LEAF PHOTOSYNTHESIS/RESPIRATION RELATIONSHIPS OF WOODY SPECIES IN THE NORTHWESTERN PART OF RUSSIA

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Objectives:

The main goal of the study is to describe the interspecific features of CO2/H2O exchange of different birch (*Betula*) species growing in forests of Republic of Karelia as well as to estimate the sensitivity of photosynthesis and respiration rates of the trees to changes of ambient conditions. About of 10.1% of the total forested area of the Republic of Karelia belongs to forest communities where *Betula* species are prevailed. Silver birch (*Betula pendula* Roth) and downy (white) birch (*Betula pubescens* Ehrh.) are characterized by high transpiration capacity and they are essential regulators of the water regime in moist habitats. Silver birch is more competitive due to high potential growth rate which helps the species actively colonize both above- and underground spaces. Downy birch, in turn, is characterized by higher morphophysiological plasticity and a broader normal response range under unfavourable ambient conditions. Karelian (curly) birch (*Betula pendula var. carelica*) as an ecological form of silver birch has a great interest for researchers because of the unique marble-like wood texture with dark brown inclusion. The role of environmental factors in formation of such unique wood texture of Karelian birch has been widely discussed in the literature (Yermakov, 1986; Vetchinnikova, 2004; Novitskaya, 2008). The gaseous CO_2 metabolism can be considered as an indicator that allows accurately reflecting the plant's reaction to the environmental conditions and its biological productivity. It appears therefore very promising to provide an aggregated study of the parameters of CO_2 metabolism of silver, Karelian and downy birches in a wide range of external factors.

Material and methods: Measurements of leaf photosynthesis, respiration and stomatal conductance of silver birch (*B. pendula* Roth), downy birch (*B. pubescens* Ehrh.) and Karelian birch (*B. pendula var. carelica*) were provided using the portable photosynthesis system LI-6400XT (Li-Cor, USA) on the experimental plots of the Forest research Institute of Karelian Research Center of RAS in Petrozavodsk, Russia (Fig. 1).

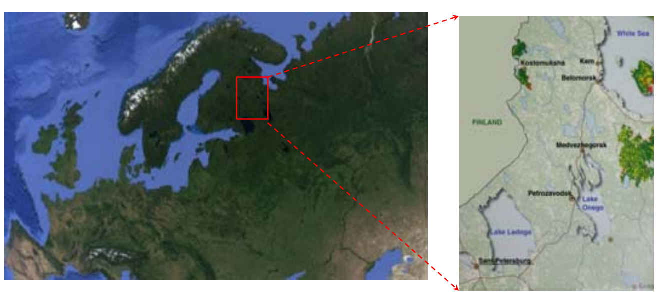

Fig. 1. Geographical location of the research areas

LI-6400XT allows to provide the direct measurements of photosynthesis and respiration rates of individual leaves at various PAR, temperatures, humidity and concentration of CO_2 in the measuring chamber (Fig. 2). During the field campaigns in 2011 the CO_2 and light response curves of photosynthesis of leaves under different air temperatures as well as the temperature response functions of dark respiration (R_d) of the leaves of different species were estimated.

Fig. 2. The LI-6400XT Portable Photosynthesis System at a forest experimental plot

During the field measurements the light and CO2 response curves of photosynthesis for the leaves of different birch species situated in different part of tree crowns as well leaf dark respiration were measured for all possible (for current weather conditions) range of air temperatures. The measurements were provided during all growing season in days without precipitation. For some selected days the diurnal patterns of photosynthesis, dark respiration and leaf stomatal conductance were measured as well.

The method suggested by Sharkey et al (2007) was used to estimate the maximal velocity of Rubisco for carboxylation (V_{cmax}), the rate of electron transport at light saturation (J_{max}), photorespiratory compensation point as well as the rate of use of triose phosphates (*TPU*) that characterizes the availability of internal inorganic phosphates in leaves for Calvin's cycle.

$$A_l = \min\{A_V, A_J, A_P\} - R_l \qquad \begin{cases} A_V = V_{CMAX} \cdot \dfrac{(C_i - \Gamma^*)}{C_i + K_c \cdot (1 + O_i / K_o)} \\ A_J = \left(\dfrac{J}{4}\right) \cdot \dfrac{(C_i - \Gamma^*)}{(C_i + 2 \cdot \Gamma^*)} \\ A_P = 3 \cdot TPU \end{cases}$$

It was assumed that the initial slope of the relationship between leaf photosynthesis rate and CO_2 concentration in sub-stomatal air space (C_i<200 ppm) can be considered as an area of Rubisco limitation of photosynthesis. The upper part of CO_2 response curve from approximately 300 ppm and higher is influenced by, first of all, the rate of regeneration of RuBP, and after that by availability of inorganic phosphate in leaves. The temperature dependences of V_{cmax}, J_{max} and *TPU* were estimated using the statistical analysis of V_{cmax} and J_{max} data set using equations suggested by Medlin et al (2002). Temperature response function of *TPU* was derived using algorithm proposed by Sharkey et al (2007).

Results: The results of the field measurements of photosynthesis and respiration of silver birch, Karelian birch and downy birch trees on different experimental plots show a relatively large daily and seasonal variability of the parameters of photosynthesis and respiration (V_{cmax}, J_{max} *TPU* and R_d) as well relatively weak differences among maximal values of these parameters (for leaf temperature T=25°C) (Fig. 3-4). Under similar weather and soil moisture conditions the maximal values of V_{cmax} (T=25°C) were obtained for the Karelian birch (V_{cmax} (T=25°C) = 117 μmol $m^{-2}s^{-1}$), and the minimum values - for the silver birch (V_{cmax} (T=25 °C) = 97 μmol $m^{-2}s^{-1}$). The maximum values J_{max} (T=25°C) are obtained for the downy birch (J_{max} (T=25 °C) = 164 μmol m^{-2} s^{-1}), and minimum also for the silver birch (J_{max} (T=25°C) = 157 μmol m^{-2} s^{-1}). Values TPU_{max} are varied from 11.0 to 12.3 μmol m^{-2} s^{-1}, and R_d (T=25 °C) - from 2.0 to 2.4 μmol m^{-2} s^{-1}.

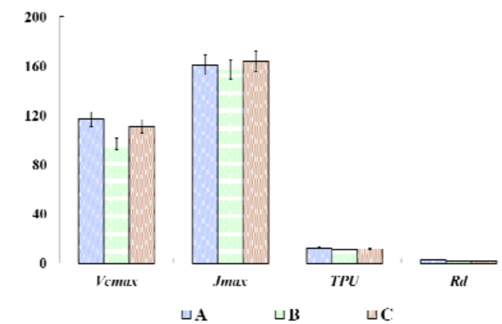

Fig. 3. The photosynthesis model parameters (V_{cmax}, J_{max}, *TPU*, R_d) for Karelian (A), silver (B) and downy birches (C).

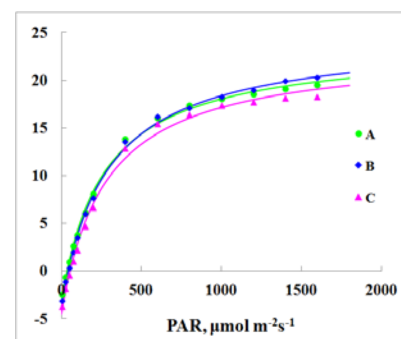

Fig. 4. Light response curves of photosynthesis (μmol m^{-2} s^{-1}) of silver (A), Karelian (B) and downy birches (C) leaves measured under similar ambient conditions.

The results of provided leaf photosynthesis, respiration and stomatal conductance measurements were used in the process-based Mixfor-SVAT model (Olchev et al 2002, 2008) to derive the possible response of CO_2/H_2O budgets of Karelian forest ecosystems to future climatic changes.

Acknowledgements: *The study was supported by grants (11-04-01622-a and 09-04-00299-a) of the Russian Foundation of Basic Research (RFBR).*