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EFFECTS OF SUPERABSORBENT AND IRRIGATION REGIME ON SEEDLING GROWTH CHARACTERISTICS OF BARLEY (*HORDEUM VULGARE* L.)

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ABSTRACT. Greenhouse experiment was carried out to study the effects of superabsorbent and water deficit stress on seedling growth of barley (*Hordeum vulgare* L.) in Urmia University of Iran. Three amounts of superabsorbent polymer (0 (S_1), 2 (S_2) and 4 g (S_3) were mixed with 500 g soil before sowing, and four levels of irrigation regimes (irrigation at 20 (I_1), 40 (I_2), 60 (I_3) and 80% (I_3) field capacity) were set as treatments. The root length, root volume, root and shoot dry weight, plant height, leaf length, leaf width, SPAD and root-shoot ratio were affected by treatments. Means comparisons indicated that the highest root length (19 cm) observed in the I_4 irrigation regime and the lowest of it (16.18 cm) obtained in I_1 condition. Barley plants that received 4 g and no superabsorbent had the utmost (1.13 cm) and lowest (0.54 cm) root volume, respectively. Whereas plant situated in I_4 and I_1 irrigation regimes produced greatest and smallest amount amount of shoot dry weight and SPAD. The maximum (12.83 cm) and minimum (8.33 cm) leaf length was obtained from S_3I_3 and S_1I_1 condition, respectively. Generally, the results showed the most of measured barley seedling traits in irrigation at 40 % field capacity (I_2) were the equal with I_3 and I_4 irrigation regimes treatments, which indicated the resistance of barley seedling to the water deficit stress. Also, we found that the improving of root dry weight and root volume of barley seedling along with increasing in the superabsorbent application.

Key words: Barley; Irrigation regimes; Root; Seedling; Superabsorbent.

INTRODUCTION

Germination and seedling growth declined with many abiotic factors such as salt and drought stress that are perhaps two of the most important abiotic stresses that limit number of seedling and seedling growth (Ashraf *et al.,* 1992; Almansouri *et al.,* 2001; Kaya *et al.,* 2006; Atak *et al.,* 2006). There are many studies such as the selecting

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plant species or the seed treatments that are helpful for alleviating the negative effects of drought and salt on plants (Ashraf *et al.,* 1992; Almansouri *et al.,* 2001; Okçu *et al.,* 2005; Kaya *et al.,* 2006; Iqbal and Ashraf, 2007). Previous studies have shown that success in seed emergence is achieved when seed could prevail over the adverse environmental conditions and show appropriate reaction (Guillen-Portal *et al.,* 2006; Waldron *et al.,* 2006). Certainly this reaction to the environmental conditions will be varied (Hakizimana *et al.,* 2000). Therefore, stand establishment and primary growth are considered as a positive factor on crop yield (Ludlow and Muchow, 1990). This preference particularly under drought stress and low temperature is more effective than other conditions (Willenborg *et al.,* 2005). Also some studies have shown that drought stress has caused decreases in chlorophyll content when compared to the control (Nazarli and Zardashti, 2010; Manivannan *et al*., 2008).

For an increased crop production in dry land environments, a greater percentage of the precipitation must be stored in soil and used more efficiently. Superabsorbent hydrogels are hydrophilic networks with a high capacity of water uptake. Superabsorbents have received prominent attention in the last decade due to their numerous applications in many areas. Superabsorbent 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 (Johnson and Leah, 1990). Superabsorbent polymer can hold 400-1500 g of water per dry gram of hydrogel (Woodhouse and Johnson, 1991; Bowman and Evans, 1991). Moreover, the initial humidity after irrigation is substantially higher for a soil where the hydrogel has been added. This allows the irrigated water not to be wasted after irrigation, but stored in the soil and released under a mechanism controlled by diffusion and driven by roots absorption and evaporation.

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). There are intensive investigations about using superabsorbent as water managing materials in agriculture and horticulture, and encouraging results have been achieved (Zhang *et al.,* 2006).

There is a little research about the study effects of superabsorbent on seedling growth of barley under drought stress. Therefore, the major objective of this study was to examine the responses in some morphological characteristics of barley seedling to application of superabsorbent and water deficit stress.

MATERIALS AND METHODS

The experiment was conducted, under greenhouse conditions, in the University of Urmia (37°32′ N and 45°41′ E) (Iran) during 2011. Daily and night temperatures were maintained at 20 and 15°C, respectively. In this research, a factorial experimental based on completely randomized design was used in three replicates. Three amounts of superabsorbent polymer [0 (S_1), 2(S_2) and 4 (S_3) g mixed with 500 g soil] and four irrigation treatments [irrigation at 20 (I_1), 40 (I_2), 60 (I_3) and 80% (I_4) of field capacity] were set as experimental treatments. In each superabsorbent and water treatment, each replication was represented by five plants. Five barley seeds (*Hordeum vulgare* cv. Valfajer) were sown in each PVC pots (10 cm diameter × 20cm length) were filled with a 500 g mixture of sand , soil and organic dry matter (2:1:1). Before seeds sowing superabsorbent polymer was added to soil in 7 cm depth in each pot. The used superabsorbent 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.

All pots were watered at the field capacity until the emergence of the first leaf. At this growing stage, water was withheld to induce water deficit as irrigation regimes treatments. Soil moisture content was kept at needs amount of field capacity during the period of the experiment by weighing the pots daily and adding by distilled water to obtain the needs wet weight. The measurement of soil humidity was done by weighing pot (Sahnoune *et al.,* 2004). The soil water measurements were done on three randomly pot for each experimental treatment.

After germination, plants were thinned to one plant per pot, and after 40 days from sowing plants were harvested. Plant height, leaf width and length were measured with a ruler with a precision of 1 mm. In order to eliminate the residue, roots were washed by water. The length of roots (in cm), was measured. Roots volume was evaluated according to the method of Musick *et al.* (1965) by immersion in a graduate test tube and measure of the displaced water volume. Roots and shoots were separated gently and were dried at 75°C for 48 hours and weighed to determine the average root and shoot dry weights (Al-Niemi and Dohuki, 2010). Root to shoot length ratio were estimated by dividing root length to shoot length.

Chlorophyll concentration was assessed using a chlorophyll meter (SPAD CCM_200, USA), 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 data were analyzed by analysis of variance using the general linear model procedure in The SAS (SAS Institute, 2003). Means were separated using Fisher's protected Duncan's Multiple Range (DMR) test at the 95% level of probability.

RESULTS AND DISCUSSION

Analysis showed that root length was influenced by irrigation regimes (*Table 1*). The highest (19 cm) and lowest (16.18 cm) root length were observed in I_4 and I_1 irrigation regimes, respectively (*Table 2*). Similar results were reported by

Kaydan and Yagmur (2008) that water deficient conditions decreased seedling growth with higher negative effects such as lower root and shoot length. Also, Duman (2006) declared that water deficit stress decrease root length of lettuce seedling. Root length is an important trait against drought stress in plant varieties; in general, variety with longer root growth has resistant ability for drought (Leishman and Westoby, 1994).

Superabsorbent had significant effect on root volume (*Table 1*). Increasing superabsorbent amount has resulted in the increase of root volume, so the highest (1.13 cm^3) and the lowest (0.54 cm^3) values were observed in 4 g and no superabsorbent application, respectively (*Fig. 1*). Roots play an important role in plant survival during periods of drought and also drought resistance is characterized by an extensive root growth and small reduction of shoot growth in drought stressed conditions (Hoogenboom *et al.,* 1987).

The root dry weight was affected by the interaction of superabsorbent and irrigation regimes (*Table 1*). The highest (0.32 g) and lowest (0.13 g) root dry weight were obtained in the S_2I_3 and S_1I_4 condition, respectively (*Table 3*). Application of 2 g superabsorbent under irrigation at 60% field capacity (I_3), lead to increase 59.37% root dry weight as compared to the control treatment under I_4 condition (*Table 3*).

Shoot dry weight was significantly affected by irrigation regimes (*Table 1*). Irrigation at 80% field capacity (I_4) and irrigation at 20% field capacity (I_1) produced the maximum (0.36 g) and minimum (0.27 g) shoot dry weight (*Table 2*). Camacho and Caraballo (1994) reported that root dry weight was identified as the major criterion for selection of maize genotypes under drought conditions. Kaydan and Yagmur (2008) found that water deficient conditions caused a reduction in shoot and root dry materials of triticale seedling. Similarly, Baalbaki *et al.* (1999) reported that root and shoot weights of all wheat cultivars declined when osmotic potential was decreased, but the extent of reduction in root growth was less than that for shoots.

Significant differences were observed among water deficit treatments with respect to plant height (*Table 1*). While increasing the stress levels, plant height was significantly reduced. So, the highest (9.5 cm) and lowest (8.02 cm) plant height was obtained from the I_3 and I_1 irrigation regimes, respectively (*Table 2*). There was an decrease plant height approximately 15.57% with irrigation at 20% field capacity (I_3) compared to the application of irrigation at 60% field capacity (I_1) (*Table 2*). 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 Schubert, 1998). Nazarli and Zardashti (2010) declared that increasing irrigation interval has resulted in the decrease of plant height.

Table 1 - Analysis of variance of some characteristics of barley seedling (*Hordeum vulgare* L.) affected by irrigation regimes under different amount of superabsorbent.

Source of variation	df	Mean square								
		Root length	Root volume	Root dry weight	Shoot dry weight	Plant height	Leaf length	Leaf width	SPAD	Root-Shoot ratio
Superabsorbent (S)	2	1.01 n.s	1.094 **	0.0023 n.s	0.0005 n.s	2.69 n.s	5.93 n.s	0.14 n.s	0.50 n.s	0.19 n.s
Irrigation (I)	3	14.71 **	0.046 n.s	0.0108 *	0.0134 **	4.09 *	1.55 n.s	1.96 *	1.07 *	0.92 **
S× I	6	1.47 n.s	0.070 n.s	0.0106 **	0.0053 n.s	0.43 n.s	6.73 *	0.47 n.s	0.03 n.s	0.06 n.s
Error	24	1.53	0.049	0.0027	0.0028	0.90	2.33	0.48	0.23	0.07
CV (%)		7.24	25.23	21.72	16.02	10.55	14.05	11.92	23.23	14.14

ns, * and ** are non significant; significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

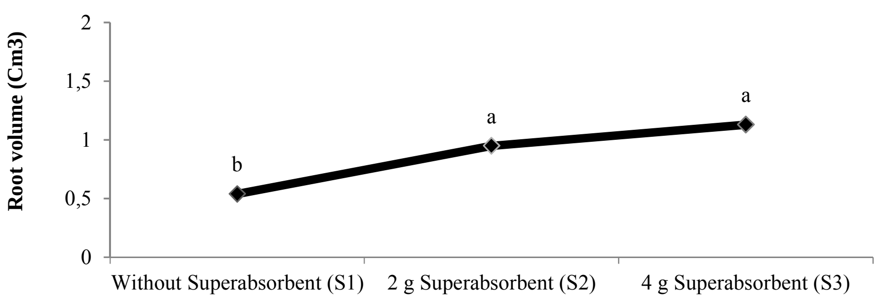

Figure 1 - Mean comparisons of root volume of barley seedling (*Hordeum vulgare* L.) affected by superabsorbent. The means followed by same letter are not significant at *P*≤0.05 (DMR Test).

Table 2 - Mean comparisons of some characteristics of barley seedling (*Hordeum vulgare* L.) affected by irrigation regimes.

Irrigation regimes	Traits					
	Root length (cm)	Shoot dry weight (g)	Plant height (cm)	Leaf width (mm)	SPAD	Root-Shoot ratio
I_1	19 ^{b}	0.27 ^{b}	8.02 ^{b}	5.17 ^{b}	1.64 ^{b}	2.41 ^{a}
I_2	16.55 ^{b}	0.35 ^{a}	9.31 ^{a}	6 ^{a}	2.03 ^{ab}	1.78 ^{b}
I_3	16.68 ^{b}	0.32 ^{a}	9.50 ^{a}	6.22 ^{a}	2.21 ^{a}	1.77 ^{b}
I_4	16.18 ^{b}	0.36 ^{a}	9.25 ^{a}	6.05 ^{a}	2.46 ^{a}	1.76 ^{b}

Within columns, means followed by same letter are not significantly at *P*≤0.05 (DMR Test); irrigation at 20% field capacity (I_1); irrigation at 40% field capacity (I_2); irrigation at 60% field capacity (I_3); irrigation at 80% field capacity (I_4).

Table 3 - Means comparison of interaction between irrigation regimes and superabsorbent application on root dry weight and leaf length of barley seedling (*Hordeum vulgare* L.).

Superabsorbent	Irrigation regimes	Traits	
		Root dry weight (g)	Leaf length (cm)
Without Superabsorbent (S_1)	I_1	0.24 ^{ab}	8.83 ^{d}
	I_2	0.27 ^{ab}	10.83 ^{abcd}
	I_3	0.25 ^{ab}	11.00 ^{abcd}
	I_4	0.13 ^{c}	9.60 ^{bcd}
2 g Superabsorbent (S_2)	I_1	0.27 ^{ab}	10.66 ^{abcd}
	I_2	0.18 ^{bc}	11.26 ^{abcd}
	I_3	0.32 ^{a}	9.86 ^{abcd}
	I_4	0.18 ^{bc}	9.10 ^{cd}
4 g Superabsorbent (S_3)	I_1	0.28 ^{ab}	12.16 ^{ab}
	I_2	0.30 ^{a}	12.00 ^{abc}
	I_3	0.19 ^{bc}	12.83 ^{a}
	I_4	0.25 ^{ab}	12.30 ^{ab}

Within columns, means followed by same letter are not significantly at *P*≤0.05 (DMR Test); irrigation at 20% field capacity (I_1); irrigation at 40% field capacity (I_2); irrigation at 60% field capacity (I_3); irrigation at 80% field capacity (I_4).

The interaction effect of superabsorbent and irrigation regimes on leaf length was significant (*Table 1*). The highest rate of leaf length (12.83 cm) was obtained from S_3I_3 treatment. Whereas, the lowest rate of leaf length (13.33%) was observed in S_1I_1 treatment (*Table 3*).

Irrigation regimes had a significant effect on leaf width (*Table 1*). The highest (6.22 mm) and lowest (5.17 mm) leaf width was observed in I_3 and I_1 irrigation regimes, respectively (*Table 2*). Nezami *et al.* (2008) reported that the decrease of soil water content to 60 and 30% field capacity caused a 20 and 46%

reduction in leaf growth as compared to the control, respectively.

The effect of irrigation regimes on SPAD reading was significant (*Table 1*). So, the highest (2.46) and lowest (1.64) SPAD reading was obtained from the I_4 and I_1 irrigation regimes, respectively (*Table 2*). There was an increase in SPAD reading approximately 50% with irrigation at 80% field capacity (I_4) compared to the application of irrigation at 20% field capacity (I_1) (*Table 2*). There was an inverse proportional relationship between increasing the irrigation interval and contents of chlorophyll from leaves. Manivannan *et al*. (2008) and Nazarli and Zardashti (2010) reported that drought stress has caused decreases in chlorophyll content of sunflower when compared to the control. 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 II, 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; Zhang *et al*., 2007)

There was significant difference in root-shoot ratio as revealed by irrigation regimes (*Table 1*). Irrigation at 20% field capacity (I_1) yielded higher root-shoot ratio in comparison with the other irrigation regimes (*Table 2*). There was a decrease in root-shoot ratio with Irrigation at 80% field capacity (I_4), by an average of 26.97 % in compared with the Irrigation at 20% field capacity (I_1) (*Table 2*). Baalbaki *et al.* (1999) reported that root and shoot weights of all wheat cultivars declined when osmotic potential was decreased, but the extent of reduction in root growth was less than that for shoots. Root to shoot length ratio increased with increasing in drought stress level (Bajji *et al.,* 2000). Okçu *et al.* (2005) reported that water stresses depressed the shoot growths of the cultivars rather than their root growths in pea. Kaydan and Yagmur (2008) found that water deficient conditions caused an increase in root-shoot ratio of triticale seedling. Moreover, this result showed that root-shoot ratio was increased with the stress conditions compared to well irrigation condition.

CONCLUSION

Barley plants that irrigated at 40% field capacity (I_2) had the same root length, shoot dry weight, plant height, leaf width and SPAD that obtained from plant irrigated at 60 and 80% field capacity. In fact these results showed that the barley seedling resistance to water deficit stress. Seedlings from high amount application of superabsorbent had greater root dry weight and root volume than those from low amount application of superabsorbent.

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