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# The Effect of Water Stress and Polymer on Water Use Efficiency, Yield and several Morphological Traits of Sunflower under Greenhouse Condition

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**Abstract**

In many part of Iran, the reproductive growth stages of sunflower (*Helianthus annuus* L.) are exposed to water deficit stress. Therefore, the investigation of irrigation management in the farm conditions is a necessary element for increasing irrigation efficiency and decreasing water losses. The objective of present study was to investigate the effect of different rates of super absorbent polymer and levels of water stress on water use efficiency (WUE), yield and some morphological traits of sunflower (cultivar 'Master'). Factorial experiment was carried out in completely randomized design with 3 replications. Factors were water stress in three levels (irrigation in 0.75; 0.50 and 0.25% of field capacity) and super absorbent polymer in five levels (0; 0.75; 0.150; 2.25; 3 g/kg of soil). Super absorbent polymer was added in eight leaves stage of sunflower to pots in deepness of roots development. Water stress treatment was also applied in this growth stage of sunflower. For stress application, pots were weighted every day and irrigated when soil water received to 0.75; 0.50 and 0.25 of field capacity, respectively. The results of ANOVA indicated that the effect of different rates of super absorbent polymer and different rates of consumed water in all traits were significant ($P<0.001$). ANOVA also revealed that the interactive effects of two mentioned factors were significant ($P<0.001$) except for seed yield trait. Polynomial model based on the ANOVA results was fitted for each trait. The results indicated that water stress significantly convert in decreasing the number of leaves per plant, chlorophyll content, 100 weight of seeds, seed yield and WUE in sunflower, whereas the application of super absorbent polymer moderated the negative effect of deficit irrigation, especially in high rates of polymer (2.25 and 3 g/kg of soil). The above mentioned rates of polymer have the best effect to all characteristics of sunflower in all levels of water stress treatment. The findings strongly suggest that the irrigation period of sunflower cultivation can be increased by application of polymer.

***Keywords:*** sunflower, water stress, polymer, yield

## Introduction

The objective of well-regulated deficit irrigation is to save water by subjecting crops to periods of moisture stress with minimal effects on yields. Iran has arid and semi arid climate, so the drought stress is considered as one of the main problems of production in this country. Water shortage is usually one of the important reasons for the reduction of performance in the unit area of arid and semi arid areas. Since 75% of our country's regions have a rainfall of less than 250 mm in year, the danger of drought is considered serious. Low water potential caused by a soil water deficit is one of the major natural limitations of the productivity of natural and agricultural ecosystems, resulting in large economic losses in many regions. In the past, irrigation has been a key solution to resolving this problem, but due to the increasing societal demands to water, today it is not a reasonable alternative and it increase financial cost (Wu and Cosgrove, 2000). Thus, the implementation of research programs for planning proper irrigation management is essential. Causing stress in a stage of plant's growth without loosing its performance from the point of view of saving water and irrigation for the arid and semi arid areas is one of the favorite research areas for researchers. On the other hand, the use of super absorbent polymers can be a general solution for the farming in the arid and semi arid areas of our country. Super absorbent polymers can hold 400-1500 g of water per dry gram of hydro gel (Boman and Evans, 1991). The use of super absorbent polymers has a great importance for their role in the increase of absorption capacity and retention of water in soil and for the fight against water shortage conditions and the decrease of bad effects of drought stress (Chatzopoulos *et al.*, 2000). Sunflower (*Helianthus annuus* L.) is one of the most important oil crops and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits from a desirable quality (Razi and Assad, 1998). Although sunflower is known as a drought tolerant crop or grown under dry land conditions, substantial yield increases are achieved by irrigation and many researchers have reported its performance decrease under water stress conditions (Erdem *et al.*, 2006; Nezami *et al.*, 2008). This experiment was carried out with the aim of investigating the effect of super absorbent polymer A200 and water stress on the chlorophyll content of leaves, the number of the leaves per plant, the 100 weight of seeds, seed yield

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and water use efficiency (WUE) in sunflower under greenhouse condition.

**Materials and methods**

Factorial experiment was carried out in completely randomized design with 3 replications on sunflower (Cultivar Master) in the summer of 2008 in the research greenhouse of Urmia University, Iran. The primary factor included three irrigation regimes including irrigation at 25%, 50% and 75% of field capacity and secondary factor included four amounts of super absorbent polymer including 0, 0.75, 1.5, 2.25 and 3 g polymer per 1 kg of soil. The super absorbent polymer A200 was provided from Rahab Rezin Company, Institute of Polymer Research, Karaj, Iran. According to the manufacturing company's protocol this substance had a maximum seven years of durability in soil and its practical capacity of water absorption was equal to 220 g.

Some properties of super absorbent polymer A200:

- Water content (%) = 5-7
- Grain size (i m) = 50-150
- Density (g/cm$^3$) = 1.4-1.5
- Ph = 6-7

The net weight of soil of each pot was cosidered 9 kg and the plantation of the pot took place in 10 June. The polymer was added to pots around the roots at the stage of eight leaves of sunflower with making ten centimeter holes in pots and right after that the pots was irrigated. Then the intended water stress was started from the stage of 8 leaves. The pots were put at distances from each other that triggered no competition for light taking. Before the irrigation, the pots were weighted by a sensitive balance and appropriate amount of water corresponding to each water stress treatment was added to pots and recorded.

In order to measure the performance of seed in capitol, first the capitol were dried in fluent air and the seeds were separated from them. The performance of seed in the capitol was calculated on the basis of 10 percent of the moisture. The weight of 100 seeds with 10 percent of the moisture was measured for each treatment combination per replication. Chlorophyll content was assessed using a chlorophyll meter (SPAD-502, Minolta) and measurements were done at three points of each leaf (upper, middle and lower part). Average of these three readings was considered as SPAD value. After pollination and with the start of seeds filling time, the number of the leaves per plant was measured. At counting time, some of the old leaves of the plants were fallen due to low irrigation; by their trace on the stem, these leaves were also considered and counted. Before the start of each irrigation interval, the amount of the used water by each treatment combination per replication was measured with graduated cylinder and recorded. Then the total performance was computed and was finally water use efficiency determined through the following formula:

(The general performance/ the used water) x 100 = Water Use Efficiency (g.lit)

Statistical analysis was carried out through SAS software version 9.0. The graphs were designed by using Microsoft Office Excel 2007 software.

**Results and discussions**

*The chlorophyll content*

The analysis of variance on chlorophyll content data revealed significant difference among super absorbent polymer and water treatments at 1% probability level (Tab. 1). The regression equation showing relationships between chlorophyll content and the amount of water and super absorbent polymer was determined as the following order:

Chlorophyll content = -10.96+70.68I-37.9I2+7.85P-0.037P3-8.5IP

This equation is polynomial in which I show irrigation and P shows the super absorbent polymer amount. Chlorophyll content in plants is an important factor in determining photosynthetic capacity. Decreasing chlorophyll content during drought stress depends on duration and severity of water stress. By using the above mentioned equation, one can found the appropriate amount of polymer corresponding to each water treatment stress in order to estimate the best level of chlorophyll that need to stop the significant reduction of photosynthesis. The results of this study showed that the chlorophyll content increased as amount of polymer increased, and in the severe stresses in which no polymer exist with the irrigation of 25% of the field capacity, the chlorophyll of the leaves showed severe reduction. With the use of the polymer treatment (1.5 g per 1 kg of soil) the impact of water stress on the amount of chlorophyll has modified to some extent, in other words, in more moderate stresses the amount of chlorophyll has slightly increased. Also the results showed that the impact of polymer is less visible in high amounts of irrigation treatments (Fig. 1). Drought stress results in the decrease of the amount of chlorophyll and protein, and also results in the cell membrane damage and lack of balance between nutrient substances in 'SH222' cultivar of sunflower. Thus, it results in the aging of cells and un matured seeds (Santos *et al.*, 2002). Even, low water deficit stress (FC=15%) resulted in significant decrease in the chlorophyll content of wheat's leaves (Ahmadi and Baker, 2000).

*Seed yield*

The analysis variance on seed yield data showed that the effect of different amounts of polymer and different amounts of irrigation on this character is significant at 1% probability level. But the interaction effect of the two mentioned factors on seed yield did not turned out significant (Tab. 1). The results showed that the highest amount of seed yield was achieved form high amounts of polymer (2.25, 3 g polymer per 1 kg soil) and also under the condition of no drought stress but the lowest amount of performance was related to the treatment of severe drought stress without using polymer (Fig. 1). According to the regression analysis, the follow equation was fitted among seed yield as response variable and polymer as well as water amount as predictor variables:

Yield = -7.64+43.73I+0.35P+3.37P2-0.981P3-2.79I2P

The equation shows the relation between the amounts of the used polymer at different levels of irrigation and the seed yield. Nezami *et al.* (2008) reported that the dry matter of sunflower increased with the increase of irrigation and the maximum dry matter earned from well watered condition. Allahdadi *et al.* (2007) reported that the use of polymer under drought stress resulted in general higher performance of soybean. They observed that some soybean yield components and yield of soybean was linearly increased by increasing the amount of polymer in drought conditions which is in accordance with our results in this study. The application of the super absorbent polymer in soil resulted in the increase of sugar beets budding roots growth, and roots performance (Dexter and Miyamoto, 1995).

*Number of leaves per plant*

The analysis of variance on the number of leaf data showed that this characteristic is significantly affected by the amounts of polymer and water. The regression equation is:

NL = 2.63+41.04I-23.45I2+2.82P-1.50IP-0.062I2P3

There was a decrease in the number of leaves in low amounts of polymer and water deficit combination. In low amounts of polymer with severe drought stress combination it was observed the old leaves of the plant were dried and the shrubs were weaken and lost their growth power. But in high amounts of polymer and good irrigation, the soil of pots were able to provide enough water for the growth of the plants. Long periods of severe soil water deficit at any growth period cause leaf-drying with subsequent reduction in seed yield. As a result, long leaf area durability (LAD) in high amounts of polymer and good irrigation resulted in the opening of stomas for long time, subsequently good $CO_2$ fixation that resulted in the increase of the dry matter of the plant. In sunflower the leaves are the primary source of the production of photosynthetic substances that needed for the filling of the seeds. Any stress resulting in decrease of photosynthetic substances, will result in the decrease of performance.

*Water Use Efficiency (WUE)*

The Tab. 1 describe the analysis of variance for efficiency of water usage and there was a significant difference between the treatments of super absorbent polymer and different amounts of irrigation. Also the interaction between amounts of polymer and irrigation levels on this characteristic was significant, too. The high amounts of

Tab. 1. Analysis of variance for the effect of drought stress and super absorbent polymer on water use efficiency (WUE), yield and some morphological traits of sunflower (*Helianthus annuus* L.) in greenhouse condition

| MS | | | | | df | S.O.V |
|---|---|---|---|---|---|---|
| WUE | YP | W100A | NL | Chl | | |
| 1707.49$^{ns}$ | 25.94$^{**}$ | 0.069$^{ns}$ | 0.86$^{ns}$ | 3.45$^{ns}$ | 2 | Replication |
| 2392415.79$^{**}$ | 1470.10$^{**}$ | 15.71$^{**}$ | 216.6$^{**}$ | 404.58$^{**}$ | 2 | Irrigation |
| 3422089.75$^{**}$ | 2930.40$^{**}$ | 31.41$^{**}$ | 410.7$^{**}$ | 753.003$^{**}$ | 1 | Linear(L) |
| 1362741.83$^{**}$ | 9.80$^{ns}$ | 0.013$^{ns}$ | 22.5$^{**}$ | 56.169$^{**}$ | 1 | Quadratic (Q) |
| 292663.32$^{**}$ | 79.27$^{**}$ | 3.26$^{**}$ | 47.27$^{**}$ | 158.01$^{**}$ | 4 | Polymer |
| 1081160.16$^{**}$ | 256.37$^{**}$ | 11.39$^{**}$ | 184.9$^{**}$ | 544.644$^{**}$ | 1 | Linear(L) |
| 391.56$^{ns}$ | 18.51$^{*}$ | 0.27$^{ns}$ | 1.34$^{ns}$ | 0.167$^{ns}$ | 1 | Quadratic (Q) |
| 88802.35$^{**}$ | 22.30$^{**}$ | 1.38$^{*}$ | 1.87$^{ns}$ | 78.96$^{**}$ | 1 | Cubic(C) |
| 299.21$^{ns}$ | 19.91$^{*}$ | 0.000022$^{ns}$ | 0.99$^{ns}$ | 8.29$^{ns}$ | 1 | Quadratic (Qt) |
| 76341.40$^{**}$ | 5.40$^{ns}$ | 0.91$^{**}$ | 2.37$^{*}$ | 23.36$^{**}$ | 8 | Irrigation × Polymer |
| 25738.80$^{*}$ | 9.20$^{ns}$ | 1.39$^{*}$ | 8.81$^{**}$ | 152.32$^{**}$ | 1 | $L_I \times L_P$ |
| 2354.58$^{ns}$ | 0.66$^{ns}$ | 1.02$^{*}$ | 0.58$^{ns}$ | 9.73$^{ns}$ | 1 | $L_I \times Q_P$ |
| 1969.05$^{ns}$ | 0.81$^{ns}$ | 1.43$^{*}$ | 0.60$^{ns}$ | 0.17$^{ns}$ | 1 | $L_I \times C_P$ |
| 2921.63$^{ns}$ | 0.0095$^{ns}$ | 1.69$^{*}$ | 0.46$^{ns}$ | 1.46$^{ns}$ | 1 | $L_I \times Qt_P$ |
| 525563.86$^{**}$ | 19.53$^{*}$ | 0.02$^{ns}$ | 0.45$^{ns}$ | 2.88$^{ns}$ | 1 | $Q_I \times L_P$ |
| 1908.88$^{ns}$ | 2.95$^{ns}$ | 1.70$^{*}$ | 2.48$^{ns}$ | 0.590$^{ns}$ | 1 | $Q_I \times Q_P$ |
| 46582.48$^{**}$ | 1.72$^{ns}$ | 0.01$^{ns}$ | 4.35$^{*}$ | 4.802$^{ns}$ | 1 | $Q_I \times C_P$ |
| 3691.89$^{ns}$ | 8.28$^{ns}$ | 0.04$^{ns}$ | 1.26$^{ns}$ | 14.98$^{ns}$ | 1 | $Q_I \times Qt_P$ |

df: degree of freedom; MS: mean of square; Chl: chlorophyll content; W100A: weight of 100 achens; NL: number of leaves per plant; YP: yield of plant; WUE: water use efficiency; *,** significant at 0.05 and 0.01 probability levels, respectively; ns: non significant

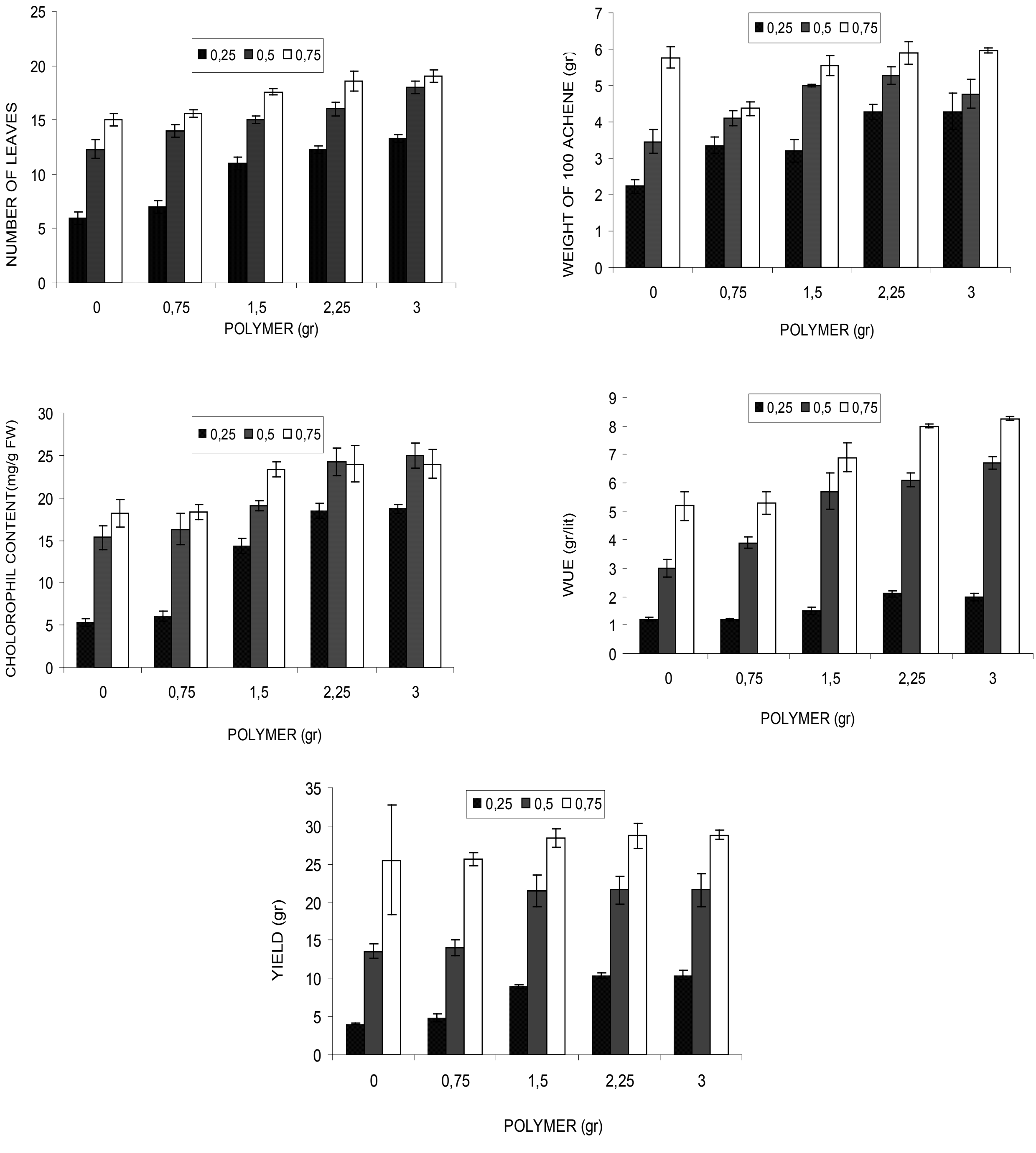


Fig. 1. The effect of water stress and polymer (A200) on water use efficiency (WUE), yield and some morphological traits of sunflower under greenhouse condition

polymer contributed to the highest usage of water efficiency, the lowest efficiency of water use was related to the treatment of severe drought stress without using polymer in which the addition of polymer increased water use efficiency. Polymer stored the water and released it on the right time which resulted in saving of the used water, also resulted in the improvement of physical conditions and probably proper access to nutrient elements and as a result the performance of dry matter has increased. In order to obtain precise results the regression analysis on interactive effects was carried out and the equation related to this characteristic was written with taking the significant effects into consideration:

$$WUE = -353.43+1904.26I-679.63I2-598.68P-3.56P3 +3568.75IP-3533.12I2P+8.63I2P3$$

This equation shows the relation between the amount of polymer usage at different irrigation intervals and water usage. This equation is polynomial and the amount of the used water can be obtained through putting different amounts of polymer and so stop unreasonable use of water. The high amount of WUE for high amounts of polymer can be related to the role of polymer in the increase of retaining capacity of moisture and the used water in soil. The performance of the dry matter and the efficiency of water use in grass sorghum were affected by the amount of polymer. By increasing polymer amount, the performance of dry matter and water use efficiency were increased (Karimi and Naderi, 2007). The application of polymers results in the absorption and retaining of the irrigated water that will be released little by little, which increased the time that the plant has access to moisture and so irrigation efficiency increased (Hutterman *et al.*, 1990). Our results were confirmed with those obtained. The efficiency of water usage did not have a significant difference in mild drought stress but, significantly decreased in severe conditions of drought stress. This condition was observed both for the plants grown in environment with normal $CO_2$ density and $CO_2$ densities with higher than normal environment (Tezara *et al.*, 2002). The application of polymer in soil increased the amount of absorbed water in red bean and silken oak. This was because of the increase in the amount of leaves transpiration and the increase in $CO_2$ absorption (Specht and Harvey-Jones, 2000).

*Weight of 100 seeds*

The results of the experiment showed that the effect of different amounts of irrigation and the application of polymer on this characteristic was significant in 1% probability level and even the interactive effect of the two above factors was also significant (Tab. 1). In this experiment the lowest amount of seed index was related to standard plant having no polymer under severe drought stress and the highest weight of 100 seeds was for 2.25 and 3 g polymer per 1 kg of soil with no drought stress. The regression equation is:

W100A = 0.71+6.35I+1.72P-0.086P3-7.092IP+
6.27IP2-2.47I P3

The weight of 100 seeds depends on length and rate of seed filling period. Reduction of moisture during the growth period especially in the genesis stage results in low photosynthesis rate and the length of seed filling period. Thus a significant reduction happens in the weight of 100 seeds in such situation. But the application of polymer provided moisture for the soil which in turn increased the rate and length of this period. The effect of the amounts of polymer on the weight of 100 soybean seeds was statistically significant and by application of polymer, the weight of 100 soybeans increased linearly (Allahdadi *et al.*, 2007). Our results were confirmed with those obtained. The weight of 100 seeds of sunflower in drought stress show significant reduction. In a research work, when the moisture of soil decreased from 100% to 30% of field capacity the weight of 100 seeds showed a decrease of 32.7% (Nezami *et al.*, 2008). Drought stress results in the closure of the foramen and decrease of leaf area index and photosynthesis. It also reduces the filling period. This will lead to weak transfer of the amounts of carbohydrates to the seed (Bieloria and Hopmans, 1975). Drought stress results in significant reduction of 37% in the weight of 100 seeds in comparison with standard plants (Igbal *et al.*, 2005).

Based on the results of this study, it can be concluded that the application of polymer can increase irrigation intervals for sunflower, thus it can be planted in regions suffering limited sources of water and irrigation.

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