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Assessment of Irrigation and Salinity Managements on Soybean in the Semi-arid Environment

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Abstract—*The declining availability of fresh water has become a worldwide problem, which promotes the development of alternative, secondary quality water resources for agricultural use. Apart from this, applying saline water without sustainable management strategies in semi-arid environment may cause secondary inland salinization. Keeping this in view, effect of different irrigation intervals on the growth of soybean and soil properties under saline water was investigated. A field experiments was conducted in a randomized completely block design as split plot with three replications. Three water salinity levels, as fresh water Viz., S_1: 1.1; S_2: 4 and S_3: 7 dS m^{-1} and three irrigation intervals: 7(I_1); 10(I_2) and 13 day (I_3) were considered as irrigation treatments. It was observed that, plant treatments irrigated with saline water gave the highest yield for treatments irrigated every 7 day compared to the treatments irrigated every 10 day and 13 days. Maximum grain yield and biomass were observed for 7 day irrigation interval (I_1) and non-saline water (S_1) amounting 3760 and 8355 kg ha^{-1}, respectively. Also, maximum water use efficiency of 9.08 kg ha^{-1} mm^{-1} was obtained for I_3S_1 treatment. Therefore, determination of suitable irrigation interval through saline water for soybean growth is very vital for achieving sustainability in grain production and soil quality in a semi-arid environment.*

Keywords: *Irrigation, Grain yield, Salinity, Sustainability, Water use efficiency*

1. INTRODUCTION

Field drainage water, urban wastewater, domestic gray water and saline water are reused and recycled for irrigation in many parts of the world. When saline water is used, several factors have to be considered: plant tolerance, irrigation system, water management strategies, irrigation intervals and soil properties. Because of increasing world population and thereafter increasing demand for food, use of fresh water resources has increased [1]. On the other hand, the world's fresh water resources are limited; that forced farmers to use low quality waters. It is well known that due to high concentrations of soluble salts, the use of such waters may result not only in the decrease of crop yield, but also in the reduction in soil water infiltration capacity (e.g., [2, 3]. A variety of strategies have been adopted to overcome problems associated with soil salinity, including improving the productivity of saline soils mainly through leaching of excess soluble salts, blending and reusing of saline drainage waters, selecting of tolerant varieties of suitable crops, and using appropriate agronomic practices [4]. Adoption of suitable salinity control measures requires determination of salt and water movement through the soil profile and prediction of crop response to soil water and soil salinity, subject to various climatic, edaphic, and agronomic factors [5]. In Iran, besides water scarcity, water quality is deteriorating and water salinity is increasing due to uncontrolled discharges of untreated or poorly treated wastewater, over-abstraction of the aquifers, and the excessive use of fertilizers in agriculture. About 12% of Iran's surface waters are saline; so the role of saline and brackish waters in the future would be undeniable [6]. Keeping this in view, soybean production is very important in the Golestan province, which more than of 50 percent of total soybean production in Iran producing in this province. Therefore, determination of suitable irrigation interval through saline water for soybean growth is very vital for achieving sustainability in grain production and soil quality in a semi-arid environment.

2. MATERIALS AND METHODS

Field experiment was conducted at the Asrieh field, GorganCity, Golestan province (Under Caspian Sea) during summer seasons of 2012. The experimental farm is located in36° 51' N latitude and 54º 29' E longitudes with an average elevation of 86m above mean sea level.The experiment was planned in randomized complete block design (RCBD) having three irrigation intervals *viz.*7 days (I_1), 10 day (I_2) and 13 day (I_3) as main plots and three saline water levels (*viz.* non saline, S_1; 4 dsm^{-1}(S_2) and 7 ds/m (S_3) as sub plots with three replications.Soybean cultivar Williams was sown in five rows within each plot of 2.5m × 3m size and the replications were separated by 2 m. The furrows were 45 cm apart with plant spacing of 10cm in each furrow. Saline water was prepared by mixing fresh water with sodium chloride salt. Same amount of irrigation water were applied for each treatment during the growing period. At the beginning of the growing period, all treatments were irrigated with fresh water. Soil samples were taken at initial condition at depths of 0-20, 20-40, 40-60 and 60-90 cm. Soil samples were analyzed to study the soil texture, soil moisture content, soil electrical conductivity, soil pH, Ca^{2+}, Mg^{2+}, and Na^{+}). Soil electrical conductivity was analyzed using saturation past.

(Table 1 and 2) shows the physical and chemical properties of the soil at initial condition.

Table 1: Physical properties of the soil in the experiment field

Depth (cm)	Soil particles (%)			Bulk density (g m-3)	FC (%)	PWP (%)
	Clay	Silt	Sand			
0-20	31	36	33	15	28	15
20-40	36	44	20	13	30	13
40-60	38	48	14	13	31	13
60-75	36	48	16	12	31	12

FC: Field capacity; PWP: Permanent wilting point

Table 2: Chemical properties of the soil in the experiment field

Depth (cm)	EC (ds/m)	pH	SAR	Cations (meq L-1)		ESP
				Na+	Ca2++Mg2+	
0-20	1.21	7.35	4.81	9.2	7.32	3.78
20-40	1.36	7.35	4.97	10.3	8.60	3.9
40-60	1.42	7.35	5.18	10.9	8.86	4.06
60-90	1.43	7.35	5.23	10.8	8.84	4.1

Irrigation water depths indicated by the soil moisture deficit (SMD) in each treatment was calculated using soil moisture content before irrigation and the root zone depth of the plant, using the Eq. (1)

$$dn=\sum_{i=1}^{n}(\Theta_{fc}-\Theta_{i})\times D_i \times B_d \quad (1)$$

Where:

dn:is the net irrigation water depth (mm), θ_{fC}:Soil water content at field capacity,θ_i: Soil water content before irrigation (weight basis in %), D_i: Depth of root development in each soil layer (mm), B_d: Bulk density of the given soil layer (g cm^{-3}) and nis the number of soil layers. The dates of irrigations, in this study were determined based on the root zone soil moisture content approached 50% of total available water (TAW) and was considered as the manageable allowable deficit (MAD), which did not cause any stress to the plant. Further, the measured quantity of irrigation was applied for a depth from the existing moisture level up to the field capacity using (Eq.1) to ensure that there is no loss of water.

Crop water use efficiency (WUE) is calculated as follows [7]:

$$WUE=\frac{Y}{ET} \quad (2)$$

Where:

Y: grain yield (kg ha^{-1}), ET: crop evapotranspiration (mm), Soil moisture were measured regularly at varying soil depths of 20cm increments up to 90 cm and also before and after irrigation treatments to measure the parameters required for estimation of actual crop evapotranspiration (ETc, mm d^{-1}) using Eq.3.

$$ETc=\frac{(I+P-D)+\sum_{i=1}^{n}(\theta_1-\theta_2)\Delta S}{\Delta t} \quad (3)$$

Where: I, P and D, are irrigation, precipitation and deep percolation from the bottom of root zone (mm), n the number of layers, ΔS is the thickness of each soil layer (mm), θ_1 and θ_2 are the volumetric soil water content (cm^{-3} cm^{-3}) 24 hr after and before next irrigation, and Δt is the time interval between two consecutive measurement (day).The furrows in the experimental plots were closed by bunds and the water table depth was below 4m from the ground surface. Therefore, the surface runoff and the vertical upward seepage or the capillary flow to the root zone was assumed negligible in the calculation of ETc using Eq. 4. Besides this, the drainage below root zone, after a number of soil-water content measurements, was considered to be negligible. So the Eq.3 was reduced to:

$$ET = I + P \pm \Delta s \quad (4)$$

The field water budgeting as mentioned above is commonly used to measure total actual water use or crop evapotranspiration (ETc) when lysimeter facilities are not available [8].

3. RESULTS AND DISCUSSION

Grain Yield of soybean

Analysis of variance for the design was carried out for the parameters studied following the standard procedures applicable to randomized complete block design (RCBD). When the treatment effects were found significant, mean differences were tested using Duncan's Multiple Range Test (DMRT) at 1% or 5% level of probability. Analysis of variance was computed using the MSTATC software.

Table 3: Amount of grain yield, biomass, crop water use efficiency (CWUE) and harvest index under different treatment

Irrigation Interval	Irrigation water applied (mm)	Grain yield (kg ha-1)	Biomass (kg ha-1)	Relative yield	CWUE (kg ha-1 mm-1)	HI
S1; Non saline irrigation water (control)						
I1: 7 day	490	3760	8355	1	7.67	0.44
I2: 10 day	415	3430	8075	0.91	8.26	0.42
I3: 13 day	350	3180	7540	0.85	9.08	0.42
S2; ECw= 4 ds m-1						
I1: 7 day	490	3470	7950	0.92	7.08	0.43
I2: 10 day	415	3090	7465	0.82	7.44	0.41
I3: 13 day	350	2765	6650	0.73	7.9	0.41
S3; ECw= 7 ds m-1						

I1: 7day	490	2680	6175	0.71	5.47	0.43
I2: 10 day	415	2390	5760	0.64	5.76	0.41
I3: 13 day	350	2030	4960	0.54	5.8	0.41

Measurements included: grain yield and biomass, water use efficiency, and harvest index. The results showed that soybean grain yield was significantly affected at ($P \leq 0.05$) level by irrigation interval and salinity treatments. The maximum and minimum yield was obtained at 7 day irrigation Interval (I_4) in interaction with non-saline irrigation water (S_1) and highest irrigation interval (I_3)in interaction with maximum saline water treatment (S_3) at the rate of 3760 and 2030 kg ha^{-1} respectively,(Table 3).Effect of interval irrigations on grain yield was significant which in 10 day (I_2) and 13 day (I_3) interval irrigation treatments reduced by 10.3% and 19.6% relative to 7 days interval irrigation treatment (I_1), respectively. Moreover, irrigation with saline water was significant effect on grain yield so that in (S_2) and (S_3) treatmentsdecreased by 10.1% and 31.5% than non-saline irrigation water (S_1).

Table 4*: Mean values of yield, biomass, WUE and HI in each salinity water and irrigation intervals*

Source	Grain yield t ha-1	Biomass t ha-1	WUE	HI
Irrigation water salinity, ds m-1				
S1; ECW: 1.1 ds m-1	3.46a	7.99a	8.34a	0.43a
S2; ECW: 4 ds m-1	3.11b	7.35b	7.47b	0.42a
S3; ECW: 7 ds m-1	2.37c	5.63c	5.68c	0.42a
Irrigation interval, day				
I1; Irrig. Inter.: 7 day	3.31a	7.49a	6.74c	0.43a
I1; Irrig. Int.: 10 day	2.97b	7.10b	7.16	0.41b
I1; Irrig. Int.: 13 day	2.66c	6.38c	7.6b	0.41b

*, ** are Significant in 0.05 and 0.01 probability levels and NS, not significant, respectively. †, I×N: Interaction effect of water and nitrogen

4. ABOVEGROUND BIOMASS

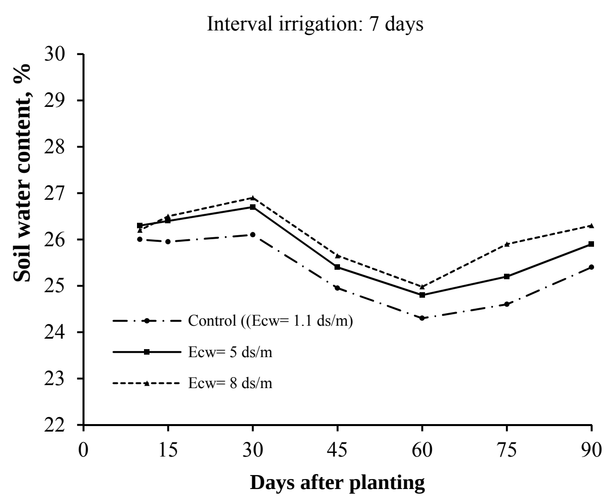
Above ground biomass was significantly affected ($P \leq 0.01$) and ($P \leq 0.05$) by different irrigation interval and salinity irrigation water (Table 6). The highest level of biomass of soybean, obtained from 7day irrigation interval treatment (I_1) under non-saline irrigation water (S_1) was 8.35 t ha^{-1} and the lowest, obtained from 13day irrigation interval (I_3) treatment in interaction with poorly water quality (S_3), 4.96 t ha^{-1} (Table 4). Moreover, Effect of interval irrigation on biomass was significant which in 10 day (I_2) and 13 day (I_3) interval irrigation treatments reduced by 5.2% and 14.8% relative to 7 days interval irrigation treatment (I_1), respectively. Also, irrigation with saline water has significant effect on grain yield so that in (S_2) and (S_3) treatments decreased by 8% and 29.5% than non-saline irrigation water (S_1).

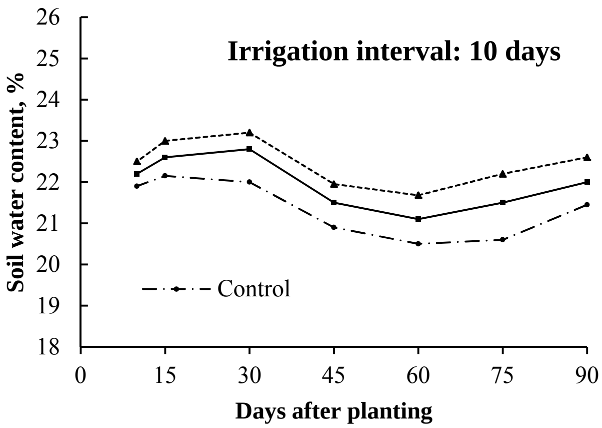
5. WATER USE EFFICIENCY

Water use efficiency (WUE) ranged from a minimum of 5.47 kg $ha^{-1}mm^{-1}$ to a maximum of 9.08 kg $ha^{-1}mm^{-1}$. Water use efficiency for 13 day irrigation interval (I_3) under non-saline irrigation water (S_1) treatment was the highest, whereas that for 7 day irrigation interval (I_1)treatment under high salinity water (S_3) was the lowest (Table 4). The maximum water use efficiency was obtained under non-saline irrigation water (S_1) for all irrigation intervalstreatments. The cumulative actual ET represented the total crop water requirement pertaining to different treatments as shown in Table 3 including the irrigation depths. However, the slope of fitted trend line representing the yield and biomass with respect to ET_a were ($7.3 < slope < 18.3$). Higher slope during the year 2012 was due to the effect of three irrigations during different crop growth stages. Moreover, the variation in use of water during crop growth period ranged from a minimum of 350 mm to a maximum of 495 mm.

Soil Moisture Content

The soil moisture content status depended on the irrigation intervals and salinity levels of irrigation water. Irrespective of the irrigation intervals, the gravimetric soil moisture content (θ_m) of the treatments irrigated with fresh water (control) was lower than that under different levels of saline water irrigation (Fig. 1). This explains the potential of plant to uptake much water under fresh water irrigation without water stress. [9]Found that, tomato plants irrigated withsaline water transpire less water than when fresh water is used. [10] Indicated that, irrespective of irrigation interval, the volumetric soil moisture under saline water treatment was higher than that under good quality water treatments.





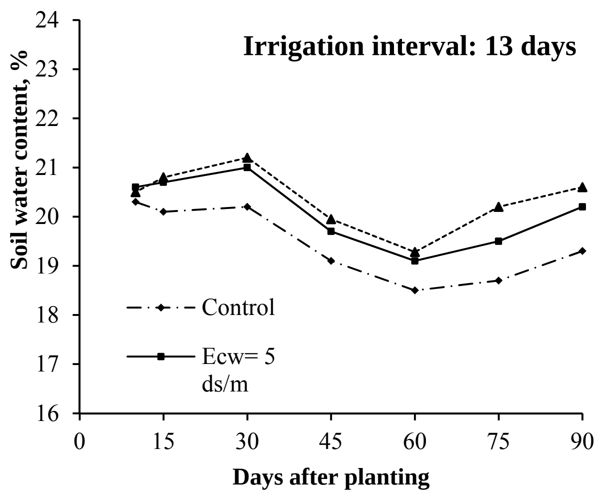


Fig. 1: Impact of saline water irrigation and irrigation intervals on soil moisture content during the growing period at depth of 0 - 30 cm

6. CONCLUSION

It was concluded from study that the soybean grain yield and above ground biomass were significantly affected by irrigation interval and salinity applied during the course of the growing season in 2012. Grain yield and biomass ranged from 2030 and 4960 kg ha^{-1} in 13day interval irrigation treatment (I_3) in interaction of highest saline water (S_3: 7dsm^{-1}) to 3760 and 8355 kg ha^{-1} in lowest irrigation interval (I_1: 7 day) in interaction with non-saline irrigation water (S_1). Water use efficiency (WUE) ranged from a minimum of 5.8 kg ha^{-1}mm^{-1} to a maximum of 9.08 kg ha^{-1}mm^{-1}. Water use efficiency for 13 day irrigation interval (I_3) under non-saline water (S_1) treatment was the highest, whereas that for 13 day irrigation interval (I_3)treatment under high salinity level (S_3) was the lowest. Accordingly, when highly saline water is used for irrigation, it is recommended to use short irrigation interval (7 day interval) instead of applying irrigation every 10 or 13day as it is practiced by the farmers. However, the short irrigation interval practice normally reduces the plant stress under saline irrigation.

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