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Effect of Drought and UV-B Stress on Leaf Morphology of Ash-Leaved Maple and Sycamore Maple

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ABSTRACT

Global climate change continues to leave irreversible effects worldwide. With the increase in the effects of climate change, especially in recent years, the amount of UV-B radiation reaching the earth's surface is also likely to increase. With increasing temperatures, the amount of precipitation in the world has decreased, and the drought has started to alarm. This study is tried to understand how plants can respond to these stresses using ash-leaf maple (*Acer negundo* L.) and sycamore maple (*Acer pseudoplatanus* L.) species. The effects of these stress factors on plant leaf morphology were investigated by applying certain intensities of drought (moderate [T2] and severe drought [T3]) and UV-B (8 kJ m^{-2} h^{-1} [T4] and 12 kJ m^{-2} h^{-1} [T5]) stresses on these two species with T1 (control) treatment. As a result, leaf width in *A. pseudoplatanus* species was at the lowest levels in individuals exposed to T3 and T9. In *A. negundo* species, leaflet length in T1, T2, T3, T4 T5, T6 (modarete+T4), T7 (modarete+T5), T8 (severe drought+T4), and T9 (severe drought+T5) treatment were 8.800, 8.704, 8.075, 8.792, 8.823, 8.516, 8.317, 7.993, and 8.605 cm, respectively. According to these values, it was observed that the leaflet length was the shortest in T8 (7.993 cm) treatment. On the other hand, the leaflet length in T9 was close to the T1 group. As a result, individuals exposed to T4 were more affected than T5 in applications applied to UV-B stress and T3. Therefore, the increase of UV-B radiation positively affects the plant's resistance to drought stress.

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Introduction

It is stated that global climate change has become an irreversible problem worldwide (Varol et al., 2021). Climate change is estimated to cause increased drought, temperature, and higher ultraviolet-B (UV-B) radiation, affecting plant production (Araújo et al., 2016). According to the 2021 Climate Change report, it is stated that most terrestrial areas are warming faster than the global average, and this warming has been at least 0.1°C every ten years since 1960. According to the report, the temperature changes are 0.2–0.3°C in north, east, and southwest Africa, Australia, Central America, Amazon, and west Antarctica, while 0.3–0.5°C in the Arabian Peninsula, Central and East Asia, and Europe per decade. It is also emphasized that temperatures change to 1°C per decade in terrestrial regions close to the Arctic and North Pole (Gutiérrez et al., 2021).

These rapid shifts in climate change may cause the effects of stress factors to be felt more and suddenly on plants (Koç, 2022a; Sargıncı and Beyazyüz, 2022; Koç and Nzokou, 2023). It is estimated that plant communities with limited mobility will have limited adaptation to these effects, and therefore, species and population losses will occur (Varol et al., 2022 a,b). Therefore, it is unknown how a change may occur in plant mechanisms against stress factors that occur in a shorter time than the time required for adaptation (Mishra and Singh, 2011).

Plants are generally exposed to various environmental stresses, including biotic and abiotic stresses (Yayla et al., 2022; Koç and Nzokou, 2023). Drought is one of the most critical abiotic stresses that adversely affect plant growth and development (Şevik and Ertürk, 2015; Salehi-Lisar and Bakhshayeshan-Agdam, 2016; Koç, 2021; Koç and Nzokou, 2022a). Global climate changes are known to be the main factor triggering drought stress worldwide (Koç et al., 2022; Koç and Nzokou, 2022b).

Drought limits plant growth and crop production worldwide more than any other environmental stress (Keyvan, 2010; Kaur and Asthir, 2017; Koç, 2021). Plant growth models (Farooq et al., 2012) and climate change scenarios (Koç, 2022b, c; Cetin et al., 2023) predict that this problem will become more severe in the future. Drought disrupts optimum plant growth and water relations and reduces water use efficiency (Koç and Nzokou, 2022a). However, plants have diverse biochemical and physiological responses at the whole organism and cellular levels, making it a more complex phenomenon (Farooq et al., 2012).

For plants, UV-B stress is perceived as an environmental signal and a potential abiotic stress factor that affects growth and adaptation (Liang et al., 2020; Ozel et al., 2021; Shi and Liu, 2021). Enhanced UV-B intensities are particularly harmful to fixed autotrophs because of their inability to avoid UV-B exposure and their mandatory sunlight requirements. UV-B radiation has many direct and indirect consequences on plants, including pollination (Booji-James et al., 2000), damage to DNA, proteins, and membranes, changes in transpiration and photosynthesis, and changes in morphology, development, and growth (Hectors et al., 2007).

UV-B radiation levels reaching the Earth's surface are highly dynamic and are determined by time of day, season, altitude, latitude, shade, and many other parameters. How plants adapt to changing UV-B levels and coordinate growth and UV-B stress responses has yet to be fully understood (Liang et al., 2020). Some plant species use hairs and waxes to reduce UV-B penetration or increase UV-B reflection (Liakopoulos et al., 2006), while some flavonoids are used in species such as *Batrachium trichophyllum* (Chaix) FW Schultz , *Carex arenaria* L., *Calamagrostis epigejos* L., *Deschampsia antarctica* Desv. (Poaceae), *Deschampsia borealis* [Poaceae], *Potamogeton alpinus* Balb., and *Vicia faba* L. to prevent UV-screening and UV-B induction (Rozema et al., 2002). Other species are used to accumulate high concentrations of UV-absorbing polyphenolic flavonoids in the epidermis (Booij-James et al., 2000).

To date, many studies have been conducted on drought and UV-B stress. Among these are the effect of drought and UV-B on *Tillia* species (Cantürk, 2023), UV-B and heavy metal on *Populus alba* L. × *Populus glandulosa* Uyeki (84K poplars) seedlings (He et al., 2023), UV-B and water stress on *Moringa oleifera* L. plants (Araújo et al., 2016) were investigated. Wu (2008), the effect of water stress on *Poncirus trifoliata* L. seedlings and soil mycorrhizal structure, Wiesner-Reinhold et al. (2021) the effect of UV-B radiation on the biosynthesis of secondary plant metabolites (carotenoids, phenolic compounds, and glycosylates), and Moradi Rikabad et al. (2019) titanium dioxide nano-particles (TiO_2 NPs) on *Crocus sativus* L. exposed to harmful UV-B radiation were studied. In addition, the effects of drought stress on *Echinacea purpurea* L. (Mizgin et al., 2020), physiological and biochemical responses of drought stress on *Stevia rebaudiana* Bertoni (Yalçın et al., 2021), *Borago officinalis* L. (Torun and Eroğlu, 2021) and *Seseli resinosum* Freyn and Sint (Torun and Aydın, 2021), physiological and antioxidant responses and tolerance reactions of drought stress, morphological, physiological, and biochemical responses of *Ostrya carpinifolia* Scop. (Yılmaz et al., 2022) were investigated.

This study investigated the effects of drought and UV-B stress on leaf morphological properties in forest tree species of *Acer negundo* L. and *Acer pseudoplatanus* L.

Material and Method

The study was conducted on *Acer negundo* L. [ash-leaved maple] and *Acer pseudoplatanus* L. [sycamore maple] species naturally distributed in Türkiye. Within the scope of the study, 3-year-old seedlings were obtained from Ordu Forest Enterprise Nursery and brought to the nylon greenhouse belonging to Düzce University Forestry Faculty. The soil of seedlings was replaced with a mixture of peat, perlite, and bare soil in equal proportions to have the same soil type. Drought stress applications were carried out on pallets approximately 15-20 cm high from the ground so that the irrigations do not affect each other.

Two doses of UV-B stress, 8 kJ m^{-2} h^{-1} (UVB1) and 12 kJ m^{-2} h^{-1} (UVB2), were applied to the UV-B lamps placed in our cabin, which is covered with aluminum inside the greenhouse. The application doses were determined by taking into account the previous studies. Drought stress was applied in three different intensities as control, moderate and severe drought on certain days of the week. Irrigation was performed once a week in moderate drought and once every two weeks in severe drought. Seedlings in the control treatment were watered twice a week. The doses and explanations of the applications are shown in Table 1.

Within the scope of the study, leaf length, leaf width, petiole, and petiole diameter characters were measured in sycamore maple, and leaflet number, leaflet width, leaflet length, petiole length, petiole diameter, leaflet stem length, leaflet stem diameter characters in ash-leaved maple. The obtained data were evaluated using the SPSS 22.0 package program with the help of variance analysis. As a result of the evaluation, the Duncan’s test was applied to the values with at least a 95% confidence level significant difference.

Table 1. Drought and UV-B stress doses and explanations

Treatments	Explanations
T1 (Control)	Irrigated twice per week without UV-B applied
T2	Irrigated once per week
T3	Irrigated once in two weeks
T4	Applied 8 kJ m^{-2} h^{-1} weekly
T5	Applied 12 kJ m^{-2} h^{-1} weekly
T6	Irrigated once per week +8 kJ m^{-2} h^{-1} weekly
T7	Irrigated once per week +12 kJ m^{-2} h^{-1} weekly
T8	Irrigated once in two weeks +8 kJ m^{-2} h^{-1} weekly
T9	Irrigated once in two weeks +12 kJ m^{-2} h^{-1} weekly

Table 2. Effects of treatments on leaf morphology of ash-leaved maple

T	NL	Wl	Sl	Lp	Dp	LP	DP
T1	4.231±0.927	5.260±2.030	8.800±1.174c	0.973±0.091	1.472±7.354	7.823±1.395	1.165±0.162a
T2	4.267±1.100	4.616±1.879	8.075±1.397ab	0.638±0.736	0.488±0.351	7.453±1.311	1.223±0.264ab
T3	3.826±0.970	5.702±2.529	8.704±1.496c	1.184±1.644	0.795±0.343	7.960±1.169	1.390±0.190cde
T4	4.333±0.976	5.172±2.149	8.792±1.601c	0.938±1.066	0.766±0.292	7.540±1.520	1.439±0.230de
T5	4.515±0.870	5.113±1.709	8.823±1.028c	0.924±0.831	0.765±0.229	7.967±1.450	1.471±0.168e
T6	4.429±0.911	4.990±1.686	8.516±1.067bc	0.917±0.929	0.778±0.266	7.587±1.173	1.331±0.152bcde
T7	4.508±0.793	4.935±1.888	8.317±1.217abc	0.820±0.914	0.733±0.266	7.860±1.076	1.342±0.151bcde
T8	4.220±0.953	4.607±1.543	7.993±1.258a	0.629±0.694	0.674±0.341	7.847±1.261	1.251±0.202abc
T9	4.279±0.897	5.164±1.980	8.605±1.072c	0.893±0.936	1.682±8.116	8.227±1.517	1.286±0.163abcd
F	1.624	1.726	3.782	1.722	0.732	0.498	4.084
S	0.117ns	0.090ns	0.000***	0.091ns	0.663ns	0.855ns	0.000***

T: Treatments; F: F value; S: Sig.; NL: Number of leaflet, Wl: Width of leaflet, Sl: Size of leaflet, Lp: Length of petiolule, Dp: Diameter of petiolule, LP: length of petiol, DP: Diameter of petiol. ns = not significant. *** = significant at 0.001 level. According to Duncan's test results, the letters a, b, etc., represent the statistical differences between each column.

Table 3. Effects of treatments on leaf morphology of sycamore maple

Treatments	WL	SL	DP	LP
T1	13.027 ± 2.003 d	10.140 ± 1.598 cd	1.664 ± 0.270 bc	11.060 ± 3.046 c
T2	11.093 ± 1.414 bc	9.220 ± 1.582 bcd	1.328 ± 0.230 abc	8.900 ± 1.371 ab
T3	10.353 ±1.281 ab	7.953 ± 1.328 a	0.881 ± 0.240 a	7.293 ± 1.790 a
T4	13.087 ± 1.691 d	10.053 ± 1.415 cd	1.261 ±0.298 abc	10.313 ± 2.578 bc
T5	11.893 ± 1.955 cd	10.227 ± 2.029 d	1.499 ±0.287 abc	10.120 ± 2.097 bc
T6	10.980 ± 1.335 bc	8.927 ± 1.068 abc	1.869 ± 2.696 c	9.100 ± 2.075 abc
T7	10.193 ± 1.785 ab	8.920 ± 1.940 abc	0.952 ± 0.281 ab	9.447 ± 2.478 bc
T8	10.260 ± 1.523 ab	7.940 ± 1.410 a	1.079 ± 0.307 ab	8.847 ± 2.853 ab
T9	9.360 ± 2.289 a	8.067 ± 1.278 ab	0.866 ± 0.282 a	8.667 ± 3.137 ab
F value	8.420	5,536	2.190	3.025
Sig.	0.000 ***	0,000 ***	0.032 *	0.004 **

WL: Width of leaf, SL: Size of leaf, DP: Diameter of petiol, LP: length of petiol. * = significant at 0.05 level, ** = significant at 0.01 level, *** = significant at 0.001 level. According to Duncan's test results, the letters a, b, etc., represent the statistical differences between each column.

Results

The effects of drought and UV-B stresses on the leaf morphological characteristics of ash-leaved maple are shown in Table 2. As seen in Table 2, the effect of applications on leaflet length and petiole diameter in *A. negundo* was statistically significant. The highest values in leaflet length were seen in T1, T3, T5, and T9, while the lowest value was observed in T8. In the petiole diameter, the highest value was obtained in T5, while the lowest was obtained in T1. It was determined that there was no statistical difference between treatments in parameters such as leaflet number, leaflet width, leaflet petiole, and petiole length in *A. negundo* species. In this case, drought and UV-B stress do not specifically affect these parameters. The effects of drought and UV-B stresses on sycamore maple (SM) leaf morphological characteristics are shown in Table 3.

As a result of the examination of the values in Table 3, it was seen that the effects of leaf width, leaf size, petiole diameter, and petiole length were statistically significant ($P<0.05$). While the highest value in leaf width was obtained in T4 and T1 treatments, the lowest value was obtained in T9 treatments. The highest value in petiole diameter was seen in T6, while the lowest values were observed in T3, T7, and T9. In petiole length, the highest value was observed in the T1 application, while the lowest value was observed in T3, T8, and T9 applications. The highest value in leaf size was obtained in the T1, T4, and T5 treatments, and the lowest value was obtained in T3 and T9 treatments.

Discussion

As a result of the study, it was determined that the applications of *A. negundo* leaflet length and petiole diameter had an effect. The highest leaflet length values were observed in the application groups in T5 (8.823 mm), T1 (8.800 mm), T3 (8.704 mm), and T9 (8.605 mm), respectively. It is seen that there is a general decrease in the leaflet lengths of the individuals in the T1 group among the treatments in the other treatment groups. It is observed that the maximum leaflet length reduction is observed in individuals (7.993 mm) exposed to both T3 and T4 treatments Among the application groups, while the leaflet length was the least in the T8 application, it was observed that the leaflet length was higher in the T9 application. It can be interpreted that this situation shows greater resistance and resistance to severe and high-level stress factors on the plant. It is observed that individuals exposed to T8 stresses are more affected than individuals exposed to T9 stresses. Therefore, *A. negundo* individuals exposed to T5 radiation with severe drought may be better adapted to drought stress.

The applications in *A. pseudoplatanus* species were observed to statistically affect leaf width, leaf size, petiole diameter, and petiole length. When the applications were examined, the leaf width was at the lowest level only in severe drought and in individuals exposed to both severe drought and high levels of UV-B. In this case, the *A. pseudoplatanus* species was less tolerant of severe drought and high-dose UV-B stress in leaf height change than the *A. negundo* species. T3, T7, and T9 applications reduced the petiole diameter of *A. pseudoplatanus*. In this case, the petiole diameter decreased when exposed to T3 and T5 stresses. The lowest leaf stem length was observed in T3 (7.293 cm), T8 (8.847 cm), and T9 (8.667 cm) applications. The petiole length was lower, especially in severe drought applications. The petiole length was lower, especially in severe drought applications. The petiole length was lowest only in individuals subjected to severe drought. It was less affected by severe drought and UV-B application than severe drought. Therefore, UV-B stress positively affects the plant's tolerance against drought stress.

Araújo et al. (2016) determined that young *Moringa oleifera* L. plants exhibited less harmful effects (in photosynthesis and antioxidant capacity) when exposed to both water stress and UV-B than when exposed to UV-B alone. Wullschleger et al. (2005) emphasized that water deficiency stress mainly reduces leaf growth and leaf area in many plant species, such as *Populus*. Wiesner-Reinhold et al. (2021) stated that applying UV-B radiation changed the secondary plant metabolites that support structure-specific health without harming the plants. Moradi Rikabad et al. (2019) stated that UV-B exposure was associated with lower plant height, fresh and dry weight, and leaf number; on the other hand, Mizgin et al. (2020) stated that drought stress decreased the leaf area of the plant, the relative water content in the leaf tissues and the membrane durability index. Wu et al. (2008), under drought stress on citrus seedlings, the plant length of the seedlings shortened by up to 25%, Waraich et al. (2011) determined that water loss in plants causes the cell membranes to shrink and the integrity of the cell membrane to decrease, and it destroys living cells.

Global climate change (Cantürk and Kulaç, 2021; Koç, 2022b), urbanization (Dogan et al., 2022; Zeren Cetin et al., 2023; Cobanoglu et al., 2023), and environmental pollution (Mutlu and Aydın Uncumusaoğlu, 2018; Emin et al., 2020; Demir et al., 2021; Tokatli et al., 2021; Çobanoğlu et al., 2022) are interconnected global problems worldwide, which have entered a very rapid process of change with the effect of the industrial revolution. It is stated that these problems are directly and indirectly related to each other (Isinkaralar et al., 2022; Sulhan et al., 2022; Kuzmina et al., 2023) and can affect both the life of all living things in the world and ecosystems in a devastating level (Varol et al., 2021; Koç, 2022c). It is emphasized that the living group that this effect will cause the most damage will be seen on plants without effective mobility (Erdem et al., 2022). Plant development is shaped under the influence of genetic structure (Sevik et al., 2012; Kurz et al., 2023) and environmental factors, such as soil (Shults et al., 2020; Cetin et al., 2022) and climate (Sevik et al., 2019; Ertugrul et al., 2021; Karacocuk et al., 2022). Therefore, it is inevitable that permanent and continuous changes in the climate will have a devastating effect on all living things, especially plants with limited mobility.

Conclusion and Suggestion

The study results suggest that *A. negundo* is less responsive to drought and UV-B stresses than *A. pseudoplatanus*. For the *A. pseudoplatanus,* the leaf length decreased with the effect of severe drought, but it was not affected by UV-B radiation. The leaflet length decreased when exposed to severe drought and low dose UV-B simultaneously in *A. negundo*. However, it was determined that it was not affected by UV-B radiation.

Therefore, it can be recommended to prefer *A. pseudoplatanus* in afforestation studies between these two species. In addition, it can be recommended to prefer *A. negundo* in areas such as landscaping, road afforestation, and erosion control, especially in urban areas.

It is stated that global climate change can devastate ecosystems and cause large-scale species and population losses. However, the number of studies on exactly how these effects will be, which species or groups will be affected, and the measures to be taken to mitigate the effects of this process is quite limited. Therefore, it is recommended that studies on the subject be continued by diversifying and increasing.

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