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Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Light response curve analysis of juvenile Püspökladányi and Üllői black locust

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Keywords: Robinia pseudoacacia, net assimilation, intercellular CO_2 level, stomatal conductance, light response curve, carbon fixation.

ABSTRACT

Assimilation (A), intercellular CO_2 level (C_i) and stomatal conductance (total conductance of CO_2 = g_{tc}) light response curves (A/PPFD, C_i/PPFD, g_{tc}/PPFD curves) of 2-year-old promising black locust clone 'Püspökladányi' and the registered one, 'Üllői', were analyzed, aiming to study A, C_i and g_{tc} in function of Photosynthetic Photon Flux Density (PPFD) levels. The natural logarithmic (A/PPFD and C_i/PPFD) and quadratic (g_{tc}/PPFD) regression functions fitted well to the measured data points for both parameters. The R^2 value for the A/PPFD is 0.9745 for 'Püspökladányi' and 0.9444 for the 'Üllői' variety. The R^2 values were 0.9499 ('Püspökladányi') and 0.8629 ('Üllői') for the g_{tc}/PPFD curves and 0.8950 ('Püspökladányi') and 0.9112 ('Üllői') for the C_i/PPFD curves. The A/PPFD curves of the tested clones increased steadily with increasing illumination level, but it flattened at the 600 µmol m^{-2} s^{-1} PPFD level, which is due to the effect of photorespiration on the assimilation rate. For 'Üllői', the A/PPFD curve decreased at the 1500 µmol m^{-2} s^{-1} PPFD level. In contrast to the results for A/PPFD, the C_i/PPFD curve decreased with increasing PPFD level. In case of g_{tc}/PPFD curve, g_{tc} values peak at 900 µmol m^{-2} s^{-1} PPFD level for 'Püspökladányi' and 600 µmol m^{-2} s^{-1} PPFD level for 'Üllői'. We found significant differences between the A values, as well as the g_{tc} ones. In Europe, negative changes, e.g. increasingly frequent drought, heat, uneven distribution of precipitation, etc., in climate are predicted for the future. Under such conditions, relatively drought-tolerant tree species such as black locust will play an important role in new afforestation and uninterrupted wood supply. Consequently, the growing and improvement of black locust, included the ecophysiological studies of relatively drought tolerant, newly-bred clones is of growing importance.

INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is one of the most widespread exotic tree species in Europe (Nicolescu et al. 2020). Due to its high site plasticity, its versatile uses (wood industry, agriculture, beekeeping, environmental development) and its high quality, durable wood, it is a dominant tree species in Hungarian forestry, especially in the Nyírség region (Nicolescu et al. 2018). The ecological challenges facing forests and tree plantations, the negative effects of global and local climate change, and the various weather events (uneven rainfall, drought, frequent heat waves, etc.) have become increasingly frequent in recent years (IPCC 2023; Vacek et al. 2023). Under water stress, the rate of photosynthesis decreases, stomata close and stomatal conductance (g_{tc}) becomes low, resulting in a decrease in intercellular CO_2 concentration (C_i) depending on the intensity of photosynthesis. And thus, these parameters affect tree growth (Farquhar and Sharkey 1982, Ashraf and Harris 2013, Meng et al. 2014). Under these conditions, relatively drought-tolerant tree species such as black locust will play an important role in new afforestation. Consequently, the growing and improvement of black locust is of increasing importance. In Hungary, research projects to improve the yield and stem quality of black locust were started in the 1960s (Ábri et al. 2023a). In a recent project newly-bred black locust clones are tested. In this trial we study the growth and physiological parameters of these clones, compared to the state-approved 'Üllői' black locust cultivar (Ábri et al. 2023b).

In this study we focused on 'Püspökladányi' candidate cultivar. We studied its net assimilation (A), stomatal conductance (g_{tc}) and intercellular CO_2 level (C_i) in function of Photosynthetic Photon Flux Density (PPFD), the light response curves (A/PPFD, C_i/PPFD, g_{tc}/PPFD) compared to the registered 'Üllői' black locust genotype.

MATERIALS AND METHODS

With the new clones ('Püspökladányi' – PL251, 'Farkasszigeti' – PL040, 'Laposi' – NK1, 'Napkori' – NK2) and the 'Üllői' cultivar, a clone trial was established in 2020 in a slightly acidic, low humus sandy soil, near the settlement of Napkor in the Nyírség region, where the the annual mean temperature was 10.6 °C, and the annual mean precipitation was 537 mm. 1-year-old vegetatively propagated rooted seedlings were planted in 3 different planting spacings: 2.5 × 2.5 m; 3 × 3 m; 4 × 4 m (Ábri et al. 2023b). Our measurements were carried out in the planting spacing 2.5 × 2.5 m.

Physiological parameters for light response curves of 2-year-old candidate cultivar 'Püspökladányi' and 'Üllői' black locust were measured on 29 June 2021. Portable photosynthesis system (LI-6800, LI-COR, Lincoln, NE, USA) was used to measure net assimilation rate, stomatal conductance to CO_2 and intercellular CO_2 levels. It can be also used to analyse transpiration, leaf water vapour saturation, and air and leaf temperatures (LI-COR 2024). The light was controlled in the sample chamber of the instrument with 90% red (625 nm) and 10% blue (475 nm) light. PPFD (Photosynthetic Photon Flux Density) was decreased in 8 levels (1500, 1200, 900, 600, 300, 150, 50, 0 µmol µmol m^{-2} s^{-1}). A LI-6800-01A fluorometer head was used as light source, the measured area of the leaf was 2 cm^2. The concentration of CO_2 was also controlled (400 µmol mol^{-1}) in the sample chamber using an injector and CO_2 cartridges. Light-adapted leaves were measured four times per leaf on three plants per plot (12 measurements/clone in total). Data were recorded after the measurement results had stabilised (coefficient of variation < 1%), but after at least 120 s.

RESULTS AND DISCUSSION

Light response curves of clone 'Püspökladányi' and the state-approved 'Üllői' were analysed. There was significant difference (p = 0.05) in the assimilation rate between the 'Püspökladányi' and the 'Üllői' at all PPFD levels, and the difference was higher at the higher photon flux densities. The natural logarithmic regression functions fit well to the measured data points (R^2 values are 0.9444 and 0.9745), so the curves of the functions showed clearly the differences. At the low PPFD levels, from 0 to 300 µmol m^{-2} s^{-1} the 'Üllői' variety had higher assimilation rate, but as the light intensity increased, the 'Püspökladányi' clone had higher photosynthesis rate, the curve of 'Üllői' ran lower than that of the other at higher than 300 µmol m^{-2} s^{-1} photon flux density level. The assimilation rate of the clone 'Püspökladányi' increased to the 1500 µmol m^{-2} s^{-1} PPFD level. In 'Üllői' cultivar the assimilation rate decreased above 1200 µmol m^{-2} s^{-1} PPFD (Figure 1).

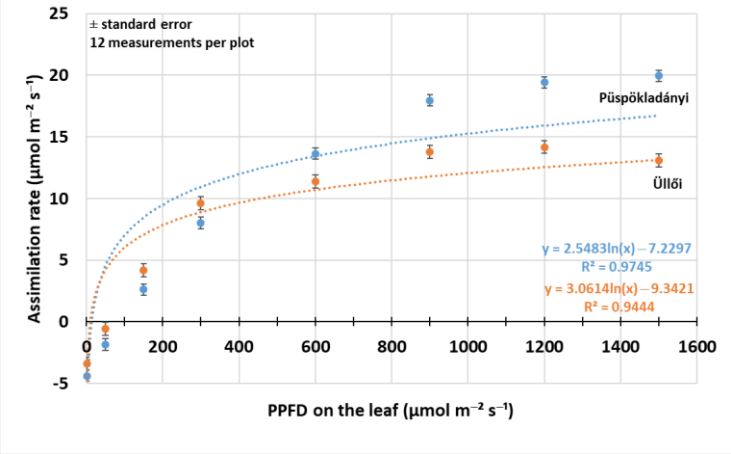

Figure 1: Assimilation rate (A) light response curve of black locust clones 'Püspökladányi' and 'Üllői'. Note: PPFD = Photosynthetic Photon Flux Density (Napkor, 29/6/2021)

For C_i the natural logarithmic regression functions also fit well to the measured data points (Figure 2), the R^2 values are 0.9499 ('Püspökladányi') and 0.8629 ('Üllői'). From the obtained results, the C_i of the

tested black locust clones decreased with increasing light intensity. At low PPFD levels (0-300 µmol m^{-2} s^{-1}), the clone 'Püspökladányi' produced the higher value (422.63-328.25 µmol mol^{-1}), but the differences were not significant at p = 5%. However, at higher PPFD levels (600-1500 µmol m^{-2} s^{-1}), the 'Üllői' had the highest values (301.55-280.18 µmol mol^{-1}), which were significant at 600; 1200 and 1500 µmol m^{-2} s^{-1} PPFD levels ($p < 0.05$). The C_i values of clone 'Püspökladányi' varied between 271.73 µmol mol^{-1} and 236.13 µmol mol^{-1} at PPFD levels 600; 900; 1200 and 1500 µmol m^{-2} s^{-1}.

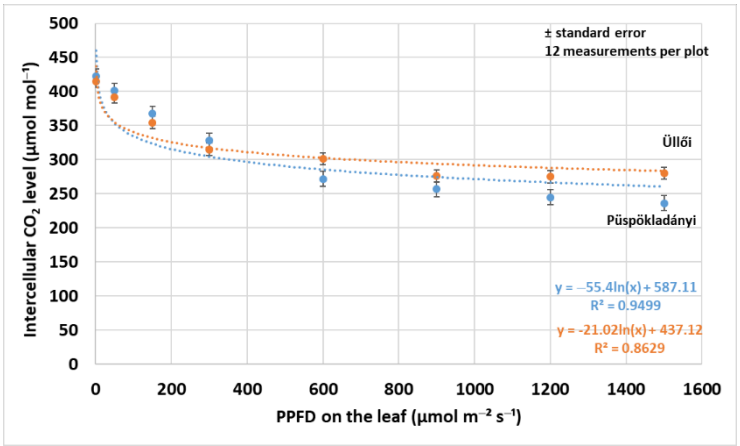

Figure 2: Intercellular CO_2 level (C_i) light response curve of black locust clones 'Püspökladányi' and 'Üllői'. Note: PPFD = Photosynthetic Photon Flux Density (Napkor, 29/6/2021)

For g_{tc}, the quadratic regression functions fit well to the measured data points (R^2 values are 0.8950–0.9112). When examining the g_{tc} of clones 'Püspökladányi' and 'Üllői' as a function of PPFD, the present study found significant ($p < 0.05$) differences at every PPFD level. The g_{tc} values peak at 900 µmol m^{-2} s^{-1} PPFD level for 'Püspökladányi' (0.1595 mol m^{-2} s^{-1}) and 600 µmol m^{-2} s^{-1} PPFD level for 'Üllői' (0.1543 mol m^{-2} s^{-1}). Furthermore, the clone 'Püspökladányi' had significantly higher g_{tc} values at all the PPFD levels (Figure 3).

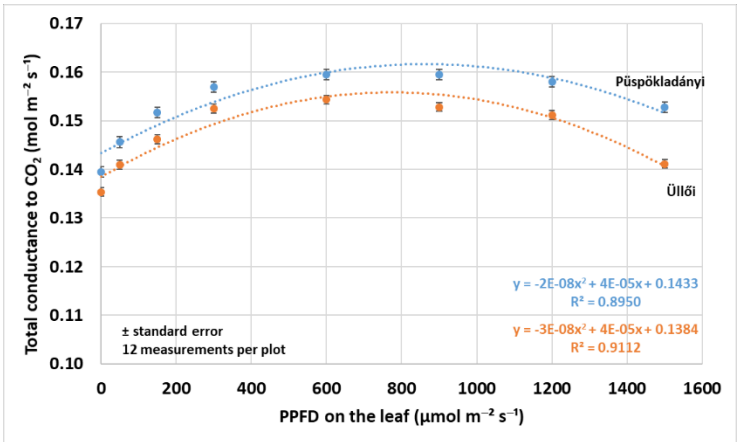

Figure 3: Total stomatal conductance (g_{tc}) light response curve of black locust clones 'Püspökladányi' and 'Üllői'. Note: PPFD = Photosynthetic Photon Flux Density (Napkor, 29/6/2021)

CONCLUSIONS

Nowadays, the study of physiological parameters (photosynthesis, carbon sinking, water use management, etc.) of relatively drought tolerant tree species, such as black locust, is crucial for local and global forest managements. In this paper, we presented an early evaluation of light response curves of newly-bred black locust clone ('Püspökladányi'), compared to the state-approved cultivar ('Üllői'). We found that logarithmic (assimilation and intercellular CO_2 level) and quadtaric (stomatal conductance) regression functions fitted well to the measured data points, the R^2 values were higher than 0.85 in all cases. Furthermore, there were significant ($p < 0.05$) differences between 'Püspökladányi' and 'Üllői' for assimilation and stomatal conductance values at all photosynthetic photon flux density levels. Based on the results, it is likely that the 'Püspökladányi' clone has better shade tolerance than the 'Üllői' variety and also makes better use of more intense lighting conditions. Clone 'Püspökladányi' seems to be a promising black locust clone, which is suitable for industrial tree plantations.

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