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Short research contribution

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LIGHT LIMITATION OF GROWTH IN 10-YEAR-OLD SEEDLINGS OF *TAXUS BACCATA* L. (EUROPEAN YEW)

ABSTRACT: *Taxus baccata* L. is a rare and endangered species with restricted occurrence. One or two-year-old yew seedlings occur quite frequently in natural stands of the species, but older seedlings are rarely observed. Therefore we investigated the relationship between light intensity and the growth rate of ten-year-old seedlings of the European yew *Taxus baccata* (L.). The study was conducted in a preservation area established in 1999 in order to protect the gene pool of the 'Cisy Staropolskie' Reserve in the Bory Tucholskie Forest (northern Poland). A total of 570 three-year-old seedlings were planted under the canopy of a 45-year-old forest stand composed of oak (50%), birch (40%) and hornbeam (10%). Measurements of seedling heights were taken in 1999, 2003 and 2005. In 2005, the current annual growth increment was measured. Relative Photosynthetic Photon Flux Density (RPPFD) up to 30% had a positive influence on the height and annual height increment of the yews, but most of individuals grew below 5% RPPFD. This suggests that increasing light level would increase growth of yew in both natural recruitment and planting.

KEY WORDS: *Taxus baccata*, light intensity, preservation area

The European yew *Taxus baccata* (L.) is not commonly found in natural forests in Poland. Most of its local populations consist

of only a few yew trees (Sokołowski 1921, Browicz and Gostyńska-Jakuszczyńska 1969, Zajac and Zajac 2001). Yew has been exposed to a strong human pressure since ancient times, mainly due to its valuable wood (Thomas and Polwart 2003) as well as various customs and superstitions (Spausta 1893, Steffen 1931, Kontny 1937). In Poland, it is an endangered species, listed in the Polish Red Book of Plants (Kruszelnicki 2001).

A decrease in its population size has been observed in most localities. The complete dying out of yew seedlings during the first or second year of growth is a general European phenomenon. Consequently, individuals older than one or two-year-old are usually not found in natural recruitment (e.g. Paczoski 1928, Hulme 1996, Boratyński *et al.* 1997, Svenning and Magård 1999, Iszkulo 2001, Thomas and Polwart 2003).

The yew is a shade-tolerant tree species (Ellenberg *et al.* 1991, Brzeziecki and Kienast 1994, Zarzycki *et al.* 2002). The limited research that has been carried out on its light requirements has focused on young seedlings (Köpp and Chung 1997, Iszkulo 2005, Iszkulo and Boratyński 2006) or

on mature trees (Saniga 2000). The precise light requirements of particular growth stages have not been established so far. Hence, the objective of this study was to determine the effect of light level on the growth of 10-year-old individuals of the European yew.

In 1995, seeds were collected from 38 trees representing the population of *Taxus baccata* in the protected area 'Cis Staropolskie' Reserve (of the name of Leon Wyczółkowski – Polish famous painter) in the Bory Tucholskie Forest (northern Poland). Three-year-old seedlings were planted in 1999 in a random block design in the forest district, 12 km away from the Reserve (53°27'N, 17°58'E). Each of the 38 mother trees was represented by 15 seedlings (half-sib families): replicates of five in three blocks. A total of 570 seedlings were planted at a spacing of 3 m × 3 m, under the canopy of a 45-year-old forest stand composed of oak (50%), birch (40%) and hornbeam (10%). The soil conditions of experimental area were: clay and sandy loam and brown podzolic soils. The entire area was fenced and protected as a preservation area. Measurements of seedling heights were taken in 1999, 2003 and 2005. In 2005, the current annual growth increment was measured.

The relative photosynthetic photon flux density (RPPFD) ($\mu\text{m m}^{-2} \text{s}^{-1}$) was measured by using a 1-m-long Apogee Line Quantum Meter with 20 sensors mounted every 5 cm. Two measurements (perpendicular to each other) were recorded in cloudy days just above each seedling and the mean value was considered as the characteristic for the light conditions. At the same time, direct light was measured in a nearby open space. Basing on the comparison between the RPPFD in sunlight and in shaded conditions in the study area, the percentage value of RPPFD for each individual was calculated. The measurements were taken in August 2006 according to the methods proposed by Messier and Puttonen (1995), Parent and Messier (1996).

To determine the relationship between light intensity and the growth of yews in the study area, the measurement results were subjected to variance and regression analyses by using the JMP software (SAS Institute Inc.). Prior to the variance and regres-

sion analyses, the RPPFD per cent data were arcsin transformed (Underwood 1997). If all five specimens of a half-sib family were missing in any of the three blocks, the whole half-sib family was excluded from the calculations.

The average light intensity in the study area was between 3 and 4% of RPPFD and most of the yew seedlings grew in deep shade, below 3% of light (Fig. 1).

The height of the yews in 2005 was on average from 58.8 to 70.4 cm, which means that their height increment over the 7 years of the field experiment ranged from 27.88 to 36.79 cm. The average annual height increment during the 10 years (including the period in the nursery) was between 5.88 and 7.04 cm. The average value of the last annual increment (2005) was higher (from 6.6 to 9.6 cm).

Already after the first year of the field experiment (1999), the influence of light on the height of the yews was significantly positive, but with a low regression coefficient $R^2 = 0.06$ (Fig. 1A). In 2003 and 2005 this coefficient was higher $R^2 = 0.18$ (Fig. 1B) and $R^2 = 0.23$ (Fig. 1C), respectively. The significantly positive influence of light was also observed in the case of the last annual increment $R^2 = 0.17$ (Fig. 1D).

The average height (68 cm) of the 10-year-old yew individuals in this study is similar to the average height of individuals at the same age from a natural recruitment in the Kórnik Arboretum – a famous collection of trees in Poland (Iszkuło and Boratyński 2005). Nevertheless, the light intensity of 3–4% RPPFD observed in the studied area was relatively low, even for the shade-tolerant yew. Furthermore, in many cases the light level did not exceed 3%, which is below the optimum for the yew (Iszkuło and Boratyński 2006). Previous research has demonstrated that the yew can grow in deep shade for many years; but its height and thickness increments are then minimal (Iszkuło and Boratyński 2006). Under experimental conditions, in which four light intensity options were tested (2%, 8%, 30% and 100% RPPFD), young European yews had the best growth parameters under the light intensity of 8 and 30% (Iszkuło 2005). Other field studies have also demonstrated that the im-

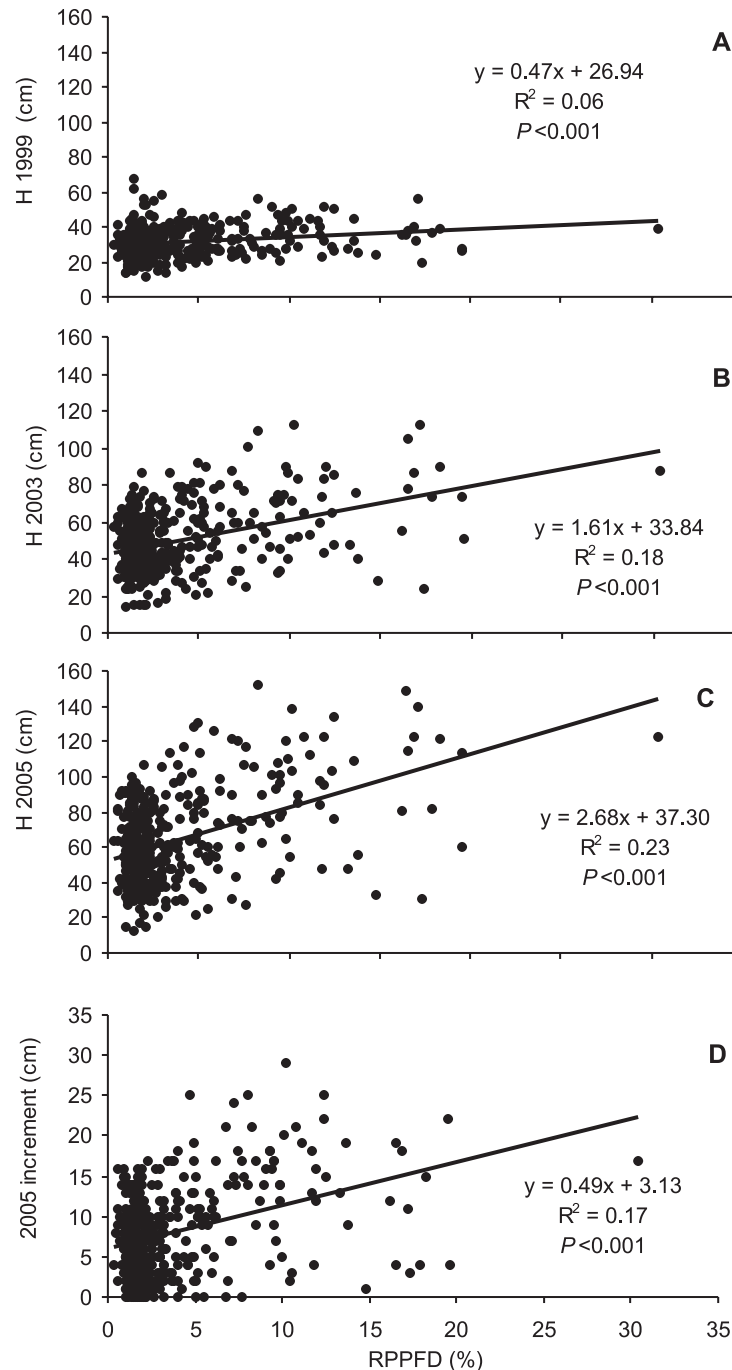


Fig. 1. Correlation between studied parameters of yew growth (A – height in 1999, B – 2003, C – 2005, D – height increment in 2005) and the RPPFD (Relative Photosynthetic Photon Flux Density).

provement of light conditions by reducing the stand density by 18 to 20% substantially enhances yew growth (Saniga 2000).

On the other hand, the low regression coefficients indicate that, apart from light, the growth of European yews is also affected by

other environmental factors, which have not been considered in this study. Additionally, the plant height and height increment are not the best determinants of the effect of light on plants. In other studies, under conditions of controlled light intensity reduction, 1-year-

old seedlings of the European yew were the highest in the most shaded conditions, i.e. 2 and 8% RPPFD, and the shortest under the highest light intensity (30% and 100%), despite the clearly positive effect of light on the dry mass of the plants. Only in the 2nd and 3rd year of the study, the height of the plants became equal, demonstrating that light shortages have a negative effect on plant growth in the long-term perspective. Fast growth in shaded conditions would be an opportunity to win the competition for light (Iszkuło 2005). The plants in our experiment were cultivated in good light conditions during the nursery period, so their reaction to light shortages in the first years of the study could be less prominent. However, the increasing value of the regression coefficient in the consecutive years of the measurements indicates the increasing effect of light intensity on the height of the yews.

It should also be noted that the relative PPFDF does not precisely reflect the actual quantity of light reaching the plants. Sunflecks (direct beam solar irradiance), which reach the forest floor for short periods on sunny days through numerous small gaps in the canopy, also can have a considerable influence on the light environment of the plant. Sunflecks can contribute a large portion of the total daily PPFDF received by understory plants (Chazdon 1988). Moreover, yew seedlings begin to grow very early in spring, before the broad-leaved tree species leaf out, and finish their growth later, after the canopy trees shed leaves, as do seedlings of other tree species (Gill *et al.* 1998, Iszkuło and Boratyński 2004).

The results of our study show that 10-year-old yews grow better at the higher light intensity. Improving the light conditions in the study area by reducing the forest stand density may accelerate the growth rate of the young yews.

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