Sesame (*Sesamum Indicum* L.) Performance Under Different Salinity Levels of Water

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Abstract: Due to the importance of water resources in arid and semi-arid areas and also environmental challenges caused by discharging of wastewater of municipal and agricultural activities, interests in the reuse of unusual water resources like drainage water is increasing. The objective of this study was investigating Sesame (*Sesamum Indicum* L.) response, irrigated by blending drainage water (DW) with river water (RW) in a warm and arid condition in south of Iran. A field study was conducted in commercial farms of Zeydun County, Khouzestan, Iran. Two sesame cultivars (Local and Line 6) were evaluated to compare grain yield, its components and biological production when irrigated with four salinity levels (blending ratios) [100%RW (EC_w=2ds/m), 50% RW+50%DW (EC_w=2.8 ds/m), 25%RW+75%DW (EC_w=4.13 ds/m), 100%DW (EC_w=5 ds/m)]. Results showed that among yield components only number of capsule per plant reduces significantly as salinity increased. Sesame Line 6 produced higher grain yield in comparison with Local under all salinity treatments with a maximum of 1500 kg/ha when irrigated with RW. Yet, relative yield of sesame Local was higher than Line 6, indicating higher salt tolerance in Local cultivar. Although all salinity levels had negative effect on sesame production, by accepting only 3-6 percent reduction in grain yield under blending ratio 50%RW+50%DW drainage water could effectively be reused for sesame production. Moreover, damaging environmental impacts of drainage water discharging could be diminished.

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1. Introduction

Nowadays water scarcity is one of the most limiting factors in agricultural production (Bouremia *et al*. 2011). This limitation particularly in arid areas like Iran is much more critical since, in addition to high evapotranspiration rate which causes water stress; stress is also amplified by salt accumulation. This in turn, raises salinity stress. To reduce salinity levels in soil most of irrigation strategies rely on leaching salt by using non-salt water. This, on the one hand can diminish water resources and on the other hand endanger natural habitats and wildlife of where the drained water is discharged (Kaffka *et al*. 2004). For this reasons, interests in applying unusual water resources such as wastewater and drainage water is increasing. Ghasemi and Danesh (2013) showed that based on Ayers and Westcot (1985) refined wastewater of Mashhad (northeast of Iran) has no restriction for agricultural usages in term of indices EC, SAR, Chloride, nitrate nitrogen and Boron. Having said that, results of a study in Ahvaz (southwest of Iran) showed that the use of refined wastewater for agricultural production is associated with high limitation in term of salinity and can cause serious consequences, yet no field work has been reported (Moazed and Hanifeloo 2006). The reuse of drainage water in production of crop plants have been showed (Kaffka *et al*. 2004., Qadir and Oster 2004). Salinity is the major problem of these waters for which some resolves like: not using at sensitive growth stages of crops, the use of chemical amendments, leveling and high–frequent irrigation have been suggested. Blending is a noticeable technique in which different ratios of saline water (drainage water) and fresh water are applied together in accordance with crop type, salinity level, amount of available water and acceptable yield reduction (Tyagi 2003). Kadhim (2013) reported that even under blending ratio 90% drainage water effluent Alforat Alsharrqi with 10% water of Euphrates river (EC= 7000 µs/cm, SAR≤12) in Iraq, there is still the possibility to produce plants such as palm, barley, sorghum and alfalfa in sandy soils. The only limitation is in September when SAR reaches to over 12 (no limitation was reported for other months). In a greenhouse study in San Joaquin Valley, California, USA relative yield of two forage crops Tall wheat and Alfalfa under irrigation with drainage water (EC= 11-18 ds/m) was 85% and 45% respectively. From quality standpoint, short-term consumption of these forages would not have any problem for beef cattle and goats, however, in long-term animal physiology could potentially be affected due to high selenium and sulfur concentration of these forages (Suyama *et al*. 2007a,b). Results of a recent study indicated that drainage water is suitable for producing halophyte species and could potentially maintain production continuity, particularly when high–quality forages are expensive and/or hard to produce (Diaz et al, 2013). This point should not be forgotten that, although the use of drainage water for crop production could reduce environmental issues (Kaffka *et al*. 2004), this strategy can lead to the accumulation of heavy and trace elements in soils under long term of usage (Suyama *et al*, 2007a). Despite the probability of saline accumulation, there is still the potential of providing mineral nutrient (N, Ca, Mg and S) to a satisfactory level through applying saline water (Ben-Gal *et al*. 2009).

No result has been reported regarding the feasibility of drainage water application in oilseed crops production so far. Sesame (*Sesamum Indicum* L.) is one of the stress–tolerate crops that produces sorts of chemical components, unavailable in other edible oils that provide a resistance to oxidative rancidity, and has made sesame well known as "Queens of oilseed crops" (Bouremia *et al*. 2011., Alyemani *et al.* 2000). Because of its tolerance, noticeable amount of high–quality oil (42-54%) and protein (22-25%), sesame is very popular in areas like Africa and Asia (Mohammadi 2013). In Iran in 2012 sesame was harvested from an area of 40000ha (FAO 2014) of which around 10000ha was in south parts of Iran, Khouzestan, Zeydun County. Therefore the objective of this study was to measure the yield and its components of sesame under irrigation with blended drainage water by river water in Zeydun County, Khouzestan, Iran.

2. Materials and Methods

A. Experimental Site

This study was conducted in a commercial farm in Zeydun County, Behbahan (30°10' N, 49°47'E) Khouzestan, southwest of Iran in 2008. Annual average temperature in Zeydun is 24°C, reaching to 33°C in summer and 14°C in winter. Annual average rainfalls are 354.2 mm with the highest amount of precipitations in November-February and around 2900 mm evaporation annually (Kasmaie 1990). Zohre River is the water source in Zeydun County where agriculture is the main consumer of this river. In some parts drainage water and other effluents are discharged into the river. Farmlands in Zeydun are leveled with an appropriate slop and irrigation system is surface type. Irrigation and drainage canals are made of soil (soil type). At the downstream of land surface drainage network collects discharged effluent.

B. Experimental Design

Effects of 4 different salinity levels by blending river water with drainage water on 2 sesame cultivars were evaluated. The experiment was carried out as split-plot in a randomized, complete-block design with three replications. Four salinity treatments [100% RW (River Water), 50% RW+50%DW (Low-Saline), 25% RW+75%DW (High-Saline), 100%DW (Drainage Water)] as main plots, were applied. Sesames tested were two widely cultivated cultivars in Zeydun and south parts of Iran known as Local and Line 6 which ware considered as subplots. Each plot was planted at July 16, 2008 using 100 seed per m^{-2} as planting rate comprised of 7 rows 50 cm apart and 3 m long. To prevent lateral penetration a 2m interval was considered between plots. For a uniform germination and seedling establishment, all plots were irrigated using river water for the first three irrigations. Afterwards, irrigation treatments were introduced every 15 days (according to the sesame irrigation plan applied in Zeydun County). To transfer irrigation water to farm and applying blending treatments a $6m^3$-valume tanker was employed. Water was sampled prior to irrigation and analyzed (Table 1). Sesame water requirement was indicated by using below equation:

$$ET_c = K_c \times ET_0$$

Where ET_c is crop evapotranspiration, K_c is crop coefficient of sesame (Sepaskhah and Andam 2001) and ET_0 is reference crop evapotranspiration based on FAO method and class A pan (Alizadeh 2007). Irrigation in each treatment applied via water meter based on 80% efficiency for surface irrigation. The nutrient requirements were determined base on soil analysis (Table 2) and were adequately met by fertilizer application as follow: 150 Kg/ha Urea, 300 kg/ha potassium sulfate and 100 kg/ha super phosphate triple. All fertilizers were applied before planting. Weeds were effectively controlled, and no pests or disease were observed during the plant growing season.

C. Sampling and Statistical Analysis

By the end of the season samples were collected from an area of $1m^2$, considering border effects. Samples were dried under 70°C for 48h and weighted using a digital scale. Total dry matter production, grain yield and its components including: capsule per plant, seed per plant and 1000 KW, were analyzed using SAS v9.2 software with salinity treatment, sesame cultivar and interaction (salinity × cultivar) as fixed factors and with block as a random factor. GLM procedure was applied, and only when interactions were significant ($P \leq 0.05$), were means compared within the salinity levels by using Duncan's multiple-range test. Graphs were drawn by using Excel 2007 software.

Table 1- water chemical features in each irrigation turn and treatment: River Water (RW), Low Saline (LS), High Saline (HS), Drainage Water (DW)

	RW			LS			HS			DW		
[1]Irrigation turn.(date)	EC (ds/m)	TDS (mg/l)	pH	EC (ds/m)	TDS (mg/l)	pH	EC (ds/m)	TDS (mg/l)	pH	EC (ds/m)	TDS (mg/l)	pH
1(Jul 16)	1.92	963	7.20	-	-	-	-	-	-	-	-	-
2 (Jul 26)	1.90	952	7.27	-	-	-	-	-	-	-	-	-
3 (Aug 10)	1.93	960	7.23	-	-	-	-	-	-	-	-	-
4 (Aug 25)	1.95	977	7.29	2.67	1342	7.34	3.95	1986	7.55	4.56	2321	7.75
5 (Sep 10)	2.09	1092	7.27	2.82	1416	7.36	4.10	2063	7.58	4.79	2401	7.70
6 (Sep 25)	2.19	1108	7.33	2.93	1460	7.41	4.22	2119	7.64	4.90	2453	7.76
7 (Oct 10)	2.20	1100	7.37	3.00	1528	7.45	4.30	2178	7.7	5.04	2546	7.69
[1]Irrigations 1 to 3 were all conducted applying river water (i.e. similar in term of salinity level)												

Table 2- Soil traits of experimental site

	Chemical					Physical				
	K (ppm)	P (ppm)	O.C (%)	pH	EC×10	S.P (%)	Clay (%)	Silt (%)	Sand (%)	Texture
[1]0-60	88	5.1	0.59	7.14	5.40	38	16	52	32	Silt Loam
[1]Active part of sesame roots										

3. Results and Discussion

A. Yield components

Number of capsule per plant was affected by salinity ($p \leq 0.05$) and cultivar ($p \leq 0.01$), as well as by interaction effect ($p \leq 0.05$) (Table 3). Salinity and cultivar did not affected grain per capsule and 1000 KW (Table 3). This could be because of their relative tolerance to salinity. Mean comparison of interaction showed that maximum (50) Number of capsule per plant was related to sesame Line 6, irrigated with RW, however, there was no significant different between this salinity level and LS (Fig. 1). Two cultivars were different for about 20 capsules per plant when irrigated with RW, but, by the increase in salinity, they became similar statistically. Capsule per plant in sesame Local only showed a slight pick (35) under LS treatment, yet salinity did not affect this cultivar.

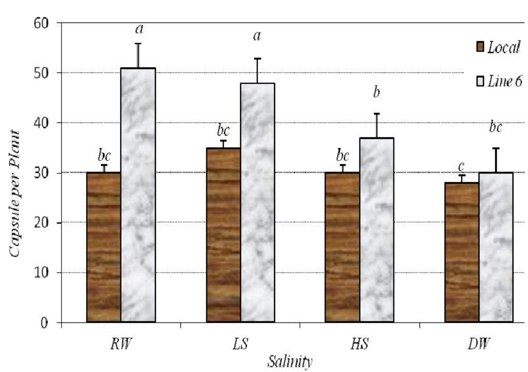

Figure. 1- Mean comparison of salinity × cultivar interaction effect on capsule per plant. Error bars represent the standard error

B. Grain Yield

ANOVA of grain yield detected significant ($p \leq 0.01$) salinity levels, cultivars and salinity × cultivar interaction (Table 3). Generally, sesame Line 6 produced higher grain yield compared to Local with the highest record of 1500 kg/ha under RW irrigation, where the production of Local was 1120 kg/ha. With the increase in DW blending ratio, yield of two cultivars reduced considerably (Fig. 2). The graph of relative yield indicates that cultivars had different salt tolerance. Although the yield of sesame Line 6 was higher (840.53 kg/ha) than that of Local (710.9 kg/ha) under DW irrigation, its yield reduction percentage was higher. The relative yield of sesame Line 6 reduced severely to 66%, while relative yield of Local was 74%, indicating higher salt tolerance in this cultivar (Fig. 3). Yield produced under LS irrigation was interestingly close to that of RW treatment, with only 3-6 per cent of yield loss in both cultivars.

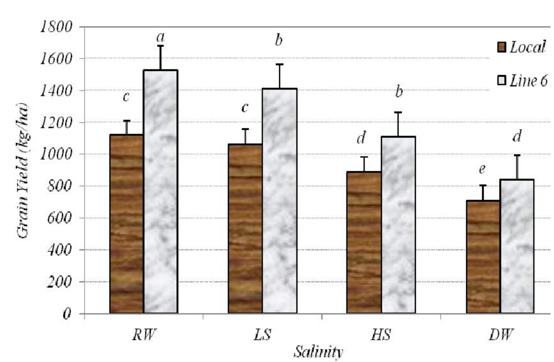

Figure. 2- Mean comparison of salinity × cultivar interaction on grain yield. Error bars represent the standard error.

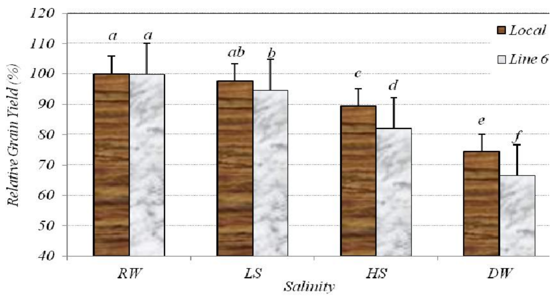

Figure. 3- Mean comparison of salinity × cultivar interaction effect on relative yield. Error bars represent the standard error

C. Biological yield

Biological yield of sesame Line 6 was higher than Local under RW (9697.33 kg/ha) and LS (9191 kg/ha) irrigation but, it was sesame Local that produced higher biological yield under HS (8180 kg/ha) and DW (6800 kg/ha) irrigation (Fig. 4). Again, sesame Local demonstrated higher salt tolerance. In grain crops harvest index (HI) which is ratio of grain yield to biological yield provides a more reliable description for crop ability to produce economical yield. Harvest index was significantly ($p \leq 0.01$) affected by salinity and it reduced as salinity increased (results are not shown).

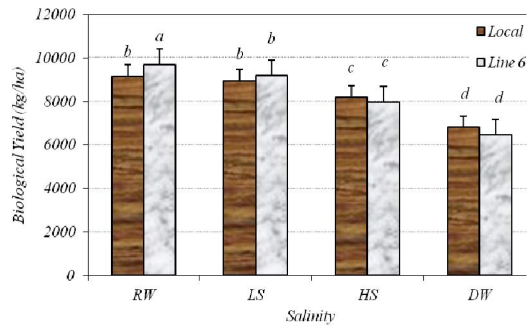

Figure. 4- Mean comparison of salinity × cultivar interaction effect on biological yield. Error bars represent the standard error

Table 3- ANOVA for yield and yield components

S.O.V	df	MS						
		Capsule per plant	Grain per capsule	1000 KW	Grain yield	Relative yield	Biological yield	HI
Replication	2	54.48^{ns}	53.81^{ns}	0.11*	20318.12^{ns}	3.97^{ns}	280864.04^{ns}	1.36^{ns}
Salinity	3	209.24**	26.97^{ns}	0.003^{ns}	366619.32**	1048.43**	9352240.94**	6.46**
Error	6	17.77	10.85	0.01	4189.02	9.35	84167.65	0.30
Cultivar	1	679.47**	0.52^{ns}	0.08^{ns}	460374.24**	121.95**	23814.03^{ns}	64.55^{ns}
Salinity×Cultivar	3	102.34*	0.10^{ns}	0.001^{ns}	23293.22**	20.71*	255000.36*	0.28^{ns}
Error	8	18.33	6.45	0.002	1386.75	6.61	63687.67	0.12
CV%	-	11.83	4.27	4.89	3.44	2.92	3.04	2.64

ns, * and ** means non-significant, significant at 5% and 1% levels of probability, respectively

Saline soil/water cause different effects on crops. Firstly, it forces the plant to spend more energy to extract water from the soil, as a result of salinity increased osmotic potential (Kadhim 2013., Koca *et al*. 2007) consequently water stress occurs. Moreover, from physiological standpoint, imbalance in received energy and its consumption rate leads to the formation of reactive oxygen species (ROS) that can damage cell membrane (oxidative stress). To tackle this problem, concentration of antioxidant enzymes such as SOD[1], CAT[2] GR[3] is enhanced and as a consequence, sorts of physiological changes like stomata closure, transpiration and RWC reduction are taken place (Singh *et al*. 2004). Such changes reduce growth rate and its rate could be various in tolerate and sensitive cultivars. Results of this study related to reduction in performance of sesame under saline condition are consistent with Fazeli *et al.* (2012) and Gaballah *et al.* (2007). All growth parameters of sesame plant reduced significantly under salinity levels: 3.12, 3.9 and 4.7 ds/m (Gaballah *et al*. 2007)

4. Conclusions

In this study feasibility of applying blended river water with drainage water in sesame production was investigated. The yield of candidate sesame varied among cultivar and salinity (blending ration). Apart from number of capsule per plant, other yield components did not reacted to treatments. Sesame Line 6 had higher grain yield than that of Local. Although it should be pointed out that relative yield of Sesame Local was higher than Line 6 under all salinity treatments, indicating higher salt tolerance in Local. The slight dominance of sesame Local in case of biomass production under HS and DW irrigation might be the reason of mentioned salt tolerance.

[1] Super Oxid Dismutase
[2] Catalase
[3] Glutathion Reductase

Considering low yield reduction (3-6%) under blending ratio 50%RW+50%DW (LS), it can be said that by accepting a maximum of 6 per cent reduction in grain yield of sesame it is possible to reuse reliable amount of drainage water effectively. Also, water resources can be applied in a more efficient way in Zeydun County. Moreover, environmental harmful effects of drainage water discharging can also be diminished. Future studies should be aimed at investigating the effects of DW on oil quality of sesame. Also, the impacts of long-term irrigation with the blending technique on soil chemical and physical features and nutrients availability should be assessed.

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