Egypt. J. Soil Sci. **Vol. 57,** No. 3, pp. 261 - 271 (2017

Deficit Irrigation Management as Strategy to Adapt Water Scarcity – Potential Application on Mediterranean Saline Soils

M. S. D. Abu-Hashim* **and K. A. Shaban***
**Soil Science Dept, Faculty of Agriculture, Zagazig Univ., Zagazig and **Soil, Water & Environmental Research Institute, Agric. Res. Centre, Giza, Egypt.*

WATER plays an essential role in yield productivity; however in the near future it is likely that many regions in the world will face water scarcity periods. Improving irrigation management can help adapting to water scarcity in the Mediterranean regions. Field experiments to assess the effects of different irrigation water amounts on yield and soil nutrients were carried out during two successive winter seasons 2012/13 and 2013/14 , respectively on high saline soils at Sahl El-Tina, North Sinai, Egypt. Three irrigation treatments with 3600m^3/ha (W1), 6000 m^3/ha (W2), and 7200 m^3/ha (W3, normal irrigation) from the El-Salam Canal were applied in a complete randomized block design, using faba bean (Saka-3, *Vicia faba L.*) as test crop. Soil salinity decreased with increasing water supply regimes by an average of 33%, 37%, and 48% for W1, W2, and W3, respectively compared to the initial soil salinity. The solute concentrations of the irrigation water change within the season from the analysed ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, $HCO3^-$, SO_4^{2-}), only magnesium, sodium, hydrogen carbonate, chloride and sulfate varied significantly during the year. Soil nutrients showed a descending order with increasing water stress. Nevertheless, the water use efficiency (WUE) showed another effect. Water regime W1 saves 50% of the supplied water and resulted in a WUE of 2.36 kg/m^3 compared to W2 and W3 with 1.75 kg/m^3 and 1.39 kg/m^3, respectively. This expressed the great potential of deficit irrigation to save water, while producing stable yields and reducing soil salinization.

Keywords: Water use efficiency, Soil salinity, Water stress , Soil nutrients, Deficit irrigation

Introduction

Increased competition of agriculture and other sectors for water resources requires efficient management of irrigation which allows water saving and maintain relevant levels of production in semi-arid regions (Costa *et al*., 2007). With water scarcity, national policies encourage the reuse agricultural drainage water for irrigation. Due to this reason, the solute concentration of the irrigation changes within seasons. The water quality as well as the soil nutrient status needs to be monitored in order to avoid soil salinization (Sallam *et al*., 2014). Optimization of irrigation is essential to maintain efficient crop production, especially in arid and semi-arid regions.

For the areas of long summer droughts and fresh water scarcity, Sahl El-Tina, North Sinai, at the Mediterranean (Fig. 1), efficient management of irrigation is important and deficit irrigation is extremely recommended for mitigating the severe yield reductions and secure low yield level (Kirda *et al*., 2004). Water use efficiency (WUE) is a parameter by which the efficiency of irrigation water in crop production is assessed. It may be expressed as the amount of crop yield (kg) produced by 1 m^3 of irrigation water (Bos, 1985). Deficit irrigation (DI) is an approach to enhance the water use efficiency (Topcus *et al*., 2007 and Bandyopadhyay *et al*., 2014). It is done by irrigating the crop with lower amount of water than the amount required for evapo-transpiration (Dorji *et al*., 2005). Marouelli and Silva (2007) reported that appropriate DI depends upon the type of soil, crop, and environmental conditions. While water stress would have adverse effect

DOI :10.21608/ejss.2017.4162

on crop biomass, tillering ability, growth and yield, the development of water saving strategy is important to find the most representative combination between acceptable yield and water use (Pereira *et al*., 2002). Alderfasi and Alghamdi (2010) irrigated faba beans using 75% of the field capacity (FC) which resulted in elevated plant heights, large numbers of plant branches, number of seeds and seed yield/ha. Nevertheless, Hirich et al. (2012) applied 50 % FC to faba beans and obtained high WUE that enhanced crop productivity. In addition, low soil water moisture decrease availability of water to plant as well as the diffusion rate of nutrients to plant roots (Marschner, 1986) and marked an obvious decrease of plant nutrient uptake.

The objective of the current study is to determine the effect of water supply regimes on soil nutrients and their distributions through the growth seasons under high saline soil conditions in a semi-arid Mediterranean regions and the effect on the crop yield and water use efficiency of faba bean in this environment.

Material and Methods

Experimental site

The trials were carried out at the experimental farm of Gellbana Village in Sahl El-Tina (Fig. 2) in North Sinai Governorate (31˚00 N and 32˚30 E) during two seasons of 2012/2013 and 2013/2014, respectively.

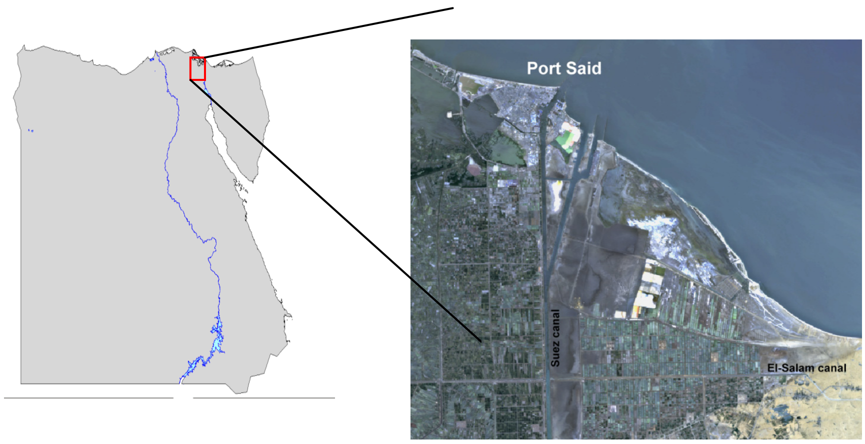


Fig.1 Port Said and the El-Salam Canal, Landsat-8 imagery from 19th of June 2014. Source: USGS.

Fig. 2. Experimental location of Gellbana village in Sahl El-Tina, North Sinai, Landsat-8 imagery from 19*th* of June 2014. Source: USGS.

This region has a continental climate with hot dry summers (Table 1). The climatological conditions of Sahl El-Tina reveal representative impact in controlling the ecology characteristics in arid regions. That show extreme aridity with long hot rainless summer and mild winters. The lowest temperature is December and January (15.3 C° and 14.6 C°), and the maximum amount of precipitation is 31.75 mm in January. In addition, the average of relative humidity and wind speed was 75.8%, and 15.64 Km.h^{-1}, respectively (Table 1). The data were collected from the meteorological station of Port Said/El Gamil, 2012-2013 (31˚28 N and 32˚23 E).

The soil is a slightly alkaline (pH 8.2) sandy loam with an organic matter content of 0.44 g.kg^{-1} and a $CaCO_3$ content of 6.90 g.kg^{-1}, respectively. The electric conductivity (EC) of the soil is 10.2 dS.m^{-1}, which is highly saline. The initial nutrients and physico-chemical properties of the soils have been analysed according to Baruah and Barthakur (1997) before the experiment. Table 2 gives an overview on the physico-chemical soil properties.

Experimental design

The experiment was laid out as a randomized complete block design with three replications. Faba bean (*Vicia faba L., cultivar* Sakha-3) was used as test crop through the experiment. Three irrigation amounts were used ; 3600, 6000, and 7200 m^3.ha^{-1} designed as W1, W2, and W3, respectively (with W3 being the amount used by the farmers in this region). Measurements of soil salinity and other parameters were done on the occasions: October, December, January, and March, designated as M1, M2, M3, and M4, respectively. The irrigation design was surface flow irrigation through line pipes performed with meter gages for controlling the amount of water supplied. In order to alleviate the soil salinity on germination, irrigation was done for duration of 4 and 7 hr in days 1 and 2, respectively following seeding. The following irrigations were done at intervals of 10 days. Seeding was done on November 25th and 28th in the first and second seasons, respectively. Each experimental plot composed of six ridges, 60 cm apart, 5 m wide, and 10 m in length (Fig. 3).

TABLE1. Meteorological data from Port Said/El Gamil station for the study area (2013).

Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. ºC	14.6	16.1	18.3	19.2	23.3	25.8	26.9	27.9	26.6	23.7	21.6	15.3
Rain mm	31.8	5.08	0	0	9.91	0	0	0	0	0	0.25	17.0
Wind speed km^{-1}	15.4	15.5	18.1	18.3	15.6	15.3	16.5	14.3	14.9	16.7	13.0	14.1

TABLE 2. Selected initial chemical properties of the soil at the test site Gellbana.

Macro- and Micro-Nutrients	N	P	K	Fe	Mn	Zn	
[mg/kg]	45.0	4.25	178.0	1.39	3.43	0.81	
Soluble ions	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
[mmolc/L]	79.6	0.93	8.83	12.9	70.0	5.33	27.0

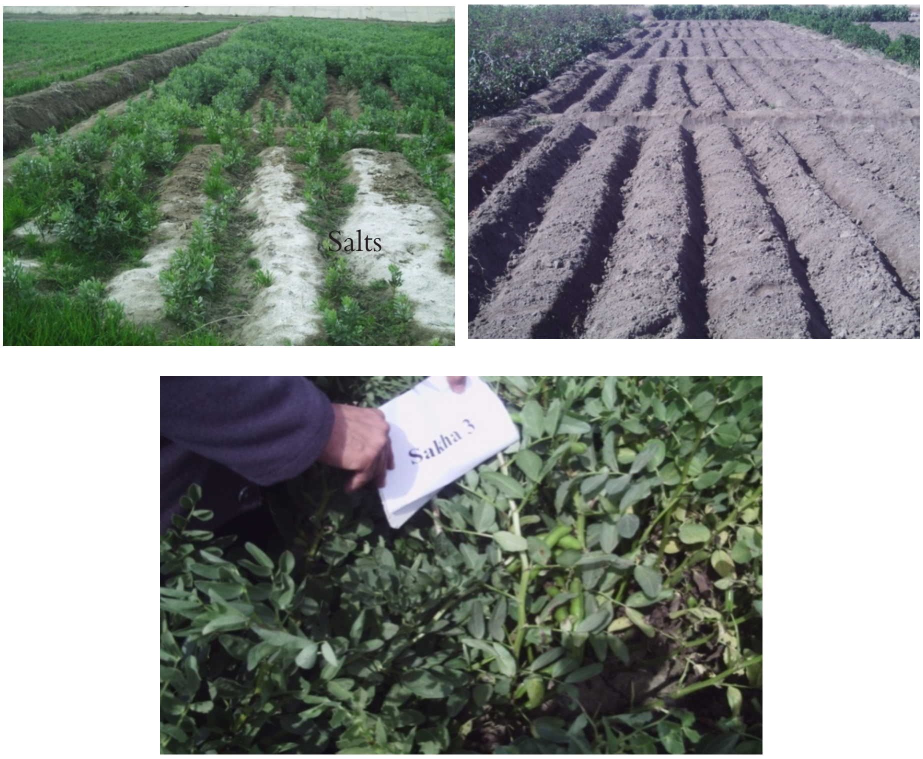


Fig. 3. Experimental plots and growth of faba bean under salinity conditions at Sahl El-Tina.

Seeding was done on one side of the ridge at a rate of 3 seeds per hill with 20 cm between hills. One plant per hill was maintained by thinning 35 days after seeding. Fertilizers N, P, and K were applied at rates of 22, 20, and 50 Kg N, P, and K per hectare as urea (460 g N kg^{-1}), ordinary superphosphate (68 g P kg^{-1}), and potassium sulphate (400g K kg^{-1}). Fertilizer P was given during soil preparation while N was given in 2 equal splits 21 and 45 days after seeding. At maturing (mid of May at both seasons), plants were harvested and weighted. Random samples of ten guarded plants from each plot were taken to estimate seed yield [$t.ha^{-1}$] and above ground biomass [$t.ha^{-1}$].

Irrigation water analysis

Representative water samples were collected from the irrigation water of the El-Salam canal during October, December, January and March for the two successive years. The irrigation water was analysed for trace elements, cations and anions according to Cottenie *et al*. (1982) and the parameters sodium adsorption ratio (SAR), adjusted sodium adsorption ratio (ASAR), and residual sodium carbonates (RSC) have been determined.

Data analysis

Differences between means were evaluated for significance using the Least Significant Differences (LSD) test, according to Sendecor and Cochran (1982). The statistical analysis was done on the consideration of a 1-factor factorial analysis.

Results and Discussion

Yield characteristics

Water irrigation amounts were associated with differences in seed and biomass yield (Table 3). The W2 gave the highest yield, and the lowest was given by W1. There was an increase in the water use efficiency (WUE) with the decrease in amount of irrigation water. Compared with the W3 treatment, the increase in WUE for W1 and W3 were 95.1 and 27.5 %, respectively regarding seed yield and 68.5 and 25.0% respectively regarding aboveground biomass.

These results are in agreement with those of Hirich *et al*. (2012) who stated that using half of the required water supply as deficit irrigation produced higher yield than applying the full irrigation. For the areas of long summer droughts and water scarcity phenomena, such Sahl El-Tina (North Sinai, Egypt), deficit irrigation could be recommended for mitigating the severe yield reductions and secure low yield level (Kirda *et al*., 2004 and Sallam *et al*., 2014).

Irrigation water characteristics

High salinity in irrigation water is a common problem in arid and semi-arid regions (Jurdi *et al*., 2001). Since the irrigation water from El-Salam canal (Nile water mixed with drainage water 1:1 ratio), the solute concentrations change within the season. From the analysed ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, $HCO3^-$, SO_4^{2-}), only Magnesium, Sodium, Hydrogen carbonate, Chloride and Sulfate varied significantly during the year. Chloride and Sulfate also show a monthly variation (Fig. 4). Among months, the solutes concentrations follow the ascending order for the next cations; Ca^{2+}, Mg^{2+}, and K^+. While Na^+ displayed another descending order among months that decreased from 6.20to 5.79 $mmol_c.L^{-1}$ and from 5.57 to be 5.26 $mmol_c.L^{-1}$ for the first and the second season, respectively. In semi-arid regions, (FAO, 2002) recommended using sodium adsorption ratio (SAR) as a parameter to evaluate the irrigation water suitability in the range of 0-15 $mmol_c.L^{-1}$.

TABLE 3. Average of seed and biomass yield, as well as water use efficiencies for seed and biomass yield in two seasons.

	Yield seed [t/ha]			Yield biomass [t/ha]			WUE yield [kg/m³]			WUE biomass [kg/m³]		
Irrigation level	12/13	13/14	Mean	12/13	13/14	Mean	12/13	13/14	Mean	12/13	12/13	Mean
W1 (3600 m³/ha)	2.84	2.87	2.86	8.39	8.56	8.48	0.79	0.80	0.80	2.33	2.38	2.36
W2 (6000 m³/ha)	3.01	3.06	3.04	10.37	10.60	10.49	0.50	0.51	0.51	1.73	1.77	1.75
W3 (7200 m³/ha)	2.86	2.93	2.90	9.87	10.04	9.96	0.40	0.41	0.41	1.37	1.40	1.40

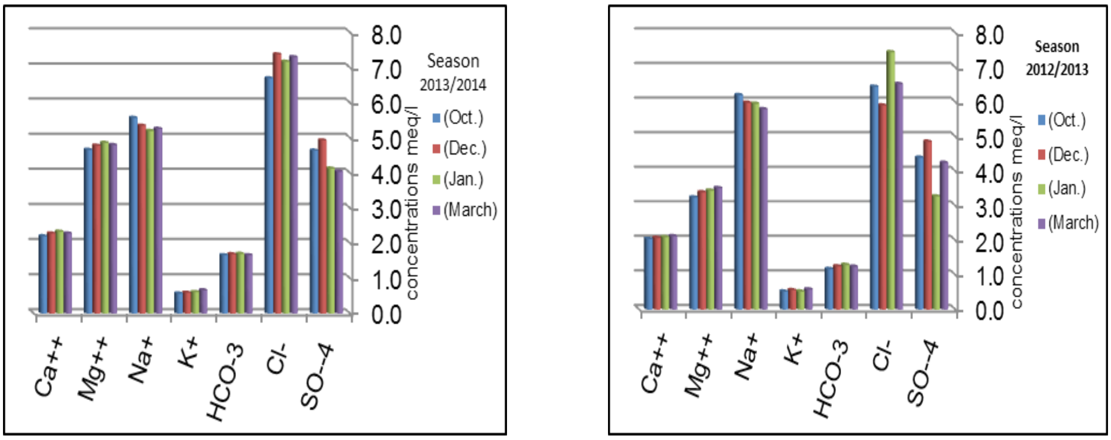


Fig. 4. Chemical parameters (meq/l) of the irrigation water of the El-Salam canal during representative months for the two successive winter seasons (2012/2013 and 2013/2014).

El-Salam canal water follows such permissible SAR limits (Table 4). Sodium adsorption ratio and adjusted Sodium adsorption ratio (adj. SAR) was highest in December. Residual sodium carbonate (RSC) was negative in each of the four sampling dates. Water pH ranged from 7.90 and 8.00. Highest salinity in water occurred in January followed by March and was lowest in October (Table 3). That is could be attributed to the Egyptian water deadline winter blockage in January, through which streams closed and amount of the water that reach to El-Salam canal would be reduced.

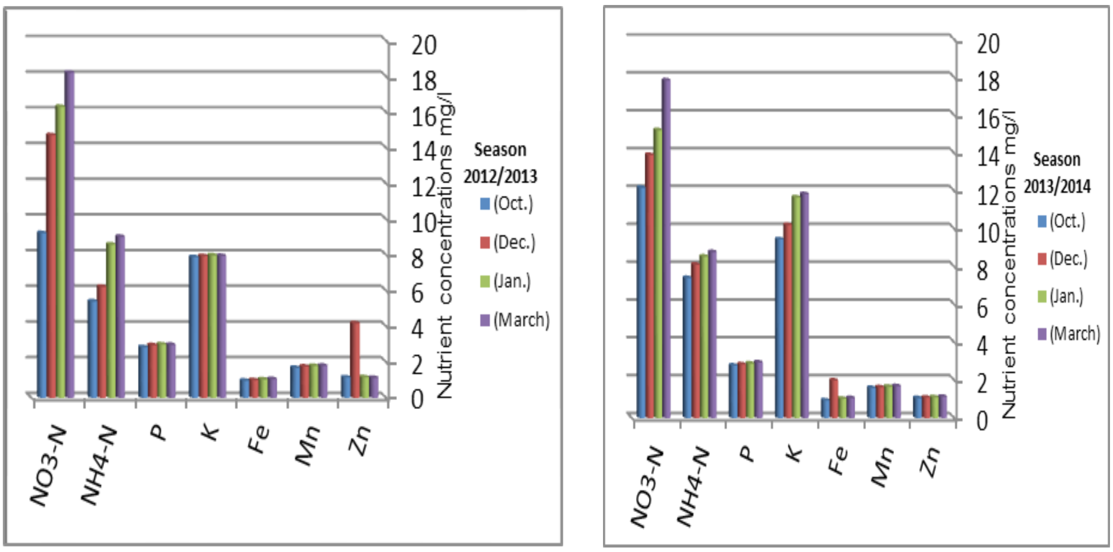
Canal elements characteristics

Contents of available nutrients followed an ascending order with time (Fig. 5); NO_3-N increased from 9.23 and 12.17 mgL^{-1} in October to 18.22 and 17.84 mgL^{-1} in March for the first and second season, respectively. NH_4-N increased from 5.40 and 7.40 mgL^{-1} in October to 9.02 and 8.77 mgL^{-1}in March for the first and second season, respectively.

The same phenomenon was observed for the phosphorus and the potassium. Regarding trace elements (Fig. 5), the highest content occurred for

TABLE 4. Water characteristics of the El-Salam canal that used for irrigation in two seasons (2012/ 2013 and 2013/ 2014).

Parameters	EC (dSm^{-1})		pH		SAR		Adj SAR		RSC	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
October	1.20	1.30	8.00	7.90	3.82	3.01	6.11	5.71	-4.11	-5.20
December	1.34	1.37	7.98	8.00	3.62	2.85	5.97	5.41	-4.21	-5.37
January	1.40	1.44	7.95	7.98	3.58	2.74	6.08	5.21	-4.24	-5.49
March	1.37	1.41	7.95	7.97	3.48	2.80	5.52	5.31	-4.39	-5.42



.Fig. 5. Nutrient concentration (mg l^{-1}) of the El-Salam Canal irrigation water

Mn (1.59-1.80 mgL^{-1}) followed by Zn (1.05-1.15 mgL^{-1}) and the lowest was Fe (0.93-1.05 mgL^{-1}). Contents of soluble N in waters of rivers and other fresh waters are usually low (Ayers & Wescot, 1994 and WHO, 2006) with ranges up to 9.02 mg L^{-1} NH_4-N and 18 mg L^{-1} NO_3-N. One of the sources of heavy metals in aquatic environment is the industrial residues, since the heavy metals are not degradable in the environment (Taylor & Shiller, 1995 and Zarazua et al., 2006). Analysis of El-Salam canal waters indicates that Fe, Zn, and Mn are within the permissible levels for irrigation (FAO, 2002). For Damietta branch, where the canal receives its water resources, (Abdo, 2004) noticed in its sediment high concentration of heavy metals that follow the order Fe>Mn>Cu>Zn>Pb>Cd. Thus waters of El-Salam canal may reach an unsafe level of heavy metals in future.

Impact of irrigation on soil nutrients

The impact of the irrigation water quantity on soil salinity and its available nutrient in the soil surface layer (0-30 cm), four days after irrigation is shown in Table 5.

The impact of water quantity on soil salinity reduction among seasons, and months reflects a

TABLE 5. Effect of different levels of irrigation supply regimes combined with the seasonal and the monthly impacts on the soil salinity (dSm^{-1}) and nutrient composition (mg kg^{-1}).

Treatment	EC	N	P	K	Fe	Mn	Zn
S1+M1+W1	8.93	62.0	4.69	180.0	2.03	3.58	0.83
S1+M1+W2	7.95	64.1	4.75	193.0	1.98	3.66	0.90
S1+M1+W3	6.52	69.8	4.89	198.0	1.96	3.70	0.92
S1+M2+W1	7.30	65.0	4.77	184.0	2.12	3.63	0.85
S1+M2+W2	6.73	67.3	4.82	197.0	2.03	3.69	0.93
S1+M2+W3	5.23	69.5	4.93	202.0	2.05	3.73	0.95
S1+M3+W1	6.95	69.7	4.80	193.0	2.06	3.75	0.88
S1+M3+W2	6.32	72.2	4.86	206.0	2.06	3.71	0.95
S1+M3+W3	5.12	74.6	4.97	208.0	2.09	3.76	0.99
S1+M4+W1	6.46	74.0	4.83	198.0	2.10	3.73	0.93
S1+M4+W2	6.20	75.6	4.88	208.0	2.08	3.74	0.98
S1+M4+W3	5.03	76.3	4.96	212.0	2.10	3.78	0.98
S2+M1+W1	7.20	60.0	4.85	195.0	2.00	3.60	0.88
S2+M1+W2	6.85	65.9	4.88	201.0	2.04	3.68	0.93
S2+M1+W3	6.10	68.3	4.92	208.0	2.06	3.73	0.95
S2+M2+W1	6.88	64.0	4.90	198.0	2.04	3.64	0.93
S2+M2+W2	5.96	68.6	4.93	206.0	2.08	3.71	0.96
S2+M2+W3	5.09	71.6	4.95	213.0	2.09	3.75	0.98
S2+M3+W1	6.20	75.0	5.00	204.0	2.08	3.67	0.96
S2+M3+W2	5.83	69.3	4.98	208.7	2.10	3.75	0.98
S2+M3+W3	4.92	75.1	4.99	216.0	2.13	3.77	1.02
S2+M4+W1	5.79	70.0	5.02	207.0	2.11	3.74	0.98
S2+M4+W2	5.40	73.1	4.91	212.0	2.13	3.78	0.99
S2+M4+W3	4.88	77.9	5.01	218.0	2.16	3.81	1.04
$LSD_{0.05}$	0.02	0.17	ns	1.48	0.03	0.04	ns

S1and S2 first and second season; M1: October, M2: December, M3: January, and M4: March; W1"irrigation with 3600 m^3/ha, W2" irrigation with 6000 m^3/ha ", and W3"Normal irrigation with 7200 m^3/ha".

significant difference at probability value $(P) \leq 0.05$ (Table 5). That treatment S1+M4+W3 is the most efficient in reducing soil salinity compared to the other treatments. Increase in available nutrients N, K, Fe, and Mn was pronounced with increasing water amount and the differences among the treatments were significant. Treatment S2+M4+W3 is the most representative in increasing N, K, Fe, and Mn, while the impact of water quantity on P and Zn among seasons, and months reflects no significant difference at $P \leq 0.05$ (Table 5). Compared with the initial soil contents of available nutrients, the soil contents following irrigation were higher (Table 6). Initial soil P value of 4.25 mg kg^{-1} increased by 14.3 %, 14.7 % and 16.5 % by W1, W2, and W3, respectively. Data in Table 6 shows changes in available nutrients and soluble salts upon using different amounts of irrigation water. Lower contents of available nutrients with low soil moisture are attributed to a decrease in diffusivity of nutrients under moisture stress (Schaff and Skogely, 1982). Zeng and Brown (2000) reported increasing of K flux in soil with increase of soil moisture. On the other hand, Hagen and Tucker (1982) attributed the decrease in Fe, Mn, and Zn availability with soil water stress to increased soil pH in soil having calcium carbonate and hence unavailable to plant roots. Low soil water availability decreases the diffusion rate of soil nutrients and/or the composition and concentration of soil solution (Marschner, 1986 and Dasgupta *et al*., 2015).

Average decrease in soil salinity was highest with using W3 and lowest with W1 (Table 6). At the beginning of the trials, the initial soil salinity for Sahl El-Tina was 10.23 dSm^{-1} (Table 1). The mean data of EC for all treatments, considering monthly and seasonal impacts show that soil salinity was relatively reduced by 46.5 % and 48.7 % for the first and second season, respectively using W3 compared to the initial soil salinity. The correlation analysis for the measured field parameters and the obtained yield in both seasons (2012/2013 and 2013/2014), reveal that the relationship of yield and the irrigation amount was positive with increasing the water supply and negative with EC (Table 7). These results are in agreement with the founding of Al-Suhaibani, (2009); Link *et al*. (2010); Alireza and Farshad, (2013) and Dasgupta *et al*. (2015).

TABLE 6. The relative change of the soil nutrients and soil salinity under different levels of deficit irrigations compared to the initial soil concentration.

Relative change	Nutrient	Initial soil		First season			Season Second season	
	W1 W2	W1	W1	W1	W1	W1	W1	W1
	N (mg kg^{-1})	45.0	50.4	55.1	61.2	49.5	53.8	62.8
	P (mg kg^{-1})	4.3	12.2	13.6	16.2	16.3	15.9	16.9
	K (mg kg^{-1})	178.0	6.1	12.9	15.2	12.9	16.3	20.1
	Zn (mg kg^{-1})	0.8	7.7	16.1	20.9	15.7	19.2	27.5
	Fe (mg kg^{-1})	1.4	49.4	46.6	47.5	47.9	50.2	51.8
	Mn (mg kg^{-1})	3.4	7.1	7.9	9.1	6.8	8.8	9.8
Decrease (%)	EC (dSm^{-1})	10.2	-27.6	-33.6	-46.5	-36.3	-41.3	-48.7

W1 "irrigation with 3600 m^3/ha, W2" irrigation with 6000 m^3/ha ", and W3"Normal irrigation with 7200 m^3/ha" 1^{st}: first season (2012/2013), 2^{nd}: is the second season (2013/2014)

TABLE 7. Correlation analysis for the measured field parameters and the obtained yield in both seasons (2012/2013 and 2013/2014).

Yield		Irrigation treatment	EC	N	P	K	Fe	Mn	Zn
Yield	1	0.885*	-0.579	0.714	0.348	0.703	0.416	0.768	0.703
Irrigation treatment		1	-0.825*	0.930**	0.529	0.787	0.507	0.939**	0.745
EC			1	-0.830*	-0.891*	-0.919**	-0.754	-0.926**	-0.877*
N				1	0.517	0.758	0.550	0.930**	0.702
P					1	0.877*	0.777	0.696	0.867*
K						1	0.866*	0.902*	0.995**
Fe							1	0.757	0.872*
Mn								1	0.863*
Zn									1

**Correlation is significant at the 0.01 level (2 tailed)
* Correlation is significant at the 0.05 level (2 tailed)

Conclusion

The production of sound yields with limited water usage is a great challenge for future agriculture. Faba bean yield is dependent on irrigation water amount, especially in semi-arid regions like North Sinai which are irrigated with water supply of mixed waters. Irrigation regimes with 50% of the amount applied by farmers gave high water use efficiency of 2.36 kg/m^3, and soil salinization was relatively decreased by 30%. Soil trace elements decreased with increasing the water stress. Thus deficit irrigation could save water that extremely important in semi-arid regions, such as North Sinai.

References

Abdo, M.H. (2004) Distribution of some chemical elements in the recent sediments of Damietta branch, River Nile, Egypt. *J. Egypt Acad. Soc. Environ. Develop*. **5**: 125-146.

Alderfasi, A.A. and Alghamdi, S.S., (2010) Integrated water supply with nutrient requirements on growth, photosyntheis productivity, chemical status and seed yield of faba bean. *Amir. Eura. J. Agron*. **3**: 8 -17.

Alireza, E. and Farshad, H. (2013) Water use efficiency variation and its components in wheat cultivars. *Am. J. Exp. Agric*. **3**, 718 – 730.

Al-Suhaibani, N.A. (2009) Influence of early water deficit on seed yield and quality of faba bean under Arid Environment of Saudi Arabia. American–Eurasian *J. Agric & Environ. Sci*. **5**, 649-654.

Ayers R.S. and Wescot, D.W. (1994) Water quality for agriculture, FAO Irrigation and Drainage Paper 29. Rome, Italy.

Bandyopadhyay, K.K., Pradhan, S., Sahoo, R.N., Ravender Singh, Gupta, V.K., Joshi, D.K. and Sutradhar A.K. (2014) Characterization of water stress and prediction of yield of wheat using spectral indices under varied water and nitrogen management practices. *Agriculture Water Management,* **146**, 1151-123.

Baruah, T.C. and Barthakur, H.P. (1997) "*Soil Analysis*" .Vikas House. New Delhi.

Bos, M.G., (1985) Summary of ICID definition of irrigation efficiency, *ICID Bull*., **34**: 28-31.

Costa, J.M., Ortuno, M.F. and Chaves, M.M., (2007) Deficit irrigation as strategy to save water:

physiology and potential application to horticulture. *Journal of Integrative Plant Biology* **49**, 1421-1434.

Cottenie, A., Verloo, M., Kikens, L., Velghe, G. and Camerlynck, R., (1982) "*Analytical Problems and Method in Chemical Plant and Soil Analysis*". Hand book A. Cottenie, (Ed.) Gent, Belgium.

Dasgupta, P., Das, B., Sen, S. (2015) Soil water potential and recoverable water stress in drought tolerant and susceptible rice varieties. *Agricultural Water Management*, **152**, 110-118.

Dorji, K., Behboudian, M.H. and Zegbe-Dominguez, J.A., (2005) Water relations, growth, yield, and fruit quality of hot pepper under deficit irrigation and partial root zone drying. *Scientia Horticulturae,* **104**, 137-149.

FAO (2002) (Food and Agriculture Organization), FAO year book; production. 55, FAO, Rome, Italy **16**, 4-6.

Hagen, J. and Tucker, B. (1982) *"Fertilization of Dry Land Irrigated Soils".* Advanced series in Agriculture science. 12. Springer Verlag, Verlin Heidelberg, New York.

Hirich, A.F., Choukr, A.R., Jacobsen, S.E., El-Youssfi, L. and El-Omari, H. (2012) Growth of faba bean as influenced by deficit irrigation with treated wastewater applied during vegetative growth stage. *International Journal of Medical and Biological Sciences,* **6**, 85-92.

Jurdi, M., KorfaliKarahagopian, S.I.Y. and Davis, B., (2001) Evaluation of water quality of the Qaraaoun reservoir, Lebanon suitability for multipurpose usage. *Environ. Monit. Assess*. **77**, 11-30.

Kirda, C., Cetin, M., Desgan, Y., Topcus, S., Kaman, H., Ekici, B., Derici, M.R. and Ozguven, A.L., (2004) Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. *Agriculture Water Management,* **69**, 191-201.

Link, W., Balko, C. and Stoddard, F.L. (2010) Winter hardiness in faba bean: physiology and breeding. *J. Field Crops Res*. **115**, 287–296.

Marouelli, W.A. and Silva, W.L.C. (2007) Water tension thresholds for processing tomatoes under drip irrigation in central Brazil. *Irrigation Science* **25**, 41–418.

Marschner, H. (1986) "*Mineral Nutrition of High Plants".* Academic Press, London.

Pereira, L.S., Oweis, T. and Zairi, A. (2002) Irrigation management under water scarcity. *Agriculture Water Management,* **57**, 175-206.

Port Said/El Gamil Meteorological Station. (2013) Climate data, Egypt. http://en.tutiempo.net/climate/egypt.html.

Sallam, A., Shaban, Kh.A. and Abu-Hashim, M. (2014) Influence of Water deficit on seed yield and seed quality of Faba bean under saline soil conditions at North Sinai, Egypt. *Egyptian Journal of Soil Science,* **54**,*3,*

Schaff, B.E. and Skogely, E.D. (1982) Diffusion of potassium, calcium and magnesium in Brozeman silt loam as influenced by temperature and moisture. *Soil Science Society of American Journal,* **46**, 521-524

Sendecor, G.W. and Cochran, W.G. (1982) "*Statistical Analysis Methods*".7th ed. Iowa State Univ. Press Iowa, U.S.A.

Taylor, H.E. and Shiller, A.M. (1995) Mississipi river methods comparison study: implication for water quality monitoring of dissolved trace elements. *Environ. Sci. Tech.* **29**,1313-1317.

Topcus, S., Kirda, C., Desgan, Y., Kaman, H., Cetin, M., Yazici, A. and Bacon, M.A. (2007) Yield response and N-fertiliser recovery of tomato grown under deficit irrigation. *European Journal of Agronomy* **26**, 64-70.

WHO (2006) Guidelines for drinking-water quality, incorporating first addendum. Recommendations. 3rd ed. Vol. 1. Geneva: World Health Organization; 515.

Zarazua, G., Avila-perez, P., Tejeda, S., Barcelo-Quintal, I. and Martinez, T. (2006) Analysis of total and dissolved heavy metals in surface water of a Mexican polluted river by Total Reflection X-ray fluorescence Spectrometry. *Spectrochim. Acta.* B **61**, 180-184.

Zeng, Q. and Brown, H.P. (2000) Soil potassium mobility and uptake by corn under differential soil moisture regimes. *Plant and Soil,* **22**, 121-134.

(*Received :* 10 / 2 /2016;
acecpted : 24 /2 /2016)

إدارة محدودية مياه الرى كاستراتيجية للتكيف مع ندرة المياه - التطبيقات الفعلية تحت ظروف الاراضى الملحية بدول حوض البحر المتوسط

محمد سعيد ابوهاشم[*] - خالد عبده شعبان[**]
قسم علوم الأراضى – كلية الزراعة – جامعة الزقازيق – الزقازيق و [1]
معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر [2]

يلعب الماء دورا أساسيا في إنتاجية المحاصيل ولكن في المستقبل القريب ستواجه العديد من المناطق في العالم فترات جفاف والتى تتطلب تحسين إدارة الري لمساعدة التكيف مع ندرة المياه على وجه الخصوص بدول حوض البحر الأبيض المتوسط. تهدف الدراسة الحالية الى تحديد وتقدير تأثير الرى بكميات مختلفة من المياه على عناصر التربة وتوزيعاتها خلال مواسم النمو في ظل ظروف الاراضى عالية الملوحة في المناطق شبه الجافة بدول حوض البحر الأبيض المتوسط وتأثيرها على أنتاجية المحاصيل وكفاءة استخدام المياه.

أجريت تجربه زراعية لموسمين متتالين ٢٠١٣/٢٠١٢ و ٢٠١٣/ ٢٠١٤ على التوالي لدراسة تاثير المعدلات المختلفة من مياه الرى على عناصر التربة وانتاجية الفول البلدى (سخا 3) في التربة عالية الملوحة (10.2 dsm^{-1}) بمنطقة سهل الطينة، شمال سيناء، مصر. واشتملت التجربة على ثلاث معدلات من مياه الرى وهى ٣٦٠٠ W١)) و ٦٠٠٠W٢)) و ٧٢٠٠ (W٣ معدل الرى المتبع بالمنطقة) متر مكعب للهكتار من ترعة السلام وكان تصميم التجربة فى قطاعات كاملة العشوائية.

أظهرت النتائج انخفاض ملوحة التربة مع زيادة معدلات مياه الري بمعدل ٣٣٪، ٣٧٪، و ٤٨٪ للW١، W٢، وW٣ على التوالي مقارنة مع ملوحة التربة الأولية. بالاضافة لذلك أظهرت عناصرالتربة محل الدراسة ترتيب تنازلي مع زيادة الإجهاد المائي. وعلى الرغم من ذلك أظهرت كفاءة استخدام المياه (WUE) تأثير آخر. حيث أوضحت النتائج أن نظام أمداد المياه W١ يوفر ٥٠٪ من إمدادات المياه، وأسفرت عن WUE من ٢,٣٦ كجم / م^3 مقارنة بنظم أمداد المياه W٣ , W٢ بقيم WUE ١,٧٥ كجم / م^٣ و ١,٣٩ كجم / م^٣ على التوالي. وهكذا الري المتناقص ساعد على توفير المياه في المناطق شبه الجافة، مثل شمال سيناء في حين أن إنتاجية المحاصيل لم تتأثر معنويا.