DOI: 10.20315/SilvaSlovenica.0026.01

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European beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill) at the North-Western edge of Carpathians; contributions to ecology and management

KEYWORDS: competition, growth, mixture, water balance

Introduction

European beech is considered as the most widespread tree species in Central Europe. In the past it naturally covered 40 - 60% of the total forested land area in the Czech Republic, while currently it covers only 9 %, despite the fact that it has been used as an amelioration tree species. It has been present in the Czech Republic with silver fir since 3-4 thousand years BC. With fir and yew, it is one of the most shade-tolerant tree species, which does not require a geologically specific substrate. Its competitiveness and growth dominate on calcareous, rich, at least moderately deep, moist and aerated soils. Stagnant water and flooding are not tolerated (Černý et al. 2024). The natural abundance of fir in the Czech Republic reaches 20 % if it were not for its decline and dieback due to emissions, pests, fungal pathogens and severe game damage. Currently in the Czech Republic it is represented only by 1.3 %. Fir is demanding regarding soil moisture and damaged by late or early frosts. Both beech and fir are well anchored in the soil and form mixed stands with spruce and other tree species. Our previous research testing the effect of elevated CO_2 fumigation into the atmosphere (Pokorný et al. 2013a, Pokorný et al. 2013b) to the changes in the amount of the beech biomass of above-ground as well as below-ground part when it grown in individual and groups admixture within the spruce stand (Novosadová et al. – under prep.) showed that under air elevated CO_2, the lowest amount of biomass in beech trees was produced in group-admixture, while the highest biomass amount in trees grown under single-admixture or in pure stand conditions. Therefore, behind pure stands, single admixture of beech could be probably recommended instead of group admixture for beech cultivation in the future.

Global climate change caused by increasing concentrations of greenhouse gases, mainly CO_2, is understood as a deviation of the Earth's climatic parameters, e.g. temperature, precipitation, wind speed, from the averages and trends that have characterised conditions over last 2000 years. The manifestation, frequency and duration of extreme weather events are increasing. Increased atmospheric CO_2 concentrations are likely to make beech more competitive as a deciduous tree species on nutrient rich and calcareous soils (Spinler et al. 2003) Beech is sensitive to drought; increased atmospheric CO_2 concentrations lead to a decrease in stomatal conductance (Hättenschwiller 2001), so the future competitiveness of beech may in turn be declining in its current range (e.g. Gessler et al. 2006) due to susceptibility to cavitation (aeration of conducting vessels; at Vapour Pressure Deficit (VPD) above -1.8 MPa), carbon starvation (McDowell et al. 2008), and strong relationship between soil moisture and increment

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(Lebourgeois et al. 2005). During drought, beech transpiration is reduced, while radial increment persists for further 1-2 years followed by starvation, so drought stress symptoms in beech are delayed. While closed vents and their faster response reduce the probability of cavitation (Lemoine et al. 2002) and the water use efficiency (WUE), it is better compared to spruce (Rötzer et al. 2017). Future predictions for beech are not optimistic (e.g. Hanewinkel et al. 2013, Thurm et al. 2018).

Efforts are made to rehabilitate firs, given its exceptional growth strategy and the possibility of replacing the loss of coniferous timber on the market due to the spruce stands breakdown. Firs benefit by biomass production from increased atmospheric CO_2 concentrations; its light requirements also seem to increase (Hättenschwiler and Körner 2000). Dendrochronological studies demonstrate fir as more resistant to long-term drought compared to Norway spruce and European beech (Vitasse et al. 2019). Preserving fir and beech under shelterwood or in a mixture with more tree species may be promising for the future.

Carpathian Mountains are the second largest mountain system in Europe, covering 210 thousand km^2. We are presenting several case studies, from two Czech regions in north-western parts of the Carpathians. Studies were focused on: 1) different thinning type on beech, oak and linden in a mixed stand located at low elevations, 2), different thinning intensity on beech tree production and its water regime at low elevations, and 3) fir regeneration and growth at the sites of different micro-climatic conditions.

1. Different thinning effect on dendrometric parameters and subsequent spontaneous growth in a beech-oak-linden stands

Research (see details in Novosadová et al. 2024, devoted to the project) focuses on different types of thinning evaluation performed in mixed stand at the University Forest Enterprise (UFE) Masaryk Forest Křtiny as the edge of the Carpathians dominated by beech and sessile oak after 35 years of continuous monitoring during 5-year intervals; specifically of crown thinning (i.e. thinning from above, intensity of 26 % reduction of Basal area; BA), low thinning (i.e. thinning from below, intensity of 16 % of BA), and heavy crown thinning (intensity of 36 % of BA) realised once in the age of stands about 50 years. As the vertical shift of even two forest vegetation zones upward is predicted in CR (Čermák et al. 2021), the mutual competition of different tree species, especially beech – oak, is under intensive research there nowadays. Results indicate that best results provide heavy crown thinning, i.e. thinning from above with a high intensity (Novosadová et al. 2024).

2. Different thinning measures to improve water balance and beech growth at low altitudes

Repeated dry periods in recent years caused drying of the primary canopy structure, usually from the tree top (Geßler et al. 2006). A set of research plots was established in 2021 at the University Forest Enterprise Masaryk Forest, Křtiny. The area belongs climatically to the warm, moderately dry region with an 8 - 9 °C average annual temperature for the 1961-2008 period and annual precipitation of 550-650 mm (Rožnovský and Litschman 2010). In the research area there are soils developed from the disintegration of carbonate rocks belonging to the rendzina with the subtypes on limestone oak-beech and enriched stony lime oak-beech stands.

High intensity thinning (releasing cut surround the target trees) with small amount of chosen target trees per hectare (50) than recommended (80-110), could be the best solution to enhance water availability for target trees in stand to support growth and good health status. Selected plots in four neighbouring stands were 50-70 years old, with dominant beech (*Fagus sylvatica*, L.), interspersed Norway maple (*Acer platanoides*, L.), sessile oak (*Quercus petraea*, (Matt.) Liebl.) and ash (*Fraxinus excelsior*, L.). Eight thinning variants (six of which were the target tree method with 50, 80 and 110 target trees per hectare, and with low (LOW; removing of 1-2 nearest competitors in crown, approx. 22 % reduction of BA) and high intensity of thinning (HIGH; 3-4 competitors, approx. 43 % reduction of BA), 1x common management treatment (CMT; 20 % reduction of BA, thinning from Above)) and one control variant without intervention (only sanitary cut) were applied. Each research plot was established as a circle of 2 500 m^2 (r = 28.2 m).

Trees with a diameter at breast height (DBH) above 5 cm were numbered in all circular plots with basic dendrometric parameters (DBH and H - tree height) measured. Using Field-Map (IFER, Czech Republic), the position and horizontal crown projection of each marked individual was located. Water gate systems were installed under canopies in all plots to quantify through-fall precipitation and interception, and stem surface flow to quantify completely net stand precipitation. Soil moisture (with three replications, in the depth 0-15 cm) was continuously monitored with TMS-4 sensors (TOMST, CR). Only target trees within the variants with 80 target trees and in common management treatment variant were monitored for transpiration flux during the first year after thinning. Sets of transpiration sensors EMS81 and EMS51 (Environmental Measuring Systems, Brno, CR) operating on the principle of stem heat balance method (Čermák et al. 1973) were used for sapflow quantification. Sample trees were determined using the quantile method according to Čermák et al. (2004).

The transpiration measurements during the first growing season (2022) after realisation of thinning show results not fitting hypotheses, but relevant due to possible shock occurrence after realising intensive thinning and opening the target tree´s crowns to high solar irradiation, wind movement and low air vapour pressure deficit conditions. In 2022, drought conditions obviously started to manifest at the end of August, when potential atmospheric evapotranspiration demands overcame available water from rain (Fig. 1.)

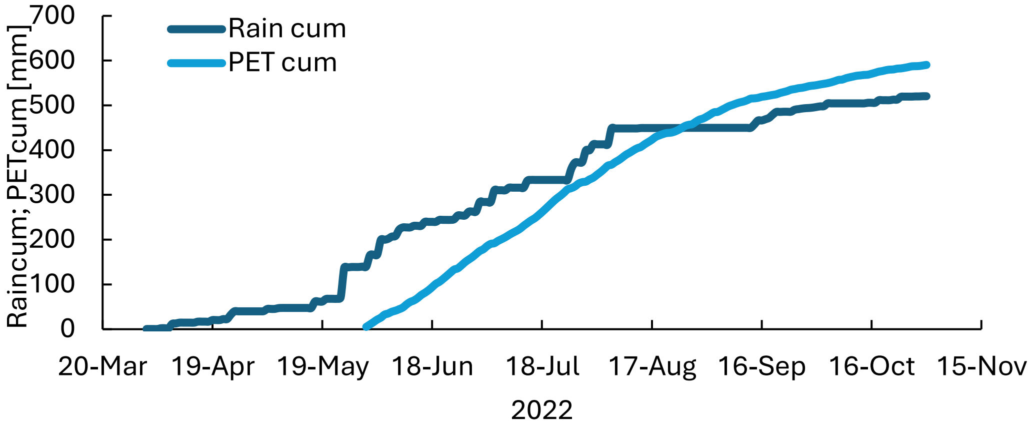

Fig. 1. Cumulative evapotranspiration demands (PETcum) calculated on the base of air humidity and temperature, and the cumulative amount of precipitation (Raincum) during the growing season 2022 at the locality of beech thinning experiments at UFE.

Due to higher canopy reduction also higher water availability for remaining target trees may be presumed. Target trees with high intensity of realising cut surrounding their crowns were stressed and their transpiration shows the lowest values mostly during the whole growing season. Low intensity thinning seems as the best solution for improvement of water regime and supporting growth increment of target trees during the first year after thinning intervention (Fig. 2.).

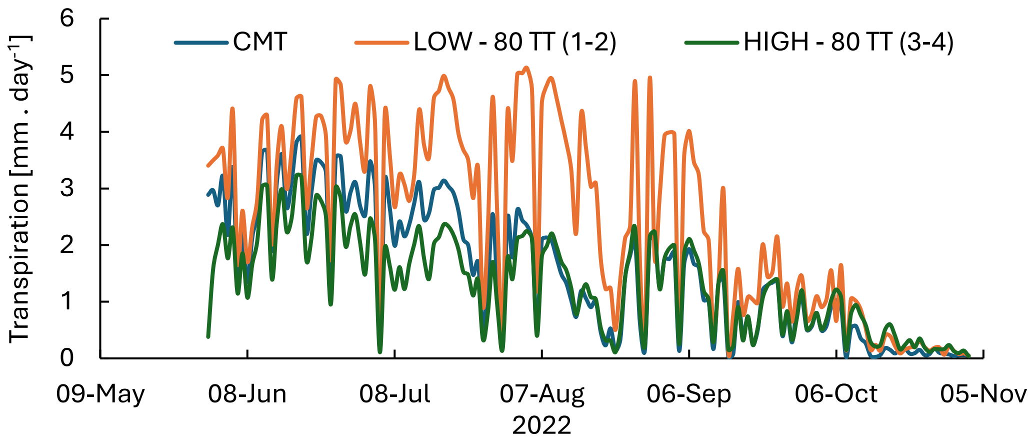

Fig. 2. Average transpiration of target trees from experimental plots with 80 tree per hectare density, when low thinning intensity (LOW TT) with reduction of 1-2 competitors and high intensity of thinning (HIGH TT) with reduction of 3-4 competitors were applied, and common management thinning (CMT).

3. Fir regeneration

Regeneration of fir under different light conditions was studied in the Moravian-Silesian Beskids with average 6-7 °C annual air temperature, 140 - 160 days of growing season and 1353mm annual precipitation (2011-2019 period). The most representative were elevations approximately between 600 - 900 m a.s.l., with mesobasic cambisoils and humus podzols. The research was carried out on seventeen young plantations of fir, where two of them reached the stadium “young-growth” with close canopy according to year of establishment (2011). Half of the plots were located at sunny exposed conditions of clear-cut area (with the size of clear cut varying from 0.54 to 4.52 ha) at the parts with the minimal distance from surrounding forest edge of two tree heights, and half of the plots at shaded light conditions of clearing areas with small dimensions (size range from 0.06 ha to 0.29 ha) with the maximum width of plot of one tree height of surrounding stand.

Tree heights (H) young fir plants were estimated for all trees on individual plots, whereas annual height increments, average length of the longest branch (D) and the ratio of height to length of the longest branch were evaluated just for chosen sample trees (n = 30 - 100). The obtained data were evaluated according to light conditions of the plots to compare the fir growth on the sun exposed and shaded conditions. The average total height of the fir trees in a stand, with regard to its year of establishment, was always higher for fir saplings plots under shade than sun exposed conditions. From the measurement of the longest branches, very variable results were found out. Morphological H/D ratio was mostly higher for shade-grown conditions. Small size clear-cut plots (gaps) with prevailing shade conditions provide more suitable conditions for the growth of fir young plantations, especially after the regeneration or establishment of stand up to the stage of the thicket stand with close canopy cover (Fig. 3).

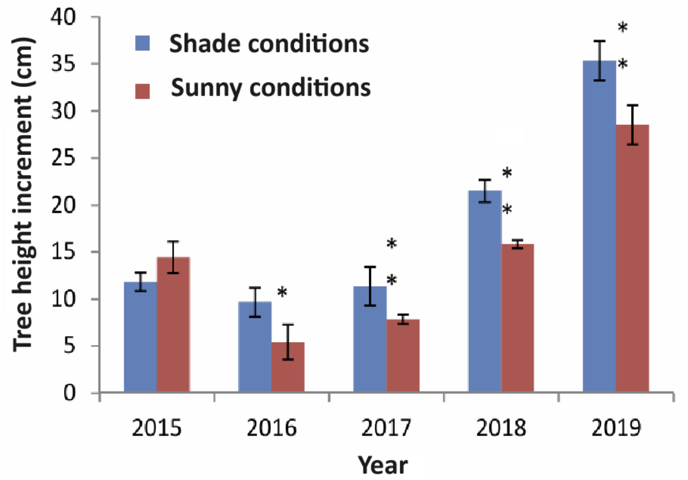

Fig. 3. Results from plot established in 2015, fir tree height increment under shade and sunny conditions of forest stand. Stars note statistically significant difference (- P < 0.05, **- P << 0.01) (after Konvičný 2020).*

Artificial planting or natural regeneration on larger open areas with high proportion of direct light (i.e. gaps or clear-cuts over 0.5 ha) does not favour fir. Best site conditions for fir are under shelter of mature stand within gaps up to 0.3 ha or at large clear-cuts (or calamity sites) in near border (up to one tree height due to still prevailing shade conditions with just shortly temporal occurrence of direct sun). Recommendations refer to the current situation at research forest sites in the Czech Republic (Konvičný 2020).

Acknowledgement

Project No. 21-47163L GACR LA.

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