https://doi.org/10.17221/120/2023-JFS

Light response curve analysis of juvenile black locust clones: A case study from eastern Hungary

Tamás Ábri[1]*, *Dániel Gaganetz*[2], *József Csajbók*[2]

[1]*Department of Plantation Forestry, Forest Research Institute, University of Sopron, Sopron, Hungary*
[2]*Institute of Crop Sciences, University of Debrecen, Debrecen, Hungary*

**Corresponding author: abri.tamas@uni-sopron.hu*

Citation: Ábri T., Gaganetz D., Csajbók J. (2024): Light response curve analysis of juvenile black locust clones: A case study from eastern Hungary. J. For. Sci., 70: 202–207.

Abstract: Assimilation (*A*) and photosystem II (*PS*II) efficiency value light response curves [*A*/*PPFD* and *PS*II/*PPFD* curves (*PPFD* – photosynthetic photon flux density)] of promising black locust clones (NK2 and PL251) and the registered Üllői clone were analysed to study the net assimilation rates and *PS*II efficiency within the function of *PPFD* levels. The natural logarithmic regression functions fitted well to the measured data points for *A*/*PPFD*, R^2 values varied between 0.9515–0.9884. For *PS*II/*PPFD* values, we used the exponential regression function with R^2 ranging from 0.9948 to 0.9989. Except for PL251, the *A*/*PPFD* curves of the tested clones increased steadily with increasing illumination levels but flattened at the 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ *PPFD* level due to the effect of photorespiration on the assimilation rate. For PL251, the *A*/*PPFD* curve decreased at the 1 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ *PPFD* level. Unlike *A*/*PPFD* results, the *PS*II/*PPFD* exponential curve decreased as the *PPFD* level increased. Europe is forecast to experience significant negative climate change factors, including increased drought, heat, and irregular precipitation. Under such conditions, relatively drought-tolerant tree species such as black locust will play a vital role in new afforestation and uninterrupted wood supply. Consequently, growing and improving newly bred black locust clones, including the ecophysiological studies of relatively drought-tolerant clones, is increasingly vital.

Keywords: assimilation; drought tolerance; ecophysiology; photosystem II

Black locust (*Robinia pseudoacacia* L.) is planted in Europe for its fast growth, excellent nectar production, relative drought tolerance, and site adaptability (Nicolescu et al. 2020). It is also an invasive tree, but strict adherence to its growing technology and optimal site selection can help reduce its invasiveness (Vítková et al. 2017).

In Hungary, black locust improvement started in the 1960s (Ábri et al. 2023a). The present study selected and propagated black locust clones with good stem quality and high yield. The Hungarian Forest Research Institute and Napkor Erdőgazdák Zrt. recently established an experimental plantation that included a clone trial involving four newly-bred clones and a state-approved cultivar – Üllői black locust (Rédei et al. 2020) as a control. The trial compared these new clones and the Üllői cultivar for growth, assimilation parameters and water use efficiency (Ábri et al. 2022, 2023b; Ábri, Csajbók 2023).

Many stress factors negatively affect plants today. Global climate change has increased the two

Supported by the Ministry of Culture and Innovation of Hungary, National Research, Development, and Innovation Fund, financed under the project frame TKP2021-NKTA-43 funding scheme, and under the KDP-2020 funding scheme, project No. 1021122.

https://doi.org/10.17221/120/2023-JFS

most significant negative factors – drought and high temperatures. The two factors combined can severely damage trees and impair photosynthesis, which affects other physiological parameters (Flexas, Medrano 2002; Chaves et al. 2009; Farooq et al. 2009; Brito et al. 2019). Figure 1 illustrates possible mechanisms that lead to decreasing photosynthesis during water stress.

Many studies have examined black locust physiology and water stress response (Zheng et al. 2012; Mantovani et al. 2014; Meng et al. 2014; Küppers et al. 2018; Choi et al. 2021; Lange et al. 2022; Ábri et al. 2023b; Ábri, Csajbók 2023).

Zheng et al. (2012) demonstrated that black locust photosynthetic light response curves initially show a rapid increase in the net CO_2 assimilation rate (*A*) under photosynthetically active radiation (*PAR*) between 0 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Then, *PAR* likely becomes a limiting factor in photosynthesis because net assimilation increases before slightly decreasing as *PAR* increases. Leaves cannot utilise high-intensity light due to enzyme system limitations (the light supersaturation phenomenon). Küppers et al. (2018) created a model to estimate the carbon flux in sun-exposed and shaded black locust leaves. The model showed that the maximum observed daily carbon gain in sun-exposed leaves was 536.3 mmol $CO_2 \cdot m^{-2} \cdot day^{-1}$, while the annual carbon gain was 46 824 mol $CO_2 \cdot m^{-2}$.

The black locust (*Robinia pseudoacacia*) exhibits its paraheliotropism to protect its photosynthetic system. Arena et al. (2008) examined leaves with restricted and unrestricted movement. Restricted leaves showed a significant decrease in net photosynthesis, stomatal conductance, effective quantum yield of photosystem II (*PS*II), and photochemical quenching, while intercellular/environmental CO_2 concentration and non-photochemical quenching significantly increased. Unrestricted leaves showed higher photosynthetic performance throughout the day. Under intense sunlight, unrestricted leaves recovered the maximum quantum yield of *PS*II photochemistry by the end of the day, while restricted leaves did not.

This paper analysed the photosynthesis parameters (net assimilation rate and *PS*II) of the newly bred PL251 and NK2 black locust clones and a state-approved Üllői cultivar in the function of photosynthetic photon flux density (*PPFD*) by recording light response curves. We have three hypotheses: (*i*) *A* of the clones PL251 and NK2 is higher than the Üllői at every *PPFD* level; (*ii*) the *A* increases with *PPFD*; (*iii*) the efficiency of *PS*II declines in higher *PPFD* levels.

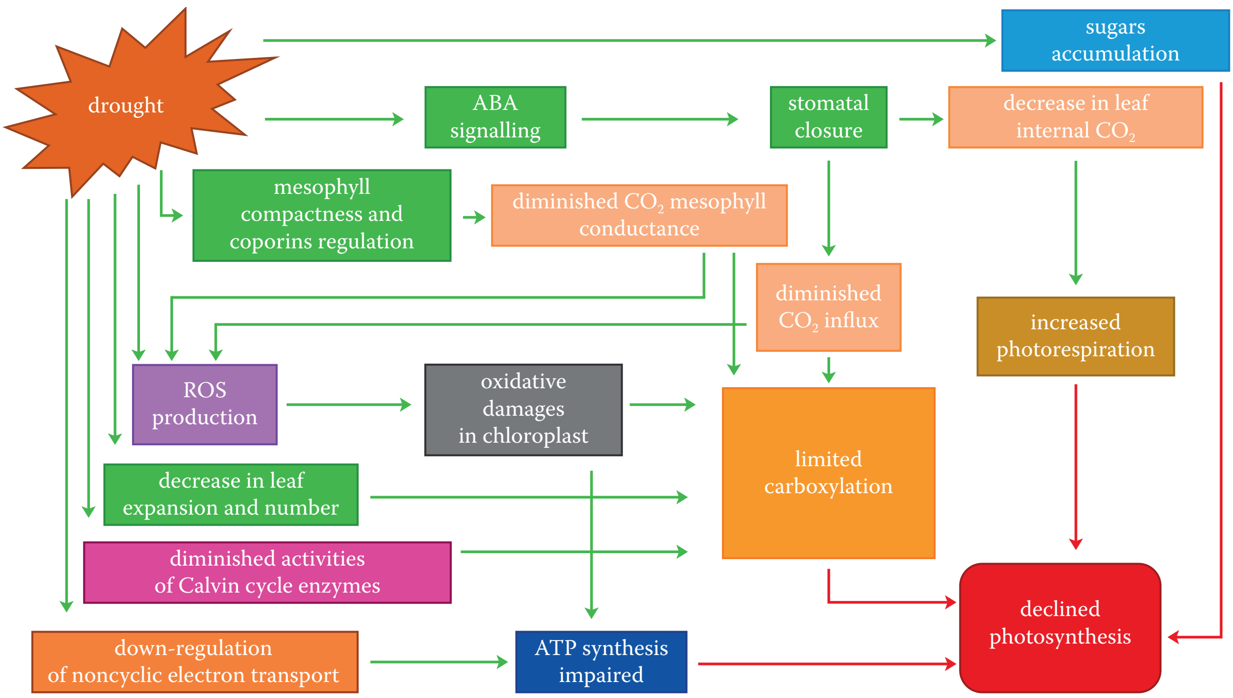

Figure 1. Possible mechanisms that lead to a decrease in photosynthesis during drought

ABA – abscisic acid; ATP – adenosine triphosphate (Farooq et al. 2012); ROS – reactive oxygen species

https://doi.org/10.17221/120/2023-JFS

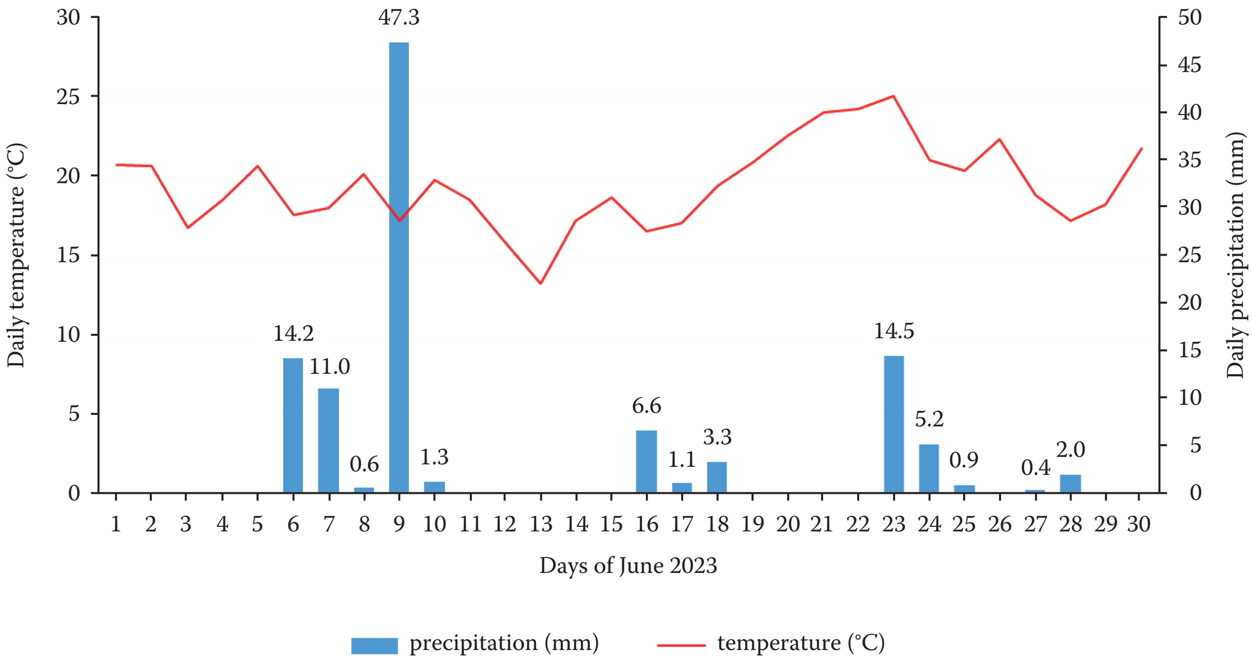

Figure 2. Daily temperature and precipitation data of the studied area in June 2023 (based on data from the Nyíregyháza-Napkor meteorological station of the Hungarian Meteorological Service)

MATERIAL AND METHODS

Study site. The experimental plantation was established in humic sandy soil in one of the main black locust growing areas in Hungary, the Nyírség region in the east (Ábri et al. 2022). Based on long-term (30-year average, 1991–2020) meteorological data provided by the meteorological station Nyíregyháza-Napkor (Hungarian Meteorological Service), the annual mean temperature was 10.6 °C and the annual mean precipitation was 537 mm in this region. The temperature was 28 °C during measurements. There was no rainfall before the clones were studied (Figure 2).

Measurements. Based on previous results from the Napkor clone trial (Ábri et al. 2022, 2023b), the study investigated the 4-year-old NK2 and PL251 clones and Üllői, which was used as a control, on June 30, 2023. LI-6800 (LI-COR, USA) portable photosynthesis system was used in the assimilation parameters measurements. The instrument recorded the net assimilation, transpiration, stomatal conductance, intercellular CO_2 concentration, *PS*II efficiency and other physiological parameters (Ábri et al. 2022, 2023b). The light was controlled in the sample chamber using 90% red (625 nm) and 10% blue (475 nm) light. We used decreasing photosynthetic photon flux density (*PPFD*) in 9 steps (2 000; 1 500; 1 200; 900; 600; 300; 150; 50; 20 $\mu mol \cdot m^{-2} \cdot s^{-1}$) for the light response curve. At each *PPFD*, *A* was recorded once the leaves had reached steady-state values, as described above. Leaf temperature at the time of all measurements varied from 26 °C to 29 °C.

The Li-6800-01A multiphase flash fluorometer head (LI-COR, USA) with a 2 cm^2 aperture served as a light source. The CO_2 concentration was controlled in the chamber: 400 $\mu mol \cdot mol^{-1}$, using an injector and carbon dioxide cartridges. Light-adapted leaves were measured six times per leaf on three plants per plot. Readings were logged when the measured parameters stabilised but after a minimum of 120 s (Ábri et al. 2022).

RESULTS

In 2023, the photosynthetic and *PS*II light response curves (*A*/*PPFD* curve and *PS*II/*PPFD* curve) of two clones (PL251 and NK2) with the best growth (Ábri et al. 2022, 2023b) and the Üllői cultivar were observed with decreasing *PPFD* (photosynthetic photon flux density) levels in 9 steps (2 000; 1 500; 1 200; 900; 600; 300; 150; 50; 20 $\mu mol \cdot m^{-2} \cdot s^{-1}$). There were significant differences between the clones in both parameters at $P < 0.0001$ level. For *A*, the natural logarithmic regression functions

https://doi.org/10.17221/120/2023-JFS

fit well to the measured data points (R^2 values varied between 0.9515–0.9884), i.e. the curves of the functions showed the differences appropriately. When examining the assimilation rate of the two clones and Üllői as a function of *PPFD*, the present study found that PL251 was the weakest at the lowest *PPFD* level (0–20 μmol·m^{-2}·s^{-1}), with a value of –7.04 μmol CO_2·m^{-2}·s^{-1}. The difference between the Üllői (–2.86 μmol CO_2·m^{-2}·s^{-1}) and NK2 (–3.03 μmol CO_2·m^{-2}·s^{-1}) was minimal. At the other *PPFD* levels, NK2 was the best, with *A* increasing steadily because of increasing *PPFD*, but the curve flattened at the 600 μmol·m^{-2}·s^{-1} *PPFD* level due to the effect of photorespiration on assimilation rates. The highest *A* value (13.58 μmol CO_2·m^{-2}·s^{-1}) occurred at the 2 000 μmol·m^{-2}·s^{-1} *PPFD* level. The Üllői cultivar and PL251 results varied and were characterised as follows. Üllői had a higher assimilation rate between 0 and 150 μmol·m^{-2}·s^{-1} *PPFD* levels; however, as light intensity increased, the PL251 clone proved superior. Although the Üllői curve ran lower than the PL251 curve at higher *PPFD* levels, its *A* value showed a steady increase, with the best value (5.79 μmol CO_2·m^{-2}·s^{-1}) at the highest *PPFD* level of 2 000 μmol·m^{-2}·s^{-1}. The assimilation rate of PL251 increased to 1 200 μmol·m^{-2}·s^{-1} *PPFD* level, reaching the highest *A* value (8.88 μmol CO_2·m^{-2}·s^{-1}) at this level (Figure 3).

The exponential regression functions also fitted well to the measured data points for the *PS*II efficiency values (R^2 values are 0.9948 for NK2, 0.9964 for PL251, and 0.9989 for Üllői). Thus, the curves of the functions clearly exhibited the differences in this case as well, i.e. the curves of the functions showed the differences suitably. From the obtained results, the *PS*II efficiency of the tested black locust clones and the Üllői black locust decreased with increasing light intensity. At low *PFPD* levels (0–300 μmol·m^{-2}·s^{-1}), the clone PL251 (0.70–0.61) produced the highest value, while at higher *PPFD* levels (600–2 000 μmol·m^{-2}·s^{-1}), the NK2 clone had the best value (0.50–0.18). However, the differences between the clones tested and the Üllői black locust were minimal, especially between clone PL251 and Üllői, which both had similar *PS*II values at many of the same light intensities (on 900; 1 200; 1 500 μmol·m^{-2}·s^{-1} *PPFD* levels the *PS*II efficiency index was 0.37; 0.29; 0.22, respectively). NK2 at 900 μmol·m^{-2}·s^{-1} *PPFD* level was visibly distinct from the other two (Figure 4).

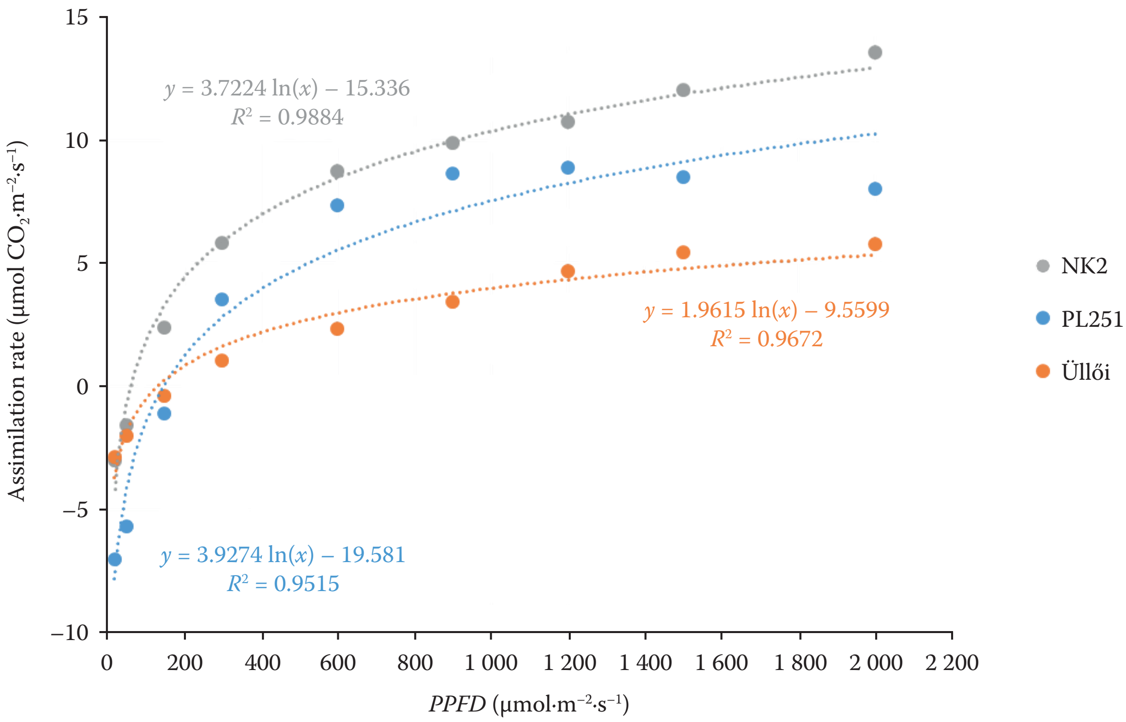

Figure 3. Assimilation rate light response curve of black locust clones PL251, NK2, and Üllői in Napkor (June 29, 2023)

PPFD – photosynthetic photon flux density

https://doi.org/10.17221/120/2023-JFS

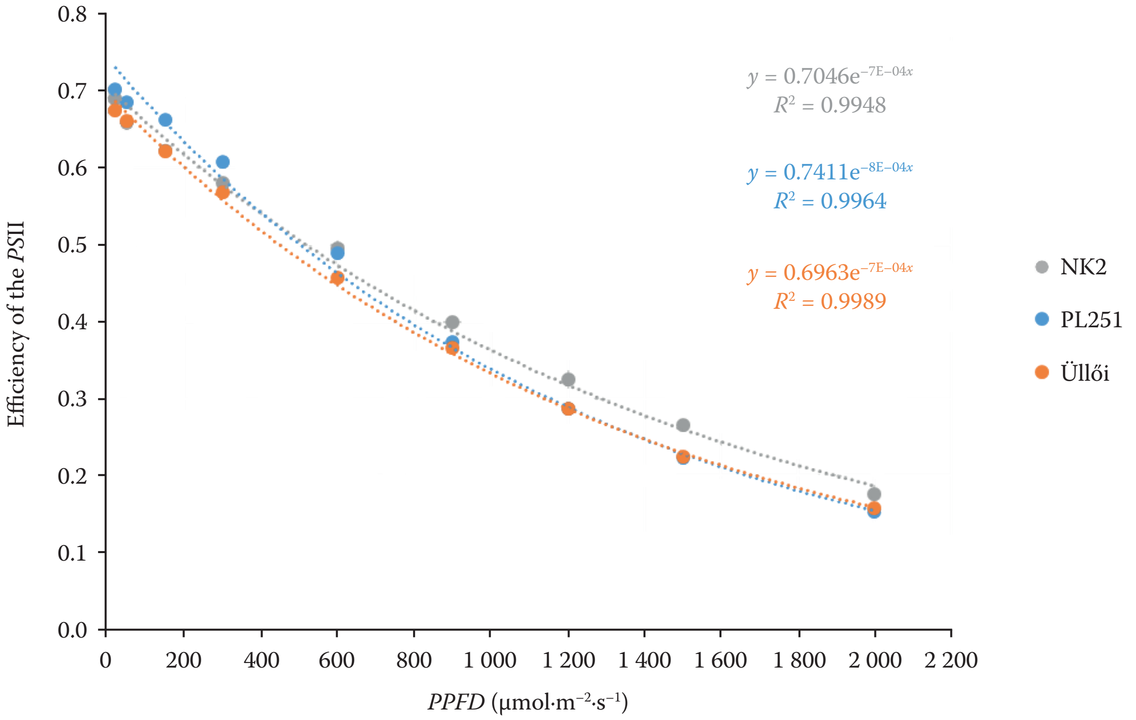

Figure 4. Photosystem II (*PS*II) light response curve of black locust clones PL251, NK2, and Üllői in Napkor (June 30, 2023)
PPFD – photosynthetic photon flux density

CONCLUSION

Black locust is planted in Europe for its ecological adaptability on degraded lands, fast growth, high biomass yields, and economic benefits. Ecophysiological studies are vital in this climate change era. The light response curves supply an opportunity for insights into black locust clone shade tolerance. NK2 clone rose above the other tested clones for shade tolerance and other studied parameters. The clone seems relatively drought tolerant, with a high assimilation rate and high *PS*II efficiency.

REFERENCES

Ábri T., Csajbók J. (2023): Comparative study of newly-bred black locust clones with regard to photosynthetic rate and water use efficiency: Early evaluation. Acta Agraria Debreceniensis, 1: 5–10.

Ábri T., Keserű Z., Borovics A., Rédei K., Csajbók J. (2022): Comparison of juvenile, drought tolerant black locust (*Robinia pseudoacacia* L.) clones with regard to plant physiology and growth characteristics in Eastern Hungary: Early evaluation. Forests, 13: 292.

Ábri T., Cseke K., Keserű Z., Porcsin A., Szabó F.M., Rédei K. (2023a): Breeding and improvement of black locust (*Robinia pseudoacacia* L.) with a special focus on Hungary: A review. iForest – Biogeosciences and Forestry, 16: 290–298.

Ábri T., Borovics A., Csajbók J., Kovács E., Koltay A., Keserű Z., Rédei K. (2023b): Differences in the growth and the ecophysiology of newly bred, drought-tolerant black locust clones. Forests, 14: 1802.

Arena C., Vitale L., Santo A.V.D. (2008): Paraheliotropism in *Robinia pseudoacacia* plants: An efficient means to cope with photoinhibition. In: Allen J.F., Gantt E., Golbeck J.H., Osmond B. (eds): Photosynthesis. Energy from the Sun. Dordrecht, Springer: 1403–1406.

Brito C., Dinis L.T., Moutinho-Pereira J., Correia C.M. (2019): Drought stress effects and olive tree acclimation under a changing climate. Plants, 8: 232.

Chaves M.M., Flexas J., Pinheiro C. (2009): Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. Annals of Botany, 103: 551–560.

Choi D., Jang W., Toda H., Yoshikawa M. (2021): Differences in characteristics of photosynthesis and nitrogen utilization in leaves of the black locust (*Robinia pseudoacacia* L.) according to leaf position. Forests, 12: 348.

Farooq M., Wahid A., Kobayashi N., Fujita D., Basra S.M.A. (2009): Plant drought stress: Effects, mechanisms and management. In: Lichtfouse E., Navarrete M., Debaeke P., Véronique S., Alberola C. (eds): Sustainable Agriculture. Dordrecht, Springer: 153–188.

https://doi.org/10.17221/120/2023-JFS

Farooq M., Hussain M., Wahid A., Siddique K.H.M. (2012): Drought stress in plants: An overview. In: Aroca R. (ed.): Plant Responses to Drought Stress. Heidelberg, Springer: 1–33.

Flexas J., Medrano H. (2002): Drought-inhibition of photosynthesis in C3 plants: Stomatal and non-stomatal limitations revisited. Annals of Botany, 89: 183–189.

Küppers M., Schmitt D., Liner S., Böhm C., Kanzler M., Veste M. (2018): Photosynthetic characteristics and simulation of annual leaf carbon gains of hybrid poplar (*Populus nigra* L. × *P. maximowiczii* Henry) and black locust (*Robinia pseudoacacia* L.) in a temperate agroforestry system. Agroforest Systems, 92: 1267–1286.

Lange C.A., Knoche D., Hanschke R., Löffler S., Schneck V. (2022): Physiological performance and biomass growth of different black locust origins growing on a post-mining reclamation site in Eastern Germany. Forests, 13: 315.

Mantovani D., Veste M., Freese D. (2014): Black locust (*Robinia pseudoacacia* L.) ecophysiological and morphological adaptations to drought and their consequence on biomass production and water-use efficiency. New Zealand Journal of Forestry Science, 44: 1–11.

Meng F., Peng M., Pang H., Huang F. (2014): Comparison of photosynthesis and leaf ultrastructure on two black locust (*Robinia pseudoacacia* L.). Biochemical Systematics and Ecology, 55: 170–175.

Nicolescu V.N., Rédei K., Mason W.L., Vor T., Pöetzelsberger E., Bastien J.C., Brus R., Benčať T., Đodan M., Cvjetkovic B., Andrašev S., La Porta N., Lavnyy V., Mandžukovski D., Petkova K., Roženbergar D., Wąsik R., Mohren G.M.J., Monteverdi M.C., Musch B., Klisz M., Perić S., Keça L., Bartlett D., Hernea C., Pástor M. (2020): Ecology, growth and management of black locust (*Robinia pseudoacacia* L.), a non-native species integrated into European forests. Journal of Forestry Research, 31: 1081–1101.

Rédei K., Keserű Z., Bach I., Rásó J., Ábri T., Szabó F., Gál J. (2020): Management of *Robinia pseudoacacia* cv. 'Üllői' – 'Üllői' locust. Acta Silvatica et Lignaria Hungarica, 16: 9–18.

Vítková M., Müllerová J., Sádlo J., Pergl J., Pyšek P. (2017): Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe. Forest Ecology and Management, 384: 287–302.

Zheng Y., Zhao Z., Zhou J., Zhou H. (2012): Evaluations of different leaf and canopy photosynthesis models: A case study with black locust (*Robinia pseudoacacia*) plantations on a Loess Plateau. Pakistan Journal of Botany, 4: 531–539.

Received: November 28, 2023
Accepted: January 23, 2024
Published online: April 11, 2024