Water Transport and Water Content of Trunk in Different Species of Trees

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Abstract – Our working group have been engaged in investigation of sap flow in trees for many years. Sap flow measurements can be divided into direct (isotope tracing) and indirect (heat balance, heat pulse) methods. As isotope tracing is very expensive, so in the present work the results measured by indirect methods are demonstrated. It was concentrated primarily to the water take up of trees after dryness because a fast water take up may be resulted an ecological advantage for a tree. The following species of trees were involved in this investigation: oaks (*Quercus petraea*, *Quercus cerris*), beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), for some years pines (*Pinus sylvestris, Picea abies, Larix decidua*) were also considered. The amount of water storage in trunk proved to be characteristic for species and by means of that some species may be able to survive dry periods. The velocity of water takes up after rain and the amount of storage water are different in different species. CT and MRI pictures show the distribution of free and structural water in trunks of different species. The decreasing level of precipitation and the lack of water in Hungarian forests in consequence of global warming can make preferable the plantation of those species which are better accommodated to dryness.

Keywords: water transport / sap flow velocity / water content in trunk / CT / MRI

1. INTRODUCTION

The dynamics of xylem transport have been widely studied in the last few years in the laboratory and field. These studies have taken advantage of the development of non-destructive monitoring techniques, such as thermoelectric methods (heat balance and heat pulse) for sap flow measurement (BORGETTI ET AL 1993, CERMAK 1972, GRANIER 1987), acoustic sensing (TYREE and DIXON 1983). Stem water content is difficult to determine because of tissue decay, the high level of hydration and geometrical constraints of the trunk. Many abiotic and biotic primary and secondary factors could be responsible for the decline forest decay and dieback of tree species. Until the mid-eighties air pollution and acid precipitation were suspected to be most important primary abiotic factors (JAKUCS 1988). Recently climatic changes induced by global atmospheric warming-up are considered as the most important ones. It is not fully understood, why different species and their healthy and unhealthy individuals respond so differently to same environmental changes in the same forest. A main symptom seems to be the disturbance in water transport of trees. In our isotopic measuring results we tried to elucidate some theoretically equivocal features of water transport and beyond that to find characteristic differences in water transport namely very fast flow confining to a very short period producing characteristic spikes and a long lasting one resulting the steady increase of ground level activity (FENYVESI at al. 1998). To interpret these data it seemed to be necessary to find good methods to determine the water containing compartment within the trunk and to estimate their area relative to the trunk cross-section.

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2. MATERIAL AND METHODS

There are a lot of different methods to estimate quantitatively the sap flow in trees. Most of these are indirect, producing relative data. Our isotope labeling technique may be the only one, offering direct velocity values (FENYVESI at al. 1998, BÉRES at al. 1998, BÉRES at al.1989). Because of the expensiveness of the isotope technique it was necessary to apply a cheaper technique, namely heat balance measurements. Heat balance technique produce relative data, so that we have to calibrate it with isotope technique. A new heat balance device was constructed by our working group, which opened new possible to broaden the range of investigated species.

Computer tomography of trees was made by means of Siemens Somatotom Plus 4 spiral CT and Philips Tomoscan AV CT. Magnetic imagining pictures was made of Philips Gyroscan T5-NT measurement. Trees were cut up and distributed to half a meter logs. To preserve the original water content the logs were immediately isolated from air by spraying shellac on them, after that they were vacuum foiled on spot. To depict the fine structure of wood serial CT slides were taken optimal window width and center. These pictures correlate through the X-ray absorptional density to the mechanical density distribution of the sample. The intrinsic X-ray absorptional density scale of the CT - in Hausfield units (HU) – was normed in a way, that the density of the water should be the zero point of scale. So that to image the water distribution within the log, the pixels around the zero point – namely those falling within the (-20HU, +20 HU and -10HU +10Hu) interval – were selected and reconstructed in three dimensions pictures. MR imaging of the same logs were made concomitantly. Proton density, T2 weighted and T1 weighted coronal sections were taken serially.

3. RESULTS AND DISCUSSION

In the figures are sap flow results measured by heat balance technique. Sap flow curves were seen in the first figure before and after watering in oaks and hornbeam, and in the second figure in beech. When a hornbeam tree and two oaks trees were compared, it seemed to be evident, that the hornbeam tree presented most impressive reaction to watering.

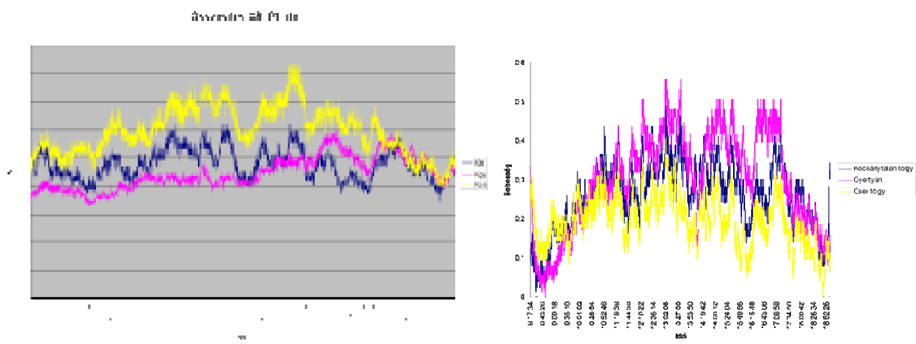
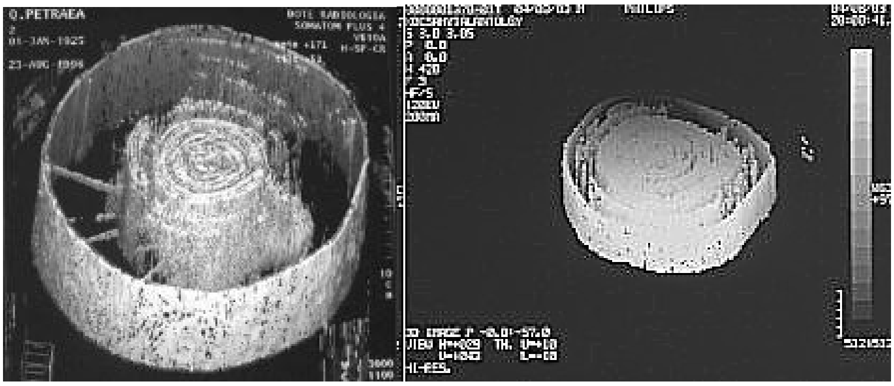


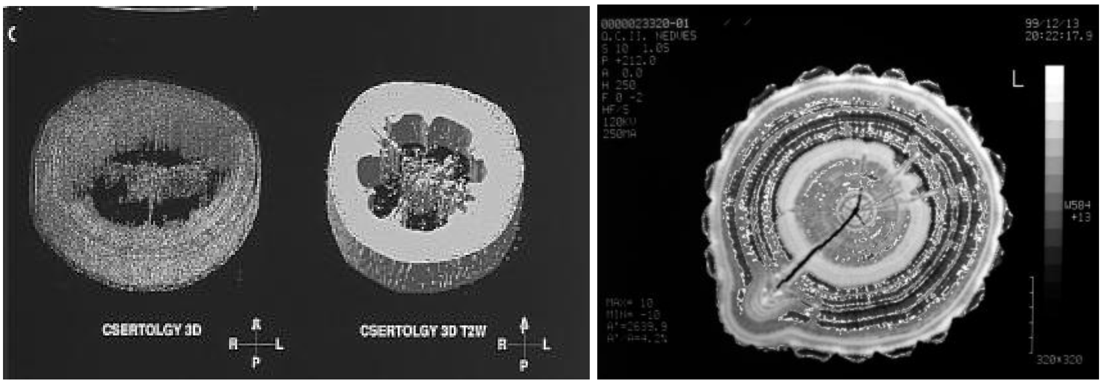
Figure 1. Two oaks tree (Quercus petraea,Quercus cerris) and a hornbeam tree (Carpinus betulus) sap flow changes are before watering (to left) and after watering (right).

In a Quercus petraea tree the centre of the trunk serves as a water reserve. This pool of reserve water has a direct connection to the tracheae on the circumference. In case of aridity this reserve water seems to be responsible for the characteristic spikes and differences in the sap flow. After watering the central water pool is saturated first (Picture 1).



Picture 1. Water content in Quercus petraea'trunk before and after watering measured by CT

After an arid period it was the *Quercus cerris* wich contains the largest water reserve. The central water pool in the trunk has a more intensive connection with the tracheae on the circumference. This moment makes possible the more even sap flow (*Picture 2*).



Picture 2. Water content in Quercus cerris'trunk before and after watering measured by CT and MRI

After irrigation the largest changes in sap flow could be demonstrated in *Carpinus betulus* tree. Take up water from the soil, its reservation in the trunk and the transport to leaves takes only 10 hours. The reserve water can be localized in the proximity of circumference (*Picture 3).*

Picture 3. Water content in the trunk of Carpinus betulus before and after watering measured by CT.

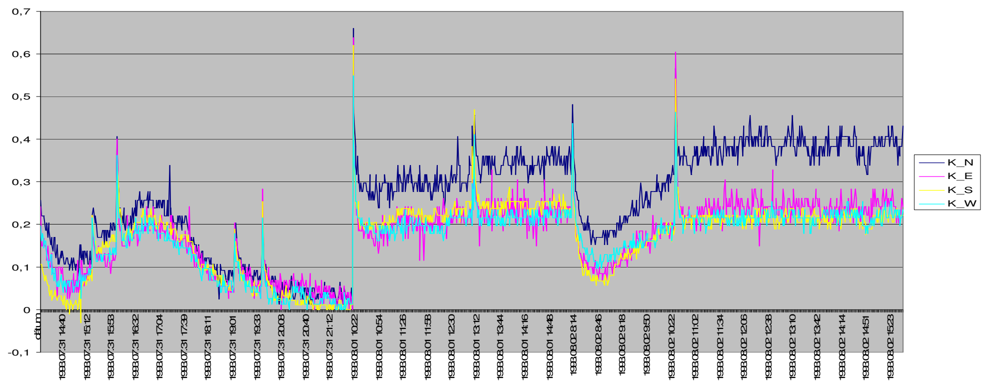
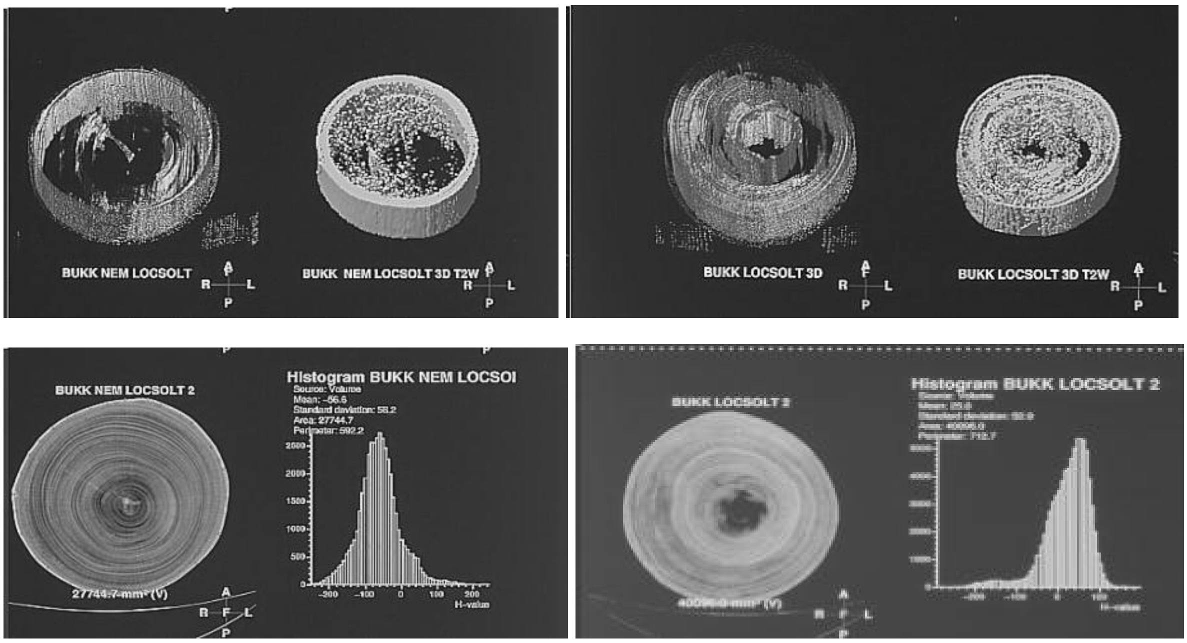


Figure 2. Water transport velocity of beech tree in the four sides of the trunk.

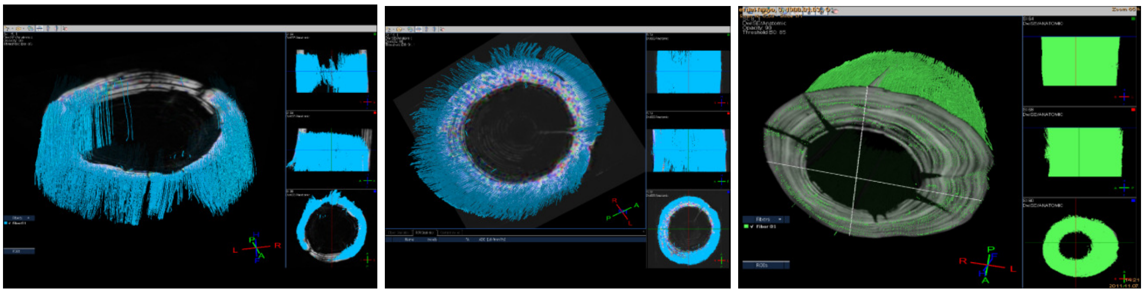
After watering the different sides of the beech tree show different water transports velocities. The most characteristic change was demonstrated in the northern side of beech trunk.



Picture 4. Water localisation of beech'trunk before watering and after watering

In the Picture 4. You can see the amount and distribution of water in the water supplied area before and after watering. On the 3D pictures can be demonstrated the actually localization of water containing compartments. It is remarkable that the distribution of water is asymmetric inside the beech trunk. It correlates our previous heat balance measurements.

Different Pinea species were investigated in this new series of investigations. Tracheas taking part actually in water transport were identified by means of MRI . On MRI pictures it was possible to depict and measure the united surface of tracheas actually active in water transport (Picture 5.).



Picture 5. Water localization in trunk of Pinea species measured by MRI

The MRI pictures demonstrate that the pattern of the actually active water transporting surfaces is highly asymmetric. On the basic of this result it seems to be totally false if the area of water transporting surface is estimated by the diameter of tree and the mean thickness of wet wood.

4. SUMMARY

The different species of trees have characteristic distribution of water reservoirs. The water pool in trunks is very important in surviving arid periods. After watering the saturation of reserve water pools occurs most quickly in *Fagus* and *Carpinus* trees. Our complex investigation methods proved to be useful and reliable for the future researches.

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