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The influence of binary irrigation (BI), humic acid (HA), and various saline water on water consumption (WC), water use efficiency (WUE) of corn (*Zea mays* L.)

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ABSTRACT

A three factorial field experiment was conducted during autumn 2018, west of Iraq in clay loam soil texture. To study role of humic acid (HA) and binary irrigation (BI) in reducing effects of irrigation with various saline water on the growth and yield of corn (*Zea mays* L.). The study was implemented according to the split-split plot design within the randomized completely block design with three replications. The three factors were saline water (1.34, 4.0, 7.0 and 10.0 $dS.m^{-1}$), The HA with two levels, (0 and 30 $kg.ha^{-1}$) and two methods of irrigation, i.e., continuous irrigation (CI) and binary irrigation. Corn seeds were planted and irrigated according to the scheduled program based on the American evaporation pan class A. Irrigation depth used in this study was 555 mm. $Season^{-1}$. The results showed that the BI had saved 50% of the total requirements of fresh water. The highest WUE was 4.30 $kg.m^{-3}$ when 1.34 $dS.m^{-1}$ irrigation water and 30 $kg.ha^{-1}$ of HA were used. The highest WC was at the stage of vegetative growth of (638.4 $m^3.ha^{-1}$) and the lowest was (212.8 $m^3.ha^{-1}$) at germination stage.

Key words *: Bilateral irrigation, Continuous irrigation, Maize, Water use efficiency.*

Introduction

Most countries in the world are suffering from severe shortages of water resources and poor quality of them as a result of environmental changes associated with industrial and agricultural expansion, which prompt researchers and experts to adopt modern irrigation systems that allow saline water to be used for irrigation by mixing or shifting their use with fresh water (Salih, 2008). Saline water has been used in many countries around the world (2.25-20 $dS.m^{-1}$) to irrigate crops and orchards cultivated in different soils and weather conditions. The use of saline water reduces total production and dry matter yields at levels based on plant type, soil properties and salinization degree of water used (Hoffman, 2010). The use of saline water in irrigation creates unsuitable environment for crop growth through the effect of the concentration and quality of accumulated salts in the absorption of water and nutrients by the plant and thus affects the growth of it, that affecting the reduction of PH, DW, leaf area and number of leaves, This varies according to plant type (Blanco *et al.*, 2007). Binary irrigation is one of the methods used in reducing the negative effects of saline water, as the irrigation is divided into two stages, the field is given in the first stage half of its water requirements of saline water and completes its water needs of fresh water in the second stage to reduce the impact of saline irrigation water on soil and plant (Al-Hadithi and Al-Jumaily 2008). Different methods and techniques was adopted to reduce the harmful effects of salinity, including the use of organic acids like HA, by adding it to the soil as a liquid and solid forms or by spraying on the plant through foliar application, as it acts as a material with adsorption on various natural surfaces, including surfaces of plant cellular membranes because it contains two different types of ingredients, one is hydrophobic and the other is hydrophilic (Samson and Visser, 1989). Many researchers used humic and fulvic acids for the purpose of reducing the damage caused by saline stress to improve growth, they are two of humus organic acids that are naturally produced from the decomposition of organic matter whose addition to soil or plant causes increased absorption of nutrient mineral elements especially when exposed to saline stress (Cimrin *et al*., 2010), it also improves the physical, chemical and biological properties of the soil and reduces the problems and damage of salinity and alkali excess, thus increases the absorption strength of the root mass (Shaaban *et al.,* 2009). The addition of organic acids is one of the most effective strategies in reducing the damage of saline irrigation water, increasing plant tolerance, improve the distribution of soil pores, which in turn increase the water holding capacity and aeration and improve root secretions such as organic acids that regulate soil pH and reduce the harmful effect of salts in soil solution (El-Dardiry, 2007). Humic acids can modify the nutritional balance in the soil, which is disrupted by an increase in certain ions at the expense of other essential nutrients (Lithourgidis *et al.,* 2007). This study aims to give a greater chance of removing salts from the rhizosphere by using the BI mechanism and to know the role of HA in reducing hazard of saline irrigation water on the corn crop.

Materials and Methods

A field experiment was conducted in an agricultural field west of Heet district/ Anbar province located on the longitude $42^0 42^- 57^=$ east and a latitude of 33^0 42^- $06^=$ north during the autumn season 2018. To study the role of hemic acid and BI in reducing the salt effect of irrigation with different saline water and the growth and yield of maize (*Zea mays* L). Representative samples have been taken of soil material before cultivation, then they dried aerially and sifted with a sieve of 2 mm. physical and chemical soil properties were estimated (Table 1), the soil was described morphologically and classified to Typic torrifluvents by the American classification (USDA, 2010).

Experiment treatments

1. The salinity of the irrigation water, which has four levels prepared by mixing drainage saline water (of 10.2 dS. m^{-1} salinity) brought from a nearby drain to the field in Al-Shaksaliyah region is mixed in certain proportions with the water of the Euphrates River with its salinity of 1.20 dS.m^{-1}, to obtain water salinity of (1.2, 4.0± 0.2, 7.0 ±0.2, and 10.0 ± 0.2 dS.m^{-1}), the mixing ratios fixed for each level of IWS according to the equation proposed by (FAO, 1985) as the following:-

Table 1. Some physical and chemical soil properties 0-30 cm

a. Physical properties

Particle size distribution (g.kg^{-1})			Soil texture	Bulk density Mg.m^{-3}	Saturated hydraulic conductivity (cm.$hour^{-1}$)	Gravimetric moisture at tensions%				
Sand	Silt	Clay				0	33	50	500	1500
390	358	252	Clayey loam	1.35	9.70	36.44	24.04	19.25	10.50	9.65

b. chemical properties

EC* dS.m^{-1}	pH*	OM g.kg^{-1}	Soluble ions (Mmol . L^{-1})								Adjusted Sodium adsorption ratio adj.SAR
			Ca^{+2}	Mg^{+2}	Na^+	K^+	Cl^-	SO_4^{-2}	HCO_3^-	$CO_3^=$	
2.5	8.10	23	9.5	7.1	3.3	1.1	7.5	9.4	3.0	0.0	5.16

$$EC = [EC_a \times a] + [EC_b (1-a)] \quad .. (1)$$

Where:

EC = the required electrical conductivity of water (dS m^{-1}). EC_a = the electrical conductivity of river water (dS m^{-1}). a = The ratio of river water in the mixture EC_b = The electrical conductivity of saline water, i.e. the water of the drainage (dS m^{-1}).

The electrical conductivity values calculated by measuring the electrical conductivity of the mixed water were confirmed and ensured that they reached the required levels, and the mixing process was carried out in galvanized metal tanks of 1 m^3 volume, some chemical characteristics of irrigation water were estimated and the quality of irrigation water was classified according to the classification of the USDA Salinity lab. (1954) (Table 2).

2. Humic Acid: HA was added to the soil at two levels 0 and 30 kg. ha^{-1}. The Chinese-origin commercial HA produced by (CO. LTD. Chin Leili Agro chemistry) was used. Table 3 shows properties of HA used in the experiment.

3. Irrigation method: irrigation is done in two ways, as the net depth of irrigation for any water quality mentioned above is added completely and called (continuous irrigation –CI-), and the second method is to add 50% of the net depth of irrigation for different types of saline water followed by the addition of 50% of the net water depth NDI of the Euphrates River water and called (BI).

Cultivation and fertilization

The soil was plowed using the mouldboard plow and perpendicularly, the soil was softened, then the field divided into three blocks and left a distance of 2 meters between one block and another, where each main block was divided into 4 main plots and left between them a distance of 2 meters, and each main plot divided into two sub-plots and levels of HA distributed randomly between them at 1.5 m distance left between them, and each sub- plot was divided into two terraces have length 2.5 m and 0.4 m wide for each, thus the area of each treatment is 1 m^2, and left a distance of 1 m between was left between each terraces where the method of irrigation was distributed randomly.

Phosphate fertilizer was added in the form of granulated DAP fertilizer (Di-Ammonium Phosphate) which contains 18% nitrogen and 45% P_2O_5 at a rate of 150 kg $P_2O_5.ha^{-1}$ before implanting mixed with soil, implantation of corn seeds (*Zea mays* L.) (Fajr-1 cultivar) at July 18th 2018 with a distance of 0.20 m among holes, three seeds were placed in each hole and then reduced to one plant after 14 days of germination. Urea nitrogen fertilizer was added 46% N at a rate of 320 kg N ha^{-1} in three batches the first batch was added by calculating the amount of added nitrogen from DAP fertilizer before cultivation by mixing with the soil surface, the second batch was added after the plant's thinning, and the third batch after forty days from the 1st batch addition, potassium fertilizer was added in the form of potassium sulfate 50% K_2O at a rate of 150 kg $K_2O.ha^{-1}$ and the second batch was added after three weeks of cultivation (Ali *et al.,* 2014). Weeding operations were carried out periodically for all treatments and were conducted manually and corn Borer was controlled using the Super Athwaite liquid pesticide at a rate of 100 ml per 100 liters of water and the use of 10% granulated Diazinon pesticide as an effective anti-control operation and by 6 kg. ha^{-1} by feeding in the heart of the plant.

The drip irrigation system was used with T-Tape drippers and 2 liters.h^{-1} discharge. The irrigation of

Table 2. Some chemical properties of irrigation water

Water quality	EC* ds.m^{-1}	pH*	Soluble ions (Mmol . L^{-1})								SAR	Class*
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	SO_4^{-2}	HCO_3^{-}	CO_3^{-}		
Euphrates river	1.34	6.5	4	2	2.5	1.35	4.30	5.0	1.9	0.0	1.45	$C_3 S_1$
Drainage	10.2	8.1	20.1	18.30	23.42	3.41	45.75	19.75	16.60	0.0	5.36	$C_4 S_1$

* according to FAO 1985.

Table 3. Some of HA Properties

ECds.m^{-1}	pH	(g.kg^{-1})				C/N Ratio	HA
		N	Organic carbon	P	K		
3.2	6.7	38	346	20	4.1	9.1	14.4

germination was performed on 18-07-2018 and soil moisture was delivered to the field capacity limits. Irrigation has been scheduled for all treatments at depletion of 50% of available water. The stages of the growth of the maize plant and the values of the crop factor were adopted as stated in (FAO, 1998). A standardization was carried out to determine the amount of evaporation from the evaporation pan, which is equivalent to the amount of evaporated water from American evaporation pan Class A (a basin of galvanized iron of 1.2 m diameter and 0.25 depth) in determining the timing of irrigation (Al-Dulaimy, 2011):

The required depth of water added to the soil (d) estimated according to the equation mentioned Kovda *et al.,* (1973):

$$d = D \times dp \times \frac{\theta F.c - \theta p.w.p}{100} \quad .. (2)$$

Where:

d = The depth of water to be added to the soil (cm), which equivalent to actual water consumption (Eta). $\theta_{F.C}$ = Soil volumetric moisture at field capacity limits. $\theta_{P.W.P}$ = Volumetric moisture at permanent wilting point. dp = moisture depletion ratio %. D= The effective depth of root zone (cm). (Adopted by observation for each stage of growth)

Water consumption has been calculated by adopting the water balance equation:

$$Eta = (P + Ir) - (D + R + In + \Delta s) \quad .. (3)$$

Eta = water consumption, P = rainfall water depth. Ir = irrigation water depth, D = deep percolation, R = surface runoff, In= plant intercepted water, Äs = the difference in soil moisture.

Assuming both surface surface water and water retained by the plant and deep interspersiup equal to zero, the equation is as follows:

$$Eta = (P + Ir) - \Delta s \ldots\ldots\ldots..(4)$$

The time of the irrigation was calculated using the equation mentioned in (Al-Hadithi *et al.,* 2010):

$$q \times t = a \times d \quad .. (5)$$

q: Discharge given to field lines, $m^3.hour^{-1}$. t: Irrigation time, hour. a: Area of wetting circle of dripper, m². d: Depth of added water, m.

The required volume of water for each irrigation turn has also been calculated, according to (Hajim and Yasin 1992):

$$V = q \times n \times t \quad .. (6)$$

V: The required volume of water addition, liters. t: irrigation time, hour. q: discharge of dripper, $liter.hour^{-1}$. n: the number of drippers in the field line.

Measures included the average Water Use Efficiency (WUE) or Water Productivity (Hillel, 2008) was estimated by dividing TY ($kg.ha^{-1}$) on the volume of added water ($m^3\ ha^{-1}$) using the equation mentioned in (Doorenbos and Pruitt, 1977):

$$WUE\ (kg.m^{-3}) = \frac{\text{Total yield } (kg.ha^{-1})}{\text{addition water volume } (m^3.ha^{-1})} \quad .. (7)$$

Statistical analysis of the results for soil and plant samples was carried out using GenStat genwin 3.2 to calculate the least significant difference L.S.D. at a significance level of 0.05.

Results and Discussion

Water consumption (WC) of maize crop

The Table 4 shows the values of WC according to growth stages of corn, where the depth of added water reached 40 mm during the germination phase, then increased with growth progression of

Table 4. Depth of added water during the growing season

No.	Growth stages	Period	Roots depth (cm)	Irrigation number	Additional water depth (mm)	Water requirements ($m^3.ha^{-1}$)
1	germination	2018/7/30 -7/18	10	2	40	212.8
2	Vegetative growth	2018/9/1 -7/31	25	6	120	638.4
3	Flowering	2018/9/13 -9/2	40	2	100	532
4	Milky phase	2018/10/7 -9/14	50	5	150	798
5	Repining phase	2018/10/25 -10/8	50	3	90	478.8
6	Maturity	2018/11/10 -10/26	50	1	55	292.6
	Total			19	555	2.952.6

stages as a result to the increase in plant's requirements of water, as well as increase the temperature as the growing season progresses. It also shown in Table 4 that the highest depth of water addition during the milk phase reached 150 mm and then decreased to 55 mm during the maturity stage due to the decrease plant's water requirement with maturity and dryness in high percentage of its tissues and parts.

Table 4 also shows the variation in the number of irrigation rounds at each plant stage, where the number of rounds reached 19 with a total water consumption of 555 mm. Season^{-1}. The stage of vegetative growth indicated the highest number of irrigation rounds reached 6 due to the long-time period of this stage (31 days) according to (Salem and Fahad, 2006).

It should be noticed from Table 4 that the total water requirement during the growth season of maize were 2,952,600 m^3.ha^{-1}. The germination stage was the least water-required stage of 212.8 m^3.ha^{-1} which accounted 7.2% of total water requirement. It is also noticed from Table 4 that water requirements increased with progress of growing season and reached their highest value of (638.4 m^3.ha^{-1}) during the vegetative growth stage, it was 21.6% of the total water requirement (Shaghleb *et al.*, 2006). The use of BI has saved 50% of the total water requirements of fresh water and reduced the damage to saline water usage in irrigation.

Water use efficiency (WUE) kg.m^{-3}:

Table 5 shows the effect of study treatments on WUE values. It should be noticed that the values varied according to the IWS, where it reached its highest values at 1.34 dS..m^{-1} compared to levels 4.0, 7.0 and 10.0 dS.m^{-1}, for any level of HA, the lowest value was at the level 10.0 dS.m^{-1} of IWS at the control treatment (without adding humic) and 1.67 and 2.08 kg. m^3 for CI and BI respectively. The values were 2.23 and 2.53 Mgm.ha^{-1} for the treatment of 30 kg..ha^{-1} of HA for CI and BI respectively. The reason for the low values of WUE may be due to lower TY production values by increasing the IWS, which has negative influence on the degradation of soil properties, which has a negative impact on plant growth, as well as the shortage of water absorbed as a result of osmotic stress, thus disrupting vital processes as well as disturbance of plant's nutritional balance because of competition among ions by increasing the concentration of some ions in the soil solution and thus the accumulation of these ions inside the plant affects the growth rate of the plant (Abbas, 2012) and (Shabib, 2010).

Results of Table 5 showed significant differences between WUE values at different levels of humic acids for any irrigation system applied. It reached its highest level at 30 kg . ha^{-1} which was 3.37 kg.m^{-3}. The HA has an important role in improving the physical, chemical and biological properties of the soil, which is the store for many necessary nutrients for plant growth and has a role in maintaining buffering capacity and improving the strength of plant growth (Eman *et al.*, 2008). The results shown in Table 5 show that BI increased the values of WUE significantly compared to CI for any level of HA with rates of 2.92 and 3.20 kg.m^{-3}for CI and BI, respectively. It may be due to the fact that BI has reduced the negative impact of saline water (Eman *et al.*, 2008).

Conclusion

The depth of water added during the season was

Table 5. Shows the impact of study treatments on WUE (kg.. ha^{-1})

IWS rate	Levels of HA kg.ha^{-1}				IWS ds.m^{-1}
	30		0		
	BI	CI	BI	CI	
3.93	4.30	4.13	3.83	3.47	1.34
3.59	4.03	3.80	3.41	3.12	4.0
2.58	3.12	2.79	2.30	2.12	7.0
2.13	2.53	2.23	2.08	1.67	10.0
	3.37		2.75		HA rate
	BI		CI		Rate of irrigation system
	3.20		2.92		
Salinization 1.025 : S	HA: H: 0.605		irrigation :I: 1.146		L.S.D 0.05
1.74 :S*H*I					

555 mm. Binary irrigation has saved 50 percent of the total water needs of fresh water. The results showed that the study treatments had a significant impact on increasing water efficiency values. The highest water efficiency was 4.30 kg.m^{-3} when irrigating with salinity water 1.34 dS.m^{-1} the humic level was 30 kg.ha^{-1} and for the binary irrigation compared to 1.67 kg.ha^{-3} when irrigation with salinity water 10 dS.m^{-1} and for the level of humic acid of 0 kg.ha^{-1} and for continuous irrigation.

References

Abbas, Saadia Mahdi Saleh, 2012. The effect of the irrigation interval and rotation of high and low salinity water under the drip irrigation system in some soil characteristics and the growth of the corn plant (*Zea mays* L.). Master's Thesis, College of Agriculture - Basra University.

Al-Dulaimy, Saad Anad Harfoush, 2011. Compare the impact of different irrigation methods with some water and physical standards and the growth and outcome of the tomatoes. Doctoral thesis. The Soil Department, College of Agriculture, University of Anbar.

Al-Hadithi, Essam Khudhair, Ahmed Al-Kubaisi and Yas Khudhair Al-Hadithi, 2010. Modern irrigation technologies and other topics in the water issue. Ministry of Higher Education and Scientific Research. University of Anbar, College of Agriculture.

Al-Hadithi, Issam Mohammed and Aboud Mohammed Al-Jumaily 2008. Dual irrigation technology under surface irrigation conditions. *Journal of Mesopotamia Engineering*. 16 (4) : 53-60.

Ali. Noureddine Shawky, Hamdallah Suleiman Rahi and Abdul Wahab Abdul Razzaq Shaker, 2014. *Soil Fertility.* Ministry of Higher Education and Scientific Research. University of Baghdad, College of Agriculture, Scientific Books Publishing and Distribution Press. Baghdad, Iraq.

Blanco, F. F., Folegtti, M. V., Ghey, H. R. and Fernandez, P.D. 2007. Emergency and Growth of Corn Sorghum under Saline stress. SCi. Agric. (Piracicoba, braz). 64 (5) : 451–459.

Cimrin, K.M., Onder, T., Metin, T. and Burcut, 2010. Phosphours and humic acid application alleviate Salinity Stress of pepper seedling *African Journal of Biotechnology.* 9 (3) : 5845–5851.

Doorenbos, J. and Pruitt, W. O. 1977. Crop Water requirements Irrigation and drainage, P: 24. Food and Agricultural Organization of the United Nations, Rome, Italy.

El – Dardiry, E. I. 2007. Effect of Soil and Water Salinity on barley grains germination under some amendments. *World J. Agric. Sci.* 3 : 329-338.

Eman, A.A., M, Abd El-Monerm, S. Saleh and E.A.M. Mostafa, 2008. Minimizing the quantity of mineral nitrogen fertilizers on using grapevine by HA , organic and biofertilizers. *Res. J. of Agric. and Biological Sci. Egypt.* 4(1) : 46-50.

FAO. 1985. Water quality for agriculture. Irrigation and Drainage papers. No. 29 by Ayers, A.S. and D.W. Westcot. Rome, Italy.

FAO. 1998 . Crop Evapotranspiration irrigation and Drainage Paper No. 56. Rome Italy.

Hajim, Ahmed Yusuf and Haqi Ismail Yassin, 1992. *Engineering of Field Irrigation systems, Bookshop for printing and publishing.* Mosul University.

Hillel, D. 2008. 40 years of drip irrigation. Crops, Soils, Agronomy" CSA" News. September 2008.53 (9): 3-7.

Hoffman, G. J. 2010. Salt tolerance of crops in the Southern Sacramento – San Joaquin delta. Final Report. California Environment Protection Agency.

Kovda, V.A. 1973. Irrigation Drainage and salinity.FAO/ UNESCO. *An International Source Book.* Hutchison and Co., Ltd. P.468,478.

Lithourgidis, A. S., Matsi, T., N. Barbayiannis and Dordas, C.A. 2007. Effect of liquid cattle manure on corn yield, composition , and soil properties. *Agron. J.* 99 (4) : 1041–1047.

Salem, Seif eddine Abdul Razzaq and Ali Abdul Fahd, 2006. Water needs of yellow corn (*Zea mays* L.) Under the conditions of scheduling full irrigation and underwater under the conditions of central Iraq. *Summaries of the Conference on Sustainable Agricultural Development and Food Security November 27*-30, College of Agriculture, Tishreen University, Latakia, Syria. 152–151.

Salih, H. O. 2008 . The role of ionic activity in classification of some groundwater on soil chemical properties and wheat yield in Erbil plain. M. SC. Thesis, College of Agriculture, Salahaddin UNIV., Iraq.

Samson, G. and Visser, S. A. 1989. Surface – active effects of HAs rubisco from *Tamarix jardanis* in the presence and absence of proline – related compalible solutes. *Physiol. Plant.* 90 : 198–204.

Shaaban, S. H. A., F. M. Manal and Afifi, M. H. M. 2009 . HA foliar application to minimize Soil applied fertilization of surface irrigated wheat. *World Journal of Agriculture Sciences.* 5 (2) : 207–210.

Shabib, Yahya Jihad, 2010. The effect of irrigation, drip and salinity of irrigation water on soil properties and plant growth in clay soils. Master's thesis. The Soil Department, College of Agriculture, Basra University.

Shaghleb, Abubaker M. Shawa, F. Samaita, A. F. and Mansor, T. 2006. Comparison of modern irrigation methods (Drip, Sprinkler) With Surface irrigation method (furrow) for maize production, Damascus university. *Journal for the Agricultural Sciences.* 22(2): 427-450.

USDA. 1954. Diagnosis and improvement of saline and alkali soils. Agriculture hand book No.60. USDA Washington.

USDA. Keys to Soil Taxonomy" Eleventh Edition. 2010. Natural Resources Conservation Service. (NRCS).