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Research Article

Increased Free Radical Scavenging Activity and Consumer Preference in Garden Cress (*Lepidium sativum* L.) Subjected to Water Stress

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Abstract

Although the Garden Cress is known to grow in a wide range of climatic conditions, there are limited studies on how water stress can affect their morphological, biochemical and sensory characteristics. In this research, these characteristics in the Garden Cress leaves were measured in response to water stress. In this study two different irrigation restrictions (50% and 25% irrigation) were applied against the control plants (100% irrigation) in four replications. As a result, the amount of proline was determined as 5.98 mg^{-1}100g in control plants, and as 36.72 mg^{-1}100g in 25% irrigated plants. While total phenolic compounds and total flavonoids varied from 61.26 to 68.04 mg of GA^{-1}100gFW and 8.35 to 11.70 mg QE^{-1}100gFW, respectively, the differences were statistically insignificant. The increase of DPPH free radical scavenging activity in line with increased water stress, however, was found to be statistically significant. In conclusion, the 50% water stress applied Garden Cress leaves were found to be most preferred by the consumers in terms of flavor and had higher radical scavenging activity than control plants. Irrigation management practices, therefore, could consider limited water use with Garden Cress production under possible negative effects of climate change on water resources.
Keywords: DPPH; garden cress, water stress, phenolic compounds, sensory quality.

Su Stresine Maruz Kalan Tere (*Lepidium sativum* L.) Bitkisinde Artan Serbest Radikal Temizleme Aktivitesi ve Tüketici Tercihi

Öz

Tere (Lepidium sativum L.) bitkisinin çok çeşitli iklim koşullarında yetiştiği bilinmesine rağmen su stresinin bitkinin morfolojik, biyokimyasal ve duyusal özelliklerini nasıl etkileyebileceğine dair sınırlı sayıda çalışma bulunmaktadır. Kontrollü atmosfer koşullarında iki farklı su stresi seviyesi uygulanarak, dört tekrarlı gerçekleştirilen bu çalışmada; terenin bazı morfolojik parametreleri, biyokimyasal özellikleri ve duyusal özellikleri ölçülmüştür. Önceki çalışmalarda su stresi nedeniyle verim kaybı değerlendirilirken, bu çalışmalarda ürünün pazarlanabilirliği ve tüketicilerin tercihi dikkate alınmamıştır. Kontrol bitkilerine (%100 sulama) karşı iki farklı sulama (%50 ve %25 sulama) uygulanan çalışma sonucunda kontrol bitkilerinde prolin miktarı 5.98 mg^{-1}100 g, olarak belirlenirken. %25 sulama suyu uygulanan bitkilerde 36.72 mg^{-1}100g olarak tespit edilmiştir.. Toplam fenolik bileşikler ve toplam flavonoidler sırasıyla 61.26 ile 68.04 mg GA^{-1}100g ve 8.35 ile 11.70 mg QE^{-1}100g arasında değişirken, farklar istatistiksel olarak önem bulunmuştur. Ancak artan su stresine ile birlikte DPPH serbest radikal temizleme aktivitesinin artması istatistiksel olarak anlamlı bulunmuştur. Sonuç olarak %50 su stresi uygulanan Tere yapraklarının tüketiciler tarafından lezzet açısından en çok tercih edildiği ve kontrol bitkilerine göre daha yüksek radikal temizleme aktivitesine sahip olduğu tespit edilmiştir. Bu nedenle sulama yönetimi uygulamaları, küresel ısınma ve iklim değişikliğinin su kaynakları üzerindeki olası olumsuz etkileri altında Tere üretimi ile sınırlı su kullanımını sağlanabilir.
Anahtar Kelimeler: DPPH, Tere, su stresi, fenolik bileşikler, duyusal özellikler.

Introduction

The availability of water resources is an important factor for optimal fruit and vegetable farming Griñán et al. (2019) and it is becoming increasingly important to ensure the preservation of existing food production (Yıldırım et al., 2022). Since water is a major component of fresh plant material and is a priority for the quality of cultivated vegetables El-Zaeddi et al. (2016), extreme variation in temperature and soil moisture can cause low yield in their production by leading to changes in their physiological and biochemical processes (Arimi, 2021).

According to Yıldırım et al. (2022) cyclic or unpredictable drought may affect roughly 33% of the world's arable agricultural land. In order to cope with future water scarcity, there is a need to adopt deficit-irrigation strategies in agricultural production (Griñán et al., 2019). Plants usually develop acclimation strategies and survival mechanisms in response to drought stress depending on the inherent plant traits and the scarcity of drought stress (Okunlola et al., 2022). A mechanism plants use to withstand drought stress is to reduce osmotic potential together with increased anthocyanin concentrations (Erken, 2022). Anthocyanins are good antioxidant compounds because they have free radical scavenging properties (Ahmadiani et al., 2014).

In recent research, there is an increased interest in plants that are natural sources of antioxidants such as the Garden Cress (*Lepidium sativum* L.) (Selek et al., 2018). Garden Cress is a fast growing annual herb in the Cruciferae (Brassicaceae) family (Painuli et al., 2022). This culinary vegetable cultivated all over Asia and Europe is native to Egypt and West Asia (Diwakar et al., 2010; Zia-Ul-Haq et al., 2012). A review carried out by Painuli et al. (2022) highlighted the wide range of therapeutic properties and nutritional values of the Garden Cress "including anticancer, hepatoprotective, antidiabetic, hypoglycemic, antioxidant, antimicrobial, gastrointestinal, and fracture/bone healing activities".

Garden Cress is most typically consumed as a garnish or as a leaf vegetable (Malar et al., 2014). According to Keutgen et al. (2021) both the microgreens and sprouts of the Garden Cress "are consumed for their slightly sour, spicy or bitter flavors and are recommended for their secondary metabolites". Another important character of the Garden Cress is that it can be grown in many different climate and soil conditions (Smolinska et al., 2017).

There, however, is limited research on how abiotic stressors effect the biochemical properties of the Garden Cress. A study carried out by Al-Sammarraie et al. (2020) for example, applied drought, salinity and high light stresses and found that the Lepidium sativum plants launched protective mechanisms against these stresses. Drought stress, in particular, increased the anthocyanin, carotenoid and protein contents, the MDA level and total APX activity in the drought treated plants. Another study, found that the growth and yield attributes of Lepidium sativum decreased and the proline content and total carbohydrates increased in response to increasing water stress (Khalil et al., 2012).

While there are very limited studies investigating the effects of water stress on the morphological and biochemical attributes of the Garden Cress, there is no known study that look at the sensory quality and consumer preference of the same plant under water stress. The objective of this research is to understand how the morphological properties, pH, chlorophyll amount, phenolic compounds, total flavonoids and antioxidant activity, as well as consumer preference of the Garden Cress (*Lepidium sativum* L.) plant is affected under deficit irrigation treatments.

Materal and Methods

Experimental design and irrigation treatment

This research was carried out in Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, Plant Stress Monitoring and Thermography Laboratory. Cress seeds were sown on January 07, 2022 in 10 liter pots in a randomized block design with 4 replications. The seeds were sown at 500-600 g per decare, which corresponds to 75 seeds for each pot with a diameter of 39.25 cm^2. The experiment was carried out in a controlled atmospheric conditions (at 25°C under 14 hours ~ 54 μE light and 10 hours of dark, and 55-60% relative humidity) (Al-Sammarraie et al., 2020). The plant pots were filled with soil at pH 6.95, 0.42 dS/cm salinity, 12.45% lime and 2.75% organic matter content. Following germination, each pot was equally fertilized with Hoagland nutrient solution at 10-day intervals. Once the seeds germinated, all pots were irrigated equally for a total of 14 days until the plants reached a sufficient size and water restriction was applied starting on January 21, 2022.

Two different water restrictions were applied to the Garden Cress plants (50% irrigation and 25% irrigation) in addition to the control plants (100% irrigation). The amount of irrigation water to be applied in the experiment was estimated gravimetrically (Jones, 2007). In order to determine the total moisture capacity of the pots, the pots with control treatments were saturated with water and left to drain under the force of gravity for 24 hours. During the growing period, plants were irrigated every three days. Control pots were weighed every three days, and water restriction was applied by taking into account the total evaporation amount from control plants.

Sample preparation and ultrasonic bath extraction

Extraction of samples was carried out using the ultrasonic bath (Daihan Scşentiic Co. Ltd., WUC-A03H, Korea) extraction method according to (Aznar-Ramos et al., 2022). Plant samples (1.00 g FW) were placed into glass homogenization vessels and 10 mL of extraction solvent (methanol) was added to each vessel. Next, the ultrasonic probe was inserted into the vessel and the extraction took place 1 hour at laboratory temperature (nearly 25°C).

Morphological parameters and leaf area

Leaf samples were weighed immediately after collection, and leaf areas were determined in cm2 using a CI-202 Portable Laser field meter (CID, Inc., USA). Leaf weights were measured using a digital balance (±0.0001 g) and diameter, length and petiole were measured using a digital caliper (±0.01 mm).

Leaf proportional water content

Proportional water content (PWC) of leaf samples were determined on the 15th day and after harvest. Initially, the leaves' fresh weights (VW) were measured, and after the leaves were kept in distilled water for 6 hours, their turgor weights (TW) were measured. Dry weights (DW) were determined after keeping the samples in a 65°C oven until their weights were constant. PWC was estimated in % using the following formula (Yamasaki and Dillenburg, 1999).

$$PWC\ (\%) = [(VW-DW) / (TW-DW)] \times 100$$

Chlorophyll content

The total amount of chlorophyll was prepared using 4 g of fresh plant leaves in 35 ml of 90% acetone solution. The samples were extracted with the ultrasonic probe extraction method Aznar-Ramos et al. (2022) for 1 hour and filtered with filter paper. The filtrate was completed to a 50 ml solution using 90% acetone. Absorbance readings were made at 645 nm, 652 nm and 663 nm wavelengths (Holden, 1976).

Proline content

In order to determine the internal proline amount, 0.5 g fresh weight of plant sample was crushed and mixed with 10 ml of 3% 5-Sulfosalicylic acid and the mixture was homogenized for 2 minutes. The resulting samples were filtered into tubes through Whatman No 2 filter papers. 2 ml of filtered sample, 2 ml of ninhydrin and 2 ml of glacial acid were added and reacted in a water bath set at 100 °C for 1 hour, followed by an ice bath. 4 ml of toluene was added to the reaction and the mixture was homogenized with a tube mixer for 15-20 seconds. The chromophore of the solution was aspirated with a fine-tipped pipette and taken into spectrophotometer tubes. The absorbance reading was taken from the spectrophotometer tubes at room temperature at 520 nm, where toluene was used as a blank sample (Bates and Waldren, 1973).

Determination of antioxidant activity

Antioxidant activity was determined using the DPPH free radical scavenging assays as described by (Brand-Williams et al., 1995; Ak and Türker, 2018). Briefly, different concentrations of cultivated Garden Cress plant extracts diluted with methanol were measured with DPPH after 30 minutes at room temperature. The absorbance of the samples was measured at 515 nm using a UV–vis spectrophotometer. The percentage of DPPH radical scavenging activity was estimated using the following equation:

$$DPPH\ scavenging\ (\%) = [(A_{control} - A_{sample}) / A_{control}] \times 100 \quad (1)$$

A_{sample} = the absorbance of the sample after reaching plateau after 15 min

$A_{control}$ = DPPH absorbance

IC_{50} inhibition values were estimated by taking into account 50% of the total DPPH radicals in the concentrations, where Lower IC_{50} indicated higher radical scavenging activity. In this test, butylated hydroxytoluen was used as a positive control.

Determination of total phenolic (TP)

The Folin-Ciocalteau method of Singleton and Rossi (1965) was employed to determine the total phenolic content of the Garden Cress extracts. 100 µl of extract, 900 µl of distilled water, 5 ml of 0.2 N Folin-Ciocalteau solution and 4 ml of 7.5% sodium carbonate solution were vortexed in test tubes. The samples were incubated for two hours at room temperature in the dark, and at 765 nm, absorbance values were measured. The Garden Cress samples' total phenol content is expressed as "mg GA^{-1}100g FW (fresh weight)".

Determination of total flavonoids (TF)

Total flavonoid concentrations of Garden Cress extracts were measured using an aluminum based colorimetric assay (Shraim et al., 2021). The test tubes were filled with 100 µl of extract, 100 µl of 1 M potassium acetate, 100 µl of 10% aluminum nitrate, and 4.4 ml of 96% ethanol, respectively. The samples were incubated for 40 minutes at room temperature in the dark, and the spectrophotometer read the absorbance values at 415 nm. The Garden Cress samples' total flavonoid content is listed as "mg $quercetin^{-1}$100 g FW (fresh weight)".

Flavor and appearance difference from control test

Differences between control and stressed Garden Cress samples in terms of flavor and appearance were determined. Leaf samples of the control (100%) and water stressed (50% and 25%) Garden Cress plants were presented to panelists (n=10). Panelists were informed that there was a blind test (control) among the test samples. Then panelists evaluated the test samples according to the differences in terms of flavor and appearance and scored from 1 to 10 as "Not Different" to "Extremely Different" (Shraim et al., 1999).

Consumer preference test

The sensory acceptability of the Garden Cress samples in terms of flavor, appearance, and general attributes was investigated with 61 participants (36 women and 25 men) aged 20 to 52 using a 7-point hedonic scale (7 = like extremely and 1 = dislike extremely) (Kiremit et al., 2023).

Statistical analyses

Statistical differences of the measured parameters among different irrigation levels of the cultivated Garden Cress plant were estimated using One-Way ANOVA the Tukey Multiple Comparison test, where p-value of <0.05 was considered to be statistically significant. Minitab 19 was used as a software for the statistical analysis.

Results and Discussion

Each trial subject was equally irrigated with 732 ml of water for a total of 14 days until all plants formed 4 true leaves before applying water restrictions. The amount of water applied during the cultivation period is given in Table 1. During the experiment, the control pots were irrigated with a total of 5170 ml of water. Pots with 50% water treatment were irrigated with a total of 2598.5 ml water and those with 25% water treatment were irrigated with one fourth of the total amount applied to control plants, corresponding to a total of 1299.25 ml of water.

Table 1. The amount of water applied per irrigation

Treatment	1	2	3	4	5	6	7	8	9	10	Total
Control	334	354	368	450	456	572	620	620	716	707	**5197.00**
50% irrigation	167	177	258	225	228	286	310	310	358	354	**2598.50**
25% irrigation	83.5	88.5	110	112.5	114	143	155	155	179	177	**1299.25**

The average leaf weight, length, width and area, and stem length measured at the end of the research are given in Table 2. According to this table, the study results showed that water constraint has statistically significant effects on the yield and quality parameters of Garden Cress. When the leaf weight, length and width, and stem length values are examined, it can be seen that the decrease of these values in line with increased water stress is statistically significant.

A study carried out by Kiremit et al. (2023) investigating the yield, growth traits and leaf nutrients of the Garden Cress under water and salinity deficiency, similarly, found that the leaf fresh weight, leaf dry weight and leaf area decreased statistically significantly under increased water stress. Another study conducted on 7 different Garden Cress cultivars in the open field, Yanmaz et al. (2010) determined the leaf lengths and widths between 6.5-12.9 cm and 3.3 to 7.6 cm, respectively. It can be seen that the results of this study, which we conducted in a controlled atmospheric setting, are similar to the above mentioned field study (Table 2). Furthermore, in this study, the average leaf area decreased significantly with increased water stress, similar to the other parameters. While the highest leaf area was obtained from plants in control pots with an average of 415.6 cm^2; it was measured as 256.3 cm^2 in pots with 50% water stress and 127.3 cm^2 in pots with 25% water stress, with each treatment falling into a separate statistical group.

Table 2. Average leaf weight, length, width and area, and stem length values based on the level of water stress

Treatment	**Leaf weight (g)**	**Leaf length (cm)**	**Leaf width (cm)**	**Leaf area (cm^2)**	**Stem length (cm)**
Control	0.931 ± 0.059 A	10.35 ± 0.342 A	4.31 ± 0.102 A	415.6 ± 35.9 A	7.035 ± 0.082 A
%50 irrigation	0.456 ± 0.034 B	7.425 ± 0.347 B	3.47 ± 0.076 B	256.3 ± 21.5 B	4.870 ± 0.379 B
%25 irrigation	0.274 ± 0.030 C	5.495 ± 0.278 C	2.76 ± 0.148 C	127.3 ± 11.4 C	4.265 ± 0.182 B
p value	0.000	0.000	0.000	0.000	0.000

***Results were expressed as mean ± std dev. Means with different letters are significantly different at p values shown in the same column.**

The amount of dry matter, pH, brix, hue and chroma values obtained at the end of the research are provided in Table 3. A statistically significant increase in the amount of dry matter was detected with the decrease in the amount of irrigation water. Uyar et al. (2013) examined dry matter in eight commonly used herbs. Among the plants they evaluated, they determined the amount of dry matter of the Garden Cress as 6.97%. In this study, while similar results were obtained from the control treatments, percent of dry matter increased with increasing water restriction. Considering the pH values, there was not a statistical significance among different water treatments. In the study conducted in greenhouse conditions by Demir and Polat (2017) the pH values of the Garden Cress cultivated in autumn were between 6.01 and 6.17 those cultivated in spring were between 5.27-5.68. In our study, the temperature was kept constant at 25^0C under controlled atmospheric conditions. When the greenhouse temperatures in the spring period are evaluated, the given pH values are similar to our study. Brix amount showed similarity with dry matter values and increased with decreased water treatment. When the leaf color was evaluated, there was no statistical difference in Hue values, which indicate the color we perceive, among different water treatments. When chroma, known as color intensity or clarity value, was evaluated, however, the control plants and plants with 50% irrigation showed statistical similarities with each other. Statistical similarity was also determined among the two test subjects treated with water restriction (Table 3).

Table 3. Dry matter, pH, brix, hue and chroma values based on the level of water stress

Treatment	**Dry matter (%)**	**pH**	**Brix**	**Hue**	**Chroma**
Control	6.058 ± 0.42 B	5.73 ± 0.01	2.90 ± 0.13 C	-0.90 ± 0.01	18.83 ± 1.01 A
50% irrigation	7.359 ± 0.31 B	5.70 ± 0.03	3.50 ± 0.13 B	-0.89 ± 0.02	17.33 ± 0.99 AB
25% irrigation	9.545 ± 0.57 A	5.68 ± 0.02	4.45 ± 0.05 A	-0.87 ± 0.01	14.57 ± 0.66 B
p value	0.001	ns	0.000	ns	0.025

*Results were expressed as mean ± std dev. Means with different letters are significantly different at p values shown in the same column. ns: not significant

The changes in the chlorophyll and proline values based on the amount of water applied to the plants are shown in Table 4. Statistical differences were found in all parameters except the chlorophyll a value. As the amount of water restriction increased, chlorophyll cells per unit area (chlorophyll b and total chlorophyll) increased. When we consider the decrease in leaf area, however, it can be said that the amount of chlorophyll in the control plants were higher than the other treatments. Chlorophyll is essential in the process of photosynthesis and is responsible for vegetative growth (Mohamed et al., 2020). Decreased chlorophyll a and b in plant leaves may also affect photosynthetic performance, which may reduce plant growth (Ehsan et al., 2014). The increase in the amount of chlorophyll with water stress, therefore, can also increase the photosynthetic ability of the plant, ensuring the prolongation of the plants' life span and the continuation of their biochemical synthesis. When we look at our research results, it can be seen that both the chlorophyll a and chlorophyll b values obtained from the control plants were the lowest. It can be said that this is due to the fact that the control plants have larger leaf area, and thus, the chlorophyll value per unit area is lower. The increase in chlorophyll values in line with increased water stress, therefore, is thought to be due to more chlorophyll cells per unit area together with decreased leaf area.

In this study the total chlorophyll content increased from 59.89 to 69.61 $mg^{-1}ml$ with increased water stress, in which the difference was statistically significantly. Similarly, Singh et al. (2020), applied three levels of water stress on the Garden Cress under controlled temperature and light conditions. They found that the total chlorophyll content ranged from 36.656 and 44.030 $mg^{-1}g$ and increased with increased water stress.

Table 4. Chlorophyll and proline values based on the level of water stress

Treatment	**Chlorophyll a ($mg^{-1}ml$)**	**Chlorophyll b ($mg^{-1}ml$)**	**Total chlorophyll ($mg^{-1}ml$)**	**Proline ($g^{-1}100g$ FW)**
Control	22.99 ± 0.12	30.53 ± 1.59 B	59.89 ± 1.15 B	5.98 ± 0.20 C
%50 irrigation	23.13 ± 0.68	44.69 ± 1.66 A	67.55 ± 2.00 A	24.72 ± 1.27 B
%25 irrigation	23.83 ± 0.51	46.20 ± 1.62 A	69.61 ± 1.64 A	36.72 ± 1.20 A
p value	ns	0.000	0.005	0.000

* Results were expressed as mean ± std dev. Means with different letters are significantly different at p values shown in the same column. ns: not significant

When plants are exposed to stressful conditions, they accumulate a number of metabolites, especially amino acids (Giordano et al., 2021). Proline is an amino acid known to play a very beneficial role in plants that are exposed stress conditions (Hayat et al., 2012). Considering the results of the research (Table 4), it was determined that proline was synthesized 5-6 times more with water restriction. Escalante-Magaña et al. (2019) also found that proline concentration increased statistically significantly with increased water stress when compared to control plants in pepper species (*Capsicum* sp.).

In trials conducted with Garden Cress, Painuli et al. (2022) reported that the amount of proline in normal growing conditions as 5.84 $g^{-1}100g$ and Zia-Ul-Haq et al. (2012) stated that the amount of proline was 4.63 $g^{-1}100g$. The amount of proline in the control plants of this research is similar to these results. Proline was found to be 24.72 and 36.72 $g^{-1}100g$ FW in this experiment in which 50% and 25% irrigation was applied, respectively (the difference was statistically significant at $p<0.05$). As a result, it can be said that the Garden Cress plant significantly increases the amount of proline with increased water stress.

Total phenolic compound (mg $GA^{-1}100g$), total flavonoid (mg $QE^{-1}100g$) and antioxidant (% inhibition) values obtained from the research are given in Table 5. According to the FW results, the total phenolic compounds decreased and the total flavonoids increased in the water stressed Graden Cress plants. These changes, however, were not statistically significant. Al-Huqail et al. (2019) also investigated the change in the total phenolic compound and the total flavonoid content in the Sweet Basil plant (*Ocimum basilicum* L.) with increased water stress. In this study, while total phenolic compounds increased, the total flavonoids decreased in DW plants with increased water stress.

Antioxidants are synthesized by plants because they play a role in minimizing the harmful effects of oxidative stress (Seyhan, 2019). In order to understand the effects of water stress on the antioxidant properties of the Garden Cress plant, the radical scavenging power of the plants subjected to different levels of stress were determined using the DPPH method. When using this method, low IC_{50} values reflect high antioxidant activity (Abdel-Aty et al. 2019). The highest radical scavenging effect (5.69%) occurred in plants exposed to severe water stress; the lowest effect (7.21%) was obtained from control plants that were not subjected to water stress. Erken (2022) has also stated that DPPH radical scavenging power increases as the severity of water stress increases. Malar et al. (2014) found the percentage of free radical activity to be 2.69% on the stem, 10.21% on the leaf, 11.63% on the seed and 12.19% on the shoots with different ethanolic extracts of *L. sativum*. The DPPH radical scavenging power determined using the same method in our research provides similar results in the leaves.

Table 5. Total phenolic content (TP), total flavonoid (TF) and radical scavenging activity (DPPH) based on the level of water stress

Treatment	TP (mg GA^{-1}100g FW)	TF (mg QE^{-1}100g FW)	DPPH (% inhibition)
Control	68,04 ± 24,97	8,35 ± 1,86	7.21 ± 0.09 A
50% irrigation	61,26 ± 21,67	11,70 ± 3,64	6.51 ± 0.05 B
25% irrigation	63,05 ± 8,39	11,55 ± 3,25	5.69 ± 0.06 C
p value	ns	ns	0.000

*Results were expressed as mean ± std dev. Means with different letters are significantly different at p values shown in the same column. ns: not significant.

The highest total phenolic substance was obtained from the control subject with 68.04 mg GA^{-1}100g FW. Although phenolic substance accumulations decreased by approximately 5-7 mg GA^{-1}100g FW as a result of water restriction, it was found to be statistically insignificant. Sat et al. (2013) determined the phenolic content of phenolic compounds between 0.573-0.774 mg GA^{-1}g DW in a Garden Cress study they conducted in Turkey in 2013.

The total flavonoid in the Garden Cress varied between 8.35-11.70 mg QE^{-1}100g FW among all treatments, which was found to be statistically insignificant. Phenolic compounds and flavonoids, which are among the important phytochemicals, are among the substances that reduce the risk of cancer Rudzińska et al. 2023). It is stated that even a 5-6 day-old fresh Garden Cress sprouts have high antioxidant properties (Abdel-Aty et al., 2019). The presence of high antioxidant substances in the Garden Cress has an important role in human nutrition.

Effects of water stress on sensorial differences and liking scores

Effects of water stress on sensorial perception, based on difference from control test in terms of flavor and appearance can be seen in Table 6. The scores of the control group as a blind control show variance among panelists. The fact that the p-value of the control scores is lower than 0.05 indicate that the panelists successfully noticed the control group among the test samples. The flavor score of the control group was 0.8, showing that the panelists had a high ability to distinguish the control group, especially in terms of flavor. When the results are evaluated in terms of water stress, it was determined that the effect of stress on flavor was significant ($p<0.05$) and there was no significant difference between 50% and 25% irrigation treatments $p>0.05$). Panelists expressed the effect of water stress as “moderate different” in terms of both sensory characteristics (flavor and appearance).

Table 6. Differences of water stressed plants from control in terms of flavor and appearance attributes

Treatment	Flavor	Appearance
Control	0.8a	2.8
50% irrigation	5.2b	4.2
25% irrigation	4.4b	4.6
±SE	0.83	1.05
p	0.0019	0.459

*Results were expressed as mean values, statistically significant at $p<0.05$

The effect of water stress on the consumer liking of the plants has been provided in Table 7. The effect of water stress was statistically significant in terms of flavor and overall acceptability ($p<0.05$). In terms of flavor, 50% water stressed plants had the highest score with an average of 4.87 and were in the “liked” part of the hedonic scale. The control group and 25% irrigation group were included in the “neither liked nor disliked” part of the hedonic scale. General acceptability scores show that there is no significant difference between the plants applied with 50% water stress and the control group. When the taste, appearance and general acceptability scores are evaluated collectively, the most preferred product by the consumers was found to be those irrigated with 50% water stress. It is common knowledge that a product’s sensory attributes have a substantial influence on consumer decision-making. So, these results ensure that 50% water stress application in agricultural production will positively affect consumer preferences for the Garden Cress. Similar to these results, (Keutgen et al., 2021). Investigated how the sensory quality of cress microgreens were affected by soilless growth systems modified with various mineral nutrition loads. They reported that the microgreens with the highest mineral content in the nutrient solution were rated as having the highest consumer acceptance in terms of visual appearance and total flavor impression.

Table 7. Consumer liking scores of the control and water stressed Garden Cress samples

Treatment	Flavor	Appearance	General Acceptability
Control	4.24a	4.92	4.72ab
50% irrigation	4.87b	5.16	4.98a
25% irrigation	4.33a	4.68	4.37b
±SE	0.18	0.17	0.16
p	0.025	0.14	0.025

*Results were expressed as mean values. Means with different letters are significantly different at p values shown in the same column.

Cano-Lamadrid et al. (2023) have explained that the overall acceptability of the microgreens of some species such as brassica were negatively linked with sourness, bitterness, and astringency. Likewise, the lower acceptability of the 25% irrigated Garden Cress plants in our study might be a result of the increased bitterness due to less water content in the water stressed leaves.

Conclusions

Increasing drought and decreasing water resources are among the biggest problems that have been experienced in recent years that directly affect agricultural production. For this reason, researchers have been conducting various studies in order to mitigate the effects of drought and to more efficiently use limited water resources. Garden Cress is an herb among the medicinal and aromatic plants of the Brassicaceae family, which is used both for medicinal purposes and as food. In this study, it has been determined that some biochemical parameters, total chlorophyll, proline and antioxidants, increased with water stress in Garden Cress leaves. Despite the increase in these substances, the decrease in yield with water stress is important in terms of agricultural production.
Loss of yield and biochemical changes have been determined in many different crops in drought and water constraint studies previously carried out. When 50% water restriction is applied to Garden Cress, approximately half of the yield is lost. When the water constraint increases further, the yield decreases to one quarter of that of the control plants. Despite the loss in yield, substances such as antioxidants, phenolic compounds and flavonoids that strengthen the immune system in humans were found to increase with water stress in this study. While the increase in phenolic compounds and flavonoids, however, was found not to be statistically significant, the increase in the antioxidant values was found to be statistically significant.

Despite the decrease in yield and increase in some components important for human health, there was no study on whether Garden Cress will be preferred by consumers with increased water stress. In this study, some morphological and biochemical changes that occur in Garden Cress with water stress and their consumers preference were determined. As a result of the tasting tests, it was seen that the majority of the consumers preferred the Garden Cress grown by applying 50% water restriction. It has been determined that against the threat of increasing global warming and climate change, in cases where 50% water saving is applied during the cultivation of Garden Cress, the product will still be preferred by the consumer in terms of flavor, appearance and general acceptability.

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