Leaf area index development and radiation use efficiency of a poplar short rotation coppice culture

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ABSTRACT
Leaf area index (LAI) is the most appropriate parameter for analyzing canopy structure and crop productivity. LAI and radiation use efficiency (RUE) were estimated to evaluate the productivity of a short rotation coppice culture of a poplar clone. RUE was calculated as the ratio between total aboveground woody biomass and available photosynthetic active radiation (PAR) accumulated during one growing season. Prior to coppicing, LAI reached a maximum value of 7.3 (in 2009), whereas the maximum LAI after coppicing was 6.8 (in 2012). The maximum RUE reached prior to coppicing was 0.25 g mol⁻¹ (in 2009), while after coppicing it was 0.20 g mol⁻¹ (in 2012), which did not represent a significant difference (p > 0.05).

INTRODUCTION
Leaf area index (LAI; m² leaf area m⁻² ground area) is a key parameter for productivity and it is frequently used to describe canopy structure (Watson 1947). LAI and radiation use efficiency (RUE; g mol⁻¹) are used to maximize productivity in a short amount of time and this agricultural technique is applied to forest crops. Biomass production of plants is dependent on available and intercepted radiation by the canopy which is used to convert CO₂ into new biomass (Gifford et al. 1984, Linder 1985). The rate of this production given available photosynthetic active radiation (PAR) is defined as RUE. The aim of this study was to compare differences in LAI and RUE prior to and after coppicing in a culture of poplar clone J-105 (Populus nigra L. × P. maximowiczii Henry).

MATERIALS AND METHODS
The experimental field site
The study was carried out on an existing short rotation coppice (SRC) culture of poplar clone J-105. The experimental site was located in Domanínek (Bystřice nad Pernštejnem, Bohemian–Moravian Highlands; 49°31’N, 16°14’E; 530 m a.s.l.) and total plantation area was 2.85 ha. Between 1981 and 2012, total annual rainfall was 609 mm and mean annual air temperature was 7.2°C. The experimental site is part of climatic region no. 7 (Havlíčková et al. 2006), which is highly suitable for poplar cultures mainly due to its soil characteristics (Trnka et al. 2008). The plantation was established in April 2002 by planting hardwood cuttings in
a double-row design with spacing of 0.7 m within rows and an inter-row distance of 2.5 m. This resulted in a planting density of 9,216 trees ha\(^{-1}\). The first rotation was 8 years (2002–2009), after which the SRC culture was harvested at 20 cm above ground level.

**Field measurements**

All measurements were made from 2008 to 2012 and spanned the entire growing season. Meteorological data (air temperature, global radiation, PAR, total annual precipitation) were recorded continuously by an automatic weather station placed at the turf grass next to the plantation. LAI was measured indirectly using a SunScan plant canopy analyzer (type SS1, Delta T, UK). This indirect method was validated using a direct method (litter collection on traps). Litter collection was conducted once prior to coppicing and twice after coppicing. Indirect LAI was measured close to traps where we collected litterfall. Data were obtained on a weekly basis during the growing season on three plots (~80 m\(^2\)) close to the center of the plantation. Using a regression equation with cumulative mean daily air temperature, data were interpolated to daily LAI data, whereby winter habits generated an LAI value of 0.

RUE was calculated as the ratio between the difference in stocking biomass at the end of each season (\(\Delta W_s\); t ha\(^{-1}\) year\(^{-1}\)), i.e. annual biomass productivity, and the amount of PAR absorbed by the canopy (APAR; mol m\(^{-2}\) year\(^{-1}\)) during the entire growing season (according to Linderson et al. 2007):

\[
RUE = \frac{\Delta W_s}{APAR} \quad (1)
\]

and

\[
APAR = PAR_{above} (1 - e^{-kLAI}) \quad (2)
\]

where \(PAR_{above}\) is incident PAR above the canopy and \(k\) is the extinction coefficient (set to 0.5; Eckersten 1984).

An allometric equation was developed (Fischer 2012) to estimate aboveground stocking woody biomass (annual productivity). We thus determined \(R^2\) values to estimate the yearly aboveground woody biomass prior to and after coppicing. At the end of growing season we performed a stem inventory and repeated the same procedure every year prior to the start of the growing season.

Data analyses were performed using the STATISTICA 9 statistical package (StatSoft, USA), in particular for an analysis of variance with post-hoc Fischer’s least significant difference to evaluate the significance of differences between treatments at \(p < 0.05\).

**RESULTS**

Stand woody biomass productivity and productivity rate for poplar hybrid clone J-105 depended on light efficiency or RUE and LAI. Prior to coppicing, the maximum productivity for poplar clone J-105 was 16.5 dry t ha\(^{-1}\) year\(^{-1}\), \(LAI_{max}\) was 7.3, and \(RUE_{max}\) was 0.25 g mol\(^{-1}\) in 2009 after 8 years of growth. After coppicing, the maximum productivity was 10.31 dry t ha\(^{-1}\) year\(^{-1}\), \(LAI_{max}\) was 6.8, and \(RUE_{max}\) was 0.20 g mol\(^{-1}\) in 2012 after 3 years of growth. Fig. 1 shows annual stand level woody biomass (dry t ha\(^{-1}\) year\(^{-1}\)) production and RUE both prior to and after coppicing (\(p = 0.75\), i.e. the differences were not significant) in a SRC culture of hybrid poplar clone J-105. LAI dynamics are shown in Fig. 2.
**DISCUSSION**

The maximum RUE was 0.25 g mol⁻¹ prior to coppicing and 0.20 g mol⁻¹ after coppicing, which is similar to values reported by Linderson et al. (2007), who estimated 0.31 g mol⁻¹ for many clones of willows in southernmost Sweden, as well as Eckersten (1984), who reported RUE of 0.43 g mol⁻¹ in western Sweden. Our values were lower than those observed by Bullard et al. (2002), who recorded 0.39–0.53 g mol⁻¹ for a similar planting density in the UK. They used extinction coefficients of 0.2–0.5 based on observations in 2-year-old plantations, and so our results are almost similar to these previous results. We used the value reported by Eckersten (1984) of \( k = 0.5 \). Values ranged from 0.4–0.6. In Pennsylvania and Wisconsin in the US., RUE values were 1.5 for poplar and balsam fir (Pothier et al. 1991).
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References


