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Assess Effect of Water Deficit Stress and Clinoptilolite on Corn (*Zea mays* L.) Crop Production

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Zeolite materials can reduce losing soil moisture in arid and semi-arid regions by soil physical improvement. These storage tanks absorb water provided by irrigation and rainfall and reduced permeability of soil. In drought stress condition, water saved in the polymer is gradually depleted and reduces need for re-irrigation.

OBJECTIVES: This research was carried out to evaluate effect different level of water stress and Clinoptilolite on effective traits on Corn seed yield.

METHODS: This study was done via split plot experiment based on randomized complete blocks design with three replications along 2021-2022 agronomic years. The main factor included Irrigation cycle based on evaporation from class A evaporation pan (I_1: 50 mm evaporation or none stress or control, I_2: 75 mm evaporation or Moderate stress, I_3: 100 mm evaporation or severe stress). Also different level of Clinoptilolite (C_1: control, C_2: 4 and C_3: 8 $t.ha^{-1}$) belonged to subplots.

RESULT: According result of analysis of variance effect of different level of water deficit and Clinoptilolite on all studied traits (instead harvest index) were significant but interaction effect of treatments was not significant. Compare different level of Clinoptilolite showed that the maximum amount of seed yield (4837.78 $kg.ha^{-1}$), biologic yield (10486.7 $kg.ha^{-1}$) and water use efficiency (1.5 $kg.m^{-3}$) belonged to 8 $t.ha^{-1}$ and lowest amount of mentioned traits were for control treatment. Mean comparison result of different level of water deficit indicated that maximum amount of measured traits was noted for control and minimum of those belonged to severe stress treatment.

CONCLUSION: Adding Clinoptilolite to the soil under water stress conditions caused a 14% increase in biological yield and a 20% increase in corn seed yield in compare to the condition of not using this mineral. So that the consumption of 8 $t.ha^{-1}$ of zeolite led to produce highest seed yield and it dose advised to farmers in studied region.

KEYWORDS: *Harvest index, Irrigation, Maize, Seed yield, Water use efficiency.*

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1. BACKGROUND

Zeolites also are one of the greatest cationic interchangers that their cationic interchange capacity is more than other types of minerals found in soils. The application of zeolites to soils increases cation exchange capacity, and as increases nutrient retention capacity (Ming and Boettinger 2001, Eroglu *et al*., 2017). Zeolites are highly hydrophilic due to low cross-links in their structure (Huang and Petrovic, 1994). Zeolites may have great potential in restoration and reclamation of soil and storing water available for plant growth and production (Zhang *et al*., 2007). Chemical treatment and agronomical crop management practices have been tried to reduce the drought effects (Manivannan *et al*., 2007), but the application of zeolite to discharged plants attracted little attention. There are more than 50 known naturally occurring zeolites (Çoruh, 2008). Natural zeolites are hydrated aluminosilicates with comprising silica and aluminum tetrahedral which result in the stable three-dimensional framework. This honeycomb structure is generally very open, containing channels and cavities, which are filled with cations and water molecules (Karapinar, 2009). The cations are bound by weaker electrostatic bonds, increasing their mobility and the capability of being exchanged with cations present in solution (Maranon *et al.*, 2006). Zeolite is used as a soil additive, nutrient reservoir and super absorbent in soil. Application of some additives such as zeolite makes it possible to use infrequent rainfalls and limited water resources for preservation and storage of water in soil. Zeolites are micro porous, crystalline aluminosilicates of alkali and alkaline materials that have a high internal surface area (Silberbush *et al*., 1993). Zeolites are hydrated aluminosilicates of alkaline with open three-dimensional structure and are able to lose or gain water reversibly and exchange extra framework cations, both without crystal structure changes (Mumpton, 1999). Zeolites can act as water moderators and can absorb up to 55% water of their own weight, later on this water released slowly as per plant water demand (Pisarovic *et al*., 2003). Zeolite minerals are hydrated aluminosilicates of alkali or alkaline-earth metals, structured in a three dimensional rigid crystalline network, formed by tetrahedral AlO_4 and SiO_4, whose rings join in a system of canals, cavities and pores. These minerals are characterized by the ease of retaining and releasing water and exchanging cations without structural changes (Mumpton, 1999) and can potentially be used in field or substrate cultivation (Harland *et al.*, 1999). There are over 40 species of natural zeolites, of which clinoptilolite is apparently the most abundant, both in soils and in sediments (Ming and Dixon, 1987).

2. OBJECTIVES

This research was carried out to evaluate effect different level of water stress and Clinoptilolite on effective traits on Corn seed yield.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This study was done via split plot experiment based on randomized complete blocks design with three replications along 2021-2022 agronomic years. Place of research was located in Ahvaz city at longitude 48°40'E and latitude 31°20'N in Khuzestan province (Southwest of Iran). The main factor included Irrigation cycle based on evaporation from class A evaporation pan (I_1: 50 mm evaporation or none stress or control, I2: 75 mm evaporation or Moderate stress, I3: 100 mm evaporation or severe stress). Also different level of Clinoptilolite (C_1: control, C_2: 4 and C_3: 8 t.ha^{-1}) belonged to subplots. This experiment had 27 plots. Each plot consisted of 5 lines with a distance of 75 cm and 5 meters length. The distance between the shrubs on every row was 15 cm. Physical and chemical properties of the soil are mentioned in table 1. Also Properties of zeolite clinoptilolite from Nasar Kooh mine inserted in table 2 and 3.

Table 1. Physical and chemical properties of studied soil

Soil depth (cm)	SP (%)	EC (ds.m^{-1})	pH	OC (%)	P (mg.kg^{-1})	K (ppm)	Sand	Clay	Silt	Soil texture
0-30	48	3.62	7.1	0.6	9.2	151	21	41.5	37.5	Clay Loam

Table 2. Properties of zeolite clinoptilolite from Nasar Kooh mine (A)

Sample	P_2O_5 (aqua) mg.kg^{-1})	K_2O (aqua) (mg.kg^{-1})	K_2O (%)	SP (%)	CEC (Meq.100gr zeolite)	pH	EC (ds.m^{-1})
Mineral zeolite	54.5	39.4	0.58	44	200	7.92	0.08

Table 3. Properties of zeolite clinoptilolite from Nasar Kooh mine (B)

Sample	CaO (aqua) (mg.kg^{-1})	MgO (aqua) (mg.kg^{-1})	Na (aqua) (mg.kg^{-1})	SAR	CL (aqua) (mg.kg^{-1})	HCO_3 (mg.kg^{-1})	CO_3 (mg.kg^{-1})	SO_4 (aqua) (mg.kg^{-1})
Mineral zeolite	56.0	19.9	202	3.21	53.3	244	0.0	343.0

3.2. Farm Management

Base fertilizers (180 kg.ha^{-1} urea, 120 kg.ha^{-1} ammonium phosphate and 50 kg.ha^{-1} potassium sulfate) were added to the soil based on soil tests and the recommendations of the Iranian Soil and Water Research Institute at the planting stage. Different levels of zeolite were used manually at a depth of 10 cm in the soil. Weed control was done manually. Diazinon pesticide with a concentration of 1.5 per thousand was used to fight Agrotis and Sesamia pests.

3.3. Measured Traits

The ripeness of the seeds was determined by creating a black layer at the base of the seeds, and the final harvest was done by removing 50 cm from the beginning and end of the lines from a surface equivalent to two square meters. In order to measure the seed yield in each experimental plot, after removing 0.5 meters from both ends of the lines, all the cobs in the three middle lines with a length of two meters were removed manually, and after drying and separating the seeds, it was done manually. Harvest index (HI) was calculated according to formula of Gardener *et al*. (1985) as follows: **Equ.1.** HI= (Seed yield/Biologic yield) ×100. Water use efficiency (WUE) was measured by following formula: WUE ($kg.m^{-3}$)= Y/ET. So y means crop yield ($kg.ha^{-1}$) and ET means evaporation and transpiration (m^3), (Huang *et al*., 2004).

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via MSTATC software and LSD test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Biologic yield*

According result of analysis of variance effect of different level of water deficit and Clinoptilolite on biologic yield was significant at 1% probability level but interaction effect of treatments was not significant (Table 4). Mean comparison result of different level of water deficit indicated that maximum biologic yield (11174.4 $kg.ha^{-1}$) was noted for control and minimum of that (8494.44 $kg.ha^{-1}$) belonged to severe stress treatment (Table 5). According result of mean comparison maximum of biologic yield (10486.7 $kg.ha^{-1}$) was obtained for 8 $t.ha^{-1}$ Clinoptilolite and minimum of that (9038.89 $kg.ha^{-1}$) was for control treatment (Table 5). Alfi and Azizi (2015) reported using zeolite in all drought stress conditions including normal irrigation regime, mild and severe drought stress caused significant increase in maize forage yield. Also zeolite increased most of the quantitative traits in maize. Using zeolite as 10 $ton.ha^{-1}$ caused 10.4% increasing in forage yield. Therefore, considering water shortage in drought area of the country and also importance of maize as a forage plant, application of zeolite can be useful to save more water that leads to produce more yields. Gholizadeh *et al.* (2010) showed that the increasing of zeolite and water stress have a significant effect on most of measured growth parameters. Zeolite provides an ideal physical root zone media for bent grass putting greens due to its particle size distribution, which provides a firm surface for foot traffic while remaining highly permeable (Huang and Petrovic, 1994). According to result of Zamanian (2008), using zeolite can preserve soil moisture for a long time; consequently application of zeolite can decrease the effects of drought stress on crop plants. In regions where water scarcity is the principal limiting factor for cultivation, farmers are interested in using some methods to deduce injurious effects of water deficiency. One possible approach to reduce the effect of drought on plant productivity is through the addition of zeolite to soil (Manivannan *et al*., 2007).

Table 4. Results of analysis of variance of studied traits

S.O.V	df	Biologic yield	Seed yield	Harvest index	Water use efficiency
Replication (R)	2	531411.11^{ns}	540683.37^{ns}	28.348^{ns}	0.034^{ns}
Water deficit (W)	2	16578533.33**	5521096.70*	27.015^{ns}	1.17**
Error I	4	567211.111	409076.87	45.488	0.064
Clinoptilolite (C)	2	4791344.44**	2315117.59**	23.965^{ns}	0.39*
W × C	4	734694.44^{ns}	954942.59^{ns}	26.465^{ns}	0.0001^{ns}
Error II	12	115666.667	323277.037	41.946	0.063
CV (%)	-	3.5	13.28	14.77	18.79

$^{ns,\ *\ and\ **}$: non-significant, significant at 5% and 1% of probability level, respectively.

4.2. *Seed yield*

Result of analysis of variance revealed effect of different level of water deficit and Clinoptilolite on seed yield was significant at 5% and 1% probability level, respectively but interaction effect of treatments was not significant (Table 4). Assessment mean comparison result indicated in different level of water deficit the maximum seed yield (5135.33 $kg.ha^{-1}$) was noted for control and minimum of that (3596.56 $kg.ha^{-1}$) belonged to severe stress treatment (Table 5). Compare different level of Clinoptilolite showed that the maximum and the minimum amount of seed yield belonged to 8 $t.ha^{-1}$ (4837.78 $kg.ha^{-1}$) and control (3845 $kg.ha^{-1}$) treatments (Table 5). Ghannad *et al*. (2014) reported the highest tuber yield was obtained from the plants treated with six tons per hectare of zeolite. Also significant increase was obtained in starch content by treated with 6 tons zeolite per hectare. Zahedi *et al*. (2009) reported that the zeolite application may improve plant growth under drought stress. By using the zeolites, we can preserve the moisture of the soil for long-term and get available to the plant, so the usage of the Zeolite can modify the effects of drought stress in the agricultural systems. Drought is one of the major environmental stresses that limit the growth of plants and the production of crops (Kavoosi, 2007).

4.3. *Harvest index*

According result of analysis of variance effect of different level of water deficit, Clinoptilolite and interaction effect of treatments on harvest index was not significant (Table 4). Another researcher confirmed that result (Ruiz-Lozano and Aroca, 2010).

4.4. *Water use efficiency*

Result of analysis of variance revealed effect of different level of water deficit and Clinoptilolite on water use efficiency was significant at 1% and 5% probability level, respectively but interaction effect of treatments was not significant (Table 4).

Table 5. Mean comparison effect of treatments on measured traits

Treatment	Biologic yield ($kg.ha^{-1}$)	Seed yield ($kg.ha^{-1}$)	Harvest index (%)	Water use efficiency ($kg.m^{-3}$)
Water deficit				
Control	11174.4	5135.33	45.74	1.73
Moderate stress	9461.11	4112	43.47	1.23
severe stress	8494.44	3596.56	42.34	1.03
LSD (5%)	605	1418	11.52	0.62
Clinoptilolite				
Control	9038.89	3845	42.43	1.1
4 ($t.ha^{-1}$)	9604.44	4161.11	43.48	1.4
8 ($t.ha^{-1}$)	10486.7	4837.78	45.63	1.5
LSD (5%)	605	1011	11.52	0.45

Means followed by similar letters in each column show non-significant difference according to LSD tests at 5% level.

Mean comparison result of different level of water deficit indicated that maximum water use efficiency (1.73 $kg.m^{-3}$) was noted for control and minimum of that (1.03 $kg.m^{-3}$) belonged to severe stress treatment (Table 5). Salehi *et al*. (2018) conducted a research with the aim of investigating the effect of zeolite on the morpho-physiological characteristics, yield and yield components of corn hybrid variety 704 under normal conditions and drought stress. The treatments included three levels of drought stress (60, 75 and 90% of field capacity) and four levels of zeolite (control, 5, 10 and 15 $t.ha^{-1}$). Based on the results, it was determined that zeolite improved the growth characteristics of the plant by increasing the water use efficiency, especially under drought stress conditions. Also the use of zeolite moderated the effect of drought stress, and use of 10 and 15 $t.ha^{-1}$ of zeolite improved grain yield, 1000 seed weight, cob weight and the number of rows of seeds per cob. Wu *et al*. (2019) in a research aimed at investigating the effect of zeolite application on drought stress on rice reported that the application of zeolite led to an increase in water consumption efficiency by 5.8% in the tillering stage and 12% in the ripening stage. According result of mean comparison maximum of water use efficiency (1.50 $kg.m^{-3}$) was obtained for 8 $t.ha^{-1}$ Clinoptilolite and minimum of that (1.10 $kg.m^{-3}$) was for control treatment (Table 5). Zahedi and Tohidi-Moghadam (2011) reported that zeolite application in soil decreased antioxidant enzymes activity. It seems that zeolite increases water retention capacity and thus water stress intensity will be decreased.

5. CONCLUSION

Adding Clinoptilolite to the soil under water stress conditions caused a 14% increase in biological yield and a 20% increase in corn seed yield in compare to the condition of not using this mineral. So that the consumption of 8 $t.ha^{-1}$ of zeolite led to produce highest seed yield and it dose advised to farmers in studied region.

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FOOTNOTES
AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

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