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EFFECT OF DROUGHT STRESS AND POLYMER ON OSMOTIC ADJUSTMENT AND PHOTOSYNTHETIC PIGMENTS OF SUNFLOWER

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ABSTRACT - Water stress affects plant growth and crop productivity in the vast semi-arid and arid regions of Iran. The present study was aimed at investigating the effect of drought stress and super absorbent polymer (SAP) on the osmotic adjustment and carotenoid content of sunflower (cv. Master) under field condition. The experiment was carried out as a split plot based on randomized complete block design with three replications. Three irrigation levels (irrigation after 6, 10 and 14 days) and five amount of super absorbent polymer (SAP) (0, 75, 150, 225, 300 kg/ha) were set as main and sub factors, respectively. Polymer was added in fourteen leaves stage of sunflower to soil in deepness of roots development (by mixing with soil) and at this same stage drought stress was applied.The results showed that effect of different rates of super absorbent polymer and water stress in all traits were significant ($P<0.001$) as well as their interactive effect of two mentioned factors were significant ($P<0.001$).Drought stress significantly increased carotenoid content. Drought stress caused an increase in the concentration of soluble sugar and proline content in the leaves of sunflower. These results indicated that lowest amount in proline and soluble sugars accumulation were achieved at 300 kg ha^{-1} polymer compared with the control (without polymer) in all rates of water even under drought stress conditions.Our results showed that SAP can absorb and retain extremely large amounts of water, so protects the plants against drought.

Keywords: Sunflower; Drought stress; Polymer; Proline; Soluble sugar.

INTRODUCTION

Superabsorbent synthetic polymers (SAP) work by absorbing and storing water and nutrients in a gel form, hydrating and dehydrating as the demand for moisture fluctuates.

The experience of companies using SAP has proved many advantages of its application in agriculture. The most important of them are the following:

- lower costs of plant production;

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- important improvement of water management and increase of water accessibility for plants (Reduces watering frequency by up to 50%);
- increased amount of soil aggregates, better permeability and soil aeration;
- easier evacuation of carbon dioxide from the root zone;increased osmotic moisture and possibility of nutrients absorption (Orzeszyna *et al.*, 2006).

Sunflower is one of the major and most important non-conventional oilseed crop in the world due to its excellent oil quality (Baydar and Erbas, 2005). Although sunflower is known as a drought tolerant crop or grown under dryland conditions, substantial yield increases are achieved withfrequent irrigation.

One of the most common stress tolerance strategies in plants is the overproduction of different types of compatible organic solutes (Serraj and Sinclair, 2002).

Compatible solutes are low-molecular weight, highly soluble compounds that are usually nontoxic even at high cytosolic concentrations. Compatible solutes are accumulated in plants at high concentrations to help in alleviating inactivation of the enzymes or loss in membrane integrity due to a water deficiency (Schwab and Gaff, 1990).

Osmotic adjustment is a mechanism to maintain water relations and sustains photosynthesis by maintaining leaf water content at reduced water potentials. Osmotic adjustment is accomplished with the accumulation of compatible solutes. Of these, proline is one amongst the most important cytosolutes and accumulates in plants during the adaptation to various types of environmental stress, such as drought, salinity, high temperature, nutrient deficiency, and exposure to heavy metals and high acidity (Oncel *et al.*, 2000).

Of the two carotenoid content classes, carotenoids show multifarious roles in drought tolerance including light harvesting and protection from oxidative damage caused by drought. Thus, increased contents specifically of carotenoids are important for stress tolerance (Jaleel *et al.*, 2009).

The objective of the present work was to determine the effect of super absorbent polymer (SAP) A 200 and drought stress on the osmotic adjustment and carotenoid content of sunflower (Cultivar Master) under field condition.

MATERIALS AND METHODS

This study was carried out as a split plot based on randomized complete block design with three replications on sunflower plant (Cv. Master) in the summerof 2008.In this study three irrigation levels (irrigation after 6, 10 and 14 days) and five amounts of super absorbent polymer (0, 75, 150, 225, 300 kg/ha) were set as main and sub factors, respectively. Polymer was added in fourteen leaves stage of sunflower to soil in deepness of roots development (by mixing with soil) and at this same stage drought stress was applied. All the agronomical practices were carried out uniformly in all the treatments. The soil amendment used was a hydrophilic polymer, Superab A 200, produced by Rahab Resin Co. Ltd., under license of Iran Polymer and Petrochemical Institute. Maximum durability of this matter is 7 years and water uptake capacity (g/g) equal with 220 in distilled water. The method of applying polymer is to locally add a small amount of polymer crystals to each plant hole. This method is extremely economical as the crystals are only applied locally to the root zone. The physiochemical characteristics of soil are presented in *Table 1*.

Determination of proline and soluble sugars. Extraction and determination of proline was performed according to the method of Bates *et al.* (1973). Leaf samples (1gr) were extracted with 3% sulphosalisilic acid. Extracts (2 ml) were held for 1 h in boiling water by adding 2 ml ninhydrin and two ml glacial acetic acid, after which called toluene (4 ml) was added. proline content was measured by a spectrophotometer at 520 nm and reported as mg/g DW.

Total soluble sugars were determined according to the method of Irigoyen *et al.* (1992).

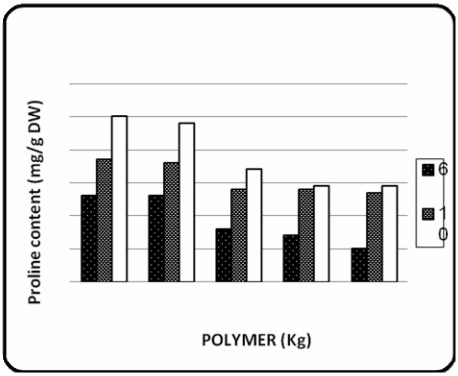
Determination of carotenoid content. Carotenoid were extracted from the leaves and estimated using the formula of Kirk and Allen (1965) and expressed in milligrams per gram fresh weight. Statistical analysis was carried out through SAS software version 9.0 while drawing graphs was done by using Microsoft Office Excel 2007 software.

Table 1 - The physiochemical characteristics of soil

PH (ds/m)	Electrical conductivity (ds/m)	Absorbable potassium (mg/kg)	Absorbable phosphorus (mg/kg)	N (%)	Organic matter(%)	Sand (%)	Clay(%)	Silt (%)	Soil texture	Bulk density (gr/cm³)	Weightedmoisture (%)	Depth (cm)
7/6	./455	0/455	449/5	%20	1/ 98	40	33	28	Clay loam	1/514	22/5	0-30
7/6	./455	0/63	331/5	%8	1/34	36	36	29	Clay loam	1/571	22/5	-60 30

RESULTS AND DISCUSSION

Proline content was significantly increased under drought stress conditions. Increasing in drought stress resulted in increase in proline content, so the highest (0.05 mg/g DW) and the lowest (0.01 mg/g DW) values were obtained in 14 days after irrigation with no polymer and 6 days after irrigation with 300 kg/ha, respectively (*Fig. 1*).



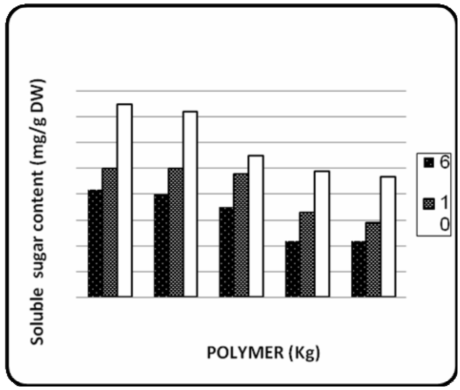


Figure 1 - Effect of polymer and drought stress on proline content and soluble sugars content in sunflower

Confirmed results were obtained by a group of workers including Zaifnejad *et al.*(1997), Kundu and Paul (1997), Sanchez *et al*. (1998).

High levels of proline enabled the plant to maintain low water potentials. By lowering water potentials, the accumulation of compatible osmolytes, involved in osmoregulation allows additional water to be taken up from the environment, thus buffering the immediate effect of water shortages within the organism (Kumar *et al*., 2003).

The proline accumulation in drought-stressed plants may play a role as osmolyte to maintain the organelles, resulting in the greenish leafwhen exposed to water deficit condition (Safarnejad, 2008).

Drought stress caused an increase in the concentration of soluble sugar in the leaves of sunflower. The highest (70 mg/g DW) and the lowest (22 mg/g DW) values were obtained in irrigation once in 14 days with no polymer and irrigation once in 6 days with 300 kg/ha, respectively (*Fig. 1*). Our results were fortified by those of Irigoyen *et al*. (1992), Sanchez *et al*. (1998) and Izanloo *et al*. (2008).

Under water stress condition the breakdown of polysaccharides caused an accumulation of soluble sugars which helpmaintenance of turgor. Alsohigh levels of soluble sugars in leaves can be caused by high requirement for osmotic adjustment and membrane stabilization. Soluble sugar content and proline improve stress tolerance by protecting and stabilizing membranesand enzymes during stress conditions (Rudolph *et al*. 1986).

Carotenoid content. The carotenoid content was found to increase progressively with the increase of drought increments (*Fig. 2*). The variance analysis of the carotenoid content showed that this characteristic is significantly affected by the amounts of polymer and the water stress (in probability level of 1%).

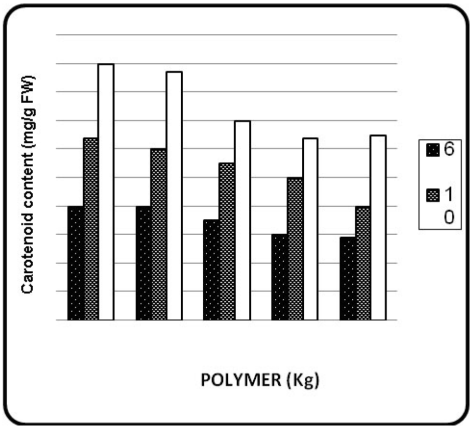


Figure 2 **- Effect of polymer and drought stress on carotenoid content in sunflower**

Wang *et al*. (2001) reported that the carotenoid content in leaves of winter wheat increased under drought stress.

The major role of carotenoid through direct quenching of triplet chlorophyll prevents the generation of singlet oxygen and protects from oxidative damage.

Chlorophyll and carotenoid absorb radiant energy, which is used for photosynthesis. In many observed cases chlorophyll content declines under drought stress conditions. Potato leaves show a significant decline in chlorophyll content with increasing water stress (Nadler and Bruvia, 1998).

All of the polymers when used correctly and in ideal situation will have at least % 95 of their stored water available for plant absorption (Johnson and Veltkamp, 1985). Our results indicated that SAP (as a water reservoir for plants) can absorb and retain extremely large amounts of water, so protects the plants against drought. Application of the SAP created the most suitable environment for root. Root system well developed on subsoil with polymer, so water retaining possibilities can be better utilized. Polymer help maintain a consistent moisture in the root zone, thus reducing water stress which can slow plant growth.

Consequently SAP is able to store water which, if necessary, is accessible for plants, so it can reduce watering frequency (with increasing irrigation interval), reducing time and money spent on irrigation labor and water costs.

Table 2 - Results of analysis of variance (mean squares) for effect of drought stress and polymer on carotenoid content and proline, soluble sugar accumulation of sunflower (*Helianthus annuus* L.) in field condition

S.O.V.	df	MS		
		Carotenoid content	Proline content	Soluble sugar content
Replication	2	**39/592**^{ns}	**0/07**^{ns}	^{ns}**0/81**
Irrigation	2	**457/75****	**5/71****	**16/6****
Linear(L)	1	**140/1****	**31/41****	**41/7****
Quadratic (Q)	1	**21/67**^{ns}	**0/014**^{ns}	**2/5***
Polymer	4	**113/81****	**3/26****	**7/27****
Linear(L)	1	**514/10****	**1/39****	0.39**
Quadratic (Q)	1	**8/62**^{ns}	**0/27**^{ns}	**1/22**^{ns}
Cubic(C)	1	**25/40****	**1/38****	1.17*
Quadratic (Qt)	1	**9/13**^{ns}	**0/00**^{ns}	0.86^{ns}
Irrigation × Polymer	8	**7/73****	**0/91****	2.38**
$L_I \times L_P$	1	**0/99****	**0/9**^{ns}	8.81**
$L_I \times Q_P$	1	**2/4**^{ns}	**1/02**^{ns}	0.58^{ns}
$L_I \times C_P$	1	**0/26**^{ns}	**1/43***	0.60^{ns}
$L_I \times Qt_P$	1	**0/21**^{ns}	**1/2***	3.8^{ns}
$Q_L \times L_P$	1	**3/05***	**0/02**^{ns}	0.45*
$Q_L \times Q_P$	1	**5/62**^{ns}	**1/70***	2.48^{ns}
$Q_L \times C_P$	**1**	**2/2**^{ns}	**0/01**^{ns}	**4/35***
$Q_L \times Qt_P$	**1**	**1/35**^{ns}	**0/04**^{ns}	**1/21**^{ns}

df: degree of freedom; MS: mean of square; *,** significant at 0.05 and 0.01 probability levels, respectively; ns : non significant

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