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EVALUATION ON EFFECTS OF DIFFERENT SALINITY LEVELS IN IRRIGATION WATER FOR CERTAIN COTTON VARIETIES UNDER SOUTHEASTERN ANATOLIA REGION CONDITIONS

SUMMARY

This study was carried out to determine the effects of different salinity levels in irrigation water for some cotton varieties under Diyarbakır Province of Southeastern Anatolia Region in 2007 using experiments utilizing lysimeter-like drainage type metal containers. Four different salinity levels (T_0: 0.32 dS/m, T_1: 5 dS/m, T_2: 9 dS/m and T_3: 13 dS/m) and 3 different cotton cultivars (P_1: Berke, P_2: Stonville-453 and P_3: Teks) were utilized during the treatments. The least affected cultivar from the salinity was Berke. Compared to the cultivar of Berke, the seed-cotton yields of Stonville-453 and Teks were less than 8.3 % and 23.1 %, respectively. The values of salinity threshold for irrigation water according to the cotton cultivars were calculated as Ct=4.45 (Berke), Ct=4.32 (Stonville-453) and Ct=3.72 (Teks). The values of salinity threshold for soil were Ct=6.58 (Berke), Ct=7.46 (Stonville-453), Ct=6.84 (Teks). The results showed there is no significant loss on seed-cotton yield when irrigation water salinity of up to the value of 4.45 dS/m was used.

Keywords: Salinity, cotton, salinity threshold value for irrigation water, salinity threshold value for soil

INTRODUCTION

Depletion of natural resources over time necessitated water and land resources to be utilized in the most economical and efficient manner. Irrigation is the primary factor in increasing plantation yield and production in the areas that are used for agriculture. Irrigation played a very significant role on the increase in production during the last 50 years (Altinok et al., 2015; Tanaskovikj et al., 2015, 2014; Abbasian et al., 2014; Dragovic et al., 2012; Soskic et al., 2001; Jensen et al., 1990; Dragovic et al., 1984) Furthermore 67% of water resources are utilized for the purposes of agricultural irrigation (Anonymous, 2007).

However, the increase in water consumption results in severe problems. For example, underground water resources are depleted; other water ecosystems are polluted and deteriorated creating several environmental problems as a result of irrigated farming. Primary among the environmental problems resulting from infield irrigation is the concentration of salt deposit in case of unsuitable

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irrigation system utilization and overwatering under poor drainage setting (Ghassami et al., 1995).

In certain countries, irrigation water quality is a more significant issue than water procurement. Especially in arid and semi-arid climate areas, depletion and pollution of natural resources as a result of agricultural irrigation, and the burden of irrigation with poor grade water result in salinization of extensively farmed land and yield them off productivity.

Sensitivity of cotton plants against salt depending on their development stage point out that water of different qualities could be used for irrigation during different cultivation periods (Gupta and Yadav, 1986). It has been noted that irrigation of cotton plants with salted water results in significant decrease in plant size and yield (Vulkan-Levy et al., 1998) and the accumulation of salt in soil has a negative effect on plant growth (Grismer, 1990).

In Harran Plain, which was the initial land where the irrigation was introduced within the Southeastern Anatolia Project (GAP) in Turkey, salinized land reached 20,000 ha (Aydemir et al.,2008). Water table salinization in Harran Plain was detected to be more than 5 dS/m in 4984 ha; 3-5 dS/m in 6908 ha and 3 dS/m in the rest of the related soil (Çelikel and Çullu, 2008).

Cotton cultivated in Southeastern, Aegean and Mediterranean Turkey (*Gossypium Hirsitum* L.) has intermediate durability against salinity. Total cultivation area in Turkey is 693,000 ha and fiber yield has a yearly average of 1330 kg/ha albeit showing annual fluctuations and depending on cultivation practices. Most concentrated cultivation area in Turkey is the Southeast Anatolia Region (44%) giving it the first place among regions (Anonymous, 2006).

Cotton, extensively farmed in Southeastern Anatolia Region and an important product for the area, is a plant that significantly needs irrigation water. Therefore, when we consider the possibility of water scarcity in the future, it would be inevitable to consider the use of recycled drainage supplies in farming of plants such as cotton, which is rather resistant to salinity. Consequently, consideration of saline water resources is a complex process in which the emphasis should be given to regional context in each area where every plant variety should be evaluated separately.

As per information provided above, different saline levels in different irrigation water resources have diverse effects on the yield of cotton plant, on various yield criteria and on water salinity, which as well differ among different cotton varieties, soil types, and climate conditions. Hence, this research investigates the reaction of cotton varieties, with an emphasis on yield, morphological and physiological characteristics, against different levels of salinity and their tolerance for salinity. In order to conduct this research, different cotton varieties are utilized in a drainage type lysimeter environment (metal tank) irrigated by saline water resources containing different levels of salt to determine the varieties that are most susceptible and resistant to salinity.

MATERIAL AND METHODS

Materials. Research was carried out at Dicle University Dept. of Agriculture testing ground, utilizing cylindrical tin tanks with 1,00m height and 0,60m diameter. Clay loam type research soil was harvested from Dicle University Dept. of Agriculture testing farmland, dried, sifted through a 6,35mm sieve and pressed into tanks in 5cm layers with the consideration of bulk density prep. (1). To provide drainage, a 5cm layer of sand-gravel compound was placed at the bottom of the tanks. Table 1 shows certain physical and chemical properties of the soil used in the tests.

Table 1. Certain physical and chemical properties of the soil used in the research

Sand (%)	Silt (%)	Clay (%)	Field Capacity (%)	Fade Point (%)	Bulk Density (g/cm^3)
6.8	73.4	19.8	37.6	24.4	1.22
pH	EC (dS/m)	KDK (%)	Organic Matter (%)	ESP (%)	Exchangeable Sodium (me/100 g)
7.86	0.04	67.73	0.68	1	0.67

Study was carried out using 4 different irrigation water salinity levels (T0=0.32, T1=5, T2=9 and T3=13 dS/m), 3 varieties (Berke, Stonville-453 and Teks) in a total of 36 tanks in random 3 blocks divided lots test pattern. Accordingly, irrigation water salinity values became the main focus. Since the determination of the reaction of cotton varieties to various salinity values will be more significant both in application and statistically, cotton varieties were evaluated in sub-lots. To obtain different qualities of water, high soluble salts such as NaCL and $MgSO_4$ were used. In preparation of saline water the ratio of Ca/Mg was preserved at 1/1 in intercurrent base since their effects on the physical characteristics of the soil are similar (Poonia and Pal, 1979). Average values of irrigation water used in the tests are shown in Table 2.

Table 2. Chemical components of irrigation water used in research.

pH	ECw (dS/m)	Soluble Cations (me/l)				Soluble Anions (me/l)					SAR
		Na^+	K^+	Ca+Mg	Top.	HCO_3^-	CO_3^-	Cl^-	$SO_4^=$	Top.	
7.4	0.32	2.4	0.2	2.5	5.0	2.1	-	5.6	4.5	12.2	2.17
7.7	5.00	61.3	0.6	5.1	67.0	4.0	-	52.1	6.6	62.7	38.38
7.5	9.00	128.7	1.4	9.7	139.8	6.8	-	119.7	8.6	135.2	58.53
7.5	13.00	231.8	1.9	14.5	248.2	7.6	-	215.5	17.6	240.6	85.96

Cotton seeds were planted on May 22nd, 2007 and 5 per tank and singled to 3 plants after first growth and above-row distance set to 20cm like in standard field conditions. A total of 14kg N/da and 7 kg P_2O_5/da base was used for fertilization (Başbuğ, 2003). On plantation 20-20 composite fertilizer, urea (45% N) for top nitrogenous fertilizer was utilized. Tap water was used for irrigation until the plants reached 5-6cm in height and saline water was used thereafter. After irrigation with saline water started, the plants were harvested on October 4^{th}, 2007 (Within this period plants were irrigated with saline water 10 times).

Methodology. To implement the irrigation program, volumes were based on evaporation from a Class A Pan (Kanber and Güngör, 1986; Kanber, 1997; Çetin and Bilgel, 2002). Consequently, irrigation interval is determined as 10 days as a result of research findings on cotton plant at GAP Region Harran Plain, which provides the closest climate conditions to the test environment (Çetin and Bilgel, 2002). Implemented volume of irrigation water was calculated based on K_{pc}=1,00 coefficient; on the cumulative (total) evaporation amount within the noted irrigation frequency, surface area of the tank and baseline depth of soil (0,90m). Under those guidelines, irrigation water volume was calculated using the equation detailed below (Kanber and Güngör, 1986; Kanber, 1997):

$$I = A \times E_p \times K_{pc} \quad (1)$$

I :Irrigation water applied to tank (L)
A: Tank surface area (m^2)
E_p: Cumulative evaporation amount within irrigation frequency (mm)
K_{pc}: Pan coefficient (1.00)

As a result of trial, total irrigation water applied to each tank is determined as 1,010mm. Irrigation water is applied in the form of surface irrigation to the cotton cultivated tanks. For irrigation evaporation values for Class A Evaporation Pan were utilized to calculate the volume of irrigation water necessary to implement to the surfaces of cotton plant cultivated tanks.

Parameters such as plant height, stern thickness, branch number, leaf number, floret number, green parts' wet weight, dry substance amount, unopened boll number, boll number, ginning yield, earliness were reviewed in addition to yield in harvested plants. Furthermore, the effects of saline water applications on cotton plant fiber quality specifications were observed. On test completion, soil samples were collected from 3 different depths in tanks (0-30cm, 30-60cm and 60-90cm) and electrical conductivity values were determined to establish salinization in the soil. The relation between soil salinity and yield and threshold values were based on salinity of the soil established in post-harvest tests. In addition, both irrigation water salinity and soil salinity threshold values were determined using unginned cotton yield data derived from the tests. For this purpose, linear regression analysis was conducted on realized yields against irrigation water salinity and soil salinization values, which fell both within and out of the control scope. Salinity threshold values were calculated using the resulting regression equation (Maas and Hoffman, 1977; Bahçeci, 2009).

Accordingly the following equation was used to calculate salinity threshold value:

$$C_t = (Y_o - Y_m)/s, \quad (2)$$

Ct: Salinity threshold value (dS/m)
Y_o: Yield obtained under unsalted conditions (T=0 dS/m) in the regression equation (g/plant)
Y_m: Yield obtained unsalted or control subject (T=0.32 dS/m) during the test (g/plant)
s: Slope of the line in regression equation

For the evaluation of findings, Water Usage Efficiency (WUE) and Irrigation Water Usage Efficiency (IWUE) were examined.

In the research, soil analyses; texture, bulk density, field capacity, wilting point, pH and electrical conductivity, lime, organic matter, cation exchange capacity, exchangeable sodium percentage and water analyses (pH, EC, cations and anions) were determined based on principles established by (Bouyoucous, 1951) and (Richards, 1954 and Tüzüner, 1990) relatively.

Statistical evaluation of research findings were evaluated in compliance with the principles set by Yurtsever, 1984.

RESULTS AND DISCUSSION

Unginned cotton yield: With respect to average yields obtained, unginned cotton yields varied between 15,14-53,31 g/plant depending on the salt content in irrigation water and cotton varieties. The highest unginned cotton yield (53,31 g/plant) was obtained from control subject irrigation water with a salinity value of 0,32 dS/m, and the lowest yield (15,14 g/plant) was achieved from the T_3 irrigation water application with the highest salinity level of 13 dS/m (Table3, Table 4).

Table 3. Variance analysis results pertaining to unginned cotton yield under different salinity levels in irrigation water and different cotton varieties

Variation sources	**S.D.**	**K.T.**	**K.O.**	**F** (calculated)	**F** (from the chart) 0.05	0.01
Recursions	2	27.50	13.75	0.20	5.14	10.92
Salinity levels (A)	3	5,526.52	1,842.17	27.46**	4.76	9.78
Error (A)	6	402.58	67.10	2.00		
Cotton Varieties (B)	2	277.81	138.90	4.14*	3.63	6.23
Interaction (AxB)	6	381.63	63.60	1.90	2.74	4.20
Error (B)	16	536.52	33.53			
Total	35	7,152.55				
Change Coef. (%) :	15.6					

*: Significant in 5% error performance, **: Significant in 1% errorperformance

Table 4. Separate effects of different levels of salt levels in irrigation water and cotton varieties on unginned yield

Main topics (Salinity level)	Unginned Cotton Yield (g/plant)	Proportional Loss in Yield (%)	Sub-topics (Cotton Varieties)	Unginned Cotton Yield (g/plant)	Proportional Loss in Yield (%)
T_0 (0.32 dS/m)	49.25 a	0.0	P_1 (Berke)	40.41 a	0.0
T_1 (5 dS/m)	45.01 a	8.6	P_2 (Stonville453)	37.06 ab	8.3
T_2 (9 dS/m)	32.55 b	33.9	P_3 (Teks)	31.06 b	23.1
T_3 (13 dS/m)	17.90 c	63.6			

*Averages indicated with the same letters are statistically identical according to LSD test (0.01)

When test results are taken into consideration, it could be stated that Berke variety is the most resilient against salinity and this cotton variety should be used in cotton cultivation and under saline irrigation water conditions.

Plant water consumption results: Water consumption altered between 1,043-1,135mm depending on test subjects. It has been observed that the differences on ET among test subjects are negligible. However, in all varieties an increase in irrigation water salinity resulted in a decrease in plant water consumption.

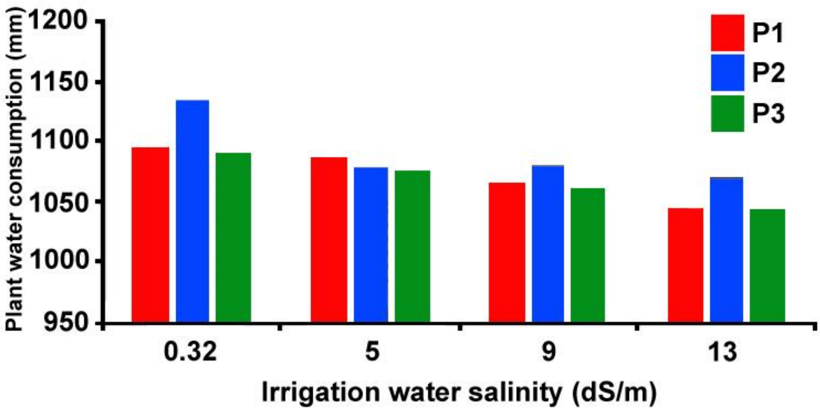

Figure1. Change in plant water consumption depending on irrigation water salinity

Water Use Efficiency: Increase in irrigation water salinity resulted in a drop both in Irrigation Water Usage Efficiency (IWUE) and total Water Usage Efficiency (WUE). The reason for low yields on higher ET levels could be explained by the fact that the increase in yield did not match the level of increase in plant water consumption.

In Table 5, water usage efficiency and irrigation water usage efficiency are shown per main topics.

Table 5. Water usage efficiencies per main topic (kg/da/mm)

Main topics (dS/m)	IWUE	WUE
T0	3.5	3.2
T1	3.3	3.1
T2	2.4	2.3
T3	1.3	1.2

Drainage water salinity: A total of 0,77 - 0,88 mm water was drained per tank and it is 0,08% of total irrigation water used. Since no separate wash water was used during the test, drained water volume was insignificant. Drainage water salinity increased from the time of initial irrigation to the last. In the beginning of irrigation period (June 28th, 2007), drainage water salinity varied between 0,32 to 0,58 dS/m. On July 29th, 2007, in correlation with the salinity levels of the irrigation water utilized, the values were 1,3 – 3,6 dS/m and 3,58 – 14,6 dS/m on September 18th, 2007 respectively. Towards the end of the irrigation period salinity of drainage water increased considerably. SAR values varied between 3,10 and 8,22 at the end of irrigation period. The SAR values increased parallel to the increase in salinity levels in the irrigation water.

Irrigation water salinity threshold values: Regression analysis was utilized to determine the level of relation between different salinity levels in irrigation water and unginned cotton yield mathematically. Results show, since Berke is the most resistant to salt and with the smallest yield loss, threshold value was also calculated as the highest (4,45 dS/m) among varieties. Irrigation water salinity threshold value for Stonville-453 is 4,32 and Teks variety is 3,72 dS/m respectively. In previous studies irrigation water salinity threshold values were determined as 5,2 dS/m by Ayers and Westcot (1989), Letey and Dinar (1986), Maas (1985) and 5,1 dS/m by McFarland et al. (2000). Consequently, by utilizing the correlation between irrigation water salinity level and unginned cotton yield in addition to the findings of our research, possible yield percentages depending on relative yield decrease or increasing salinity levels were calculated (Table 6).

Table 6. Relative yield decrease by irrigation water salinity (dS/m)

Varieties	Relative decrease in yield (%)										
	100	90	80	70	60	50	40	30	20	10	0
P_1	4.5	6,0	7.5	9.1	10.6	12.1	13.6	15.1	16.0	18.2	19.7
P_2	4.3	5.5	6.7	7.9	9.0	10.2	11.4	12.5	13.7	14.9	16.0
P_3	3.7	5.3	6.8	8.4	9.9	11.5	13.1	14.6	16.2	17.7	19.3

Salt deposit in soil: Although the salt deposit in soil profile increased as a function of increasing salinity level in irrigation water, salt deposits in soil strata did not show any variations. The post-irrigation period analyses showed the highest T_3 salinity level of 20,04 dS/m.

Soil salinity threshold values: Soil salinity threshold values were calculated as 6,58 dS/m in Berke, 7,46 dS/m in Stonville-453, 6,84 dS/m in Teks varieties respectively. Soil salinity threshold values for all 3 cotton varieties are calculated close to each other and also parallel to irrigation water salinity threshold values. However the most sensitive cotton variety, Teks diverged from other varieties for the irrigation water salinity value for this variety was calculated very close to soil salinity threshold value.

Irrigation Water Salinity and Dry Matter Quantity: The highest dry matter quantity was obtained in the control application in the test with a salinity value of 0,32 dS/m. Control application demonstrated a 6,59% decrease in dry matter for 5 dS/m; 11,28% for 9 dS/m; %19,66% for 13 dS/m respectively.

Fiber quality and morphological properties: All properties measured showed an adverse impact due to an increase in irrigation water salinity.

CONCLUSION

Increasing salt content in irrigation water resulted in a decrease in yield across the board for all cotton varieties. However no statistically relevant interaction was discovered between the salinity levels in irrigation water and varieties. Since the irrigation water application with a salinity value of 0,32 dS/m, used as control, produced the highest unginned cotton yield, the yields achieved in other applications were compared to arrive at modulating yield values. Accordingly, a yield decrease of 5,3% at 5 dS/m; 30,2% at 9dS/m; 63,6% at 13 dS/m occurred. Berke variety appeared to be the most resilient against salinity among the varieties utilized in the test. Soil and irrigation water salinity threshold values were determined for cotton varieties. For different varieties irrigation water threshold values are; Berke: Ct=4,45, Stonville–453: Ct=4,32 and Teks: Ct=3,72 respectively.

Increase in salt deposit in irrigation water resulted in salt deposit increase in soil. At the end of the test, soil salinity reached 20,04 sD/m in T_3 subject for which the irrigation water salinity was the highest, whereas for the control subject it stayed at a level of 1,70 dS/m. In addition, soil salinity threshold values for different varieties were found as follows: Berke: Ct=6,58, Stonville–453: Ct=7,46, and Teks: Ct=6,84. For all varieties, dry matter quantities measured after harvest decreased as a function of an increase in irrigation water salinity levels.

It is possible to suggest that the loss in yield could be considered insignificant where irrigation water with salinity up to 4,45 dS/m is used. Furthermore, salt deposit in soil after irrigation by salty waters would not create short-term problems, however in the long term salt deposit levels would be significant, and a loss in production would be imminent.

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