Ježík, M., Blaženec, M., Střelcová, K., Kovalčíková, D.: Relations between potential evapotranspiration, sap flow and maximum daily stem shrinkage of spruce trees in growth stages of a pole- and trunk-mature forest during irrigation experiment. Šiška, B. – Hauptvogl, M. – Eliašová, M. (eds.). Bioclimate: Source and Limit of Social Development International Scientific Conference, 6th – 9th September 2011, Topoľčianky, Slovakia

RELATIONS BETWEEN POTENTIAL EVAPOTRANSPIRATION, SAP FLOW AND MAXIMUM DAILY STEM SHRINKAGE OF SPRUCE TREES IN GROWTH STAGES OF A POLE- AND TRUNK-MATURE FOREST DURING IRRIGATION EXPERIMENT

Marek Ježík[1], Miroslav Blaženec[1], Katarína Střelcová[2], Danka Kovalčíková[1]

[1] Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic, e-mail: jezik@savzv.sk ; [2] Faculty of Forestry, Technical University Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovak Republic,

Abstract. On both plots (25 and 90 years old forests), subjected in 2009 to an irrigation experiment, significant differences between the irrigated and control group of trees were observed. Several drought periods affected transpiration, stem circumference changes and their mutual correlations. During the periods with sufficient availability of soil water, tight correlation between measured sap flow and estimated potential evapotranspiration was observed. In the irrigation period, the control groups trees showed decreased sap flow whilst the slope of their regression axis related to potential evapotranspiration was milder. Maximum daily stem shrinkage positively correlated with sap flow. With lower availability of soil water their values per a sap flow unit were increasing indicating a decrease of water potential in conducting and surrounding tissues not backward saturated by sufficient water intake. The correlations were similarly manifested in the irrigation period, more distinctly in the younger stand.

Introduction

Water is an essential factor determining the growth and distribution of Norway spruce (*Picea abies* Karst. L) trees.

Transpiration, driven by the energy from solar radiation, is the necessary consequence, and, at the same time, the precondition for photosynthesis – the fundamental process running in the plants. Water demands for transpiration are supplied by sap flow. In case of water shortage, assimilatory organs put limits on their stomatal conductivity, and limiting, in such a way, also synthesis of metabolites in photosynthetic processes. This is subsequently reflected in physiological and growth processes. The objective of this contribution is to present the link between atmospheric evaporative demands, spruce sap flow and diurnal stem circumference shrinkage during the irrigation experiment.

Data and methods

On both stands were selected 2 groups of dominant trees: 6 spruce sample trees watered and 6 sample trees without watering (control).

The younger stand is located in central Slovakia on the site Hriňová, stand 283_2 (48°35' N, 19°31' E, 655 m a.s.l.). The trees are growing in a closed, even-aged, homogeneous stand with a 0.8 stocking. The dominant tree species is spruce representing 99% of the population. The average d.b.h. diameter in the irrigated individuals was 18.6 cm, in the control group 17.6 cm. The mean tree height in the irrigated trees was 17.2 m, in the control group 16.9 m.

The trunk.mature stand is located on the site Iviny, stand 219a (48°35' N, 19°23' E, 484 m a.s.l.). The stand structure is differentiated, the stocking value is about 0.5.The dominant tree species is spruce (*Picea abies* L.) representing 67% of the population. The main admixed species is oak. The average d.b.h. diameter in the irrigated group was 45.0 cm, in the control group 40.2 cm. The mean tree height in the irrigated trees was 37.1 m, in the control group 35.8 m

Meteorological variables were measured continually on an open plots (temperature (°C), relative air humidity (%), global radiation ($W.m^{-2}$) (Minikin TH (EMS Brno, CZ), atmospheric precipitation totals (mm) (MetOne 370, Oregon, USA). Soil water potential (Bar) was measured continually, over the whole growing season, using gypsum blocks MicroLog SP3 (EMS Brno, Cz).

Potencial evapotranspiration (PET) was calculated with the Penman equation, using a constant wind speed and soil water potential (0.5 Bar), with the aim to determine evapotranspiration demands of atmosphere unlimited by water deficit.

Sap flow (SF) in individual trees was measured by applying the heat balance method (THB) elaborated by Čermák and Kučera (Čermák et al., 1973). The data were recorded every 20 minutes, at a height of 1.3 m above the ground.

Changes in stem circumference were registered with automatic band dendrometers DR 26 (EMS Brno, Czech Republic) installed at 2.5 m above the ground surface.

Maximum diurnal stem shrinkage (contraction) (MDS) was calculated as the difference between the morning (0–11h) one-hour maximum and afternoon (12–23h) one-hour minimum.

The date of the first irrigation on younger stand was July 16, on older stand July 28, the date of the last one was August 27 on both stands. On younger stand irrigation was performed during 19 days using 23 m^3 of water. On older stand irrigation was performed during 6 days using 18 m^3 of water.

Results and disscussion

In Fig. 1A,B 2A, B is visible the close relation between PET and SF values, varying in the both groups according to the SWP level. The data processing with covariance analysis has confirmed interaction between SWP and PET as the most important factor influencing SF variability.

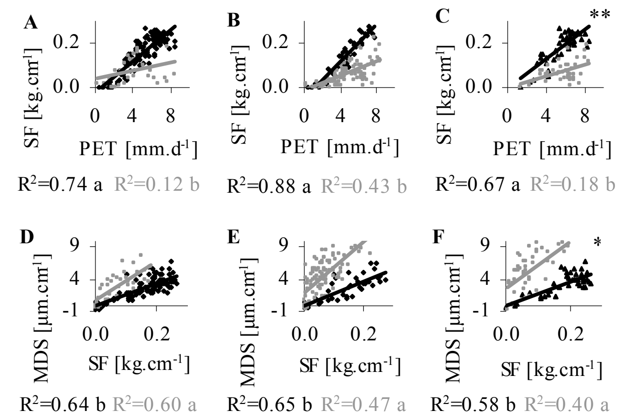

Figure 1. Younger stand; A, B – Relations between PET and average sap flow (SF) of irrigated (A) and control (B) trees at soil water potential (SWP) levels > −3.0 Bar (black points and line), and < −3.0 Bar (grey points and line); C – relations between PET and average SF of irrigated (black points and line) and control (grey points and line) trees during irrigation period;
D, E – Relations between average SF and average maximum daily stem shrinkage (MDS) of irrigated (D) and control (E) trees at soil water potential (SWP) levels > −3.0 Bar (black points and line), and < −3.0 Bar (grey points and line); F – relations between SF and MDS of irrigated (black points and line) and control (grey points and line) trees during irrigation period (R^2 – coefficient of determination, a, b... – represent homogeneous groups of regression coefficients within irrigated and control groups of individuals at $P < 0.05$ sorted fom the highest regression coefficient in alphabetical order, * regression coefficients within irrigation period are different at level $P < 0.05$, ** regression coefficients within irrigation period are different at level $P < 0.01$).

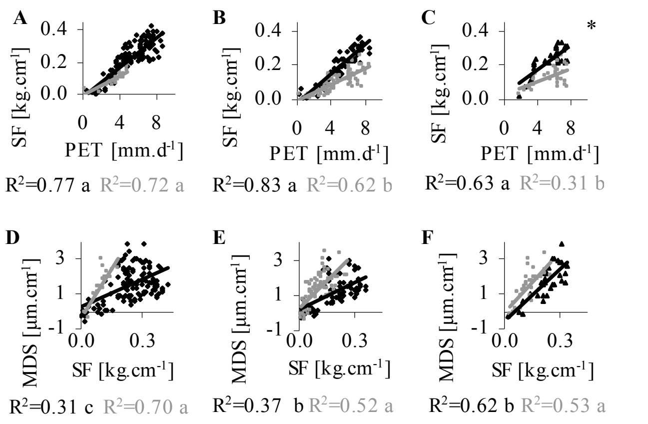

Figure2. Older stand; A, B – Relations between PET and average sap flow (SF) of irrigated (A) and control (B) trees at soil water potential (SWP) levels > −3.0 Bar (black points and line), and < −3.0 Bar (grey points and line); C – relations between PET and average SF of irrigated (black points and line) and control (grey points and line) trees during irrigation period;
D, E – Relations between average SF and average maximum daily stem shrinkage (MDS) of irrigated (D) and control (E) trees at soil water potential (SWP) levels > −3.0 Bar (black points and line), and < −3.0 Bar (grey points and line); F – relations between SF and MDS of irrigated (black points and line) and control (grey points and line) trees during irrigation period (R^2 ; a, b... ;*; ** – the same meaning as in Fig. 1).

The same facts are valid for relations between SF and MDS values (Fig1D, E, 2D, E). The most important factor affecting MDS variability was interaction between SWP levels and SF. These facts were reflected in different relations between compared variables for irrigated and control trees during irrigation period (Fig 1C, F 2C, F). These differences were more distinctly manifested in the younger stand probably affected by considerably smaller distance between the measurement points and tree crowns and/or differences in the wood structure conditioned by site differences in the older stand. The underlying cause for stem size variations associated with varying water balance is that the plants can temporarily use the water stored in their tissues (e.g. Herzog et al., 1995; Offenthaller et al., 2001; Zweifel a Häsler 2001; Zweifel et al., 2001; Čermák et al., 2007; Sevanto et al., 2008). Tree tissues, stem tissues included, represent water reservoirs compensating increased transpiration demands. The diurnal stem shrinkage are caused by the lag between the water absorption and transport and the high losses due to transpiration, causing the drop in tissues water potential.

Conclusions

The relations between atmospheric evaporative demands, sap flow and diurnal stem shrinkage vary on different levels of soil water availability. A more detailed recognition of these relations should enable us to make estimations about sap flow or about stress load due to physiological drought.

Acknowledgements „This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0022-07 and by VEGA 0160-09 and VEGA 0006-11 projects of the Grant Agency of Ministry of Education and Slovak Academy of Sciences“

References

Čermák, J., Deml, J., Penka, M., A New Method of Sap Flow Rate Determination in Trees. Biologia Plantarum 15, 171–178, 1973.
Čermák, J., Kučera, J., Bauerle, W.L., Phillips, N., Hinckley, T.M., Tree water storage and its diurnal dynamics related to sap flow and changes in stem volume in old-growth Douglas-fir trees. Tree Physiology 27, 181–198, 2007.
Herzog, K. M., Häsler, R., Thum, R., Diurnal changes in the radius of a subalpine Norway spruce stem: their relation to the sap flow and their use to estimate transpiration. Trees 10, 94-101, 1995.
Offenthaller, I., Hietz, P., Richter, H., Wood diameter indicates diurnal and long-term patterns of xylem water potential in Norway spruce. Trees 15, 215-221.

Sevanto, S., Nikinmaa, E., Daley, M., Pettijohn, J.C., Mikkelsen, T.N., Phillips, N., Holbrook, N.M., Linking xylem diameter variations with sap flow measurements. Plant and Soil 305, 77–90, 2008.

Zweifel R, Häsler R., Dynamics of water storage in mature subalpine *Picea abies*: temporal and spatial patterns of change in stem radius. *Tree Physiol.*, 21: 561-569, 2001.

Zweifel, R., Item, H., Häsler, R., Link between diurnal stem radius changes and tree water relations. Tree Physiology 21, 869-877, 2001.