Cercetări Agronomice în Moldova
Vol. XLIII , No. 3 (143) / 2010

THE EFFECT OF DROUGHT STRESS AND SUPER ABSORBENT POLYMER (A200) ON AGRONOMICAL TRAITS OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) UNDER FIELD CONDITION

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Received April 17, 2010

ABSTRACT - In many areas of Iran, the reproductive growth stage of sunflower is exposed to the drought stress. Therefore, the investigation of irrigation management in the farm was necessary for increasing irrigation efficiency and decreasing water loss. The objective of the present study was to investigate the effect of different amounts of super absorbent polymer (A200) and levels of drought stress on morphological characteristics, such as: head diameter, stem diameter, plant height, 100-seed weight, seed yield and physiological characteristics, such as: relative water content (RWC), chlorophyll concentration of sunflower (cv. Master) under farm conditions. The experiment was carried out as a split plot based on randomized complete block design with three replicates. Three irrigation levels (irrigation after 6, 10 and 14 days) and five amounts of super absorbent polymer (0, 75, 150, 225 and 300 kg/ha) were set as main and sub-factors, respectively. Polymer was added at the fourteen leaf stage of sunflower to soil in deepness of root development. At this same stage, drought stress was applied. Polynomial models of each traits based on the ANOVA were fitted. The results indicated that drought stress has decreased significantly all the measured traits. In this study, seed yield has shown a significant decrease. After 6 days, irrigation has resulted in higher yields than other irrigation intervals. The highest seed yield was related to 300 kg/ha polymer application and the lowest one was related to irrigation after 14 days with no application of polymer. Regarding the limitation of water resources, super absorbent polymer could be a useful strategy for the sustainability of yield under drought stress in sunflower.

Key words: sunflower, drought stress, polymer, relative water content (RWC), yield

REZUMAT – Efectul stresului provocat de secetă şi al polimerului superabsorbant (A200) asupra caracteristicilor agronomice ale florii-soarelui (*Helianthus annuus* l.), în condiţii de câmp. În multe zone din Iran, floarea-soarelui este expusă, în stadiul de formare a organelor de reproducere, la

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stresul provocat de secetă. De aceea, sunt necesare cercetări privind managementul irigării în ferme, pentru a creşte eficienţa irigaţiei şi a reduce pierderile de apă. Obiectivul acestui studiu îl reprezintă efectul diferitelor cantităţi de polimer superabsorbant (A200) şi al stresului provocat de secetă asupra unor caracteristici morfologice: diametrul capitulului, diametrul tulpinii, înălţimea plantei, greutatea a 100 achene, producţia de floarea-soarelui, precum şi caracteristici fiziologice: conţinutul de apă, conţinutul în clorofilă al florii-soarelui (cultivarul Master), în condiţii de fermă. Experimentul a fost realizat pe o parcelă divizată, într-un bloc complet randomizat, în trei repetiţii. Cele trei niveluri de irigare (irigarea după 6, 10 şi 14 zile) şi cele cinci cantităţi de polimer superabsorbant (0, 75, 150, 225, 300 kg/ha) au fost stabilite ca principalii factori şi, respectiv, subfactori. În sol, polimerul a fost adăugat în stadiul de 14 frunze ; în acelaşi stadiu, a acţionat şi stresul provocat de secetă. Au fost propuse modele polinomiale (ANOVA). Rezultatele au arătat că stresul provocat de secetă a dus la o scădere semnificativă a tuturor caracteristicilor analizate. Producţia de sământă, în perioada de creştere a intervalelor de irigare, a scăzut semnificativ. Irigarea, după o perioadă de 6 zile, a dus la creşterea producţiei, în comparaţie cu alte intervale de irigare. Cea mai mare producţie de sământă a fost realizată când s-au aplicat 300 kg/ha polimer, iar cea mai mică producţie s-a obţinut în cazul irigării după 14 zile, fără aplicarea polimerului. În ceea ce priveşte limitarea resurselor de apă, polimerul super absorbant poate fi o strategie folositoare pentru durabilitatea producţiei de floarea-soarelui, în condiţiile stresului cauzat de secetă.

Cuvinte cheie: floarea-soarelui, stresul cauzat de secetă, polimer, conţinutul de apă, producţie

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops and due to its high content of unsaturated fatty acids and to the lack of cholesterol oil has a desirable quality (Razi and Asad, 1998). Mazahery-Laghab *et al.,* (2003) reported that irrigation at the flowering stage increases the seed yield by more than 60% in comparison to the control. In an experiment on 14 sunflower cultivars, Razi and Asad (1998) indicated that irrigation has resulted in an increase in head size, stem diameter, plant height, 1000-seed weight and seed yield.

Erdem and Delibas (2003) demonstrated that the highest seed yield was obtained in the control treatment (T_1), in which crop water requirement was applied during the total growth period and the lowest seed yield was obtained in the T_7 treatment, where no irrigation water was applied during the total growth period.

Gas exchange parameters, transpiration (Tr) and net photosynthesis (Pn), regulated by stomatal conductance (gs) decrease as water stress increases in sunflower. Relative water content (RWC) is one of the most important parameters, which are most commonly used to assess plant water condition (Tezara *et al.,* 2002). Low RWC and leaf water potential inhibit the photosynthesis capacity of sunflower (Tezara *et al.,* 2002). Drought stress has caused decreases in chlorophyll content when compared to the control (Manivannan *et al*., 2008). Although sunflower is moderately tolerant to water stress, its production is greatly affected by drought conditions (Tahir *et al*., 2002).

For an increased crop production in dryland environments, a greater percentage of the precipitation between crops must be stored in soil and the stored water and growing season precipitation must be used more efficiently. Super absorbent polymer may have great potential in restoration and reclamation of soil and storing water available for plant growth and production. Incorporation of polymer into soil has increased wheat dry weight (Jounson and Leah, 1990).

Super absorbent polymer can hold 400-1500 g of water per dry gram of hydrogel (Woodhouse and Johnson, 1991; Bowman and Evans, 1991).

Due to the limited water resources in the world, it is essential to save and economize their use. All types of hydrogels when used correctly and in ideal situation will have at least 95% of their stored water available for plant absorption (Johnson and Veltkamp, 1985). The aim of this study was the evaluation of the effect of five amounts of polymer (0, 75, 150, 225 and 300 kg/ha) and of three irrigation intervals (6, 10 and 14 days) on the morphological traits of sunflower (cv. Master) under field conditions.

MATERIALS AND METHODS

This experiment was carried out at the farm of Urmia University in 2008. This region is found at latitude 37° and 32' N and longitude 45° and 5'E; its height is 1313 above the sea level. The climate of the region is cold and semidry. According to the 16-year statistics, the average rainfall amount and the area temperature are 184 mm and 12°C, respectively. Soil texture is clay loam, Electeric Conduct (EC) is equal to 1.3 mm cm and P.H is 7.6 ds/m at 0-30 cm depth. In this study, three irrigation levels (irrigation after 6, 10 and 14 days) and five amounts of super absorbent polymer (0, 75, 150, 225 and 300 kg/ha) were set as main and sub factors, respectively. The experiment was carried out as a split plot based on randomized complete block design with three replicates. Sunflower seeds (cv. Master) were cultivated in five lines of 5 m with 60 cm line interval and 20 cm bush interval on 9 May. During the growth season, hand weeding was done in necessary times, too. Polymer was added at the fourteenth leaf stage of sunflower to soil in deepness of root development; at this same stage, drought stress was applied. All the agronomical practices were carried out uniformly in all the treatments. The used soil amendment was a hydrophilic polymer, Superab A200, produced by Rahab Resin Co. Ltd., under license of Iran Polymer and Petrochemical Institute. The maximum durability of this matter is 7 years and the water uptake capacity (g/g) is equal to 220 in distilled water.

In the present study, five bushes were selected randomly from the middle part of each plot and all the traits of examined cases including 1000 seed weight, head diameter, height of stem, diameter of stem and seed yield were noted.

Chlorophyll concentration was assessed using a chlorophyll meter (SPAD-502, Minolta), measurements being taken at three points of each leaf (upper, middle and lower part). The average of these three readings was considered as SPAD reading of the leaf.

The upper most fully expanded leaves were used for water status measurement, and observations were made between 10:00 h and 14:00 h.

RWC was determined as RWC = FW-DW/ TW-DW, where FW is fresh weight and TW is turgid weight after 24 h rehydration at 4°C in a dark room with the petioles placed in a container with distilled water; DW is dry weight after oven drying for 24 h at 80°C. In all cases, half of lamina of sampled leaf was used for RWC determination (lamina with midrib vein).

Statistical analysis was carried out through SAS software version 9.0, while drawing graphs was done by using Microsoft Office Excel 2007 software.

RESULTS AND DISCUSSION

Plant height was significantly affected by water stress (irrigation frequency) (*Table 1*). Increasing irrigation interval has resulted in the decrease of plant height, so the highest (183.4 cm) and the lowest (98.2 cm) values were observed in 6 day irrigation interval and 300 kg/ha polymer and 14 days irrigation interval and no hydrogel, respectively (Figure 1). Polynomial model of this trait is plant height = 143.33 + 966×10^{-7} IP^2 – 1757 $10^{-6}I^2P$.

Drought stress led to the reduction in stem cells, water potential to a lower level needed for cell elongation and, consequently, shorter internodes and stem height. The decrease in shoot length as response to drought may be either due to the decrease of cell elongation resulting from water shortage, which led to a decrease in each cell turgor, cell volume and, eventually, cell growth (Boyer, 1988) or due to blocking up of xylem and phloem vessels, thus hindering any translocation through (Lovisolo and Schuber, 1998).

Highly significant ($P<0.01$) differences were observed among water deficit treatments with respect to seed weight (*Table 1*). While increasing the irrigation interval, 100-seed weight was significantly reduced. Polynomial model of this trait is: W100A = 5.509 + 4111×10^{-6} IP - 244×10^{-6} I^2 P.

Our results were according to those obtained by Mekki *et al*., 1999; Goksoy *et al*., 2004; Chimenti *et al*., 2002. Drought stress had negative effect on current photosynthesis and remobilization, decreasing the mobilization of photosynthetic materials to the developing seeds. In addition, a reduction of 100-seed weight may occur due to a lower photosynthate production, because of excessive loss of leaves at the flowering stage (Rauf, 2008). High 100-seed weight, resulting from more irrigation, was probably due to the availability of adequate soil moisture and assimilates from source to sink during seed formation and seed ripping stages. Application of polymer tended to increase 100-seed weight of sunflower compared to the control (without polymer). Confirmed results were obtained by Allahdadi *et al.,* 2005.

Data on head diameter showed that irrigation frequency had a significant effect on this parameter. Head diameter decreased by increasing the drought stress. Polynomial models of this trait equal with $H.D = 32 - 1.827\ I + 0.0445\ I^2$ and $H.D = 13.73 - 0.063\ P + 163\times10^{-5}\ P^2 - 83\times10^{-7}\ P^3 + 1\times10^{-8}\ P^4$.

Table 1- Results of analysis of variance (mean squares) for the effect of drought stress and super absorbent polymer on the morphological traits of sunflower (*Helianthus annuus* L.) under field conditions

S.O.V	*df*	MS				
		DC	PH	DS	Y	W100A
Replicate	2	95.01	8174.78ns	2.25ns	4093150.5**	4.60ns
Irrigation	2	212.87**	6864.94**	1.76**	20901995.3**	16.56**
Linear (L)	1	420.67**	13614.1**	3.50**	41757841.2**	29.02**
Quadratic (Q)	1	5.07**	115.78**	0.02ns	46149.4ns	4.10**
Polymer	4	153.59**	2847.15**	2.44**	31417578.8**	25.16**
Linear (L)	1	595.16**	10980.8**	9.59**	121977890.8**	99.09**
Quadratic (Q)	1	1.05ns	32.67ns	0.01ns	59758.2ns	0.01ns
Cubic (C)	1	5.61**	356.56ns	0.03*	3211866.7**	1.31ns
Quadratic (Qt)	1	12.53ns	18.53ns	0.13ns	420799.2ns	0.23ns
Irrigation× Polymer	8	1.03**	365.63*	0.13**	420400ns	1.95*
LI×LP	1	0.38**	598.12**	0.20*	483842.4ns	6.23**
LI×QP	1	3.0ns	872.74ns	0.39*	1336609.7ns	1.58ns
LI×CP	1	0.09ns	1.93ns	0.00*	356664.6ns	0.02ns
LI×QtP	1	0.69ns	316.19ns	0.15*	64728.1ns	0.31ns
QI×LP	1	3.89ns	1083.78	0.00ns	709388.9ns	4.06
QI×QP	1	0.12ns	1.31ns	0.02*	2365ns	3.33ns
QI×CP	1	0.02ns	49.57*	0.01ns	147347.2ns	0.03*
QI×QtP	1	0.04ns	1.37ns	0.28ns	262253.7ns	0.03ns

df: degree of freedom; MS: mean of square; DC: diameter of capitol; PH: Plant height; DS: diameter of stem; Y; seed yield; W100A: weight of 100 achenes; *,** significant at 0.05 and 0.01 probability levels, respectively; ns: non significant.

Human *et al*., 1990 declared that the head size was significantly reduced as water stress increased. In addition, comparable results were detected by Mekki *et al*., 1999 and Nezami *et al*., 2008. Irrigation after 6 days and 300 kg/ha polymer gave significantly large head diameter (28.06 cm) against the lowest one (9.34 cm), recorded under irrigation after 14 days and no application of polymer. If head diameter was higher, more seeds would be produced. The results indicated that the effect of different amounts of polymer and different rates of consumed water had a significant (P<1%) effect on this parameter, but the interactive effect of the two above-mentioned factors was not significant (*Table 1*).

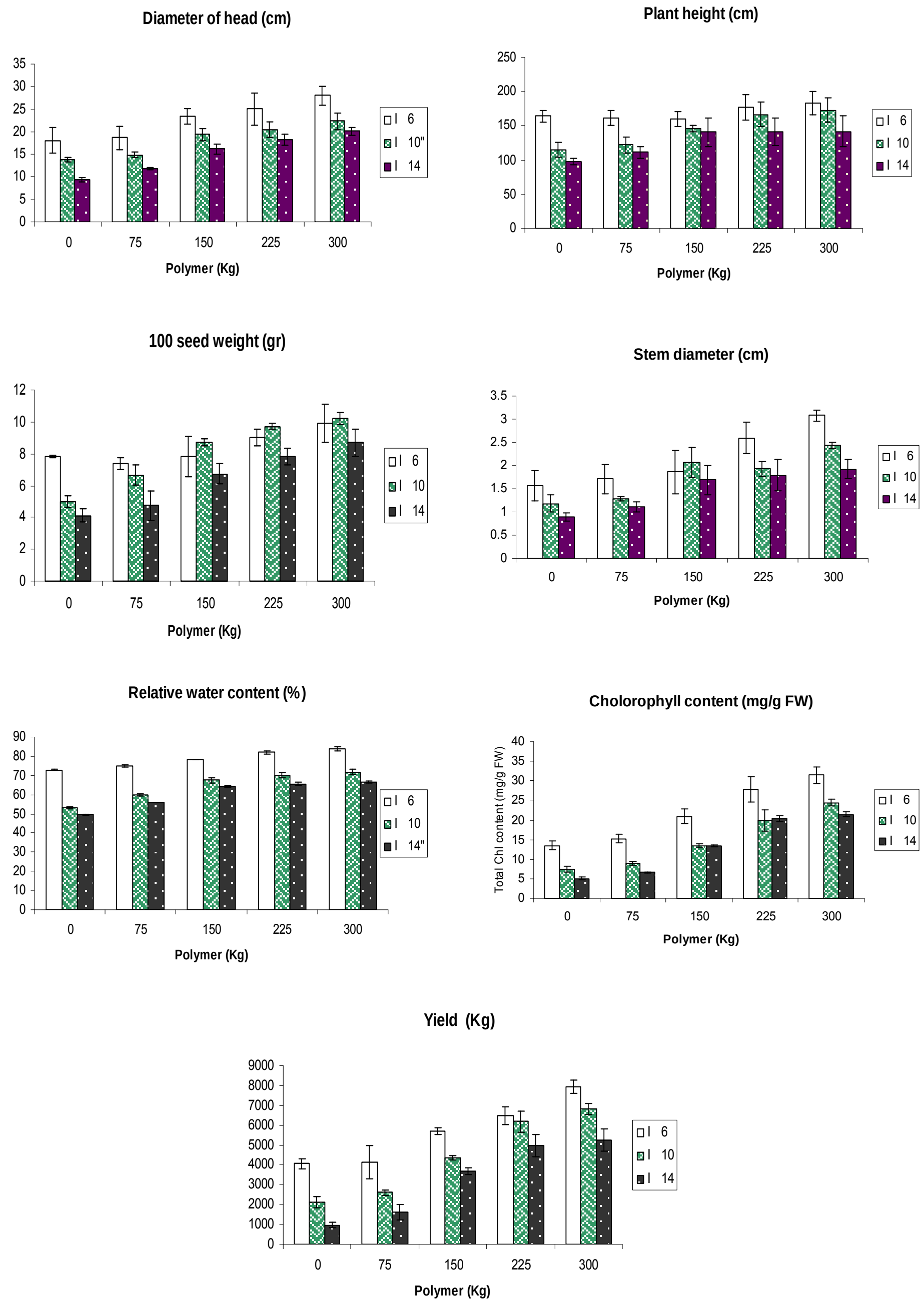

Figure 1 - Effect of polymer and drought stress on agronomical traits in sunflower

Stems are an important structure of carbohydrate source in seed filling period. Our results showed that the effects of super absorbent polymer and irrigation regime ($p<1\%$) and their interactions were significant ($p<5\%$) for stem diameter (*Table 1*). The highest effect of polymer addition on the stem diameter is related to 225 and 300 kg/ha. The highest (3.08 cm) and the lowest (0.88 cm) values are related to 6 day irrigation interval and 300 kg/ha polymer and 14 day irrigation interval and no hydrogel, respectively (*Figure 1*). The polynomial model of this trait is stem diameter = $1.472 - 706\times10^{-6}$ IP + 632×10^{-8} IP^2.

Nezami *et al*. (2008) reported that the decrease of soil water content to 60 and 30% field capacity (FC) caused a 20 and 46% reduction in stem diameter, as compared to the control, respectively. Abedi-koupai and Asadkazemi (2006) indicated that the greatest effect of polymer addition on the shoot diameter of ornamental plant (*Cupressus arizonica*) was related to 6 g/kg.

Our results indicated that the effect of different amounts of polymer and different rates of consumed water had a significant ($P<1\%$) effect on this parameter, but the interactive effect of the two above-mentioned factors was not significant (*Table 1*). Severe drought stress caused 77% diminution in seed yield compared to the control.

The polynomial models of this trait equal with $Y = 7787.77 - 379.82 I + 4.24 I^2$ and $Y = 2389.1 - 18.049 P + 0.434 P^2 - 0.0018 P^3 + 2\times10^{-6} P^4$.

Comparable results were detected by Karam *et al*. (2007) and Erdem and Delibas (2003). There were marked responses in the seed yield, because of polymer application and increase in polymer concentration. Different amounts of polymer and irrigation interval have influenced seed yield. The results have shown that the highest seed yield (6944 kg/ha) was observed at 6 day irrigation interval and 300 kg/ha polymer and the highest irrigation interval without application of polymer caused the lowest yield (970 kg/ha). With increasing polymer, the yield of forage maize increased (*Karimi and Naderi, 2007*). *Allahdadi et al. (2005)* declared that yield and yield components of soybean were affected by polymer amounts, according to this highest yield and yield components obtained at 6 day irrigation interval and 225kg/ha. Finally, regarding the limitation of water resources, super absorbent polymer could be a useful strategy for yield sustainability under drought stress in sunflower.

In addition, our results indicated that the effects of super absorbent polymer, irrigation regimes and their interactions were significant ($P<1\%$) for the relative water content (RWC) parameter (*Table 2*).

Polynomial model of RWC trait is RWC = $60.843 + 0.0158$ IP + 328×10^{-7} IP^2 $- 1385\times10^{-6}$ I^2P.

RWC has significantly diminished once with water stress application. Increasing irrigation intervals has resulted in the decrease in RWC, so the highest (83.82%) and the lowest (49.7%) values were observed in the 6 day irrigation interval and 300 kg/ha polymer and 14 day irrigation interval and no hydrogel, respectively (*Figure 1*). Poormohammad Kiani *et al*. (2007) declared that RWC of well-watered plants in recombinant inbred lines (RILs) of sunflower ranged from 80.4 to 91.7%, while in water-stressed plants, it ranged from 59.5 to 80.7%. Our results were concordant with those obtained by Jing and Huang (2002) and Unyayar *et al*. (2004). Stomata are mainly sensitive to leaf water status, tending to close once with decreasing leaf water potential. In this situation, the rate of photosynthesis declined while the respiration rate increased.

SPAD reading was significantly affected by irrigation frequency (*Table 2*). There was an inverse proportional relationship between increasing the irrigation interval, on the one hand, and contents of chlorophyll from leaves, on the other hand.

Table 2- Results of the analysis of variance (mean squares) for the effect of drought stress and super absorbent polymer on relative water content (RWC) and chlorophyll content of sunflower (*Helianthus annuus* L.) under field conditions

S.O.V	df	MS	
		RWC	Ch
Replicate	2	10.43ns	13.92**
Irrigation	2	1332.35**	305. 43*
Linear(L)	1	2415.98**	532.73**
Quadratic (Q)	1	248.73**	78.13ns
Polymer	4	382.68**	504.40**
Linear(L)	1	1437.44**	1954.21**
Quadratic (Q)	1	78.28ns	10*
Cubic(C)	1	5.16**	53.14**
Quadratic (Qt)	1	9.83ns	0.27*
Irrigation × Polymer	8	13.29**	2.02ns
LI×LP	1	32.29*	0.46ns
LI×QP	1	33.92ns	3.59ns
LI×CP	1	0.07ns	2.19ns
LI×QtP	1	7.27ns	0.02ns
QI×LP	1	25.25**	1.34*
QI×QP	1	6.59ns	4.91ns
QI×CP	1	0.50**	3.57ns
QI×QtP	1	0.11ns	0.09ns

df: degree of freedom; MS: mean of square; RWC: relative water content ; Ch: chlorophyll content

*, ** and ns: significant at 0.05 and 0.01 levels and non significant, respectively

Polynomial models of chlorophyll concentration trait were equal with $Ch = 42.801 - 4.547\ I + 0.174\ I^2$ and $Ch = 8.651 - 0.0147\ P + 521\times10^{-6}\ P^2 - 366\times10^{-9}\ P^3 - 2\times10^{-9}\ P^4$

Ahmadi and Baker (2000) showed that the moderate water stress (15% of FC) has significantly reduced the content of chlorophyll from wheat leaf.

Retardation in the content of photosynthetic pigment, because of water stress, was attributed to the ultra structural deformation of plastids, including the protein membranes forming thylakoids, which in turn cause untying of photo system 2, which captures photons, so its efficiency declined, thus causing declines in electron transfer, ATP and NADPH production and eventually CO_2 fixation processes (Maslenkova and Toncheva (1997) and Zhang *et al*. (2006)).

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