HortiS (2025) 42(2):51-56
http://doi.org/10.16882/HortiS.1663801

HORTICULTURAL STUDIES

RESEARCH PAPER

Changes in Morpho-Physiological Characteristics of Melon (*Cucumis melo* L.) Seedlings under Different Levels of Drought Stress

Gamze KAYA[1]

[1] Bilecik Şeyh Edebali University Agriculture and Natural Sciences Faculty Horticulture Department, 11230, Bilecik, Türkiye

Article History
Received 28 November 2024
Accepted 23 March 2025
First Online 17 April 2025

Corresponding Author
E-mail: pascalcik@hotmail.com

Keywords
Abiotic stress
Chlorophyll content
Electrolyte leakage
PEG-6000
Water deficit

Abstract

Drought stress is one of the most common abiotic stresses that negatively affects crop production. The purpose of this study was to determine the morpho-physiological characteristics of melon plants in response to increasing levels of drought stress induced by different polyethylene glycol (PEG-6000, molecular weight 6000) concentrations. Melon cultivar 'Kırkağaç 589' seedlings with a 2 true-leaf stage were grown in a growth medium containing peat: perlite: vermiculite (6:1:1, by volume) mixed with 5%, 10%, 15%, and 20% PEG-6000. Thirty days after drought treatment, plant height, stem diameter, fresh and dry weight, dry matter, leaf area, leaf temperature, chlorophyll content (SPAD), relative water content, turgor loss, and electrolyte leakage were measured. The findings indicated that as the severity of the drought increased, there was a notable decline in plant height, fresh weight, dry weight, and relative water content. In contrast, drought stress led to increased dry matter, leaf temperature, chlorophyll content, electrolyte leakage, and turgor loss. The plant height and fresh weight were particularly susceptible to drought stress, with significant inhibition observed even at a concentration of 5% PEG. Compared to the control, the relative water content decreased from 81.3% to 69.0%, while electrolyte leakage increased from 20.9% to 27.2%. It was concluded that electrolyte leakage serves as an indicator of drought stress and that the drought severity of 10% PEG should be regarded as the critical level for melon plants at the seedling growth stage.

1. Introduction

Melon (*Cucumis melo* L.), a member of the Cucurbitaceae family, is a vegetable plant with a variety of plant growth habits, fruit shape, size, and color. They can adapt to various soil and climatic conditions in open fields and greenhouses (Vural et al., 2000). In Türkiye, the total sowing area of melon was 55.000 ha, with a fruit production of 1.4 million tons in 2023 (Anonymous, 2024). It is an important plant for crop rotation in the Central Anatolian region because of its tolerance and high adaptation ability to drought under rainfed conditions.

Abiotic stresses, including drought, salinity, extreme temperature, and heavy rainfall have adversely affected plant growth and productivity (Yang et al., 2021). Drought stress is an ordinary situation in arid and semi-arid regions with insufficient rainfall. In drought-stress conditions, the life cycle of plants, from germination to harvest, is constrained (Adıgüzel et al., 2023; Kaya, 2024). This leads to delayed or inhibited germination, emergence, seedling growth, plant development, and reduced yield, which are affected by some physiological processes (Seleiman et al., 2021). Similarly, drought affects the morphological and physiological characteristics of the melon plant, leading to a reduction in fruit yield (Akhoundnejad and Dasgan, 2020; Astaraki et al., 2022). For example, Kavas et al. (2013) demonstrated that increased drought stress resulted in a decrease in both the fresh and dry weights of roots. A similar reduction in plant height was reported by Seymen et al. (2024) in melon plants subjected to drought stress. Furthermore, drought stress reduced stem diameter (Rehman et al., 2024), fresh weight (Seymen et al., 2024), dry weight (Wang et al., 2024), and leaf area (Bagheri et al., 2019). The decline in morphological characteristics is closely associated with the changes in physiological processes and consequently fruit yield. In response to drought stress, the water content within leaf tissues decreased, leading to a loss in relative water content, and an increase in dry matter (Ansari et al., 2018; Rehman et al., 2023). Melon plants subjected to drought stress had higher electrolyte leakage (Kavas et al., 2013; Rehman et al., 2023). Leaf temperature under drought stress imposed by limited irrigation water increased with a lower water supply (Akhoundnejad and Dasgan, 2020).

The responses of melon seedlings to increasing drought severity and the drought tolerance threshold have not been thoroughly examined. Therefore, the purpose was to examine the changes in morphological and physiological characteristics of melon plants under different drought stresses and to identify the threshold level of drought stress.

2. Materials and Methods

The laboratory experiment was performed under controlled conditions at the Seed Science and Technology Laboratory, Eskişehir Osmangazi University, Eskişehir, Türkiye in 2024. Seeds of the melon cultivar 'Kırkağaç 589' and polyethylene glycol (PEG) 6000 creating different drought severities were used as materials.

2.1. Experimental setup

The seeds were planted into plastic tray with 80 cells and incubated in a plant growth chamber under a temperature regime of 22°C day/16°C night, and a photoperiod of 18/6 hours with a relative humidity of 65-70%, until the plants reached a 2-true leaf stage. Following the incubation period, they were transplanted into plastic pots with a volume of 0.45 L containing a total of 130 g of the mixture of peat, perlite, and vermiculite (6/1/1, by volume).

The severity of the drought was arranged by the addition of varying concentrations of PEG 6000 (5%, 10%, 15%, and 20% and 6.5, 13.0, 19.5, and 26.0 g PEG 6000 per pot, respectively) to each pot before seedling transplantation. These concentrations roughly correspond to osmotic potentials of 1.5, 3.0, 5.0, and 6.0 bar, (Michel and Kaufmann, 1973). One hundred milliliters of ½ strength of Hoagland's solution were applied to each pot. The pots were then placed in a growth chamber that was set at 24°C/18°C and 18/6 hours with a relative humidity of 50-60%. Weighing the pots every other day to determine moisture loss and the deficit of water was completed by adding distilled water. The plants were harvested thirty days after the drought stress and all measurements were taken.

2.2. Measurement of characteristics

The plant height, stem diameter, fresh and dry weights, and dry matter of above ground parts of melon seedlings were measured after cutting them from the soil surface. The ImageJ Program was used to measure the leaf area on the scanned leaves. After the above-ground parts of the plants were dried in an oven at 80°C for 48 h, the dry matter was calculated as a percentage by dividing the dry weight by the fresh weight and multiplying the result by 100. The portable chlorophyll meter Konica Minolta SPAD-502 was used for determining the chlorophyll content as the SPAD index. The relative water content (RWC) of the leaf was determined with the following formula.

$$RWC(\%) = \left[\frac{(FW - DW)}{(TW - DW)}\right] \times 100$$

Where,

FW= fresh weight of leaf
DW= dry weight of leaf
TW= turgid weight of leaf

$$Turgor\ loss\ (\%) = \left[\frac{(TW - FW)}{TW}\right] \times 100$$

Dry weight was determined after drying at 80°C for 24 h and turgid weight was weighed after the leaf samples were immersed in distilled water in a falcon tube for 24 h in the dark at 20°C (Kaya et al., 2003).

2.3. Statistical analysis

The data were statistically analyzed by a completely randomized design with five replicates, and differences between the means were compared by the Least Significant Differences (LSD) test at a 5% level. The JMP 13.0 software was used for all of the statistical analysis.

3. Results and Discussion

The analysis of variance revealed that there were significant differences in morphological characteristics including plant height, stem diameter, fresh and dry weight, leaf area, and dry matter due to the levels of drought severity (Figure 1). As drought severity increased, the height of melon plants exhibited a significantly reduced. However, no significant reduction in plant height

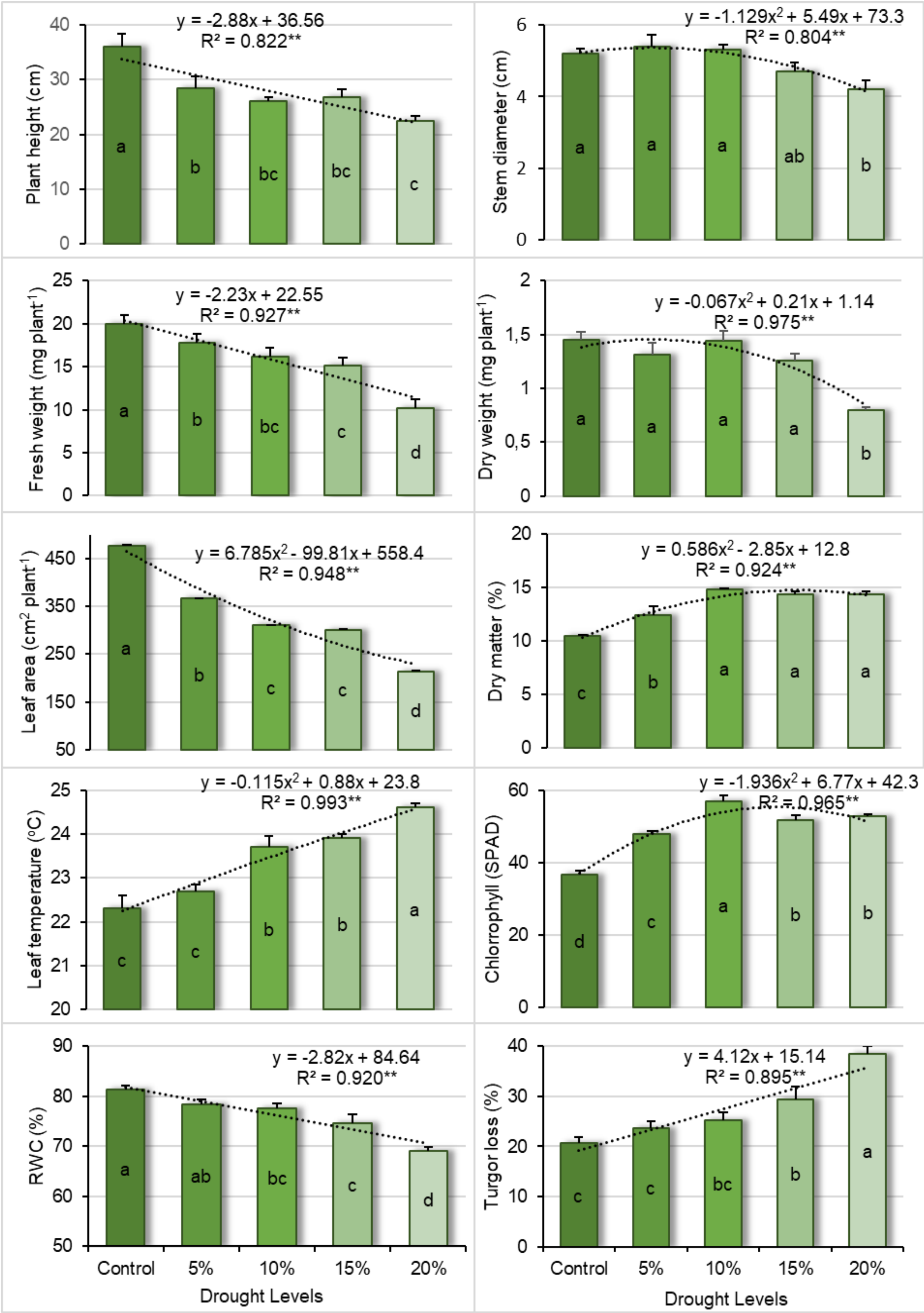

Figure 1. Changes in the investigated parameters of melon plants subjected to various drought stresses (Letters and bars on each column denote significance level at 5% and standard error, respectively. RWC: Relative water content).

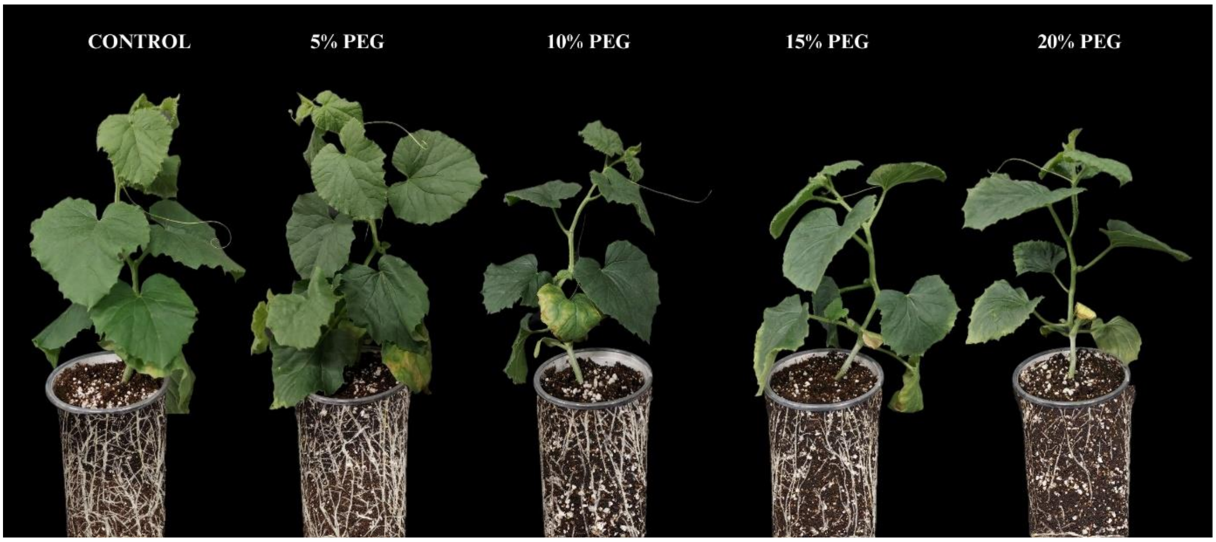

Figure 2. Melon plants subjected to various drought stresses.

was observed between 5% and 15% drought severity levels (Figure 2). The plant height decreased from 36.0 cm in control to 22.4 cm in 20% PEG. This result supports the findings of Seymen et al. (2024) in melon and Wang et al. (2024) in cucumber, who observed a reduction in plant height under water-deficit conditions.

The impact of increasing drought severity on stem diameter was not substantial up to a level of 15% PEG. Still, a notable decline was observed at the highest level of drought severity, which was 20% PEG. This result is confirmed by the finding of Rehman et al. (2024), who found a reduction in the stem diameter of melon. The application of increasing levels of drought stress reduced the fresh weight of melon plants. The fresh weight of the melon plants exhibited a 50% reduction due to the effects of drought stress, which indicates a high level of sensitivity to drought. Seymen et al. (2024) reported a 64.8% decrease in plant fresh weight due to drought stress. Although there was no change in dry weight with increasing drought severity up to 15% PEG, it was remarkably reduced under 20% PEG (Figure 1). Similarly, Wang et al. (2024) found a drastic decline in the dry weight of cucumber at 10% PEG and Seymen et al. (2024) recorded that the dry weight of melon declined by 52% under 50% water-deficit conditions. The enhancement of dry matter was observed in melon plants subjected to 5% and 10% PEG, as evidenced by changes in fresh and dry weight. Similar to this result, Kirnak and Dogan (2009) reported that dry matter production of watermelon plants was decreased by drought stress. However, the dry matter content was found to be similar at 10%, 15%, and 20% PEG. The total leaf area exhibited a decline in correlation with increasing drought severity. Bagheri et al. (2019) and Karimi and Zare (2023) reported similar results regarding decreased leaf area in melon with irrigation water supply. Furthermore, Ansari et al. (2019) observed that the prolonged duration of drought stress resulted in a reduction in the leaf area of melon.

The increase in drought severity significantly affected chlorophyll content, leaf temperature, relative water content, turgor loss, and electrolyte leakage of melon plants. The plants subjected to various drought stresses showed elevated chlorophyll content, while it declined at 15% and 20% PEG (Figure 1). No significant differences were observed between 10% and 20% PEG. Similarly, Astaraki et al. (2022) reported that chlorophyll content increased from 72 SPAD in control to 82 SPAD in drought-stressed plants of melon, and Seymen et al. (2024) found an increase in chlorophyll content (SPAD) in plants grown under a 50% water deficit. Leaf temperature gradually increased by elevating drought stress, reaching a maximum of 24.6°C in 20% PEG treatment. This result aligns with the findings of Akhoundnejad and Dasgan (2020) and Seymen et al. (2024), who determined that leaf temperature increased in melon plants grown under water-deficit conditions. The highest relative water content was identified in the control plants, and it was diminished by increasing drought severity. A significant decline was observed in 20% PEG. Similar findings were reported by Ansari et al. (2018) and Rehman et al. (2023), who demonstrated that the relative water content decreased under drought conditions, and this decrease was significantly greater when the duration of drought stress was extended. It is proposed that the reduction in the relative water content resulted in an elevation of leaf temperature, as indicated by their significant and negative correlation coefficient r=-0.724**. Furthermore, Kavas et al. (2013) found a sharp decline in the relative water content of melon at -0.4 MPa, which is similar to the result of the present study. Turgor loss was observed to be higher in melon plants subjected to drought, with an increase in the severity of drought resulting in a corresponding

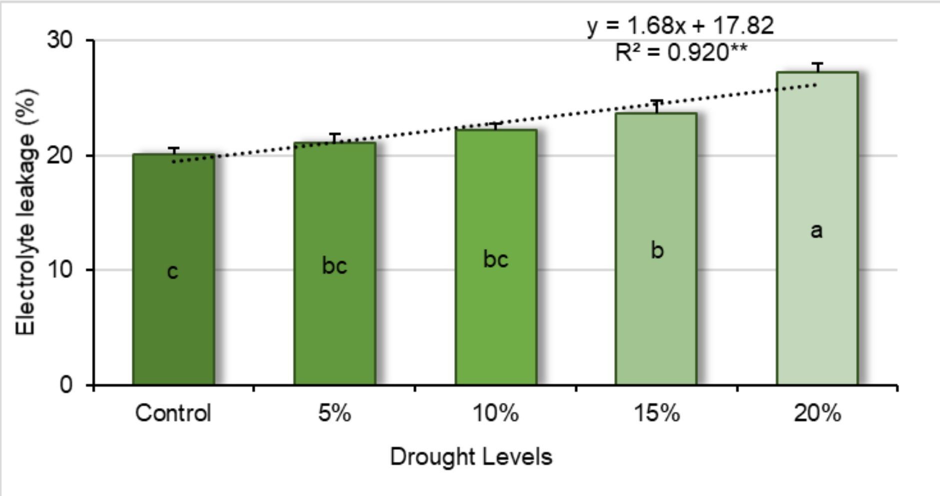

Figure 3. Changes in the electrolyte leakage of melon plants subjected to various drought stresses (Letters and bars on each column denote significance level at 5% and standard error, respectively).

Table 1. The correlation coefficient (r) between the investigated characteristics of melon plants exposed to various drought stresses.

	LT	Chl	PH	SD	FW	DW	RWC	DM	TL
Chl	0.661**	1.000							
PH	-0.637**	-0.711**	1.000						
SD	-0.391	-0.127	0.403*	1.000					
FW	-0.819**	-0.581**	0.774**	0.560**	1.000				
DW	-0.574**	-0.293	0.638**	0.638**	0.889**	1.000			
RWC	-0.724**	-0.470*	0.557**	0.409*	0.832**	0.725**	1.000		
DM	0.758**	0.849**	-0.567**	-0.073	-0.589**	-0.217	-0.583**	1.000	
TL	0.695**	0.413*	-0.546**	-0.429*	-0.829**	-0.752**	-0.995**	0.515**	1.000
EL	0.468*	0.279	-0.406*	-0.354	-0.629**	-0.671**	-0.591**	0.281	0.602**

LT: Leaf temperature, Chl: Chlorophyll content, PH: Plant height, SD: Stem diameter, FW: Fresh weight, DW: Dry weight, RWC: Relative water content, DM: Dry matter, TL: Turgor loss, and EL: Electrolyte leakage.
*, **: significant at p<0.05 and p<0.01, respectively.

increase in the observed loss. Electrolyte leakage increased markedly in melon plants subjected to drought stress (Figure 3). This result supports the findings of Kavas et al. (2013) and Rehman et al. (2023), who reported an increase in oxidative damage under drought stress, which was accompanied by a reduction in electrolyte leakage. The increase in electrolyte leakage was minimal at up to 15% PEG, while it increased considerably at 20% PEG, which should be considered as the critical threshold and used for the selection of drought-tolerant melon genotypes. Additionally, increased drought severity was associated with elevated electrolyte leakage; suggesting that it may serve as a valuable indicator for assessing drought tolerance levels in melon, as previously reported by Garty et al. (2000) and Bajji et al. (2002). Similarly, Jothimani and Arulbalachandran (2020) noticed that electrolyte leakage in black gram (*Vigna mungo* L.) linearly increased with increasing levels of PEG, reaching the maximum value at 20% PEG with a 60% increase.

The correlations between the characteristics affected by different drought severities were calculated with significance levels and are presented in Table 1. A significant and negative correlation coefficient (r= -0.819**) was observed between leaf temperature and fresh weight. Conversely, the correlation between chlorophyll content and dry matter was positively significant. Electrolyte leakage is negatively correlated with fresh weight, dry weight, relative water content, and leaf temperature, indicating that electrolyte leakage is relatively enhanced by a reduction in these characteristics. Plant height and fresh weight were negatively linked with dry matter, turgor loss, and electrolyte leakage, indicating that a decrease in plant height was associated with increased turgor loss and dry matter. Similar linkages were determined by Karimi and Zare (2023).

4. Conclusions

Drought stress has detrimental effects on germination, early or late growth stages, and the growth and yield of crop plants. However, the tolerance level of drought stress varies depending on the growth stage of plants, species, and even cultivars. In this study, different levels of drought severity were induced by PEG 6000, and melon seedlings were grown in the respective conditions. The results demonstrated that drought negatively affected the growth of melon seedlings, with a notable restriction in root growth. Although increased drought severity reduced the growth of melon, 10% PEG exhibited a particularly pronounced inhibitory effect by disrupting the water balance in tissues and increasing electrolyte leakage. Consequently, electrolyte leakage may serve as an indicator for drought-tolerant melon plants, with 10% PEG representing a critical threshold for drought stress in melon. Further studies connected with the results of field experiments should be recommended to attain a more precise decision on drought tolerance in melon.

Acknowledgement

The author would like to thank MSc student Elif Yaman for the preparation of photos, Dr. Nurgül Ergin, Dr. Engin Gökhan Kulan, and PhD student Pınar Harmancı for their kind help during the experiment.

References

Adıgüzel, P., Nyirahabimana, F., Shimira, F., Solmaz, İ., & Taşkın, H. (2023). Applied biotechnological approaches for reducing yield gap in melon grown under saline and drought stresses: an overview. *Journal of Soil Science and Plant Nutrition,* 23(1):139-151.

Akhoundnejad, Y., & Dasgan, H.Y. (2020). Photosynthesis, transpiration, stomatal conductance of some melon (*Cucumis melo* L.) genotypes under different drought stress. *Fresenius Environmental Bulletin,* 29(12):10974-10979.

Anonymous. (2024). https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr. Data accessed: December 24, 2024.

Ansari, W.A., Atri, N., Singh, B., Kumar, P., & Pandey, S. (2018). Morpho-physiological and biochemical responses of muskmelon genotypes to different degree of water deficit. *Photosynthetica,* 56(4):1019-1030.

Ansari, W.A., Atri, N., Ahmad, J., Qureshi, M.I., Singh, B., Kumar, R., Rai, V., & Pandey, S. (2019). Drought mediated physiological and molecular changes in muskmelon (*Cucumis melo* L.). *PloS One,* 14(9):e0222647.

Astaraki, H., Ramshini, H., Lotfi, M., & Izadi Darbandi, A. (2022). Yield stability of melon genotypes under drought stress conditions. *International Journal of Horticultural Science and Technology,* 9(2):185-199.

Bagheri, S., Hassandokht, M.R., Mirsoleimani, A., & Mousavi, A. (2019). Effect of palm leaf biochar on melon plants (*Cucumis melo* L.) under drought stress conditions. *Advances in Horticultural Science,* 33(4):593-604.

Bajji, M., Kinet, J.M., & Lutts, S. (2002). The use of the electrolyte leakage method for assessing cell membrane stability as a water stress tolerance test in durum wheat. *Plant Growth Regulation,* 36:61-70.

Garty, J., Weissman, L., Tamir, O., Beer, S., Cohen, Y., Karnieli, A., & Orlovsky, L. (2000). Comparison of five physiological parameters to assess the vitality of the lichen *Ramalina lacera* exposed to air pollution. *Physiologia Plantarum,* 109(4):410-418.

Jothimani, K., & Arulbalachandran, D. (2020). Physiological and biochemical studies of black gram (*Vigna mungo* (L.) Hepper) under polyethylene glycol induced drought stress. *Biocatalysis and Agricultural Biotechnology,* 29:101777.

Karimi, S., & Zare, N. (2023). Silicon pretreatment at the transplanting stage, a tool to improve the drought tolerance and subsequent growth of melons in the field. *Silicon,* 15(11):4921-4929.

Kavas, M., Baloğlu, M.C., Akca, O., Köse, F.S., & Gökçay, D. (2013). Effect of drought stress on oxidative damage and antioxidant enzyme activity in melon seedlings. *Turkish Journal of Biology,* 37(4):491-498.

Kaya, C., Ak, B., & Higgs, D. (2003). Response of salt-stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. *Journal of Plant Nutrition,* 26: 543-560.

Kaya, G. (2024). Combined effects of drought and low temperature on germination and seedling growth of melon cultivars. *Black Sea Journal of Agriculture,* 7(2):139-143.

Kirnak, H., & Dogan, E. (2009). Effect of seasonal water stress imposed on drip irrigated second crop watermelon grown in semi-arid climatic conditions. *Irrigation Science,* 27:155-164.

Michel, B.E., & Kaufmann, M.R. (1973). The osmotic potential of polyethylene glycol 6000. *Plant Physiology,* 51:914–916.

Rehman, A., Weng, J., Li, P., Yu, J., Rahman, S.U., Khalid, M., Shah, I.H., Gulzar, S. Chang, L., & Niu, Q. (2023). Differential response of two contrasting melon (*Cucumis melo* L.) genotypes to drought stress. *Journal of Plant Biology,* 66(6):519-534.

Rehman, A., Khalid, M., Weng, J., Li, P., Rahman, S.U., Shah, I.H., Gulzar, S., Tu, S., Ningxiao, F., Niu, Q., & Chang, L. (2024). Exploring drought tolerance in melon germplasm through physiochemical and photosynthetic traits. *Plant Growth Regulation,* 102(3):603-618.

Seleiman, M.F., Al-Suhaibani, N., Ali, N., Akmal, M., Alotaibi, M., Refay, Y., Dindaroglu, T., Abdul-Wajid, H.H., & Battaglia, M. L. (2021). Drought stress impacts on plants and different approaches to alleviate its adverse effects. *Plants,* 10(2):259.

Seymen, M., Burak, T.Ö., Yavuz, D., Kıymacı, G., Türkmen, Ö., Kurtar, E.S., Yavuz, N., & Kal, Ü. (2024). Water stress during seedling growth: examining physiological, biochemical and agronomic dynamics in *Cucumis melo*. *Pakistan Journal of Agricultural Sciences,* 61(1):73-83.

Vural, H., Eşiyok, D., & Duman, İ. (2000). Culture Vegetables (Vegetable Cultivation). Ege University Press, İzmir, Türkiye, pp: 364-377 (in Turkish).

Wang, X., Sun, H., Lian, X., Feng, J., Zhao, J., Wang, Y., & Liu, Y. (2024). Physiological and biochemical characteristics of cucumber seedlings under different levels of drought stress (PEG 6000 concentrations). *Horticultural Science,* 51(3):202-211.

Yang, X., Lu, M., Wang, Y., Wang, Y., Liu, Z., & Chen, S. (2021). Response mechanism of plants to drought stress. *Horticulturae,* 7(3):50.