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The Effect of Priming, Growth Regulators and Calcium on Yield and Some Physiological Traits of Maize under Drought Stress

Javad Nejat*, Ahmad Naderi**, Yahya Emam, Adel Modhej**** and Alireza Bagheri********

**Department of Agronomy, College of Agriculture,*
Khouzestan Science and Research Branch, Islamic Azad University, Ahvaz, Iran
***Agricultural and Natural Resources Research Institute, Khuzestan, Iran*
****Department of Agronomy, Shiraz University, Iran*
*****Department of Agronomy, College of Agriculture, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran*
******Department of Agronomy, Eghlid Branch, Islamic Azad University, Fars, Iran*

(Corresponding author: Ahmad Naderi)
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ABSTRACT: Drought like many other environmental stress, has adverse effects on crop production. Low water availability is one of the major causes for crop yield reductions which affect agricultural production globally. This experiment was conducted to study the effect of seed priming with growth regulators, calcium fertilizer application and drought stress on maize (*Zea mays* L. SC 704). The factors were: drought stress in three levels (normal irrigation, irrigation after 50% depletion of easily accessible water; moderate stress, irrigation after 60% depletion; extreme drought stress, irrigation after 70% depletion). Calcium fertilizer was in three levels (0, 1 and 0.5 L/ha calcium fertilizer). Seed priming with growth regulators in three levels. Results showed that grain yield was affected the highest by auxin hormone × calcium the normal irrigation. In both years, the average of the highest grain yield (18348 kg/ha) was achieved in auxin × 0.5 L/ha calcium × normal irrigation and auxin × 0.5 L/ha calcium × moderate stress. The lowest grain yield was observed in priming with water × no calcium × extreme drought stress in both years. In this treatment which shows 62.7% reduction, compared with the highest grain yield in each year. Generally, in moderate stress, applying auxin and calcium alleviated the effect of drought stress.

Keywords: auxin, brasinosteroid, seed priming, *Zea mays* L.

INTRODUCTION

Drought stress is one of the most important environmental factors in reduction of growth, development and production of plants. It can be said that it is one of the most devastating environmental stresses. Iran, with an annual rainfall of 240 mm, is classified as one of those dry regions (Jajarmi, 2009). According to geographical location and topographic conditions, Iran has always been faced with drought over the last centuries, about 10 percent of the Iran's areas have more than 500 mm of rainfall over the years and the rest have to be watered for the plants growth (Mazaheri and Majnoun-Hosseini, 2005). Under drought stress, a plant's ability to absorb and transfer materials is disturbed which affects the access to food (Lauer, 2003). At present, there is no method for increasing atmospheric precipitation during drought periods. Therefore, the best way for counteracting drought is to use suitable agronomic practices and drought tolerant cultivars (Rahba and Uprety, 1998). Maize (*Zea mays* L.) is one of the most importantly grown plants in the world. Superior position of maize is due to its very wide and variety utilization. During the centuries maize plant was known for it's multifariously uses. Maize is used as human food, livestock food, for producing alcoholic and non-alcoholic drinks, built material, fuel, and like medical and ornamental plant (Alahdadi *et al.*, 2011; Khodarahmpour, 2011; Bekric and Radosavljevic, 2008). The first biological response of plants under drought stress is the reduction of growth. Reduction of shoot growth and enhancement of root growth for absorbing water from lower soil layers are plant mechanisms for resistance against low water condition under long periods of drought stress (Yin *et al.* 2005). Hormones are plant growth regulating substances. Hormonal regulation and metabolism of plants is complicated and is resulted from the interaction of hormones ratios in different environmental conditions (Lenoble *et al.* 2004). In maize plant induced-water stress yield reduction ranges from 10 to 76% although this percentage may be affected by several factors (Bolaòos and Edmeades, 1993). It should be pointed that maize is more responsive to environmental changes such as drought stress mainly around flowering stage (Ne Smith and Ritchie, 1992). Maize has many mechanisms for adaptation to stress conditions among them we can name stomatal closure which is rapidly occurs considered as a first line defense against water stress in comparison to alteration of root growth, changes in leaf surface area and chloroplast and pigment proteins structure which are the following steps (Faver *et al.*, 1996).

The objective of this study was to evaluate the effect of seed priming with growth regulating substances, application of calcium fertilizer and drought stress on yield and physiological traits of maize for increasing the sustainability of maize production and improvement of water use efficiency.

MATERIAL AND METHOD

This two year experiment was conducted in 2012 and 2013 in Marvdasht, Iran. Marvdasht is 45 km away from Shiraz and is 1490 m above the sea level. According to the long-term metrological statistics, average annual precipitation of the area is 245 mm. The experiment was conducted in split-split plot in the form of a randomized complete block design with three replications and three treatments:

The main factor. Drought stress in three levels including (1) normal irrigation, in which irrigation was conducted after 50% depletion of easily accessible water, (2) moderate stress, in which irrigation was conducted after 60% depletion and (3) extreme drought stress, in which irrigation was conducted after 70% depletion of easily accessible water.

The sub factor. Calcium fertilizer in three levels including 0, 1 and 0.5 L/ha calcium fertilizer.

The sub-sub factor. Seed priming with growth regulators in three levels including 12 hours of treating seeds with water, auxin and brasinosteroid.

Samples were taken from soil and weight percentage of soil moisture content was measured. Then, weight percentage of soil moisture content in field capacity point (FC) and permanent welting point (PWP) was obtained. Easily accessible water was considered the 50% point between FC and PWP. According the treatments of the experiment, soil water potential after depletion of 50%, 60% and 70% of easily accessible water was measured by Pressure Plate instrument. The time of irrigation based on the three water potentials was determined by installing three calibrated tensiometer? in field. In each irrigation, 80 mm water was given to the field. The calcium fertilizer was sprayed to the canopy at the eight leaves stage.

The field consists of 81 plots in each year and there were six planting rows in each plot. Harvest was conducted repeatedly during the growing period to evaluate the variation of the measured traits. To obtain yield, sampling was conducted from the two middle rows of each plot. Total N was determined by a micro-Kjeldahl method (Sparks, 1996). Data were analyzed using SAS software and means were compared according to the LSD test. Bartlett test indicated that there was no significant difference in error variance of both years; so, the combined analysis was conducted to analyze the data of two years.

RESULT AND DISCUSSION

Analysis of variance indicated the significant effect of plant growth promoting substances on measured traits (Table 1). In both years, the highest biomass was 38968 kg/ha which was 14.5% higher than the control. Results showed that plants treated with hormone and Ca fertilizer had significantly higher biomass compared with the plants treated only with hormone. Moreover, studying the effect of interaction of drought stress × hormone on biomass showed that in both years, under normal irrigation, application of auxin hormone resulted in the highest biomass (39159 kg/ha) which was significantly similar to brasinosteroid. The lowest biomass was achieved in extreme drought stress × no hormone applied. Under extreme and moderate drought stress levels, auxin application increased biomass by 12.6% and 13.2%, respectively, compared with the control (Fig. 1, 2).

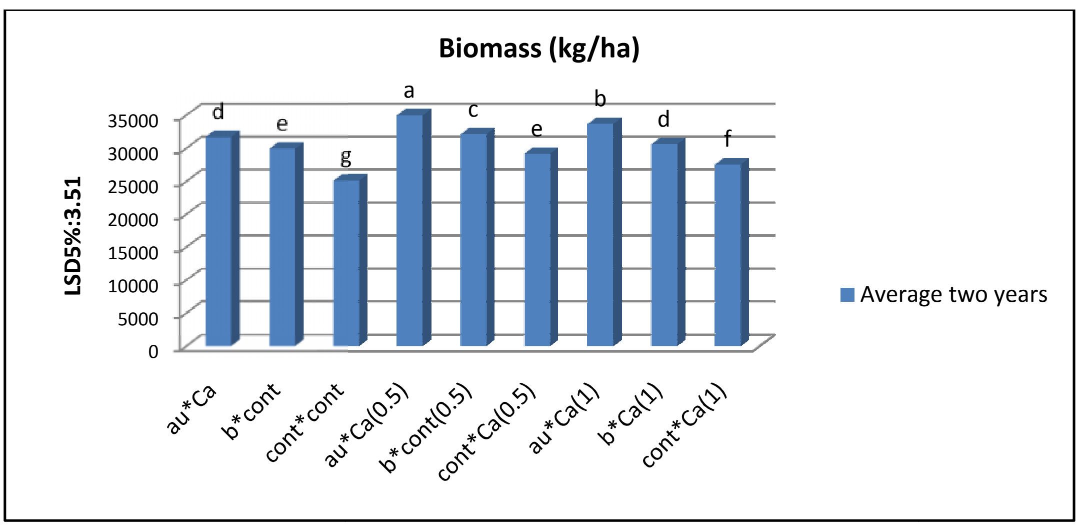

Fig. 1. The effect of interaction of drought stress × calcium fertilizer on biomass (Au, auxin; b, brasinosteroid; cont, control)

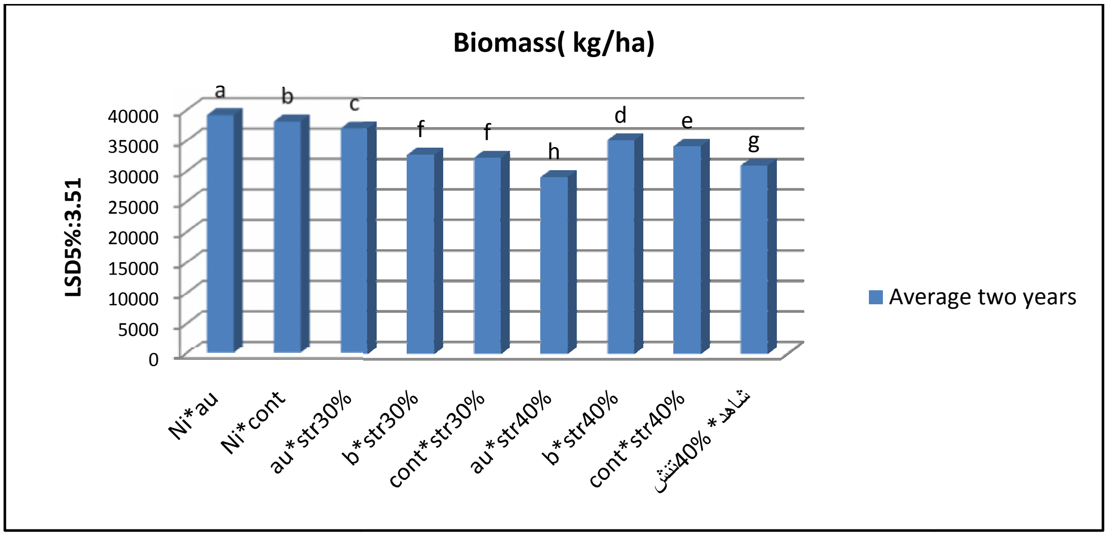

Fig. 2. The effect of interaction of drought stress × hormone on biomass.
(Ni, normal irrigation; str, drought stress; au, auxin; b, brasinosteroid; cont, control)

Results indicated that the combined analysis of the three-fold interaction of drought stress × hormone × Ca fertilizer had significant effect on grain yield (Table 1). Mean comparison showed that under normal irrigation condition in both years, grain yield was the highest (18343 kg/ha) in auxin × 0.5 L/ha ca fertilizer which was 58.1% higher than the control and was significantly similar to 1 L/ha Ca. Under extreme drought stress level in both years, grain yield was the highest (15796.5 kg/ha) in auxin × 0.5 L/ha Ca which was 60.7% higher than the control and was significantly the same with 1 L/ha Ca fertilizer. A similar trend was also observed for moderate stress level; grain yield was the highest (16929.5 kg/ha) in auxin × 0.5 L/ha Ca which was 51.95% higher than the control and was significantly similar to 1 L/ha Ca fertilizer application (Fig. 3).
Results indicated that the interaction of auxin hormone and calcium fertilizer increased the number of kernels under moderate and extreme drought stress conditions; it was more effective under extreme stress.

Table 1: Combined analysis of variance of the effect of treatments on the measured traits.

SOV	df	Mean Squares (MS)			
		Grain yield	Biomass	RWC	EC
Year (Y)	1	11320075**	55489.5497**	0.3092916 **	56.74738628 **
Replication	4	4671137	1824.8372	0.10031001	0.41199355
Irrigation (I)	2	105820**	1314.68**	0.11474116*	1.54645644**
Y × I	2	1864422**	1007.577**	0.00320763 ns	0.22299545
Error a	8	83354	58.606	0.01902828	0.03517667
Ca	2	732221**	3118.7**	1.14379395 **	7.21519627**
I × Ca	4	100211**	228.79ns	0.04906324 ns	2.4733359**
Y × Ca	2	735832**	52.155ns	0.03860796 ns	1.82991837**
Y × I × Ca	4	4364375**	220.0051ns	0.09232024 *	0.24045827 ns
Error B	8	1039919	70.8154	0.02563965	0.2900112
Hormone (H)	2	125223154**	1920.397	0.23591578 **	1.72261035**
I × H	4	1614349ns	70.3ns	0.0947065*	0.40486125 *
Ca × H	4	1586094ns	24.50649ns	0.03677787 ns	0.05126035 ns
Y × H	2	470110ns	401.5441*	0.06083276 ns	0.00146017ns
Y × I × H	4	4639399**	16.8735ns	0.02017799 ns	0.23466971 ns
Y × Ca × H	4	978194ns	53.755ns	0.01404948 ns	0.47265292 *
I × H × Ca	8	1277502ns	44.664ns	0.0228329 ns	0.2173835 ns
Y × I × Ca × H	8	11994407**	43.5608ns	0.0467718 ns	0.57815093 **
Error	88	67642	132.32459	0.0390646	0.1547317
CV (%)	-	6.01	6.62	13.5	11.7

Ns, not significant; *, 5%; **, 1%.

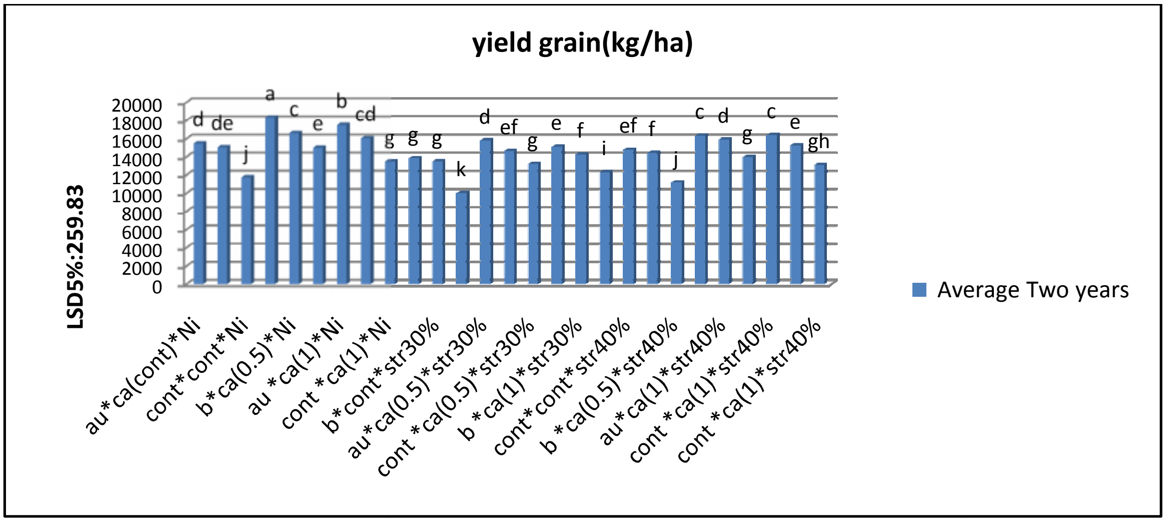

Fig. 3. The effect of interaction of drought stress × hormone × calcium on grain yield.

(Ni, normal irrigation; str, drought stress; au, auxin; b, brasinosteroid; cont, control; ca, calcium).

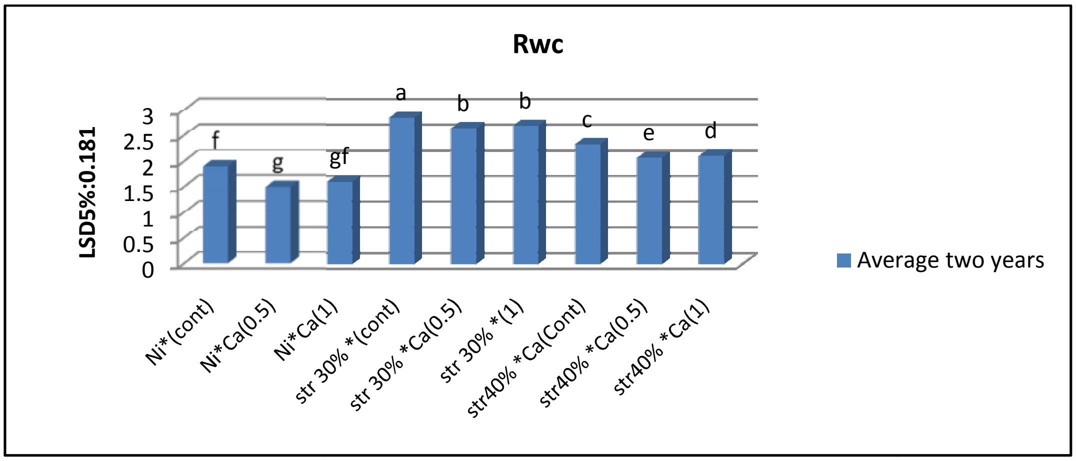

Fig. 4. The effect of interaction of drought stress × calcium on RWC. (Ni, normal irrigation; cont, control; ca, calcium.str, drought stress)

After auxin, brasinosteroid had the highest effect on the number of kernels under different drought stress levels in both years. Moreover, the interaction of auxin and calcium was more effective on the number of kernels compared with the individual application of auxin or Ca. Because sufficient water absorption in grain formation stage results in the enhancement of the number of kernels, and because root growth and development is affected by hormones and especially auxin, so, priming seeds with auxin increases root growth of the seedling and plant and consequently results in higher water absorption. Moreover, calcium promotes cell division, cell differentiation, cell polarity and photomorphogenesis which in turn results in the enhancement of yield components and yield (Fathy and Ismailpur, 2000). Salantur *et al.* (2006) tested the effect of drought stress on growth and yield of maize and reported that the stress inhibited the growth and development of female inflorescence. When severe water shortage occurs, amino acids, proline in particular, collects in plant tissue and the increase is sometimes over 100 times the normal level Betaine, like the accumulation of proline is related to stress. Corn under stress condition increases the amino acids glycine and serine. Protein synthesis was very sensitive to water stress, which caused reduced protein. During stress, proline, as a nitrogen storage tank reduces the osmotic potential of the cytoplasm.

Results indicated that (Fig. 4) the highest relative water content was related to the normal irrigation and application of 1 L/ha Ca fertilizer and the lowest RWC in both years was related to the extreme drought stress level and no Ca fertilizer. Under normal irrigation condition, the highest RWC was achieved when 1 L/ha Ca fertilizer was applied which was 18.7% higher than the Ca free treatment.

Under extreme drought stress condition, the highest RWC was also achieved when 1 L/ha Ca fertilizer was applied which was 15.5% higher than the Ca free treatment; this trend was also observed in moderate stress level. Moreover, in all levels of irrigation, application of brasinosteroid was effective on RWC enhancement, after auxin hormone application. The cytoplasmic membrane which is also known as the plasma membrane, is a membrane covering the internal surface of plant cell membrane. This membrane is made of different protein and lipid layers. The cytoplasmic membrane has negative charges so shows selective permeability for the movement of polar and non-polar solutions. It seems that the cytoplasmic membrane holds the concentration of soluble materials at high levels in plant cells and maintains cell turgor pressure through ion pumps or Na/K pumps.
Bandurska (2000) reported that cell membrane stability under stress condition is the most important factor for resistance against drought stress.

Debi *et al.* (1996) determined cell membrane stability for four types of groundnuts by PEG test and concluded that drought stress resistance is correlated with the electrical conductivity. Results of our experiment (Fig. 5 and 6) showed that the highest instability of cell membrane in both years was related to the extreme stress condition and absence of Ca fertilizer. Moreover, the highest stability of cell membrane was related to normal irrigation and application of 1 L/ha Ca fertilizer, which was significantly the same as 0.5 L/ha Ca fertilizer. Based on the cell membrane stability test, the solution which contains the plant tissue with higher electrical conductivity, implies the higher level of permeability of the cell membrane of those plant tissues (Kocheva *et al.*, 2004). Bandurska (2000) also reported that the most important factor that helps plants to resist better under drought stress condition is the stability of cell membrane.

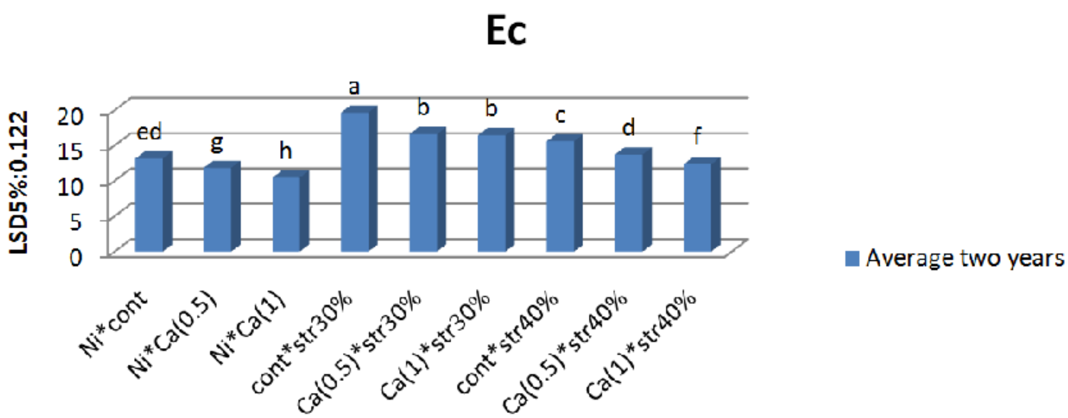

Fig. 5. The effect of interaction of drought stress × calcium on EC.
(Ni, normal irrigation; cont, control; ca, calcium.str; drought stress)

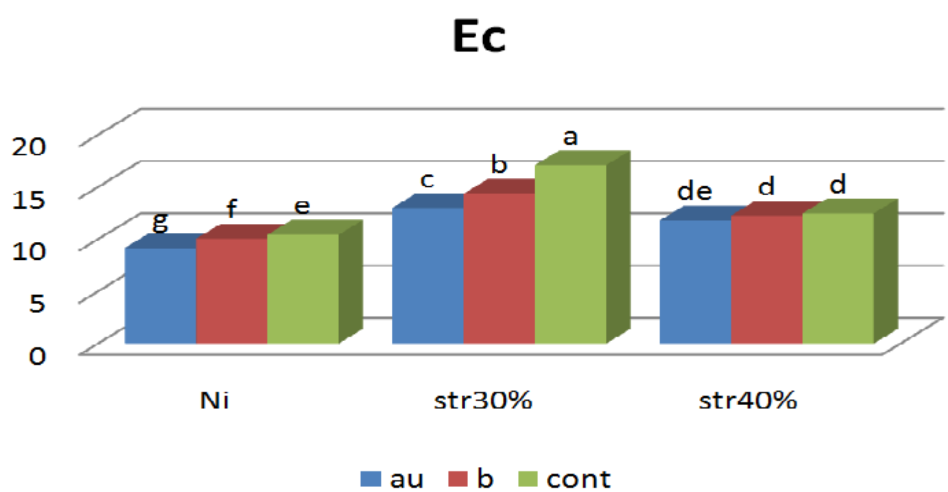

Fig. 6. The effect of drought stress on EC.
(Ni, normal irrigation; str, drought stress)

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