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Ultrasound acoustic emission in water-stressed plants of *Picea abies* Karst.

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Introduction

It is widely known that cavitative events taking place in woody stems can be detected by monitoring acoustic emissions due to the vibrations of the xylem vessel walls. If operating at audio frequencies (Milburn and Johnson, 1966), noise from the surroundings can mask the faint sounds coming from wood elements. The use of sensors operating at ultrasonic frequencies (Tyree and Dixon, 1983) overcomes this problem. We report the occurrence of ultrasonic acoustic emissions from the stems of potted saplings of *Picea abies* Karst. during the summer, relating these to transpiration rate and water potential, since this technique has rarely been used under field conditions and water stress is a major limiting factor of wood production in mediterranean climates.

Materials and Methods

The experiment took place in the nursery of the School of Forestry of the University of Firenze. Potted 5 yr old plants of *Picea abies* were used, 10 of them were irrigated on a daily basis, while 10 others were assigned to drought treatment, witholding water from them during the periods 15–21 July, 8–14 August and 16–25 August 1987. Measurements were made from dawn to sunset on July 21, July 30, August 25 and September 10. Xylem water potential was measured with a pressure chamber every 2 h on plants among the 10 belonging to each group. The 6 remaining plants in each treatment were used for measurements of acoustic emission rate using a broad band Bruel and Kjaer model 8312 sensor, and a counting device similar to the one described by Sandford and Grace (1985), modified. The transducer was pressed on the stem using a spring-loaded handpiece, for a period of 5 min; the stem had been prepared by removing the bark; the exposed surface was coated with petroleum jelly to prevent water loss, and an ultrasound gel was applied to improve acoustic transmission. On the same plants, the transpiration rate was measured gravimetrically and stomatal conductance was measured using a porometer. Leaf area of each plant was measured at the end of the experiment.

Results

On July 21 (Fig. 1a), the drought-treated plants were stressed, as shown by physio-

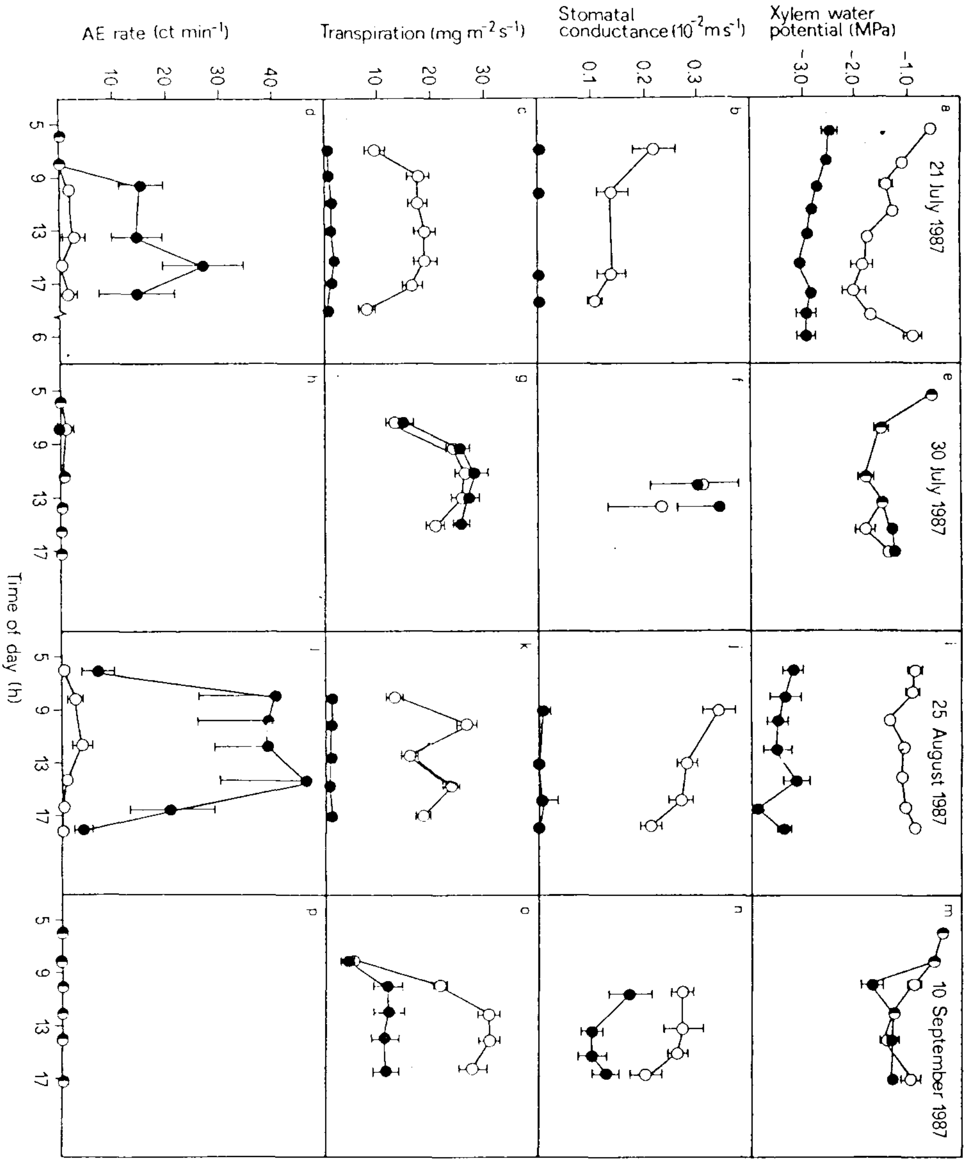

Fig. 1. Diurnal variation in xylem water potential, stomatal conductance transpiration rate and ultrasonic acoustic emissions. ◐: well-watered plants; ●: drought-treated (21 July and 25 August) or recovered (30 July and 10 September) plants; O: close data points. Bars are standard errors. (Reprinted from *Tree Physiol.* 5, 1989, with permission of Heron Publishing, Victoria, Canada.)

logical data. The difference in acoustic emission rate between these plants and the well-watered plot is also evident. Afterward, the stressed plants were watered until July 30, when the measurements were repeated. (Fig. 1b). The differences

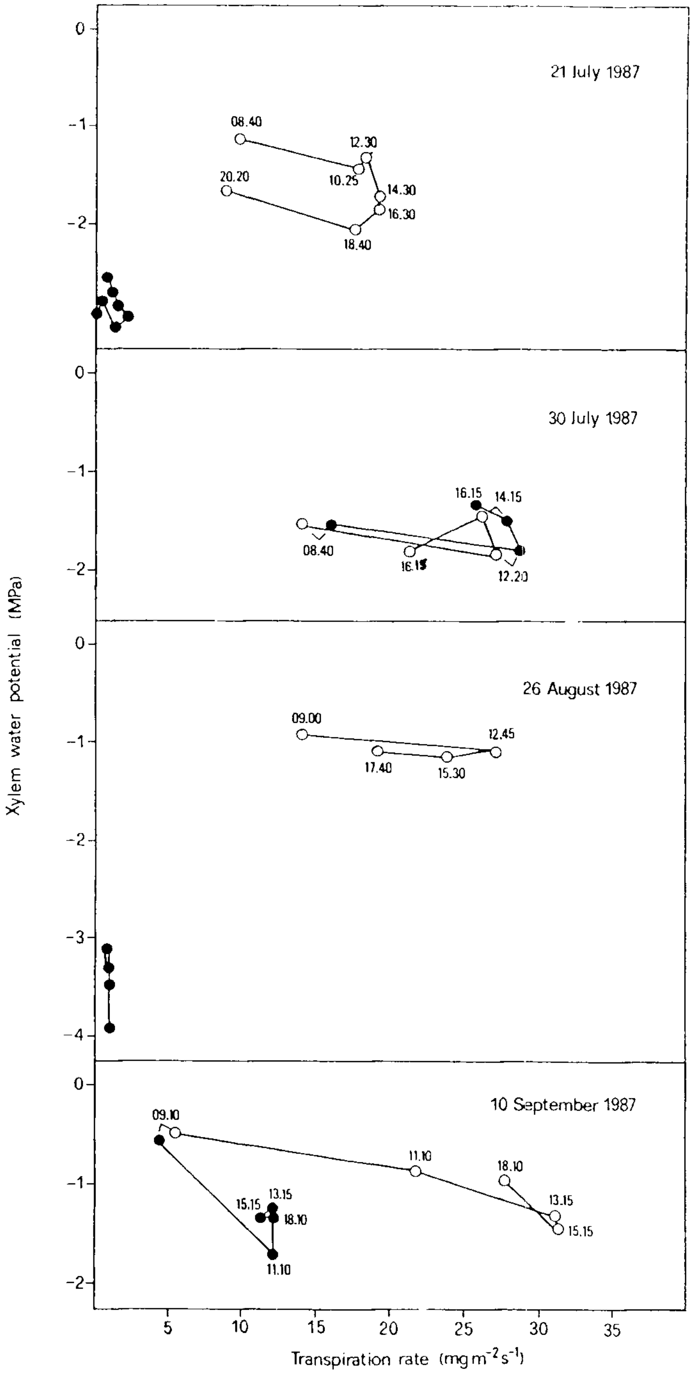

Fig. 2. Relationship between transpiration rate and water potential. O: well-watered plants; ●: drought-treated (21 July and 25 August) or recovered (30 July and 10 September) plants. (Reprinted from *Tree Physiol.* 5, 1989, with the permission of Heron Publishing, Victoria, Canada.)

in physiological data and acoustic emission rate between the recovered and the well-watered plants were not statistically significant. During August, the stressed plants were subjected to 2 periods of stress; after that, the abovementioned parameters were measured again on August 25 (Fig. 1c). The physiological data show that water stress was greater than before and the acoustic emission rate was much higher. Measurements were made again on September 10, after a long recovery period (Fig. 1d). The physiological parameters show the different behaviors of the 2 plots: transpiration and stomatal conductance did not recover completely in the stressed one, but the acoustic emission rate was very low for all the plants.

Discussion

Since acoustic emission is a consequence of cavitation events taking place in xylem elements, and it is widely accepted that each acoustic event corresponds to the cavitation of water in one tracheid, a reduction of hydraulic conductance can be expected as a consequence of cavitation due to water stress. To assess the magnitude of changes in hydraulic resistance, we plotted the transpiration rate against the water potential (Fig. 2), obtaining the hydraulic resistance as the slope of this relationship. A calculation based on the dimensions of tracheids, the listening distance of the sensor and the average number of cavitations detected on a typical sunny day, suggests that after the 3 cycles of drought, the hydraulic conductance should be substantially reduced. In fact, on September 10, the conductance of previously stressed plants was about 28% of that of well-watered plants.

Conclusions

The ultrasound sensor seems to be a useful new tool for studying water stress in field plants, although the use of data in a quantitative manner is still difficult. However, it seems that ultrasound sensing in woody plants has progressed to the point where the output from the sensor might be used for practical purposes.

References

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