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Short Communication

Can net photosynthesis and water relations provide a clue on the forest decline of *Quercus suber* in North Tunisia?

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Net photosynthesis, sap flow density (SFD) and water use efficiency (WUE) were measured in a *Quercus suber* forest in north Tunisia in an attempt to explain the forest decline. In general, sap flow was positively related to light intensity and water loss, indicating that high light intensities can increase the SFD up to the saturation point in the cork oak. CO_2 assimilation of cork oak in this region was light intensity-dependent. Cork oak showed a general increase in photosynthetic rates with increasing light intensity up to the light saturation point. Increased radiation probably increased the photosynthesis and growth above ground in this area, whereas the below-ground soil had insufficient moisture for uptake through the roots because the high light intensity and temperature induced high evapotranspiration.

Key words: Decline, evaportranspiration, light intensity, *Quercus suber*, sap flow density, water use efficiency.

INTRODUCTION

Quercus suber is a valuable tree species for economic and ecological purposes and one of the native woody species in Tunisia. It grows at the upper parts of only limited high elevation areas on the border between Tunisia and Algeria. The distribution areas are located at the northern part of Tunisia. The *Q. suber* population in the Ain Snoussi area together with water budget changes was examined in this study because it showed the widest distribution and the most severe decline among all areas. *Q. suber* forests represent 10% of the total forest area in Tunisia and 4.3% of the world's cork oak. However, its surface area has decreased dramatically from 148,000 to 70,000 ha within the years of 1920 and 2005 (Selmi, 2006). Unfortunately, the decline in this area is still unexplained.

Therefore, the objective of this study was to test the hypothesis that, the effects of net photosynthesis and sap flow density (SFD) on the different light intensities will explain the water loss on *Q. suber* during the growing season and the consequent variation in the water use efficiency on *Q. suber* stands in north Tunisia. This effect leads to physiological imbalances on individual trees and ultimately, the visible decline of the *Q. suber* forests.

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Abbreviations: a.s.l., Above sea level; P_N, net photosynthetic rate; **PPFD,** photosynthetic photon flux density; **SFD,** sap flow density; **TDP,** thermal dissipation probe; **WUE,** water use efficiency.

MATERIALS AND METHODS

Study site

The experiment was carried out during the 2008 season in a cork oak forest located in Ain Snoussi (Latitude N: 36° 47' 50"~36° 52' 40", Longitude E: 8° 52' 07"~8° 57' 01" Altitude: 640 m a.s.l.) with a 6 to 9° sloped topography, oriented North. The climate is humid and temperate with a mean annual precipitation of 1,550 mm and a mean temperature of 10.6 to 19.7°C. The tree ages were estimated to be between 71 and 131 years old, with a high density of about 300 to 400 trees ha^{-1}. The diameter at breast height varied from 70 to 132 cm.

Sapflow density

Four trees were chosen and equipped with a thermal dissipation probe (TDP) sensor of Granier et al. (1994). The sensors were continuously heated and inserted to a depth of 2 cm inside the woody core after striping the cork. Data were recorded in a data logger, monitored every 30 s and stored every 30 min. Every sensor in each tree in the southeast direction was installed. The TDP method, largely described by Granier et al. (1994) was used. The SFD J (10^6 m^{-2} s^{-1}) was calculated using the calibration equation:

$$J = 136.828 \times [K]^{1.2997}$$

The flow index K was obtained by:

$$K = (dTmax - dT)\ dT^{-1}$$

Where, dTmax is the temperature difference at zero flow, J = 0, dT is the measured temperature difference at a given flow density J.

Net photosynthesis and water use efficiency

The net photosynthetic rate (P_N) was measured on the fourth, fully expanded and mature leaf counted from each shoot apex on every individual tree in the treatments. P_N was measured with a broad-leaf cuvette of the *Licor-6400* portable photosynthesis system (*Licor*, Lincoln, NE, USA). The leaf was sealed and the CO_2 concentration was maintained at ambient levels. The airflow through the analyzer was adjusted to maintain the leaf cuvette relative humidity near ambient (45 to 60%) during measurement. The average cuvette temperature was maintained at 25°C. Each tree measurement was replicated four times. After the gas exchange measurements, the water use efficiency (WUE) was determined by calculating the ratio of net photosynthesis to the transpiration rate (Wang et al., 1998).

RESULTS AND DISCUSSION

SFD is a convenient measure of changes in a plant's physiology and can be viewed as a key functional trait. In general, sap flow showed a positive relation between light intensity and water loss, up to a light intensity of 500 µmol m^{-2} s^{-1} (Figure 1A). In other words, high photosynthetic photon flux density (PPFD) can increase the SFD in the cork oak, up to the saturation point.

The result of the photosynthetic rates generally indicated significant differences that were attributed to PPFD. In other words, CO_2 assimilation of cork oak in this region was light intensity-dependent. Cork oak demonstrated a general increase in photosynthetic rates with increasing light intensity up to the light saturation point (Figure 1B). However, most of the WUE measurements under high light intensities of more than 500 µmol m^{-2} s^{-1} exhibited a lower WUE (Figure 1*C*).

During the summer, cork oak trees suffer from drought at high elevation. The high summer temperature prohibits water absorption from the soil through the roots and causes dehydration of the plants tissues. For survival, tree populations at high elevation should be adapted to the long, high-temperature summer desiccation and to the physiological summer drought (Bergh and Linder, 1999). In the studied area, severe drought starts in approximately

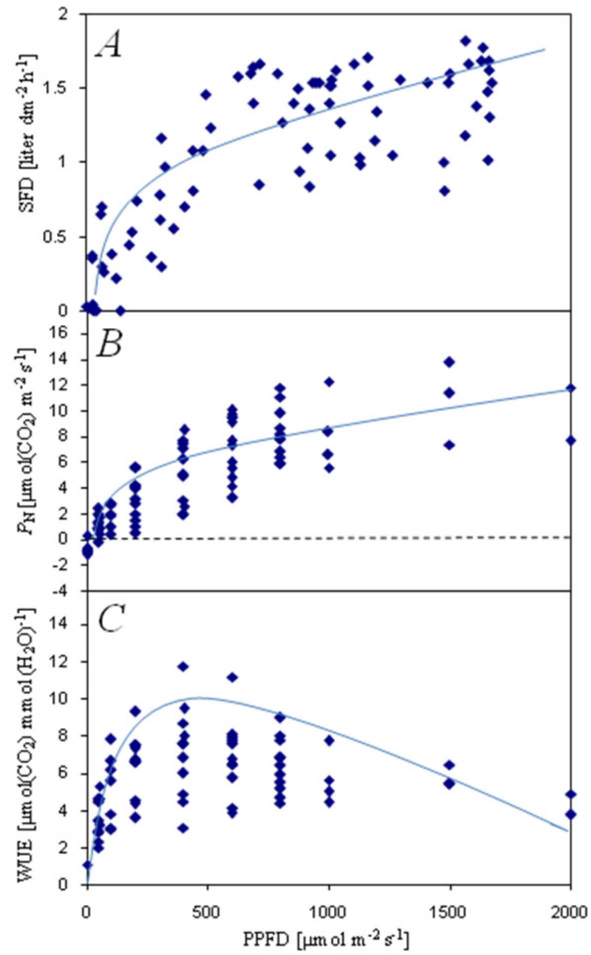

Figure 1. PPFD response curves of sap flow density (SFD) in *Quercus suber* grown in North Tunisia.

June at high elevation and rare rainfall made the drought stress to continue from summer to early winter. During the summer, high radiation can induce large water loss from the cork oak, which necessitates increased water supply from the roots. Increased radiation probably results in higher photosynthesis and growth above ground in this area, but below-ground soil has insufficient moisture for root uptake because high light intensity and temperature can induce high evapotranspiration (Figures 1A and B).

The increased drought stress on the trees with high radiation on the soil was attributed to the inability of the trees to carry out root elongation and develop new roots in the low soil water conditions (Bergh and Linder, 1999; Woo et al., 2004). The drought environment in the early summer affected the conservative strategy of trees by maintaining a lower stomatal openness. The resulting poor growth preparation of *Q. suber* at high elevation has been attributed to the imbalance between water uptake and transpiration (Gazal and Kubiske, 2004; Pregitzer et al., 2000). Obviously, net photosynthesis and SFD showed

strong positive relations (Figure 1A and B). In high radiation, this species may need much water to maintain both high photosynthesis and SFD. However, the below-ground soil is unable to provide much water due to the high evapotranspiration, which severely reduces the WUE (Figure 1C), plant body, branches and leaf moisture. Global warming probably increases the photosynthesis above ground on *Q. suber*, but the below-ground soil cannot provide high water movement during summer.
WUE was strongly reduced when compared to trees at elevated soil temperature due to the high light intensity.

In conclusion, the hypothesis states that elevated light intensity changes SFD and reduces water use efficiency during growing season and alters the water movement on cork oak stands growing in northern Tunisia. This fact causes the physiological imbalance on the individual trees and ultimately show the visible phenomenon in either the dieback or healthy cork oak stands. The results support our hypothesis. However, our data cautiously suggest that the elevated light intensity has tremendous effects on water use efficiency of the cork oak forest. Ultimately, the dieback phenomenon was seen in many populations.

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