TOK VODY V KMENI SMRKU ZTEPILÉHO A JEHO ZÁVISLOST NA RŮZNÝCH MIKROKLIMATICKÝCH FAKTORECH

SAP FLUX OF NORWAY SPRUCE TREES AND ITS DEPENDENCE ON VARIOUS MICROCLIMATIC FACTORS

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Abstract

Tree sap flow rates were measured by the heat pulse method in two *Picea abies* trees in the Beskydy Mts. during a 10-day period in spring 1998. Potential relationships between the specific sap flux values (SSF) and different microclimatic factors were examined in order to ascertain a possible simulation.

The SSF data were in close correlation with relative humidity and temperature of the air as well as with the derived water potential deficit at 2m height (canopy height equals to 5.6m). Moreover, in daytime, the SSF data were highly correlated with incident global radiation at one hour time lag. Wind speed did not correlate well with the SSF data. The best simulation was based on multiple regression of all the above mentioned factors, except for wind speed (without any time lag) provided that instrumental error (i.e. 0.005 $l.hr^{-1}.cm^{-2}$) was excluded from the analyzed set of data.

Keywords: microclimate factors, *Picea abies*, sap flux, transpiration

Introduction

Water regime of forest trees is influenced by many factors. Transpiration of an individual tree depends on its age, structure, health status, as well as growing conditions (*i.e.* mineral supply, air temperature, amount of incident global radiation, air humidity, soil water availability, etc.) (*e.g.* Lu et al. 1995, Granier et al. 1996).

Tree transpiration is inevitably linked to the microclimatic conditions of the stand. This is the reason why the microclimatic data can be used as a predictor of tree transpiration. This paper brings up some relationships between specific sap flux and incident global radiation, air temperature, relative air humidity, wind speed and water potential deficit.

Material and methods

All measurements were carried out on two Norway spruce trees (*Picea abies* [L.] Karst.) located in an even aged monoculture with a stand density of 2100 trees per hectare, on the Experimental ecological study site of Bílý Kříž in the Beskydy Mts. (for a more detailed description of site conditions *see* Kratochvílová et al. 1989). Moreover, the measurements were carried out during 10 day-period (15. – 24.5.) in spring 1998. Weather conditions during the measurements were without some extreme climatic situations.

Sampled tree height (H) and stem diameter at breast height (DBH) were of 6.8m and 8.4cm, and 6.6m and 7.9cm, respectively. The sampled trees were chosen according to the above mentioned biometrical characteristics (*i.e.* H and DBH), to their crown structure and representative position within the stand owing to its density. Mean tree height and stem diameter at breast height of stand typical tree (measured in the end of the vegetation season 1997, mean ± standard error) were of 5.6±0.1m and of 7.1±0.1cm. The sum of all trees sapwood area (SA) within the stand (0.25 ha) amounted to 2.081 m^2. Sapwood area of an individual tree was calculated using an interrelationship between DBH and SA (*see* Pokorný 2000).

Heat pulse method (Sapflow Meter SF 300, Greenspan Technology, Australia) was used for sap flow measurements on sampled trees (two depth per tree: 1cm and half of sapwood). Thereby, 1.8 seconds length of heating pulse and 15minutes data recording interval were used. Sap flux values obtained for the sampled trees and sapwood area at each measurement point were used for calculating the mean specific sap flux (SSF) values. These mean values as well as sapwood areas of all stand trees are then useful for scaling up the transpiration data from the sampled trees to the stand level.

Following microclimate characteristics: air temperature (T), relative air humidity (RH), wind speed (WS) and incident global radiation (GR) were measured. RHA1 sensors (Delta-T, England) for T and RH measurements and AN1 sensors for WS data recording (Delta-T, England) were used. All the sensors were positioned on a meteorological mast at several canopy layers (at 2, (5- only WS), 6, 7, 8, and 11m high) except the global radiation sensor (Kipp & Zonen Delf BV-CM5, Holland) which was located above the canopy on the nearby research station. The meteorological mast was located in the center of experimental plot. From the observed T and RH, a water potential deficit (VPD) was calculated for the corresponding canopy layers, as well. All the data were stored by a data logger (Delta-T, England).

Results and discussion

Daily courses of microclimatic factors as well as mean SSF values are presented in Fig. 1a, 1b and 1c. The strongest linear relationships between SSF values and all the above mentioned microclimate characteristics, according to the Pearson correlation coefficient, were as following: T (r = 0.84), RH (r = -0.88), and VPD (r = 0.81) estimated at 2m canopy height, while WS (r = 0.30) at canopy profiles was above the 5m in height. Statistical analysis were also done separately for daytime data (time interval from 4:30 to 19:00, sunrise - sunset) and for night time data. The low plateau of SSF curve (Fig.1a) measured during the night time was taken as an instrumental error ($0.005\ l.hr^{-1}.cm^{-2}$) and thus, was excluded from the data set. Instrumental errors as well as some possible errors of the method are described by Hatton et al.(1995). Therefore, when we separated the daytime in two parts, the correlation coefficients were as following: I) during the daytime T (r = 0.89), RH (r = -0.93), VPD (r = 0.97) - all of them at 2m of canopy height, WS (r = 0.41) at 7m of canopy height, and GR (r= 0.84); and II) during the night time T (r = 0.48) throughout all the canopy profiles, RH (r = -0.57) and VPD (r = 0.61) at 2m canopy height, WS (r = 0.30) at all canopy profiles positioned above the 6m high level. All the presented coefficients were found to be the strongest when no time lag occurred except for GR. This last one was found to be the strongest with one hour time lag when a 15 minutes test step was done. Unfortunately, conversely to Green's et al. (1989) results, SSF values were quite independent on microclimatic factors during the night time. Furthermore, all the coefficients changed negligently in the case of a 15 min time shift. Then, they strongly decreased. Slow stomatal reactivity caused small changes of the correlation coefficients after the 15 minutes time lag. Thus, we considering sap flux measurements in Norway spruce trees, a heat pulse method is quite good enough to be used with a recording interval between 15 and 30 minutes. Norway spruce stomata reacting time ranged in an interval close to 18 minutes (*e.g.* Apholo and Jarvis 1993). In our case, the interval 18-20 minutes was proved to be good (unpublished data).

The most accurate multiple regression during daytime on the basis of correlation between mean SSF values and individual microclimatic factors was build (without any time lag) as following:

$$SSF = 6.1.\ 10^{-5}\ T_2 + 2.\ 10^{-4}\ RH_2 + 6.\ 10^{-6}\ GR + 3.71.\ 10^{-2}\ VPD_2 - 1.67.\ 10^{-2},\ (r^2 = 0.95) \qquad (1)$$

where SSF represents mean specific sap flux of all trees within the stand [$l.hr^{-1}.cm^{-2}$ of sapwood], T_2 is air temperature [°C] at 2m height canopy level, RH_2 is relative air humidity [%] at 2m height, GR is incident global radiation [$W.m^{-2}$], and VPD_2 is derived water potential deficit [kPa] at 2m height. In the case of all daily SSF simulations, the night time flux needs to be taken equal to zero or as a constant (e.g. Green et al.1989). But, as we showed above, sap flux continues after sunset (1 hour time lag after GR, Fig. 1a), weather conditions for evaporation still exist (*see* correlation coefficient of VPD during the night time, Fig. 1b, 1c, especially day 10) and stomata are not exactly fully closed. Moreover, sap flux values did not decrease to a low plateau during the night time especially during sunny days (Fig. 1a, day 5-7 and 10). It seems to be a question of water content in woody-tissue cells reparation.

However, the SSF values were quite independent on microclimatic factors during the night time; it is possible for all daily SSF simulations to use the following simple equation:

$$SSF= 6.44.\ 10^{-4}\ T_2 - 3.4.\ 10^{-4}\ RH_2 + 3.5.\ 10^{-2}\ ,\ (r^2 = 0.91) \qquad (2)$$

From the derived SSF value an instrumental error needs to be substracted as well. The presented relationships are in a good agreement with our previous results (*see* Pokorny 2000), when air temperature and relative air humidity appeared also to be the best predictors of SSF values. Nevertheless, the canopy level changed from 5m height in forest stand with a high density (2600 trees. ha^{-1}) to 2m in height for a stand of low density (2100 trees.ha^{-1}). Therefore, the best canopy height for microclimate factors measurements depends on the stand density and on the stand structure parameters, especially tree heights.

Conclusion

Sap flux was strongly correlated with microclimatic data. Thus, they can be used to simulate SSF values. The above presented results indicated that the strongest dependence was determined between SSF value and RH as well as with VPD during both separated time intervals (day and night time). All founded relationships between individual microclimatic factors and SSF values were the most significant without any time lag except for GR.

Acknowledgements

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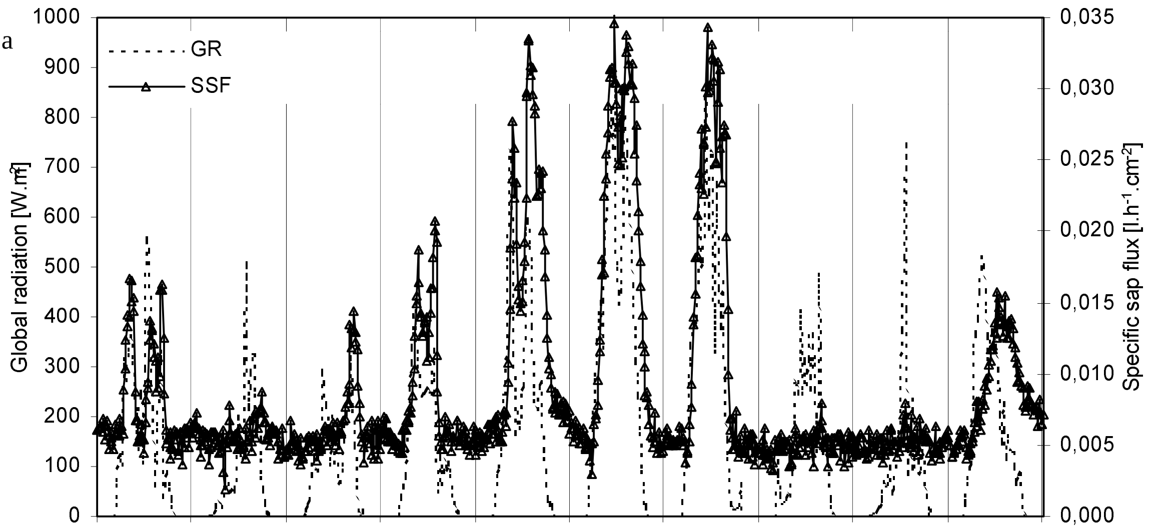
Fig. 1a. Daily courses of incident global radiation and mean specific sap flux values.

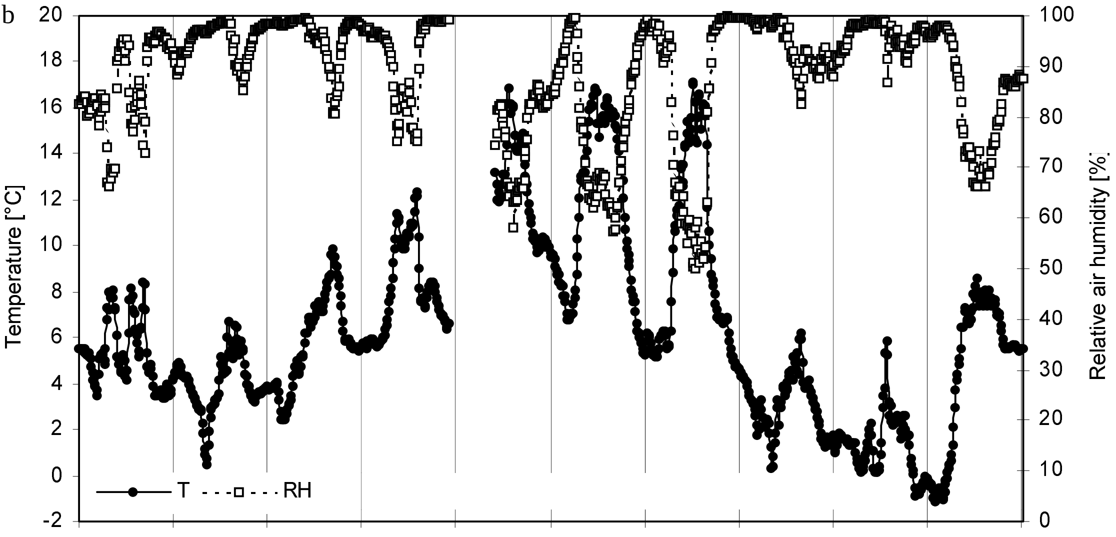
Fig. 1b. Daily courses of air temperature and relative air humidity measured at 2m height canopy level.

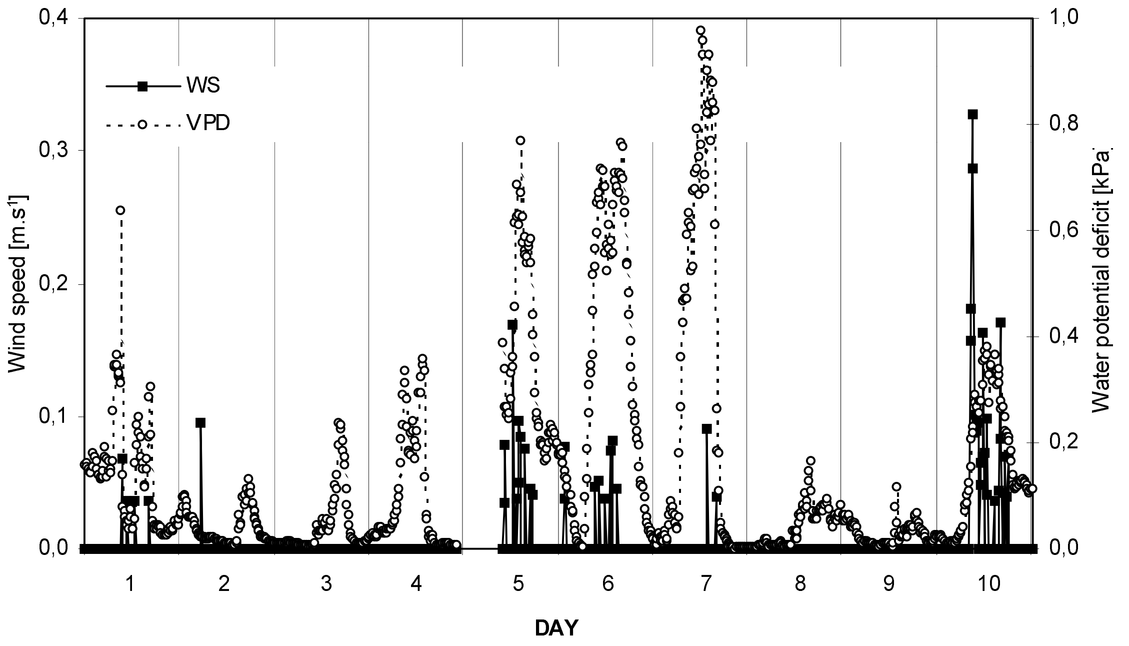
Fig. 1c. Daily courses of wind speed measured at 7m canopy height and derived water potential deficit estimated at 2m canopy height. The 1st day represents May 15th, 1998.

1a



1b





1c

Abstrakt

Příspěvek se zabývá sledováním změn toku vody v kmeni jedinců smrku ztepilého (*Picea abies* L. Karst.) v závislosti na měnících se klimatických podmínkách okolí. Pro měření rychlosti toku vody v kmenech dvou vybraných jedinců s výčetní tloušťkou 8.4 a 7.9cm, a výškou 6.8 a 6.6m byl použit přístroj Sapflow Meter SF300 (Greenspan Technology, Austrálie). Jedinci byli vybráni z cca 20-ti leté monokultury smrku (2100 ks.ha^{-1}) na základě následujících reprezentativních parametrů: i) pozice v porostu vzhledem k jeho hustotě, ii) výčetní tloušťka kmene a výška stromu, a iii) struktura koruny. Z mikroklimatologických charakteristik byli meřeny: i) dopadající globální radiace (GR), ii) teplota vzduchu (T), iii) relativní vlhkost vzduchu (RH), a iv) rychlost proudění větru (WS). Z hodnot T a RH byl stanoven deficit vodní páry ve vzduchu (VPD). WS, T a RH byli měřeny uvnitř porostu, a to v několika výškových úrovních.

Z výsledků vyplývá, že specifická rychlost transpiračního proudu (SSF) silně závisí na T a RH, a samozřejmě na VPD. Tyto vztahy jsou mnohem průkaznější v průběhu dne než v průběhu noci, i když i tehdy existují podmínky pro možnost výparu. V průběhu dne závisí SSF také na GR, ovšem s asi 1 hodinovým zpožděním. WS neměla větší vliv na tok vody v kmeni jedinců uvnitř porostu. Vzhledem k jednotlivým výškovým profilům měřených mikroklimatologických charakteristik vykazovaly největší korelaci s hodnotami SSF charakteristiky měřené ve výšce 2m nad povrchem půdy. V porovnání s předchozími výsledky (Pokorný 2000) z obdobných měření v hustším porostu (2600 ks.ha^{-1}) vyplývá, že nejvhodnější výška pro sledování mikroklimatu se mění s hustotou a výškou porostu.

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