DOI: 10.20315/SilvaSlovenica.0026.05

Matjaž Čater[1,2], Pia Caroline Adamič[2,3], Eva Darenova[4]

Response of beech and fir in the Carpathians and Dinarides

KEYWORDS**:** silver fir, beech, light response, Carpathians, Dinarides

Introduction

Mixed fir-beech forests are an essential component of Central and South-Eastern European Forest ecosystems and landscapes (Bledy *et al.*, 2024). Vegetation changes in the Carpathian forests can be attributed to various processes (Šamonil and Vrška, 2007), such as air pollution and the competitive influence of tree seedlings (Łysik, 2009). Of particular interest is how silver fir will cope with recent climate trends (Maiorano et al., 2013). Adamič et al. (2023) already confirmed different stem radial growth in beech and fir since 1950s and their response to climate conditions along the Carpathians, while Darenova et al. (2024) related soil respiration spatial variability with soil water content, soil carbon and nitrogen content with no significant effect connected with canopy gaps.

On the Balkan Peninsula, the response of beech and fir from the southern, sites already served as a future prediction for less extreme sites in the north (Čater and Levanič, 2019), while Carpathian Mountains are more complex and exhibit a sufficient latitudinal and longitudinal gradient associated with significant differences in temperature/precipitation as well as differences in seasonal patterns (Micu et al., 2016). Quantum yield (Φ) in various light microsites proved beech as more efficient in exploiting direct radiation in sun exposed parts of the gap, compared to silver fir (Čater et al., 2024).

Our aim was to compare the light responses of beech and fir in the Carpathian and Dinaric Mountains (1), and to verify the relationship between climatic parameters and light response along both complexes (2).

Material and methods

19 permanent research plots were located above an altitude of 800 m a.s.l., with abundant natural regeneration of both tree species. Eight plots were established in the Carpathians, and eleven in the Dinarides. Two old growth reserves were selected in the Carpathians (plots 3 and 8) and three in the Dinarides (plots 3, 7 and 8, Fig. 1).

[1] Department of Yield and Silviculture, Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia

[2] Department of Silviculture, Faculty of Forestry and Wood Technology, Mendel University, Zemedelska 3, 613 00 Brno, Czech Republic

[3] Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana, Slovenia

[4] Department Of Matters And Energy Fluxes, Global Change Research, Institute of the Czech Academy of Sciences, Bělidla 4a, 60300 Brno, Czech Republic

Corresponding author: Matjaž Čater **-** matjaz.cater@gozdis.si

- Three light intensity categories were defined on each plot based on the analysis of hemispherical photographs (Čater et al. 2024).
- Monthly mean temperatures (°C) and monthly total precipitation data were interpolated for the 0.5° grids from the 'Climate Explorer' website (http://cliexp.knmi.nl). Data from the last 50-year average period (1981-2020) were used.
- Total leaf nitrogen concentration (N_{tot}) [mg/g] was determined from leaves and needles taken from the upper canopy position (Čater et al., 2014). Leaves were dried to constant weight at 105 °C for 24 hours and weighed in the laboratory to determine leaf mass per area (LMA) [g/m^2].

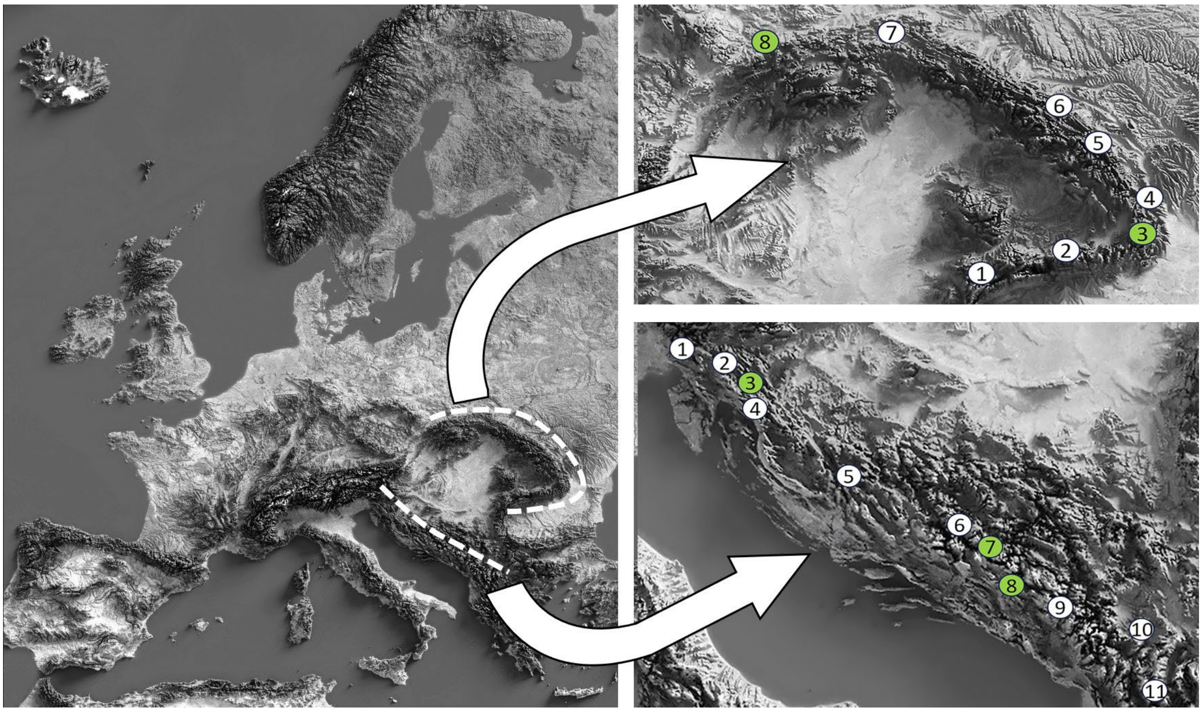

Fig. 1. Research plot location

- Light saturation measurements were carried out in June and July in three consecutive growing seasons, at least 8 young trees with a portable LI-6400 (Li-Cor, USA) system (Čater et al. 2024).
- The maximum quantum yield (Φ), defined as the maximum amount of fixed CO_2 per amount of absorbed light quanta (Lambers et al., 1998) measured as the initial slope of the light response curve of CO_2 fixation, were determined for each light category, species and plot, as described in Čater et al. (2024).
- Differences between the same years for the LMA, N_{tot}, A_{max} and Φ were tested using two-way ANOVA with tree species (beech and fir) and light (open, edge, canopy) as dependent variables. HSD Tuckey post-hoc test was performed after testing data to meet conditions of normality. Probability values of $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***) were considered significant. Data analyses were performed using Statistica Data Analysis Software System (2011).

Results

Long-term average temperatures show homogeneous conditions over Dinarides and more variable conditions in Carpathians. The average annual precipitation in the Carpathians is lower.

Foliar nitrogen (N_{tot}) *i*n all plots was highest for both beech and fir in the open and lowest in the closed canopy, without significant differences between light categories and years. On all studied plots N_{tot} was within the optimal thresholds (Yang et al., 2022; Bachofen et al., 2020). The same trend was observed for LMA. N_{tot} and LMA were non significantly lower in all categories of Carpathians compared to Dinarides.

Quantum yield (Φ) followed the pattern of precipitation and temperature; it was highest for beech in the open light and under closed canopies for fir. In old growth reserves of the Dinarides, Φ was shifted towards the response of open light and the absolute values were higher in all light categories than in the neighbouring managed forest stands (data not shown). Areas with the highest Φ for both species and complexes were defined for beech in the central Dinarides and western Carpathians and for fir in Northern Dinarides and also western Carpathians. With post-hoc analyses significant differences between light categories for Φ in Dinarides were confirmed. In Carpathians differences between light categories were not so pronounced.

Table 1. ANOVA for beech and fir in different light conditions and complexes.

Complex	Df 1;2	Species		Df 1;2	Light category		Df 1;2	Species X Light category	
		F	p		F	p		F	p
Carpathians	1; 1096	622.2	2e-17***	2; 1096	214.9	2e-17***	2; 1096	2869.5	2e-17***
Dinarides	1; 1578	73.0	2e-16***	2; 1578	231.0	2e-16***	2; 1578	775.4	2e-15***

Positive correlation between Φ and annual precipitation increased with the light intensity for beech in all light categories in Carpathians and Dinarides. The correlation for fir decreased with increasing light and was highest when the canopy was closed. Φ of beech in both complexes decreased with increasing annual temperature. Φ for fir in the Carpathians decreased with increasing annual temperature, while in the Dinarides, it increased (Fig. 2).

The average annual temperatures at the selected Carpathian sites ranged between 12 and 14 °C with the exception of sites 4 and 1, while the average annual temperatures at the Dinaric sites showed more homogeneous conditions (13 to 14 °C). The average precipitation in the Dinarides decreased evenly from the north-west to south-east, while the amount of precipitation in the Carpathians decreased from west to east. Φ in Dinarides was highest for beech in the central area, for fir in the north-western part, while in the Carpathians it was highest at the beginning and end of the studied transect. In both complexes, Φ were higher for beech in the open, and for fir highest under shaded conditions. Differences between old-growth forests and neighbouring managed forests were less pronounced in the Carpathians than in the Dinarides (Čater et al., 2024).

Variability of Φ and between light categories were higher for both species in the Dinarides, possibly reflecting the more diverse growing conditions and more abundant water availability compared to the Carpathians (Micu et al., 2016). We believe water to be the most important limiting parameter, as the response of both species at all study sites in the Carpathians, except the first two, corresponded to sites in Dinarides with annual precipitation below 500 mm.

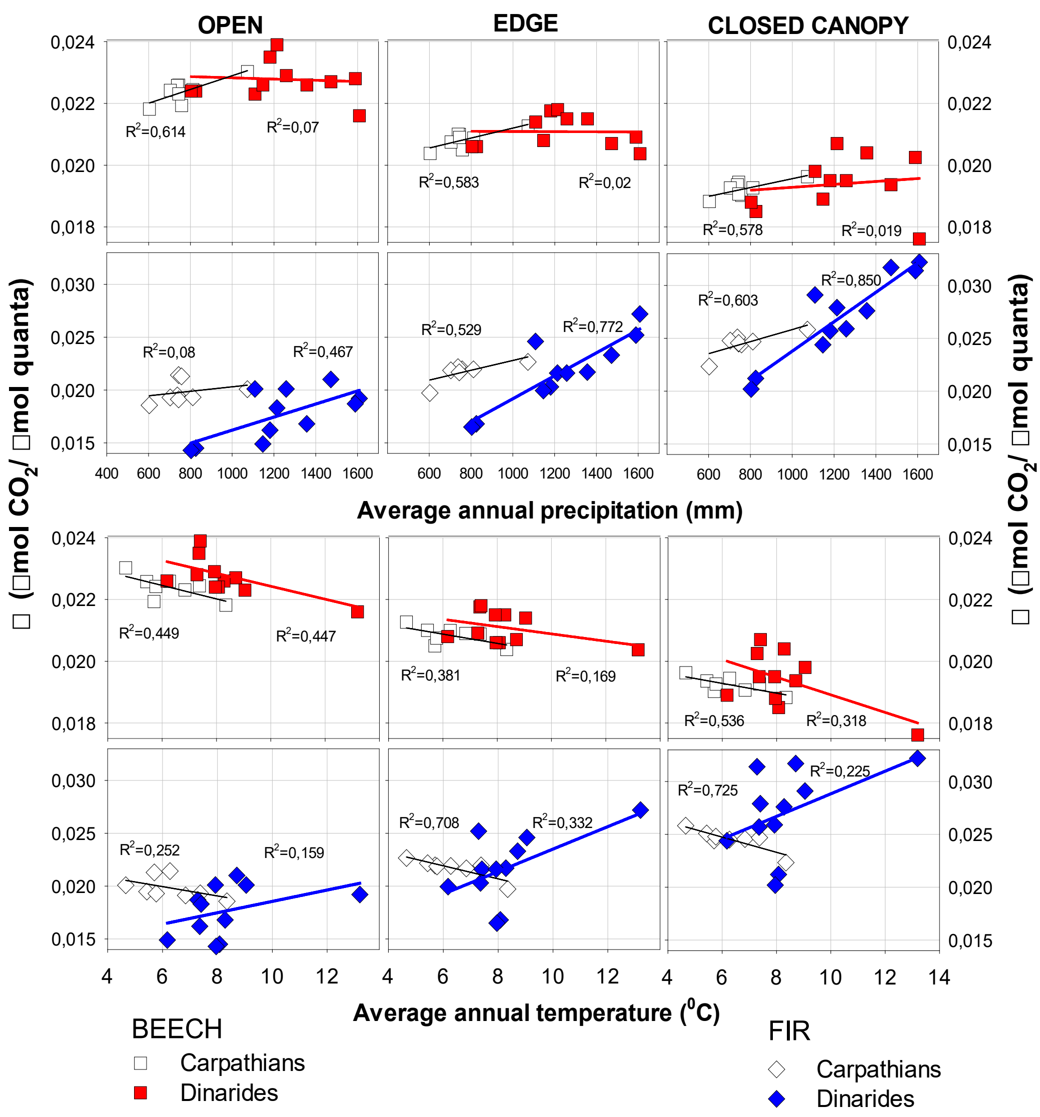

Fig. 2. Quantum yield (Φ) vs. precipitation and temperature

The assimilation response in young beech and fir trees was in good agreement with the growth response in adult trees (Čater and Levanič, 2019); study of Adamič et al. (2023) confirmed clear differences in the growth response to climate (temperature and precipitation) between southern, eastern and northern locations on the same study plots. Accordingly, the quantum yield of beech and fir showed the lowest values in the eastern part and the highest values in the west.

In the Dinaric Mountains growth of fir responded more strongly to climate than that of beech in the same study plots. Both temperature and precipitation had a stronger influence on the growth of fir. The climate signal of fir became weaker from NW to SE, with only the drought indices remaining significant, while the response of beech to climate was weaker in all plots and decreased from NW to SE, similar to fir (Čater and Levanič, 2019).

Short-term ecophysiological responses of beech and fir provided information on the behaviour at three different light intensity categories compared to long-term radial growth observations, which were consistent. The main difference between the two larger areas was the response of young fir to increasing temperatures, which correlated positively with increasing temperatures in the Dinarides and negatively in the Carpathians. In our opinion, this difference is related to the high precipitation in the Dinaric Mountains and the low precipitation in the Carpathians.

Funding

The author acknowledges the financial support from the Slovenian Research Agency (research core funding P4-0107 Program research at the Slovenian Forestry Institute, project grant No. J4-3086, by the Young Researcher program of the Slovenian Research Agency and by the Czech Science Foundation GAČR No. 21-47163L.

Acknowledgement

Sincere thanks to Dr. J. Kermavnar, R. Krajnc, Dr. S. Poljanšek, Dr N. Potočić, BSc Ing D. Mioć, Prof Dr D. Ballian, Prof. Dr O. Huseinović, BSc Ing Z. Čančar, Mr G. Damjanović, Mr R. Orbović, Mr E. Pupović, BSc Ing N. Kryeziu, Prof Dr M. Karadelev, BSc In S. Hanko and Dr. M. Hanzu. No plants or animals (including human) were harmed during this study.

References

ADAMIČ, P.C., LEVANIČ, T., HANZU, M., ČATER, M., 2023: Growth response of European beech (Fagus sylvatica L.) and Silver Fir (*Abies alba* Mill.) to climate factors along the Carpathian massive. Forests 14: 1318.

BACHOFEN, C., D'ODORICO, P., BUCHMANN, N., 2020: Light and VPD gradients drive foliar nitrogen partitioning and photosynthesis in the canopy of European beech and silver fir. Oecologia 192: 323–339.

BLEDÝ, M., VACEK, S., BRABEC, P., VACEK, Z., CUKOR, J., ČERNÝ, J., ŠEVČÍK, R., BRYNYCHOVÁ, K., 2024: Silver Fir (*Abies alba* Mill.): Review of Ecological Insights, Forest Management Strategies, and Climate Change Impact on European Forests. MDPI Forests, in press.

ČATER, M., LEVANIČ, T., 2019: Beech and silver fir's response along the Balkan's latitudinal gradient. Scientific Reports 9: 16269.

ČATER, M., ADAMIČ P.C., DARENOVA E., 2024: Response of beech and fir to different light intensities along the Carpathian and Dinaric Mountains. Front. Plant Sci. 15: 1380275. doi: 10.3389/fpls.2024.1380275

DARENOVA, E., ADAMIČ P.C., ČATER, M. 2024: Effect of temperature, water availability, and soil properties on soil CO_2 efflux in beech-fir forests along the Carpathian Mts. Catena 240: 107974. https://doi.org/10.1016/j.catena.2024.107974

ŁYSIK, M., 2009: A 13-year change in ground-layer vegetation of Carpathian beech forests. Polish Journal of Ecology 57: 47–61.

MAIORANO, L., CHEDDADI, R., ZIMMERMANN, N., PELLISSIER, L., PETITPIERRE, B., POTTIER, J., LABORDE, H., HURDU, B., PEARMAN, P., PSOMAS, A., 2013: Building the niche through time: using 13,000 years of data to predict the effects of climate change on three tree species in Europe. Global Ecology and Biogeography 22: 302–317.

MICU, D.M., DUMITRESCU, A., CHEVAL, S., BIRSAN, M.-V., 2016: Climate of the Romanian Carpathians. Springer.

ŠAMONIL, P., VRŠKA, T., 2007: Trends and cyclical changes in natural fir-beech forests at the north-western edge of the Carpathians. Folia Geobotanica 42: 337–361.

YANG, F., BURZLAFF, T., RENNENBERG, H., 2022: Drought hardening of European beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill.) seedlings in mixed cultivation. Forests 13: 1386.