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Zeolite and Compost as Soil Amendments to Rationalize Irrigation Water for the Barley Crop under Salt Affected Soils

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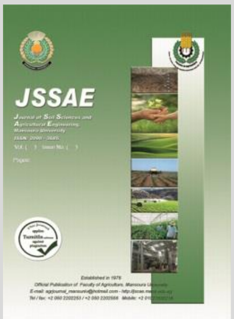

ABSTRACT

The availability of irrigation water needs to be modified by some irrigation management and the application of water-rationalizing strategies. Therefore, field experiments were conducted in two successive winter sessions during 2019-2020 and 2020-2021 at Sakha Agricultural Research Station Farm, Kafr El-Sheikh Governorate, Egypt. This research was carried out to study the effect of irrigation number/season ie. using only sowing irrigation (I_1), sowing irrigation+ one irrigation (I_2) and sowing irrigation+ two irrigations (I_3) and application of some soil amendments (zeolite and compost) and their combinations on some soil properties, some water relations and yield of barley (*Hordeum vulgare L.*) Giza 2000. Results showed that the values of seasonal water applied, actual consumptive use (CU) out of two seasons took the following descending order: $I_3 > I_2 > I_1$. While, I_1 gave the highest values of water productivity (WP), and irrigation water productivity (IWP). The plots that received sowing irrigation+ two irrigations (I_3) with zeolite+compost showed a pronounced improvement of soil salinity (ECe), Exchangeable sodium percentage (ESP), soil bulk density (BD), soil basic infiltration rate (IR), and yield and its components of barley. The application of zeolite and compost alleviated the adverse effect of drought on soil properties and barley productivity.

***Keywords**:* Barley, Zeolite and Compost, water productivity.

INTRODUCTION

Barley (*Hordeum vulgare L.*) came in the fourth place among grains (maize, rice, and wheat) in terms of its total production (141million tonnes) in 2016. In 2016, the world's harvested barley acreage was 46.92 million acres). On the other hand, the total harvested area of barley in Egypt was 77,566 hectares in 2016/2017. Drought is a key limiting factor for agriculture and inhibits plant development by affecting water availability. Munns (2002) studied plant productivity in arid and semi-arid environments. A wide range of physiological and metabolic activities, including the process of photosynthesis were occurred on plant due to drought (Abdalla, 2011).

Drought has detrimental influences on fresh and dry biomass yield of crop (Lisar *et al.* 2012). In Egypt, restricted water resources, low groundwater and precipitation and climate change are an additional burden on the availability and accessibility of water (Abd Ellah 2020). So, drought stress causes negative changes in plant growth and is considered a serious issue of food security (Chandra *et al.* 2021).

Barley is the major crop farmed on a big scale in Egypt's rain-fed areas because of its ablility to survive and thrive in harsh environments such as drought. Therefore, barley is regarded as one of the most adaptable crops, capable of growing in a wide range of soil conditions and under a variety of unfavorable conditions. It is critical for a crop to be able to generate satisfying yields in a variety of stress and non-stress settings. Finlay (1968) thought that the environmental stability and yield potential are more or less independent of one another. Barley is a critical dry crop and is regarded as resistant to drought, land degradation, and adaptation to climate change (Fahad *et al.*, 2016, Wang *et al.* 2018 and Hughes *et al.* , 2019). In Egypt, barley grain production was decreased from 3.03 ton ha^{-1} to 1.54 t ha^{-1} from 2001 to 2015 (Naser *et al.* 2018). Egyptian barley Giza 126, Giza 131 and Giza 2000 were found to be drought tolerant cultivars with the highest values of all morphological and physiological traits (Mariey *et al.*, 2020).

The application of some water-saving strategies are needed to face water scarcity. So, deficit irrigation is one strategy of management of irrigation to increase the crop output per irrigation water unit (Maseko *et al.*, 2020**;** Avola *et al.*,2020**;** Patanè *et al.* ,2020**;** Ierna and Mauromicale 2020 and Wang *et al.* 2020). Also, the application of soil amendment may be used to mitigate the adverse impact of drought stress on crops and soil (Besharati *et al.* ,2021). Compost is one of the important organic amendments, as it is available and applicable (Rabot *et al.* ,2018**;** Gravuer *et al.*, 2019 and Siedt *et al.*, 2021). Compost may be used to alleviate the effect of deficit irrigation and promote sustainable crop production and water productivity (Abd El-Mageed *et al.*, 2019**;** Ding *et al.* 2021 and Jiang *et al.*, 2021). In general, the application of compost improves the soil properties, increases total porosity and aggregate stability, decreases the bulk density, and improves soil moisture content (Carlson *et al.*, 2015**;** Yazdanpanah *et al.*, 2016**;** and Kranz *et al.*, 2020). Also, application of compost had a positive effect on soil chemical properties (Day *et al.*, 2019; Murtaza *et al.*, 2019; Amer *et al.*, 2020 and El-Sharkawy *et al.*, 2021), where it caused redistribution of soluble cations and increased Ca^{2+} and organic matter in the root zone.

On the other hand, application of zeolite under deficit irrigation has more pronounced effects on soil and crop production (Gholamhoseini *et al.*, 2018; Khalifa *et al.*,

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2019; Rahayu *et al*., 2019 and Bahador and Tadayon, 2020) and they concluded that applying zeolite to soil improvement its chemical properties. In addition, the application of zeolite can reduce the exchangeable Na^+ (Wang *et al*., 2012 and Wen *et al*., 2018). It has good water and nutrient retention capacities (WHC); it improves infiltration rate, saturated hydraulic conductivity, cation exchange capacity and prevents loss of water by deep percolation (Xiao *et al*., 2020 and Mondal *et al*., 2021). Also, zeolite addition increased the plant's drought resistance and water-nitrogen use efficiency under drought conditions (Wu *et al*., 2019).

Therefore, this study aims to evaluate the effect of zeolite and compost applications and irrigation some managements on barley productivity and soil properties.

MATERIALS AND METHODS

Experimental Design and Agriculture Practices:

Field experiments were conducted at Sakha Agric. Res. Station Farm during the two consecutive growing seasons (2019/020 and 2020/021). The site is located in North Nile Delta area (30°-57/ N latitude, 31°-07/E longitude) with an elevation of about 6 meters above mean sea level. The meteorological data of the area during the two growing seasons are depicted in Table (1). The soil texture in the experimental fields is clayey as illustrated in Table (2).

The total area of the experiment was 90 m x 30 m (2700 m^2), which is divided into 10 m x 90 m (900 m^2) for each irrigation treatment, while each irrigation area was divided into10 m x 10 m (100 m^2) for each soil amendment. Plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water. The soil amendments (zeolite and compost) and calcium superphosphate (15.5 % P_2O_5) were added directly before sowing with the tillage process. Barley grains were sown at a rate of 120 kg $ha.^{-1}$ on 25th Nov. 2019 and 18th Nov, 2020 and harvested on 15th Apr. ,2020 and 25th Apr., 2021. All local recommendations for barley were uniformly followed. The main plots were assigned to the irrigation treatments, i.e. (I_1) only sowing irrigation + rainfall, (I_2) sowing irrigation + one irrigation + rainfall and (I_3) sowing irrigation + two irrigations+ rainfall**.** While the sub treatments included soil amendments i.e., (CK) without treatment ,(Z) 714 kg zeolite ha^{-1} and (Z+C) 714 kg zeolite ha^{-1}+ 9.5 tons compost ha^{-1}.

The composition of zeolite was: SiO_2, Al_2O_3, CaO, K_2O, Fe_2O_3, MgO, Na_2O, TiO_2, CEC and BD (72.90, 11.95, 5.75, 4.10, 1.65, 1.50, 1.85, 0.30%, 150 cmol kg^{-1} and 1780 kg m^3, respectively). The chemical composition of compost was: pH (7.62), EC (3.59 dS m^{-1}), OM (31.92%),OC (18.56%), N (16.2 g kg^{-1}), P (1.6 g kg^{-1}), K (1.01 g kg^{-1}), and C/N ratio (11.46).

The daily weather data for both seasons, including maximum and minimum temperatures, solar radiation, and rainfall were collected from a nearby eddy covariance station (Table 1).

Table 1. Some meteorological data of the experimental area during the two winter growing seasons (2019/020 and 2020/021).

Season	Month	Temperature, C°			Relative humidity, %			WS	Pan evap.	Rainfall, mm month^{-1}
		Max.	Min.	Mean	Max.	Min.	Mean			
Season 2019/2020	Nov.	27.4	25.1	26.3	82.8	48.3	65.60	36.6	2.31	---
	Dec.	21.4	13.4	17.4	86.9	58.9	72.9	38.5	2.66	60.68
	Jan.	18.4	11.8	15.1	86.7	62.7	74.7	30.0	2.09	67.50
	Feb.	20.4	12.7	16.6	84.6	56.5	70.6	51.0	1.83	14.30
	Marc.	22.6	15.6	19.1	81.1	53.9	67.9	80.1	5.12	60.8
	Apr.	26.0	18.9	22.5	80.0	45.1	62.6	98.8	6.08	---
	seasonal	22.70	16.25	19.50	83.68	54.23	69.05	55.83	3.35	203.28
Season 2020/2021	Nov.	25.0	17.5	21.3	86.6	56.8	71.80	46.9	2.28	---
	Dec.	22.9	13.7	18.3	87.7	55.7	71.7	44.9	2.49	18.78
	Jan.	21.0	13.5	17.25	86.7	59.5	73.1	39.2	2.57	14.05
	Feb.	21.5	12.5	17.0	87.5	55.9	71.7	58.3	3.56	---
	Marc.	23.8	15.2	19.5	83.8	49.8	66.8	83.4	4.48	5.4
	Apr.	27.6	19.4	23.5	74.6	45.8	60.2	95.0	7.28	---
	seasonal	23.63	15.30	19.48	84.48	53.92	69.22	61.28	3.78	38.23

***Pan evap.: Pan evaporation (mm day^{-1}); WS: Wind velocity, km d^{-1} at 2 m height**

Soil Analysis and Climatic Conditions

Soil samples were collected before the experiment and after the first and second seasons in three consultative depths (0-20, 20-40 and 40-60 cm) for physical, chemical and nutritional analysis according to stander methods of Page *et al*., (1982) and Klute, (1986) as shown in Table (2).

Table 2. Some soil physio-chemical analysis before barley cultivation.

Soil depth (cm)	pH	EC (dS m^{-1})	SAR	ESP	Soluble cation (meq L^{-1})				Soluble anion (meq L^{-1})			
					Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3	$HCO_3^=$	Cl^-	SO_4^{2-}
0-20	8.12	5.09	11.80	13.86	10.4	5.9	33.7	0.9	-	3.5	25.6	21.8
20-40	8.26	5.81	12.55	14.71	11.8	6.8	38.3	1.2	-	4.5	28.8	24.8
40-60	8.45	6.49	13.21	15.42	13.3	7.5	42.6	1.5	-	6.0	31.6	27.2
Mean		5.80	12.52	14.7	11.8	6.7	38.2	1.2	-	4.7	28.7	24.6

Soil depth (cm)	Particle size distribution (%)			Texture grader	Soil Moisture characteristics			B.D. (Mgm^{-3})	IR (cm h^{-1})
	Sand	Silt	Clay		F.C %	W.P %	A.W %		
0-20	15.95	32.25	51.80	Clayey	42.85	22.11	20.74	1.26	0.7
20-40	14.75	32.92	52.33	Clayey	40.57	21.50	19.07	1.31	
40-60	13.98	33.45	52.57	Clayey	38.75	20.16	18.59	1.36	
Mean	14.90	33.87	52.23	Clayey	40.72	21.26	19.47	1.31	

***pH: was determined insoil : water suspension (1:2:5); ECe: was determined in saturated soil paste extract; SAR : sodium adsorption ratio; ESP : exchangeable sodium percentage.; F.C. field Capacity; w.p.; Wilting point; A.W: available water; B.D.: bulk density and IR: soil basic infiltration rate.**

Irrigation parameters:

Water applied (Wa):

Wa was calculated according Giriappa, (1983) as follow:

$$Wa = Iw + Re + \Delta S \qquad (1)$$

Where:

Iw: irrigation water applied
Re: effective rainfall
ΔS: amount of soil moisture contribution to consumptive use from water table
Values of ΔS were neglected, due to the long duration of the growing season.

Irrigation water applied (IWa):

Submerged flow orifice with fixed dimension was used to convey and measure the irrigation water applied using the equation of Michael, (1978):

$$Q = CA\sqrt{2gh} \qquad (2)$$

Where

Q = Discharge through the orifice, ($cm^3\ sec^{-1}$).
C = Coefficient of discharges (0. 61).
A = Cross sectional area of orifice, cm^2.
g = Acceleration due to gravity, $cmsec^{-2}$ (980 $cmsec^{-1}$).
h = Pressure head over the orifice center (cm).

The total amounts of irrigation water applied for I_1, I_2 and I_3 treatments are listed in Table (3).

Soil moisture monitoring:

Time Domain Reflect meter (TDR) probe was used to monitor soil moisture before each irrigation, two days after irrigation or rainfall and at 7 day-intervals between irrigation and harvesting in four consultative depths (0-15, 15-30, 30-45 and 45-60 cm).

The effective rainfall (ER):

ER" was estimated according to Chavan *et al*., (2009):

$$\mathbf{ER = Incident\ rainfall \times 0.7} \qquad (3).$$

Soil moisture depletion: "SMD" was calculated using the equation of Majumdar (2002) as follow:

$$SMD = \sum_{i=1}^{i=n}\left(\frac{\theta_2-\theta_1}{100}\times\rho_{bi}\times D_i\right) \qquad (4)$$

Where:

SMD: Soil moisture depletion,
n: Number of soil layers (1-4),
DI: Soil layer thickness (15 cm),
ρ_{bi}: Bulk density ($Mg\ m^{-3}$) of the layer,
θ_1: Soil moisture before the next irrigation, and
θ_2: Soil moisture, 48 hours after irrigation..
I=Number of soil layers, each (15 cm) depth.

Water application efficiency (WEa%):

WEa as described by Downy (1970):

$$WEa\% = \frac{cu}{IWa}\times 100$$

Water productivity (WP): It was calculated according to Ali *et al*. (2007).

$$WP = GY/ET \qquad (6)$$

Where, GY : grain yield (kg ha^{-1}) and ET: Total water consumptive use of the growing season (m^3ha^{-1}).

Irrigation water productivity (IWP): It was calculated according to Ali *et al*. (2007).

$$IWP = GY / IWa \qquad (7)$$

Where, IWa : irrigation water applied ($m^3\ ha^{-1}$).

Crop growth and yield measurements:

Ten plants were chosen randomly from each plot to measure the 1000-grain weight and plant heights, grain and straw yields of barley as kg ha^{-1}.

Statistical Analysis:

It was done according to Gomez and Gomez, (1984), all acquired data was submitted to analysis of variance . All statistical analysis was carried out with the h elp of the Costat, (2005) copmuter software pprogramme, which used the analysis of variance approach.

RESULTS AND DISCUSSION

Crop-water relations:

Seasonal water applied (Wa): Water applied (Wa) to barley consists of irrigation water (IW) and rainfall (RF) as shown in Table (3).

Irrigation water (IW):

IW for I_1 treatment was the lowest value , while its value for for I_3 treatment was the highest. The mean values of IW (mean of the two seasons) for I_1, I_2, and I_3 treatments were 1225, 2195, and 3105 $m^3\ ha^{-1}$, respectively. The total number of irrigation events were 1, 2 and 3 for I_1, I_2 and I_3 respectively, including sowing irrigation. The amounts of irrigation water in the 1st season were more than that in the 2nd season due to the difference in the rainfall. The amount of sowing irrigation was the same for all irrigation treatments. The average effective rainfall was 909 m^3 for both growing seasons. It is obvious from the data that the amount of irrigation water applied was gradually increased as a result of the vegetative growth development that required a higher amount of irrigation to meet its water requirements, and then it decreased again after maturity. These findings may be attributed to growth stages and the availability of soil water content in the root zone. These data indicate that using I_1 treatment (only sowing irrigation) saved water by about 60.7% (1680 m^3ha^{-1}) compared with I_3 treatment (the conventional irrigation),

Table 3. Number of irrigation events and the amounts of irrigation water applied (m^3ha^{-1}) under different irrigation treatments during both growing seasons.

Irrigation events	1st Season			2nd Season			Mean (m^3ha^{-1})		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
Sowing irrigation	1200	1200	1200	1250	1250	1250	1225	1225	1225
First irrigation	0.0	960	960	0.0	980	980	0.0	970	970
Second irrigation	0.0	0.0	900	0.0	0.0	920	0.0	0.0	910
Total (m^3ha^{-1})	1200	2160	3060	1250	2230	3150	1225	2195	3105

***(I_1) only sowing irrigation + rainfall; (I_2) sowing irrigation + one irrigation + rainfall and (I_3) sowing irrigation + two irrigations+ rainfall**

Effective rainfall:

Values of seasonal rainfall for both growing seasons are listed in Table (1). Rainfall events were distributed from December to March in the 1st season and from November to March in the 2nd season. Thereby, the rainfall is distributed during the barley growing season and could be considered as a portion of its water requirements. Mean values of the monthly rainfall are 60.68 , 67.50, 14.30, and 60.8 mm for Dec., January, Feb. and March during the 1st season, respectively and18.78,14.05, 0.0 and 5.4 mm for Dec., January, Feb. and March during the 2nd season, respectively. The total seasonal rainfall was 203.28 and 38.23 mm for the 1st and 2nd season, respectively. The effective rainfall (ER) is rainfall multiplied by 0.7 according to equation 3 (Chavan *et al*., 2009). Consequently, barley as a winter crop, received 1422 and 267 $m^3\ ha^{-1}$ of the effective rainfall in the 1st season and the 2nd season, respectively with an average of about 845 $m^3\ ha^{-1}$as shown in Table (4). The amount of rains is not suffecient for irrigating barley crop, thus it needs to the complementary irrigation, but the rains saves the irrigation water.The amount of rains is considered unreliable for irrigation, thus it needs to the complementary irrigation, but the rains saves the irrigation water.

Table 4. IW, total Wa and the effective rainfall ($m^3\ ha^{-1}$) as affected by irrigation and soil amendments during the both growing seasons.

Treatment		Season 2019/2020			Season 2020/2021			Mean of 2 seasons		
		IW	ERF	Wa	IW	ERF	Wa	IW	ERF	Wa
	CK	1200	1422	2622	1250	267	1517	1225	845	2070
I_1	Z	1200	1422	2622	1250	267	1517	1225	845	2070
	Z+C	1200	1422	2622	1250	267	1517	1225	845	2070
	CK	2160	1422	3582	2230	267	2497	2195	845	3040
I_2	Z	2160	1422	3582	2230	267	2497	2195	845	3040
	Z+C	2160	1422	3582	2230	267	2497	2195	845	3040
	CK	3060	1422	4482	3150	267	3417	3105	845	3950
I_3	Z	3060	1422	4482	3150	267	3417	3105	845	3950
	Z+C	3060	1422	4482	3150	267	3417	3105	845	3950

Water consumptive use (WCu):

The data in Table (5) reveal that WCu values were increased as the irrigation water applied increased. Barly grown under I_3 treatment recorded the highest value of water consumption followed by that grown under I_2 and I_1 treatments. Mean values of seasonal WCu were 2328, 2800 and 2920 $m^3\ ha^{-1}$ for I_1, I_2, and I_3 treatments, respectively. On the other hand, the seasonal Cu were significantly increased by the application of soil amendements. The WCu values were 2534, 2689 and 2824 $m^3 ha^{-1}$ for CK., Z and Z+C, respectively. The most probably explanation for these results is that soil moisture was more available for plant with more irrigation events, giving chance for consumption of water, which ultimately resulted in enhancing transpiration from barly plants and water evaporation from the soil. Therefore, the higher amount of irrigation water applied provids a chance for more consumption. These results are in great harmony with those obtained by Aiad (2019). The highest value of WCu (3089 $m^3\ ha^{-1}$) was obtained from I_3* (Z+C) while the lowest value (2169 $m^3\ ha^{-1}$) was found with I_1* CK (as a mean of both seasons).

Table 5.Water consumptive use (WCu) as affected by irrigation and soil amendments

	Season 2019/2020				Season 2020/2021				Mean of 2 season			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Cont.	2554	3202	3302	3019	2147	2627	2627	2467	2351	2914	2964	2743
Z	2764	3405	3410	3193	2265	2677	2789	2577	2515	3041	3099	2885
Z+C	2901	3460	3531	3297	2507	2797	3029	2778	2704	3129	3280	3038
Mean	2740	3356	3414		2306	2700	2815		2523	3028	3114	
	I	Sa		I*Sa	I	Sa		I*Sa	I	Sa		I*Sa
$LSD_{0.05}$	42.71	7.53		42.71	197.86	55.66		197.86	17.59	30.80		17.59
F-Test	**	**		**	**	**		*	**	**		*

Water Application Efficiency (WEa):

The water application efficiency (WEa) of an irrigation system indicates how efficiently it accomplishes its primary goal of getting water from the system to the crop. The goal of the irrigation is to apply and store water to the root zone to fulfil the crop's water needs. Ea is the percentage of total water applied to the field that stored in the root zone to fulfil the crop's evapo-transpiration (ET). Treatment I_1 has the value of WEa (128%) as shown in Table (6). This finding might be attributed to the contribution of water table in crop water requirements with I_1 treatment.

The mean values of seasonal water applied are 2070, 3040, and 3950 $m^3 ha^{-1}$ while the mean values of seasonal water consumptive use were 2523, 3028 and 3114 $m^3\ ha^{-1}$ for I_1, I_2, and I_3 treatments, respectively (mean of both soseans). As a result, the contribution of the water table to Cu is the difference between water applied and crop consumption for I_1 (-453 $m^3 ha^{-1}$) which received only sowing irrigation as well as the rains. The same finding was declared those obtained by Doorenbos and Kassam (1979), who stated that the consumptive efficiency was increased due to the increasing of crop water consumption and with the decrease of water applied. So, by implementing rain-fed irrigation, contribution from the water table to crop water consumption could be enhanced. This contribution were about 10.3% and 27.9% under the rain-fed irrigation regime of treatments I_1 during the 1st and 2nd seasons, respectively. Thus, the contribution resulted in (1) lowering water table, (2) improving the aeration status into the effective root zone and (3) improving the drainage condition of the cultivated area. The previous results show that the first irrigation treatment(sowing irrigation only) related with shallow water table regions.

Table 6.Water application efficiency, WEa (%) as affected by irrigation and soil amendement treatments.

Amendment	Season 2019/2020				Season 2020/2021				Mean of 2 season			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
CK	97	89	74	87	142	105	77	108	119	97	75	97
Z	105	95	76	92	149	107	82	113	127	101	79	102
Z+C	111	97	79	96	165	112	89	122	138	104	84	109
Mean	104	94	76		152	108	83		128	101	79	
	I	Sa		I*Sa	I	Sa		I*Sa	I	Sa		I*Sa
$LSD_{0.05}$	1.59	0.46		1.59	14.11	2.01		14.11	7.05	1.05		7.05
F-Test	**	**		**	**	**		**	**	**		**

I = irrigation treatments, Sa = soil amendaments

Yield and its components for barley crop:

The data in Table (7) represent the effect of irrigation treatment, soil amendments on yield and yield components of barley. The data indicated that plots irrigated by the traditional way (I_3) gave the highest values of plant height, 1000-grain weight, grain yield and straw yield compared to those under other irrigation treatments. The reduction in these parameters (as a mean of the 2 seasons) with I_1 resulted from the decrease of irrigation water applied less than I_3 by 6.32, 1.16, 24.63, and 30.64%, respectively. It could be observed that the effect of the reduction of water availability was more pronounced on plant growth and yield production. Similar results were obtained by Fahad *et al*., (2016**);** Naser *et al*., (2018**)** and Mariey *et al*., (2020), who reported that water shortage causes reductions in barley yield component parameters.

In regarde to the effect of soil amendments, the data reveal that barley yield and its components were significantly affected by the application of soil amendments. It could be arranged that the effect of soil amendments in the following descending order: (zeolite+compost) > zeolite > CK. The superiority of zeolite+compost may be due to their effects on improving soil properties and water-nutrient use efficiency. These results are in line with those obtained by Abd El-Mageed *et al*., (2019**);** Xiao *et al*., (2020**);** Ding *et al*., (2021**);** and Jiang *et al*., (2021).

Concerning the interaction effect, the data showed that the pplication of soil amendments, especially zeolite+compost increased barley yield and its components under different irrigation treatments. As a mean of both growing seasons, the application of zeolite+compost under I_3 irrigation treatment achieved the highest effects on barley yield , since increased plant height, 1000-grain weight, grain yield, and straw yield by 3.37, 11.92, 33.66, and 14.43%, respectively, compared with the lowest values recorded with CK. The superiority of zeolite+compost may be due to that the soil amendments enhanced the plant's drought resistance under drought conditions. These results are in line with those obtained by Wu *et al*., (2019) and Besharati *et al*., (2021).

Plant high:

Regarding the effect of water regimes, the data showed that the talest plants in both seasons were recorded with I_3 as comperd with the other water regimes. The mean values of barley plant height for both seasons with I_1, I_2, and I_3 were 89, 93 and 95 cm, respectively. Concerning the effect of soil amendements, the obtained data indicated that the greatest plant height of barley were achieved with (Z+C) treatment under the three water regimes comparing to othe amendment treatments. The mean values of the plant height for the two seasons with CK, Z, and (Z+C) were 88, 93 and 95 cm, respectively. The interaction between irrigation treatments and soil amendments significantly affected the plant heighet. The highest plant height as a mean of both seasons (99 cm) was obtained by I_3*(Z+C) interaction, while the lowest value (86 cm) was obtained with I_1 in untreated soil (CK). This finding is agreed with that of Fahad *et al*., (2016), who found that deficit water significantly decreased the plant height.

1000-grain weight (1000GW):

With respect to 1000-grain weight, a highly significant effects of irrigation and amendment treatments as well as their interactions were obtained in both seasons as shown in Table (7). Regarding the effect of water regimes, 1000-grain weight of barley was the greatest with I_3 as comperd with the other water regimes in both seasons.The mean values of 1000-grain weight due to I_1, I_2, and I_3 were 52.82, 53.09 and 53.44 gm, respectively. Concerning the effect of soil amendements, barley plant hight was greatest with (Z+C) comparing to other soil amendment tratments under all water regimes. The mean values of 1000-grain weight recorded in CK, Z, and (Z+C) plots were 49.64, 53.35 and 56.36 gm, respectively. The highest 1000-grain weight (56.77 gm) was obtained with Z+C under I_3 treatment, while the lowest value (48.94 gm) was obtained in untreated plots under I_1 treatment. This finding is agreed with that of Naser *et al*., (2018**).**

Grain yield (GY):

The data of GY as affected by irrigation and soil amendment treatments are listed in Table (7). Regarding the effect of water regimes on GY, the data indicated that I_3 treatment achieved the highest GY as compared with either I_1 or I_2 treatments in both growing seasons. The mean yields of both growing seasons due to I_1, I_2, and I_3 water regimes were 2604, 3118, and 3455 kg ha^{-1}, respectively. The increase in GY due to I_3 in relation to I_1 or I_2 treatments were 24.6 or 9.7%, respectively. So, significant reduction in GY was resulted from the decrease of irrigation water applied (I_2) or use sowing irrigation only (I_1).

Concerning the effect of soil amendements, the GY was greater with the (Z+C) treatment than that produced with either Z treatment or untreated plots (CK) in both growing seasons. Mean GY of both seasons due to CK, Z, and (Z+C) amendment treatments are 2408, 3140 and 3630 kg ha^{-1}, respectively. The increase of GY in plots amended by (Z+C) was higher than that in CK and Z plots by 33.66% and 20.17% , respectively .as compared with (mean of both seasons). In regarde to the interaction treaments, the data revealed that the highest GY (4288 kgha^{-1}) was obtained by I_3*Z+C interaction treatment, while the lowest yield (4008 kgha^{-1}) was obtained from the unamended plots (CK) under I_1 treatment.

Straw yield (SY):

The data of the statistical analysis indicated that "SY" was significantly influenced by the irrigation and soil amendment treatments as shown in Tables (7). Regarding to the effect of irrigation treatments, the traditional treatment (I_3) yielded the highest SY (6511 kg ha^{-1}) with an increase of 30.64 and 14.96% over that obtained with I_1 and I_2, respectively (mean of two seasons). About the effect of soil amendments, the SY under the soil amendemet treatments had the same trend in both seasons. The highest SY value was 5938 kgha^{-1} for the amendment treatment of (Z+C) followed by Z treatment (5545 kgha^{-1}) and CK (5081kg ha^{-1}) as amean of the two seasons. The effects of the interaction between the irrigation and soil amendement treatments were statistically significant and reveled that the I_3*(c+z) interaction had the highest SY (7255.13 kgha^{-1}). The lowest value of SY (4312.57 kg ha^{-1}) was obtained from I_1 in CK plots. The reason of the positive effect of the interaction treatments on GY and SY might be due to the optimum supply of soil moisture for barely crop which created by the proper irrigation and soil amendments (zeiolite and compost). It is evident from the results that GY and SY in the 2nd season was higher than that in the 1st season. Similar results were found by Araya *et al*., 2010 and Alderfasi, (2009).

Table 7. plant height, (cm); 1000-grain weight, (g); Grain yield, (kg ha^{-1}); straw yield, (kg ha^{-1}) and harvest index during the two seasons.

Treatment	Season 2019/2020					2020/2021				
	PH	TGW	GY	SY	HI	PH	TGW	GY	SY	HI
I_1	87	48.38	2725	5415	0.43	90	51.20	2484	5415	0.46
I_2	92	52.98	3256	6852	0.43	94	53.90	2980	6852	0.43
I_3	93	55.87	3663	8473	0.43	96	57.25	3247	8473	0.38
$LSD_{0.05}$	0.41	0.51	130.18	210		0.28	0.52	62.35	210	0.008
F-Test	**	**	**	**	ns	**	**	**	**	**
CK	87	49.20	2527	6489	0.37	89	50.08	2289	6489	0.36
Z	92	52.68	3299	6970	0.44	94	54.03	2981	6970	0.44
Z+C	94	55.36	3819	7280	0.47	97	57.35	3441	7280	0.48
$LSD_{0.05}$	0.22	0.20	85.27	29	0.006	0.17	0.25	44.10	29	0.006
F-Test	**	**	**	**	**	**	**	**	**	**
I_1* CK	84	45.06	2236	5266	0.37	88	46.20	2057	5266	0.39
I_1*Z	88	47.82	2855	5375	0.44	90	50.17	2586	5375	0.48
I_1*Z+C	90	52.27	3083	5603	0.47	94	54.55	2809	5603	0.50
I_2*CK	88	50.86	2595	6458	0.37	89	51.08	2348	6458	0.36
I_2*Z	93	53.26	3355	6993	0.44	96	54.07	3100	6993	0.44
I_2*Z+C	94	54.82	3819	7104	0.47	96	56.56	3493	7104	0.49
I_3* CK	88	51.67	2749	7744	0.37	92	52.95	2463	7744	0.32
I_3*Z	94	56.96	3686	8543	0.44	97	57.84	3256	8543	0.38
I_3*Z+C	97	58.98	4555	9132	0.47	100	60.95	4021	9132	0.44
$LSD_{0.05}$	0.41	0.51	130.17	210		0.28	0.52	62.35	210	0.008
F-Test	**	**	**	**	ns	**	**	**	**	**

PH: plant height (cm); TGW: 1000-grain weight (g); GY: Grain yield, (kg ha^{-1}); SY: straw yield, (kg ha^{-1}) and HI: harvest index.

Water productivity (WP):

Water productivity expressed in kg grain or straw m^{-3} of water consumed as presented in Tables (8). The obtained results showed that the highest WP value was recorded from the traditional irrigation treatment (I_3), whereas the lowest one was obtained from of I_1 which recieved only the sowing irrigation. The I_1 and I_2 have high consumptive use because of the contribution of ground water to the plant's water consumption which led to a decrease in the WP of both treatments. These results could be attributed to the significant differences among barley grain yields, and evapotranspiration due to water consumptive use. The mean of WP due to I_1, I_2, and I_3 water regimes were 1.03, 1.04, and 1.11 kg grain m^{-3} and 2.46, 2.60, and 3.03 kg straw m^{-3} , respectively.

Table 8. Water productivity (WP) ,irrigation water productivity IWP as a mean of both growing seasons.

Treatment	Season 2019/2021				Season 2020/2021				Mean of 2 seasons			
	WP (grain)	IWP (grain)	WP (straw)	IWP (straw)	WP (grain)	IWP (grain)	WP (straw)	IWP (straw)	WP (grain)	IWP (grain)	WP (straw)	IWP (straw)
I_1	0.99	1.04	2.57	2.85	1.07	1.51	2.35	2.62	1.03	1.28	2.46	2.74
I_2	0.97	0.91	2.65	2.36	1.10	1.14	2.54	2.25	1.04	1.03	2.60	2.31
I_3	1.07	0.82	3.04	2.14	1.14	0.92	3.01	2.14	1.11	0.87	3.03	2.14
$LSD_{0.05}$	0.009	0.017	0.035	0.041	0.005	0.048	0.056	0.040				
F-Test	**	**	**	**	**	**	**	**				
Cont.	0.84	0.73	2.69	2.28	0.93	0.95	2.62	2.21	0.89	0.84	2.25	2.66
Z	1.04	0.95	2.78	2.46	1.16	1.23	2.68	2.35	1.10	1.09	2.41	2.73
Z+C	1.16	1.09	2.79	2.61	1.23	1.39	2.60	2.45	1.20	1.24	2.53	2.70
$LSD_{0.05}$	0.013	0.012	0.006	0.012	0.012	0.018	0.008	0.010				
F-Test	**	**	**	**	**	**	**	**				
I_1*Cont.	0.88	0.86	2.64	2.74	0.96	1.25	2.45	2.54	0.92	1.06	2.55	2.64
I_1*Z	1.04	1.09	2.59	2.86	1.14	1.58	2.37	2.60	1.09	1.34	2.48	2.73
I_1*Z+C	1.06	1.18	2.48	2.96	1.12	1.71	2.23	2.71	1.09	1.45	2.36	2.84
I_2*Cont.	0.81	0.73	2.56	2.19	0.89	0.90	2.46	2.12	0.85	0.82	2.51	2.16
I_2*Z	0.99	0.94	2.68	2.39	1.16	1.18	2.61	2.30	1.08	1.06	2.65	2.35
I_2*Z+C	1.11	1.07	2.71	2.49	1.25	1.33	2.54	2.34	1.18	1.20	2.63	2.42
I_3*Cont.	0.84	0.61	2.88	1.91	0.94	0.70	2.95	1.96	0.89	0.66	2.92	1.94
I_3*Z	1.08	0.82	3.06	2.13	1.17	0.92	3.06	2.16	1.13	0.87	3.06	2.15
I_3*Z+C	1.30	1.02	3.19	2.37	1.33	1.14	3.01	2.31	1.32	1.08	3.10	2.34
$LSD_{0.05}$	0.009	0.017	0.035	0.041	0.005	0.048	0.056	0.040	0.92	1.06	2.55	2.64
F-Test	**	**	**	**	**	**	**	**				

***WP: water productivity and IWP: irrigation water productivity. Note:no statistical was done on mean of 2 seasons.**

Concerning the effect of soil amendment on WP, the greatest value was given with (C+Z) treatment. The mean values of WP in the two growing seasons in untreated plots (CK), plots amended by Z or (C+Z) were 0.89, 1.1 or 1.20 kg grain m^{-3} and 2.66, 2.73 and 2.70 kg straw m^{-3}, respectively. The increase of WP caused by (C+Z) treatment was 25.76% over the CK and 8.3% over Z treatment.. These findings could be attributed to the highly significant differences of GY and SY as well as differences in water consumed among different treatments. The present results are in line with those reported by Ghadiri and Majidian, (2003)**,** Abdel-Mawly and Zanouny, (2005)**,** El-Bably, (2007) and El-Atawy, (2007)**,** who mentioned that the efficiency of water use was decreased as the soil moisture was maintained high by frequent irrigation.

Irrigation water productivity (IWP):

IWP is used to measure the relationship between the amount of crop produced and the amount of water involved in crop production and it is expressed as crop production per unit volume of water. Different irrigation water productivity indices result from different water input options. In the present study the irrigation water productivity was calculated as a ratio crop yields achieved from the irrigation water input (Pereira *et al*., 2002). A higher irrigation IWP resulted in either the same production from less water resources, or a higher production from the same water resources, depending on irrigation water management, tillage practices and soil fertility. As shown in Table (8), IWP was increased significantly with application of soil amendment and decreasing of water applied.

Regarding the effect of water regimes, I_1 treatment gave the highest IWP value as compared with other amendment treatments. The mean values of IWP (over the two season) due to I_1, I_2, and I_3 water regimes were 1.28, 1.03, and 0.87 kg m^{-3}, respectively. These results could be attributed to the significant differences among barley grain yield, and water applied values. Results in tables (7&8) cleared that with increasing the number of irrigation, both IWP of grain and straw yield decreased. The highest average values of IWP 1.28 kg grain and 2.74 kg straw m^{-3} , were obtained under I_1 watering treatmen, while the lowest ones 0.87 kg grain and 2.14 kg kg straw/m^3, respectively were obtained under I_3 watering treatmen. These results indicate that increasing irrigation from I_1 up to I_3 increased the IWP of grain and straw yield by about 32.03% and21.89% respectively.

Effect of different amendments on soil properties

The obtained results illustrated in Table (9) indicated that the irrigation and soil amendment treatments individually or in combination showed a pronounced improvement of soil salinity (ECe), exchange sodium percentage (ESP), soil bulk density (BD) and soil basic infiltration rate (IR). In general, the studied soil characteristic in surface layer (0-20 cm) were more affected by different treatments compared to the their initial values. The ECe, ESP and BD values were significantly decreased in both seasons with increasing irrigation water applied as follows: $I_3 > I_2 > I_1$. In the contrast, the IR values followed the converse order.

Table 9. Effect of different irrigation and soil amendment treatments on some soil properties.

1st Season										
Soil depth		**EC**			**ESP**			**BD**		**IR**
(cm)	**0-20**	**20-40**	**40-60**	**0-20**	**20-40**	**40-60**	**0-20**	**20-40**	**40-60**	
I_1	4.45	5.48	6.16	13.25	14.39	14.90	1.22	1.27	1.31	0.79
I_2	4.13	5.03	5.56	12.91	13.94	14.36	1.21	1.27	1.31	0.87
I_3	3.88	4.58	5.06	12.64	13.48	13.72	1.21	1.26	1.30	0.94
$LSD_{0.05}$	0.098	0.101	0.102	0.112	0.153	0.118	0.007	0.008	0.006	0.027
F-Test	**	**	**	**	**	**	*	**	**	**
Cont.	4.53	5.49	6.00	13.32	14.55	14.70	1.23	1.28	1.32	0.74
Z	4.12	5.12	5.87	12.74	14.03	14.34	1.22	1.26	1.31	0.83
Z+C	3.81	4.48	4.91	12.74	13.24	13.94	1.20	1.26	1.29	1.03
$LSD_{0.05}$	0.071	0.084	0.073	0.082	0.074	0.094	0.005	0.003	0.003	0.013
F-Test	**	**	**	*	**	**	**	*	**	**
I_1* CK.	4.84	5.96	6.58	13.66	15.11	15.31	1.23	1.29	1.33	0.66
I_1*Z	4.34	5.56	6.45	13.07	14.49	14.91	1.22	1.27	1.32	0.77
I_1*Z+C	4.16	4.93	5.45	13.03	13.58	14.47	1.21	1.26	1.30	0.93
I_2* CK.	4.47	5.42	5.94	13.34	14.63	14.78	1.23	1.28	1.32	0.75
I_2*Z	4.12	5.20	5.87	12.69	13.99	14.33	1.22	1.26	1.30	0.81
I_2*Z+C	3.80	4.46	4.88	12.69	13.20	13.96	1.20	1.26	1.30	1.07
I_3* CK.	4.27	5.09	5.48	12.96	13.90	13.99	1.22	1.27	1.32	0.80
I_3*Z	3.89	4.60	5.28	12.45	13.62	13.79	1.21	1.25	1.30	0.90
I_3*Z+C	3.47	4.04	4.41	12.50	12.93	13.38	1.19	1.24	1.29	1.10
$LSD_{0.05}$	0.098	0.101	0.102	0.112	0.153	0.118	0.007	0.008	0.006	0.027
F-Test	**	**	**	**	**	**	*	**	*	**
					2ndSeason					
		EC			ESP			BD		IR
Soil depth (cm)	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	
I_1	4.19	4.86	5.93	12.81	13.88	14.54	1.22	1.26	1.31	0.82
I_2	3.79	4.52	5.25	12.28	13.30	13.83	1.20	1.26	1.31	1.03
I_3	3.44	4.21	4.69	11.84	12.66	13.03	1.18	1.23	1.27	1.12
$LSD_{0.05}$	0.102	0.108	0.103	0.107	0.151	0.112	0.010	0.011	0.012	0.034
F-Test	**	**	**	**	**	**	**	*	*	**
CK	4.28	5.16	5.63	12.96	14.15	14.33	1.21	1.27	1.31	0.82
Z	3.73	4.65	5.66	12.14	13.47	13.93	1.20	1.25	1.29	0.98
Z+C	3.41	3.78	4.58	11.83	12.22	13.14	1.19	1.24	1.27	1.17
$LSD_{0.05}$	0.064	0.082	0.091	0.072	0.085	0.091	0.008	0.008	0.009	0.023
F-Test	**	**	*	**	**	**	*	*	**	**
I_1* CK.	4.65	5.59	6.30	13.44	14.83	15.09	1.22	1.28	1.32	0.68
I_1*Z	4.05	4.94	6.27	12.65	14.11	14.69	1.22	1.27	1.31	0.80
I_1*Z+C	3.87	4.05	5.23	12.33	12.70	13.85	1.21	1.24	1.29	0.97
I_2*Cont.	4.22	5.08	5.60	12.96	14.25	14.40	1.21	1.27	1.32	0.86
I_2*Z	3.74	4.72	5.67	12.10	13.45	13.91	1.20	1.25	1.30	0.99
I_2*Z+C	3.41	3.77	4.49	11.77	12.18	13.17	1.20	1.25	1.30	1.23
I_3* CK.	3.96	4.81	4.99	12.47	13.36	13.50	1.21	1.26	1.30	0.92
I_3*Z	3.40	4.29	5.04	11.67	12.86	13.20	1.18	1.22	1.26	1.14
I_3*Z+C	2.96	3.52	4.03	11.39	11.77	12.40	1.17	1.22	1.24	1.30
$LSD_{0.05}$	0.102	0.108	0.103	0.107	0.151	0.112	0.010	0.011	0.012	0.034
F-Test	**	**	**	**	**	**	*	*	*	**

ECe: soil salinity; ESP: exchange sodium percentage; BD: soil bulk density and IR: soil basic infiltration rate.

Concerning In case of the effect of soil amendments, the ECe, ESP and BD values in both seasons were significantly decreased , while IR value was increased in plots treated by Z+C, more than that in other treatments. The application of Z+C decreased the main values of ECe, ESP and BD by 24.11, 9.25 and 4.58% in the 1st season and by 32.30, 15.45 and 5.80 % in the 2nd season, respectively compared to the initial values. While the IR values was increased with this treatment by 47.62 and 67.14% in both seasons, respectively. These results are agree with those obtained by Rahayu *et al*., (2019), Khalifa *et al*., (2019); Day *et al*., (2019); Murtaza *et al*., (2019); Amer *et al*., (2020) and El-Sharkawy *et al*., (2021).

On the other hand, adding soil amendments alleviating the adverse effect of deficit irrigation on soil properties in both seasons. No significant changes were observed in ECe, ESP, BD, and IR in plots treated by zeolite + compost with drought stress (I_1) compared with their values in the untreated plots under normal irrigation (I_3). So, the drought stress without soil amendments deteriorated soil properties. These results are in line with those obtained by Abd El-Mageed *et al*., (2019) and Aiad, (2019).

CONCLUSION AND RECOMMENDATIONS

North Nile Delta region receives considerable amount of rain, therefore its impact on the amount of water applied and yield of barley is a good approach to enhance its WP. In this study, I_1 rainfall treatment (recieved only sowing irrigation) recorded the lowest values of Wa, consumptive use (CU), and crop yield, and vice versa for Wp and IWP. For treatments I_1, I_2, and I_3, the mean average contribution of rainfall in Wa was 42.60, 29.28 and 22.65%, respectively. Rainfall treatment,I_1 yielded about 75% of that produced with I_3 treatment. More research should be done to underline the need of combining rainfall irrigation with application of soil amendments to winter crops in the North Nile Delta such as barley, especially with the current water scarcity situation. Under the strategy of irrigation management, the soil amendments mitigate the adverse effect of deficit irrigation on crop production and soil properties. The average contribution of water tables to barley water needs was about 28%.

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الزيوليت والكومبوست كمحسنات للتربة لترشيد مياه ري الشعير تحت ظروف التربة المتأ ثرة بالأملاح

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بسبب نقص مياه الري نحتاج إلى تعديل إدارة الري وتطبيق استراتيجيات ترشيد المياه. لذلك تم إجراء تجارب ميدانية فى موسمين متتاليين خلال الفترة ٢٠١٩-٢٠٢٠ و٢٠٢٠-٢٠٢١ بمحطة البحوث الزراعية بسخا بمحافظة كفر الشيخ- مصر. تم إجراء هذا البحث لدراسة استخدام ثلاث معاملات ري: (I_1) فقط رية الزراعة + الأمطار ، (I_2) رية واحدة + رية الزراعة + الامطار، و (I_3) ريتين + رية الزراعة + الامطار و مصادر مختلفة من محسنات التربة : معاملة المقارنة (بدون اضافات) ،اضافة زيوليت ،اضافة (زيوليت + كومبوست) وتاثير ذلك على بعض خواص التربة، بعض العلاقات المائية ، وإنتاجية الشعير (*Hordeum vulgare L.*) صنف جيزة ٢٠٠٠. أظهرت النتائج أن قيم المياه المضافة ، الاستهلاك المائى الفعلي (CU) خلال الموسمين انخفض بالترتيب : $I_3 > I_2 > I_1$. حيث اعطت المعاملة (I_1) أعلى قيم إنتاجية المياه (WP) وإنتاجية مياه الري (IWP). أظهرت قطع الأراضي التي تروى ريتين + رية الزراعة (I_3) + اضافة (الزيوليت + الكومبوست) تحسنًا واضحًا في ملوحة التربة (ECe) ونسبة الصوديوم المتبادل (ESP) والكثافة الظاهرية للتربة (BD) ومعدل النفازية للتربة (IR) ومحصول الشعير مكوناته. وقد خففت معاملة التربة بالزيوليت و الكومبوست من التأثير السلبي للجفاف على خصائص التربة وإنتاجية الشعير.