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Measurement of electric potential difference on trees

András Koppán[1]*, András Fenyvesi[2], László Szarka[1], Viktor Wesztergom[1]

[1]Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, Sopron, Hungary, [2] Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

ABSTRACT Electrical potential differences have been continuously recorded since 1997 between electrodes inserted in sixteen selected sites of the trunk of a Turkey oak (*Quercus cerris* L.) and in the ground. The measured electric potential difference data have a characteristic sinusoidal daily variation. The annual fluctuation of the mean daily amplitudes of these diurnal variations has at least two maxima per year. We found a remarkable correlation between electric potential differences (EPD), the water potential of air and sap flux density data. It means that the EPD follows the variations of the sap flow intensity.
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KEY WORDS

electric potential difference
sap flow
Turkey oak

It is an old geophysical experience, that telluric-magnetotelluric measurements are distorted when one of the electrodes is placed in the vicinity of a living tree. Since the trees, together with other "electromagnetic noise sources" might sometimes create problems in geophysical field measurements, we turned our attention to the problem of electrical processes related with trees. We have been studying the evolvement and temporal variation of the electric field in trees since 1995 (Koppán et al. 1999). Electrical potential differences (EPD) in the trunk of a Turkey oak (*Quercus cerris* L.) tree have been continuously recorded in the Geophysical Observatory "István Széchenyi" of the Hungarian Academy of Sciences since 1997. With this experiment we followed and extended an earlier French experiment (Morat et al. 1994), which lasted only for a few weeks. The continuous EPD monitoring was completed with measurements of meteorological and geophysical data and a direct measurement of sap-flow by using Granier's radial flowmeter technique (Granier 1987) to give more precise information about the xylem-sap flow.

Materials and Methods

Sixteen non-polarising electrodes were inserted beneath the cambium into the sapwood in four levels (0, 2, 4 and 6 m height). Four electrodes (corresponding to S,W,N and E sides of the tree) were installed in each level. The EPDs were measured between the trunk electrodes and a common ground. The sampling interval was kept as short as 1 sec, and 1-min mean values have been continuously recorded since 14 July, 1997. A microclimatological station was also installed next to the experiment site (temperature, relative humidity, wind-speed, precipitation and radiation data are available). Various geophysical measurements have also been carrying out in the observatory: *e.g.* atmospheric electricity, point discharge, geomagnetic and electric fields of the Earth. The sap flow was simultaneously recorded from July 1999 to December 1999 with Granier's radial flowmeter technique (Granier 1987) by a four-channel (four thermocouple) system. The heating elements of the four thermocouples were inserted into rough-drilled holes in the sapwood, in four directions (S, W, N and E) at a level of 1m. The reference probes - which were not heated and remained at wood temperature - were installed below with 15 cm. The system measured the temperature of each probe. The sampling rate was 5 minute. The temperature difference between the heated and the reference probes (DT(u)) is influenced by sap flux density (u) in the vicinity of the heated probe. From the temperature differences it is possible calculate a sap flux index (K) which is in straight relation with sap flux density: K=[DT(0)/DT(u)-1], where DT(0) is the maximum temperature difference (when there is no sap flux - during the night, when vapor pressure deficit equals or is close to zero).

Results and Discussion

During the analysis of EPD data series the characteristic daily variations were found as the most conspicuous variations. These variations appear in springtime right at the beginning of growing period and disappear in late autumn, after the defoliation. The daily maximum can be measured between 6 and 8 a.m., whilst the minimum occurs between 3 and 6 p.m. (local summer time). The amplitude of daily variations changes between 15-50 mV during the vegetation period. The general character of the daily variation is similar for each channel, but slight differences can be observed in the amplitudes. The observed differences may be of both internal and external origin, first of all the structural inhomogeneity of the trunk and the different micrometeorological conditions around the trunk should be considered. The annual fluctuation of mean daily amplitudes has at least two maxima (Fig. 1). The first peak occurs at frondescence (because of the very intense transport processes within the tree), while the second one appears in early summer (this might correspond to a maximum in the transpiration, Breda and Granier 1996).

The comparison of the electric potential differences (EPD) and the measured Granier's thermometric data (TH) shows a strong correlation (Fig. 2), but sometimes a 1-2 hours

*Corresponding author. E-mail: koppan@ggki.hu

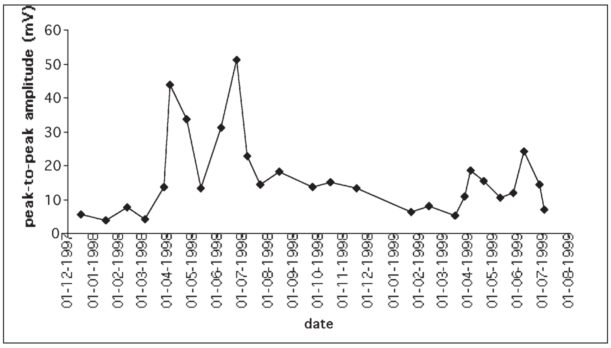

Figure 1. Annual fluctuation of the arithmetic mean of the mean daily amplitudes for the electrodes at level 6 m height (December 1997 - July 1999).

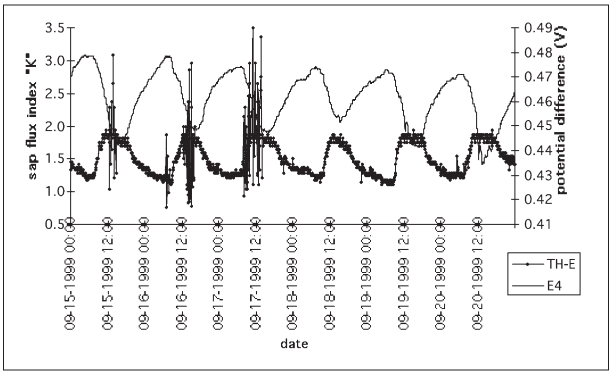

Figure 2. Variation of electric potential differences (E4) and the sap flux index (TH-E) derived from Granier thermometric method (15-20 September 1999).

phase lag can be observed between the EPD and the TH curves. A remarkable correlation was also found between electric potential differences (EPD) and the water potential of air, this latter was derived from air temperature and relative humidity. These results indicate that the sap streaming due to the transpiration and root pressure generates the largest part of measured potential differences. In order to decompose the EPD into its components (electrode potentials, concentration potentials and streaming potentials) and to provide a numerical model of electric field of tree it would be indispensable to know the mineral composition of sap. As we have found it, it is not sufficient to have one "snapshot" about the sap condition: a continuous monitoring of concentration of the elements is needed. Namely, in contrast with measurements carried out on cutted stems (where the ratio of the flow velocity of a diluted solution forced through stems and the potential differences was found to be constant: Gindl et al. 1999), in our in-vivo experiments the relationship between the sap flux and EPD is non-linear, which probably means that the conductivity (*i.e.* ion concentration) of the xylem sap itself also has a daily fluctuation.

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