The fertilizer effect makes possible a decrease in cost for chemical fertilizers on sewage sludge used soils (Petersen et al. 2003). But, the master problem of the application of sewage sludge are plant toxicity due to heavy metals in sewage sludge (McGrath et al. 2000).

Agricultural land of the world decreases due to urbanization, industrialization and global warming. Salinity is one of the most important problems of the arid and semi-arid climatic regions particularly with global warming on the places where the natural drainage conditions aren't enough. (Ekmekçi et al., 2005; Qadir et al., 2006). The increased salinity in the soil limits the ability of agricultural production to be commercialized by affecting plant growth, quality and yield in the negative direction. (Grieve et al., 2005; Grieve and Poss, 2010; Dölarslan and Gül, 2012; Akat and Saraçoğlu, 2017). Reclamation of saline soils has great importance both in terms of environment and economy.

Saline soils can be improved by physical, biological, chemical, hydro-technical and electro- reclamation methods (Qadir et al., 2007; Angın and Yağanoğlu, 2009). As biological reclamation method, adding to soil of organic materials such as farm yard manure, green manure, forest waste, organic artificial fertilizers, mycorrhizal fungi, solid waste composts and sewage sludge is the most preferred application (Angın, 2010; Akat et al., 2013a; Aynacı and Erdal, 2016). Recently stabilized domestic and Municipal sewage sludges which is below the specified heavy metal limits content can be use to reclamation soil is an environmentally friendly method. (Kranert et al., 2008; Topal and Topal, 2013; Akat et al., 2015).

This study was conducted in order to determine the effects of different doses of municipal sewage sludge on plant growth, yield and flower quality of *Limonium sinuatum* under salinity conditions.

MATERIAL and METHODS

This study was conducted on the experimental greenhouse of Ortaca vocational school in 2015-2016. *Limonium sinuatum* 'Compindi White' cultivar was preferred as plant material. *Limonium sinuatum* is the most commonly cultivated and highly recognized cut flowers crop. The common name "Statice" is actually used in most references for this genus although "sea lavender" is alternatively used because of its lilac-colored flowers and the fact that it naturally inhabits mainly coastal areas (Steven, 2008).

Seeds were sowed on October 9th, 2015. Seedlings were planted to 1:1 peat-perlite mixture in 0.5 lt pots. After a month they were replanted to their actual beds in 10 lt pots on November 07th, 2015. The current experiment was conducted by using the two factor random plots experimental design with 3 replicates and in such a way as to have 5 plants in each plot. In this study, 50 mM (S1) and 100 mM (S2) NaCl was administered. The situation in which salt is not applied was evaluated as a control (S0). Salt treatment was repeated once two week up to the end of the experiment.

The sewage sludge material used in the current study was obtained from the Gökova-Akyaka Waste Water Treatment Plant and then its physical and chemical characteristics were determined (Table 1). Also, fecal coliform bacteria have not been determined in the results of microbiological analysis of the sewage sludge.

The heavy metal content of the sewage sludge used this experiment is under the maximum heavy metal content allowed for standardized sewage sludge to be used in the soil specified in the "Regulation on the Use of Domestic and Municipal Sewage Sludge in Soils". The sewage sludge used in this experiment was added to the soil in the doses of 25 % (SS1), 50 % (SS2) and 75 % (SS3) of pot volume and the soil material on its own made up the control group (SS0). Each treatments were mixtured five times. In general, the study soil was Sandy-loam in texture, slightly alkaline in reaction (pH), moderate organic matter. The soil showed no symptom of salt problem (Table 1).

The Hoagland nutrient solution with a pH of 6.0-6.5 (Brohi et al., 1994) was applied once a week, with drip irrigation system two weeks month after planting for growth of the plants. Composition of nutrient solution was (mg l^{-1}): 270 N, 31 P, 234 K, 200 Ca, 64 S, 48 Mg, 2.8 Fe, 0.5 Mn, 0.5 B, 0.02 Cu, 0.05 Zn and 0.01 Mo. The number of the leaves (piece $plant^{-1}$), the number of flowers harvested per plant (piece $plant^{-1}$), flower peduncle length (cm) and thickness (mm) were determined after every salt treatment. At the end of this experiment, the root length (cm), the fresh (g) and dry weight (g) of upper parts of plant, the root fresh (g) and dry weight (g) were determined. The obtained datas were analyzed in SPSS (version 11.0) statistical program package. Data was analyzed using one-way ANOVA and means were compared with least significant difference (LSD) method and the LSD was calculated at $P \leq 0.05$.

RESULTS and DISCUSSION

In this study aiming to determine whether the sewage sludge treatments are effective in the cultivation of *Limonium sinuatum* 'Compindi White' cultivar in salinity conditions, the analyses's results of plant vegetative growth criterias examined are given in Table 2. *L*. sinuatum species can survive even in soil with high salinity (Carter et al., 2005; Dinga et al., 2010, Akat, 2012). Thus; there was a slight decrease at S2 level (100 mM NaCl application) while no adverse effect occurred in the dose of S1 (50 mM NaCl application) relative to the control without salt administration (S0). In the light of the results of the study, after the first salt application we observed the number of leaves, root length, upper part of the plants and

root's fresh and dried weight to find out the changes in plant development. Statistically the increases of salinity level have no significant negative effects on the vegetative growth of the plant. But, when compared to S0 (non-salinity condition), S2 dose decreased the number of the leaves by 1 %, fresh weight of upper parts by 18 %, dried weight of upper parts by 13 %, root length by 14 %, root fresh weight by 7 % and root dry weight by 8 % (Table 2). Due to the salt applications, all of the observed criterias have been some loss. *Limonium* species are known to complete their life cycles under hypersaline conditions, because halophytic *Limonium* species accumulate nitrogenous compounds and soluble carbohydrates in high mounts. (Aronson, 1989). *L sinuatum* is rated as moderately salt tolerant (Grieve et al. , 2005).

Grieve et al. (2005) concluded *Limonium perezii* species had 50 % less plant badges compared to the control group when the saline concentration was risen from 2.5 dS m^{-1} to 7 dS m^{-1}. Moreover when the salinity reached at 30 dS m^{-1} this rate was 25 %. This finding has been similar the results of in our experiment. Some researchers were pointed out that salinity stress had negative effects on the upper parts and root of plant and commensurated with our datas (Carter and Grieve, 2006; Akat and Saraçoğlu, 2017).

The increasing doses of sewage sludge have positively significant effects on the vegetative development of plants. When compared to SS0 (without sewage sludge condition), SS3 dose increased the number of the leaves by 39 %, fresh weight of upper parts by 87 %, dried weight of upper parts by 73 %, root length by 93 %, root fresh weight by 93 % and root dry weight by 111 % (Table 2).

In the plant cultivation, the use of sewage sludge put forwards positive results for plant growth due to the organic matter and nutrients it contains. Soumare et al. (2003) found that 25, 50 and 100 t ha^{-1} compost applications on the lawn grass produced good grass texture at increasing doses, increased dry matter yield, and put forward good plant growth. Tüfekçi et al. (2008) reported that sewage sludge significantly increased the development of *Eucalyptus camuldulensis, Eucalyptus grandis* and *Pinus brutia* saplings in studying the use of sewage sludge in different ratios. Larchevêque et al. (2006) reported that sewage sludge application (0, 20 and 40 kg / m^2) at different doses to *Quercus ilex, Pinus halepensis* and *Pinus pinea* seedlings resulted in an increase in plant length and diameter in all nurseries. Li et al. (2009) for *Canna indica*, Çelebi et al. (2010) for *Lolium perenne* and Patel and Patra (2014) for Tagates mitula reported that the sewage sludge applications affected plant growth positively. Our results concur with these findings reported in the literatures.

The increasing doses of sewage sludge in both salt applied and non-applied conditions affected the vegetative growth criteria of the plant positively. When compared to S0*SS0 (without salinity condition and sewage sludge), S2*SS0 (100 mM NaCl application + without sewage sludge) dose decreased the number of the leaves by 2 %, fresh weight of upper parts by 2 %, dried weight of upper parts by 26 %, root length by 9 %, root fresh weight by 6 % and root dry weight by 4 %. With 75 % sewage sludge application (S2*SS3) this situation was increased by 32 %, 64 %, 65 %, 33 %, 42 % and 79 %, respectively.

Salt applications in the study affected negatively the flower related parameters such as vegetative growth parameters of the plant. When compared to S0 (non-salinity condition), S2 dose decreased the number of the flowers harvested per plant by 7 %, the length of flower peduncle by 9 % and the thickness

Table 1. The results of several physical and chemical analyses of stabilized sewage sludge and soil
Çizelge 1. *Stabilize kanalizasyon çamurunun bazı fiziksel ve kimyasal analizlerinin sonuçları*

Parameters	Soil (SS0)	Stabilized sewage sludge	SS1 25 %	SS2 50 %	SS3 75 %	Limit values in regulation*
pH	7.01	7.51	7.08	7.18	7.34	-
EC (dS/m)	0.27	1.97	0.49	1.12	1.48	-
Organic matter (%)	3.27	47.78	8.25	19.48	32.50	-
Texture	Sandy-loam	-	-	-	-	-
C/N (Carbon/Nitrogen)	-	8.24	2.25	4.02	6.14	-
Total Nitrogen (mg/g)	0.14	3.81	0.58	1.48	2.24	-
Total Phosphorus(mg/kg)	45.3	2176.0	354.4	857.8	1427.5	-
Total Potassium (mg/kg)	897	1332.0	914	1155	1201	-
Total Cadmium (mg/kg)	-	1.02	0.25	0.41	0.74	10.00
Total Lead (mg/kg)	-	9.13	2.11	4.03	6.18	750.00
Total Nickel (mg/kg)	-	77.2	17.8	33.7	49.4	300.00
Total Copper (mg/kg)	-	51.6	12.1	22.8	29.9	1000.00
Total Aluminum (mg/kg)	-	1728.0	403.0	985.1	1247.5	-
Total Iron (mg/kg)	2.05	4083.0	327.1	1852.7	2687.1	-
Total Zinc (mg/kg)	4.11	385.5	49.6	123.4	210.5	-

SS0: without sewage sludge condition; **SS1:** % 25 sewage sludge application; **SS2:** % 50 sewage sludge application; **SS3:** % 75 sewage sludge application

*27661 Sayılı Evsel ve Kentsel Arıtma Çamurlarının Toprakta Kullanılmasına Dair Yönetmelik

of flower thickness by 7 % (Table 3). All of examined flower peduncle quality and yield parameters have been a slight decrease due to the salt applications.

Akat and Özzambak (2013) reported that *Limonium sinuatum* 'Compindi White' flower peduncle thickness had 10.61 % loss and *L. sinuatum* 'Compindi Deep Blue' had 19.64 % loss in salty soil (Salt: 0.674 %) compared to the control group. The literature presents considerable body of findings on negative effects of salinity on flower quality and development (Grieve et al., 2005; Doğan et al., 2009; Aydınşakir et al., 2010). Akat (2008) pointed out the significance of negative effects of saline applications on flower peduncle values of *Gerbera jamesonii*. As a conclusion, in terms of flower peduncle length and thickness values of our study are consistent with previous literature findings.

The increasing doses of sewage sludge have positively significant effects on the flower related parameters such as vegetative growth criterias of the plant. When compared to SS0 (without sewage sludge condition), SS3 dose increased the number of the flowers harvested per plant by 70 %, the length of flower peduncle by 14 % and the thickness of flower peduncle by 23 % (Table 3).

Aydinşakir et al. (2009) found that the yield, values of the length and thickness of the flower peduncle increased as compost was increased in which the effects of urban solid waste compost (20, 40 and 80 t ha^{-1}) were studied in anemone cultivation.and that the best results were obtained with 80 t ha^{-1} application. In the study of *Begonia semperflorens, Salvia splendens* "Maestro" and *Tagetes patula* carried out by Grigatti et al. (2007), reported that the application of 25 % treatment sewage sludge *B. semperflorens* caused an increase in the number of flowers and with application of sewage sludge application had a greater number of flowers than the control. Morever, it was reported that *Tagetes patula* at 5 % sludge application had more flowers than control. It has been reported by Xue and Huang (2013) that the application of sewage sludge at different doses of *Paeonia suffruticosa* (Peony) significantly increases the number of flowers per plant. Similar findings were obtained in our study.

The increasing doses of sewage sludge in both salt applied and non-applied conditions affected the flower related parameters positively. When compared to S0*SS0 (without salinity condition and sewage sludge), S2*SS0 (100 mM NaCl application + without sewage sludge) dose decreased the number of the flowers harvested per plant by 12 %, the length of flower peduncle by 7 % and the thickness of flower peduncle by 1 %. With 75 % sewage sludge application (S2*SS3) this situation was increased by 39 %, 4 % and 11 %, respectively.

Table 2. The effect of sewage sludge applications on plant growth in saline conditions
Çizelge 2. *Arıtma çamuru uygulamalarının tuzlu koşullarda bitki gelişimine etkisi*

Applications	Number of Leaves (piece $plant^{-1}$)	Fresh Weight of Upper Parts (g)	Dry Weight of Upper Parts (g)	Root Length (cm)	Root Fresh Weight (g)	Root Dry Weight (g)
S0	75.43	225.94	43.79	21.92	19.27	3.25
S1	79.59	230.47	46.94	21.33	23.09	3.96
S2	74.58	184.44	37.88	18.92	17.89	2.94
LSD	ns	ns	ns	ns	ns	ns
SS0	62.82 c	149.25 c	31.11 c	14.68 c	13.98 c	2.18 b
SS 1	73.18 b	190.83 bc	39.48bc	17.00 bc	16.85bc	2.73 b
SS 2	82.97 a	234.57 ab	46.92ab	22.89 ab	21.90ab	4.01 a
SS 3	87.16 a	279.81 a	53.97 a	28.33 a	26.93 a	4.61 a
LSD	4.436**	56.548**	8.61**	7.23**	5.30**	1.037**
S0*SS0	66.28	141.01	30.78	15.68	13.09	1.98
S0*SS1	73.67	192.94	38.99	17.33	16.17	2.63
S0*SS2	80.23	254.58	49.18	23.00	18.95	3.35
S0*SS3	81.54	315.21	56.21	31.68	28.90	5.02
S1*SS0	66.98	167.83	39.73	14.00	16.54	2.64
S1*SS1	73.69	206.41	42.83	16.33	19.31	3.01
S1*SS2	85.48	254.93	50.21	25.00	26.83	4.93
S1*SS3	92.19	292.72	55.00	30.00	29.67	5.27
S2*SS0	55.20	138.91	22.82	14.33	12.33	1.91
S2*SS1	72.17	173.15	36.63	17.33	15.08	2.54
S2*SS2	83.20	194.19	41.36	20.68	19.96	3.77
S2*SS3	87.75	231.50	50.70	23.33	22.22	3.54
LSD	ns	ns	ns	ns	ns	ns

S0: non-salinity condition; **S1**: 50 mM NaCl application; **S2:** 100 mM NaCl application
SS0: without sewage sludge condition; **SS1:** % 25 sewage sludge application; **SS2:** % 50 sewage sludge application; **SS3:** % 75 sewage sludge application
ns: nonsignificant; Within each column. values followed by same letters are not significantly different according to LSD test. ** Significant at p<0.01. * Significant at p<0.05 level

Table 3. The effect of sewage sludge applications on flower quality in saline conditions
Çizelge 3. *Arıtma çamuru uygulamalarının tuzlu koşullarda çiçek kalitesine etkisi*

Applications	Number of Flowers (piece plant^{-1})	Flower Peduncle Length (cm)	Flower Peduncle Thickness (mm)
S0	14.68 b	53.54	6.13 a
S1	18.68 a	51.01	5.71 b
S2	17.62 ab	48.98	5.72 b
LSD	3.069*	ns	0.324*
SS 0	12.23 b	48.13 c	5.30 c
SS 1	15.67 b	49.37 bc	5.55 c
SS 2	19.52 a	52.48 ab	6.05 b
SS 3	20.83 a	54.73 a	6.51 a
LSD	3.544**	4.184*	0.375**
S0*SS0	9.29	49.94	5.42
S0*SS1	14.66	51.03	5.78
S0*SS2	16.93	56.07	6.42
S0*SS3	17.86	57.12	6.91
S1*SS0	13.91	48.02	5.15
S1*SS1	17.15	49.07	5.21
S1*SS2	20.19	52.01	5.98
S1*SS3	23.46	54.94	6.50
S2*SS0	13.47	46.42	5.35
S2*SS1	15.19	48.01	5.66
S2*SS2	20.64	49.35	5.74
S2*SS3	21.19	52.13	6.12
LSD	ns	ns	ns

S0: non-salinity condition; **S1**: 50 mM NaCl application; **S2:** 100 mM NaCl application
SS0: without sewage sludge condition; **SS1:** % 25 sewage sludge application; **SS2:** % 50 sewage sludge application; **SS3:** % 75 sewage sludge application
ns: nonsignificant; Within each column. values followed by same letters are not significantly different according to LSD test. ** Significant at p<0.01. * Significant at p<0.05 level

CONCLUSION

The negative effect of salinity is slight in the cultivation of *Limonium sinuatum*. This situation is the result of *L. sinuatum* being a halophytic plant. Appearing this negative effect on the plant growth, yield and flower quality, however; they were affected positively by removing by the application of sewage sludge. If the heavy metals in the sewage sludge are below the limit values allowed in the regulation, this material has been reached as a result that can be used as a strategy for the remediation of saline soils.

In addition, after the treatment of sewage sludge the accumulation of heavy metals in the soil must be controlled in an every using. With this application will allow the remediation of salty soils as well as the sewage sludge disposal easily and economically.

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