Effects of Microbial Fertilization on Turfgrass Quality and Performance in Tall Fescue Varieties (*Festuca arundinacea* schreb.) Growed in Different Salt Irrigation Water Levels

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Abstract

Stated that our country will be negatively affected by climate changes that will occur due to global warming, especially the decrease in water resources, the increase in the need for quality water, drought and desertification and the ecological deterioration associated with these. It is expected that these will gradually increase the irrigation salinity levels water used in crop production. In this context, knowing and managing the salinity tolerance of grass species and varieties frequently used in lawn areas is of great importance. *Festuca arundinacea* L. (Tall Fescue) is a grass species that is successfully used in green area establishments both in the Mediterranean Region and throughout our country and can create a quality grass cover. The aim of this study was to measure the responses of tall fescue grass cultivars to saline irrigation water and to investigate the effect of microbial fertilization in alleviating salinity stress. In the study, seeds of new fescue-like cultivars "Meister, Eyecandy and Tomcat" were planted in pots with microbial fertilizer application (0-10^7 CFU/g) in Akdeniz University Faculty of Agriculture Greenhouses. Irrigation was carried out at 4 different saline irrigation water levels, which were applied at 0-5-15 and 30 dS/m levels. The experiment, was carried out with the non-salty class soil, was planned as a randomized plots trial design with three replications and a total of 72 pots were studied. Grass varieties were evaluated in leaf burn rate, grass quality, shoot and root dry weight, amount of cutting products and SPAD readings. As a result, it was observed that tall fescue varieties were affected by saline irrigation water applications, but microbial fertilization applications did not have a positive/negative effect on salinity stress. Differences in damages related to salinity applications were determined based on varieties, but microbial fertilization was not enough to correct this deformation. A healing effect is definitely expected in studies where the dose of microbial fertilizer is increased and the salinity level is slightly reduced.

Key words: *Festuca arundinacea* L., Grass quality, Salinity, Microbial fertilization

Farklı Tuzlu Sulama Suyu Seviyelerinde Yetiştirilen Kamışsı Yumak (Festuca arundinacea Schreb.) Çeşitlerinde Mikrobiyal Gübrelemenin Çim Kalite ve Performansına Etkileri

Özet

Küresel ısınmaya bağlı olarak meydana gelecek iklim değişikliklerinden, özellikle su kaynaklarındaki azalma, kaliteli suya olan ihtiyacın artması, kuraklık ve çölleşme ve bunlarla ilişkili ekolojik bozulmalardan ülkemizin olumsuz etkileneceği belirtilmiştir. Bunların, bitkisel üretimde kullanılan sulama suyunun tuzluluk seviyelerini kademeli olarak artıracağı beklenmektedir. Bu bağlamda, çim alanlarında sıklıkla kullanılan çim tür ve çeşitlerinin tuzluluk toleransını bilmek ve yönetmek büyük önem taşımaktadır. *Festuca arundinacea* L. (kamışsı yumak), hem Akdeniz Bölgesi'nde hem de ülkemiz genelinde yeşil alan işletmelerinde başarıyla kullanılan ve kaliteli bir çim örtüsü oluşturabilen bir çim türüdür. Bu çalışmanın amacı, kamışsı yumak çeşitlerinin tuzlu sulama suyuna tepkilerini ölçmek ve mikrobiyal gübrelemenin

tuzluluk stresini hafifletmedeki etkisini araştırmaktır. Çalışmada, Akdeniz Üniversitesi Ziraat Fakültesi Seralarında, kamışsı yumak çeşitleri "Meister, Eyecandy ve Tomcat" ile mikrobiyal gübre uygulaması (0-10^7 CFU/g) şeklinde ile saksı denemesi olarak yürütülmüştür. Sulama, 0-5-15 ve 30 dS/m seviyelerinde uygulanan 4 farklı tuzlu sulama suyu seviyesinde gerçekleştirildi. Araştırma düşük tuz sınıfında ait toprak ile kurulmuş, tesadüf parselleri deneme desenine göre kurulan deneme 3 tekerrürlü olarak planlanmış ve toplamda 72 saksıda çalışılmıştır. Çim çeşitleri yaprak yanma oranı, çim kalitesi, sürgün ve kök kuru ağırlığı, biçim ürün miktarı ve SPAD okumaları kriterleri yönünden değerlendirilmiştir. Sonuç olarak, kamışsı yumak çeşitlerinin tuzlu sulama suyu uygulamalarından etkilendiği, ancak mikrobiyal gübreleme uygulamalarının tuzluluk stresi üzerinde olumlu/olumsuz bir etkisinin olmadığı gözlemlenmiştir. Çeşitlere göre tuzluluk uygulamalarına bağlı hasarlarda farklılıklar belirlenmiş, ancak mikrobiyal gübreleme dozunun bu deformasyonu düzeltmek için yeterli olmadı sonucuna varılmıştır. Mikrobiyal gübre dozunun artırıldığı ve tuzluluk seviyesinin daha düşük dozlara azaltıldığı çalışmalarda kesinlikle bir iyileştirme etkisi beklenmektedir.

Anahtar kelimeler: *Festuca arundinacea* L. Çim kalitesi, Tuzluluk, Mikrobiyal gübreleme

Introduction

In recent years, with the rapid development of urbanization in parallel to the population improvement, the longing for nature of people who have to live in dense buildings that grow with the increase in construction enhances. Particularly, as a result of developments in construction technology, the spaces between dense and high-rise buildings are evaluated as green areas, and the building environment is improved in terms of human life by reducing the hard and cold appearance of technological concrete (Monteiro, 2017). Grass covers, one of the most important elements of green areas, not only provide visual refreshment to human beings, but also have extremely important elements both environmentally and for the health of people who use these areas for recreational purposes (Kuşvuran, 2012). Grass areas consist of plants or plant communities that cover the soil surface homogeneously and create an orderly distribution. Grass plants used in sports and playgrounds as well as around buildings (Hatamzadeh et al. 2014), provide aesthetically beautiful and wealthy appearances to urban living environments (Karagüzel, 2007), along with the functions they undertake such as creating a green cover that allows for sports, playing and resting (Shahin et al. 2014). Creating a grass area that is long-lasting, suitable for purpose, requires low maintenance, is superior in terms of color and quality (Huxley et al., 1992), does not require much shaping, has a high rate and rate of coverage, is minimally affected by adverse conditions, has a high ability to renew itself and can spread these features throughout the year, and maintaining these desired features for a long time is a matter that requires expertise. Moreover creating grass areas, one of the primary criteria is that grass plant species complete their germination in a short time and quickly cover the area immediately afterwards. As, mankind desire to benefit from these areas as soon as possible and see the green cover immediately (Kuşvuran and Tansı, 2013). Meanwhile grass areas where continuous maintenance operations such as irrigation, fertilization and mowing, are intensively applied. Nevertheless, many abiotic factors such as global warming, salinity and drought make it arduous for plants to grow and develop. Reports indicated that our country will be negatively affected by climate changes due to global warming, especially the diminish in water resources, the enhance in the need for water quality, drought and desertification and the ecological deterioration associated with them (Miyamoto et al., 2005; Miyamato and Chacon, 2006; Türkan and Demiral, 2009). Furthermore, substantial importance to know the salinity tolerance of grass species and varieties frequently used in grass areas and to manage this prominently (Hujun et al., 2001; Jajali et al., 2010). Salinity, a abiotic stress sources, that deleterious plant growth (Gökkaya and Arslan, 2023), development and fertility. The significant inhibitory effect of salinity on plants is due to: (1) osmotic effect, (2) ion toxicity, and (3) nutrient deficiency, leads to diminished photosynthetic efficiency and other

physiological irregularity (Almodares et al., 2008). Salinity causes excessive accumulation of reactive oxygen species (ROS) (Zhao et al., 2020; Quamruzzaman et al., 2021a, 2021b), stomatal opening-closing process (Akcin and Yalçın, 2023)., increased production of antioxidant enzymes (Pan et al., 2021), DNA damage (Gao et al., 2016)., lipid peroxidation (Kara et al., 2019), protein oxidation and interaction with essential plant cell components (Shabala, 2009). Recently, many studies have been carried out to reduce the negative effects of stress factors such as salinity, and these studies have started to increase in agronomic methods rather than long-term and costly processes such as breeding methods. Among these, microbial fertilizers come to the forefront. The presence of microorganisms that directly or indirectly affect plant development stimulates the defense mechanism against possible damage and has a healing effect (Massahi et al., 2018). As known, the saline irrigation water problem affects total agricultural production and creates serious problems in grass areas. Also, turfgrass management, where the effects of salinity can be reduced through the application of microbial-containing fertilizers, will make significant contributions both environmentally and in terms of cost. The aim of this research is to maintain the turf quality under saline water irrigation stress with the effect of microbial fertilization application of tall fescue (*Festuca arundinacea* L.) varieties, which are frequently preferred in turf areas in the coastal strip of Antalya Province, which is located in the Mediterranean Region and has many turf sports fields, especially golf courses, and a large amount of urban green space.

Materials and Methods

The experiment was carried out in greenhouses located in the Research and Application Area of Akdeniz University Faculty of Agriculture between October 2023 and February 2024. The research was set up as a randomized block design with 3 turfgrass varieties, 2 microbial fertilizer applications (0, 150 g/da), 4 saline irrigation water levels (0, 5, 15 and 30 dS/m), and a total of 72 pots with 3 replications. In this study, "Meister, Eyecandy and Tomcat" varieties of the *Festuca arundinacea* species, which are preferred when creating green areas in our country and around the world, were used as plant material. The microbial fertilizer, planned to make plants more resistant to salinity, is sold under the registered brand name Biowish. Biowish contains "*Bacillus subtilis* 1 x 10^7 CFU/g, *Bacillus amyloliquefaciens* 1 x 10^7 CFU/g, *Bacillus licheniformis* 1 x 10^7 CFU/g ve *Bacillus pumilus* 1 x 10^7 CFU/g". This microbial fertilizer material product was used for the first time in turfgrass plants against salinity stress conditions. Additionally, $CaCl_2$, NaCl and $MgCl_2$ salts were used in the preparation of salt water in the experiment. Considering the Sodium Adsorption Rate (SAR) of the draw well water used, the electrical conductivity (EC_i) values of the water in saline water subjects were adjusted with an EC-meter in the laboratory. In addition, considering that high salt doses could cause sudden toxic effects, the desired salt concentration was reached gradually. And after reaching the target levels, irrigation water at the specified salinity level was applied to each subject. Some properties of the irrigation water used in the experiment were given in Table 1.

Table 1. Chemical properties of irrigation water used in the experiment

pH	EC (dS m^{-1})	K (me L^{-1})	Ca (me L^{-1})	Mg (me L^{-1})	Na (me L^{-1})	Cl (me L^{-1})	SAR
7.3	0.75	0.07	5.62	1.35	0.93	1.46	0.785

In salinity stress experiments, the amount of irrigation water (AW_t, L) to be given to the pots at each irrigation was determined with the equation $AW_t = (W_{fc} - W_a)/\rho w / (1\text{-}LF)$. LF is the leaching rate, W_{fc} and W_a are the field capacity (kg) and current weight (kg) of each pot before irrigation, respectively, and ρw is the density of water (1 kg L^{-1}). In order to prevent excessive salt accumulation in the pots, the leaching rate

was taken as 25% (Maas and Hoffman, 1977; Ayers and Westcott, 1989). The soil to be used in the experiment was passed through 2 mm sieve and mixed to form a volumetric mixture of 4:1:1 (garden soil + washed river sand + peat) to prepare the growing medium. In addition, the prepared soil samples were analyzed and their physical and chemical properties were determined (Table 2, Kacar, 2016). The test soil, in the clay loam texture class, was found to have a slightly alkaline reaction, salt-free, high calcareous content, insufficient organic matter and available phosphorus, and sufficient exchangeable potassium, calcium and magnesium content. In terms of micronutrient elements, iron content was determined to be sufficient, as zinc, copper and manganese contents were detected to be insufficient (Alparslan et al., 2005). Seeds were planted in pots prepared with 50 g/m^2 sowing rate. No salt water application was made until the first development of turfgrass varieties in pots was achieved. Turfrass was mowed from 4 cm height when it grew to 8-10 cm during the trial. Pots were fertilized with NPK (15:15:15) fertilizer once every 2 weeks with 5 g/m^2/month rate until the end of the trial.

Table 2. Some chemical and physical properties of the soil used

pH	EC (dS m^{-1})	Lime (%)	OM (%)	N (%)	P (kg da^{-1})	K (kg da^{-1})
7.90	0.617	29.50	1.10	0.089	2.26	21.00
Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Texture
5237	307	2.25	4.12	0.42	0.75	CL

Weekly, the rate of burning (drying) of turfgrass leaves in each pot was determined using a scale of 0–100% (Uddin et al., 2009). The evaluation of grass quality was observed using a quality scoring scale of 1–9 (Alshammary et al., 2004). In the experiment, plants were harvested by separating them from each other from the root crown and dried at 72 °C for 48 hours to found their dry weight (Alshammary et al., 2004). The mowing residues obtained during the experiment were collected and the total mowing product weight was detected. In addition, SPAD readings on turfgrass plant leaves were used to noted chlorophyll content using a Minolta SPAD-502 device. In this study, in the statistical evaluation of the data obtained, variance analysis was applied according to the randomized block design with 3 replications, and Duncan multiple comparison test was applied to determine the groups. For this purpose, SPSS package program (2021) was used.

Results and Discussion

In this study, leaf burn rate, grass quality, shoot and root dry weight, amount of cutting products and SPAD of tall festuca varieties to which different rates of saline irrigation water were applied with biological fertilizer application were determined and the obtained data were subjected to variance analysis and the results were given in Table 3. The effects of different tall festuca varieties on LBR, GQ, RDW, SDW and SPAD properties were found to be statistically significant at $p>0.01$. Biowish microbial fertilizer had a substantial effect only on SPAD value by 1%. Saline irrigation water applications caused a statistically remarkable difference on LBR, GQ, SDW and SCP properties ($p<0.01$). Variety and Biowish with variety saline irrigation water applications had statistically prominent effects on LBR, SDW and FCP properties by 1%, respectively. Although triple interactions caused certain changes, they were not found to be statistically significant, and Biowish and saline irrigation water had a considerable effect on RDW and SPAD properties by 1%.

Table 3. Variance analysis table for the effects of different doses of saline irrigation water on some characteristics of tall festuca varieties with biological fertilizer applications.

SV	df	LBR	GQ	RDW	SDW	FCP	SCP	SPAD
V	2	13.13**	9.87**	6.74**	16.10**	4.91*	0.83^{ns}	6.53**
B	1	0.70^{ns}	1.66^{ns}	0.04^{ns}	1.33^{ns}	1.48^{ns}	1.37^{ns}	0.05**
S	3	113.30**	82.65**	1.25^{ns}	12.40**	0.74^{ns}	8.53**	1.35^{ns}
V*B	2	5.99**	1.28^{ns}	0.25^{ns}	6.63**	1.59^{ns}	0.61^{ns}	0.23^{ns}
V*S	6	1.71^{ns}	1.49^{ns}	1.07^{ns}	2.04^{ns}	4.78**	0.94^{ns}	1.08^{ns}
B*S	3	0.95^{ns}	1.69^{ns}	4.78**	0.91^{ns}	2.44^{ns}	0.64^{ns}	4.79**
V*B*S	6	2.10^{ns}	1.17^{ns}	0.42^{ns}	0.81^{ns}	0.79^{ns}	1.54^{ns}	0.41^{ns}

*Significant at the 0.05 probability level.**Significant at the 0.01 probability level. ns: non significant (Source of Variance, V: Varieties, B: Microbial Fertilizer, S: Saline irrigation water, LBR: Leaf Burn Rate, GR: Grass Quality, RDW: Root Dry Weight, SDW: Shoot Dry Weight, FCP: First Cutting Products, SCP: Secod Cutting Products)

Burning (scorching, drying) on the leaves of tall festuca plants during saline irrigation water stress is one of the most major criteria that reveals the damage of salinity stress. The burning rate occurring in the leaves of plants under salinity stress is an undesirable physiological response that diminishes the quality of tall festuca. Therefore, desired to be at the lowest feasible level. On the other hand, the values related to tall festuca quality indicated similar results with the leaf burning rate. The results related to tall festuca quality defined that there was a difference between varieties and saline irrigation water doses (Figures 1 and 2). Salinity, the most harmful environmental factors, inhibit and stunt plant growth and development globally (Reddy et al., 2017). The deleterious effects of excessive salinity levels can be uncovered throughout the entire life cycle, from restriction or postpone of germination to death of the plant (Parida and Das 2005).

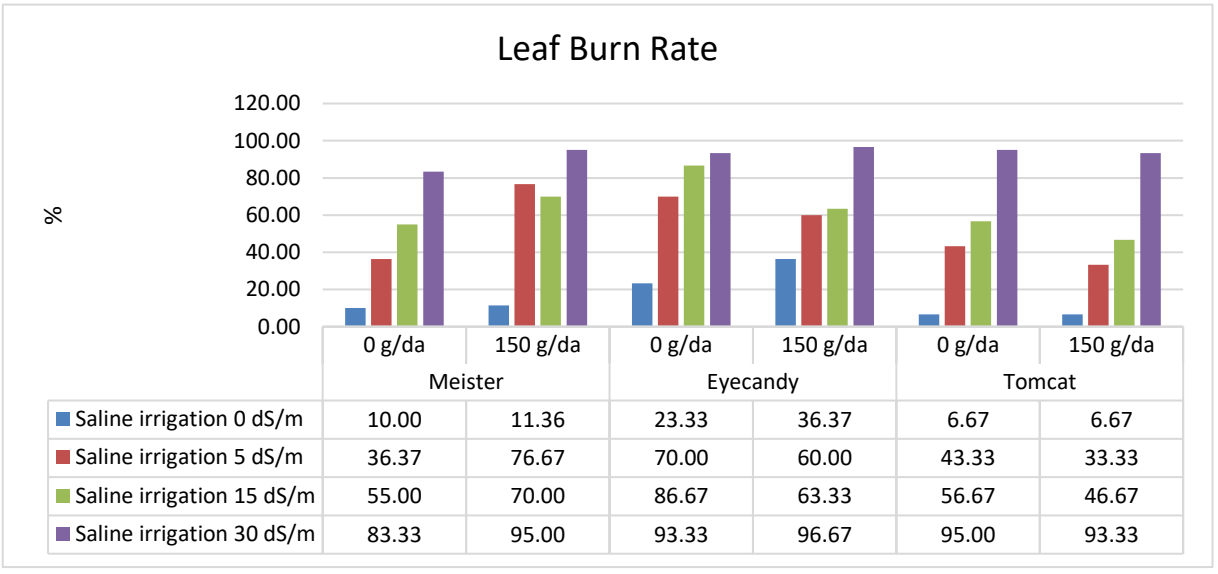


Figure 1. Effect of Biological Fertilizer Applications and Different Doses of Saline Irrigation Water on Leaf Burning Rate of Tall Festuca (%)

As the salinity tolerances of tall festuca grass varieties under biological fertilizer applications were examined, reported that the highest leaf burn rate was in the Eyecandy variety (66.25%) and the lowest leaf burn rate was in the Tomcat variety (47.71%) (Figure 1). Determined that salinity significantly crucially mitigated grass quality. However, Tomcat variety had the highest grass quality value (4.63), meantime

Eyecandy variety was the lowest grass quality value (3.25) (Figure 2). Besides, a extreme uptake of Cl^- may trigger to chlorophyll damage (Tavakkoli et al. 2010). It also may crucially alleviate turfgrass quality and ornamental perspective (Chen et al. 2014).

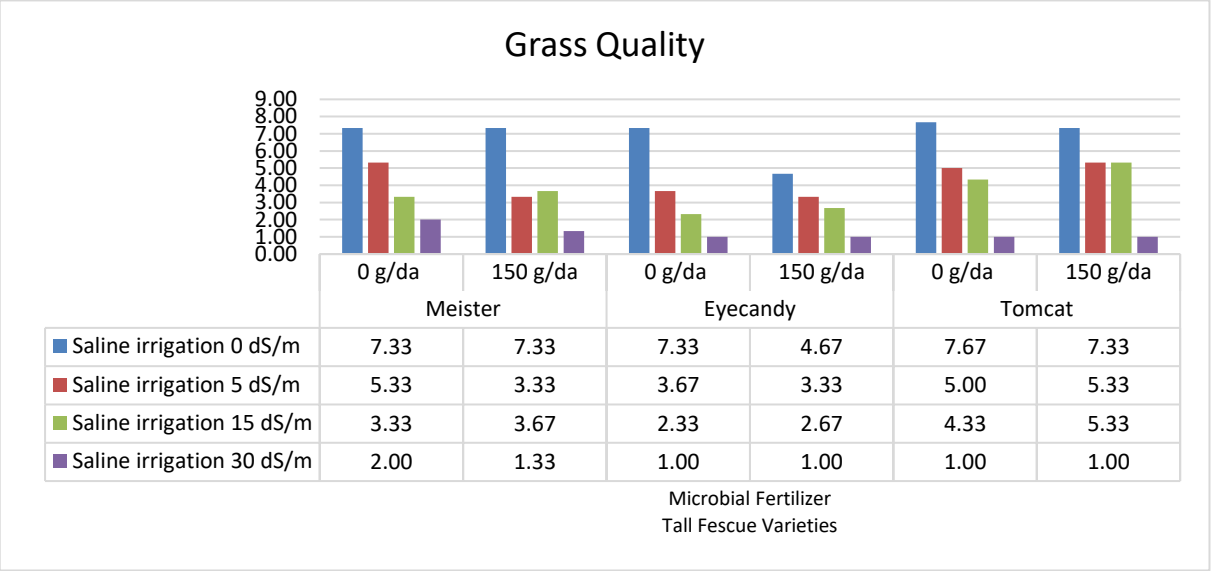


Figure 2. Effect of Biological Fertilizer Applications and Different Doses of Saline Irrigation Water on Grass Quality of Tall Festuca

When the root dry weight was examined, concluded that increasing saline levels caused mitigation in root dry weight. Hence, in terms of average root dry weight, the highest value was realized at the Eyecandy with 18.13 g, as the lowest value was found at the Meister variety with 11.23 g (Figure 3). Sevostianova et al. (2011a) reported that tall fescue has a greater rooting depth than other cool-season grasses, which may be a defense or avoidance mechanism against saline conditions. Consequently, long root length naturally leads to weight. Studies showed that the application of growth-promoting bacteria minimize the negative effects of salt stress by enhancing root activity (Massahi et al., 2018). Gao and Li (2014) determined that shoot and root total quantity diminished by 58% and 63%, respectively, in saline applications compared to the control.

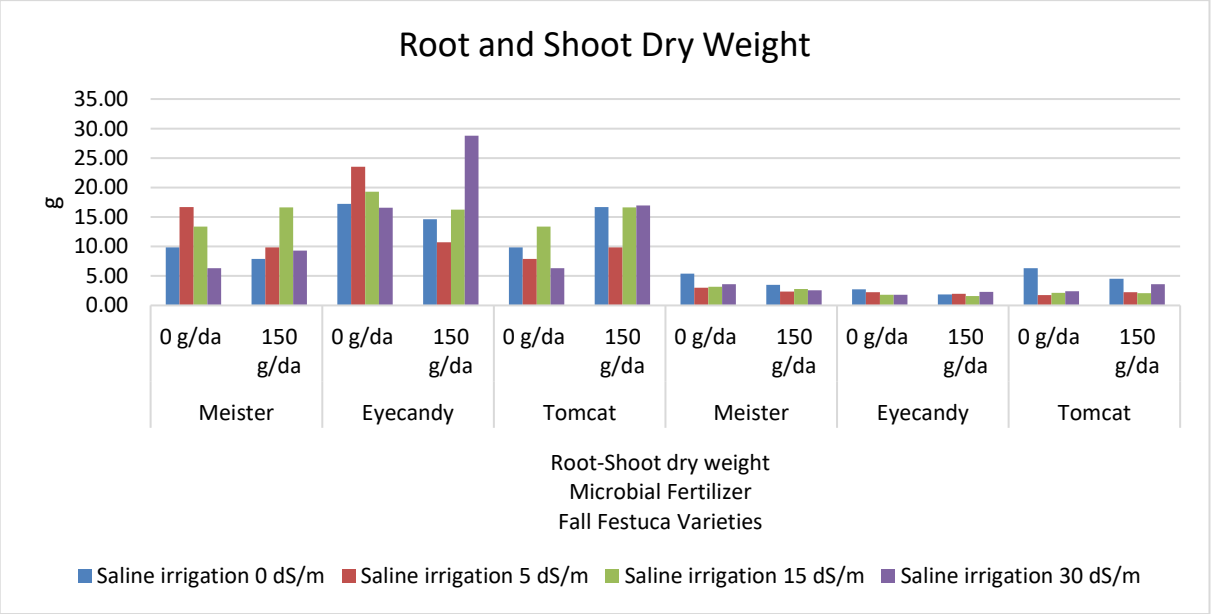


Figure 3. Effect of Biological Fertilizer Applications and Different Doses of Saline Irrigation Water on Root and Shoot Dry Weight of Tall Festuca (g)

The highest shoot dry weight value was reported in the Meister variety with 3.29 g, whilst the lowest was obtained from the Eyecandy variety with 2.04 g. The Tomcat variety had a shoot dry weight of 2.79 g. As no positive contribution of Biowish biological fertilizer application was realized, it was also observed that enhancement saline concentrations caused a decrease in shoot dry weight (Figure 3). Economic problems originating from the boosting cost of chemical fertilizers and bioenvironmental problems resulting from the unconsciously consumption of fertilizers conduct the use of microbial biotechnology and biological strategies to the agenda. One of the methods used to prevent deformations that occur in salinity conditions is to coat or inoculate seeds with different types of bacteria and fungi living in the soil. Microbiological fertilizers directly or indirectly fix growth of plant component by using one or more particular mechanisms (Bashan et al. 2014; Fahad et al. 2015). First features to be considered during the installation phase of grass areas are the seed germination and the rapid, regular and sustained improvement of the plant. That is accepted, saline conditions produce osmotic stress, exchange the ion balance and induce plant cells nutritional stress, adjourning germination and plant growth (Türkan and Demiral, 2009; Guo et al., 2010). Masshi et al. (2018) stated that the diminish in fresh and dry weights of tall fescue under saline conditions may be due to osmotic effects on the roots and the minimize in water absorption of plant. In such stress conditions, numerous photosynthetic parameters such as plant water potential, osmosis of leaf, optical absorption, and assimilation production source may decrease to the lowest levels. Hence, transpiration, leaf temperature, and leaf relative water content can alter, so plant development and shoots and roots fresh and dry weights are abated (Wang et al. 2007; Emadi et al., 2009). Pessarakli and Touchane (2006) reported that lengths of shoot and root were revived at lower levels of NaCl, but fundamentally reduced at higher levels. Meantime, the saline stress exposure time continued, fresh and dry weights of shoot and root were violently influenced relative to shoot and root lengths.

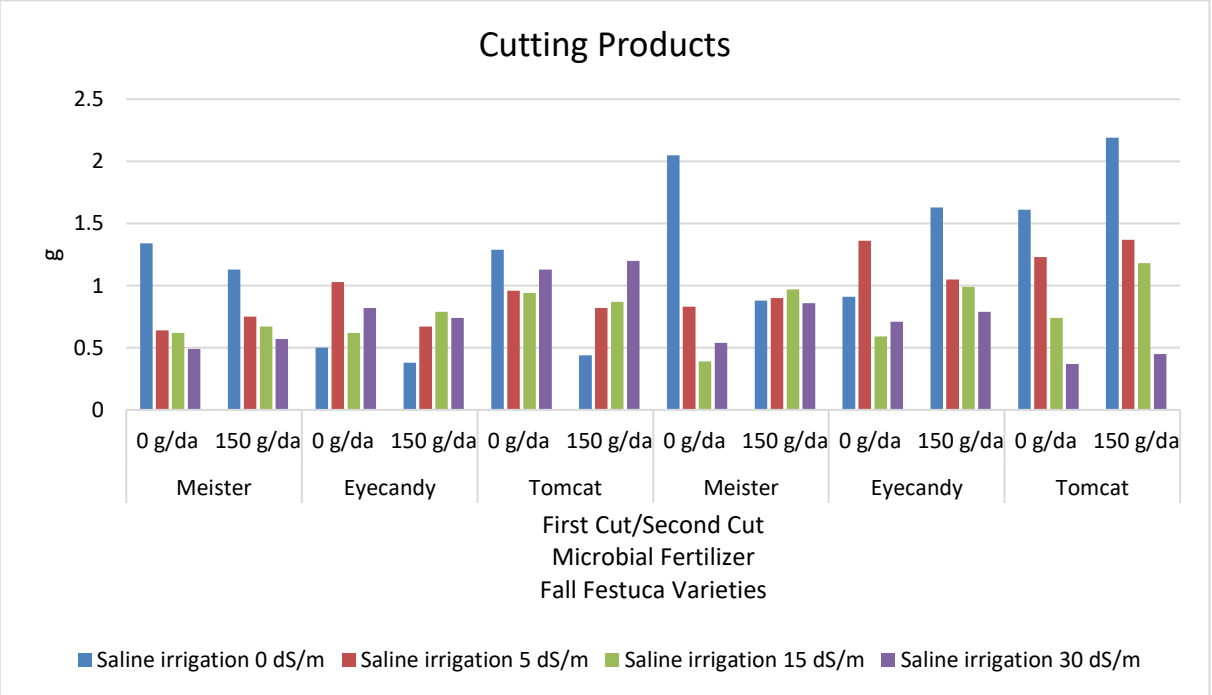
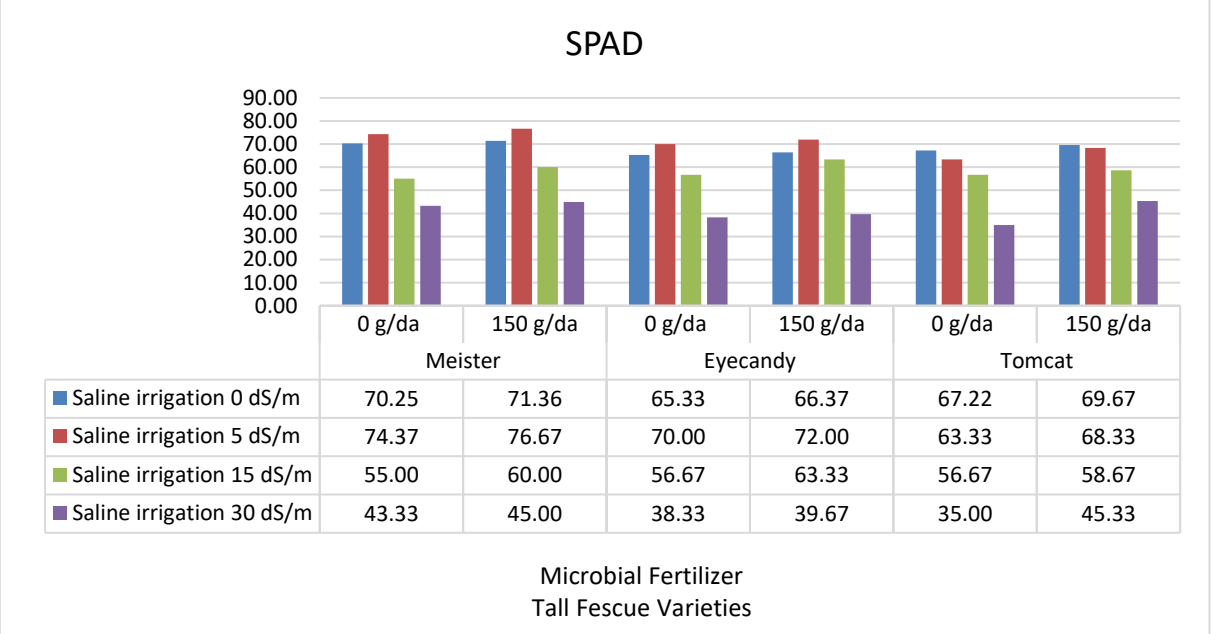


Figure 4. Effect of Biological Fertilizer Applications and Different Doses of Saline Irrigation Water on the First and Second Forms of Tall Festuca (g)

The highest value of cutting product (0.96 g/pot) was obtained from the Tomcat variety, as the lowest value (0.69 g/pot) was found from the Eyecandy variety. Increasing saline doses created a diminishment in the amount of shaping product residue in varieties (Figure 4). The data determined in the second cutting

showed a slight increase compared to the first cutting. Nevertheless, increasing saline doses caused a reduction in the material established as shaping result (Figure 4). The negative effects of salinity on plants, changes in plant physiology, defense mechanisms developed by plants, yield and quality decreases vary depending on the salt concentrations exposed (Arslan et al., 2013).



	0 g/da	150 g/da	0 g/da	150 g/da	0 g/da	150 g/da
	Meister		Eyecandy		Tomcat	
Saline irrigation 0 dS/m	70.25	71.36	65.33	66.37	67.22	69.67
Saline irrigation 5 dS/m	74.37	76.67	70.00	72.00	63.33	68.33
Saline irrigation 15 dS/m	55.00	60.00	56.67	63.33	56.67	58.67
Saline irrigation 30 dS/m	43.33	45.00	38.33	39.67	35.00	45.33

Figure 5. Effect of Biological Fertilizer Applications and Different Doses of Saline Irrigation Water on SPAD Values of Tall Festuca

The SPAD readings showing the color values of tall fescue varieties under different saline concentrations were measured as 61.75, 58.50 and 57.50 for Meister, Eyecandy and Tomcat varieties, respectively (Figure 5). Peacock et al. (2004), Lee et al. (2004), Adavi et al. (2006) and Abdel-Fattah et al. (2008) reported that saline irrigation water abates growth, and root density and length as well as necrosis of leaves due to yellowing. Shahin et al. (2014) mentioned that chlorophylls a and b in the leaves were diminished qua saline quantity was boosted, as carotenoides contents were regularly rised with enhancement saline level.

Conclusion

The problem of salinity and saline irrigation water continues to affect agricultural production and is progressively influential in larger areas. Moreover, it becomes a threat to agricultural production. This problem affects parks and gardens, slopes, golf courses and football fields where turfgrass areas are quite dense and solutions are sought for these areas. This situation occurs particularly when coastal turfgrass areas (golf courses etc.) are exposed to higher salt levels due to the use of groundwater as irrigation water. In this study, salinity tolerance levels of *Festuca arundinecea* L. grass varieties, which are highly preferred in green area facilities in Mediterranean Coastal Conditions, and the effects of microbial fertilizer applications on reducing saline irrigation water stress in tall festuca varieties were investigated. When the results were examined, it was observed that the Eyecandy variety had the highest damage in terms of leaf burn rate, Tomcat had the highest grass quality, Eyecandy was found the highest root dry weight, Meister was determined the highest shoot dry weight, Tomcat was the highest cutting product and Meister had the highest value in terms of SPAD values. On the other hand, although biological fertilizer applications were observed to partially tolerate salt damage in some characteristics of turfgrass varieties in lawn irrigation water conditions, they did not provide the desired improvements. Thought that in future studies, the

microbial fertilizer dose applied may be applied at different levels and this tolerance may be achieved at other doses.

Conflict of interest: There is no conflict of interest between the authors.
Author Contribution: The authors declared that they have contributed to the article equally. All authors discussed the results and contributed to the final manuscript.
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