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ORIGINAL ARTICLE

Water-Super Absorbent Polymer Increases Biomass Production Under Drought in Safflower, Alfalfa, and Common Vetch

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Abstract

Many countries located in arid and semiarid areas suffer from drought. Water-super absorbent polymers (SAP) are synthetic products used for water retention in soil. The goal of the study was to determine the water-superabsorbent polymer effect on safflower, alfalfa, and common vetch biomass production and physiological traits under drought. This research was carried out as a factorial experiment based on a completely randomized design. Factors included water-super absorbent polymer amount and drought. Plant species included safflower, alfalfa, and common vetch. Water-superabsorbent polymer levels contained S1=0, S2=84, S3=168, and S4=336 kg per ha of soil, and drought levels included irrigation intervals of 6 (non-drought, I6) and 12 (drought, I12) days. Results showed that in safflower, I12 reduced seedling fresh weight and leaf chlorophyll content. In alfalfa, I12 reduced seedling fresh weight, seedling dry weight, and leaf chlorophyll content. In common vetch, I12 reduced leaf relative water content and leaf chlorophyll content. With the increase in the use of SAP, the leaf fresh weight, stem fresh weight, seedling fresh weight, leaf dry weight, stem dry weight, seedling dry weight, plant height, and leaf relative water content increased in all three plants: safflower, alfalfa, and common vetch. The results showed that with increasing the water-superabsorbent polymer rate, the seedling dry weight in safflower increased more than alfalfa and common vetch. Overall, application of SAP can increase the growth characteristics of the plant and can be used as one of the agronomic operations.
Keywords: Chlorophyll, Cool-season plants, Hydrogel, Irrigation interval, Water deficit stress.

1. Introduction

Environmental stresses result in a decrease in crop yields. They include two kinds of stresses: biotic and abiotic. Biotic stresses include insects, weeds, and fungal diseases, which are responsible for 20 percent loss of the potential yield. Abiotic stresses such as heavy rainfall, frost, drought, flooding, salinity, and nutrient imbalances may affect plant growth conditions by little or gradual changes (Hans et al., 1996). In terms of agriculture, drought is the lack of accessible water including precipitation and soil moisture storage capacity during crop growing season leading to crop yield reduction (Ober et al., 2005). Super absorbent polymer (SAP) is a dry polymeric matter that can absorb the aqueous solution to many times of its weight and with the ability to maintain it and then, slowly releasing it to their surroundings (Sannino et al., 2004). Superabsorbent polymers as reservoirs of water applied in agriculture, since when mixed into the soil; they can hold a lot of water and nutrients (Huttermann et al., 2006). The research showed that applying these SAP did not make any problem for human beings, plants, soil, and the environment. These materials absorbed about 200 to 500 times as much water as their weight and after 5 to 12 years were slowly destroyed because of microbial decomposition or sunray effect and were decomposed into the water, carbon dioxide, and ammonium (Poresmaiil et al., 2007).

Afsharmanesh (2009) reported that drought reduced fresh and dry weight in sorghum and alfalfa. Gajurel et al. (2024) reported that drought reduced plant biomass in peanut. Composite hydrogel based on biochar increased seedling fresh weight in tobacco under drought, but no significant difference was observed in dry weight. The hydrogel improved the leaf relative water content of seedling and reduced the adverse effects of drought on tobacco seedlings (Jia et al., 2024). In a research, the effect of two commercial hydrogels (Polyter and Stockosorb) on the above and underground growth of *Picea abies* seedlings during a 5-week drought period was studied. If plants were grown in soil amended with polyether, plant biomass was higher compared to Stockosorb treatment and control. Better performance of polyter-amended seedlings was due to slow release of water from the hydrogel, while Stockosorb released excess soil water content prematurely (Biehl et al., 2023). A greenhouse experiment was conducted using four hydrogel concentrations of 0, 0.25, 0.5, and 1% (w/w) on the growth characteristics of *Zea mays*. It was observed that with increasing use of hydrogel, plant height, fresh and dry weight and stem diameter increased (Albalasmeh et al., 2022). In research, the effect of superabsorbent polymer (SAP) and also a mixture of SAP and plantain bark biochar as a soil conditioner was investigated on the growth and yield of potato (*Solanum tuberosum* L.) and spinach (*Spinacia oleracea* L.). Hydrogel–biochar mix soil amendment increased spinach yield (Dhiman et al., 2021).

In the study of the effect of the type and amount of hydrogel (0.05, 0.1, 0.2, 0.4 weight percent of hydrogel in soil) on the growth characteristics of fenugreek, it was observed that the highest concentration (0.4 percent) of hydrogen had the highest plant height, root length, root dry weight and shoot dry weight (Ahmed, 2024). Hydrogel affects soil bulk density, available soil water, soil electrical conductivity, cation exchange capacity, and crop performance in arid and semi-arid regions (Piccoli et al., 2024). In the study of the effect of two types of full and limited irrigation regimes and two types of water-superabsorbent on red cabbage growth, it was observed that the use of water-superabsorbent increased the soil moisture content, increased the water productivity of the crop and reduced the water requirement of the plant (Kishor et al., 2024). The study of the effect of water-superabsorbent polymer and sewage on the emergence of the cowpea seedling showed that the application of water-superabsorbent polymer, in addition to having a positive effect on the emergence of the plant, acts as a vital source of moisture for the plant (Araújo et al., 2024). Hydrogel maintains soil moisture, reduces evaporation from the soil surface and provides moisture for plant roots (Reimov and Auezov, 2024). In the study of the effect of bio-based hydrogel as an alternative growth medium for soil, it was observed that the growth of Ipomea aquatica was better in hydrogel than in soil (Palanivelu et al., 2023).

Sadeghi et al. (2007) reported that irrigation and super absorbent had a significant effect on the dry weight of foxtail millet. They observed that drought reduced seedling dry weight, but amending soil with super absorbent polymer increased seedling dry weight. In *Cuminum cyminum,* applying potassic zeolite led to increased seedling emergence percentage (Ahmadi et al., 2013). Application of zeolite under drought conditions led to an increase in the emergence percentage, average daily emergence, and seedling establishment in canola (Armandpisheh et al., 2010). Drought reduced chlorophyll content and photosynthesis rate in six canola genotypes, but the application of superabsorbent polymer increased leaf chlorophyll content by absorbing and maintaining water (Tohidi Moghaddam et al., 2009). Drought decreased the leaf relative water content and chlorophyll concentration of peanut (Meher Shivakrishna et al., 2024).

Safflower (*Carthamus tinctorius* L.), alfalfa (*Medicago sativa* L.), and common vetch (*Vicia sativa* L.) are cultivated in arid and semiarid areas of the world. One of the problems of plants is the improper establishment of plants in the field. This problem is especially seen in the case of small seeds. Drought is one of the factors that disrupts the germination and establishment of seedlings. Therefore, in this research, water-superabsorbent was used to increase the establishment and growth of plant seedlings, especially small seeded plants. Little information is available to increase seedling establishment and growth under drought. So, the experiment aimed at determining the water-superabsorbent polymer effect on biomass production and physiological traits in safflower, alfalfa, and common vetch under drought at the seedling establishment stage.

2. Materials and Methods

A pot experiment was conducted at the College of Agricultural Science and Engineering, Razi University in 2015. This research was carried out as a factorial experiment based on a completely randomized design. Factors included water-super absorbent polymer, and drought. Plant species included safflower (*Carthamus tinctorius* L.), alfalfa (*Medicago sativa*), and common vetch (*Vicia sativa*). Water-superabsorbent polymer levels contained S1=0, S2=84, S3=168, and S4=336 kg per ha, and drought levels included irrigation intervals of 6 (non-drought, I6) and 12 (drought, I12) days. To calculate the rate of water-superabsorbent polymer application per hectare, it was done as follows: first, the rate of water-superabsorbent polymer application in the pot was calculated as grams per kilogram of soil. Then, to convert it to kilograms per hectare, the soil bulk density of the field (1.4 grams per cubic centimeter) and the area of one hectare were used. Also, the depth of the field soil was considered to be 30 cm. Since all the plants were supposed to be compared in terms of irrigation interval, their irrigation interval was considered the same. The irrigation interval was determined based on a preliminary test. In this way, before conducting the experiment, one pot was selected like the test pots and placed in the environmental conditions of the experiment, and then the optimal irrigation interval, i.e., 6 days, was determined based on the appearance of the soil that needed water. A double irrigation interval, i.e., 12 days, was considered as drought stress.

Ten seeds of the safflower, alfalfa and common vetch were sown in pots with a diameter of 7 cm and a depth of 7.5 cm. The pots were filled with field soil. The soil inside the pots was uniform and free of foreign materials such as stones and plant remains. The soil texture and pH were clayey silt and 7.2, respectively. The electrical conductivity (dS/m) of soil and water were 1.6 and 0.6, respectively. Water-super absorbent polymer was planted around seeds. Water-superabsorbent polymer A200 with moisture absorption capacity (g/g) of 220 was used in this research (a product of Iran's Polymer and Petrochemical Research Institute). After absorbing water, the diameter of the superabsorbent particles increases and all the stored water is available to the plant. For this reason, it is called hydrogel. This material can increase the interval of irrigation and reduce the drought stress effects on the plant. This material can give it back at the same speed as it absorbs water and return to its original form. The frequency of water absorption and drying of the hydrogel is repeatable and this material is able to maintain moisture in the long term (Karimi et al. 2009). The experiment lasted three weeks. Leaf fresh weight, stem fresh weight, seedling fresh weight, leaf dry weight, stem dry weight, seedling dry weight, plant height, leaf relative water content, and chlorophyll index were measured. Plant height from the ground to the last leaf was measured by the millimeter rule. To measure the fresh and dry weight of leaf, stem, and seedling, five plants per pot were picked up and transported to the laboratory. In the laboratory, leaves and stems were separated then immediately fresh weight of stems, leaves, and the total was weighed with digital scale with milligram accuracy. Leaf and stem samples were kept in an oven at 75 °C for 72 hours. Then dried samples were weighed.

To measure leaf relative water content, at first, fresh leaves were weighed then leaves were put into distilled water for 24 hours to measure turgid weight. Finally, leaves dried in an oven at 85 °C for 24 hours. Leaf relative water content (RWC) was calculated using the following equation (Eq (1), Turner and Kramer, 1980):

$$\text{RWC (\%)} = (\text{Wet weight} - \text{Dry weight}) / (\text{Turgid weight} - \text{Dry weight}) \times 100 \quad (1)$$

The last developed leaf of the plant was used to measure the relative water content of the leaf and leaf chlorophyll. Leaf sampling was done at noon with a razor. Leaf chlorophyll content was measured using a chlorophyll meter (model Minolta- 502).

Outlier data were detected using Minitab software and removed if necessary considering statistical principles. Before analyzing the data, the normality of the data was evaluated using the Minitab software. First, the data were subjected to variance analysis. Data were analyzed using MSTATC and SAS software. Duncan's multiple range test was used to compare means at the probability level of the 5%.

3. Results and Discussion

3.1. Leaf fresh weight

Variance analysis of the data showed that irrigation had a significant effect on leaf fresh weight in safflower, but its effect on stem fresh weight in alfalfa and common vetch was not significant (Tables 1-3). The mean comparison showed that the 12-day irrigation interval (I12) decreased the leaf fresh weight of safflower (Table 4). Water-superabsorbent polymer (SAP) had a significant effect on the leaf fresh weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the leaf fresh weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the fresh weight in alfalfa increased more than safflower and vetch. Water deficiency reduces leaf area index by reducing leaf production and increasing leaf aging. Increasing the stress, in addition to decreasing the leaf area index, reduces the turgor pressure in the cells. This reduction in turgor pressure causes less water to remain inside the cells and thus reduces the volume of the cells, which in turn reduces the weight of the cells and ultimately the leaf fresh weight (Cakir, 2004).

3.2. Stem fresh weight

Variance analysis of the data showed that irrigation had a significant effect on stem fresh weight in safflower, alfalfa, and common vetch (Tables 1-3). The mean comparison showed that I12 decreased the stem fresh weight of the safflower, alfalfa, and common vetch (Table 4-6). SAP had a significant effect on the stem fresh weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the stem fresh weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the stem fresh weight in alfalfa increased more than safflower and vetch. During drought stress, the decrease in the leaf relative water content of the plant reduces the turgor of the cells and consequently reduces their growth and development. Therefore, the stem weight is reduced (Sanchez et al., 1998). Ahmad et al. (2006) showed that with increasing drought severity, shoot weight decreased in *Helianthus annuus* hybrids.

Table 1. Analysis of variance for effect of drought and water-superabsorbent polymer on safflower traits

Source of Variation	DF	Leaf fresh weight	Stem fresh weight	Seedling fresh weight	Leaf dry weight	Stem dry weight	Seedling dry weight	Plant height	RWC	Chlorophyll index
Irrigation (I)	1	202**	416**	1199**	4.17ns	0.29ns	6.67ns	0.08ns	0.00030ns	0.60**
Superabsorbent polymer (S)	3	45333**	11763**	103263**	507**	437**	1887**	13.35**	0.00150**	0.78**
(I×S)	3	7ns	0.25ns	4ns	0.15ns	0.3ns	0.88ns	0.06ns	0.00003ns	0.2ns
Error	16	20.23	15.58	43	1.84	1.13	3.92	0.42	0.00080	0.06
C.V (%)		6.51	2	6.52	3.28	6.88	3.48	5.69	1.61	2.46

** and ns are significant at 0.01 and non-significant, respectively

Table 2. Analysis of variance for effect of drought and water-superabsorbent polymer on alfalfa traits

Source of Variation	DF	Leaf fresh weight	Stem fresh weight	Seedling fresh weight	Leaf dry weight	Stem dry weight	Seedling dry weight	Plant height	RWC	Chlorophyll index
Irrigation (I)	1	6.34ns	19.53**	39*	2.45ns	1.18ns	7.04**	0.11ns	0.00060ns	6.20**
Superabsorbent polymer (S)	3	384**	129**	804**	59.59**	5.06**	98.87**	3.39**	0.00300**	3.84ns
(I×S)	3	0.89ns	0.32ns	1.74ns	0.06ns	0.08ns	0.21ns	0.003ns	0.00007ns	0.06ns
Error	16	2.01	1.07	4.57	0.54	0.27	0.18	0.03	0.00020	3.35
C.V (%)		6.24	7.37	6.10	13.14	21.05	5.40	5.94	1.84	0.69

**, * and ns are significant at 0.01, 0.05 and non-significant, respectively

Table 3. Analysis of variance for effect of drought and water-superabsorbent polymer on common vetch traits

Source of Variation	DF	Leaf fresh weight	Stem fresh weight	Seedling fresh weight	Leaf dry weight	Stem dry weight	Seedling dry weight	Plant height	RWC	Chlorophyll index
Irrigation (I)	1	3.63ns	11*	28ns	0.07ns	2.26ns	3.61ns	1.42ns	0.00050*	3.68**
Superabsorbent polymer (S)	3	894**	302**	1202**	71**	173**	467**	207**	0.00200**	3.37**
(I×S)	3	0.16ns	1.1ns	0.65ns	0.93ns	0.50ns	0.33ns	0.74ns	0.00002ns	0.08ns
Error	16	7.39	1.56	7.71	1.01	4.36	5.82	0.34	0.00008	0.10
C.V (%)	-	2.89	1.06	1.31	6.80	9.80	6.68	1.83	1.10	1.25

**, * and ns are significant at 0.01, 0.05 and non-significant, respectively

Table 4. Mean comparison for the effect of irrigation interval and water-superabsorbent polymer on growth traits of safflower

Source of variation	Leaf fresh weight (mg)	Stem fresh weight (mg)	Seedling fresh weight (mg)	Leaf dry weight (mg)	Stem dry weight (mg)	Seedling dry weight (mg)	Plant height (cm)	Leaf relative water content (%)	Chlorophyll (Spad index)
Irrigation									
Drought (12 days)	290.2b	192.6b	482. 9b	40.9a	15.46a	56.3a	11.4a	82a	35.3b
Control (6 days)	296.1a	201.0a	497.0a	41.7a	15.6a	57.3a	11.5a	74a	35.6a
Polymer									
0 kg/ha (control)	214.5c	156.1b	370.6b	32.2b	7.1d	39.3d	10.1c	79c	36.4a
84 kg/ha	221.7c	161.0b	382.7b	34.9b	9.2c	44.2c	10.3c	80bc	36.0ab
168 kg/ha	361.2b	233.0a	594.2a	47.1a	21.5b	68.6b	12.3b	82ab	35.2b
336 kg/ha	375.3a	237.2a	612.4a	51.1a	24.1a	75.2a	13.1a	83a	34.2c

Means with the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Test.

Table 5. Mean comparison for the effect of irrigation interval and water-superabsorbent polymer on growth traits of alfalfa

Source of variation	Leaf fresh weight (mg)	Stem fresh weight (mg)	Seedling fresh weight (mg)	Leaf dry weight (mg)	Stem dry weight (mg)	Seedling dry weight (mg)	Plant height (cm)	Leaf relative water content (%)	Chlorophyll (Spad index)
Irrigation									
Drought (12 days)	22.22a	13.19b	33.72b	5.28a	2.25a	7.53b	3.21a	82a	34.29b
Control (6 days)	23.25a	15.00a	36.31a	5.92a	2.69a	8.61a	3.34a	81a	35.31a
Polymer									
0 kg/ha (control)	14.50d	9.22b	23.00c	2.50d	1.44c	3.94d	2.46d	79c	35.85a
84 kg/ha	17.56c	11.22b	27.67c	3.44c	2.06c	5.50c	2.89c	81bc	34.93a
168 kg/ha	27.50b	16.78a	41.83b	7.28b	2.83b	10.11b	3.60b	83ab	34.43a
336 kg/ha	31.39a	19.17a	47.56a	9.17a	3.56a	12.72a	4.16a	84a	33.98a

Means with the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Test.

Table 6. Mean comparison for the effect of irrigation interval and water-superabsorbent polymer on growth traits of common vetch

Source of variation	Leaf fresh weight (mg)	Stem fresh weight (mg)	Seedling fresh weight (mg)	Leaf dry weight (mg)	Stem dry weight (mg)	Seedling dry weight (mg)	Plant height (cm)	Leaf relative water content (%)	Chlorophyll (Spad index)
Irrigation									
Drought (12 days)	93.4a	117.4b	210.8a	14.8a	20.9a	35.7a	31.9a	81b	34.3b
Control (6 days)	94.2a	118.8a	212.9a	14.9a	21.6a	36.5a	32.4a	82a	35.1a
Polymer									
0 kg/ha (control)	86.3b	110.6d	196.9d	11.4c	16.2b	27.6c	26.0d	80b	35.7a
84 kg/ha	89.5b	113.8c	203.3c	12.5c	17.2b	29.7c	28.3c	81b	34.8ab
168 kg/ha	98.1a	122.0b	220.1b	16.8b	24.8a	41.6b	35.7b	82ab	34.3ab
336 kg/ha	101.3a	125.9a	227.2a	18.7a	26.9a	45.6a	38.4a	84a	33.9b

Means with the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Test.

3.3. Seedling fresh weight

Variance analysis of the data showed that irrigation had a significant effect on seedling fresh weight in safflower and alfalfa, but its effect on seedling fresh weight in common vetch was not significant (Tables 1-3). The mean comparison showed that I12 decreased the seedling fresh weight of the safflower and alfalfa (Table 4-5). SAP had a significant effect on the seedling fresh weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the seedling fresh weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the seedling fresh weight in alfalfa increased more than safflower and vetch.

It seems that the fresh seedling weight loss in drought-treated plants is due to inhibition of cell development and growth resulting from the reduction of turgor pressure (Rane et al., 2001). These results showed that SAP could reduce the adverse effects of drought by increasing water absorption and retention in the soil. Super absorbent also increases the supply of nitrogen, phosphorus, sulfur, and cation exchange capacity. Increasing ventilation by improving soil structure is another positive effect of SAP leading to increase growth and yield of plants (Nazarli et al., 2010).

3.4. Leaf dry weight

Variance analysis of the data showed that irrigation had no significant effect on leaf dry weight in safflower, alfalfa, and common vetch (Tables 1-3). The mean comparison showed that there was no significant difference between tow irrigation intervals in terms of leaf dry weight in safflower, alfalfa, and common vetch (Table 4-6). SAP had a significant effect on the leaf dry weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the leaf dry weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the leaf dry weight in alfalfa increased more than safflower and vetch. Drought stress severely reduces stem dry weight, leaf dry weight, and plant dry matter yield, because when a plant is exposed to drought, it reduces its foliage, which is the main source of transpiration in the plant.

Also in these conditions, the plant keeps its stomata half-closed or closed, which reduces the absorption of CO_2. The plant also reduces its leaf area during stress, which reduces photosynthetic production. With the reduction of photosynthetic materials, the dry weight of leaves and stems decreases (Taheri Asghari, 2010). In the presence of water-superabsorbent polymer, plant root access to available water is high and the plant is less affected by drought stress conditions (Azzam, 1980).

3.5. Stem dry weight

Variance analysis of the data showed that irrigation had no significant effect on stem dry weight in safflower, alfalfa, and common vetch (Tables 1-3). The mean comparison showed that there was no significant difference between tow irrigation intervals in terms of stem dry weight in safflower, alfalfa, and common vetch (Table 4-6).

SAP had a significant effect on the stem dry weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the stem dry weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the stem dry weight in safflower increased more than alfalfa and common vetch.

3.6. Seedling dry weight

Variance analysis of the data showed that irrigation had no significant effect on seedling dry weight in safflower and common vetch, but its effect on seedling dry weight of alfalfa was significant (Tables 1-3). The mean comparison showed that there was no significant difference between tow irrigation intervals in terms of seedling dry weight in safflower and common vetch, but in alfalfa, I6 produced higher seedling dry weight than I12 (Table 4-6). SAP had a significant effect on the seedling dry weight of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the seedling dry weight increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). The results showed that with increasing the amount of water-superabsorbent, the seedling dry weight in alfalfa increased more than safflower and vetch. Drought reduced biomass production. These results are in accordance with the results of Hojati et al. (2007) and Turner et al. (2006). Seyed Sharifi and Seyed Sharifi (2008) reported that with increasing drought stress intensity, seedling dry weight, shoot dry weight, and root weight decreased significantly. Barnabas et al. (2008) reported that water deficit elevated abscisic acid (ABA) synthesis and transport.

ABA reduced water potential and stomatal conductance. By closing stomata, carbohydrate production reduces then cell division and expansion are arrested. Finally, crop yield will be reduced. Drought leads to stomata closing. This stops gas exchange necessary for photosynthesis. Finally, photosynthetic material and growth can reduce. Leaf relative water content reduction due to drought increases leaf and canopy temperature that ultimately increases respiration (Siddique et al., 2000). Respiration increasing by drought is a reason for biomass production reduction.

3.7. Plant height

Variance analysis of the data showed that irrigation had no significant effect on plant height in safflower, alfalfa, and common vetch (Tables 1-3). The mean comparison showed that there was no significant difference between tow irrigation intervals in terms of plant height in safflower, alfalfa, and common vetch (Table 4-6). SAP had a significant effect on the plant height of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the plant height increased in all three plants: safflower, alfalfa, and common vetch (Tables 4-6).

The results showed that with increasing the amount of water-superabsorbent, the seedling height in alfalfa increased more than safflower and vetch. One of the first signs of water deficiency is a decrease in turgor pressure and consequently cell growth and development, especially in the stem. With reduced cell growth, organ size is limited and that is why the first noticeable effect of dehydration on plants can be distinguished from plant height (Hassani, 2006). The results showed that by increasing the amount of SAP, plant height was significantly increased. Berenguer and Faci (2001) and Mirzakhani and Sibi (2010) reported that drought reduced plant height, but SAP increased plant height.

3.8. Leaf relative water content

Variance analysis of the data showed that irrigation had no significant effect on leaf relative water content in safflower and alfalfa, but its effect on leaf relative water content in common vetch was significant (Tables 1-3). The mean comparison showed that in common vetch, I6 had higher leaf relative water content than I12, but there was no significant difference between tow irrigation intervals in terms of leaf relative water content in safflower and alfalfa (Tables 4-6). SAP had a significant effect on the leaf relative water content of safflower, alfalfa, and common vetch (Tables 1-3). With the increase in the use of SAP, the leaf relative water content increased in all three plants: safflower, alfalfa, and common vetch (Tables

4-6). The results showed that with increasing the amount of water-superabsorbent, the RWC increased in all three crops. In addition, with increasing irrigation interval from 6 days to 12 days, the RWC decreased. Leaf relative water content shows the moisture state of the leaf and is used as an index for drought assessment. SAP improved leaf relative water content under drought.

It was probably due to increasing water availability for plant roots. Paknejad et al. (2007) reported that the first effect of drought stress was to reduce the leaf relative water content and to close the stomata, which reduced yield through disruption of the photosynthetic system. It has been reported that drought stress reduced the leaf relative water content of *Aegilops biuncialis* genotypes, possibly due to stomatal closure (Molnar et al., 2002).

3.9. Chlorophyll content

Variance analysis of the data showed that irrigation had significant effect on leaf chlorophyll content in safflower and alfalfa, and common vetch (Tables 1-3). The mean comparison showed that I6 had higher leaf chlorophyll content than I12 in all three plants: safflower, alfalfa, and common vetch (Tables 4-6). SAP had a significant effect on the leaf chlorophyll content of safflower and common vetch, but SAP had no significant effect on the leaf chlorophyll content in alfalfa (Tables 1-3). With the increase in the use of SAP, the leaf chlorophyll content reduced in safflower and common vetch (Tables 4 and 6). Antolin et al. (1995) found that with increasing drought stress, leaf chlorophyll content decreases but the chlorophyll a/b ratio increases.

It is noteworthy that some researchers believe that increasing the chlorophyll a/b ratio causes the leaves to darken and increases the number of chlorophyll meters (Estill et al., 1991). Leaf chlorophyll is an index of photosynthesis and its reduction reduces photosynthesis. In the study, drought and SAP simultaneously increased chlorophyll content. It was probably due to that drought reduced leaf area and increases leaf thickness, so chloroplast pigments accumulated in the area unit (Heidari et al., 2011).

4. Conclusions

Drought applied by increasing the irrigation interval caused a decrease in some growth characteristics in safflower, alfalfa, and common vetch. The water-superabsorbent polymer increased dry matter production and leaf relative water content compared to control in safflower, alfalfa, and common vetch. SAP could improve the plant growth probably by increasing water absorption and retention in the soil. Soil ventilation, supply of nutrients, and increasing cation exchange capacity are some possible reasons for improving plant growth by SAP.

One of the limitations of this work was the irrigation interval. If the irrigation interval was longer than 12 days, perhaps its effect on the growth of the studied plants would be more evident. One of the strengths of this work is to solve the problem of seedling establishment with small seeds such as alfalfa, especially in drought stress conditions. The results of this research showed that it is possible to use water-superabsorbent to increase the growth and establishment of seedlings of small seeds. Overall, SAP can be used as one of the agronomic operations. Due to the rising trend of dry matter production by SAP application, it is suggested to study water-superabsorbent polymer rates of more than 336 kg per ha on plant growth.

5. Disclosure Statement

No potential conflict of interest was reported by the authors

6. References

Afsharmanesh, G. (2010). Evaluation of some morphological characteristics and selection of drought resistant varieties of alfalfa in Jiroft. *Ecophysiology Journal, 3*, 109-118.

Ahmad, S., Ahmad, R., Ashraf, M., & Waraich, E.A. (2006). Sunflower (*Helianthus annuus*) response to drought stress at germination and seedling growth stages. *Pakistan Journal of Botany, 41(2),* 647-654.

Ahmadi, A., Khasheai Sivaki, A., & Bagheri Moghadam, M. (2013). Assess the impact of K zeolite on time and emergence percentage *of Cuminum cyminum*. In *Twelfth Conference on irrigation and evaporation reduction*. Kerman, Iran.

Ahmed, A.F. (2024). Enhancing water use efficiency and phytochemical responses of fenugreek plants cultivated under drought stress using superabsorbent hydrogel. *Emirates Journal of Food and Agriculture*, *36*, 1-10. https://dx.doi.org/10.3897/ejfa.36.2024.122137

Albalasmeh, A.A., Mohawesh, O., Gharaibeh, M.A., Alghamdi, A.G., Alajlouni, M.A., & Alqudah, A.M. (2022). Effect of hydrogel on corn growth, water use efficiency, and soil properties in a semi-arid region. *Journal of the Saudi Society of Agricultural Sciences, 21*, 518-524. https://doi.org/10.1016/j.jssas.2022.03.001.

Antolin, M. C., Yoller, J., & Sanchez-Diaz, M. (1995). Effects of temporary drought on nitrate fed and nitrogen-fixing alfalfa plants. *Plant Science, 107,* 159-165. https://doi.org/10.1016/0168-9452(95)04108-7

Araújo, E.D., Assis, M.O., Guimarães, C.M., Araújo, E.F., Borges, A.C., & Cunha, F.F. (2024). Superabsorbent polymers and sanitary sewage change water availability during the cowpea emergence phase. *Nativa*, *12(1),* 37-48. https://doi.org/10.31413/nat.v12i1.16922

Armandpisheh, A., Allah Dadi, A., Ebadi, A., & Keliaie, A.A. (2010). Reducing the adverse effects of stress with applying zeolite on the characters of seed in rapeseed (*Brassica napus* L). *Plant and Ecosystem, 6(24)*, 67- 75.

Azzam, R. (1980). Tailoring polymeric gels for soil reclamation and hydroponics. *Communication in Soil Science Plant Analysis, 16 (10),* 1123-1138. https://doi.org/10.1080/00103628509367670

Barnabas, B., Jager, K., & Feher, A. (2008). The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell and Environment*, 31, 11–38.

Berenguer, M.G., & Faci, J.M. (2001). Sorghum (*Sorghum bicolor* L.) yield compensation processes under different plant densities and variable eater supply. *European Journal of Agronomy, 15*, 43- 55. https://doi.org/10.1016/S1161-0301(01)00095-8

Biehl, J., Sandén, H., & Rewald, B. (2023). Contrasting effects of two hydrogels on biomass allocation, needle loss, and root growth of Picea abies seedlings under drought. *Forest Ecology and Management, 538*, 120970. https://doi.org/10.1016/j.foreco.2023.120970.

Cakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Agronomy Journal, 89,* 1-16. https://doi.org/10.1016/j.fcr.2004.01.005

Estill, K., Delany, R. H., Smith, W. K., & Ditterline, R. L. (1991). Water relations and productivity of alfalfa leaf chlorophyll variants. *Crop Science, 31,* 1229-1233. https://doi.org/10.2135/cropsci1991.0011183X00 3100050030x

Dhiman, J., Prasher, S.O., ElSayed, E., Patel, R.M., Nzediegwu, C., & Mawof, A. (2021). Effect of hydrogel based soil amendments on yield and growth of wastewater irrigated potato and spinach grown in a sandy soil. *Environmental Technology & Innovation, 23,* 101730. https://doi.org/10.1016/j.eti.2021.101730.

Gajurel, G., Hasan, R., & Medina-Bolivar, F. (2024). Water-deficit stress induces prenylated stilbenoid production and affects biomass in peanut hairy roots: Exploring the role of stilbenoid prenyltransferase downregulation. *Plant Physiology and Biochemistry, 210*, 108596. https://doi.org/10.1016/j.plaphy.2024.108596

Hans, J., Bohnert, G., & Richad, G. (1996). Strategies for engineering water stress tolerance in plants. *Journal of Trends in Biotechnology, 14,* 89.97. https://doi.org/10.1016/0167-7799(96)80929-2

Hassani, A. (2006). Effect of water deficit stress on growth, yield and essential oil content of *Dracocephalum moldavica*. *Iranian Journal of Medicinal and Aromatic Plants, 22(3),* 256-261.

Heidari , H., Jahansooz, M.R., Yunusa, I., Hosseini, S.M.B., Chaichi, M.R., & Jafari, A.A. (2011). Effect of alternate irrigation on root-divided Foxtail Millet (*Setaria italica*). *Australian Journal of Crop Science, 5,* 205-213.

Hojati, M.m, Zareei, M., Simkesh Zadeh, N., & Bani Nasab, B. (2007). The effect of different amounts of natural zeolite on growth of *Trigonella Foenum*. In *Abstracts of the fifth congress of Iranian horticultural science*. Shiraz University, Shiraz, Iran, September 15, 2007. 396 p.

Huttermann A., Zommorodi, M., & Reise, K. (2006). Addition of hydrogels to the soil for prolonging the survival of *Pinus halepensis* seedlings subjected to drought. *Journal of Soil Tillage Research, 50,* 295-304. https://doi.org/10.1016/S0167-1987(99)00023-9

Jia, H., Xia, M., Li, J., Li, H., Chang, D., Yan, D., Lai, M., Wei, Y., Chang, P., Yang, X., & Ji, X. (2024). Effect and mechanism of biochar-based hydrogel to alleviate drought stress in tobacco. *Plant Stress, 12*, 100499. https://doi.org/10.1016/j.stress.2024.100499.

Karimi, A., Noshadi, M., & Ahmadzadeh, M. (2009). Effects of super absorbent polymer (Igeta) on crop, soil water and irrigation interval. *Journal of Crop Production and Processing, 12 (46)*, 403-414. http://jcpp.iut.ac.ir/article-1-1132-fa.html

Kishor, N., Khanna, M., Rajanna, G.A., Singh, M., Singh, A., Singh, S., Banerjee, T., Patanjali, N., Rajput, J., & Kiruthiga, B. (2024). Soil water distribution and water productivity in red cabbage crop using superabsorbent polymeric hydrogels under different drip irrigation regimes.

Agricultural Water Management, 295, 108759. https://doi.org/10.1016/j.agwat.2024.108759.

Meher Shivakrishna, P., Ashok Reddy, K., & Manohar Rao, D. (2018). Effect of PEG-6000 imposed drought stress on RNA content, relative water content (RWC), and chlorophyll content in peanut leaves and roots. *Saudi Journal of Biological Sciences, 25*(2), 285-289. https://doi.org/10.1016/j.sjbs.2017.04.008

Mirzakhani, M., & Sibi, M. (2010). Safflower physiological characteristics response to water stress and apply of zeolite. In *Abstracts of the second national conference on agriculture and sustainable development, opportunities and challenges ahead*, Islamic Azad University, Shiraz, Iran, March 11-12, 2010. P 21.

Molnar, I., Gaspar, L., Stehli, L., Dulai, S., Sarvari, E., Kiraly, I., Galiba, G., & Molnar-Lang, M. (2002). The effects of drought stress on the photosynthetic processes of wheat and of *Aegilops biuncialis* genotypes originating from various habitats. *In Proceeding of the seventh Hungarian Congress on Plant Physiology*. *Acta Biologia, 46*, 115-116.

Nazarli, H., Zardashti, M.R., Darvishzadeh, R., & Najafi, S. (2010). The effect of water stress and polymer on water use efficiency, yield and several morphological traits of sunflower under greenhouse condition. *Iranian Journal of Biological Sciences, 2,* 53-58. https://doi.org/10.15835/nsb244823

Ober, E.S., Bloa, M., Clark, C.J.A., Royal, A., Jaggard, K.W., & Pidgeon, J.D. (2005). Evaluation of physiological traits as indirect selection criteria for drought tolerance in sugar beet. *Journal of Field Crops Research, 91,* 231-249. https://doi.org/10.1016/j.fcr.2004.07.012

Paknejad, F., Majidi heravan, E., Noor mohammadi, Q., Siyadat, A., & Vazan, S. (2007). Effects of drought stress on chlorophyll fluorescence parameters, chlorophyll content and grain yield of wheat cultivars. *American Journal of Biochemistry and Biotechnology, 5,* 162-169.

Palanivelu, S.D., Gan, S., Salleh, K.M. Lindsey, K., Sairi, F., Che-Othman, M.H., & Zakaria, S. (2023). Assessment of bio-based hydrogel as an alternative growth medium for seed germination and seedling growth in urban farming. *Cellulose, 30*, 7791-7803. https://doi.org/10.1007/s10570-023-05334-1

Piccoli, I., Camarotto, C., Squartini, A. Longo, M., Gross, S., Maggini, M., Cabrera, M. L., & Morari, F. (2024). Hydrogels for agronomical application: from soil characteristics to crop growth: a review. *Agronomy for Sustainable Development, 44*, 22. https://doi.org/10.1007/s13593-024-00958-4

Poresmaiil, P., Habibi, D., & Roshan, B. (2007). Superabsorbent polymer a way for reducing agricultural water use. *Agricultural and Natural Resources Engineering Disciplinary Organization, 15,* 80-82.

Rane, J., Maheshwari, M., & Nagarajan, S. (2001). Effect of pre-anthesis water stress on growth, photosynthesis and yield of six wheat cultivars differing in drought tolerance. *Indian Journal of Plant Physiology, 6,* 53-60.

Reimov, N.B., & Auezov, I.A. (2024). The necessity to use hydrogels in conditions of island water shortage in the aral region. *Acta Innovations*, *51*, 9–14. https://doi.org/10.62441/ActaInnovations.51.2

Sadeghi, H., Mousavi, S.Q.R., Seqeh Alaslam, M.J., & Alizadeh, A. (2007). The effect of deficit irrigation on the yield and yield components of millet nutrifeed. *In Sixth national conference of agricultural sciences and natural resources of young researchers club*, Islamic Azad University of Karaj, December 7-8, 2007, P 199.

Sanchez, F.J., Manzanares, M., Andres, E.F., Ternorio, J.L., Ayerbo, L., & Deandles, E.F. (1998). Turgor maintenance, osmotic adjustment and soluble sugar and proline accumulation in pea cultivars in response to water stress. *Field Crops Research, 59(3),* 225-235. https://doi.org/10.1016/S0378-4290(98)00125-7

Sannino, A., Mensitieri, G., & Nicolais, L. (2004). Water and synthetic urine sorption capacity of cellulose based hydrogels under a compressive stress field. *Journal of Applied Polymer Science, 91(6),* 3791-3796. https://doi.org/10.1002/app.13540

Seyed Sharifi, R., & Seyed Sharifi, R. (2008). Evaluation the effects of Polyethylene glycol on germination and growth seedling Carthamus cultivars. *Iranian Journal of Biology*, *21,* 400-410.

Siddique, M.R.B., Hamid, A., & Islam, M.S. (2000). Drought stress effects on water relations of wheat. *Botanical Bulletin of Academia Sinica*, *41,* 35-39.

Taheri Asghari, M. (2010). Effects of water deficit stress on some characteristics of chicory (*Cichorium intybus* l.) under different plant densities. *Journal of Crop Ecophysiology, 2(3),* 147-155.

Tohidi Moghaddam, H. R., Shirani Rad, A. H., NourMohammadi, G.h., Habibi Modarres, D., Sanavy, S. A. M., Mashhadi Akbar-Boojar, M., & Dolatabadian, A. (2009). Response of six oilseed rape genotypes to water stress and hydrogel application. *Agricultural Research in the Tropics Journal, 39,* 243-250.

Turner, N.C., & Kramer, P.J. (1980). *Adaptation of plant to water and high temperature stress*. Wiley Interscience, New York.

Turner, N.C., Shrestha, R.K.H.M., Siddique, D.W., & Speijers, J. (2006). A water deficit during pod development in lentils reduces flower and pod number but not pod size. *Journal of Australian Journal of Agricultural Research, 57(4),* 427-438. https://doi.org/10.1071/AR05225