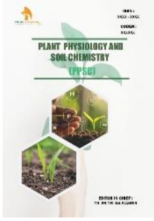
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2805-5063 (Online)
CODEN: PPSCCU

Plant Physiology and Soil Chemistry (PPSC)

DOI: http://doi.org/10.26480/ppsc.02.2021.53.57



CrossMark

RESEARCH ARTICLE

DIFFERENT SOURCES AND CONCENTRATIONS OF CALCIUM ALTERD GRAIN YIELD, OSMOTIC COMPONENTS AND SOME PHYSIOLOGICAL TRAITS IN MAIZE UNDER DROUGHT STRESS

Mostafa Heidari*, **Javad Pahlevan**

Shah rood University of Technology, Agronomy and Plant Breeding Department, Shah rood, Iran.
****Corresponding author E-mail: m_haydari@shahroodut.ac.ir***

ARTICLE DETAILS

Article History:

Received 05 September 2021
Accepted 07 October 2021
Available online 13 October 2021

ABSTRACT

Lack of sufficient water around the world, is the most important factor to reducing the growth and yield of crops. The use of nutrient elements such as calcium can partially prevent its adverse effects on plants. Therefore, this experiment performed to study the effect of sources and different concentrations of calcium (C_1=control, C_2= 1.5, C_3= 3g/l calcium chloride, C_4= 1.5 and C_5= 3 g/l calcium silicate) on maize under drought stress (W_1= 8 (control), W_2= 12 and W_3= 16 days irrigation interval). The results showed that by increasing drought level from W_1 to W_3, grain yield, biomass, the weight of thousand seeds and the number of seed per plant were reduced. Application of calcium, especially 3 g/l calcium silicate improved them. Drought stress decreased the amount of chlorophyll "a", relative water content (RWC), and increased electrolyte leakage, soluble carbohydrate and proline in leaf tissues. In the absence of drought stress, calcium silicate had a better effect than on maize plant. At the highest level of drought stress (W_3), also application of 3 g/l calcium silicate improved the grain yield by reducing the amount of electrolyte leakage, increasing the synthesis of proline and soluble carbohydrates and also improving the yield components compared to calcium chloride. Therefore, it can be stated that calcium silicate at drought stress conditions has a greater effect than calcium chloride on maize plant.

KEYWORDS

Biochemical components, Calcium chloride, Calcium silicate, Drought stress, Maize

1. INTRODUCTION

The role of mineral nutrition in alleviation of drought stress has widely been shown in crop plants. Among these minerals, calcium (Ca) is one of the macro elements in plants. This element has an important effect on improving the growth, physiological and biochemical activities in crops at different environmental conditions. Calcium is a plant nutrient that has a direct role in cell growth regulation. It is a mineral which essential for plant function and second messenger in cells. It impacts on cell membrane stability and helping plants tolerant to abiotic stress such as salinity and drought stress (Kapilan et al., 2018). In addition, as an essential plant nutrient, Ca plays a vital role in plant growth and development, like structural roles in the cell wall and membranes, counter-cation for inorganic and organic anions in the vacuole, and as an intracellular messenger in the cytosol (Hochmal et al., 2015). Calcium has an important role in tolerant mechanisms that are caused by environmental stress (Cousson, 2009). About the effect of Ca on alleviating water stress has also been investigated in many crops such as *Arabidopsis thaliana* and maize (Naeem et al., 2018; Huang et al., 2018).

Drought stress can be simply defined as a shortage of water which induces dramatic morphological, biochemical, physiological and molecular changes. All of these changes reduce plant growth and crop production (Sallam et al., 2019). This stress is one of the most important threatening factors for the production of crop plants in the arid and semi-arid regions of the world. Understanding plant responses to drought is of great importance and also a fundamental part of making crops stress tolerant (Farshadfar et al., 2013). A group researchers indicated that crops that exposed to drought stress, often show serious biochemical and physiological functions, including: reduction in potential of turgor in leaves tissues, decreasing in growth and photosynthetic rate, as well as damage to different cellular components (Xu et al., 2008). When plants are exposed to drought stress, they physiologically change to tolerate this stress. Drought-tolerant plants try to have less reduction in water content, membrane stability, and photosynthetic activity. The tolerant group tries to accumulate soluble sugars, proline content, amino acids, chlorophyll content and enzymatic and non-enzymatic antioxidant activities (Abid et al., 2016).

One of the important crop in the cereal family, is Maize (*Zea mays* L.). It is grown on more than 170 million hectares worldwide (FAO statistical database, http://faostat3.fao.org/home/E). Studies had shown that grain yield, yield component and the growth of maize are reduced under water stress. Some researchers reported that water stress has a destructive effect on development stages and physiological traits in maize plants, and can reduce biomass and grain yield in maize (Payero et al., 2008). Drought stress at various stages such as vegetative and reproductive, has a destructive effect on leaf area index and leaf growth of maize and decrease its yield (Çakir, 2004). Meanwhile, maize is somewhat resistant to low drought stress conditions, especially in the early stages of vegetative growth and late of grain filling stages (Ding et al., 2006).

Although many researches have been done on maize and drought stress, but few studies have been conducted on the role of calcium and its effect

Quick Response Code	Access this article online	
	Website: www.ppsc.org.my	**DOI:** 10.26480/ppsc.02.2021.53.57

Cite The Article: Mostafa Heidari, Javad Pahlevan (2021). Different Sources and Concentrations of Calcium Alterd Grain Yield, Osmotic Components and Some Physiological Traits in Maize Under Drought Stress. *Plant Physiology and Soil Chemistry, 1(2): 53-57.*

on the resistance of crops under drought stress. It is widely accepted that calcium ions can facilitate plants resist drought stress. Therefore, the purpose of this experiment was to investigate the effect of various concentrations and sources of calcium on maize at a drought stress condition. In this experiment, the aim was to investigate the effect of different concentrations of calcium from different sources on growth and yield of maize and also to investigate its effect on some physiological and biochemical traits and finally, determine the effectiveness of these treatments on growth and yield of maize under drought stress.

2. Materials and Methods

This study was performed at the farm of Agricultural collage, Shahrood University of Technology, Iran (latitude of 36° 29 'N and longitude of 55° 57' E with an elevation of 1366 m) in 2019. The characteristics of the soil in field was sandy loam in texture, pH, 7.05; EC, 0.65 ds.m^{-1}; 0.55% of organic carbon; 0.0205% N, 42.5 and 121 ppm of available P and K, respectively. This study was as a split plot design based on randomized complete block with three replications. The treatment of drought stress was W_1= 8 (control), W_2= 12 and W_3= 16 days irrigation interval as main plot (At W_1, the plants were irrigated every 8 days and at W_3, plant were irrigated every 17 days), and the treatment of sources and concentrations of calcium including: C_1=control or without application of calcium, C_2= calcium chloride with concentration of 1.5 g per liter of water, C_3= calcium chloride with concentration of 3 g per liter of water, C_4= calcium silicate with concentration of 1.5 g per liter of water and C_5= calcium silicate with concentration of 3 g per liter of water as sub plot.

The maize variety cultivated in this project was single cross 704. It was sown on 31th May 2019. The length and width of each row were 4 and 0.60 m, respectively. There were five rows in each plot. Before sowing, the soil was fertilized with N, P and K at a rate of 150, 100 and 100 kg ha^{-1} as urea, super phosphate triple and potassium sulfate, respectively. The 1/2 rate of N was used at sowing time and the residue of N, applied at the 6-8 leaves stage. Seeds were placed at 3-5 cm depth. Drought stress started from 8 leaves stage by adjusting irrigation interval based on the plot and continued until the end of growth period. Foliar application of calcium sources was applied to the plants in one step at the beginning of flowering. According to measure to the photosynthetic pigments and some physiological traits in leaves tissues, samples were taken from the young leaves at the 3 weeks after flowering stage.

2.1 Grain yield and grain yield components

At the maturity stage, in order to measure the biological and grain yield, all plants and seed produced within middle of the two central rows in each plot, were removed. Then, the grain and biological yield were recorded on a dry weight basis. Grain and biological yield were defined as g m^{-2} and then calculated on the basis of kg ha^{-1}. The grain yield components and plant height, also were calculated on 5 plants per plot. The grain yield components which measured in this study, were thousand seed weight and the number of seed per plant.

2.2 Soluble carbohydrate and Proline

Total soluble carbohydrate in leaves tissues was measured by the phenol sulphoric acid method (Chow and Landhausser, 2004). Free proline in leaves tissues also was measured based on the (Bates et al., 1973). For proline, samples were homogenized in 5 ml of sulphosalycylic acid (3%). Then about 2 ml of extract in a test tube, 2 ml of glacial acetic acid and 2 ml of ninhydrin reagent were added. The mixture was boiled in a water bath at 100°C for 30 min. and allowed to cool. After it was cool, 6 ml of toluene was added and the combination transferred to a separating funnel. After thorough mixing, the chromophore containing toluene was separated and the absorbance was read at 520 nm in a spectrophotometer against a toluene blank.

2.3 Relative water contains (RWC) and Electrolyte leakage determination

According to the method of the content of RWC in leaf tissue was measured (Unyayar et al., 2004). Therefore, leaf discs from leaves were weighted (FW). Immediately for 2 h, it placed in distilled water at 25°C, and then their turgid weights (TW) were recorded. Finally, the samples in an oven at 70°C for 48 h (DW), were dried. RWC was calculated by the following formula:

$$RWC= (FW-DW)/ (TW-DW)*100$$

For electrolyte leakage in leaf tissue, sample disks were cut from fresh leaves and then it introduced to test tubes containing 10 ml of deionized water. After 24 h, the electrical conductivity of the bathing solution (EL_1) was measured with a conductometer (Inolab Cond 7110, company WTW). Then, the solution with leaf disks was boiled (90°C) for 10 min, until the destruction of membrane integrity, leading to the leakage of all the electrolyte from cells. After cooling to a temperature of 20°C and centrifugation to remove the plant material, electrical conductivity of the bathing solution was measured (EL_2). Finally relative electrolyte leakage was calculated according to (EL_1/EL2)*100%

2.4 Photosynthesis pigment in leaves

Three photosynthesis pigment in leaves included chlorophyll ‘a’ & ‘b’ and carotenoid in leaves were extracted with 80% acetone and measured according to the Arnon’s method (1967). The spectrum absorptions for chlorophyll ‘a’ & ‘b’ and carotenoid were 663, 645 and 440 nm, respectively.

2.5 Statistical analyses of data

Finally, after measuring traits, all data were analyzed with SAS Institute Inc. 9.2 software. To determine significant (P=0.05, firstly all data analyzed by ANOVA. And then the significant differences between treatments means were determined using LSD test.

3. Results and Discussion

3.1 Grain yield and yield components

The analysis of data showed that interaction between drought stress and calcium treatment had a significant effect on grain yield in maize plants (Table 1). By increasing drought levels from W1 to W3, the grain yield decreased and the lowest grain yield was obtained at the W3. Although drought stress reduced grain yield of maize, but application of calcium, silicate or chloride, reduced the damage of drought stress on grain yield. Among these, the greatest effect was related to the concentration of 3 g per liter of water and also in the source, silicate was more effective than chloride. So that the maximum grain yield was obtained at W1C5 and the lowest was at the W3C1 treatments (Table 2).

Biomass, the weight of thousand seed and the number of seed per plant were the grain yield of components in maize that affected by the interaction between of drought stress and calcium treatments in this experiment (Table 1). According to the results which showed in Table 2, with increasing calcium application from 1.5 to 3 g per liter of water, the biomass of maize at all levels of drought stress, increased. Also, with raising the drought stress level from W1=8 to W3=16 days irrigation interval, the biomass showed a significant decreased between 23 to 40%. Then the highest biomass was obtained at W1C3 and W1C5 treatments which were equal to 20911.9 and 20518.3 kg ha-1 respectively. The lowest biomass amongst all treatments, was observed in W3C1 which was equal to 8099.7 kg ha-1. At drought levels of W2 and W3, it was observed that the application of calcium silicate source was better than chloride and produced more biomass.

At W3, the amount of biomass produced at a concentration of 3 g per liter of water from silicate source, the production of biomass was 17% higher than on 3 g per liter of water from chloride source (Table 2). The analysis of data showed that interaction between drought stress and calcium treatment had a significant effect on the weight of thousand seeds and the number of seed per plant (Table 1). By increasing drought stress from W1 to W3, in all calcium levels, like the number of seed per plant, the weight of thousand seeds decreased. The lowest of them were observed W3C1.

W_1= 8 (control), W_2= 12 and W_3= 16 days irrigation

C_1=control or without application of calcium, C_2= calcium chloride with concentration of 1.5 g per liter of water, C_3= calcium chloride with concentration of 3 g per liter of water, C_4= calcium silicate with concentration of 1.5 g per liter of water and C_5= calcium silicate with concentration of 3 g per liter of water.

In the absence of drought stress, calcium silicate had a better effect than on the yield and yield components of maize than chloride and the application of 3 g per liter of water silicate had a greater effect. Then the highest weight of thousand seeds was obtained at W_1C_5 and the number of seed per plant was obtained at W_1C_2 treatment (Table 2). In conditions of drought stress, the use of calcium increases the weight of thousand seeds and this increase continues until the level of W_2. And then by increasing the level of stress and reaching to W3, the weight of thousand seeds was reduced. This decrease in the silicate source was less than chloride source. The number of seed per plant decreased with increasing drought levels from W_1 to W_3, but this decrease in silicate was less than chloride source (Table 2).

3.2 Proline and soluble carbohydrate

Proline and carbohydrates as two osmotic regulating compounds in this study were affected by the interaction of drought stress and calcium treatment (Table 1). Based on the results, it was found that with increasing drought stress at all levels of calcium application, the amount of proline increased. This increase was much greater in the treatments that used calcium, especially calcium silicate, than the control treatment. Then the highest amount of proline was observed at W3C5 treatment, which was equal to 102.6 µmol g fresh weight. Soluble carbohydrates also changed like proline. However in the W1 there was no significant between different treatments in terms of soluble carbohydrates, but with increasing drought levels in treatments that used calcium, soluble carbohydrates significantly compared to the control, increased (Table 2). The maximum soluble carbohydrates were observed at W3C5, which was equal to 599.1 mg g fresh weight.

Table 1: Analysis of variance calcium and drought stress treatments on grain yield, grain yield components and some physiological parameters in maize plant

Source of variance (S.O.V)	df	Grain yield	Biomass	Weight of thousand seeds	Number of seed per plant	Soluble carbohydrate	Proline	Chlorophyll "a"	Chlorophyll "b"	Carotenoid	Electrolyte leakage	RWC
Block	2	1323017^{ns}	1768678^{ns}	4340*	1691^{ns}	2634^{ns}	77.1^{ns}	2.02^{ns}	0.45^{ns}	0.021^{ns}	327.4^{ns}	61.8*
Drought	2	32697366**	136004361**	3505*	185186**	186104*	5456.5**	13.3**	2.02**	0.873**	61093.4**	3049**
Error (a)	4	443259	3669312	548	1826	2503	73.4	0.9	0.01	0.02	837	10.9
Calcium	4	877831*	39320800**	4866**	5827^{ns}	8499**	294.2**	2.49**	0.315**	0.178**	6610.1**	382.2**
Drought* Calcium	8	9604950**	15970673*	8842**	14878**	5475**	160.5**	0.89*	0.044^{ns}	0.72*	9053.1**	200.4**
Error (b)	24	1061709	4164683	1163	3101	932	27.3	0.41	0.06	0.18	842.5	48.9
C. V (%)		13.5	13	9.8	9.4	7.1	7.1	18.7	15.7	13.2	9.7	8.6

*, ** and ns: significant in 5%, and 1% of the probability levels and non-significant, respectively

Table 2: Mean square of the calcium and drought stress treatments on grain yield, grain yield components and some physiological parameters in maize

	Calcium	Grain yield	Biomass	Weight of thousand seeds	Number of seed per plant	Soluble carbohydrate	Proline	Carotenoid	Chlorophyll "a"	Electrolyte leakage ds cm^{-1}	RWC %
		Kg ha^{-1}		g		mg g fresh weight	µmol g fresh weight	mg g fresh weight			
W_1=8	C_1	6728.3dc	13471.7edf	292.0e	320.9cd	323.6e	55.4e	0.9bcd	2.9def	276.1gef	80.8dc
	C_2	9649.7a	19388.8ab	330.2cde	475.4a	320.4e	54.9e	1.4a	4.8ab	241.5g	85.9bc
	C_3	9684.7a	20911.9a	393.0b	460.1a	325.7e	55.8e	1.41a	4.6ab	239.7g	87.3ab
	C_4	9519.7a	19586.5a	316.8ed	428.1a	320.0e	54.8e	1.3a	4.5abc	231.4g	87.3ab
	C_5	9678.0a	20518.3a	485.1a	442.5a	318.6e	54.6e	1.4a	4.9a	235.6g	91.7a
W_2=12	C_1	6431.8ed	13213.2edf	348.5bcde	267.2edf	378.4d	64.8d	0.9cd	2.8def	321.8cde	65.5fg
	C_2	7107.2cd	13714.0ed	343.9bcde	293.7cd	406.5cd	69.6cd	1.0bc	3.4cde	295.9def	70.8ef
	C_3	7395.0bcd	15816.8dc	348.5bcde	309.6cd	396.0cd	67.8cd	1.0bc	3.8bcd	274.4gef	73.5e
	C_4	8244.4abc	16085.6bcd	319.5ed	327.3bc	442.1bc	75.7cb	1.1ab	3.8bcd	271.8gf	75.6de
	C_5	9090.1ab	17693.2abc	354.9bcd	364.0b	481.0b	82.4b	1.2a	4.0abc	236.2g	81.3c
W_3=16	C_1	3696.8f	8099.7g	292.2e	164.6h	424.8cd	72.7cd	0.6e	1.9g	418.8a	54.7h
	C_2	6034.6ed	13426.8edf	361.0bcd	200.7gh	564.3a	96.6a	0.8ed	2.1f	381.7ab	63.1g
	C_3	5810.7ed	12961.2ef	313.8ed	217.5gfh	548.9a	94.0a	0.7ed	2.5ef	367.2bc	71.4e
	C_4	6479.4d	13190.3edf	319.9ed	232.7efg	582.9a	99.8a	0.8cde	2.9de	346.7bc	71.3e
	C_5	7481.4bcd	15711.4dc	380.6bc	276.0ed	599.1a	102.6a	1.0bc	2.8def	329.2dc	73.8e

"Means within columns not followed by the same letter are significantly different at the P<0:05 level by LSD test

3.3 Photosynthesis pigments in leaves

According to the statistical analysis interaction between drought stress and calcium treatments had significant effects on photosynthesis pigment such as chlorophyll “a” and carotenoids in leaf tissues in maize (Table 1). But in relation to chlorophyll “b”, drought stress and calcium treatment had significant effect and interaction between these two treatments had no significantly affect on that. The results showed that calcium at all levels of drought stress, increased the content of chlorophyll “a”. Therefore, in all levels of drought stress treatment (W_1, W_2 and W_3), the lowest chlorophyll “a” was observed in the treatment of not using calcium sources (control).

Among the calcium sources, calcium silicate increased the amount of chlorophyll “a” in leaves more than calcium chloride. Then the maximum of chlorophyll “a” was observed at W_1C_5 treatment (Table 2).

About carotenoids, like chlorophyll “a”, the lowest number of carotenoids at all levels of drought stress, was observed in the absence of calcium or control. By increasing drought level from W_1 to W_3, in all calcium levels, the amount of carotenoids in leaves decreased. This shows the destructive effect of drought stress on the content of leaf chlorophylls (Table 2).

3.4 RWC and Electrolyte leakage determination

The interaction effect of drought stress and calcium treatment had significantly effect on RWC and Electrolyte leakage in leaves of maize plants (Table 2). The results showed that the range changes of RWC in leaves was 37%. The highest amount of RWC was 91.7% and the lowest was 54.7%. Also, the results showed that by increasing drought level from W_1 to W_3, the relative water content of the leaves decreased. On the other hand, calcium application moderated the effects of drought stress. Accordingly, the maximum content of RWC, was observed in the W_1C_5 with an average of 91.7% and the lowest at the W_3C_1 with an average of 57.7% (Table 2).

In this experiment, the relationship between RWC and the electrolytes leakage was negative. Accordingly, the results of the interaction between of drought stress and calcium treatments showed that the maximum amount of electrolyte leakage was observed in the W_3C_1 which was equal to 418.8 dS m^{-1} and the lowest amount was obtained at the W_1C_4 treatment. In addition, the results showed that calcium chloride had a less positive effect on electrolyte leakage than calcium silicate (Table 2).

4. Discussion

Drought is one of the most widespread abiotic limitations in agriculture. Drought stress on plants occurs when the rate of transpiration is greater than the rate of water uptake. Drought can effect on growth, nutrient uptake and mobility in soil and therefore, alters various physiological and antioxidative plant responses (Luo et al., 2011). In this experiment, it was observed that drought stress reduced the growth and grin yield in maize. Decreased in grain yield was due to the effects of drought stress on yield components and reduced biomass produced in this plant (Table 2). In this experiment, it was also found that in the absence of calcium, grain yield and yield components of maize were reduced under drought stress conditions. And this decrease was even greater at level W3. Foliar application of calcium partially prevented this reduction. Meanwhile, calcium silicate was more effective than calcium chloride (Table 2). A group researchers reported water stress decreased grain yield and yield components in Sesame (Sesamum indicum L.) but calcium chloride (even up to 15 mM, at all of water stress treatments) altered and improved them (Heidari et al., 2019).

Increasing of osmolites such as soluble carbohydrate and proline in plant tissues, can protect cellular structures and functions as well as maintain water balance and delay dehydrative damage at environmental stress (Taiz and Zeiger, 2006). In this case, proline accumulation increases under environmental stress conditions such as water and salinity stress, which not only helps in maintaining cell turgor but also involving in quenching free radicals, maintaining subcellular structures, and buffering cellular redox potential (Ashraf and Foolad, 2007). Proline and soluble carbohydrates are two osmolites which examined and determined in this study. At the presence of drought stress, the concentration of these two compounds in the leaf tissue of maize were increased and by increasing stress level from W1 to W3, their amount was also increased. By application of calcium, the amount of these two compounds also increased with increasing drought stress from W1 to W3. But calcium silicate source had a greater effect than calcium chloride during drought stress on accumulation of these two compounds in leaf tissue (Table 2).

Accumulation of organic osmolites, is also a part of water stress avoidance mechanisms. Proline and other ammonium compounds are key osmolites, which help to plants maintain their turgor of cells (Huang et al., 2000). The results obtained in this experiment showed that by increasing the amount of osmolites such as soluble carbohydrate and prolin, the reduction of electrolyte leakage in the leaf tissue partially prevented and then the relative water content in leaves, improved (Table 2). Plant membranes are exposed to changes, often associated with the increases in permeability and loss of integrity under environmental stresses (Blokhina et al., 2003). Then, the ability of cell membranes to control the rate of ion movement in and out of cells is used as a test of damage to a great range of tissues. Calcium one of the important element, helping plants to resist many kinds of environmental stress. It necessary for functioning as a second messenger in cells, and can influence on membrane structures (Kapilan et al., 2018). In this study, it was obtained that drought stress increased the amount of electrolyte leakage in leaf tissue and as a result decreased the RWC of leaves. But application of calcium, especially calcium silicate, had a greater effect on reducing the amount of electrolyte leakage in leaf tissue at all of drought levels than calcium chloride. And 3 g per liter of water from calcium silicate had the greatest effect (Table 2).

5. Conclusions

The results in this experiment showed that due to lack of sufficient available water and then drought stress, the grain yield and yield components in maize decreased. Drought stress also reduced photosynthetic pigments such as chlorophyll “a”. During drought stress, the relative water contains in leaf decreased and the amount of electrolyte leakage in leaf tissue was increased. By increasing the level of drought stress from W1 to W3, their value increased and the highest amount on these two parameters were obtained at W3. Drought stress in this experiment also changed the amount of osmolites in leaves tissues. The results showed that, drought stress increased the amounts of osmolites such as proline and soluble carbohydrate were increased in the leave tissues. These osmolites make the plant resistance to stress. Meanwhile, application of calcium had a positive effect on maize under drought stress. So that application of calcium improved the growth and yield in maize. This increase was due to the improvement of yield components and reducing electrolyte leakage. In this experiment, especially application of calcium silicate source with a concentration of 3 g per liter of water had a greater effect on the maize plant than calcium chloride. In most of the traits measured (under drought and also non drought stress)in this experiment, treatment C5 (3 g per liter of water from calcium silicate) had the greatest on yield, yield components, proline and soluble carbohydrates in maize plant.

References

Abid, M., Tian, Z., Ata-Ul-Karim, S.T., Cui, Y., Liu, Y., Zahoor, R., Jiang, D., Dai, T., 2016. Nitrogen Nutrition Improves the Potential of Wheat (*Triticum aestivum* L.) to Alleviate the Effects of Drought Stress during Vegetative Growth Periods. Front Plant Sci. 7, Pp. 981. doi: 10.3389/fpls.2016.00981.

Arnon, A. N, 1967. Method of extraction of chlorophyll in the plants. Agron J. 23, Pp. 112-121.

Ashraf, M., Foolad, M.R., 2007. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ Exp Bot., 59, Pp. 206-216. doi: 10.1016/j.envexpbot.2005.12.006

Bates, L.*S*., Waldern, R.P., Teare, L.D., 1973. Rapid determination of free proline for water uses studies. Plant Soil., 39, Pp. 205-208.

Blokhina, O., Virolainen, E., Fagerstedt, K.V., 2003. Antioxidants, oxidative damage and oxygen deprivation stress. Ann Bot. 91, Pp. 179-194. doi: 10.1093/aob/mcf118

Çakir, R., 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res. 89, Pp. 1–16. doi: 10.1016/j.fcr.2004.01.005

Chow, P.S., Landhausser, S.M., 2004. A method for routine measurements of total sugar and starch content in woody plant tissues. Tree Physiol. 24, Pp. 1129-1136. doi: 10.1093/treephys/24.10.1129

Cousson, A., 2009. Involvement of phospholipase C-independent calcium-mediated abscisic acid signaling during *Arabidopsis responseto* drought. Biol Plant. 53, Pp. 53-62. doi:10.1007/s10535-009-0008-0.

Ding, D., Cai, H., Wang, J., Zhang, X., 2006. A study on compensative growth of maize under regulated deficit irrigation. Agric Res Arid Areas. 3, Pp. 64–67.

Farshaadfar, E., Rashidi, M., Mahdi, M.J., Zali, H., 2013. GGE biplot analysis of genotype × environment interaction in chickpea genotypes. Eur J Exp Biol., 3, Pp. 417-423.

Heidari, M., Aamirfazli. N., Ghorbani, H., Zafarian, F., 2019. Calcium chloride and drought stress changed grain yield and physiological traits in Sesame (*Seamum indicum* L.). Sci Agric Bohem, 50 (4), Pp. 211–218. doi: 10.2478/sab-2019-0029

Hochmal, A.K., Schulze, S., Trompelt, K., Hippler, M., 2015. Calcium-dependent regulation of photosynthesis. Biochim Biophys Acta. 1847 (9), Pp. 993–1003. doi: 10.1016/j.bbabio.2015.02.010

Huang, J., Hirji, R., Adam, L., Rozwadowski, K.L., Hammerlind, J.K., Keller, W.A., Selvaraj G., 2000. Genetic engineering of glycine betaine production toward enhancing stress tolerance in plants: metabolic limitations. Plant Physiol., 122, Pp. 747–756. doi: https://doi.org/10.1104/pp.122.3.747

Huang, K., Peng, L, Liu, Y., Yao, R., Liu, Z., Li, X., Yang, Y., Wang J., 2018. Arabidopsis calcium-dependent protein kinase AtCPK1 plays a positive role in salt/drought-stress response. Biochem Biophys Res Commun., 498, Pp. 92-98. doi: 10.1016/j.bbrc.2017.11.175

Kapilan, R., Vaziri, M., Zwiazek, J.J., 2018. Regulation of aquaporins in plants under stress. Biol Res. 51 (4), Pp. 1-11.doi.org/10.1186/s40659-018-0152-0

Luo, Y., Zhao, X., Zhou, R., Zuo, X., Zhang, J., Li, Y., 2011. Physiological acclimation of two psammophytes to repeated soil drought and rewatering. Acta Physiol Plant., 33, Pp. 79-91. doi: 10.1007/s11738-010-0519-5

Naeem, M., Naeem, M.S., Ahmad, R., Ihsan, M.Z., Ashraf, M.Y., Hussain, Y., Fahad, S., 2018. Foliar calcium spray confers drought stress tolerance in maize via modulation of plant growth, water relations, proline content and hydrogen peroxide activity. Arch Agron Soil Sci., 64, Pp. 116-131. doi.org/10.1080/03650340.2017.1327713

Payero, J.O., Tarkalson, D.D., Irmak, S., Davison, D., Petersen, J.L., 2008. Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. Agric Water Manag., 95, Pp. 895-908. doi: 10.1016/j.agwat.2008.02.015

Sallam, A., Alqudah, A.M., Dawood, M.F.A., Baenziger, P.S., Borner, A., 2019. Drought stress tolerance in wheat and barley: advances in physiology, breeding and genetic research. Int Mol Sci., 20, Pp. 3137-3173. doi:10.3390/ijms20133137

Taiz, L., Zeiger, E., 2006. Plant physiology. 4th Edn. Sunderland, MA: Sinauer Associates Inc.

Unyayar, S., Keles, Y., Unal, E., 2004. Proline and ABA levels in two sunflower genotypes subjected to water stress. Bulg J Plant Physiol,. 30 (3/4), Pp. 34-47.

Xu, X., Peng, G., Wu, C., Korpelainen, H., Li, C., 2008. Drought inhibits photosynthetic capacity more in females than in males of *Populus cathayana*. Tree Physiol., 28, Pp. 1751-1759.