Impact of hydrogel polymer on parsley (*Petroselinium crispum* (Mill.) Nyman) growth and development (#76809)

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Impact of hydrogel polymer on parsley (*Petroselinium crispum* (Mill.) Nyman) growth and development

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The recent pandemic and extending drought pressure due to climate change, showed the importance of food supply as a global priority. In this study, the possibility of using hydrogels, which is one of the chemical components that can be used in water shortage conditions and against the expected water scarcity, was investigated. Parsley was used as the model organism. Two different water treatments (50% and 100%) and four different hydrogel concentrations (0%, 50%, 75%, and 100%) were used as the study. Root width and length, leaf width and length, main stem length, and the number of tillers were investigated. According to the results, while no improvement was observed in the plants with 100% hydrogel concentration, the best results were obtained from 50% hydrogel application. The results obtained from 75% hydrogel application were found to be higher than 100% hydrogel but lower than 0% hydrogel application. Under 50% hydrogel conditions (water-restricted), all plant growth parameters were higher compared to the plants with 100% (full irrigation) water application. The results of the study suggest that hydrogels have significant potential to mitigate the effects of drought on vegetable crops.

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ABSTRACT

The recent pandemic and extending drought pressure due to climate change, showed the importance of food supply as a global priority. In this study, the possibility of using hydrogels, which is one of the chemical components that can be used in water shortage conditions and against the expected water scarcity, was investigated. Parsley was used as the model organism. Two different water treatments (50% and 100%) and four different hydrogel concentrations (0%, 50%, 75%, and 100%) were used as the study. Root width and length, leaf width and length, main stem length, and the number of tillers were investigated. According to the results, while no improvement was observed in the plants with 100% hydrogel concentration, the best results were obtained from 50% hydrogel application. The results obtained from 75% hydrogel application were found to be higher than 100% hydrogel but lower than 0% hydrogel application. Under 50% hydrogel conditions (water-restricted), all plant growth parameters were higher compared to the plants with 100% (full irrigation) water application. The results of the study suggest that hydrogels have significant potential to mitigate the effects of drought on vegetable crops.

Keywords: Drought, hydrogel, parsley (*Petroselinium crispum*), deficit irrigation.

INTRODUCTION

Petroselinum crispum is cultivated worldwide in temperate and subtropical climates and is often used as an aromatic herb in cooking, in traditional medicine for its active ingredient, and for landscaping. The parsley vegetable is cultivated for both its leaves (either flat or broad leaves) and its tuber (root). The main varieties of the parsley vegetable are Italian or flat-leaf, curly-leaf and root parsley (*Miller et al., 2020*). *Petroselinum crispum*, whose green leaves have a mild, pleasant flavor, contains antioxidants, the flavonoid luteolin, vitamins C and A. Being a source of iodine and iron, this vegetable is also rich in folic acid (*Stephens, 1994; Ajmera et al., 2019*). *Petroselinum crispum* has antioxidant properties, protects against DNA damage and inhibits proliferation and migration of cancer cells (*Tang et al., 2015*). However, the possible curative effect of hydrogels on parsley development has not been studied before.

Hydrogels are a type of gel obtained from the chemical synthesis of hydrophilic polymers (*Kabir et al., 2017; Qasim et al., 2018*). Hydrogels retain their structural integrity and absorb the water from the environment (*Montesano et al., 2015; Domalik-Pyzik et al., 2019; Qu & Luo, 2020*). Water hydrogels can be classified into 3 groups; 1) Synthetic hydrogels containing polyacrylic, polyacrylamide, and polyacrylonitrile, 2) semi-synthetic hydrogels containing starch-polyacrylonitrile, starch-polyacrylamide, and starch polyacrylic acid, and 3) hydrogels such as cellulose and guar gum originating from natural raw materials. The biggest limitations on the use of Synthetic and semi-synthetic hydrogels in agriculture are cost, environmental effects, and most importantly, their non-biodegradability.

More than 70% of the water used in agricultural irrigation consists of usable water. One of the greatest advantages of hydrogels is the ability to obtain them from natural wastes and their potential uses in soil water conservation (*Sharma et al., 2021; Milijković et al., 2021*). There were only a few studies reported the use of hydrogels in agriculture. *Wilske et al.* (2014) reported that the dissolution rate of polyacrylate hydrogel, one of the synthetic hydrogels, was just 0.45% within 24 weeks. The sodium alginate/polyacrylamide hydrogel developed by *Elbarbary et al.* (2017) stimulated corn growth and sustained nutrient release into the soil.

A hydrogel developed from gum arabic by *Hasija et al.* (2018) significantly increased the water holding capacity of the soil. It has been reported that amino ethyl chitosan and acrylic acid obtained by free radical polymerization, was able to hold water and release the stored water into the soil, and was excellent in the trials under salt and drought stress conditions (*Fang et al., 2018*). The high degradability of the biogel is undesirable in soil applications (*Song et al., 2020; Dhanapal et al., 2021*). For these reasons, hydrogels that are degradable in soil but more stable and can be used at least in one or more of the plant growth cycles are to be preferable in agricultural areas (*Kai et al., 2016; Hasija et al., 2018*).

With the issues in the food supply and demand, the producers used more synthetic fertilizers (especially N, P, and K) per unit area, which shook the foundation of not only sustainable agriculture but also traditional agriculture. According to *Prakash et al.* (2021) and *Sabyasachi & Prakash* (2019), the use of hydrogels may provide water conservation with reduced and controlled irrigation. While it is clear that even the countries with large economies have been affected by the food supply problem that has arisen due to the pandemic, there is even more uncertainty about how the food shortage will affect the whole world. It will be an obligation to make water optimization in agriculture, digital systems with real-time monitoring capabilities and innovative resources, and the use of hydrogel in agricultural activities is shown as a solution to water shortages, especially in arid and semi-arid areas. The use of biodegradable hydrogel reduces the frequency of irrigation, positively affects the infiltration and water holding capacity of the soil, and also eliminates the need for environmental protection. Thus, the protection of water resources in agriculture is ensured (*Skrzypczak et al., 2020*).

Water stress, which is manifested by the lack of moisture in the plant root zone, causes early leaf senescence, low chlorophyll content, low seed yield, and less fruit, and flower formation. Hydrogels can have a positive effect on agriculture by reducing the effect of drought, which causes the formation of oxygen radicals. The addition of hydrogel to the soil, in different soils and different hydrogel amounts, increases the water holding capacity of the soil by 50 to 70%. With the use of hydrogel, the unit volume weight of the soil is reduced by 8-10% (*Neethu et al., 2018; Ekebafe et al., 2011*). It is estimated that by 2050, approximately 50% more water will be needed compared to today's water usage (*Abobatta, 2018*). It is a necessity to find a solution to the water shortage problem in agriculture. Unfortunately, agriculture is the area most affected by water scarcity. Drought is one of the most destructive environmental stresses in the arid areas of many countries, and simultaneously with heat stress, it negatively affects the productivity of plants (*Subbarao et al., 1995; Erskine et al., 2011*). Therefore, in this study, the role of hydrogels on plant growth and development was investigated with parsley as the model organism.

MATERIAL & METHODS

Experiment location

The study was conducted in Siirt University Faculty of Agriculture, Department of Field Crops Tissue Culture Laboratory.

Plant Material

Aspuzu variety of parsley, which is small, slightly curved, oval shaped, striped, gray-green in color, loving regions with high humidity, temperate climate and strongly aromatic, was used as plant material in the experiment.

Experimental Treatments and Design

The experiment was conducted under laboratory conditions with three replications according to the randomized complete blocks experimental design. In total, 3 measurements were carried out on each block. Root width and length, leaf width and length, main stem length, and the number of tillers were determined.

Methods

The plants were grown in 1-liter pots filled with peat as three replications. The amount of water to be given to each block was determined according to the results of TDR (time-domain reflectometry) measurements. Two water levels (I1; 50 % and I2; 100 %) were applied as water treatments. Distilled water was applied as irrigation water. The nutrients were dissolved in water and given with irrigation. 0% (H1), 50% (H2), 75% (H3), and 100% (H4) ratios of Polyacrylate Polymer are used (Figure 1). The plant growth medium was prepared by mixing the hydrogel at the determined rates in each pot. 0% only peat was included in the pots. In the pots of 100%, the hydrogel was completely contained. One plant was grown in each pot. And 5 pots were included in each replication. All plant measurements were performed on 3 plants in each replicate.

Observation

Plant growth measurements were started 15 days after planting and were continued at 10 days intervals. The length of the main root and the overall root width was determined using a digital caliper. The Leaf length was determined with the petiole separated from the main stem and 3 leaves in each plant by using a caliper. The Leaf width was also measured with a caliper in leaves measured in leaf length. The Main Stem Length was determined by measuring with a ruler from the root collar. Tillers that originate from the same root and are located around the main stem are obtained by counting.

INSERT FIGURE 1

Statistical Analysis

The analysis of the data was done using the SAS 9.1 statistical software (SAS Institute. 2011) according to the randomized complete blocks experimental design. The least significant difference (LSD) multiple comparison tests were used for comparing the treatment mean.

RESULTS & DISCUSSION

All evaluated traits were significantly affected by the different rates of hydrogel application and irrigation levels (Table 1). Plant development was completely stopped and all plants died 15 days after planting when hydrogel level was used at 100%. For this reason, no plants to be measured were found in the H4 application, even in the first measurement. The H3 application had lower values compared to H2 and H1 applications. The H2 had the highest values in all measurements, while the H1 application shared the same statistical group with the H2 application except leaf width and height, and main stem length. It has been noted that hydrogel application enhances plant growth, but higher rates of hydrogel did not induce any better effect. It was concluded that the hydrogel addition of 50% to the plant growth medium had a positive effect on the growth of the plants. It has also been found that 50% water application (drought treatment) had higher values than full water application (Table 1).

INSERT TABLE 1

When the interactions of hydrogel and irrigation regimes were examined, it was determined that the highest measurement values in all measurements were obtained from the 50% hydrogel and 50% water application, which was followed by H1 × I1 and H1 × I2 groups (Table 2).

INSERT TABLE 2

Since no measurements were recorded in the H4 × I1 and H4 × I2 interaction groups, it was noted that these interaction groups took the last place (Table 1). Control (0% hydrogel) and 50% hydrogel applications differed significantly from other applications in terms of shape, and the highest value 50% hydrogel application ranked first in all applications. (Figure 2, Figure 3 and Figure 4).

INSERT FIGURE 2
INSERT FIGURE 3
INSERT FIGURE 4

Pictures of the measured parsley plants are presented in figure 5. In particular, the attachment of hydrogel to the roots of the plants can be clearly seen. It was determined that high doses of hydrogel applications caused the plant roots to not develop. At the same time, it was determined that high water application (H3 × I2) prevented the roots from fringing and developing in depth. Although vertical root development in all plants varied according to the applications, it is reflected in picture 1 that the fringe rooting changes according to irrigation and hydrogel ratios. Adhesion of hydrogels in the fibrous roots of plants with 50% hydrogel is an indication that this plant group has grown higher than the other treatments (Figure 5).

INSERT FIGURE 5

According to *Liu et al.* (2020), the use of hydrogel increased work efficiency, but most importantly, it had a positive effect on the growth of plants and provided a net economic benefit. The results of our 50% application were similar to the report of *Liu et al.* (2020) which provided water economy and sustainable water use. Similarly, in the study of *Liu et al.* (2020), positive results were obtained in the water infiltration and capacity of the soil when hydrogel powders were mixed into sandy soils. Similar findings were found in studies conducted on different crops such as wheat (*Shooshtarian et al., 2012*), rice (*Nazarli & Zardashti, 2010*), millet (*Singh, 2012; Keshavars et al., 2012*), and peanut (*Langaroodi et al., 2013*). The aqueous environment around the roots of the plant, reduces the effect of drought by prevents the moisture loss in the soil in dry conditions and acts as a buffer, especially in the early stages of the plant development (*Borivoj et al., 2006*). The control group in our experiment had lower plant growth values than the plants with 50% hydrogel application, and our results were in a similar range with the previous reports. *Shankarappa et al.* (2020) found that hydrogel application increased pod and seed yield in lentils. In our experiment, the increase in leaf and root size, main stem length, and number of tillers in parsley were found to be higher than *Shankarappa et al.* (2020), while the results were in the same direction. The use of hydrogel had also improved the quality properties of the product such as color, shape, and biomass (*Shubhadarshi & Kukreja, 2020*). According to *Elbarbary & Ghobashy* (2017) and *Ibrahim et al.* (2015), hydrogel used in corn production increased the cob quality, early and higher yield in the plants. *Ghasemi & Khushkhui* (2008), who found similar findings, reported an increase in the number of flowers, root/shoot ratio, and plant habit of the chrysanthemum. In our study, the use of hydrogel had a positive effect on all measurements of the parsley in line with the findings of *Shubhadarshi & Kukreja* (2020). *Song et al.* (2020) determined that the hydrogels not only enhanced the soil water holding capacity but also increased the saturated hydraulic conductivity, water holding curve, and nutrient holding capacity. It has been determined that hydrogels increase the soil moisture capacity and support the development of plants and increase yield (*Boatright et al., 1997; Davies et al., 2000*). In arid conditions, hydrogels also increased the life span (approximately 9-14 days) of plants (*Song et al., 2020; Shankarappa et al., 2020*). The negative effect of full hydrogel application (H4) might be due to limited oxygen availability in the root zone. As *Demitri et al.* (2013) who achieved similar results to our findings on plants in a 100% hydrogel environment, stated that the powder or granular hydrogel mixed with the soil swells when it finds water, creating air spaces in the soil at the same time. A study carried out on tomato (*Demitri et al., 2013*), determined that hydrogel-applied plants did not need additional irrigation compared to the control group. It has been determined that the use of hydrogel is economical (*Chaudhary et al., 2020*). In these conditions, hydrogels can be used in agricultural production to reduce the problem of water scarcity (*Shubhadarshi & Kukreja*, 2020; *Das et al., 2021; Louf et al., 2021*). Hydrogels that create a water source in the root zone also increase the usable field capacity, increase plant growth and yield, and reduce the production cost. We can say that one of the reasons for the contribution of hydrogels to plant growth is that they prevent the nutrient from being drained by irrigation water, as *Song et al.* (2020) stated. According to the findings of *Song et al.* (2020), the leaching of nitrogen, total phosphorus, and available potassium in both nitrate and ammonium form with irrigation water is prevented by the use of hydrogels. Also according to *Shubhadarshi & Kukreja* (2020), hydrogels are not affected much by salinity. One of the biggest advantages of hydrogels is that they provide water to the root zone of the plant in a controlled way. Agricultural production is severely, even fatally affected by drought. Because under dry conditions, the application of fertilizer to plants is also negatively affected, significantly reduces plant yield (*Ashraf et al., 2021*).

If the main purpose is to keep enough water in the soil in the root zone of the plant, to ensure plant development without damage, and to obtain high yields under various drought conditions, hydrogels may be a solution. Because with the use of hydrogel, it is ensured that there is constant moisture in the root regions of the plant. If the development and yield deficiencies of plants due to insufficient soil moisture under completely arid or semi-arid regions are eliminated as a result of the use of hydrogel, likely, one of the solutions sought by mankind for the frightening drought conditions foreseen in the future is the use of hydrogel. As *Ashraf et al.* (2021) indicated that the global horror experienced in the days of the pandemic has shown us that such promising solutions need to be multiplied and further developed.

At the beginning of the twentieth century, one of the biggest challenges in the world, especially in the arid and semi-arid regions, has been water management. Unfortunately, according to the calculations, we will face a 50% increased water use as of 2030. Since, more than 70% of the water used in agricultural irrigation is usable/clean water, water conservation becomes an urgent issue. One of the possible solutions is the use of hydrogel in soil management practices. It has been reported that the hydrogel returns the water to the dried soil after storing it in its body.

When combined with the predictions that more products should be added to the rapidly increasing world population, and the coming years will be affected by drought, everything shows a grave chaotic environment. There is an urgent need to eliminate drought and the negativities caused by drought. This study is the first study that deficit irrigation with hydrogel application yielded higher than full irrigation.

CONCLUSIONS

The recent epidemic and the intensifying drought pressure brought on by climate change demonstrated the significance of the world's food supply. The utilization of hydrogels, one of the chemical components that can be used in water shortage situations and to combat the anticipated water scarcity, was looked into in this study. We utilized parsley as our model organism. Four distinct hydrogel concentrations (0%, 50%, 75%, and 100%) were employed as the study topic, along with two different water treatments (50% and 100%). We looked at root breadth and length, leaf width and length, main stem length, and tiller count. The best outcomes were obtained while applying 50% hydrogel to the plants, but no improvement was seen in those with 100% hydrogel concentration. Results from a 75% hydrogel application were shown to be better than those from a 100% hydrogel application but worse than those from a 0% hydrogel application. All plant growth parameters were higher under 50% hydrogel circumstances (water restriction) compared to the plants receiving 100% (full irrigation) water application. The study's findings indicate that hydrogels have a great deal of potential for reducing the impacts of drought on vegetable crops.

ADDITIONAL INFORMATION AND DECLARATIONS

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The author(s) received no specific funding for this study.

Competing Interests

The authors declare that they have no conflicts of interest to report regarding the present study.

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Figure 1

Polyacrylate Polymer used in the experiment

The hydrogel (Polyacrylate Polymer) is used at the experiment.

Figure 2

Effect of hydrogel and irrigation interactions on root length and width

it is seen that the highest measurement in both root length and root width values was obtained from 50% hydrogel aplication

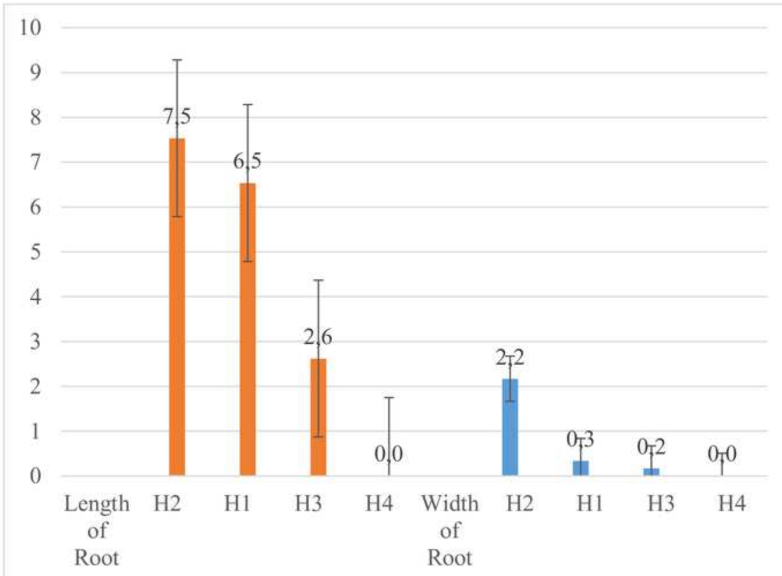
10
9
8
7
6
5
4
3
2
1
0
7.5
6.5
2.6
0.0
2.2
0.3
0.2
0.0
Length of Root
H2
H1
H3
H4
Width of Root
H2
H1
H3
H4

Figure 3

Effect of hydrogel and irrigation interactions on leaf length and width

In the leaf length and width measurements, as in the root length and root width measurements, the highest values were obtained from 50% hydrogel application.

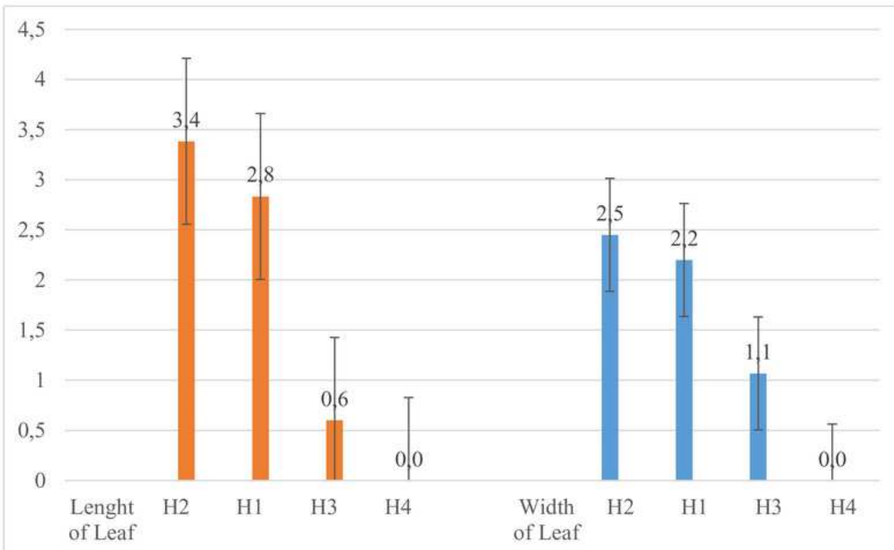
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
3,4
2,8
0,6
0,0
2,5
2,2
1,1
0,0
Lenght of Leaf
H2
H1
H3
H4
Width of Leaf
H2
H1
H3
H4

Figure 4

Effect of hydrogel and irrigation interactions on main stem length and number of tillers

It is understood that the main stem length values and the values of tillering numbers obtained in 50% hydrogel environment are better than other hydrogel applications.

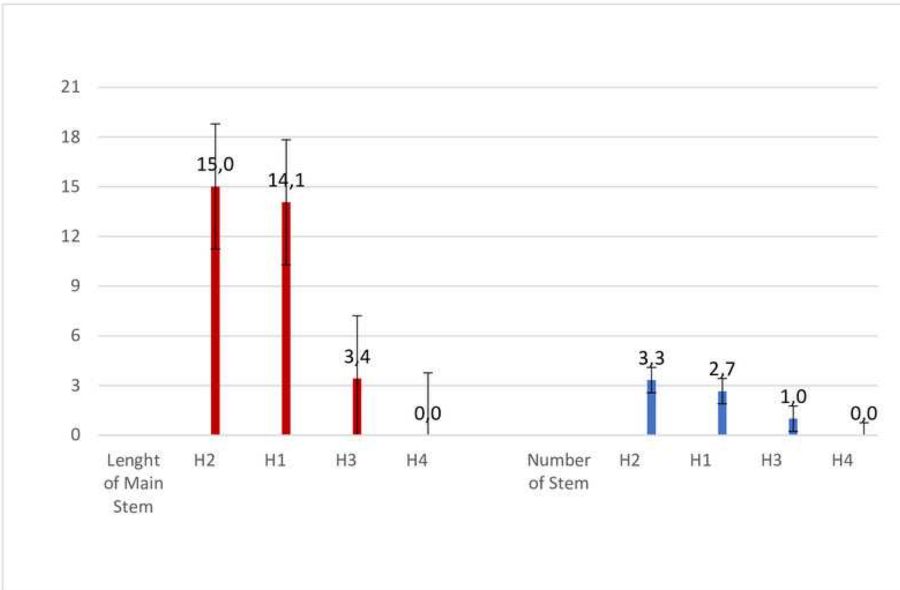
21
18
15
12
9
6
3
0
15,0
14,1
3,4
0,0
3,3
2,7
1,0
0,0
Lenght of Main Stem
H2
H1
H3
H4
Number of Stem
H2
H1
H3
H4

Figure 5

Parsley seedlings under different hydrogel and irrigation applications

Adhesion of hydrogels in the fibrous roots of plants with 50% hydrogel is an indication that this plant group has grown higher than the other treatments

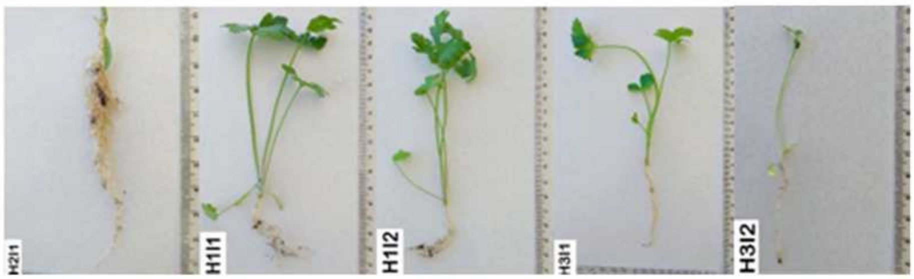
H2I1
H1I1
H1I2
H3I1
H3I2

Table 1(on next page)

Effects of hydrogel levels and irrigation on parsley morphological properties

It was concluded that the hydrogel addition of 50% to the plant growth medium had a positive effect on the growth of the plants. It has also been found that 50% water application (drought treatment) had higher values than full water application

Table 1:

Effects of hydrogel levels and irrigation on parsley morphological properties

	Applications	Root length (cm)	Root width (cm)	Leaf length (cm)	Leaf width (cm)	Main stem length (cm)	Tillers (number)
Hydrogel	H1 (0%)	6.5 b	0.3 b	2.8 b	**2.2 a**	**14.1 a**	2.7 b
	H2 (50%)	**7.5 a**	**2.2 a**	**3.4 a**	**2.5 a**	**15.0 a**	**3.3 a**
	H3 (75%)	2.6 c	0.2 bc	0.6 c	1.1 b	3.4 b	1.0 c
	H4 (100%)	**0.0 d**	**0.0 c**	**0.0 d**	**0.0 c**	**0.0 c**	**0.0 d**
	Std. Error	0.14976	0.05527	0,13228	0.08457	0.44386	0.16666
	P value	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001
Irrigation	I_1 (50%)	**4.9 a**	**1.1 a**	**2.2 a**	**1.9 a**	**9.4 a**	**2.0 a**
	I_2 (100%)	3.4 b	0.3 b	1.2 b	1.0 b	6.9 b	1.5 b
	Std. Error	0.105	0.039	0.093	0.059	0.314	0.118
	P value	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001

Table 2(on next page)

Effects of hydrogel and irrigation interactions on parsley morphological properties

When the interactions of hydrogel and irrigation regimes were examined, it was determined that the highest measurement values in all measurements were obtained from the 50% hydrogel and 50% water application.

Table 2:

Effects of hydrogel and irrigation interactions on parsley morphological properties

	Applications	Root Length (cm)	Root Width (cm)	Leaf Length (cm)	Leaf Width (cm)	Main Stem Length (cm)	Number of tillers (Number)
Hydrogel x Irrigation	H1 x I_1	6.5 b	0.3 bc	2.8 b	2.2 b	14.1 b	2.7 b
	H2 x I_1	**9.9 a**	**3.8 a**	**4.9 a**	**3.6 a**	**18.0 a**	**4.3 a**
	H3 x I_1	3,2 d	0,2 cd	0,9 d	1,6 c	5,5 d	1,0 c
	H4 x I_1	**0.0 f**	**0.0 d**	**0.0 e**	**0.0 e**	**0.0 e**	**0.0 d**
	H1 x I_2	6.5 b	0.3 bc	2.8 b	2.2 b	14.1 b	2.7 b
	H2 x I_2	5.1 c	0.5 b	1.8 c	1.3 c	12.0 c	2.3 b
	H3 x I_2	2.0 e	0.2 cd	0.9 d	0.5 d	1.3 e	1.0 c
	H4 x I_2	**0.0 f**	**0.0 d**	**0.0 e**	**0.0 e**	**0.0 e**	**0.0 d**
	Std. Error	0.21180	0.07817	0.18708	0.11960	0.62771	0.23570
P value		p<,0001	p<,0001	p<,0001	p<,0001	p<,0001	p<,0001