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Water Deficit Affects Growth, Physiology and Some Quality Parameters of Cress

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Abstract

One of the important issues limiting crop growing in agricultural areas is drought. The study was conducted to evaluate the impacts of irrigation levels on growth and quality characteristics of cress. In the study, cress (Lepidium sativum L.) seeds were planted in 26 L pots and 4 different irrigation levels (100%, 85%, 75%, 55%) were applied according to field capacity at sowing. 36 days after sowing, the plants were harvested and the growth, antioxidant enzyme activity, chlorophyll content, hydrogen peroxide (H_2O_2), malondialdehyde (MDA), proline and sucrose content were investigated. Significant differences occurred between the applications and doses in terms of the parameters examined. At the end of the research, it was determined that the decrease in irrigation level significantly reduced plant growth and chlorophyll content in cress. Lower irrigation levels elevated the H_2O_2, MDA, proline and sucrose content of cress. Irrigation levels affected plant growth and quality in cress significantly, but there was not much change in plant growth at 85% irrigation level compared to 100% irrigation level. In the study, it was concluded that at the point of efficient use of existing water resources, 15% water savings can be produced with the same yield and higher nutrient content in terms of plant production.

Keywords

Cress, Drought stress, Water deficit, Yield, Quality

Su KısıtınınTerede Büyüme, Fizyoloji ve Bazı Kalite Parametrelerini Etkilemesi

Özet

Tarımsal alanlarda bitkisel üretimi sınırlayan önemli problemlerden biri de kuraklıktır. Bu çalışma, farklı sulama düzeylerinin terede bitki gelişimi ve kalite üzerindeki etkilerini belirlemek amacıyla yapılmıştır. Çalışmada tere (Lepidium sativum L.) tohumları 26 L'lik saksılara ekilmiş ve ekim ile birlikte tarla kapasitesine göre 4 farklı sulama seviyesi (%100, %85, %75, %55) uygulanmıştır. Ekimden 36 gün sonra bitkiler hasat edilmiş ve bitki büyüme parametreleri incelenmiştir. Antioksidan enzim aktivitesi, klorofil içeriği, hidrojen peroksit (H_2O_2), malondialdehit (MDA), prolin ve sakkaroz içeriği gibi parametreler incelenmiştir. İncelenen parametreler açısından uygulamalar ve dozlar arasında önemli farklılıklar meydana gelmiştir. Araştırma sonunda sulama seviyesindeki azalmanın tere bitki büyümesini ve klorofil içeriğini önemli ölçüde azalttığı belirlenmiştir. Kuraklık stresinin terede H_2O_2, MDA, prolin ve sakkaroz içeriği ile antioksidan enzim aktivitesini arttırdığı belirlenmiştir. Çalışmada, sulama düzeylerinin terede bitki gelişimini ve kalitesini önemli ölçüde etkilediği ancak %85 sulama düzeyinde %100 sulama düzeyine göre bitki büyümesinde çok fazla bir değişim olmadığı belirlenmiştir. Çalışmada, mevcut su kaynaklarının verimli kullanılması noktasında bitkisel üretim açısından %15 oranında su tasarrufu ile aynı verim ve daha yüksek besin içeriği sağlanabileceği sonucuna varılmıştır.

Anahtar Kelimeler

Tere, Kuraklık stresi, Su kısıtı, Verim, Kalite

1. INTRODUCTION

Drought is a global climate event that occurs in direct proportion to the precipitation being lower than the average for many years and that occurs at any time and in any place. It directly and indirectly affects every aspect of living life, including the environment, urban life, economy, technology, water resources, health and agriculture (Kapluhan, 2013).

70% of the clean water in the world is used for agricultural irrigation. It is predicted that in the future, water scarcity will gradually increase and irrigated farming opportunities will decrease. In order to be able to produce with decreasing resources, limited irrigation methods are gaining importance as an alternative to the full irrigation methods currently used in plants. Drought is one of the stress factors that most affect agricultural areas and prevents plant growth in arid and semi-arid areas (Blum, 1986; Rao et al., 2006; Gerçek et.al.2017). The stunned growth caused by drought stress is the loss of turgor with the loss of water in plant cells (Levitt, 1980). With water deficit, plant water potential and turgidity decrease and plant cells become unable to perform their normal functions (Rahdari and Hoseini, 2012). With the closure of plant stomata in drought, transpiration decreases and photosynthesis is adversely affected (Cowan, 1982). Drought stress causes negative impacts on many parameters in plants. Peroxidation of lipids in the membranes leads to an increase in MDA content and reactive oxygen species (ROS) (Kuşvuran et al., 2020). In addition, as a result of water deficit, it causes an increase in antioxidant enzyme activities such as peroxidase (POD), catalase (CAT) and superoxide dismutase (SOD) (Hayat et al., 2008). In plants under drought conditions, growth and development may be affected due to cell division, elongation and differentiation as a result of loss of turgor, deterioration in enzyme activities and decrease in energy resulting from photosynthesis (Ding et al., 2013; Osakabe et al., 2014). The responses of the plants in the case of drought vary according to the severity of the stress and the duration of the stress, and the plant's responses after the stress is relieved are very important (Zlatev and Lidon, 2012). Irrigation is at the forefront of the indispensable basic principles in terms of economic vegetable production. Vegetables, like all plants, always need water, which is one of the most important factors that form the basis of the sustainability of physiological events for both vegetative and generative growth and development. The plants close their stomata in their leaves to prevent water loss as a physiological defense mechanism as a result of short-term exposure to drought stress. As a result of long periods of drought, permanent damage occurs to plants and eventually death occurs in tissues and plants (Ekinci et al., 2015).

Cress (Lepidium sativum L.) is one of the annual vegetable species whose leaves are consumed in the Cruciferae family. Irrigation is important in leafy vegetable species such as cress, and water deficit less than the plant needs causes significant changes. Cress is a very rich plant species in terms of B6 and folate, especially vitamin C. It is also very rich in mineral substance content such as potassium, iron and calcium. In many previous studies, it has been determined that especially the vegetable species whose leaves are consumed are very sensitive to drought stress, and low irrigation levels adversely affect yield and quality (Mohamoud, 2019; Yavuz et al., 2021; Chaski and Petropoulos, 2022; Kiremit et al., 2023). In a study, the applications were made with varying irrigation intervals of 5, 10 and 15 days and spraying the plants with different concentrations of exogenous proline (1, 5 and 10 mM). According to the results obtained from the research, it was observed that plant growth and yield parameters decreased as the water stress time increased. Significant increases occurred in proline content and percentage of total carbohydrates. There was also an increase in oil content under moderate stress and a decrease with increasing drought severity (Khalil and El-Noemani, 2012).

As it is known, irrigation is the most important input in both increasing the yield and improving the yield in plant production. The demand for water resources, which is decreasing with the increase in the world population and the effects of global warming, is increasing day by day. Usable water resources are decreasing. The largest user of freshwater resources is the agricultural sector. Therefore, it has become a necessity to increase the efficiency of water used in agriculture. In this study, it was aimed to evaluate the effect of irrigation levels on plant growth and quality of cress.

2. MATERIALS AND METHODS

This study was carried out under natural daylight conditions in the greenhouses and the temperature and photoperiod values were determined as approximately 25 ºC - 18/6 (day/night). Garden cress (Lepidium sativum L. cv. Bu Ter) flat-leaved cultivar seeds were planted in 26-liter pots prepared with a mixture of sand, soil and peat. The pots were prepared by mixing soil: sand: peat in a ratio of 2:1:1 (v:v:y). Sowing was carried out in three rows at a depth of 1 cm, with 50 seeds per row. After planting was completed, the pots were randomly placed on the benches in the greenhouse. Emergence started 3 days after sowing.

The amount of irrigation water to be given to the plants and the amount of moisture in the pots were determined on a volume basis using a portable moisture meter. After the field capacity of the pots is determined, water deficit applications were made as fallow; 100% (D0), 85% (D1), 75% (D2) and 55% (D3) of field capacity, and field capacity was determined regularly according to the average greenhouse interior temperature (min. 15,2 ºC, max. 26,2 ºC) and irrigation continued with an average of 2-3 days. Irrigation applications started with the seed planting process and 14 applications were made, was continued until the plants were harvested 36 days after sowing.

To evaluate the impacts of the irrigations on cress plants, some measurements, weighing and observations were carried out. In the study, plant fresh weight (PFW), plant dry weight (PDW), root fresh (RFW) and dry weight (RDW), leaf area (LA), LRWC, chlorophyll analysis, H_2O_2, antioxidant enzyme analysis (CAT, POD, SOD), MDA, sucrose, and proline amounts were determined using the following methods.

2.1. Leaf relative water content (LRWC)

Calculated according to the formula (LRWC = [(FW – DW) / (TW – DW)] x 100) specified by Kaya et al. (2003).

2.2. Chlorophyll content

The chlorophyll amounts of the samples taken from the leaf samples were measured spectrophotometrically (Multiskan GO Microplate Spectrophotometer) as a spectrophotometer in the laboratory at 645 nm and 663 nm wavelengths and calculated as mg/g on a fresh weight basis (Joshi et al., 2013).

2.3. Antioxidant enzyme analysis

In the study, an extraction process of Angelini and Federico (1989) and Angelini et al. (1990) was used. In addition, CAT (catalase), POD (peroxidase) and SOD (superoxide dismutase) activity were determined. Results were expressed as enzyme units per leaf (eu/g leaf) of each enzyme activity (Angelini et al., 1990; Agarwal and Pandey, 2004; Gong et al., 2000; Havir and Mchale, 1987; Yordanova et al., 2004).

2.4. Hydrogen peroxide (H_2O_2)

The analysis of H_2O_2 was made according to the method specified by Ozden et al. (2009).

2.5. Malondialdehyde (MDA)

MDA were determined according to Zhang et al. (2009). The absorbance of the sample taken from the mixture was read in the spectrophotometer at 450, 532 and 600 nM.

2.6. Proline

In the determination of proline using the method used by Bates et al. (1973), the absorbance of a sample taken from the mixture was read in a spectrophotometer to determine the amount of proline.

2.7. Sucrose

The sucrose ($C_{12}H_{22}O_{11}$) concentration was measured using the method specified by Chopra et al. (2000).

2.8. Statistical analysis

Randomized plot experimental design was used in the study and the data obtained as a result of the study were analyzed by using the SPSS package (Statistical Package for the Social Sciences) program, and the difference between the means was determined by Duncan multiple range tests.

3. RESULTS AND DISCUSSION

In this study, water deficit applications at different irrigation levels (100%, 85%, 75% and 55%) in cress plant were investigated in terms of height, stem diameter, chlorophyll, LA, PFW, PDW, RFW, RDW, LRWC, SOD, POD and CAT activity, MDA, H_2O_2, sucrose and proline content.

It was determined that water deficit levels significantly reduced weight of root and aerial parts of the cress (Table 1). The decrease in PFW, PDW, RFW and RDW was the highest with D3 compared to D0 application, with the rates of 72%, 62%, 54% and 61%, respectively. In addition, height, diameter and LA decreased in parallel with the increasing water deficit (Table 2). In these parameters, compared to the control (D0), there was a decrease of 1%, 3% and 3% with D1 application, however, there was a decrease of 40%, 47% and 65% (respectively) with the most severe water deficit (D3). Drought negatively influences plant growth by inhibiting various physiological and biochemical processes (Bahreininejad et al., 2013). Similar to our work; four different irrigation levels (100%, 10%, 30% and 50% of field capacity) were applied in the study in which the responses of two flat-leaved and curly-leaved parsley cultivars (Petroselinum crispum L.) to drought stress were investigated. It was determined that water deficit applications decreased the yield in plants depending on the severity of water stress, but water stress relatively improved some quality parameters in both cultivars (Najla et al., 2012).

Table 1. Effects of different irrigation levels on plant fresh, plant dry, root fresh and root dry weight of cress

Irrigation	Plant fresh weight (g)	Plant dry weight (g)	Root fresh weight (g)	Root dry weight (g)
D0	1,55 a	0,13 a	0,13 a	0,018 a
D1	1,53 a	0,12 a	0,11 b	0,015 b
D2	0,82 b	0,08 b	0,07 c	0,009 c
D3	0,43 c	0,05 c	0,06 d	0,007 c

D0: irrigation with field capacity (%100), D1: irrigation of 85% of field capacity, D2: irrigation of 75% of field capacity, D3: irrigation of 55% of field capacity. Means given by same letter in the same column are not significantly different at the 5% level

Table 2. Effects of different irrigation levels on LRWC, plant height, stem diameter and leaf area of cress

Irrigation	LRWC	Plant height (cm)	Stem diameter (mm)	Leaf area (cm^2/plant)
D0	81,36 a	12,00 a	1,48 a	44,61 a
D1	74,75 b	11,83 a	1,43 a	43,15 a
D2	67,88 c	9,72 b	1,04 b	23,49 b
D3	59,61 d	7,17 c	0,79 c	15,73 c

D0: irrigation with field capacity (%100), D1: irrigation of 85% of field capacity, D2: irrigation of 75% of field capacity, D3: irrigation of 55% of field capacity. Means given by same letter in the same column are not significantly different at the 5% level

Drought led to a decrease in the cress tissue relative water content (LRWC) (Table 2). Compared to the control, LRWC decreased by 8% with D1 application, 17% with D2 application and 25% with D3 application. Low irrigation levels reduce the LRWC value in plants and damage the cell membrane (Villar-Salvador et al., 2004). In a study on changes in relative water content (RWC), water relations, stomatal conductivity, leaf area and various physiological parameters of marjoram (Origanum majorana) under drought stress conditions, it was found that as water stress increased, essential oil content, total lipids, dry weight, leaf area and leaf area decreased (Rhizopoulou et al., 1991).

According to the results obtained from our study, chlorophyll a, chlorophyll b, total chlorophyll amount and leaf area decreased in cress in low level irrigations and this decrease is 32%, 28% and 31% with D3, respectively (Table 3). Since photosynthetic systems are very sensitive in plants exposed to drought stress, damage occurs primarily in these structures. This causes a decrease in the chlorophyll content (Hua et al., 2012). Other studies also support the results obtained. It was stated that the amount of chlorophyll a, b, total chlorophyll and carotenoids in the Savrun spinach variety were found to be lower in drought application compared to the control (Turfan, 2017). There are many studies on the reduction of chlorophyll amount in plants by water stress in arid conditions (Sahin et al., 2018).

Table 3. Effects of different irrigation levels on chlorophyll a, chlorophyll b and total chlorophyll content of cress

Irrigation	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)
D0	3,58 a	1,50 a	5,08 a
D1	2,94 b	1,27 b	4,21 b
D2	2,55 c	1,06 c	3,61 c
D3	2,42 c	1,08 c	3,50 c

D0: irrigation with field capacity (%100), D1: irrigation of 85% of field capacity, D2: irrigation of 75% of field capacity, D3: irrigation of 55% of field capacity. Means given by same letter in the same column are not significantly different at the 5% level

According to the results of the study, H2O2 and MDA accumulation, proline and sucrose content in cress increased at low irrigation levels (Figure 1). While the increase in H2O2, MDA, proline and sucrose content with D1 application (85% of field capacity) was 12%, 70%, 33% and 35%, respectively, in the most severe water deficit (D3), the increase in these parameters was 78% 86%, 33% and 148%, respectively. Drought stress usually triggers oxidative stress due to the accumulation of reactive oxygen species (ROS) in plant cells. The stress-induced increase in free radicals may be partially related to lipoxygenase activity. Further damage to the fatty acid can produce small fragments of hydrocarbons, including MDA. Drought stress causes damage to cell membranes, causing ions to leak out of the environment. Determining the amount of leakage of these solutions as a result of stress applications allows the detection of tissue damage (Maldonado et al., 1997). Similar to our study, drought stress increases the amount of MDA in wheat (Naveed et al., 2014). The accumulation of MDA and H2O2 increased in cress under high temperature stress, while the anthocyanin, carotenoids and protein content decreased. It has been determined that this situation causes oxidative stress and tissue damage due to the high temperature conditions of the plant (Al-Sammarraie et al., 2020). In another study conducted in parallel with our findings, it was determined that water deficit decreased plant growth, photosynthetic activity and stomal conductivity, while MDA content and electrical conductivity increased in Solanum scabrum, an edible leafy vegetable. In addition, it has been suggested in the study that high mineral and proline content under stress conditions may reduce the damage of stress by contributing to the osmotic regulation of plants (Assaha et al., 2016). Similarly, in studies on different plant species; it was determined that the proline content of plants grown under stress in arid regions increased (Ghoulam et al., 2002; Girija et al., 2002).

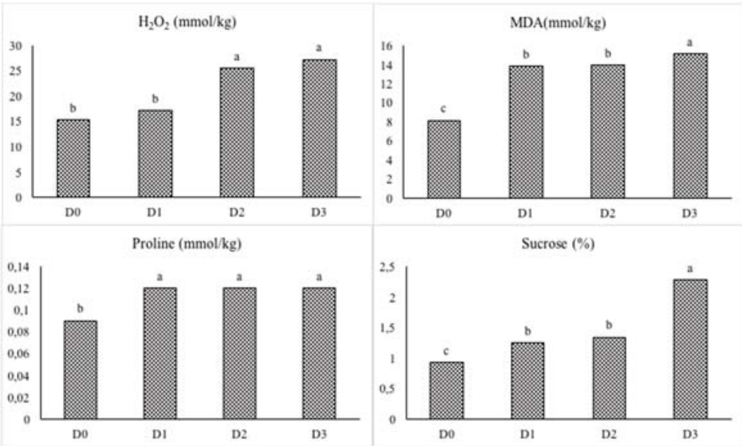

Figure 1. Effects of different irrigation levels on H2O2, MDA, proline and sucrose content of cress. D0: irrigation with field capacity (%100), D1: irrigation of 85% of field capacity, D2: irrigation of 75% of field capacity, D3: irrigation of 55% of field capacity. Means given by same letter on the bars are not significantly different at the 5% level

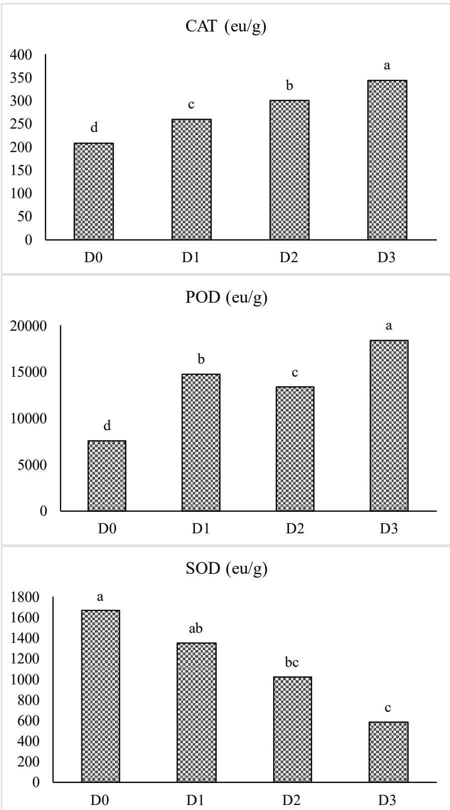

Figure 2. Effects of different irrigation levels on CAT, POD and SOD content of cress. D0: irrigation with field capacity (%100), D1: irrigation of 85% of field capacity, D2: irrigation of 75% of field capacity, D3: irrigation of 55% of field capacity. Means given by same letter on the bars are not significantly different at the 5% level

The results from the study indicated that POD and CAT activity increased, while SOD activity decreased due to drought stress (Figure 2). Plants develop tolerance to stress factors with enzymatic antioxidant protective systems. While the main task of non-enzymatic antioxidant molecules is to protect the photosynthetic cell membrane, enzymatic antioxidant molecules prevent their accumulation by reducing ROS (Farooq et al., 2009; Osakabe et al., 2014; Dolferus, 2014). Drought stress creates osmotic stress in plant cells. The production of harmful compounds (ROS) such as H2O2 increases due to drought stress. These ROS negatively influence cellular structures and metabolism (Bartels and Sunkar, 2005).

4. CONCLUSION

Irrigation is one of the most important inputs in agricultural production, both in increasing the yield and in diversifying the plant pattern. In concluded increasing water deficit negatively, affected plant growth and development in cress. On the other hand, it was concluded that at the point of efficient use of existing water resources, 15% water savings can be produced with the same yield and higher nutrient content in terms of plant production.

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