Research Journal of Recent Sciences ____ ISSN 2277-2502
Vol. **4(2),** 1-7, February (**2015**) *Res.J.Recent Sci.*

Effect of Drought Stress and Using Zeolite on Some Quantitative and Qualitative Traits of Three Maize Varieties

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Available online at: www.isca.in, www.isca.me
Received 12th June 2013, revised 19th September 2014, accepted 8th January 2014

Abstract

In order to study of the effects of drought stress and using zeolite on three maize varieties, an experiment was conducted in Seed and Plant Improvement Institute in Karaj, Iran in 2011. The experiment laid out as split plot in randomized complete block design with three replications. Treatments included three irrigation levels as main plots (irrigation after 70, 100 and 130 mm evaporation from standard class A evaporation pan), application of zeolite in two levels as sub plots included using 10 ton/ha zeolite and control (not using zeolite) and three maize varieties as sub sub-plot (Hybrids; SC704, SC705 and SC720). Among evaluated quantitative traits, drought stress led to decrease plant height, ear yield, forage yield and dry matter. The highest and lowest forage yield with averages 54.7 and 31.9 ton/ha resulted from normal and severe drought stress conditions, respectively. Drought stress reduced chlorophyll content of leaves significantly. Zeolite had significant effect on the morphological traits and using it increased forage yield about 9.42 percent in compare to control treatment. Using zeolite also had a significant increasing effect on chlorophyll content. SC720 had higher forage yield than two other varieties.

Keywords: Maize, Drought stress, zeolite, forage yield, forage qualitative Indices.

Introduction

Changes in climatic condition in recent decades caused reduction of amount of rainfall in arid and semi-arid regions in the world especially in Middle East. Due to shortage of water resources and sequential cropping in many areas, it is necessary to regulate the irrigation water, because this would cause inadequate irrigation. Therefore, in order to achieve the maximum yield and efficient use of available water, prevention of waste of water is necessary. Therefore, considering change in drought stress patterns, change in appropriate strategies to reduce difference of actual yield and yield potential in such regions is necessary[1]. Drought stress decreases yield of maize and other crops mainly because of reducing photosynthesis active radiation absorption, light use efficacy and harvest index. Dry matter production is also reduced by reduction in available water in maize[2]. Jafari and Imani[3] evaluated effect of drought stress on ear yield in three growth stages including before flowering, flowering stage and filling the grains. They found that drought stress led to significant decrease in yield in all three stages. Flowering stage was the most sensitive stage to drought stress leading to 42% reduction in yield. Researches of Imam and Ranjbar [4] on the effect of drought stress in vegetative stage on yield, yield components and water use efficiency in maize showed that drought stress reduced ears cob and ear diameter significantly and it caused reduction of ear yield in maize. Some material such as crop residues, compost, and super absorbent polymer hydrogels can store different amount of water and increase capacity of saving water in soil. Water stored in these materials is released in soil and can be used by plants in drought stress condition[5]. 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[6]. The unique cation exchange, adsorption, hydration-dehydration, and catalytic properties of natural zeolites have prompted slow release fertilizers and other materials[7]. Therefore such 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. According to Zamanian[8], using zeolite can preserve soil moisture for a long time; consequently application of zeolite can decrease the effects of drought stress on crop plants. Gholi-zadeh et al.,[9] studied effects of drought stress and natural zeolite on qualitative and quantitative traits of *Dracocepha lummoldavica*. They reported that zeolite had significant increasing effect on plant fresh weight, root dry weight, number of leaves, leaf area and percentage of essences. Also, significant effect of using zeolite on plant height, leaf to stem ratio, leaf area, water use efficiency and forage yield of maize hybrid SC704 under different drought stress conditions has reported in some researches[10]. Gholamhosseini et al.,[11] showed that for the most quantitative traits in canola forage, using zeolite (6 and 9 tones per hectares) were highly significant.

Mines of zeolite has been reported in six regions in Iran which it is easily and cheaply accessible, therefore using zeolite can be recommended as a soil amendment for increasing qualitative and quantitative yield in many crops[12]. In this study, using zeolite has evaluated as water storing material as well as effect of drought stress on some morphological traits including yield and some other qualitative traits in three maize varieties.

Material and Methods

This experiment was conducted in the experimental field of Seed and Plant Improvement Institute in Karaj, Iran in 2011. Experimental filed is located in 50° 55´ western latitude and 35° 47´ northern altitude with 1254 meters above mean sea level. According to climatic statistics and considering amber thermic curves, the region is considered as a hot and dry Mediterranean climate with 150-160 days and sometimes 200 days without rain, and it is also considered as semi-arid region with cold and humid winters and hot and dry summers. According to statistics of last 30 years weather report, the region's annual average rainfall is 240 mm and rainfalls occur mostly at the end of autumn and beginning of the spring. Soil of the experimental location had Sandy loam texture with pH = 7.5, Ec = 0.7 $ds.m^{-1}$, 0.1% nitrogen, 8.7 ppm phosphorus and 265.2 ppm potassium.

The experimental design laid out as a split plot in randomized complete block with three replications. Treatments included three irrigation levels as main plots (irrigation after 70, 100 and 130 mm evaporation from standard class A evaporation pan as control, mild and severe drought stress conditions respectively) application of zeolite in two levels as sub plots (using 10 $ton.ha^{-1}$ zeolite and not using zeolite as control) and also three maize varieties (KSC704, KSC705 and KSC720) that were considered as sub sub-plots.

10 $ton.ha^{-1}$ zeolite was used on the treatment plots before cultivation. 300 $kg.ha^{-1}$ phosphorus before cultivation and 400 $kg.ha^{-1}$ urea (200 kg before cultivation and 200 kg in 6-8 leaves stage) were added to soil. Distance between rows and plants per row were considered 75 and 15.5 cm (85000 $plants.ha^{-1}$) respectively. Each sub sub-plot included 4 rows each 6 meter long. Drought stress treatments were applied after thinning. Irrigation time was determined using daily evaporation from standard class A evaporation pan. To determine the volume of water for irrigation, a soil sample was taken from each plot in depth of root development region before irrigation. The samples were kept in oven 80°C for 24 hours. Weight of the soil moisture content was calculated and the volume of water needed for irrigation was determined by using equations 1 and 2.

$$H = \rho_b (\theta_{F.C} - \theta m) D \qquad (1)$$
$$V = H \times A \qquad (2)$$

Where, H is the water height in the plots. Soil bulk density (ρ_b) and moisture at field capacity ($\theta_{F.C}$) were 1.36 gr/cm^3 and 26%, respectively; θ_m is plot moisture at irrigation time, D is the root development depth evaluated by drilling tools in different growth stages, V is the volume of irrigation water needed for each plot and A is the plot area (18 m^2).

According this formula the number of irrigation for 70, 100 and 130 mm evaporation was 13, 11 and 10 and the volume of irrigated water was 6670.6, 5897.4 and 5128.2 $m^3.ha^{-1}$ for the three irrigation regimes, respectively. Quantitative traits including plant height forage yield without ear, ear yield, dry matter (DM), digestible dry matter (DDM), crude protein (CP), and chlorophyll content index (CCI) that was measured by chlorophyll-meter Opti-Science CCM-200, Percentage of digestible dry matter and crude protein were measured by Near Infrared Reflectance (NIR) Perten 8260. Software SAS Ver. 9.1 was used for the statistical analyses and treatment means were compared at 5% statistical probability level using LSD for Zeolite levels and Tukey's HSD tests for the other comparisons.

Results and Discussion

Plant Height: Drought stress had significant effect on plant height (table-1). Means comparison revealed that plant height is decreased by increasing in severity of drought stress. The highest plant (174 cm) was resulted from normal irrigation regime and the lowest plant height (150.4 cm) was obtained in severe drought stress condition (table-2). Results of various studies have indicated that reduction in available water causes morphological changes in the plants. Neilson and Nelson[13] also found that plant height is reduced with increasing in drought stress. Application of zeolite had significant effect on plant height at 1% probability level (table-1) leading to 4.3 percent increase in plant height (table-2). When zeolite was used as soil amender, selective absorption and controlled release of food elements leads to development of plant growth[14]. There was significant difference in varieties for plant height (table-1). The highest and lowest plant heights (166.8 and 157.6 cm respectively) were observed from SC704 and SC705, respectively (table-2). There were significant interaction effect for zeolite application and drought stress, drought stress and varieties, and varieties and zeolite application (table-1). Plant height is reduced for all varieties by increasing in drought stress. Hybrid SC704 had the highest plant height under normal irrigation (table-3). Using zeolite leads to higher plant height in all three drought stress conditions. Application of zeolite caused 5.62% and 3.33% improvement for plant height in normal irrigation and severe drought stress respectively, in compare with not using zeolite (table-3).

Plant Weight without Ear, Ear Yield, Total Forage Yield: Drought stress, zeolite and varieties had significant effect ($P<0.01$) on Plant weight without ear, ear yield, and total forage yield. Interaction of drought stress with zeolite and also varieties with drought stress was significant ($P<0.01$) for these traits (Table 1). Means comparison showed that normal irrigation caused the highest weight for plant weight without ear, and ear yield (36792, 17899 $kg.ha^{-1}$ respectively). They reduced significantly by increasing in drought stress to 25685 and 6211 kg/ha respectively in severe stress condition (table-2). Increase of plant weight without ear under normal irrigation regime was due to easiness of absorption and delivery of elements by plants, expansion and development of leaf area and better use of sunlight which leads to provide strong physiological sources by photosynthesis products[15]. Dry matter also is reduced due to drought stress. Some of this reduction have resulted from reduced grains in middle and lower parts of the ears. It may be because of diminished photosynthesis. It seems that treatments causing reduction in photosynthesis such as drought stress may cause reducing in grain development in the upper parts of the ears[16,17]. By increase in drought stress, forage yield also decreased and each irrigation regimes were separate in different statistical groups. The highest and lowest forage yield (54692 and 31897 kg/ha) obtained from normal irrigation and severe drought stress conditions (table-2). These results are in agreement with findings by Osborne et al.,[2] and Sepehri et al.,[18] that biological function is reduced due to drought stress.

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Table-1
Mean squares† for different traits under normal irrigation regime, mild and severe drought stress and effect of natural zeolite

Source of Variation	Df	Plant height		Plant weight without ear		Ear yield		Forage yield		‡ DM		DDM%		CCI		CP%	
Block	2	31.5		22633		8580983		8022921		69557		1.4		54.6		0.2	
Stress	2	2624.0	**	558250278	**	614741448	**	2341169519	**	532595	*	19.7	ns	921.6	**	22.5	ns
Stresses vs. normal condition	1	3726.8	**	906031208	**	919643581	**	3651298832	**	856240	**	1.0	ns	1714.0	**	30.1	ns
Block × stress	4	131.8		3515250		2507756		10988734		57232		50.1		27.3		4.0	
Zeolite	1	632.9	**	723658296	**	51129204	**	245150403	**	638634	**	43.2	ns	144.3	**	0.2	ns
Zeolite × stress	2	34.8	*	4055146	**	2197542	**	428519	ns	25980	**	3.3	ns	20.3	**	2.8	ns
Block × zeolite (stress)	6	5.5		357797		155340		800062		3068		38.4		0.3		5.2	
Varieties	2	390.8	**	135714765	**	52623734	**	280998657	**	27372	*	0.8	ns	17.7	*	1.1	ns
Stress × Varieties	4	118.3	**	5123105	**	5655142	**	15708548	**	43231	**	62.6	*	10.0	ns	5.8	ns
Zeolite × Varieties	2	22.3	ns	2327811	ns	139556	ns	2481010	ns	25278	*	58.8	ns	0.1	ns	1.3	ns
Zeolite × stress × Varieties	4	42.4	**	4485413	**	1830692	*	6271738	**	16340	ns	23.5	ns	0.5	ns	2.8	ns
Error	24	7.3		925950		635221		1100010		5963		23.4		4.2		3.5	
Coefficient of Variance		1.7		3.1		6.6		2.4		5.8		7.9		7.1		20.4	

† *, **, and *ns* denotes significance at 5%, and 1% probability level and non-significance, respectively. ‡ DM= Dry Mater, DDM= Digestible Dry Matter, CCI= Chlorophyll Content Index and CP= Crude Protein

Table-2
Means comparison of irrigation regimens, zeolite application and varieties for different traits

Treatments	**Plant height (cm)**	**Plant weight without ear (Kg/ha)**	**Ear yield (Kg/ha)**	**Forage yield (Kg/ha)**	**† DM (g/m^2)**	**DDM%**	**CCI**	**CP %**
Irrigation Regimens								
Normal irrigation (control)	174.5 a	36793 a	17899 a	54692 a	1519.9 a	60.9 a	36.9 a	8.2 b
Mild stress	163.4 b	30521 b	12079 b	42600 b	1328.9 b	61.6 a	26.8 b	9.1 ab
Severe stress	150.4 c	25686 c	6211 c	31897 c	1176.6 c	59.6 a	23.1 c	10.4 a
Zeolite								
Non-zeolite	159.4 b	29842 b	11090 b	40932 b	1233.0 b	59.8 a	27.3 b	9.2 a
Using zeolite	166.2 a	32158 a	13036 a	45194 a	1450.5 a	61.6 a	30.6 a	9.3 a
Varieties								
SC704	166.8 a	31474 b	10592 c	42067 b	1373.6 a	60.8 a	28.5 b	9.3 a
SC705	157.7 c	28048 c	11658 b	39705 c	1298.6 b	60.8 a	30.1 a	9.4 a
SC720	163.9 b	33478 a	13939 a	47417 a	1353.5 ab	60.5 a	28.6 ab	8.9 a

Means followed by different letters are significantly different at the P≤0.05 probability level, according to Tukey's HSD test for Irrigation regimes and varieties, and LSD for zeolite levels comparisons. † DM= Dry Mater, DDM= Digestible Dry Matter, CCI= Chlorophyll Content Index and CP= Crude Protein.

Table-3
Means comparison for interaction of Irrigation regimes with varieties, and Irrigation regimes with zeolite application

Treatment		**Plant height (cm)**	**Plant weight without ear (Kg/ha)**	**Ear yield (Kg/ha)**	**Forage yield (Kg/ha)**	**†DM (g/m^2)**	**DDM%**	**CCI**	**CP %**
Irrigation regimes and varieties									
Normal irrigation	**SC704**	178.3 a	37710 a	16040 bc	53750 b	1446 bc	62.13 a	35.22 a	8.30 ab
	SC705	171.0 bc	33140 b	17440 b	50570 c	1510 ab	59.17 a	38.96 a	7.74 b
	SC720	174.4 ab	39530 a	20220 a	59750 a	1604 a	61.34 a	36.52 a	8.45 ab
Mild stress	**SC704**	162.7 de	30770 c	9974 e	40740 e	1413 bc	61.70 a	25.48 bcd	9.88 ab
	SC705	160.1 e	27170 d	11570 d	38740 e	1244 de	59.47 a	27.72 b	8.68 ab
	SC720	167.5 cd	33630 b	14690 c	48320 d	1329 cd	63.70 a	27.32 bc	8.76 ab
Severe stress	**SC704**	159.5 e	25950 d	5761 f	31710 g	1262 de	58.68 a	23.87 bcd	9.71 ab
	SC705	142.0 g	23840 e	5967 f	29800 g	1141 e	63.68 a	23.49 cd	11.82 a
	SC720	149.8 f	27270 d	6906 f	34180 f	1127 e	56.31 a	21.79 d	9.64 ab
Irrigation regimes and zeolite application									
Normal irrigation	**Control**	169.5 b	35860 b	16850 b	52710 b	1372 b	60.40 a	34.07 b	8.56 ab
	Using Zeolite	179.6 a	37730 a	18950 a	56680 a	1668 a	61.36 a	39.72 a	7.76 b
Mild stress	**Control**	160.7 c	29690 d	10800 d	40490 d	1223 c	60.29 a	25.55 cd	8.77 ab
	Using Zeolite	166.1 b	31360 c	13350 c	44710 c	1435 b	62.96 a	28.12 c	9.43 ab
Severe stress	**Control**	147.9 e	23980 f	5620 f	29600 f	1105 d	58.69 a	22.26 e	10.16 ab
	Using Zeolite	153.0 d	27390 e	6802 e	34190 e	1249 c	60.43 a	23.84 de	10.62 a

Means followed by different letters are significantly different at the P≤0.05 probability level, according to Tukey's HSD test. † DM= Dry Mater, DDM= Digestible Dry Matter, CCI= Chlorophyll Content Index and CP= Crude Protein

Using zeolite caused 7.2% and 14.9% increase in Plant weight without ear and ear yield, respectively (table 2). These results are compatible with findings by Ranjbar Choubeh[12]. Kouhestani et al.,[19] declared that use of super absorbent improves maize yield through increasing water storage capacity in the soil, reduced leaching, and rapid and optimal root growth. Application of zeolite increased forage yield by 9.4% (table 2). Torabi et al.,[20] examined effect of using super absorbents on morphological traits in sorghum and reported that fresh forage increased significantly by increase the use of super absorbent.

There was significant difference between varieties for Plant weight without ear, ear yield, and total forage yield. Hybrid SC720 had the highest amount for these three traits. In addition, SC705 had the lowest plant weight without ear, forage yield and ear yield and SC704 had the lowest ear yield (table-2).

Plant weight without ear for SC704, SC705 and SC720 is reduced by 31.2%, 28.1%, and 31% respectively in severe drought stress condition. In this regards, the highest plant weight without ear was obtained from SC720 under normal irrigation regime (table-3). Means comparison for using zeolite in different drought stress showed that application of zeolite in the three irrigation regimes led to significant improvement in plant weight without ear. The highest plant weight without ear (37730 $kg.ha^{-1}$) was obtained after application of zeolite in normal irrigation regime (table-3). Means comparison for varieties in the three irrigation regimes revealed that forage yield was decreased in all treatments by severity of drought stress. SC720 in normal irrigation regime had the highest forage yield (20220 $kg.ha^{-1}$) among the other treatments in all the irrigation regimes. Hybrids SC704 and SC705 had similar forage yield in mild drought stress for forage yield (table-3). Application of zeolite led to 19.1% increase in ear yield (13350 $kg.ha^{-1}$) compared to not using it in mild drought stress condition (10800 $kg.ha^{-1}$). SC720 had higher forage yield compared to two other varieties in the three irrigation regimes. Forage yield reduced significantly in all varieties by increasing in stress severity; the highest forage yield (59750 $kg.ha^{-1}$) resulted from SC720 under normal irrigation regime (table-3). Means comparison for interaction of zeolite with drought stress showed that application of zeolite increased forage yield significantly in the three irrigation regimes; the highest forage yield (56680 $kg.ha^{-1}$) was resulted from using zeolite in normal irrigation regimes and the lowest (29600 $kg.ha^{-1}$) was for not using zeolite in severe drought stress condition (table-3).

Dry Matter and Digestible Dry Matter Percentage: None of drought stress treatments, varieties and zeolite application and their interactions had significant effect on percentage of digestible dry matter (table-1). In addition, the results indicated that drought stress had significant effect ($P<0.05$) on dry matter (table-1). Dry matter was reduced significantly by increase drought stress; it decreased from 1519.9 $g.m^{-2}$ in normal irrigation regime to 1176.6 $g.m^{-2}$ in severe stress condition (table-2). Results of many studies on different plants suggest reduction of dry matter under drought stress[21,22].

Dry matter was significantly and positively affected by application of zeolite (table-1 and 2). Harvey[23] also reported that use of super absorbent in kidney bean leads to increase dry matter and drought tolerance. Difference of varieties for dry matter was significant in 5% probability level (table-1) as SC705 had the lowest dry matter (1298.6 $g.m^{-2}$ table-2).

Interactions of zeolite application with drought stress, drought stress with varieties and zeolite application with varieties were significant for dry matter (table-1). Means comparison of interaction of drought stress with varieties showed that, SC720 had significant superiority for dry matter in normal irrigation regime; the highest and lowest dry matter was obtained from SC720 in normal irrigation regime and severe stress (1604 and 1127 $g.m^{-2}$) respectively, which suggests higher sensitivity of SC720 to drought stress condition (table-3). Interaction of drought stress with zeolite application showed that using zeolite in all irrigation regimes led to increase in dry matter. Also using zeolite in normal irrigation regime caused higher dry matter (1.67 $g.m^{-2}$) (table-3).

Crude Protein: Drought stress conditions, varieties, zeolite application and their interactions had not significant effect on crude protein (table-1). Although effect of drought stress on protein was not significant, it was increased by intensify stress severity. The lowest amount of crude protein (8.2%) resulted from normal irrigation regime and the highest amount (10.4 %) occurred with severe drought stress (table-2). There are different reports for effect of drought stress on crude protein in different plants and parts of the plants. Increased protein in drought stress condition is supported by Nabati and Rezvani Moghaddam[24] and Asay et al.,[25]. According to Buxton[26], drought stress prevents growth of tillage in forage plants and causes rapid death of tillage, and then their protein is transferred from older leaves to younger organs.

Chlorophyll Content Index: Drought stress, application of zeolite ($P<0.01$) and varieties ($P<0.05$) had significant effect on chlorophyll content; interaction of zeolite with drought stress was significant for chlorophyll content (table-1). Means comparison showed that leaf chlorophyll content is decreased considerably by increasing in drought stress. Highest chlorophyll content (36.9%) was obtained from normal irrigation and lowest chlorophyll content (23%) was obtained from severe drought stress condition; it denotes 37.4% reduction in chlorophyll content in severe stress condition compared to normal irrigation regime (table-2). Drought stress has direct effect on reducing leaf chlorophyll content and yield[27]. In drought stress condition, electron transfer is disturbed in photosystem II[28] and excessive electrons release from water that causes reactive oxygen species production and therefore cell membrane is damaged because of peroxidation of lipids and oxidation of proteins leads to reduce chlorophyll content in the plant[29]. Application of zeolite caused significant increasing in leaf chlorophyll content; the highest chlorophyll content (30.6%) was obtained from using zeolite treatment and the lowest content (27.3%) was obtained from control treatment (table-2). Since chlorophylls have nitrogen structure and zeolite causes increase in efficiency of elements consumption especially nitrogen as well, therefore using zeolite can increase chlorophyll content considerably. Difference in chlorophyll content among the varieties was significant (table-1); SC704 had lower chlorophyll content compared to the two other varieties. Hybrids SC705 and SC720 didn't show significant difference (table-2).

Conclusion

Using zeolite in all drought stress conditions including normal irrigation regime, mild and severe drought stress caused significant increase in maize forage yield. Findings in this study indicated that 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 yield.

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