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Maximize faba bean production under water salinity and water deficit conditions

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ABSTRACT

Conservation of water is prerequisite for prospective and high production of crop; therefore this work was carried out to investigate the effect of irrigation water salinity deficit irrigation (90 and 75 % from evapotranspiration, ET) and on faba beans (*Vicia faba* L. Giza 46) growth characters, yield components and water crop productivity during two consecutive winter growing seasons of 2015/2016 at Research and Production Station, National Research Centre, El-Nubaria District, El-Beheara Governorate, Egypt. Enhancement of protein seeds was more pronounced issue not only in the present, but also in the future, especially with increasing population and increase food demand. Faba bean is one of the most important foods used in Egypt. Whereas, the coincidence of drought, water shortage and poor soil and water loss is the challenge in crop production under salinity conditions. Results reveal that the examined irrigation treatment effect on the components i.e. plant height, numbers of branches per plant, leaves number and leaf area under irrigation water salinity. Results showed that deficit irrigation management and irrigation water salinity have a significant effect on growth faba bean characters and irrigation water salinity have the highest biological yield and pod yield compared with control. Results indicated that the importance of water deficit for good yield and better utilization of water. The irrigation water applied at specific water deficit, which meet the crop demand and fertilizers used the lower amounts of water than irrigation water salinity. Irrigation water use efficiency of water stress treatments were higher and differed regarding to the water salinity treatments in the growth season ($P<0.05$). However, the irrigation water use efficiency did differ significantly for deficit irrigation and water salinity interactions. The deficit-irrigated treatments produced higher WUE in comparison to full-irrigated in all treatments accepted T3 but not reached to significant in growth season. Increased water deficit from 90 till 60 % associated with decrease in WUE from 3.54 to 2.68 and from 3.44 to 2.41 kg m^{-3}at the first season and from 3.67 to 2.25 and from 3.67 to 2.65 kg m^{-3} for the second one for fresh and saline irrigation water. Also, the reduction percentage in WUE for the 1st season (9%) was higher than the second one (8%). .It can also be deduced from the results of the percentage difference in water use efficiency compared between irrigation treatments**.** Faba bean yield ranged from 1216 to 1590 kg/fed at 60 and 90% ETo under saline and fresh irrigation water salinity, respectively. Same trend was attained for crude protein content. Also, increase water salinity from 0.68 to 2.45 dS/m lead to reduced yield and WUE from 1450 to 1319 and from 29.57 %, respectively with reduction percentage 9 % for both.

Key words: Water salinity, water deficit, loamy sand, faba bean, plant growth, yield component, WUE.

Introduction

Drought is one of the vital environmental stresses, which affect directly on the agriculture production, especially under semiarid regions which consider as a consequence of global climate change and water use for agriculture is reduced. Also, it is severely detrimental to the growth and yield of agricultural crops from side and from the other side is not seriously detrimental to yield and could result in increased yield (Nautiyal *et al.,* 1999). Deficit irrigation is an irrigation requirement that can be applied by different application methods. The correct application of deficit irrigation

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requires thorough understanding of the yield response to water deficit (English, 1990), however, homogenous root system may improve a plants ability to continue growth during drought.

Water salinity is reliable source of water even in drought areas. It provides a unique and viable opportunity to augment traditional water supplies (Asano, 2002). The arid and semiarid areas of the world can easily augment 15 to 20% of their water supply through reuse of wastewater, however, water recycling and reuse is expanding rapidly throughout the world. Rough estimates indicate that at least 20 million hectares in 50 countries are irrigated with wastewater (Hussain *et al*., 2001). Thus the necessity of saline irrigation water has been realized and recognized worldwide resulting in increased expansion of saline water irrigation programmers. Maximized use of store soil water, increased biomass productivity per unit water use and highest productivity into economic yield under limited-water conditions are the principal goals of drought research (Krishnamurthy *et al*., 2007), where Abdelhamid *et al*. (2013) mentioned to the importance of existing soil organic matter not only as absorb soil water and supply the plants by needed moisture but also could release some of macro, micronutrients for plant needed and/or keep them from losing by leaching.

Faba bean is considered one of the most important crops which thrive in the newly reclaimed sandy soils as a leguminous crop of high nutritive value. Addition of fertilizers is necessary to increase soil fertility by supplying nutrients needed for maximizing crop production (ELsheikh *et al*., 2005). Legumes are the major source of proteins not only for human but also livestock, especially in poor countries, where animal protein is expensive (Hubbell and Gerald, 2003), which is consider the main food due to it's highly protein content.

Crop productivity can be increased by the application suitable amount of water wither saline or not under specific condition (Ebtisam *et al*., 2015). Efforts throughout the world are directed towards improving the irrigation system to face the shortage of fresh water through maximizing water use efficiency, especially under drought conditions. So, the objective of this study is to determine the effect of irrigation water salinity on the yield and yield characters of faba bean under different deficit irrigation treatments.

Material and Methods

Field experiments were carried out in two winter successive growing seasons (2015/2016) at Research and Production Station, National Research Centre, El-Nubaria, El-Beheara Governorate, Egypt, to examine the effect of irrigation water salinity on faba bean growth and yield components under deficit irrigation.

Soil texture is loamy sand. Soil reaction (pH) and electrical conductivity were measured *by Hanna* Instruments HI 2550 pH/ORP/EC/TDS/NaClBenchtop Meter,$CaCO_3$ after Soil Survey Division Staff (1993), organic matter, total nitrogen and extractable P (21 ppm) in soil were determined after (Rebecca, 2004). Soil water retention at 0.1 (Field capacity) and 15.0 (Wilting point) bars were estimated after (Klute, 1986). Soil available water was calculated by subtracting FC – WP.

Table 1: Some physical and chemical properties of the soil and irrigation water used in experiment.

Chemical characters	EC (dSm^{-1})	pH	Soluble cations and anions (meq/l)							$CaCO_3$	OM
			$Ca+Mg^{2+}$	Na^+	K^+	$CO^{=}_3$	HCO^-_3	Cl^-	$SO^{=}4$	%	
Soil	3.87	7.86	17.1	21.4	0.2	0	2.15	25.8	10.8	4.5	1.25
Irrigation water											
Saline water	2.45	7.58	11.6	12.7	0.2	0	1.05	5.2	1.4	SAR	5.27
Fresh water	0.68	7.62	3.2	3.5	0.1	0	0.75	4.8	1.2	SAR	2.77

Experimental design was in a split plot arrangement with three replicates. Irrigation water salinity (0.68 and 2.45 dS/m) was placed in main plots and irrigation deficit treatments are distributed in submain plots at rate of ET (90, 75 and 60 %ET). Plant distances were 0.25 m apart; 0.90 m among rows with total length of lateral 30 m. Sub-Plot area was 30 m length × 6 laterals, with total area of 180 m^2. One lateral was lifted between each two irrigation treatments as a protected area. Agriculture practices of faba bean cultivation were carried out regarding to recommendations of the Ministry of Agriculture.

Experimental soil was treated by the FYM rates (10 m3/fed) and well ploughed till 25 cm with 150 kg/fed of superphosphate (15 % P_2O_5) and 50 kg /fed potassium sulphate (50 % K_2O). Seeds of the faba beans (*Vicia faba* L. Giza 46) inoculated by rhizobia and sown by hand (2-3 seeds per hole) on mid-November 2015and 2016, at rate 72 kg/fed. The experiment was drip irrigated. Ammonium sulphate at 48 kg /fed was applied through irrigation system in 4 doses after 12 from sowing and each 15 days. Flowering stage started 8 weeks after planting date and lasted 31 days. Faba bean plants were harvested after 142 days and irrigation was stopped 15 days before. Total calculated 601.4 and 458.6 m^3/fed for 90 , 75 and 60 % irrigation treatments, respectively.

Ten plants from each treatments were taken to determine some growth characters, i.e. biological weight, pods weight, seeds/pod, total seeds/plant, seeds weight; seed index, plant height, no. branch, plant weight, no. pods/plant. At harvest seed biological and economical yield (seeds) expressed in ton/fed were determined for each treatments. Plant samples were taken at harvest for measurement of dry weight of shoot, total-N, proline, and some mineral contents of shoots. Seed yield and some chemical constituents of the yielded seeds were also determined at harvest. Plant samples were oven dried (70 °C) for 48 h and total nitrogen was estimated for faba bean by Kjeldahl method, according to A.O.A.C. (2000).

Water crop productivity from irrigation unites (WCP) for seeds was calculated according to FAO (1982) as follows:

$$\text{WCP (kg/m}^3\text{)} = \frac{\text{Seed yield (kg)}}{\text{Total irrigation applied (m}^3\text{)}}$$

Data were subjected to the analysis of variance (ANOVA) allocate to the split plot in a randomized complete block design after to the procedure out- lined by (Despekhove, 1984). The significant differences (LSD) between treatments were compared with the critical difference at 5% probability level.

The soil depth of the effective root zone is increased from 0.15 m at planting to 0.40 m in flowering, pod formation and seed formation stages. At harvest time, two central rows in each plot were harvested to determining pod yield and then; seed yield per hectare was calculated. Sub sample of 10 plants was taken from each plot to measuring plant height in cm, No. of branches/plant, No., leaf area, leaves No., biological and pod yield (kg/ha). The sum of differences in soil water and applied irrigation water plus rainfall were calculated as ETa using water balance equation, assuming negligible deep percolation, groundwater contribution and runoff. Evapotranspiration (ETa) was calculated using the soil water balance method (Allen *et al*., 1998):

$$Evapotranspiration\ (ET) = P + I - D \pm \Delta W \quad \ldots\ldots (1)$$

Where P is the rainfall (mm); I is the irrigation applied to individual plots (mm); D is the deep percolation; and ΔW is the change in water storage of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored. Water productivity was calculated according to the following equation:

$$\text{Water productivity (WUE)} = Yield\ (Kg\ fed^{-1})\ /Total\ water\ applied\ (m^3) \quad \ldots\ldots (2)$$

Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.05 level (SAS, 2002).

Results and Discussion

Results presented in Table (2 and 3) reveal that the examined irrigation treatment effect on the components i.e. plant height, numbers of branches per plant, leaves number and leaf area under irrigation water salinity. These results may be due the parameters of growth components increased with increasing amount of organic fertilizers applied. This can be due to the role of soil bio mass in plant physiology and improving the quantity and quality growth characterization and could provide plants with essential elements required (Lin *et al*., 2010). The values of all the plant growth parameters were not significant among the various deficit irrigation compared with the irrigation treatments.

Table 2: Effect of water salinity, water deficit on plant growth characters of faba bean first season

Irrigation water salinity (A) dS/m	Water deficit (B) ET%	Biological weight Kg	No. of Branch	Plant height cm	Plant weight g	No. of Pods	Pods weight g	Seeds /pod	Total seeds/ plant	Seeds weight/ plant G	Seed index/ w 100 seeds
0.68	60%	547.3	11.3	97.0	261.3	23.5	286.0	3.5	84.0	165.3	71.2
	75%	593.2	12.6	103.0	292.0	25.6	301.2	4.1	93.6	198.2	75.4
	90%	878.4	14.7	114.2	308.7	26.8	569.7	4.6	125.4	302.0	79.2
	Mean	673.0	12.9	104.7	287.3	25.3	385.6	4.1	101.0	221.8	75.3
2.45	60%	477.9	8.7	95.2	241.2	23.2	236.7	3.5	76.7	134.7	70.2
	75%	524.3	11.0	97.7	246.3	24.0	278.0	4.0	81.2	164.3	71.3
	90%	654.0	14.3	101.0	253.7	25.4	400.3	4.3	108.0	219.3	72.3
	Mean	552.1	11.3	98.0	247.1	24.2	305.0	3.9	88.6	172.8	71.3
LSD%	A	15.2	1.1	0.7	98.4	20.8	0.2	14.6	30.2	2.5	1.4
	B	13.6	0.9	0.6	88.3	18.6	0.1	12.8	28.1	2.1	1.2
	AxB	18.2	1.6	1.2	101.6	23.5	0.3	15.7	33.6	3.2	1.4

Table 3: Effect of water salinity, water deficit on plant growth characters of faba bean second season.

Irrigation water salinity (A) dS/m	Water deficit (B) ET%	Biological weight Kg	No. of Branch	Plant height cm	Plant weight g	No. of Pods	Pods weight g	Seeds /pod	Total seeds/ plant	Seeds weight/ plant G	Seed index/ w 100 seeds
0.68	60%	554.2	10.4	96.5	256.4	22.4	278.4	3.4	83.2	166.2	72.1
	75%	589.1	12.5	105.4	287.8	25.8	298.3	4.2	94.1	201.2	76.5
	90%	823.1	14.3	115.2	302.4	27.1	315.2	4.6	124.8	308.7	79.4
	Mean	655.5	12.4	105.7	282.2	25.1	297.3	4.1	100.7	225.4	76.0
2.45	60%	485.2	8.5	94.2	251.3	22.1	231.5	3.5	75.2	133.2	69.4
	75%	531.3	10.8	97.5	255.7	23.7	274.6	4.1	82.3	157.4	71.8
	90%	652.1	14.1	100.2	254.1	25.7	295.3	4.4	105.4	215.3	73.2
	Mean	556.2	11.1	97.3	253.7	23.8	267.1	4.0	87.6	168.6	71.5
LSD	A	12.8	0.9	0.5	88.3	17.6	0.1	12.6	25.1	2.0	1.1
	B	14.1	1.0	0.7	91.2	20.2	NS	14.1	28.4	2.3	1.5
	AxB	15.9	1.2	1.1	92.3	21.5	0.2	14.3	30.6	2.7	1.6

Results showed that deficit irrigation management and irrigation water salinity have a significant effect ($P < 0.05$) on growth faba bean characters (Table 2 and 3) and irrigation water salinity have the highest biological yield and pod yield compared with control. While the biological yield and pod yield increased. By studying the effect of drought stress on peanut, Vorasoot *et al*. (2003) and El- Boraie *et al*. (2009) concluded that under stress condition, the yield was decreased. And these effects might be due to that in organic fertilizers system a set of soil microorganisms, processing the ability of mobilizing the unavailable forms of nutrient element to available forms has been successfully.

No dough that increased salinity of irrigation water associated with dramatically decrease of the faba bean plant and yield characters (biological weight, no. of branch, plant height, plant weight, no. of pods/plant ,pods weight, seeds/pod, total seeds/plant, seeds weight/plant and seed index), where the reduction percentage were 18, 12, 6, 14, 4, 21, 5, 12, 22; 5 % for the first season and 15, 10, 8, 10, 5, 10, 2, 13, 25; 6 for the seasons relative comparing saline irrigation water with fresh one. Whereas, those plant growth and yield characters under water deficit at 60 and 75 % on base of ETo relative to the control (90 % ETo) had a negative effect with reduction percentage 33, 31, 11, 11, 46, 21, 31, 42, 7% and 27, 19, 7, 4, 50, 9, 25, 30; 3% under 60 and 75 % water deficit, respectively for the first growing season in same sequences. While the values were 30, 33, 11, 9, 16, 16, 23, 31, 43, 7 and 24, 18, 6, 2, 6, 6, 8, 23, 32, 3%in at the second growing season, in same sequence. Root traits associated with drought tolerance are important for drought resistant mechanisms of plant. Root characteristics such as root length density, rooting depth and root distribution have been established as constituting factor of drought resistance (Matsui and Singh, 2003).

Also, results indicated that, irrigation water use efficiency (WUE) were presented in (Table 4 and Fig.1), indicated the importance of water deficit for good yield and better utilization of water, this can be attributed mainly to sufficient and homogeneity moisture distribution in root zone in improving

crop resistance to water stress (Abdelhamid *et al*., 2013 and Rahimizadeh *et al*., 2007). The irrigation water applied at specific water deficit, which meet the crop demand and fertilizers used the lower amounts of water than irrigation water salinity. Irrigation water use efficiency of water stress treatments were higher and differed regarding to the water salinity treatments in the growth season ($P<0.05$). However, the irrigation water use efficiency did differ significantly for deficit irrigation and water salinity interactions. The deficit-irrigated treatments produced higher WUE in comparison to full-irrigated in all treatments accepted but not reached to significant in growth season.

Table 4: Effect of water salinity, water deficit on yield, water use efficiency and crude protein of faba bean

Irrigation water salinity (A) dS/m	Water deficit (B) %ET	First season			Second season		
		Yield kg/fed	WUE Kg/m3irrig	Crude protein content (%)	Yield kg/fed	WUE Kg/m^3 irrig.	Crude protein (%)
0.68	60	1350	3.68	27.8	1355.2	3.69	27.8
	75	1411	3.08	29.7	1422.3	3.10	29.7
	90	1590	2.64	31.2	1588.2	2.64	31.2
	Mean	1450	3.13	29.6	1455.2	3.15	29.57
2.45	60	1216	3.31	27.4	1230.4	3.35	27.4
	75	1286	2.80	26.3	1290.1	2.81	26.3
	90	1456	2.42	26.6	1445.3	2.40	26.6
	Mean	1319	2.85	26.8	1321.9	2.86	26.77
LSD 5%	A	345	0.45	1.2	164	0.54	1.23
	B	367	0.61	1.4	172.1	0.58	1.31
	AxB	377	0.63	1.5	176.2	0.61	1.41

One can notice that increased water deficit from 90 till 60 % associated with increase in WUE from 2.64 to 3.68 and from 2.44 to 3.31 kg m^{-3}at the first season and from 2.64 to 3.69 and from 2.40 to 3.35 kg m^{-3} for the second one for fresh and saline irrigation water. Also, the reduction percentage in WUE for the 1st season (9%) was higher than the second one (8%).

Regarding to the effect of the deficit irrigation treatment, values of WUE were b2.25, 2.94; 3.49 and 2.45, 2.96; 3.52 kg m^{-3} with reduction percentage 16, 11 and 15, 11 % for 60 and 75 % relative to the 90 %ET for the first and second seasons, respectively .It can also be deduced from the results of the percentage difference in water use efficiency compared between irrigation treatments. Songsri *et al*. (2009) showed that drought stress play an important role in a reduction of efficiency of seeds water consumptive under unstressed condition. Also, Rucker *et al*. (1995) reported that a large root system may improve a plants ability to continue growth during drought stress.

Faba bean yield ranged from 1216 to 1590 kg/fed at 60 and 90% ETo under saline and fresh irrigation water salinity, respectively. Same trend was attained for crude protein content. Also, increase water salinity from 0.68 to 2.45 dS/m lead to reduced yield and WUE from 1450 to 1319 and from 29.57 %, respectively with reduction percentage 9 % for both.

With respect to the water deficit effect on the yield and crude protein content, data notice that, there a reduction after water deficit treatments 90 , 75 and 60% on base of ETo associated with a reduction percentage by 11, 16 and 3, 4 % for both seasons , respectively for yield and crude protein content, respectively.

Regarding to the seeds content of N, P and K as affected by water salinity and water deficit treatments (Table 5). Data on hand revealed that negative effect was observed resulted from decreased water deficit and increase water salinity. The highest values were observed after fresh water and 90 % ETo water deficit treatment. Also, N, P and K content in seeds was higher under fresh water than saline ones, with increase percentage 6, 1, 1 % and 4, 5, 2 %, respectively for the 1st and 2nd seasons. While trend of the water deficit was clear observed in the 1st season that was high than the 2nd ones, with no significant differences among them.

The reduction percentage in N, P and K content in faba bean seeds were 6, 1, 1 for the first season and 4, 5 and 2% for the second season as affected by increased water salinity, respectively. Also, the values of the N, P and K content in water deficit treatments were higher in the first season than the second one. The values of the of the N, P and K content decreased with increased water

deficit from 90 to 75 and 60 % ETo. The reduction percentage was 0.16, 0.16, 0.04 and 0.11, 0.11, 0.0 for the first season and 0.15, 0.08, 0.08 and 0.11, 0.03 and 0.05 % for 60 and 75 % relative to the 90 %ETo, respectively. In this respect, it is worthy mention that the major problem facing grain legumes production in Egypt northern governorates is synchronizing of inadequate rainfall incidences during the most drought susceptible stage of growth and development. Most studies on grain legumes for improving yield confirmed that pod development and seed filling stages were the most droughts sensitive (El-Hamadany, 2005 and Attia and Bersoum, 2013). Negative correlation between the morphological traits and the drought tolerance in faba bean. Drought is an important environmental factor, which induces significant alterations in plant physiology and biochemistry. Some plants exhibit a number of physiological adaptations that allow them to tolerate water stress conditions (Abdellatif *et al*., 2012).

Table 5: Effect of water salinity, water deficit on N, P, and K content of faba bean

Irrigation water salinity (A) dS/m	Water deficit (B) %ET	First season			Second season		
		N	P	K	N	P	K
		%					
0.68	60	0.57	0.093	0.812	0.55	0.094	0.822
	75	0.61	0.095	0.857	0.63	0.095	0.855
	90	0.69	0.098	0.929	0.69	0.097	0.946
	Mean	0.62	0.10	0.87	0.62	0.10	0.874
2.45	60	0.55	0.089	0.842	0.52	0.089	0.842
	75	0.57	0.096	0.851	0.61	0.091	0.866
	90	0.63	0.099	0.873	0.67	0.093	0.874
	Mean	0.58	0.09	0.86	0.60	0.09	0.861
LSD5%	A	342	0.41	1.1	160	0.50	1.19
	B	365	0.54	1.3	166.1	0.54	1.41
	AxB	378	0.73	1.4	171.2	0.61	1.51

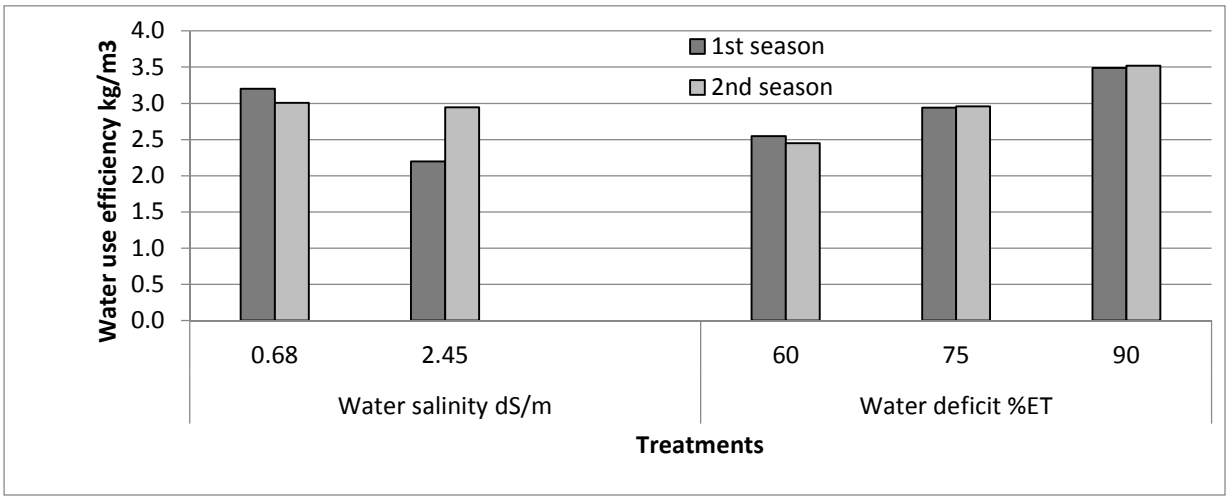

Fig. 1: Effect of water salinity and water deficit on water use efficiency of faba bean

Conclusion

Irrigation water salinity treatment did not affect to somewhat on the faba bean yield characters compared with control. Also, deficit irrigation treatments could be useful to obtain the most suitable yield characters of faba bean under experiment condition. The most sensitive to water stress, therefore we must not cut irrigation in this stage, but the interaction between deficit irrigation under water stress conditions to obtain the optimum seeds yield of faba bean.

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