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Comparison of dendrometer measurements with lysimeter data at Agroscope Reckenholz

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Zusammenfassung

Der Durchmesser eines Pflanzenstängels ändert sich nicht nur aufgrund des Wachstums, sondern auch in Folge des Wassergehalts im Stängel. Dieser ist abhängig von der Differenz zwischen Wasseraufnahme und Transpiration. Es wurden vier Dendrometermessgeräte an unterschiedlichen Rapspflanzen auf einem Lysimeter des Agroscope Reckenholz installiert, um die Durchmesseränderung des Stängels zu messen. Dieser wurde mit der tatsächlichen Verdunstung, Bodenfeuchte und Bodensaugspannung in verschiedenen Tiefen verglichen. Die Dendrometermessungen zeigen einen typischen Tagesgang einer Rapspflanze (siehe *Figur 3*), deren Durchmesser am Morgen – nach der Nacht ohne Transpiration – ein Maximum erreicht, und am Abend minimal ist weil die für die Photosynthese benötigte Transpiration durch den Tag höher ist als die Wasseraufnahme. Dendrometermessungen können helfen den Pflanzenwasserhaushalt besser zu verstehen, insbesondere das zeitliche Verhalten des Wassertransports vom Boden in die Atmosphäre. Somit kann eine Wissenslücke eines Teils im Wasserkreislauf geschlossen werden, und es können für die landwirtschaftliche Praxis hilfreiche Informationen gewonnen werden.

Schlagwörter: Evapotranspiration, Tagesgang, Durchmesser, Pflanzenwasserhaushalt, Wasseraufnahme

Summary

Changes in the diameter of plant stems occur not only due to their growth but also due to changes in the water content within the stem as a function of differences in root water uptake and transpiration. Four dendrometer devices were installed on rapeseed plants on a lysimeter at Agroscope Reckenholz to measure changes in diameter of the plant stem, and were compared to actual evapotranspiration (AET), soil moisture and soil suction at different depths. The dendrometer measurements show typical sub-daily cycles in the diameter of the rapeseed stems with diameter being maximal in the morning, after the night period with no plant transpiration, and minimal in the evening, as transpiration during the day – when photosynthesis takes place – is higher than root water uptake. Dendrometer measurements can give an insight into plant water use and especially the temporal coupling of water transport from soil to the atmosphere, filling a gap in the knowledge of the water cycle and giving helpful information for agricultural practice.

Keywords: evapotranspiration, daily cycles, stem diameter, plant water supply, root water uptake

Introduction

Changes in the diameter of plant stems occur not only due to their growth (added biomass) but also due to changes in the water content within the stem as a function of differences in root water uptake and transpiration. Dendrometers are measurement devices that can be placed on the plant stem or shoot to measure such changes in diameter. They are a non-invasive technique with which plant growth and the water content within a plant stem can be measured, for example to determine the start and end of growing periods, to identify drought conditions, to control irrigation, etc. (MMM Tech Support 2018). As transpiration induces water transport in the stem at rates higher than root water uptake, also sub-daily cycles in the diameter of shoots can be observed and recorded by dendrometers. The sub-daily cycle (its amplitude) can provide an indirect measurement of transpiration which is similar to direct measurements of sap flow and stomatal conductance in trees (Zweifel et al. 2001). Installation of dendrometers on plants in lysimeters provides a complementary assessment of the timing and magnitude of actual evapotranspiration (AET). It is the aim of this poster to present first results of such a combined measurement.

Material and Methods

Four dendrometer devices of the type DD-S (producer: ECOMATIK (2016)) were installed on rapeseed plants for a period of 71 full days (April 12 to June 22, 2018) on a lysimeter at Agroscope Reckenholz (*Figure 1*). The dendrometer measurement devices were installed on four different plants at a height of around 35 cm, and measured the stem diameter change with a temporal resolution of 1 minute. A weighted lysimeter with the same type of soil and the same culture was taken as reference for comparison of dendrometer measurements with soil moisture and soil suction at different depths at a temporal

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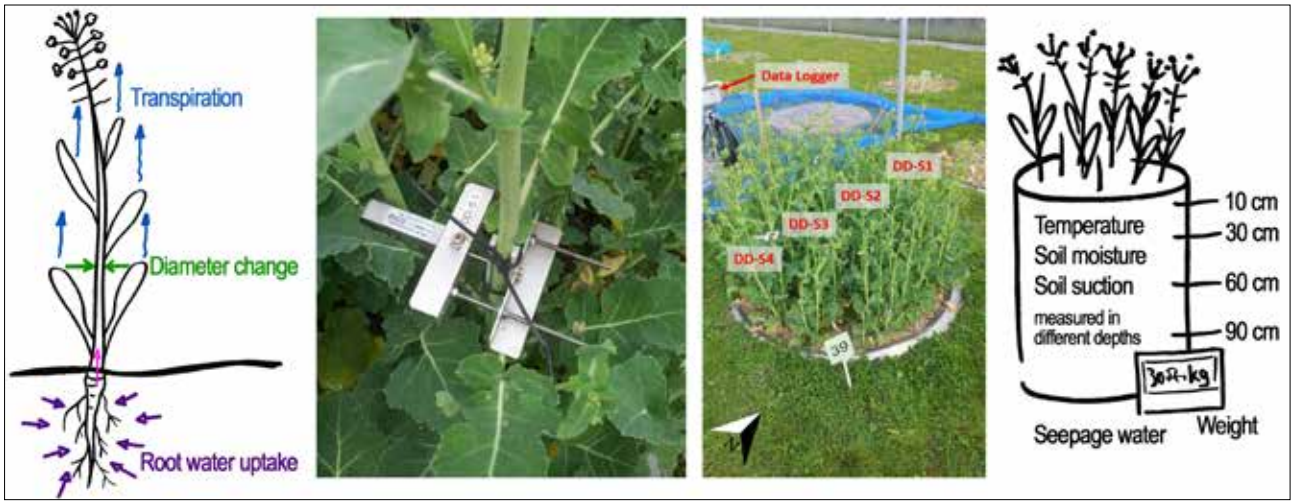

Figure 1: **Dendrometer device installation on a rapeseed plant stem and measurement setup of the four dendrometers in 2018, as well as the measurements in the lysimeter.**

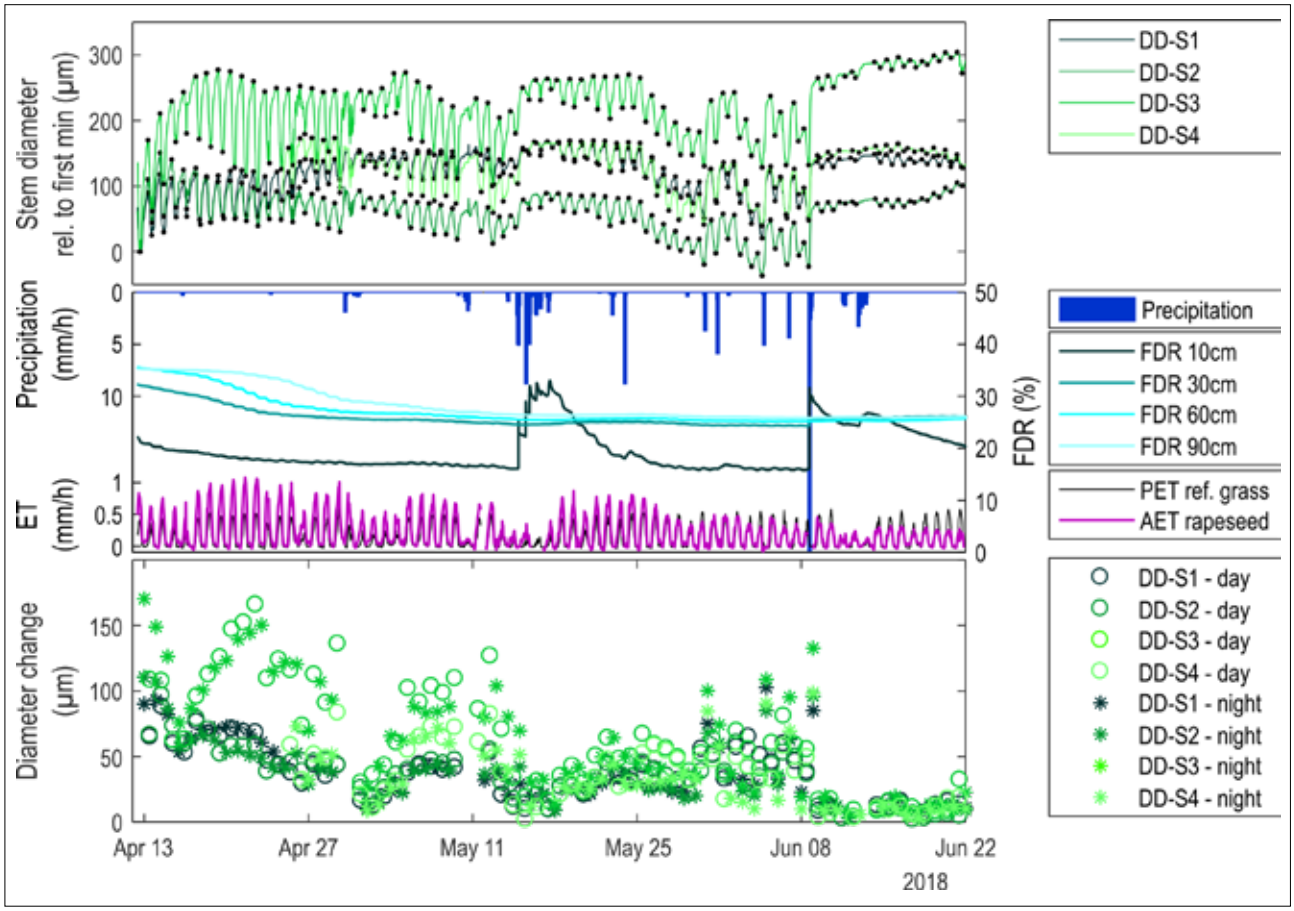

Figure 2: **Stem diameter measured by four dendrometers for the whole measurement period, together with soil moisture in four different depths measured by frequency domain reflectometry (FDR), precipitation measured at a meteo swiss station nearby, evapotranspiration measured with a weighable lysimeter and extracted changes in diameter over day and night measured by the four dendrometers. The dots in the uppermost plot indicate the observed maximum and minimum diameter.**

resolution of 10 minutes, and estimates of AET with an hourly resolution. The meteorological parameters used to calculate potential evapotranspiration (PET) were measured at the meteo swiss station (Zürich / Affoltern (REH)) nearby.

Results

The dendrometer measurements show typical sub-daily cycles in the diameter of the rapeseed stems with diameter being maximal in the morning, after the night period with

no plant transpiration, and minimal in the evening, as transpiration during the day – when photosynthesis takes place – is higher than root water uptake. *Figure 2* shows an overview of the whole measurement period. Until mid-April, a daily increase in the diameter of the plants can be observed during the early growth stage prior to flowering. As soon as the plants reached maturity, the maximum diameter reached does not change significantly anymore.

The stem diameter changes not only due to growth. It is clearly affected by a superposition of different processes, at short-term timescale mainly by transpiration and root water uptake. Plant transpiration is driven by meteorological parameters such as radiation, vapor pressure deficit, wind speed, etc., at the leaf surface, but also by the regulation of the stomata opening and closure by the plant. By measuring the lysimeter weight, transpiration was measured as the main part of AET. Root water uptake is dependent mainly on the gradients in soil moisture tension between the roots and the soil matrix and the flow of water through the plant stem. Some evidence of this superposition of transpiration and root water uptake can be seen in the long-term behavior of diameter change, together with ET and soil moisture.

In times with high PET and low soil moisture over a period of several days, the overall plants diameter gets smaller, as the root water uptake does not meet the transpiration rate (*Figure 2*, May 4 – 10). In times with low radiation and comparatively low temperatures and thus low PET, the overall diameter increases, indicating that the transpiration is lower than root water uptake (*Figure 2*, May 13 – 18). There is a tendency that with conditions where water is not limited (*Figure 2*, May 15 – 24 / after June 8th), the daily diameter change is smaller than in dry conditions.

A continuous decline of AET compared to PET, beginning at the end of May was observed. On the 8th of June, after a heavy rainfall, the daily fluctuations in plant diameter suddenly dropped, this was also in the period where senescence started and the plants were drying.

A close up of a few days (*Figure 3*) shows that the stem diameter change begins with a slight delay compared to the onset of AET as measured by the lysimeter. The same behavior can be observed at all four measured plants.

As the diameter decrease during the day is induced by the transpiration of the plant, we expect it should be related to the daily AET measured by the lysimeter. These relations are shown for all four dendrometers and two different periods in *Figure 4*. The correlation of AET and diameter change during the day from the whole measurement period (*Figure 4*, left) is rather small. However, when a period with low and constant soil moisture is analysed separately (*Figure 4*, right), this increases the coefficient of determination to almost 80% for most of the dendrometers.

Discussion

If the transpired amount of water in a plant is not recovered by root water uptake from the soil, water is extracted from the stem itself, leading to a temporary decrease in plant stem diameter. Looking at *Figure 3*, one can observe a delayed decrease of stem diameter compared to the onset of AET. This could be related to the position of the dendrometer on the plant stem, which is not reflecting the start of the transpiration process. In future experiments it could be interesting to measure the onset of diameter change at different heights of the plant stem.

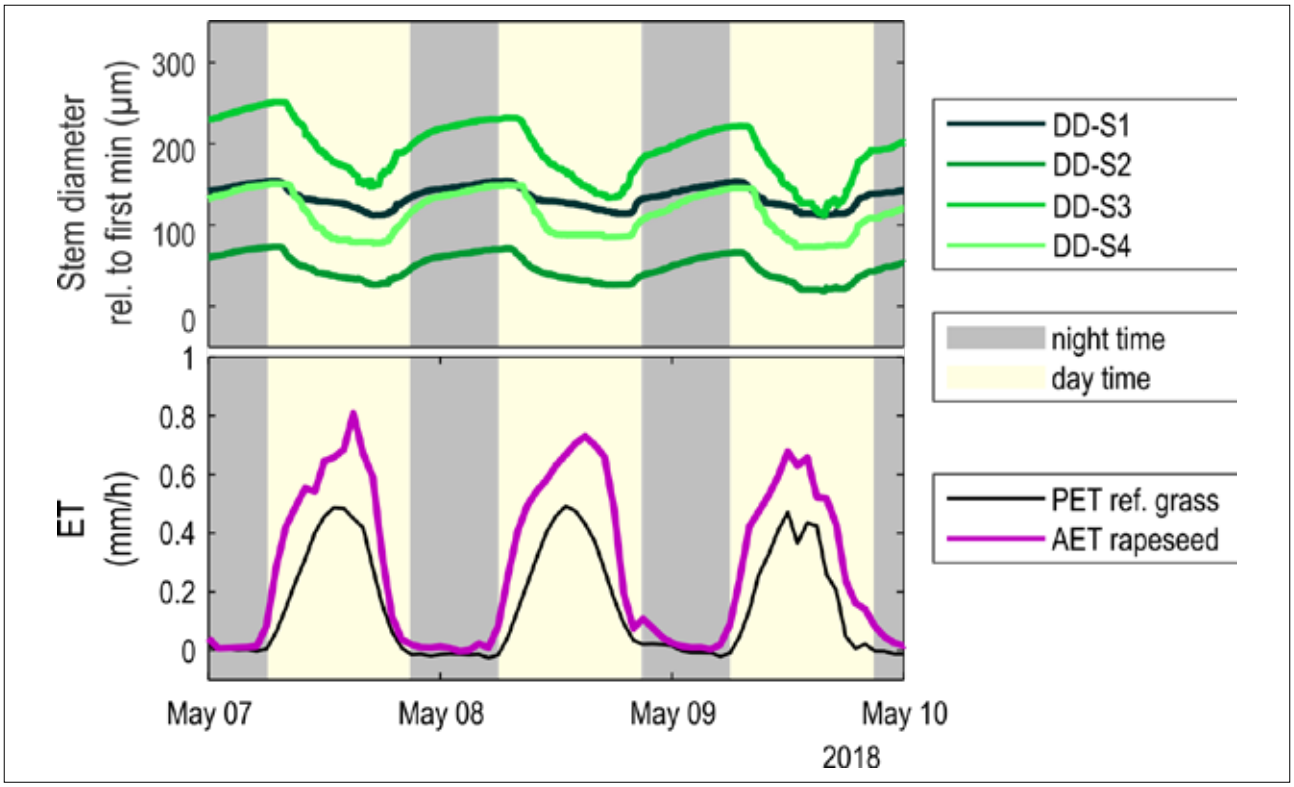

Figure 3: **Dendrometer measurements and evapotranspiration, measured with a weighted lysimeter, for three days in the first half of May.**

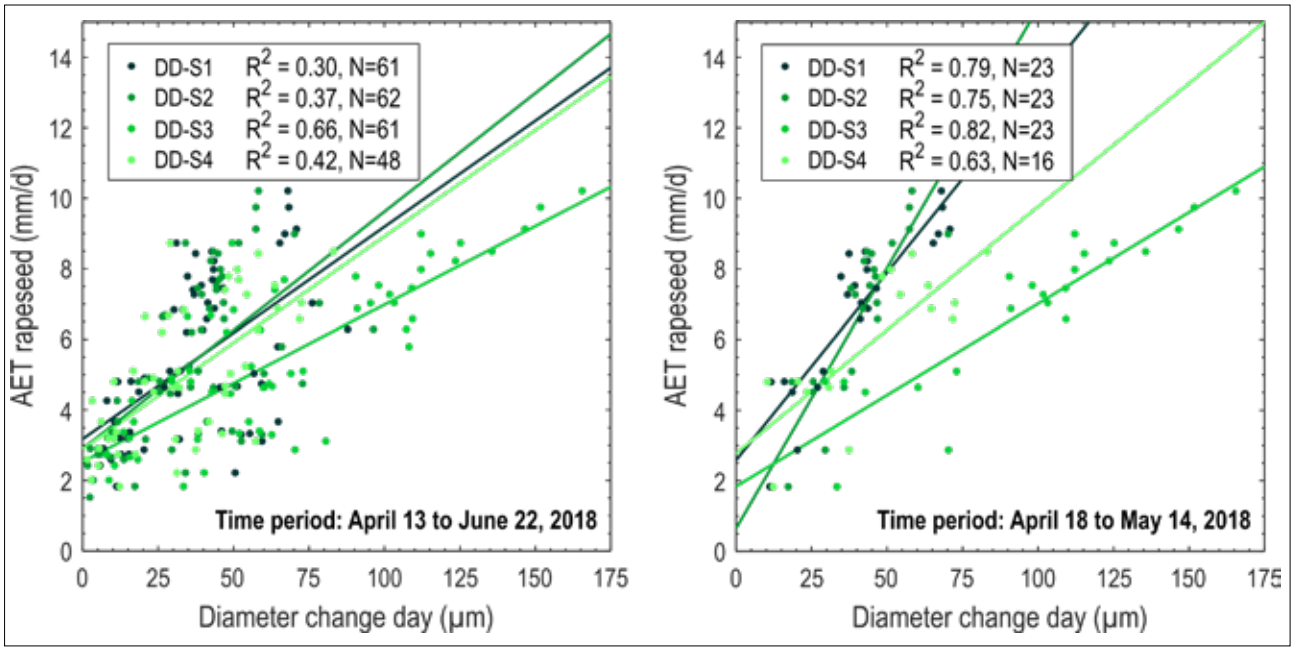

Figure 4: **Actual evapotranspiration (AET) of rapeseed versus corresponding changes in diameter of rapeseed plants during the day with a linear regression line plotted for each dendrometer and coefficient of determination. Left: Correlation over the whole measurement period. Right: Correlation for a period of four weeks with constant dry soil conditions in the uppermost layer.**

The rate at which the diameter decreases might be indicative of the stomata opening, being fully opened in the morning leading to high rates in diameter decrease and starting to close throughout the day to reduce water loss.

The observed decrease in daily maximum of AET over the second half of the measurement period is indicative for the ripening and slow dry-out of the plants. The precipitation event on the 8th of June falls together with a strong reduction in the daily cycles of the dendrometer measurements. With our data we cannot clearly conclude if this is the result of the plants being dry and not transpiring or another reason.

Overall, this experiment showed that dendrometer measurements of daily temporary diameter change on plants during the growing season provide a reasonable estimate of AET. Since stem diameter changes are different for different shoots, as well as root water uptake differs with soil conditions, a direct link of stem diameter change to AET seems to be difficult. Nevertheless, dendrometer measurements can give an insight into plant water use and especially the temporal coupling of water transport from soil to the atmosphere, filling a gap in the knowledge of the water cycle and giving helpful information for agricultural practice. Further measurements are planned to confirm the results found and to collect data in different environmental and soil moisture conditions.

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