Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Effect of Zeolite Soil addition under Different Irrigation Intervals on Maize Yield (*zea mays* L.) and some Soil Properties

Cross Mark

El-Sherpiny, M. A.*; A. G. Baddour and M. M. El-Kafrawy

Soil, Water and Environment Res. Institute, Agric. Res., Center, Giza, Egypt.

ABSTRACT

The adequate supply of irrigation water is a crucial factor controlling the growth and productivity of crops.Under water poverty conditions in Egypt and most arid regions, sustaining the irrigation water in the root zone as long as possible becomes very necessary.Consequently, two field trials were performed aiming to evaluate the effect of zeolite soil addition of as main plots[Z_0:without zeolite(control)and Z_1: with zeolite at rate of 10 Mg h^{-1}]under three irrigation intervals as subplots [I_1: irrigation every 12 days (traditional irrigation) in addition to irrigation every 14(I_2)and 16(I_3) days, which represented the deficit irrigation treatments]. The execution of the research trail was done in a split-plot design with three replicates. Maize was used as an experimental plant based on its significant response to water alterations in the root zone. Biochemical plant characters including total chlorophyll, total phenols and proline contents were measured in leaves at period of 60 days from sowing. In addition, vegetative growth parameters (plant height) as well as quantitative (*e.g.*, No.of grain ear^{-1},No.of rows ear^{-1}, grain and biological yield) and qualitative (*i.e.*,carbohydrates, protein and oil)yield characteristics were determined at harvesting stage. Findings of this study showed that the zeolite soil addition before sowing (Z_1) with irrigation interval of maize plants every14days (I_2) as combined treatment realizes better results for improving quantitative and qualitative yield characteristics than non-addition of zeolite (Z_0) under traditional irrigation interval (I_1:every12days).Post-harvest soil analysis indicated that the usage of zeolite improves some studied soil properties *e.g.*, bulk density, total porosity, CEC and FC.

Keywords: Zeolite, irrigation intervals, water poverty and soil properties.

INTRODUCTION

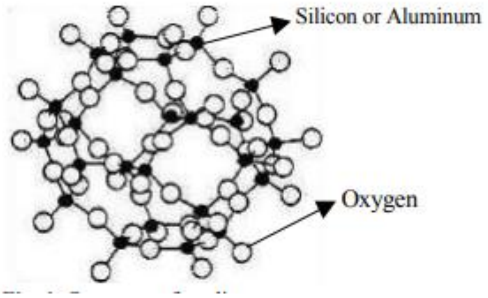
In Egypt, maize (*Zea mays* L.) is one among the more important crops in terms of nutritional value and cultivated area, where it comes in the third order behind wheat and rice (Abo El-Ezz and Haffez, 2019). Maize grain is used for the preparation of corn oil, dextrose, corn starch, corn syrup, corn flakes, grain cake and gluten as well as lactic acid and acetone, which are used by different industries i.e. food industries, fermentation, textile, foundry as well as is used in the poultry and livestock feeds industry tremendously (Awwad *et al.* 2015). Maize is a food source for human and animals (Ganzour *et al.* 2020 and Yaseen *et al*, 2020). Maize as a summer crop is pronouncedly influenced by the climate change; therefore, it is expected that the applied irrigation amount will increase by about 10-19% by the year 2040 in all Egypt governorates (Ouda *et al.* 2016). Another study expected an increase irrigation water needs by about 16% for summer crops by the year 2050 based on climate change scenarios (El-Hamdi *et al.* 2020). .

On the other hand, the gap between demands and supplies of water is widening and is reaching such alarming levels that it is posing a threat to human existence in some parts of the world. In Egypt, the human share is less than poverty limit (FAO, 2009). To face large water consumption of irrigated agriculture, there is an urgent need for raising water-efficient cropping systems (El- Agrodi *et al.* 2010 and Abdelhameid, 2020). Taking into consideration the stable water budget of Egypt, saving irrigation water is one of the priorities of the Egyptian Ministry of Agriculture and soil Reclamation. Thus, the major step of the Egyptian government strategy is raising agricultural productivity from the unit area with the minimum quantity of water losses (Sadik and Abd El-Aziz, 2018 and El-Hadidi *et al.* 2020). The essentiality for water supplies causes urgent need to find new irrigation techniques to sustain productive output rates with saving the irrigation water (El-Hamdi *et al.* 2020). In this regard, soil amendments application is one of the most eco-friendly techniques for improving water use efficiency in arid and semi-arid regions.

Zeolite, as soil amendment, improves soil properties by reducing water leaching, thus saving soil water for agronomic crops. Zeolite may hold substantial amounts of water and nutrients and release them as required for plants, thereby improving plant growth with limited supply of irrigation water (Bernardi *et al.* 2009; Azarpour *et al.* 2011 and Khalifa, *et al*. 2019). Zeolite is one of the class minerals known as "tectosilicates" that naturally occur as hydrated aluminosilicate minerals, three-dimensional tetrahedral frameworks of AlO_3 and SiO_4 (Gomah, 2015). Zeolite improves the efficiency of water use by increasing the water holding capacity of soil and its availability to plant (Bernardi *et al.* 2010). Furthermore, Zeolite as a soil conditioner leads to an increase in the CEC of soil (DeSutter and Pierzynski, 2005 and Ozbahce *et al.* 2015). Using zeolite could be beneficial strategy for improving nutrient retention in soil and their use efficiency. Ahmed *et al.* (2010) showed that the use of mineral fertilizers mixed with zeolite

* **Corresponding author.**
E-mail address: m_elsherpiny2010@yahoo.com
DOI: 10.21608/jssae.2020.160919

pronouncedly increased nutrients uptake, and their use efficiency by maize plant due to high capacity of zeolite to hold the nutrients as long as possible. Khalifa, *et al.* (2019) showed that the use of zeolite can enhance available macronutrients, CEC, total porosity, available water values, field capacity and permanent wilting point. Kulikova *et al.* (2020) reported that zeolite is an environmentally friendly product. Mosa *et al.* (2020) stated that natural zeolite has a well-distributed porous structure; however, its surface area is largely lower than most carbonaceous sorbents.



Zeolite structure (citation from Azarpour *et al.*2011)

Therefore, the objective of the current study is to evaluate response in terms of maize performance and yield as well as some soil properties to soil addition of zeolite under deficit irrigation water.

MATERIALS AND METHODS

1.Experimental setup.

Two field trials were performed at a private farm located in Met Antar Village, Talkha District, Dakahlia governorate, Egypt (31° 3′ 17.05″ N latitude, 31°22′32.32″ E longitude, with an elevation of about 6 meters above mean sea level) during the two successive summer seasons of 2019 and 2020. The work aimed to evaluate the effect of soil addition of zeolite as main plots [Z_0: without zeolite (control) and Z_1: with zeolite at rate of 10 Mg h^{-1}] under three irrigation intervals as sub plots [I_1: irrigation every 12 days (traditional irrigation) in addition to irrigation every 14 (I_2) and 16 (I_3) days, which represented the deficit irrigation treatments],starting after first irrigation. The execution of the trial was done in a split-plot with three replicates. The experimental plot area was 10.5 m^2. The source of irrigation water was main canal near the experimental field (Nile River). Before cultivation, soil sample (0-30 cm depth) was taken from experimental soil and analyzed according to Buurman *et al.* (1996) and some of its physical and chemical characteristics are presented in Table 1. Before cultivation, soft zeolite (from Alex Zeolite Company) was mixed with the soil surface layer (0-30 cm depth).Table 2 contains the characteristics of the studied zeolite. Maize seeds "*Zea mays* L. Cv single Hybride 10" were sown on May 30th and harvested on September17th during the studied two seasons. The traditional agricultural practices and fertilization (organic and inorganic fertilizers) were done for the maize production according to the recommendation of the Ministry of Agri. and soil Rec (MASR). Before sowing, all plots received compost at rate of 20 Mg ha^{-1} and phosphatic fertilizer at rate of 0.476 Mg calcium superphosphate (6.6%P) ha^{-1}. The rates of N and K fertilizers were as follows: 0.285 Mg N ha^{-1}, which was divided into two equal doses of ammonium sulphate (20.6 % N), the first dose was applied before life watering (the 2nd irrigation), and the 2nd dose was applied before the next one (the 3rd irrigation), while potassium fertilizer was applied at rate of 0.119 Mg potassium sulphate (39.8 % K) ha^{-1} in one dose before the fourth irrigation. Water was applied through surface irrigation and plants were irrigated by 7, 6 and 5 irrigations under I_1, I_2 and I_3 irrigation regimes, respectively. Table 3 shows the dates of irrigation process.

2.Measurement traits.

At a period of 60 days after sowing, random samples of five maize plants were taken from each subplot to estimate the following traits in the plant leaves:

a- Total chlorophyll content was measured according to Sadasivam and Manickam, (1996).

a- Total phenols were analyzed calorimetrically using the modified Folin-Ciocaltue colourimetric method (Eberhardt *et al.* 2000).

b- Proline was determined using 3% aqueous sulfosalicylic acid according to Bates *et al.* (1973)

While at harvest stage (110 days from sowing), random samples of five maize plants were taken from each subplot to estimate maize plant height as an average as well as some qualitative traits as follows:

c- Crude grain protein content was calculated by using the following formula: Crude protein % = Nitrogen (N) × 5.75. N content of maize grain was determined by Micro-Kjeldhal method as described by Anonymous, (1990).

d- Total carbohydrates in grain was determined using ethanolic mixture according to Hedge and Hofreiter (1962).

e- Crude grain oil content was determined by Soxhlet fat extraction method (AOAC, 1990).

Table 1. Some characteristics of the investigated soil before sowing.

Soil chemical properties															
EC, dS m^{-1}	pH in soil suspension	$CaCO_3$ %	OM %	CEC, (c mol kg^{-1})	Soluble ions, meq L^{-1}								Available Macro-Nutrients (mgKg^{-1})		
					Cations				Anions						
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO^{2-}_3	HCO^{-}_3	Cl^{-}	SO^{2-}_4	N	P	K
0.85	8.0	2.65	1.26	39.5	1.5	3.2	3.7	0.18	--	2.41	2.74	3.43	55.0	8.00	203

Soil physical properties							Soil moisture properties			
Particles size distribution(%)			Texture class	Real density	Bulk density	T. Porosity	Field capacity	Wilting point	Available water	Saturation %
Sand%	Silt %	Clay%		(Mg m^{-3})		%		%		
18.85	31.93	49.22	Clay	2.585	1.23	50.03	40.15	20.07	20.07	80.30

Table 2. Chemical composition of zeolite used.

Properties	EC (dsm^{-1})	CEC (cmol kg^{-1})	SiO_2	K_2O	FeO	P_2O_5	AlO_3	Na_2O	CaO
			(%)						
Value	2.35	158.50	64.75	5.20	6.00	1.05	12.50	1.50	9.00

Table 3. Irrigation water schedule (the same dates were during both seasons).

Irrigations No.	Date of irrigation		
	I_1	I_2	I_3
The 1st irrigation	31th May	31th May	31th May
The 2nd irrigation	12thJune	14thJune	16thJune
The 3rd irrigation	24th June	28st June	2nd July
The 4th irrigation	6th July	12th July	18th July
The 5th irrigation	18th July	26th July	3rdAugust
The 6th irrigation	30th July	10th August	-----------------
The 7th irrigation	11th August	-----------------	------------

3. Yield characteristics.

At harvest stage (17th September), criteria measured of yield (as average of five plants) were as follows:

a- Ear length and diameter
b- No. of rows ear^{-1} and No. grains ear^{-1}
c- Weight of 1000 grain
d- Grain yield and biological yield (grain yield + straw yield).
e- Harvest index % that calculated as the following equation;

$$\text{Harvest index} = \frac{\text{Economical yield (grain yield)}}{\text{Biological yield (grain + straw yields)}} \times 100$$

4. Soil measurements.

After harvesting stage of maize plants (after 110 days from sowing); soil samples (0-30 cm depth) from each plot were taken in order to evaluate the impact of studied treatments and analyzed according to Buurman *et al.* (1996), where the soil parameters measured for assessment of the combined effect of studied treatments were as follows:

a. Soil chemical characteristics *i.e.* available nutrients content (N, P, K), pH, electrical conductivity (EC), cation exchange capacity (CEC).

b. Soil physical characteristics *i.e.* total porosity (TP), bulk density (BD) and soil moisture characteristics *i.e.* field capacity (FC), wilting point (WP) and available water (AW) and saturation percentage (SP). Soil paste extract was prepared by a suction machine to determined saturation percentage, while the other characteristics were calculated as follows: %SP= 2%FC= 4%WP.

5. Statistical Analysis.

It was done according to Gomez and Gomez, 1984, using CoStat (Version 6.303, CoHort, USA, 1998–2004)].

RESULTS AND DISCUSSION

Results.

1.Maize growth and yield Performance.

a- Biochemical parameters at 60 days after sowing

Data in Table 4 showed that soil addition of zeolite at rate of 10 Mg h^{-1} pronouncedly affected content of total chlorophyll, total phenols and proline (mg g^{-1} F.W) in maize plant leaves at period of 60 days from sowing, where the values of chlorophyll content significantly increased with soil addition of zeolite compared to control treatment (without zeolite), while, the plants grown without zeolite produced total phenols and proline in leaves more than that grown under soil addition of zeolite.

Data in the same Table exhibited highly significant differences among the different irrigation intervals studied. It is clear that values of chlorophyll content of maize plant significantly increased as irrigation intervals decreased, where the highest value is realized when maize plants were irrigated every 12 days (I_1), followed by irrigation every 14 days (I_2),while the lowest value was obtained at 16 days irrigation interval regime (I_3). In a related behavior, findings illustrated that water stress caused remarkable increases of total phenols and proline content in maize plant leaves, where the increase of irrigation intervals caused increasing plant production from total phenols and proline content in leaves to resist irrigation water deficit. Generally, water stress under irrigation every 16 days gave the highest values of total phenols and proline content in maize plant leaves.

Regarding the interaction effect, data of Table 4 showed that the combination of zeolite treatments and irrigation intervals was significant. Concerning chlorophyll content, maize plants amended with zeolite and irrigated every 12 days recorded the highest values, while the lowest values were recorded when maize plants were untreated with zeolite and irrigated every 16 days. On the contrary, the lowest values of total phenols and proline content in maize plant leaves were noticed at [I_1 (irrigation every 12 days) × Z_1 (with zeolite)] treatment, while the highest values are realized at I_3 (irrigation every 16 days) × Z_0 (without zeolite) treatment. Generally, maize plants fertilized with zeolite gave better results than that grown without zeolite addition under each studied irrigation interval. Moreover, mixing zeolite with soil surface before sowing (Z_1) with irrigation of maize plants every 14 days (I_2) as combined treatment improved maize plant performance than that without zeolite addition (Z_0) under irrigation every 12 days (I_1).

Table 4. Effect of soil addition of zeolite, different irrigation intervals and their interactions on performance of maize plant (combined data over both seasons) at 60 days from sowing.

Characters		T. Chlorophyll	Total phenols	Proline
Treatments		(mg g^{-1} F.W)		
		Zeolite		
Z_0		1.184^b	14.69^a	4.01^a
Z_1		1.367^a	12.14^b	3.32^b
LSD at 5%		0.042	0.43	0.02
		Irrigation intervals		
I_1		1.395^a	10.29^c	2.83^c
I_2		1.274^b	14.22^b	3.90^b
I_3		1.158^c	15.73^a	4.26^a
LSD at 5%		0.029	0.20	0.08
		Interaction		
Z_0	I_1	1.314^c	11.10^e	3.07^e
	I_2	1.156^e	15.75^b	4.30^b
	I_3	1.082^f	17.21^a	4.65^a
Z_1	I_1	1.476^a	9.47^f	2.59^f
	I_2	1.391^b	12.70^d	3.49^d
	I_3	1.235^d	14.24^c	3.88^c
LSD at 5%		0.042	0.28	0.11

Notes Z0: without zeolite; Z1: with zeolite; I1: irrigation every12 days; I2: irrigation every14 days; I3: irrigation every16 days.

b- At harvest stage (yield and measurement qualitative traits).

Data of Table 5 showed the influence of zeolite soil addition (Z_0: without zeolite and Z_1: with zeolite), various irrigation intervals (I_1: irrigation every 12 days, I_2: irrigation every 14 and I_3: irrigation every 16 days) and their interactions on grain quality traits *i.e.* carbohydrates, protein and oil (%) and yield characteristics *i.e.* No. of grains ear^{-1}, No. of rows ear^{-1}, ear length and diameter (cm), weight of

1000 grain (g), grain and biological yield (Mgh^{-1}), harvest index (%) and plant height (cm), of maize plant.

Additive of zeolite caused marked increase in plant height, yield and its quality parameters, where the highest values of all aforementioned traits were realized with soil addition of zeolite at rate of 10 Mg h^{-1}, while maize plants grown on corresponding untreated soil recorded the lowest values.

Concerning irrigation treatments, the traditional irrigation was the superior followed by irrigation every 14 and 16 days, respectively for all studied yield and quality traits.

In fact, the performance of maize plant at harvest stage took the same trend of its performance at period of 60 days from sowing, where maize plants fertilized with zeolite gave better results than that grown without zeolite under each studied irrigation interval. Meantime, maize plants fertilized with zeolite and irrigated every 12 days recorded the highest values of all aforementioned quality and yield traits, while the lowest values were recorded with maize plants grown on untreated soil with zeolite under irrigation every 16 days. Taking into account that soil addition of zeolite before sowing (Z_1) with irrigation of maize plants every 14 days (I_2) as combined treatment realized better results than non-addition of zeolite (Z_0) under traditional irrigation (every 12 days).

The pronounced promotional effect of zeolite may be attributed to its ability in enhancing the use of NH_4 -N and NO_3 -N, reducing leaching losses of nutrients in cation form as well as acting as a slow-release fertilizer as mentioned by Bernardi *et al.* (2009) in addition to its role in preventing soil moisture losses. Generally, zeolite is useful for performance and yield of maize due to its high content of nutrients (Table 2). This result is in accordance with those of (DeSutter and Pierzynski, 2005; Bernardi *et al.* 2009; Ahmed *et al.* 2010; Azarpour *et al.*2011; Gomah, 2015 ; Ozbahce *et al.* 2015 and Khalifa, *et al*. 2019). Beside, Najafinezhad *et al.* (2015) who concluded that soil addition of zeolite led to increase chlorophyll content (SPAD) and yield of sorghum and corn plant.

The maize plants under drought stress without zeolite produces antioxidants such as phenols and proline more than that with zeolite soil addition. It is known that antioxidants production increased in tissues under stress conditions such as drought in order to protect the plant from these conditions but with the continuing stress conditions for a long time, the production of antioxidants declines. This fact applies to the contents of total phenols and proline in maize leaves, where deficit irrigation treatments I_2 and I_3 reduced plant performance through over production of Reactive Oxygen Species (ROS), which might damage different macromolecules and cellular structures, thus this plant is forced to secrete more amounts of total phenols and proline to resist these ROS (Gharibi *et al*. 2016). This finding explains increase of contents of total phenols and proline in leaves of plants grown without zeolite addition under deficit irrigation. Generally, zeolite reduces the maize plant requirements from these antioxidants due to ability of zeolite for holding water and other nutrients. The adverse effect of produced ROS in tissues under deficit irrigation reflects on yield and its quality. This result is in accordance with those of Mahajan and Tuteja, (2005); Farooq *et al.* (2009) on maize; He and Gao, (2009) on wheat and Terzi *et al.* (2014) on maize.

Table 5. Effect of soil addition of zeolite, different irrigation intervals and their interactions on grain quality traits, yield characteristics and plant height of maize plant at harvest stage (combined data over both seasons).

Characters / Treatments		Grain quality traits			Yield characteristics								Plant height
		Carbohydrates	Protein	Oil	No. of grains ear^{-1}	No. rows ear^{-1}	Ear length	Ear diameter	Weight of 1000grain	Grain yield	Biological yield	Harvest index	
		(%)					(cm)		(g)	($Mg\ ha^{-1}$)		(%)	(cm)
Zeolite													
Z_0		70.24b	11.40b	4.48b	367.67a	13.44b	15.04b	2.86b	311.21b	5.42b	11.00b	49.16b	202.66b
Z_1		72.09a	13.76a	5.07a	394.78a	15.11a	17.69a	3.47a	329.89a	6.40a	12.48a	51.25a	216.09a
LSD at 5%		0.55	0.08	0.01	n.s	0.82	0.09	0.29	1.86	0.01	0.08	0.23	0.75
Irrigation intervals													
I_1		72.33a	14.11a	5.14a	397.33a	15.50a	18.13a	3.53a	332.77a	6.55a	12.57a	52.05a	217.95a
I_2		71.16b	12.59b	4.77b	382.50b	14.17b	16.37b	3.17b	320.57b	5.94b	11.60b	51.08b	208.03b
I_3		69.99c	11.04c	4.41c	363.83c	13.17c	14.60c	2.78c	308.32c	5.26c	11.05c	47.49c	199.90c
LSD at 5%		0.42	0.08	0.11	14.48	0.88	0.18	0.08	3.72	0.04	0.08	0.58	0.65
Interaction													
Z_0	I_1	71.55^{c}	13.17^{c}	4.90^{c}	383.67^{bc}	14.67^{bc}	17.07^{c}	3.27^{c}	324.63^{c}	6.18^{c}	12.03^{c}	51.41b	213.07c
	I_2	70.03^{e}	11.09^{e}	4.38^{e}	367.67^{cd}	13.00^{d}	14.73^{e}	2.77^{e}	308.10^{e}	5.32^{e}	10.69^{e}	49.75c	198.10e
	I_3	69.13^{f}	9.93^{f}	4.16^{f}	351.67^{d}	12.67^{d}	13.33^{f}	2.53^{f}	300.90^{f}	4.76^{f}	10.27^{f}	46.33e	192.33f
Z_1	I_1	73.11^{a}	15.05^{a}	5.38^{a}	411.00^{a}	16.33^{a}	19.20^{a}	3.80^{a}	340.90^{a}	6.91^{a}	13.12^{a}	52.68a	222.83a
	I_2	72.30^{b}	14.08^{b}	5.15^{b}	397.33^{ab}	15.33^{ab}	18.00^{b}	3.57^{b}	333.03^{b}	6.55^{b}	12.50^{b}	52.42a	217.97b
	I_3	70.86^{d}	12.15^{d}	4.67^{d}	376.00^{c}	13.67^{cd}	15.87^{d}	3.03^{d}	315.73^{d}	5.75^{d}	11.82^{d}	48.65d	207.47d
LSD at 5%		0.60	0.11	0.15	20.47	1.25	0.25	0.12	5.26	0.05	0.12	0.82	0.65

See footnotes of Table 1 for treatment designations

2- Soil properties.

Post-harvest soil analysis indicated that all studied soil properties pronouncedly differed as a result of studied treatments, where data of Table 6 showed the effect of soil addition of zeolite and different irrigation intervals on average values of some soil properties, where the displayed parameters' values are mean of the two seasons.

Soil moisture characteristics (FC, WP, AW and SP, %): All soil moisture characteristics of soil after the harvest of maize pronouncedly were affected by soil zeolite addition more than the corresponding soil without zeolite under all studied irrigation intervals, which have slightly impact on these soil moisture characteristics. This behaviour could be due to that zeolite conditioner holds a high quantity of irrigation water in its pores, where zeolite can retain irrigation water in the root zone to be used by plants when required, thus zeolite helps in resisting the deficit irrigation treatments (I_2 and I_3) as mentioned by Al-Busaidi *et al.*(2008). It can be said that use of zeolite is one way to improve soil moisture characters and prevent soil moisture losses due to that aluminosilicates is scaffold structure and water molecules occupation in its cavities and removable in its structure so that ion exchange reactions and dehydration do as reversible (Khalifa *et al*. 2019). These findings are in harmony with those obtained by Pisarović *et al.* (2003) who reported that zeolite conditioner can absorb up to 55% water of that can be used in metabolic activities of plants.

Bulk density (P_b, Mg m^{-3}) and total porosity (TP, %): Table 6 illustrated that mixing zeolite with soil surface before sowing at rate of 10 Mg ha^{-1} led to a reduce soil bulk density and increase its total porosity under all studied irrigation intervals, which possessed slight effect on these physical properties. P_b is considered as a good indicator for the enhancement of the major physical soil properties; the decrease in its value means that the different structure parameters are desirable for various biological and chemical processes in soil. Obtained results in Table 3 showed that Soil P_b values remarkably decreased with soil addition of zeolite, where the lowest values are obtained at Z_1 treatment. TP is a result of relationship between real density (P_s, as constant = 2.585 Mg m^{-3}) and bulk density (P_b) according to the following equation

$$\left(\mathbf{TP} = \mathbf{1} - \frac{\textbf{Bulk density }(\boldsymbol{Pb})}{\textbf{Real density}(\boldsymbol{Ps})} \times \mathbf{100}\right).$$

Table 3 showed that TP value of soil treated with zeolite is higher than that of untreated soil with zeolite. Increase of soil TP may be attributed to the high porosity of zeolite amendment, which improved soil structure and decreased soil bulk density. Generally, reduction of P_b and Increase of TP as a result of applying zeolite may be due to that zeolite improves the soil physical properties. These results are in agreement with those obtained by Habashy and Abdel-Razek (2011) and Rosalina *et al.* (2019).

Electric conductivity (EC, dSm^{-1}): At maize harvest stage, soil EC values pronouncedly increased due to applying zeolite as compared to untreated soil (without zeolite). It can be said that zeolite increased soil salinity. On the other hand, traditional irrigation interval I_1 caused a reduction in soil EC values as compared to deficit irrigation treatments, (I_2 and I_3),where the soil EC value increased as irrigation intervals increased. This may be attributed to irrigation every 12 days gives more water in the season, thus leaching of salts out of the soil root zone is more far.

Soil reaction (pH): pH is considered a soil parameters which is unable to be easily changed. So, the effect of studied treatments on soil reaction (pH) was not significant with a slight reduction of pH value in treatments amended with zeolite. This is mainly attributed to the buffering capacity of soil, which resist against wide variation in soil pH values.

Cation exchange capacity (CEC, $cmol.kg^{-1}$): The most effective factor, which affected soil CEC was zeolite. The pattern of response to zeolite addition showed a marked increase in soil CEC. These increases may be due to the high CEC value of zeolite is 3-4 times greater than that in studied soils (158.5 cmol kg^{-1}). This result is in agreement with those of Habashy and Abdel-Razek (2011) and Ozbahce *et al.* (2015).

Available nitrogen and potassium ($mgkg^{-1}$): Data in Table 6 illustrated that soil addition of zeolite clearly increased available N and K in soil. This could be revealed to the ability of zeolite additives improved the capacity of soil toward retention of N and K in the root zone. Further to this, the high K concentration in zeolite might provide a released supply of K in soil. These findings agree with those of Azarpour *et al.* (2011) and Khalifa, *et al.* (2019).

Table 6. Some soil properties as affected by soil addition of zeolite and different irrigation intervals after maize harvest (average of both seasons).

Characters		Chemical characters					Physical characters		Moisture characteristics			
		EC	pH	CEC	AN	AK	TP	P_b	FC	WP	AW	SP
Treatments		$dS.m^{-1}$		$cmol.kg^{-1}$	mg kg^{-1}		%	Mg m^{-3}	%			
Initial soil before sowing		0.858	8.00	39.5	55.0	203	50.03	1.24	40.15	20.07	20.07	80.30
Z_0	I_1	1.10	7.98	42.30	56.0	210.2	52.80	1.22	40.00	20.00	20.00	80.00
	I_2	1.17	8.00	42.51	56.9	212.3	53.19	1.21	40.19	20.09	20.09	80.38
	I_3	1.23	7.99	42.83	57.5	213.0	53.96	1.19	40.13	20.06	20.06	80.26
Z	I_1	1.43	7.93	46.33	62.3	218.3	55.12	1.16	43.2	21.60	21.60	86.40
	I_2	1.52	7.96	46.54	63.5	220.2	55.9	1.14	43.3	21.65	21.65	86.60
	I_3	1.57	7.98	46.95	63.9	220.9	56.67	1.12	43.5	21.75	21.75	87.00

See footnotes of Tables 1 and 2 for treatment designations. Values are means, without statistical analysis.
Notes EC: electrical conductivity; pH: soil reaction; CEC: Cation exchange capacity; AN: Available nitrogen; AK: available potassium; TP: total porosity; P_s: bulk density; FC: Field Capacity, SP: Saturation Percentage, AW: Available Water, WP: permanent wilting Point

CONCLUSION

Results obtained increase our knowledge concerning the efficacy of zeolite on the improvement of plant performance and crop yield. Findings confirmed that soil addition of zeolite improved the most of soil properties including water holding capacity of the soil and its capacity toward nutrients retention, therefore, the use of zeolite is one way to prevent soil moisture losses.

It can be concluded that zeolite represent an attractive option for programs of sustainable crop management under deficit water circumstances.

ACKNOWLEDGEMENT

The authors wish to express their sincere gratitude to Prof. Dr. Mahmoud Saied, ARC- SWERI, Giza, Egypt, may Allah be merciful to him for his helpful guidance and introducing all facilities needed to accomplish this study.

Authors' contribution:

1- Mohamed Atef El-Sherpiny (33.3 %).

2- Ahmed Gamal-Eldien Abd El-Khalek Baddour (33.3%).
3- Mohamed Mostafa El-Kfarawy (33.3%).

Funding: Self-funding by the authors of the manuscript.

REFERENCES

Abdelhameid, N. M. (2020). Effect of mycorrhizal inoculation and potassium fertilization on grain yield and nutrient uptake of sweet sorghum cultivated under water stress in calcareous soil. Egyptian Journal of Soil Science, 60 (1): 17-29.

Abo El-Ezz, S.F and Haffez, S.H (2019). Effect of nitrogen fertilization, proline, plant spacing and irrigation intervals on growth of maize Plant. Journal of Soil Sciences and Agricultural Engineering, 10(8):447-456.

Ahmed, O. H., Sumalatha, G and Muhamad, A. N. (2010). Use of zeolite in maize (*Zea mays*) cultivation on nitrogen, potassium and phosphorus uptake and use efficiency. International Journal of Physical Sciences, 5(15): 2393-2401.

Al-Busaidi, A., Yamamoto, T., Inoue, M., Eneji, A. E., Mori, Y and Irshad, M (2008). Effects of zeolite on soil nutrients and growth of barley following irrigation with saline water. Journal of Plant Nutrition, 31(7): 1159-1173.

Anonymous, (1990). "Official Methods of Analysis of the Association of Official Analytical Chemists". 15th Ed. Vol. 11. Helrich (Ed.) Assoc. off. Ana. Chemists. Inc., Virginia, USA.

AOAC, (1990). "Official Methods of Analysis. Association of official Analytical Chemists". 15th Arlington, Virginia, USA.

Awwad, M., El-Hedek, K., Bayoumi, M and Eid, T. (2015). Effect of Potassium Humate Appliction And Irrigation Water Levels on Maize Yield, Crop Water Productivity And Some Soil Properties. Journal of Soil Sciences and Agricultural Engineering, Fac. Agric. Mans. Univ, Egypt, 6(4):461-482.

Azarpour, E., Motamed, M. K., Moraditochaee, M and Bozorgi, H. R. (2011). Effects of zeolite application and nitrogen fertilization on yield components of cowpea (*Vigna unguiculata* L.). World Applied Sciences Journal, 14(5): 687-692.

Bates, L.S., Waldren, R.P and Teare, I.D. (1973). Rapid determination of free proline for water stress studies. Plant and Soil, 39:205-208.

Bernardi, A. D. C., da Mota, E. P., Souza, S. D. C. H. D., Cardoso, R. D and Oliveira, P. (2010). Ammonia volatilization, dry matter yield and nitrogen levels of Italian ryegrass fertilized with urea and zeolite. In World Congress of Soil Science. 2010;19. Brisbane. Soil solutions for a changing world-Anais. Brisbane: ASSSI, 2010. p.22-25.

Bernardi, A. D. C., Mendonça, F. C., Haim, P. G., Werneck, C. G., and Monte, M. D. M. (2009). Water availability and rice yield due to levels of zeolitic concentrate. Irriga, Botucatu, 14(2): 123-134.

Buurman, P., Van Lagen, B and Velthorst, E.J. (1996). ″Manual for Soil and Water Analysis″. Backhuys.

CoStat version 6.303 copyright (1998-2004). CoHort Software 798 Lighthouse Ave. PMB 320, Monterey, CA, 93940, USA.

DeSutter, T. M and Pierzynski, G. M. (2005). Evaluation of soils for use as liner materials: A soil chemistry approach. Journal of environmental quality, 34(3): 951-962.

Eberhardt, M.V., Lee, C.Y and Liu, R.H. (2000). Antioxidant activity of fresh apples. Nature 405:903–904.

El-Agrodi, M. W. M., Shams El-Din, H. A., Labeeb, G and Khalifa, T. S. H. (2010). Effect of different irrigation systems and potassium and phosphorus levels on maize. Journal of Soil Sciences and Agricultural Engineering, Fac. Agric. Mans. Univ, Egypt, 1(7):713-721.

El-Hadidi, E.M ., Meleha, A.M.I., El-Tobgy, S.M.M and Abo El-Ezz, S.F. (2020). Response of rice (*Oriza Sativa* L.) to some antitranspiratiors under water stress in North Nile Delta, Egypt. Plant Archives, 20(2): 2210-2220.

El-Hamdi, K. H., Khair, A. S and Abu Ishwayrib, H. M. (2020). Simulation of water stress and climate change impacts on canola yield, seed quality and water productivity at north delta, Egypt .Journal of Soil Sciences and Agricultural Engineering, Fac. Agric. Mans. Univ, Egypt, 11(8):377-383.

FAO (2009). FAO's Information System on Water and Agriculture (online). Available at" http://www.fao.org/nr/water/aquastat/countries_regions/egypt/index.stm". Viewed April 4, 2014.

Farooq, M., Aziz, T., Wahid, A., Lee, D. J and Siddique, K. H. (2009). Chilling tolerance in maize: agronomic and physiological approaches. Crop and Pasture Science, 60(6): 501-516.

Ganzour, S., Ghabour, T., Hemeid, N. M and Khatab, K. A. (2020). Impact of Biofertilizers on Maize (*Zea mays* L.) Growth and Yield under Calcareous Soil Conditions. Egyptian Journal of Soil Science.

Gharibi, S., Tabatabaei, B. E. S., Saeidi, G and Goli, S. A. H. (2016). Effect of drought stress on total phenolic, lipid peroxidation, and antioxidant activity of *Achillea* species. Applied biochemistry and biotechnology, 178(4), 796-809.

Gomah, H. H. (2015). In-Situ Remediation of Heavy Metals in Sewage Sludge Using Some Pesticides and Inorganic Amendments. Egypt J. Soil Sci, 55(4):453-462.

Gomez; K. A and Gomez, A.A (1984). "Statistical Procedures for Agricultural Research". John Wiley and Sons, Inc., New York.pp:680.

Habashy, N. R and Abdel-Razek, M. K. M. (2011). Effect of some natural and organic soil amendments on improving some clayey soil properties and its productivity. Journal of Applied Sciences Research, 7(11):1721-1731

He, L and Gao, Z. (2009). Pretreatment of seed with H_2O_2 enhances drought tolerance of wheat (*Triticum aestivum* L.) seedlings. African Journal of Biotechnology, 8(22): 6151-6157.

Hedge, I.E. and Hofreiter, B. T. (1962). “Carboydrate Chemistry i7 (Eds Whistler R.L. and Be Miller, J.N.) Academic Press New York.

Khalifa, T. H. H., Elsaka, M. S., Shabana, M. A and Abo-Elsoud, H. M. (2019). Effect of zeolite and mineral fertilizers on some soil properties and growth of Jew's mallow in clayey and sandy Soils. International Journal of Plant and Soil Sci, 3(12): 1-12.

Kulikova, A., Zakharov, N., Yashin, E., & Khairtdinova, N. (2020). Efficiency of zeolite as maize fertilizer of Middle Volga chernozem. In BIO Web of Conferences (Vol. 27). EDP Sciences.

Mahajan, S and Tuteja, N. (2005). Cold, salinity and drought stresses: an overview. Archives of biochemistry and biophysics, 444(2): 139-158.

Mosa, A., El-Ghamry, A and Tolba, M. (2020). Biochar-supported natural zeolite composite for recovery and reuse of aqueous phosphate and humate: Batch sorption-desorption and bioassay investigations. Environmental Technology & Innovation,(19): 100807.

Najafinezhad, H., Sarvestani, Z.T., Mohammad,S.A., Sanavy, M and Naghavi, H. (2015). Evaluation of yield and some physiological changes in corn and sorghum under irrigation regimes and application of barley residue, zeolite and superabsorbent polymer. Archives of Agronomy and Soil Science, 61(7):891-906.

Ouda, S., Abd El-Latif, K., and Khalil, F. (2016) Water requirements for major crops. In Major crops and water scarcity in Egypt (pp. 25-32). Springer, Cham.

Ozbahce, A., Tari, A. F., Gönülal, E., Simsekli and Padem, H. (2015). The effect of zeolite applications on yield components and nutrient uptake of common bean under water stress. Archives of Agronomy and Soil Science, 61(5):615-626.

Ozbahce,A., Tari, A.F., Gönülal, E., Simsekli, N and Padem, H. (2015). The effect of zeolite applications on yield components and nutrient uptake of common bean under water stress Arch. Agron. Soil Sci. 61(5):615–626.

Pisarović, A., Filipan, T and Tišma, S. (2003). Application of zeolite based special substrates in agriculture-ecological and economical justification. Periodicum biologorum, 105(3):287-293.

Rosalina, F., Gafur, M.A.A., Irnawati, I., Soekamto, M.H., Sangadji, Z and Kahar, M.S.(2019). Utilization of Compost and Zeolite as Ameliorant on Quartz Sand Planting Media for Caisim (*Brassica Juncea*) Plant Growth. In Journal of Physics: Conference Series (Vol. 1155, No. 1, p. 012055).

Sadasivam, S and Manickam, A (1996). Biochemical Methods, 2nd Ed. New age inter. India.

Sadik, A and Abd El-Aziz, A (2018). Yield response of squash (*Cucurbita pepo* L.) to water deficit under East Owainat conditions. Egyptian Journal of Soil Science, 58(2): 161-175.

Terzi, R., Kadioglu, A., Kalaycioglu, E and Saglam, A. (2014). Hydrogen peroxide pretreatment induces osmotic stress tolerance by influencing osmolyte and abscisic acid levels in maize leaves. Journal of Plant Interactions, 9(1): 559-565.

Yaseen, R., Hegab, R., Kenawey, M and Eissa, D. (2020). Effect of super absorbent polymer and bio fertilization on Maize productivity and soil fertility under drought stress conditions. Egyptian Journal of Soil Science, 60(4): 379-389.

تأثير الإضافة الأرضية للزيوليت مع فترات ري مختلفة على محصول الأذرة وبعض خصائص التربة

محمد عاطف الشربيني ،احمد جمال الدين عبد الخالق بدور ومحمد مصطفي الكفراوي

معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر

يعتبر الإمداد الكافي بمياه الري عاملاً يؤثر بشكل مباشر على نمو وإنتاجية المحاصيل. في ظل ظروف الفقر المائي في مصر، يصبح الاحتفاظ بمياه الري في منطقة الجذور لأطول فترة ممكنة أمرًا ضروريًا للغاية. لذلك، تم إجراء تجربتين حقليتين بهدف تقييم إضافة الزيوليت للتربة كمعاملات رئيسيه [Z_0: بدون زيوليت و:Z_1 مع إضافة الزيوليت بمعدل 10 طن/الهكتار] تحت ثلاث فترات ري كمعاملات منشقة [I_1:الري كل 12 يومًا (الري التقليدي) بالإضافة إلى الري كل14 (I_2) و 16(I_3) يومًا كمعاملات عجز مائي]. تم تنفيذ التجربة في تصميم قطع منشقه مرة واحدة بثلاث مكررات. تم استخدام الأذرة كنبات تجريبي بسبب استجابته الكبيرة لتعديلات المياه في منطقة الجذور. تم تقدير محتوي الكلوروفيل الكلي، الفينولات الكلية والبرولين في الأوراق عند فترة 60 يومًا من الزراعة. كذلك تم تقدير طول النبات كمدلول للنمو الخضري وخصائص المحصول (عدد الحبوب وعدد الصفوف في الكوز، محصول الحبوب ومحصول القش والحبوب معا) وصفات جودة الحبوب (الكربوهيدرات، البروتين، الزيت) عند مرحلة الحصاد. أظهرت النتائج أن إضافة الزيوليت للتربة قبل الزراعة (Z_1) مع ري نباتات الأذرة كل 14 يومًا (I_2)كمعاملة مشتركة تحقق نتائج أفضل من عدم إضافة الزيوليت (Z_0) تحت الري التقليدي :(I_1 كل 12 يومًا). يشير تحليل التربة بعد الحصاد إلى أن استخدام الزيوليت حسن من بعض خواص التربة مثل الكثافة الظاهرية والمسامية الكلية والسعة التبادلية الكاتيونية والسعة الحقلية.