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Height increment formation of hybrid aspen: empirical model

Aris Jansons, Juris Rieksts-Riekstins, Martins Zeps, Oskars Krisans
Latvian State Forest Research Institute "Silava", Rigas 111, Salaspils, LV-2169
**correspondence:* aris.jansons@silava.lv

Highlights: Model predicting height growth rate based on mean daily temperature was statistically significant ($p < 0.01$), both intercept and slope coefficient were significantly different from zero ($p < 0.01$) and determination coefficient high R^2=0.83. Model predictions for height increment in next season did not differ significantly from the measurements. It can be used as part of the system for predictions of effect of global climatic changes on height growth in hybrid aspen plantations.

Keywords: Height increment, shoot elongation, temperature, *Populus tremuloides* x *Populus tremula*

INTRODUCTION

Hybrid aspen (*Populus tremuloides* x *Populus tremula*) is one of the most promising alternatives for the establishment of plantations on abandoned agricultural lands in the Baltic Sea region countries (Tullus et al., 2011). Its growth rate notably (2-6 times) exceeds that of any of the parent species (Li and Wu, 1996), and biomass production can reach as much as 8 t of dry matter per hectare and year in the second rotation (Rytter, Stener, 2005). Notable differences among clones within family and among families in traits characterising stem wood density, fibres, productivity as well as leaf area, number, size, intensity of photosynthesis, water use efficiency and others were found (Beuker, 2000; Yu, 2001). Therefore rather intensive breeding has been carried out for this hybrid in Latvia, starting in 1960th with the aim to create a basis for supply of raw material for matches' production and continued from late 1990th with a target to develop suitable clones for cellulose and biomass production. Notable increase in productivity has been achieved, similar to that reported in Sweden: starting from 16 $m^3h^{-1}y^{-1}$ on average in first stands established during 1960th and reaching 20-25 $m^3h^{-1}y^{-1}$ in current stands and selections of the best clones (Stener, 2001).

Superior productivity of hybrid aspen clones has been attributed both to longer growth period and higher growth intensity (Li et al., 1998). Length of the growing (shoot elongation) period is related to adaptation to climatic conditions of particular area: genotypes starting the bud burst too early in spring have a high risk of being affected by spring frosts, but those genotypes that continue the growth for too long before dormancy – by autumn frosts or cold temperatures of winter. Exact fit of growth period to environmental conditions ensures possibilities to maximize photosynthetic productions (Kolari et al., 2007) and therefore provides competitive advantage for particular genotypes. Long time series of observations demonstrate the effect of rising temperature on data of bud-burst. For example, Linkosalo et al. (2009) found the advancements of 7.6 days per century in the bud burst of European aspen in Finland. Thermal time models, describing the start of the bud development – formation of components for new cells (Sarvas, 1972) – from a fixed calendar date in spring and using temperature sum (above certain threshold) accumulation to predict bud burst, was found to be accurate (Linkosalo et al., 2008). Bud set time of *Populus* species has been found to depend on both photoperiod and temperature (Jonsson and Óskarsson, 2007; Rohde et al., 2011). Using these models changes in length of growth period due to climatic changes can be predicted, but not the second parameters with equal importance to determine total length of height increment: growth intensity. Therefore aim of our study was to develop mathematical model linking meteorological conditions and shoot elongation rate of hybrid aspen that could serve as initial information for development of process-based model for predictions of height growth in future environmental conditions.

MATERIAL

Development of model was based on data on shoot growth rates, collected in hybrid aspen trial. Trial was established in central part of Latvia (latitude 56°26' longitude 22°52'), on former agricultural land in year 2007 using one year old containerized plants obtained via microclonal propagation. Initial spacing 3x3m, no thinning carried out prior to measurements. Ramets of 15 clones were randomly distributed in 25 replications. Mainly due to browsing damages some trees had not survived and the growth of others was severely hampered, therefore only trees higher than 1 m were included in analysis and each clone was represented by 18 ramets on average (ranging from 12 to 23 ramets).

Height measurements were carried out during the 5th and 6th growth periods with frequency once per week on average from May until October.

Pearson's correlation coefficient was used as a measure of linear dependency between the intensity of height increment and climatic factors. Multiple linear regression analysis with forward selection criteria was performed using mean daily temperature, mean daily rainfall and sum of rainfall as independent variables and height increment per day as the dependent variable. Model indicated that only mean daily temperature had a significant (α=0.05) effect on the height increment and the other variables did not improve the model.

RESULTS AND DISCUSSION

Model best describing height growth rate based on measurements at 5th growing season was:

$$Hi=7.3934+0.9939*t \qquad (1),$$

where:

- Hi – height growth rate, mm per day;
- t – mean daily temperature, °C.

Obtained model was statistically significant ($p < 0.01$), both intercept and slope coefficients were significantly different from zero ($p < 0.01$) and R^2=0.83, which indicates a very strong linear relationship between the temperature and height increment. Using the model it was possible to predict the height growth rate for the next season and the obtained results were not statistically significantly different from the actual measurements.

The regression model was used to estimate formation of height increment in the end of the century, year 2099, using simulated temperatures for the territory of Latvia (Cepīte-Frišfelde et al., 2012). Beginning of the growth period was estimated based on the temperature sum for bud burst data from 5th and 6th growth period and the same temperature sum requirement were assumed to remain in year 2099, resulting in prediction of one-week earlier bud-burst. Ending of the vegetation period was assumed to be dependent on the mean daily temperature, and in 2099 it was two weeks later than in 2010.

Estimated values of height increment in 2099 were tested against the real values in 2010 using two-sided t-test assuming equal variances. Results did not indicate statistically significant differences which means that the average growth intensity would not change in the future, but as the vegetation period would become longer, the total increment might increase by 11 % (Fig. 1). If the vegetation period in 2099 was assumed to be exactly the same as in 2010, the increase in height increment was only 5 %, which is due to slight increase in the mean temperature. Rather small (and insignificant) increase in daily mean temperature in specific year (2099) in comparison to year of measurements (2010) can be the main cause of detected minor differences in annual height increment among the years. Further study will address the impact of predicted climatic (30 year average) differences in temperature on length of height increment.

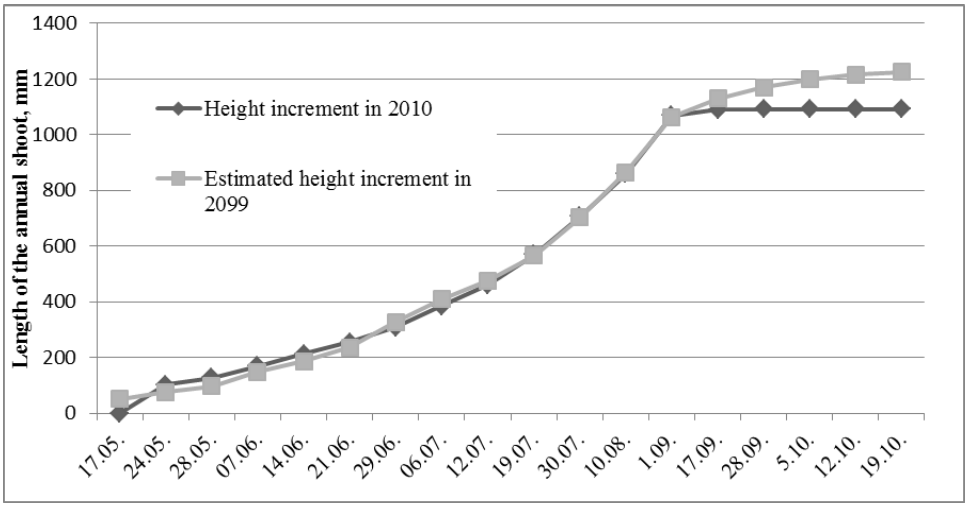

Fig.1. Development of height increment in year 2010 and year 2099 (estimated)

Model can serve as initial basis for development of prediction of height growth in hybrid aspen plantation in future climatic conditions. Study is limited by only one soil type and relative small number of clones, creating difficulties in the extrapolation of results. Data for height growth development have been obtained from young trees, however, comprehensive study of hybrid aspen height growth in Sweden (10 sites, 38-107 clones per site) demonstrates no age-related trends in mean annual height increment for trees from age 2-4 years to age 15-18 yeas (Rytter and Stener, 2005), that is close to the optimal rotation length of hybrid aspen (around 20 years). Also predicted increase in CO_2 level might not have a direct influence on the predictions – it was found that European aspen relative quickly adapts to elevated levels of carbon dioxide no permanent effect on growth can be detected (Tjoelker et al., 1998). Accuracy of predictions can be affected by changes in soil temperature (Landhäusser et al., 2001) and predicted changes in rate of precipitation and higher evapotranspiration that might reduce the growth and change biomass allocation (Liu and Dickmann, 1992). Predicted increase of temperature might also cause differences in growth period: increase the relative importance of chilling in determination of time of bud-burst (Linkosalo, 2000) and change the bud set time as response to photoperiodic conditions (Welling, 2002). Responses to climatic conditions are affected by genetic factors, further decreasing the possibilities for accurate general predictions.

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