

## EFFECTS OF BARK-STRIPPING ON THE WATER RELATIONS OF *QUERCUS SUBER* L.

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### RESUM

*Quercus suber*, font primària de la indústria del suro, es posa en producció cada 9-10 anys. L'objectiu principal d'aquest treball és investigar la influència de la lleva o pela del suro sobre l'activitat estomàtica i les relacions hídriques de la surera. Amb aquest propòsit s'han mesurat els canvis diürns de transpiració, la conductància estomàtica i el potencial hídric, en fase prèvia i posterior a la pela, durant el mesos de juliol i agost dels anys 1989 i 1990. La pela es va efectuar amb diferents intensitats. Les pèrdues d'aigua de la superfície pelada també van ser objecte de mesura. Els resultats mostren que les pelades severes poden determinar una disminució de la conductància estomàtica i considerables pèrdues d'aigua. L'«stress» determinat per l'extracció del suro no guarda relació clara amb el coeficient de pela sinó amb l'aigua perduda pel tronc, que varia d'arbre en arbre probablement segons la composició dels teixits del floema.

### ABSTRACT

*Quercus suber* is the primary source of industrial cork and can produce cork every 9-10 years. The main objective of this work was to investigate the influence of bark stripping on the stomatal activity and water relations of cork-oak. For this purpose, diurnal changes on transpiration, stomatal conductance and water potential were measured before and after bark stripping during July and August 1989 and 1990. The stripping on the trees had been done at various intensities. The water loss by the stripped surface was also measured. These results show that severe bark-stripping may lead to a decrease in stomatal conductance and considerable water losses. The stripping stress is not clearly dependent on the stripping coefficients, but rather on the water lost by the trunk which varies from tree to tree probably according to the phloemic tissues composition.

**Key words:** bark-stripping, *Quercus suber*, transpiration, water relations.

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### INTRODUCTION

Since *Quercus suber* trees are submitted to recurrent cork extractions, excessive stripping is an important stress factor which may affect the tree productivity. The effects of bark-stripping are very complex; the large amount of water lost from the stripped surface is most likely to influence the water balance and, direct or indirectly, limit the physiological processes.

Until now bark-stripping has been controlled in terms of periodicity and quantity of cork extracted. By law the period of extraction is limited to a 9-years periodicity. Moreover, the stripping height must not exceed 3-times the trunk perimeter at breast height in full mature and yielding trees, i.e., 3 is the maximum stripping coefficient

allowed. Several definitions of «stripping coefficient» have been proposed. Some authors define it as the *maximum stripping length : perimeter at breast height* ratio (Natividade, 1950; Montero & Grau, 1987) while others prefer to measure it as the *total stripping length : perimeter at breast height* ratio (according to the «Inventário Florestal do Sobreiro», 1990). These coefficients are equivalent when applied to single trunks, but present different values when two or more branches are also stripped.

The effect of the stripping intensity was first studied by Brito dos Santos (1940) and Natividade (1938, 1950), who related it with changes in stomatal activity and, consequently, on the productivity. These studies were limited to the observation of stomatal behavior during the so-called «stripping crisis», i. e., the period between the extraction and the regeneration onset of the new cork layer. Brito dos Santos (1940) observed a stomatal activity break, with total stomatal closure for a relatively long period. This author suggests that stomata close only a few hours after stripping, and that the length of this inactivity period (25 to 30 days) depends on the stripping intensity. Natividade (1938) had already observed that trees stripped with a coefficient above 2 presented a decrease of about 10% in trunk radial growth, while in the trees with a stripping coefficient of 4 that value was of 30%. It should be noted that the methodology then used, microscopic observation of closed stomata percentage in the leaf epidermis, was not a practical one, and presented several problems. As a consequence, there is a considerable interest in approaching the consequences of several stripping levels through modern techniques like those employing portable porometers and climatized leaf chambers, which provide gas exchange measurements under natural conditions.

## MATERIALS AND METHODS

The field experiments were conducted in two Tejo valley «montados», about 50 km southeast of Lisboa, at Infantado in summer 1989 and at Rio Frio in summer 1990. In both sites six mature and productive cork-trees representative of the dominant and typical trees of these «montados» were selected and numbered 1 to 6.

At Infantado those trees had been bark-stripped three or four times previously. Tree number 6 was again stripped on 27/7/1989, at 11:00, and trees 2 and 3 on the 31/7/1989, at 9:00 and 12:00, respectively. Trees 1 and 5 were not stripped and served as controls.

At Rio Frio trees 2, 3, 5 and 6 were stripped on the 19/7/1990 at 14:00. Trees 1 and 4 were not stripped and served as controls. Data shown for this site are the mean values from similar trees: 1-4, non-stripped; 2-3, 5-6, with different levels of water loss by the stripped surface (Table 1). All the trees had been stripped more than three times before.

Diurnal patterns of leaf transpiration ( $Tr$ ), stomatal resistance and climatic factors under natural environmental conditions were measured on four days, by the time of the stripping. For these measurements a ventilated steady-state porometer (LiCor LI-1600) was used, following the procedure described by Tenhunen *et al.* (1981). All measured data were recorded at one-hour intervals from dawn to dusk and taken from three south-facing leaves (from each tree) at 1.5 m above the ground. Data from tree 4 (Infantado) are not presented. The water lost from the stripped surface was also

**Table 1.**—Stripping characteristics of the trees under study. CD, stripping coefficient calculated as maximum stripping length / trunk perimeter at breast height (Natividade, 1950; Montero & Grau, 1987). QD, stripping coefficient calculated as total stripping length / trunk perimeter at breast height («Inventário Florestal do Sobreiro», 1990). ID, bark-stripping intensity, calculated as total stripped surface / trunk radial area at breast height (Montero & Grau, 1987).

Trees	Infantado - 1989					Rio Frio - 1990				
	Stripped area (m <sup>2</sup> )	CD	QD	ID	Water lost by the stripped surface (Kg. h <sup>-1</sup> )	Stripped area (m <sup>2</sup> )	CD	QD	ID	Water lost by the stripped surface (Kg. h <sup>-1</sup> )
1	n. s.	-	-	-	-	n. s.	-	-	-	-
2	6.98	2.23	3.45	40.2	2.21	5.71	2.26	3.85	40.1	1.41
3	2.72	1.15	1.15	17.2	0.62	3.91	1.20	2.86	22.6	1.00
4	2.39	0.81	0.81	13.2	0.91	n. s.	-	-	-	-
5	n. s.	-	-	-	-	4.18	1.44	2.25	29.9	0.52
6	5.20	1.29	2.37	22.8	1.61*	4.07	1.35	1.93	17.8	0.60

n.s. = non-stripped  
\* see Materials and Methods

measured with the same porometer. The leaf chamber was modified in order to adapt it to the stem surface and prevent gas leaks. These measurements were performed in the morning (immediately after stripping, on the first day), at midday and in the afternoon. At Infantado these measurements were also performed 55 days after stripping.

Parallel to the diurnal time courses xylem water potential,  $Y$ , was determined from terminal shoots holding four to five leaves, with a pressure chamber (Scholander *et al.*, 1965). Data from tree 4 (Infantado) are not shown.

Bark stripping characteristics of these trees are outlined in Table 1. Different stripping coefficients were applied to the trees under study. The water loss, expressed in  $\text{kg} \cdot \text{h}^{-1}$  for each tree, was calculated from the mean water loss by the stripped surface on the day of stripping, and the total exposed surface area. Since sufficient data was unavailable, for tree 6 the mean transpiration values of the other trees were used to evaluate its water loss on the day of stripping (Table 1).

## RESULTS AND DISCUSSION

*Quercus suber*, like other native evergreen-sclerophyllous vegetation, is subjected to long periods of soil drought during summer, which immediately follow the main period of growth (Mooney & Dunn, 1970; Mooney & Kummerow, 1981; Montenegro, 1987). It is during this drought period that cork is extracted. Clearly, one of the main effects of stripping is the excessive water loss from the exposed surface. This water is thus deviated from the root-to-leaf pathway during the dry season, with consequences

at the productivity level.

Our observations indicate that on the first day after stripping the trees loose the largest amount of water (Fig. 1), with a marked reduction (about 50%) of trunk evaporation on the 4th day. In fact, stripped trees present a large exposed area of living tissues and their proximity to the transport system facilitates water evaporation (Infantado,  $8.6 \mu\text{g}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$ ; Rio Frio,  $4.1 \mu\text{g}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$ ). Immediately after stripping the tissues exposed to the air and to external factors progressively die, thus contributing to the thickening of the dead tissue layer and forming, after 2 or 3 days, a first protective cover (Brito dos Santos, 1940). Probably for this reason a marked decrease of water loss was observed from the 1st to the 4th day. However, it seems that this new layer is not thick enough to prevent water loss by evaporation, and a gradual decrease is observed until the 9th day, when the values seem to stabilize ( $1.6 \mu\text{g}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$ , Fig. 1). Machado (1935) and Natividade (1938) refer the formation, about 20 days after stripping, of a new phellogen layer with immediate cork regeneration function which, due to cork's impermeability, limits the water loss by evaporation. However, after 55 days water loss from the stripped surface was still observed in our study, with a similar value to the 9th day. This fact leads us to assume that either the new cork layer was not still completely formed after 55 days, or the new cork layer was already formed after 9 days and the subsequent constant values of water loss derive from the lenticels.

The differences observed between the two sites are interesting. The trees from Rio Frio lost less water through the stripped surface, showing a 53 % reduction comparing with the values from Infantado (Fig. 1). This fact may be related with a different composition of the trees' phloemic tissues in each site. In some mature cork-trees these tissues may consist of more than 50 % of sclerenchyma (Natividade, 1950). The presence of a larger quantity of dead tissues in Rio Frio trees could thus explain why their trunks appear to be more effectively protected against water loss.

Climatic conditions during the study periods are shown in Fig. 2. It can be noted that air temperature ( $T_a$ ) and vapor water deficit ( $\Delta W$ ) are closely dependent on the

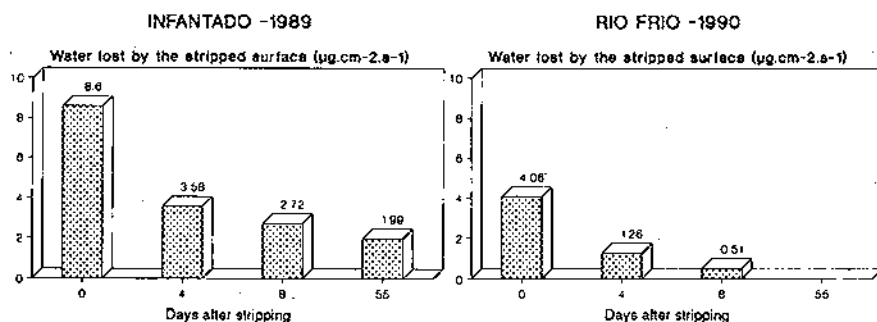
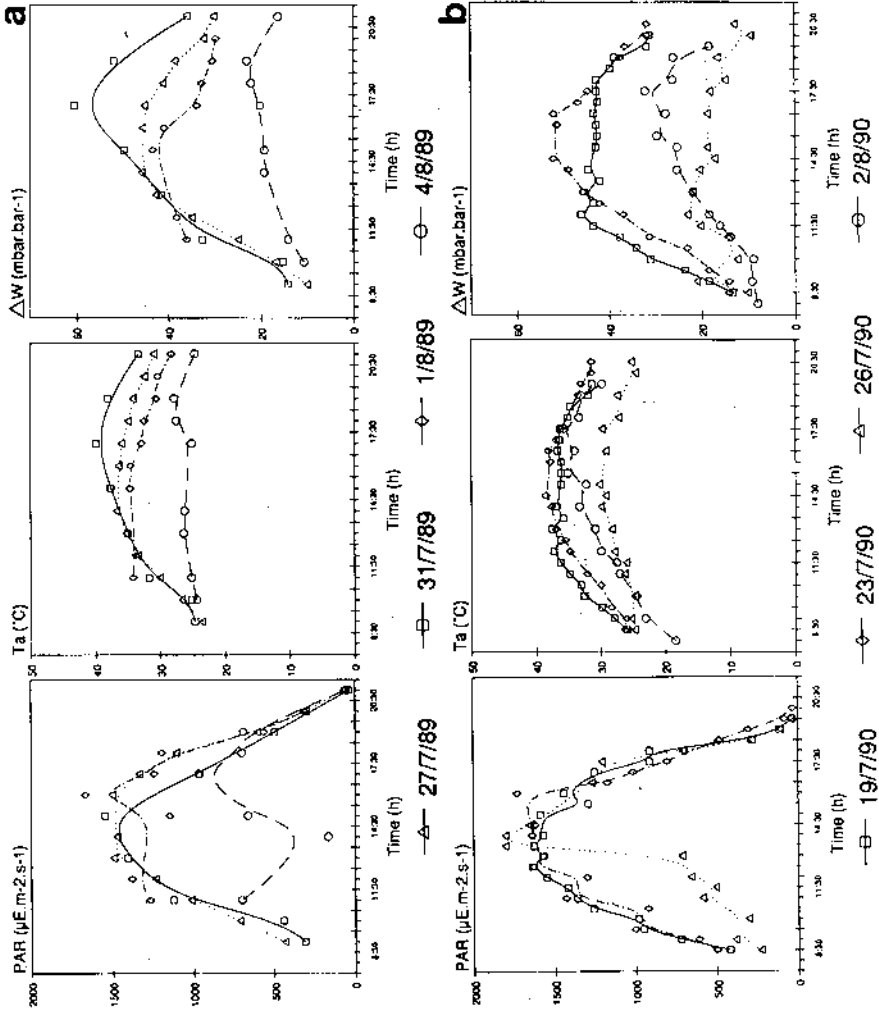


Figure 1.- Water lost by the stem surface following bark-stripping - diurnal mean values. Days 4 and 55 - mean of the four trees; days 0 and 9 - mean of trees 2, 3 and 4 (at Infantado). For Rio Frio mean values from the four trees are presented. Day 0 was the day of the stripping.



**Figure 2.** Diurnal courses of climatic conditions on four days at the study site. Photosynthetically active radiation (PAR), air temperature (Ta) and air-to-leaf vapor pressure difference ( $\Delta\text{W}$ ). a) Infantiado, b) Rio Frio.

solar radiation (PAR). On 31/7/1989 (Infantado) Ta was very high throughout the day, with maximum values of 41°C, and a maximum  $\Delta W$  of 64 mbar.bar<sup>-1</sup>. On the fourth day (4/8/1989) a marked decrease of Ta and  $\Delta W$  was recorded, associated with lower values of radiation (Fig. 2, a). At Rio Frio, in spite of similar values of PAR and Ta,  $\Delta W$  did not reach comparable values. There is a difference between the two first days, which presented a higher maximum Ta (40°C) and  $\Delta W$  (56 mbar.bar<sup>-1</sup>), and the two later days, with lower values ( $\Delta W$  below 33 mbar.bar<sup>-1</sup>) (Fig. 2, b).

Despite of the Mediterranean rainfall regime, there was no pronounced soil water shortage during the study period. Predawn xylem pressure potentials remained fairly high, between -0.7 and -5.0 bar on both sites. Root density and deep penetration probably ensured water supply to the shoots, and the results from this study suggest a good water availability, even during hot days. It seems likely that this type of adaptation is extremely useful for plants growing in the Mediterranean region, where precipitation is restricted on the summer months (Kummerow, 1981; Mooney & Kummerow, 1981).

Under the conditions of these investigations and for the trees studied, transpiration rate patterns followed the diurnal course of climatic factors, although differences arose between trees, resulting from genetic variability and polymorphism of the species.

During this study a progressive decrease in transpiration was observed (Infantado), with lower values on the last day, 4/7/1989 (Fig. 3, a). This was probably related with the high air temperatures and evaporative demand occurring on that period, submitting the trees to an intense vapor pressure deficit (Fig. 2 - 3) which seems to be an important factor in the transpiration control (Tenhunen *et al.*, 1981; Lange *et al.*, 1982; Lösch *et al.*, 1982). Comparing the values from 27/7/1989 and 31/7/1989, a marked decrease in Tr is observed (Fig. 3, a) accompanied by a higher  $\Delta W$  on the 31/7/1989, in spite of similar radiation levels (Fig. 2, a).

For trees 2 and 6, with higher stripping coefficients (Infantado, Table 1), there is an immediate Tr reduction after stripping, maintaining lower values than the others in the following days. On the 31/7/1989 trees 2 and 6 presented a constant value of Tr throughout the day (below 2 mmol.m<sup>-2</sup>.s<sup>-1</sup>). These low rates can explain the Y patterns presented on the same period by tree 6 (Fig. 4, a), which displays higher values than the other trees, despite of the excessive water loss by its exposed surface. Tree 2 shows a recovery of Y after 14:00 probably related with a significant reduction (31%) of water loss occurring in the afternoon (data not presented).

At Infantado, trees 4 (data not shown) and 3, with low stripping coefficients (0.81 and 1.15, respectively), do not present a decrease in transpiration, which seems to agree with previous observations by Natividade (1950), who refers C.D. below 2 as having no significant influence on the tree productivity.

Already observed at Infantado the species variability was also apparent at Rio Frio, where the trees presented wide ranges of Tr rates (Fig. 3, b). There was no significant effect of stripping on the Tr and Y of these trees (Fig. 3, b and 4, b), in spite of similar stripping coefficients to those from Infantado (Table 1). Rio Frio trees seem to have a better hydraulic conductivity than the trees in Infantado because although they maintain the same Tr rate after stripping, with an additional water loss by the exposed surface, they exhibit the same values of Y as before.

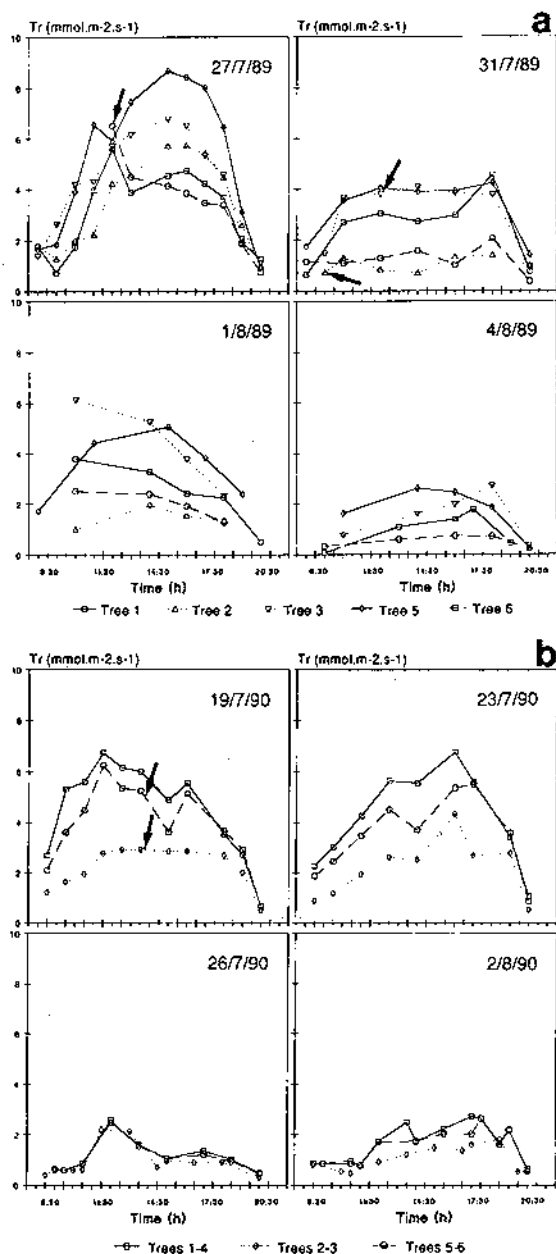
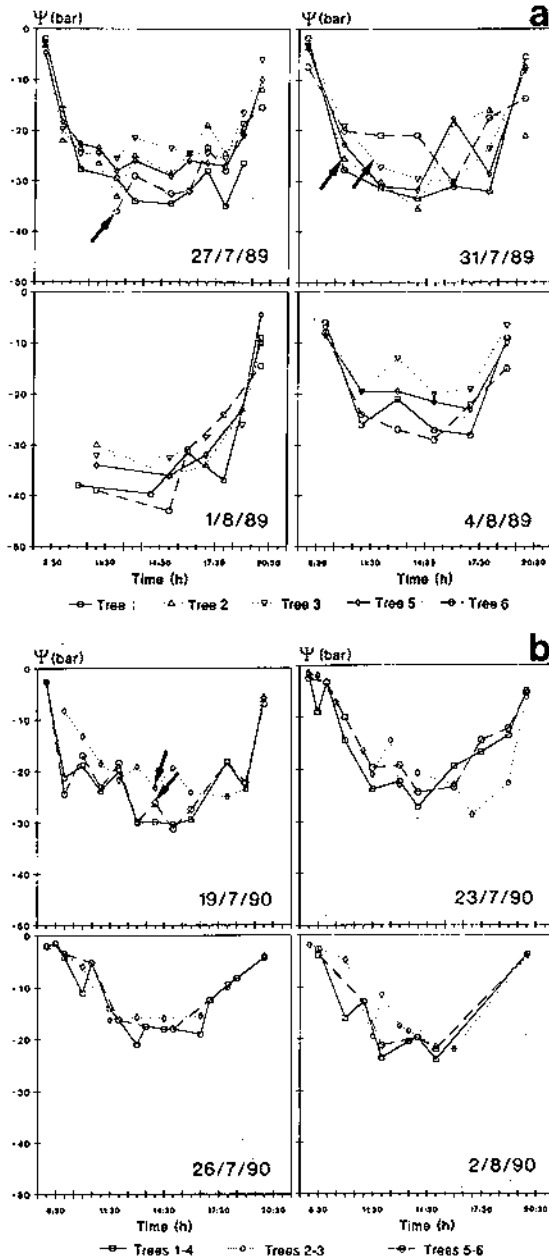


Figure 3.- Diurnal courses of leaf transpiration,  $Tr$ , on the four days, from the *Q. suber* trees under study.  $\downarrow$  moment of stripping. a) Infantado. \_\_\_\_\_ non-stripped, - - - - stripped on the 27/7/89, ..... stripped on the 31/7/89. b). Rio Frio. \_\_\_\_\_ non-stripped, - - - - trunk water loss above  $1.0 \text{ kg}\cdot\text{h}^{-1}$ , ..... trunk water loss below  $1.0 \text{ kg}\cdot\text{h}^{-1}$ .



**Figure 4.-** Diurnal courses of water potential,  $\Psi$ , on the four days, from the *Q. suber* trees under study. ↓ moment of stripping. a) Infantado. — non-stripped, - - - stripped on the 27/7/89, ..... stripped on the 31/7/89. b) Rio Frio. — non-stripped, - - - trunk water loss above  $1.0 \text{ kg} \cdot \text{h}^{-1}$ , ..... trunk water loss below  $1.0 \text{ kg} \cdot \text{h}^{-1}$ .



### FINAL REMARKS

It is apparent that these trees respond very differently to the combined effects of stripping and atmospheric stress conditions. From this study there is evidence that trees from Rio Frio (Fig. 4) seem to regulate water loss more effectively, under conditions of high  $\Delta W$ , than the Infantado ones.

Although only one individual was studied for each stripping level, the difference observed in the responses of trees 2, 3 and 6 (Infantado) suggests that stomatal activity might be directly related with the stripped surface area rather than with the C.D. Nevertheless, at Rio Frio none of the trees seemed to react with stomatal closure after stripping, in spite of similarly high values of stripped area. Furthermore, these trees presented lower values of water loss by the exposed surface than trees 2 and 6 from Infantado.

These results indicate that the stripping effects on the water relations are not clearly related with the stripping coefficients. In fact, when the trees present several stripped branches (like those from Rio Frio), C.D. does not correctly reflect the stripping stress, since trees with similar coefficients may present very different exposed surface areas. According to Montero & Grau (1987), the true indicator of bark-stripping intensity, I.D., is the relationship between the stripped surface and the trunk diameter. However this index (Table I) does not seem to reflect the stripping pressure in our study. Although Rio Frio trees presented I.D. similar to trees 2 and 6 at Infantado, they showed no stomatal closure after stripping. Trees 2 and 6 (Infantado) lost the largest amount of water from the stem surface and, as already referred, exhibited a marked decrease in  $T_r$  after stripping.

The quantity of water lost from the stem surface depends on the stripped area and on its water evaporation rate. Therefore we can conclude that in addition to the stripped area, one of the relevant aspects of the effect of stripping on water relations is the phloemic tissue composition of each tree, which will determine the extent of water loss by evaporation. For this reason we think that general application of the stripping coefficients is not very useful unless a specific optimal coefficient is determined for each cork-oak stand.

The present study suggests that severe bark-stripping leads to considerable water losses and a decrease in stomatal conductance which may reflect upon the photosynthetic activity and consequently on the productivity. One might speculate that such a response is promoted by a chemical signal generated by reduced water potential or turgor in the leaves. It should be noted that it is in this period of reduced stomatal activity that the tree regenerates its cork layer and makes new tissues, with a considerable energy cost. These functions are accomplished at the expense of previously accumulated reserves, decrease of cambial activity and, thus, of trunk growth. It would be interesting to see if a decrease of fruit and leaf production occurs in the following years.

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