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ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (17): 2824-2830, 2007
ISSN 1028-8880

Salt Tolerance of Wheat According to Soil and Drainage Water Salinity

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Abstract: To determine salt tolerance of spring wheat genotype (On_Farm 9) to soil salinity (ECe) and drainage water salinity (ECd), a pot experiment containing three irrigation water salinities of 4, 9 and 12 dS m^{-1} and four leaching levels of 3, 20, 29 and 37% was conducted in a completely randomized design arranged as factorial with 7 replications on a silty clay loam soil during 2005. The results showed that decrease of leaching water quality and quantity significantly increased soil and drainage water salinity and decreased crop yield and evapotranspiration. Application of leaching water fraction in the range of 20-29% were highly significant in decreasing soil salinity, drainage water salinity and increasing grain yield, while the most increase in crop evapotranspiration occurred in the range of 29-37%. This study shows that the effects of increase of soil salinity on grain relative yield are more significant than effects of increase of salinity of drainage water and wheat has greater threshold value in drainage water salinity than soil salinity method. The correlation of relative grain yield (Ry) with ECe and ECd indicated that ECd could estimate Ry as well as ECe.

Key words: Leaching, soil salinity, drainage water salinity, crop evapotranspiration, wheat, relative yield

INTRODUCTION

Land degradation caused by water logging and soil salinity problems has adversely affected food production in irrigation commands and salinity is one of the major factors reducing plant growth and productivity world wide (El-Hendawy *et al*., 2005; Sharma *et al*., 1994). Use of saline and saline drainage water for irrigation is a subject of increasing interest because of the increasing water requirements for irrigation and the competition between human, industrial and agricultural use and disposal of such waters is a serious problem for crop production and soil (Katerji *et al*., 2000). Ponnamieruma (1984) reported a dangerous trend of a 10% per year increase in the saline area throughout the world. Therefore not only adverse effect of salinity isn't controlled, but also these effects are increased and caused a serious problem for future human life. In Iran about 15% of lands, that is about 25 million ha, are suffering from different degrees of salinity and sodicity, including 320000 ha of lands in Isfahan province (Feizi, 1993, 1996). Wheat is the most important and widely adapted food cereal in Iran. Although, Iran recently has been caused to supply all of its annual domestic demand for wheat, but salinity of soil and water resources especially in arid and semi arid regions such as central part of Iran effectively decreased wheat productivity (Golafra, 2005). Most researchers reported the adverse effects of salinity of irrigation water and soil on wheat yield and yield components (Katerji *et al*., 2003, 2005; Sairam *et al*., 2002; Saqib *et al*., 2004; Soltani *et al*., 2006). Although several studies has been conducted for determination of wheat genotype salt tolerance, but these results are different for various weather conditions (Katerji *et al*., 2001, 2003; Poustini and Siosemarde, 2004). Plant breeding is a complementary and a more permanent approach for minimizing the deleterious effects of salinity, with the development of cultivars that can grow and produce economic yield under moderately saline conditions (Flowers and Yeo, 1995; Shannon, 1997). Whatever selection of tolerant wheat genotype is effective for decrease of salt deleterious effect, but long term application of saline water caused soil degradation and in this condition tolerant genotype couldn't have satisfactory yield. Application of leaching levels is suitable for soil salinity reduction, but the quality and quantity of leaching on soil desalinization and crop improvement should be site specific. While some researchers found that the best estimation for leaching level for soil desalinization can be made based on soil depth but other believe that appropriate leaching level is related to salinity of drainage water (Khosla *et al*., 1979; Hoffman *et al*., 1979). Application of specific levels of

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leaching in long period especially in high salinity causes more increase in soil salinity (El-Haddad and Noaman 2001; Feizi, 1993). Therefore in this study we attempted to investigate the role of leaching quantity and quality on soil salinity, drainage water, crop evapotranspiration and grain yield and to determine wheat salt tolerance according to soil and drainage water salinity.

MATERIALS AND METHODS

To achieve the objectives of the study, a saline soil (typical soil of Rudasht wheat farm) with silty clay loam texture, was used to conduct this experiment in a greenhouse of Isfahan University of Technology in 2005.

The Rudasht region (65 km east of Isfahan, 32°29′N and 52°10′E, 1560 m asl) consists about 50000 ha of salt affected soils. In this area, because of high evapotranspiration demand, low annual rainfall, rising water tables, limitation of fresh river water and use of saline underground and drainage water for irrigation, the soils has lost their productivity continuously due to salinity problems. Some physical and chemical properties of soil under study are given in Table 1. In this research three irrigation water salinity of 4, 9 and 12 dS m^{-1} (Table 2) and four leaching water fraction of 3, 20, 29 and 37% were used in a factorial experiment using a completely randomized design with 7 replications. Eighty four plastic pots each with depth of 0.4 m and diameter of 0.3 m having a hole at the bottom for drainage were used for the experiment. Bottom of each pot was covered with 5 cm course gravel to act as a filter. Drainage water was collected in to a cane placed under each pot to measure the quality and quantity of drainage water at each irrigation intervals. The irrigation was based on reduction of pot weight. The soil bulk density in each pot (1.34 g cm^{-3}) was similar to soil of Rudasht area. The seeds of spring wheat (*Triticum aestivum* L.) genotype On_Farme 9 were planted in each pot on 18 March 2005. FC and WP soil moisture of all pots were determined and irrigations timing were based on soil moisture deficit of 50% (Alizadeh, 2001). Ten irrigations were applied during the cropping season. Drainage water was collected from each pot and weighted and its salinity measured. Soil samples from each pot were collected at different growing stages, from two soil depths of 0-15 and 15-30 cm and electrical conductivity of saturated paste extract was determined. Plants were harvested on 20 June 2005 and grain yields were measured for each pot and average grain yields of each plant were calculated.

Data were analyzed for analysis of variance (ANOVA) following the methods described by Gomez and Gomez (1984). SAS computer software was used to carry out the statistical analysis.

Table 1: Soil physical and chemical properties

Soil physical properties					
Sand (%)	Silt (%)	Clay (%)	$CaSO_4.2H_2O$ (Meq^{-100} soil)	Lime (%)	Bulk density (g cm^{-3})
7	52.9	40.1	10	38	1.34
Soil chemical properties					
ECe (dS m^{-1})	pH	SAR	Ex Na	CEC	ESP (%)
13.2	4.22	11.31	4	18.5	21.6

Table 2: Irrigation water characteristics

	Character							
Water sample	EC (dS m^{-1})	pH	Na^+	Ca^{2+}+ Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3	SAR
			(meq L^{-1})					
Sample 1	4.1	7.3	29.6	17.2	28.2	14.3	3.3	10.1
Sample 2	9.1	7.3	60.7	32.5	65.3	26.9	5.0	15.1
Sample 3	12.1	7.5	102.8	38.0	88.5	46.9	4.4	23.6

RESULTS AND DISCUSSION

The analysis of variances showed that irrigation water salinity levels, leaching levels and interaction of the two factors had high significant effect on average soil salinity during growth period, salinity of drainage water, crop evapotranspiration and wheat grain yield.

Soil salinity: The soil salinity (ECe) at the end of season shows that as the irrigation water salinity increases or leaching level decreases, ECe increases. Also increase of leaching level caused more salt leached from soil profile. As shown in Table 3 the highest soil salinity was belonged to irrigation water salinity of 12 dS m^{-1} and leaching level 3%. The effect of each irrigation water salinity and leaching level treatments were significantly different on soil salinity. Figure 1 and 2 indicates that ECe in top layer soil (0-15 cm) was greater than the salinity of lower layer soil (15-30 cm) in both irrigation water salinity and leaching level treatments. Effects of irrigation water salinities and leaching levels are significantly higher for top layer soil as compared to the lower layer soil. The highest difference between salinity of top layer soil and lower layer soil occurred at irrigation water salinity of 12 dS m^{-1} and leaching level of 3%. Table 4 presents the effects of different treatments on soil salinity, drainage water, evapotranspiration and grain yield. The comparison of soil salinities at beginning, middle and end of season (Table 1 and 4) indicated that in addition to rate of leaching level, the irrigation water quality for desalinization of the saline soil has an important role in salt removal from the soil and maintenance of salt balance. Leaching levels of 20, 29 and 37% in salinity of 4 dS m^{-1} and leaching level of 37% in salinity of 9 dS m^{-1} were able to decrease soil salinity during the season. In the other treatments initial soil salinity increased such that low water quality and quantity of leaching water intensified this increase. De Pascale *et al.* (2005) reported the

Table 3: Mean Comparison of ECe, ECd, ETc and grain yield influenced by irrigation water salinity and leaching level

		Parameter			
Treatments		ECe (dS m^{-1})	ECd (dS m^{-1})	ETc (mm)	Grain yield (g per plant)
Salinity	4	8.75c*	20.3c	343.3a	0.64a
(dS m^{-1})	9	15.73b	29.0b	279.1b	0.19b
	12	20.3a	33.4a	261.2c	0.053c
Leaching	3	21.6a	34.0a	250.0d	0.109d
(%)	20	15.7b	29.1b	274.8c	0.215c
	29	12.4c	25.5c	306.5b	0.379b
	37	10.0d	21.7d	346.9a	0.477a

Values followed by different letters are significantly different at 5% level according to the duncan multiple range test

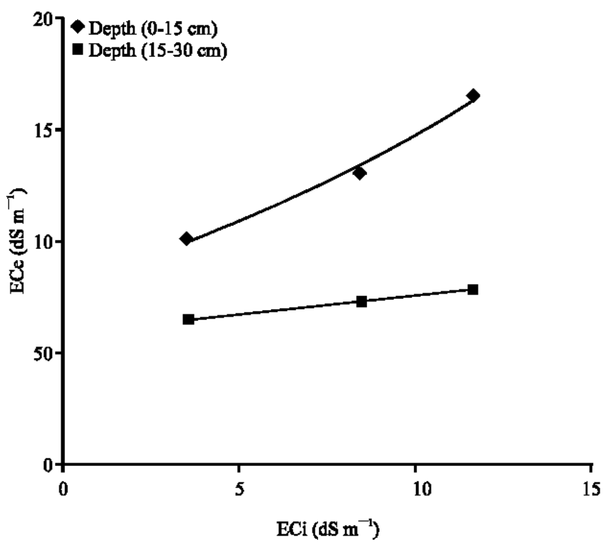

Fig. 1: Soil salinity vs. irrigation water salinity

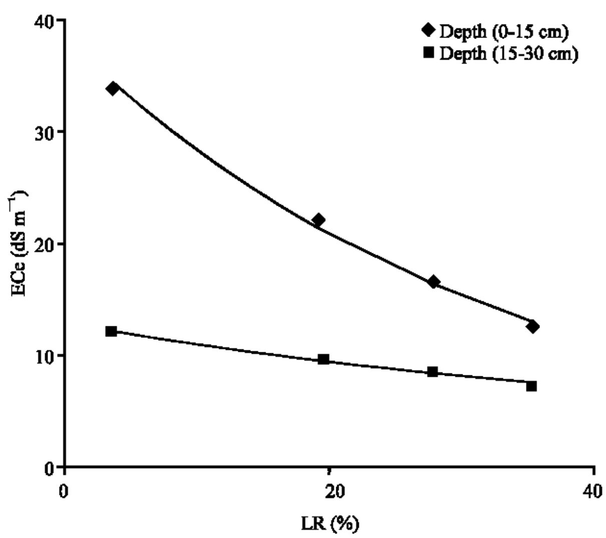

Fig. 2: Soil Salinity vs. leaching level

effective use of precipitation (high water quality) on desalinization of soils irrigated with saline water throughout the growing season. Application of 37% Leaching level and irrigation water salinity of 4 dS m^{-1} had the highest soil salinity reduction of up to 72.8%. Leaching level of 3% and irrigation water salinity of 12 dS m^{-1} showed highest salt accumulation of about 125 percent in primary soil condition. Irrigation water salinity of 9 dS m^{-1} and leaching level of 37% had about 20% salt decrease with respect to initial soil salinity. So, application of moderately high saline water in arid and semi-arid region which suffering from fresh water resources should be considered with sufficient rate of leaching water to maintain soil salt balance.

Drainage water: Electrical conductivity of all drainage waters at the end of growing season were greater than applied salinity of irrigation water, due to relatively high amount of initial soil salinity. Increasing of irrigation water salinity from 4 to 12 dS m^{-1} showed 64.5% increase in salinity of drainage water (Table 3). El Haddad and Noaman (2001) reported increase of salinity of drainage water due to irrigation water salinity enhancement. Application of 3 to 37% leaching levels shows significant reduction of drainage water salinity (Table 3). Table 4 presents that 34% increase of leaching level (from 3 to 37%) in irrigation water salinity treatments of 4, 9 and 12 dS m^{-1} had 57.5, 35.4 and 19.1% decrease in salinity of drainage water respectively and greatest reduction happened in the lowest irrigation water salinity (4 dS m^{-1}). As shown in Fig. 3 increasing of leaching levels decreased salinity of drainage water as soil salinity on two stages of growing season. Salinity of drainage water is consisted of soil salt and salt of irrigation water

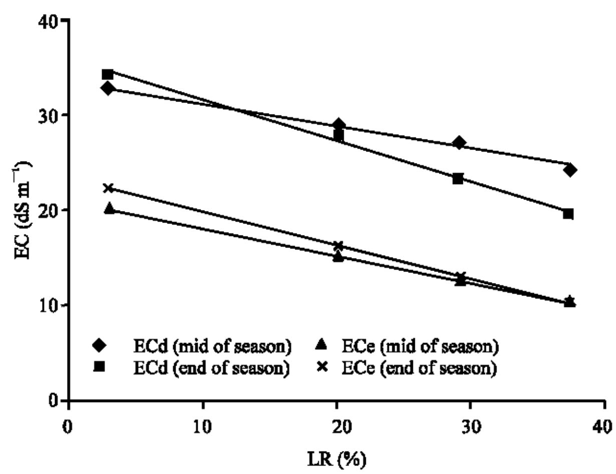

Fig. 3: ECe and ECd vs. LR on mid and end of season

Table 4: Effects of treatments on ECe, ECd, grain yield and ETc

		Factor				
Treatment EC (dS m^{-1})	LR (%)	ECe mid (dS m^{-1})	ECe end (dS m^{-1})	ECd end (dS m^{-1})	ETc (mm/season)	Grain yield (g/plant)
4	3	13.6	15.6	29.9	275.3	0.27
	20	9.9	8.5	22.2	311.4	0.50
	29	7.1	5.5	16.5	365.8	0.85
	37	6.1	3.7	12.7	420.7	0.943
9	3	21.2	22.3	36.1	244.2	0.05
	20	16.0	17.1	29.8	264.1	0.11
	29	13.5	14.9	26.8	284.4	0.22
	37	10.6	10.2	23.3	323.7	0.38
12	3	26.7	30.4	36.1	230.4	0.01
	20	18.9	23.5	35.3	248.9	0.03
	29	15.9	17.7	33.1	269.2	0.07
	37	13.9	15.4	29.2	296.2	0.10

which applied. Although drainage water salinity of high leaching levels is lower than salinity of less leaching levels, but amount of salt removal from the soil is related to both quality and quantity of irrigation water. So, amount of salt removal was raised with increasing of leaching water rate. In low leaching level (3%), not only soil salinity does not decrease, but also due to salt accumulation caused by irrigation water, soil salinity increased during the season. In high leaching level treatments in addition to remove some irrigation water salt, some accumulated soil salts were also leached during each irrigation intervals. Therefore soil salinity decreased continuously during leaching. Decrease of soil salinity is the main reason for reduction of drainage water salinity during the season in the high leaching level treatments. According to the results, by increasing of leaching levels, difference of salinity of drainage water on mid and end of season become greater and mean time the difference of soil salinity becomes less (Fig. 3). Salinity of soil is less than salinity of drainage water in all treatments too.

Table 5: Slope of relationship between grain yield, ECe, ECd and ETc with leaching levels

	Leaching level		
Parameters	3-20	20-29	29-37
Grain yield	0.008	0.02	0.011
ECe	0.460	0.48	0.330
ECd	0.460	0.65	0.440
ETc	1.800	4.00	4.500

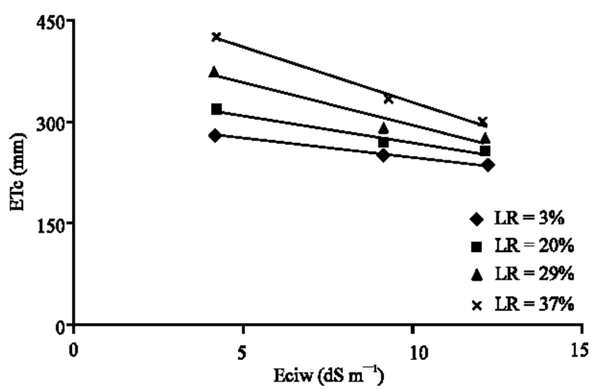

Fig. 4: Crop evapotranspiration vs. irrigation water salinity

Crop evapotranspiration: Crop evapotranspiration was calculated by differences of total water applied and amount of drainage water during the season. Increase of irrigation water salinity and decrease of leaching level reduced crop evapotranspiration effectively. Table 3 indicates that the highest crop evapotranspiration belong to salinity of 4 dS m^{-1} and leaching level of 37%. As shown in Fig. 4, increasing irrigation water salinity in all leaching level treatments caused crop evapotranspiration to decrease, but according to slope of lines, the highest and lowest slope was belonged to leaching level 29 to 37 and 3 to 20%, respectively (Table 5). Increase of soil salinity (application of high irrigation water salinity and low leaching level) caused more osmosis pressure and this resulted to water stress. Therefore increase of water stress is main reason for crop evapotranspiration deficit.

Grain yield: Grain yield significantly depends on crop evapotranspiration. Deficit of crop evapotranspiration caused reduction of crop growth and yields. In addition to water stress, reduction of root density intensifies deficit of crop evapotranspiration. Grain yield effectively decreased by increasing of irrigation water salinity, but application of leaching through decreasing of soil salinity, could increase grain yield (Table 3). Interaction of leaching level and irrigation water salinity on grain yield was highly significant. As shown in Table 4, the greatest yield was obtained in the least salinity (4 dS m^{-1}) and most leaching level (37%). Although, effect of leaching on grain yield increases with reduction of salinity of irrigation water, but level of leaching is so important. For instance application of leaching level 37% in salinity of 9 dS m^{-1} caused more yield compared to the salinity of 4 dS m^{-1} and leaching level 3%. Meantime application of irrigation water salinity of 12 dS m^{-1} and higher leaching level (37%)

couldn't compensate for yield as much as irrigation water salinity of 4 dS m^{-1} and leaching level 3%. Although the results of this study show that by increasing of salinity of irrigation water, leaching level should be higher to maintain optimum yield and soil salt balance, but due to drainage and water logging problems, application of high leaching levels should be minimize.

Leaching levels: In Table 5 measured parameters of ECe, ECd, ETc and grain yield vs. leaching levels showed different trend lines in the three ranges of leaching. The relationship between each mentioned parameters and three leaching ranges were investigated and slope lines in each ranges were determined. Effect of leaching levels on ECe, ECd and grain yield, were significantly increasing specially within ranges of 3-20 and 20-29%, but in range of 29-37% the effect became lower. Effect of leaching levels on ETc was highly increased in the three ranges. In general, high leaching efficiency was clearly seen on grain yield, soil salinity and salinity of drainage water up to leaching level 29%, where as in case of crop evapotranspiration leaching efficiency shows sharp increasing trend until leaching level 37%.

Wheat salt tolerance: Several researchers investigated crop salt tolerance according to different methods. In this research wheat salt tolerance was determined according to methods of soil salinity, crop evapotranspiration and drainage water salinity. The highest yield was belonged to the lowest soil salinity which resulted from irrigation water salinity of 4 dS m^{-1} and leaching level of 37%. In Fig. 5 the result of the linear regression analysis of the relationship between grain relative yield and ECe is presented according to the Maas and Hoffman (1977) equation. The values of b (line slope, expressing percentage yield depression per dS m^{-1}) and a (threshold value) were obtained equal to 7.85 and 5.1 dS m^{-1}, respectively. Katerji *et al.* (2003) by lysimeter experiment founded that durum wheat is salt tolerant and has b value of 1.9 while Maas and Hoffman (1977) reported b value of 3.8 for durum wheat and a and b values of 6 dS m^{-1} and 7.1 for bread wheat respectively. Feizi (2002) also reported a and b values of 5.9 dS m^{-1} and 8.2 for Roshan bread wheat cultivar, respectively. The main reasons for difference between these values are type of wheat genotype and weather condition (Katerji *et al*, 2003). Therefore the results of this study are close to values reported by Maas and Hoffman (1977) and Feizi (2002).

Figure 6 predicted the relative yield base on relative evapotranspiration deficit that proposed by Stewart *et al.* (1977). In this study linear regression analysis of relative yield vs. relative evapotranspiration deficit resulted b value of 2.48. This value is greater than value which reported by Katerji *et al.* (2003) for durum wheat (0.6). The lower the slope coefficient (b) means that if due to stresses such as salinity and drought, crop evapotranspiration decreases, therefore crop yield reduction will be less than condition which b is higher. So, higher b is resulted to stronger drought effect. Spring wheat genotype On-farm 9 has lower drought tolerance than durum wheat which reported by Katerji *et al.* (2003) by assuming same condition in two experiments. Relative yield significantly decreased due to increase of drainage water salinity. Figure 7 indicates that relative yield have high correlation with salinity of drainage water (R^2 = 0.93) and Maas and Hoffman (1977) model could be applied for expressing the relationship between salinity of drainage water and relative yield. According to the linear regression analysis of relative yield vs. drainage water a and b values are equal to 11.5 dS m^{-1} and 4.28, respectively. While threshold value in method of soil salinity (5.1 dS m^{-1}) is less than method of drainage water

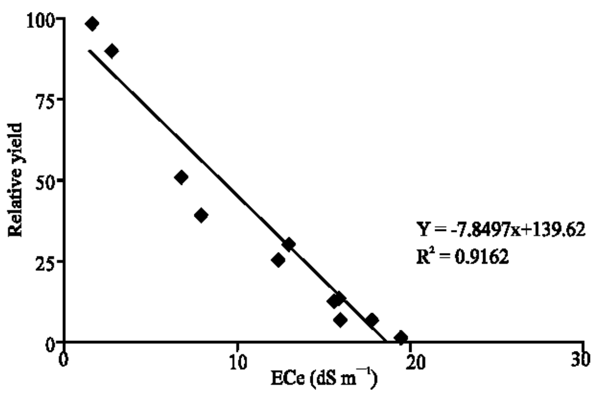

Fig. 5: Relative yield vs. soil salinity

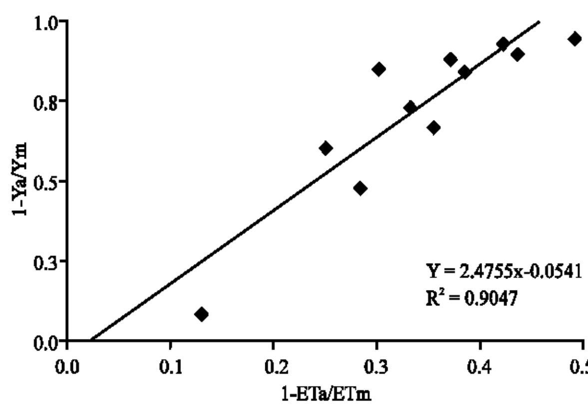

Fig. 6: Relative yield vs. relative evapotranspiration deficit

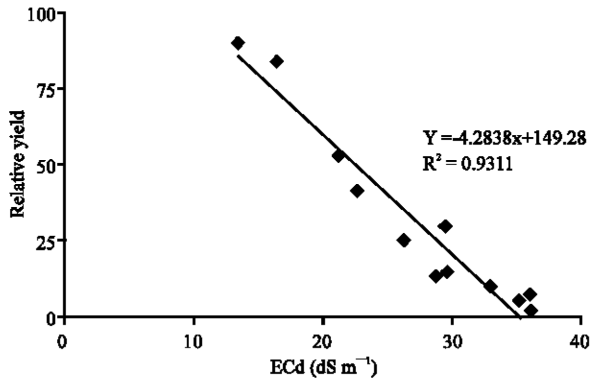

Fig. 7: Relative yield vs. salinity of drainage water

(11.5 dS m^{-1}), but the slope of decreasing yield is higher than drainage water method. Thus 1 unit increase in salinity of drainage water resulted less yield reduction than 1 unit increase in soil salinity. However, the results show that three mentioned methods could predict yield and use of any methods depend on the availability of data.

CONCLUSION

This study indicates that increase of irrigation water salinity caused increase of soil salinity, salinity of drainage water and decreases crop evapotranspiration and grain yield. Application of leaching levels significantly reduced adverse effect of salinity, decreased soil salinity and increased crop evapotranspiration and grain yield. Therefore, increasing of leaching water quality and quantity caused more decrease in soil salinity and increase of grain yield. Thus irrigation water salinity of 4 dS m^{-1} and leaching level of 37% and salinity of 12 dS m^{-1} and 3% leaching was the best and worst treatments, respectively and had greatest difference between amounts of mentioned parameters. Although salinity of drainage water decreased by increasing of leaching level, but total amount of salts which removed from soil are greater than low leaching level. Therefore leaching level 37% caused the most salt removal and the least soil salinity. While leaching efficiency in case of crop evapotranspiration increased until leaching level 37%, but in cases of soil salinity, salinity of drainage water and grain yield increased until leaching level 29% and then the trend slightly decreased. The grain yield estimated according to soil salinity and drainage water salinity and both methods could predict wheat grain yield with high correlation values. This study also showed that threshold value of drainage water salinity (11.5 dS m^{-1}) is higher than threshold value of soil salinity (5.1 dS m^{-1}) in comparing two methods. Effects of soil salinity on yield are more important than effects of salinity of drainage water because b value (7.85) in soil salinity method is greater than b value (4.28) of drainage salinity method.

ACKNOWLEDGMENT

This research was funded by Isfahan University of Technology and Isfahan Agricultural and Natural Resource Research Center. This assistance is gratefully acknowledged.

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