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Anatomical Adaptations in Vegetative Structures of Apricot Tree (*Prunus armeniaca* L.) cv. 'Amor El Euch' Grown under Water Stress

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ABSTRACT

Frequent drought events that prevail in central Tunisia represent a major limiting factor of apricot (*Prunus armeniaca* L.) orchards that affect plant growth and production. Leaf anatomical variations of cv. 'Amor El Euch' using three irrigation levels ranging from rainfed (T_0), moderately stressed ($T_{50\%}$) and full irrigation ($T_{100\%}$) were carried out during the 2003 to 2005 cropping seasons. Irrigation levels (T_0, $T_{50\%}$ and $T_{100\%}$) were estimated using theoretical crop evapotranspiration (ET_C) where water supply corresponded to 0, ½ and 1 ET_c respectively. The adaptation of 'Amor El Euch' to water stress (T_0) is attributed to a thickening of leaves, mature branches and new shoot tissues and an increase in the number of leaf stomata that is associated with a reduction in the length of the stomatal aperture. However, minerals were abundant in the foliar palisade spongy parenchyma while the palisade parenchyma was made up of 2-3 cell layers. For the mid-vein, severe water stress reduced the thickness of the upper collenchyma and both the lower and upper sclerenchyma by 19.4, 11.9 and 33.9%, respectively. Significant variation in the thickness of petiole tissues depended on the water treatments. Water stresses (T_0 and $T_{50\%}$) negatively affected the thickness of the suber, phelloderma and cortical parenchyma of new shoots. The phloem was thickened by moderate water stress and reduced by severe water stress.

Keywords: anatomy, apricot tree, leaf, mature branch, new shoot, water stress
Abbreviations: **ET_0**, reference crop evapotranspiration; **ET_c**, seasonal crop evapotranspiration; **SD**, stomatal density; **SA**, stomatal aperture

INTRODUCTION

Water scarcity is the main problem limiting plant productivity. Moreover, in several species, vegetative production is proportional to the availability of water resources such as wheat, *Triticum durum* (Kamel and Loser 1995) and lemon, *Citrus limon* (Domingo *et al.* 1999). Water stress involves characteristic morphological and anatomical adaptations in the leaf. In olive tree (*Olea europaea*), an increase in cuticle thickness and reduction in cell size of the leaf epidermis and mesophyll were detected (Bosabalidis and Kofidis 2002; Guerfel *et al.* 2009).

For some others plants, epidermis thickness (Ashton and Berlyn 1994) and palisade parenchyma thickness (Karaba *et al.* 2007) have all been reported to be associated with tolerance to water stress.

In the same approach, Chartzoulakis *et al.* (2002) found that anatomical alterations in water-stressed leaves of avocado, *Persea americana*, were associated with physiological adaptations such as transpiration and photosynthesis, specifically with closing stomata and structural changes in the mesophyll. Bussotti *et al.* (1995) found that limited soil moisture caused a major thickening of the mesophyll, especially in the leaf cuticle and spongy parenchyma of the beech plant, *Fagus sylvatica*. These anatomical leaf changes seem to affect stomatal conductance and consequently the photosynthetic rate (Evans *et al.* 1994). However, there may be a relationship between anatomical characteristics and short-term water stress tolerance based on physiological responses (Kulkarni *et al*. 2010).

The objective of this investigation was to study the effects of water stress on the leaf anatomical changes and some adaptation mechanisms of apricot (cv. 'Amor El Euch').

MATERIALS AND METHODS

Field experiment

The experiment was conducted from 2003 to 2005 in 16-years-old apricot trees (*Prunus armeniaca* L. cv. 'Amor El Euch') grafted onto 'Oasis-Mechmech' rootstocks grown in sandy loam soil with drip irrigation in a commercial orchard located in Chebika, Tunisia (35° 36′ 35″ N; 9° 55′ 10″ W; altitude 124 masl). The average annual rainfall in this area is 171 mm.

Irrigation treatments

Three irrigation treatments were used:
$T_{100\%\ irrigation}$: Full irrigation without water stress: irrigation at 100% Et_c (seasonal crop evapotranspiration);
$T_{50\%\ irrigation}$: Moderate water stress: irrigation at 50% Et_c;
$T_{0\%\ irrigation}$: Severe water stress: irrigation only with rainfall water.

Water treatments were applied every three days during the vegetative growth period during the three experimental years from early February to late September during 2003, 2004 and 2005. From October, the leaves senesce and the tree becomes dormant to resume budding in early February.

Treatments were carried out using a completely randomised design with three replications each.

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Original Research Paper

Measurements

1. Leaf epidermis print

A leaf epidermis print was done during the postharvest period (i.e., two months after harvest). Mature leaves (25/treatment) were gathered from the southern part of three apricot trees. To determine stomatal density (SD) on the abaxial leaf-surface, a thin layer of clear nail polish (Eyeslipsface) was applied to the abaxial epidermis. Once dry after half an hour in the open, the nail polish layer was carefully peeled-off with adhesive tape, and then fixed on the surface of a microscope slide (Jones 1983). SD and stomatal aperture (SA) measurements were assessed twice for each half of the leaf using both sides of the mid-vein. Total number of observed samples is 50 per treatment.

2. Preparation of transverse cross of leaf, mid-vein, petiole, mature branch and new shoot for microscopic examination

For the anatomical study of the transversal sections, leaf samples were composed of 10 mm^2 central portions on both sides of the mid-vein. Mature branches or new shoots were cut one-third the level from the base up.

Vegetative material (leaf, mid-vein, petiole, mature branch and new shoot) was disinfected in 5% sodium hypochlorite followed by three washes with distilled water. Once dry in the open, samples were fixed in a mixture of (FAA) formalin: acetic acid: alcohol (ethanol) according to Johansen (1940) and dehydrated in an increasing series of ethanol concentrations then in toluene. Dehydrated samples (2-3/block) were embedded in paraffin blocks made with Leukart moulds and set according to the direction of the desired section. Histological sections, 6 µm thick, were made with a rotary microtome (Ernest Leitz Wetzaler) and placed in microscope blades (76 × 26 mm, 7706 Labomoderne).

To allow for clear observation of vegetative material samples, blades were stained in a mixture of haematoxylin and eosin (Gabe 1968) during 30 min. After adding a drop of Canada balsam, the sections adhered to the blade, covered with slips and were ready for microscopic observation.

The dimensions of various tissues in the leaf, mature branches and new shoots were assessed using computer software Win Dias 2.0.

Statistical analysis

Analyses of variance was performed on the data following separation of the treatment means using the student Newman-Keul's multiple range test at $P < 0.05$. Data was analyzed using SPSS version 11.0. According to the clarity of the transverse section samples, the choice of the number observed per treatment is 15 to the leaf lamina (**Table 1**) and the new shoot (**Table 5**), and 9 for the mid-vein (**Table 2**), the petiole (**Table 3**) and the mature branch (**Table 4**).

RESULTS

Leaf epidermis print

Observations of the abaxial epidermis indicated that the SD oscillates between 301 and 355 stomata/mm² of leaf area. The length of the SA varied between 23.4 and 17.4 µm for $T_{100\%\ irrigation}$ and $T_{0\%\ irrigation}$, respectively (**Figs. 1, 2**). For the moderate stress treatment ($T_{50\%\ irrigation}$), the SD and SA values were intermediate to those of $T_{0\%\ irrigation}$ and $T_{100\%\ irrigation}$.

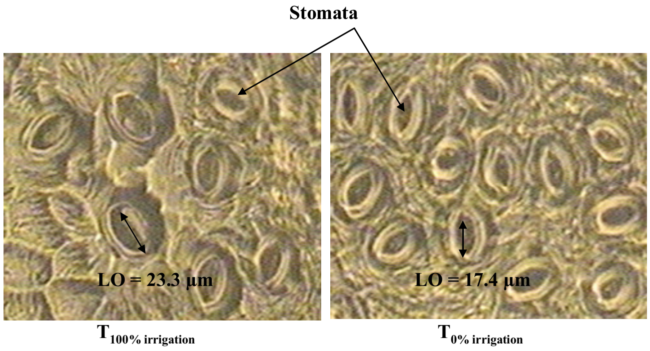


Fig. 1 Comparison of the stomata in the adult leaf of apricot tree (cv. 'Amor El Euch') (X250) taken at post-harvest and subjected to $T_{0\%\ irrigation}$ and $T_{100\%\ irrigation}$ treatments.

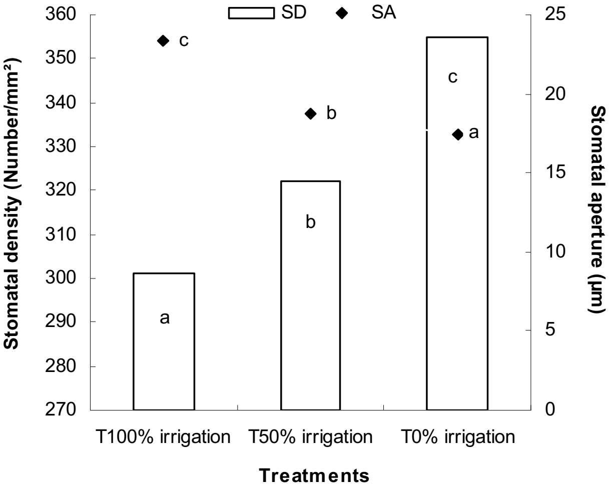


Fig. 2 Effect of water treatments on stomatal density and length of the stomatal aperture in the adult leaf of apricot tree (cv. 'Amor El Euch'). N = 50 (according to Student-Newman-Keul's test)

Table 1 Anatomical characteristics of lamina in the leaf of 'Amor El Euch' variety under three water treatments.

Treatments Thickness (µm)	$T_{0\%\ irrigation}$ (severely stressed)	$T_{50\%\ irrigation}$ (moderately stressed)	$T_{100\%\ irrigation}$ (fully irrigated)
Leaf	205.3 ± 12.8 a	215.8 ± 14.3 b	218.5 ± 13.2 b
Upper epidermis	36.6 ± 3.2 a	35.5 ± 2.8 a	44.5 ± 3.2 b
Mesophyll	152.9 ± 12.2 a	163.3 ± 9.1 b	157.2 ± 12.7ab
Palisade parenchyma	56.8 ± 4.9 a	61.9 ± 3.9 b	59.6 ± 5 ab
Spongy parenchyma	96.1 ± 10.1 NS	101.3 ± 9.5 NS	97.6 ± 10.7 NS
Lower epidermis	16.4 ± 1.9 b	14.8 ± 1.2 a	17.9 ± 1 c

Means followed by different letters within a row are significantly different at $P < 0.05$ (Student-Newman-Keul's). NS: Not significantly different. Each value is the mean of 15 repetitions per treatment.

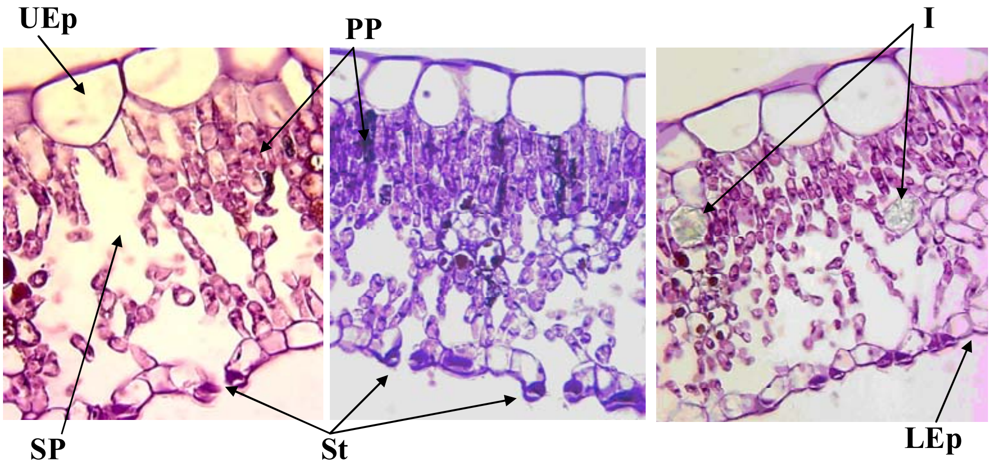
Table 2 Anatomical characteristics of mid-vein in the leaves of 'Amor El Euch' variety under three water treatments.

Reatments Thickness (µm)	$T_{0\%irrigation}$ (severely stressed)	$T_{50\%irrigation}$ (moderately stressed)	$T_{100\%irrigation}$ (fully irrigated)
Mid-vein	947.5 ± 110.6 b	836.5 ± 98.7 a	965.7 ± 26.2 b
Upper epidermis	17.1 ± 1.4 NS	17.3 ± 2.1 NS	17.2 ± 0.9 NS
Upper collenchyma	140.2 ± 10.5 a	165.4 ± 15.3 b	173.9 ± 15.5 b
Upper sclerenchyma	74.1 ± 7.3 a	84.1 ± 7.3 b	78.7 ± 5.1 ab
Wood	98.8 ± 5.7 NS	104.1 ± 9.4 NS	100.0 ± 5.6 NS
Cambium	22.4 ± 1.8 NS	22.2 ± 1.9 NS	22.7 ± 1.9 NS
Phloem	54.6 ± 7.8 a	72.9 ± 9.2 b	71.7 ± 7.4 b
Lower sclerenchyma	47.2 ± 8 a	71.4 ± 6.2 b	69.4 ± 6.8 b
Lower collenchyma	56.7 ± 4.5 a	53.0 ± 4.4 a	64.2 ± 2.9 b
Lower epidermis	10.2 ± 0.9 NS	10.5 ± 0.9 NS	10.5 ± 1.0 NS

Means followed by different letters within a row are significantly different at $P < 0.05$ (Student-Newman-Keul's). NS: Not significantly different. Each value is the mean of 9 repetitions per treatment.

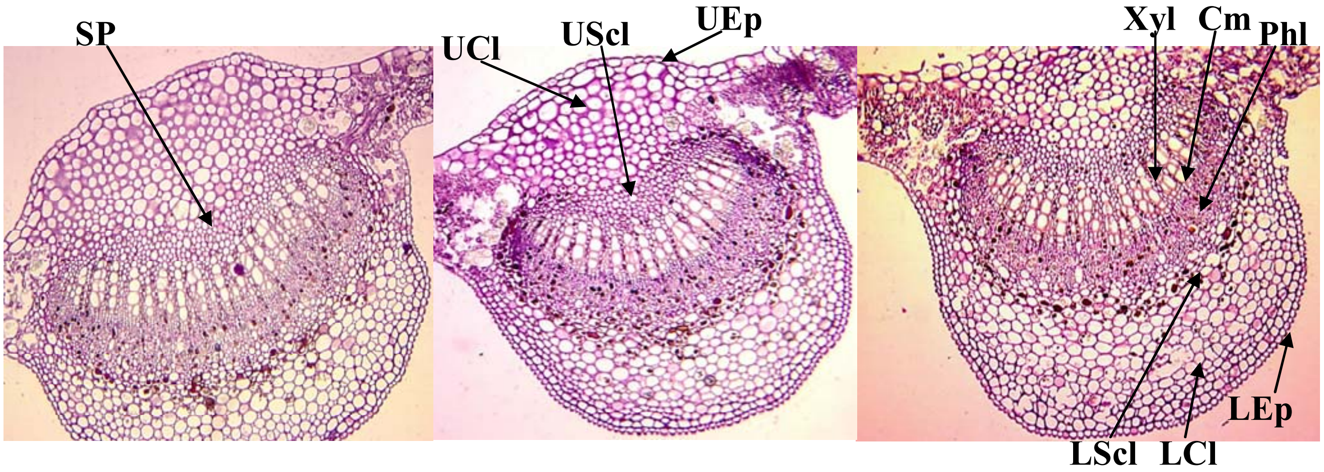
Anatomical study of lamina, mid-vein and petiole of the leaf in apricot tree

Transverse sections of leaf lamina showed that the palisade parenchyma is composed of a base of 2-3 joined and elongated cells. Rosette inclusions are found as deep as two palisade and spongy parenchyma cell layers, particularly in the $T_{0\%irrigation}$ leaves. These inclusions, 14-61 µm in diameter (**Fig. 3**), appear to accumulate starch, tannin, essential oils or phenols. The lower and upper epidermises are



$T_{100\%\text{ irigation}}$ $T_{50\%\text{ irrigation}}$ $T_{0\%\text{ irrigation}}$

Fig. 3 Cross section of the lamina of the adult leaf of apricot tree (cv. 'Amor El Euch') subjected to severe stress (T$_{0\%\text{ irrigation}}$, X400), moderate stress (T$_{50\%\text{ irrigation}}$, X400) and complete irrigation (T$_{100\%\text{ irrigation}}$, X400). I: inclusion; LEp: lower epidermis; PP: palisade parenchyma; SP: spongy parenchyma; St: stomata; UEp: upper epidermis.

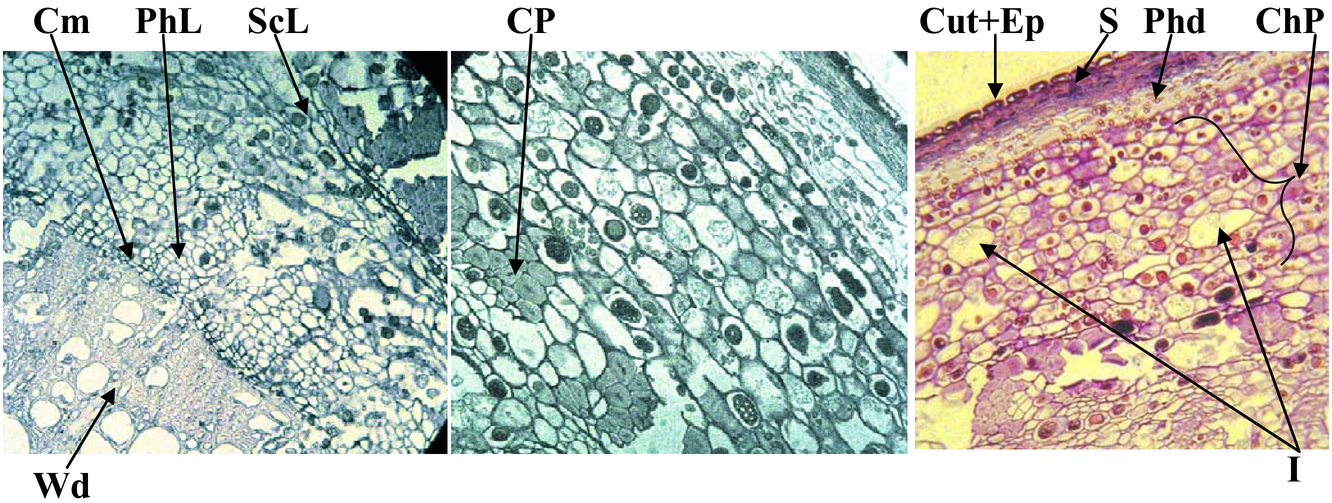


$T_{100\%\text{ irrigation}}$ $T_{50\%\text{ irrigation}}$ $T_{0\%\text{ irrigation}}$

Fig. 4 Cross section of the mid-vein of the adult leaf of apricot tree (cv. 'Amor El Euch') subjected to severe stress (T$_{0\%\text{ irrigation}}$, X100), moderate stress (T$_{50\%\text{ irrigation}}$, X100) and the complete irrigation (T$_{100\%\text{ irrigation}}$, X100). Cm: cambium; LCl: lower collenchyma; LEp: lower epidermis; LScl: lower sclerenchyma; Phl: phloem; PP: palisade parenchyma; SP: spongy parenchyma; St: stomata; UCl: upper collenchyma; UEp: upper epidermis; UScl: upper sclerenchyma; Xyl: xylem.

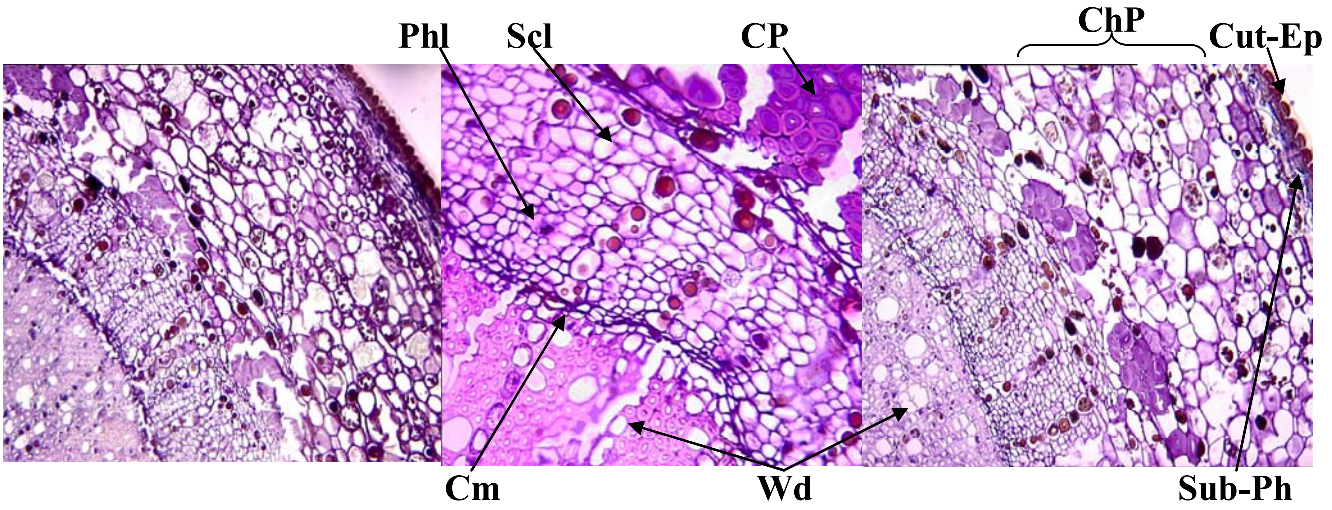
$T_{100\%\text{ irrigation}}$ $T_{50\%\text{ irrigation}}$ $T_{0\%\text{ irrigation}}$

Fig. 5 Cross-section of a petiole of the adult leaf of apricot tree (cv. 'Amor El Euch') subjected to severe stress (T$_{0\%\text{ irrigation}}$, X50), mode-rate stress (T$_{50\%\text{ irrigation}}$, X100) and complete irrigation (T$_{100\%\text{ irrigation}}$, X100). Cl: collenchyma; Cm: cambium; Ep: epidermis; Phl: phloem; Scl: sclerenchyma; SP: spongy parenchyma; Xyl: xylem.



$T_{100\%\ irrigation}$ $T_{50\%\ irrigation}$ $T_{0\%\ irrigation}$

Fig. 6 Cross-section of a mature branch of apricot tree (cv. 'Amor El Euch') subjected to severe stress ($T_{0\%\ irrigation}$, X200), moderate stress ($T_{50\%\ irrigation}$, X400) and complete irrigation ($T_{100\%\ irrigation}$, X400). ChP: chlorophyllous parenchyma; Cm: cambium; CP: cortical parenchyma; Cut-Ep: cuticle-epidermis; I: inclusion; Phd: phelloderm; Phl: phloem; S: suber; Scl: sclerenchyma; Wd: wood.



$T_{100\%\ irrigation}$ $T_{50\%\ irrigation}$ $T_{0\%\ irrigation}$

Fig. 7 Cross section of a new shoot of apricot tree (cv. 'Amor El Euch') subjected to severe stress ($T_{0\%\ irrigation}$, X200), moderate stress ($T_{50\%\ irrigation}$, X400) and complete irrigation ($T_{100\%\ irrigation}$, X200). Cut-Ep: cuticle-epidermis; Sub-Ph: suber-phelloderm; ChP: chlorophyllous parenchyma; CP: cortical parenchyma; Scl: sclerenchyma; Phl: phloem; Cm: cambium; Wd: wood.

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bordered by a very fine impermeable cuticle.

The thickness of the spongy parenchyma is 62% as thick as the mesophyll under full irrigation or moderate stress and 63% as thick under severe stress. Except for the spongy parenchyma, all tissues of the lamina were affected by severe and moderate water stress. Moderate stress ($T_{50\%irrigation}$) reduced the thickness of both lower and upper epidermises by 20.2 and 17.3%, respectively compared to the control. Severe water stress ($T_{0\%irrigation}$) reduced the thickness of the lamina by 6% compared to full irrigation, and reduced the thickness of the mesophyll and the palisade parenchyma by 6.5 and 8.2%, respectively, compared to $T_{50\%irrigation}$ (**Table 1**).

Transverse sections of the mid-vein indicated that only the primary and secondary xylem and phloem are developed slightly compared with the secondary xylem and phloem (**Fig. 4**).

In the control treatment, the thickness of the lower and upper epidermises of both xylem and cambium were not affected by irrigation level. However, $T_{0\%irrigation}$ reduced the thickness of the upper collenchyma by 19.4% compared to the control. Lower and upper sclerenchyma and the phloem were reduced by 11.9, 33.9 and 25.1%, respectively compared to $T_{50\%\ irrigation}$, which in turn caused a reduction in the thickness of the lower collenchyma by about 17.4% compared to the control (**Table 2**).

The petiole has a structure similar to the mid-vein. Only the lower sclerenchyma could not be consistently identified and the spongy parenchyma appeared to have some mineral inclusions under the phloem tissue (**Fig. 5**).

Irrigation level (i.e., water stress) did not have the same effect on the thickness of petiole tissues: $T_{0\%\ irrigation}$ reduced the thickness of the spongy parenchyma by 11.4% compared to $T_{100\%\ irrigation}$. Sclerenchyma, xylem and cambium were reduced by 14.4, 13.8 and 30.5%, respectively compared to $T_{50\%\ irrigation}$ (**Table 3**).

Anatomical study of the mature branch of apricot tree

Microscopic examination indicated that epidermis thickness, composed of a layer of cells with a cellulose wall and pro-

Table 3 Anatomical characteristics of petioles in the leaf of 'Amor El Euch' variety under three water treatments.

Treatments		$T_{0\% \text{ irrigation}}$ **(severely stressed)**	$T_{50\% \text{ irrigation}}$ **(moderately stressed)**	$T_{100\% \text{ irrigation}}$ **(fully irrigated)**
Circumference of petiole (µm)		4.89 ± 0.12 NS	4.97 ± 0.24 NS	4.71 ± 0.13 NS
Thickness (µm)	Epidermis	13.2 ± 1.01 NS	12.2 ± 1.16 NS	12.2 ± 1.04 NS
	Collenchyma	85.1 ± 7.8 NS	78.0 ± 6.8 NS	77.2 ± 6.7 NS
	Spongy parenchyma	184 ± 17.2 a	204.8 ± 17.9 b	207.7 ± 14.2 b
	Sclerenchyma	74.2 ± 7.5 a	86.7 ± 9.2 b	81.9 ± 6.4 b
	Xylem	133.3 ± 14.2 a	154.7.1 ± 10 b	143.0 ± 12.1 ab
	Cambium	13.2 ± 1.7 a	19 ± 1.1 c	17.4 ± 1.8 b
	Phloem	104.7 ± 6.7 NS	98.9 ± 4.6 NS	100.3 ± 4.7 NS

Means followed by different letters within a row are significantly different at $P < 0.05$ (Student-Newman-Keul's). NS: Not significantly different. Each value is the mean of 9 repetitions per treatment.

Table 4 Anatomical characteristics of mature branches of 'Amor El Euch' variety under three water treatments.

Treatments		$T_{0\% \text{ irrigation}}$ **(severely stressed)**	$T_{50\% \text{ irrigation}}$ **(moderately stressed)**	$T_{100\% \text{ irrigation}}$ **(fully irrigated)**
Thickness (µm)	Cuticule + epidermis	18.32 ± 2.56 NS	16.32 ± 1.60 NS	17.03 ± 1.79 NS
	Suber	29.64 ± 2.85 ab	27.39 ± 3.65 a	31.69 ± 3.92 b
	Phelloderm	34.54 ± 2.30 a	36.63 ± 1.98 a	41.73 ± 4.17 b
	Cortical parenchyma	202.67 ± 10.39 a	215.33 ± 13.04 a	237.78 ± 28.42 b
	Sclerenchyma	113.22 ± 8.89 b	88.11 ± 5.80 a	86.78 ± 4.79 a
	Phloem	162.44 ± 17.44 a	196.33 ± 5.07 b	244 ± 18.7 c
	Cambium	16.29 ± 4.17 a	19.32 ± 3.82 a	26.52 ± 4.15 b
	Wood	946.7 ± 88.5 a	1254.6 ± 80.4 c	1120.4 ± 88 b
Diameter of medullar parenchyma (µm)		981.7 ± 17 b	865.3 ± 13.6 a	1159.3 ± 19.7 c

Means followed by different letters within a row are significantly different at $P < 0.05$ (Student-Newman-Keul's). NS: Not significantly different. Each value is the mean of 9 repetitions per treatment.

Table 5 Anatomical characteristics of new shoots of 'Amor El Euch' variety under three water treatments.

Treatments		$T_{0\% \text{ irrigation}}$ **(severely stressed)**	$T_{50\% \text{ irrigation}}$ **(moderately stressed)**	$T_{100\% \text{ irrigation}}$ **(fully irrigated)**
Thickness (µm)	Cuticule + epidermis	10.3 ± 1.2 NS	10.7 ± 1.1 NS	10.2 ± 0.8 NS
	Suber + phelloderm	28.4 ± 2.1 a	33.1 ± 3.3 b	35.6 ± 3.8 b
	Cortical parenchyma	69.8 ± 6.1 b	60.9 ± 5.5 a	80.0 ± 5.1 c
	Sclerenchyma	63.8 ± 3.8 NS	63.3 ± 3.1 NS	57.8 ± 8.2 NS
	Phloem	107.9 ± 11.0 a	123.7 ± 6.9 b	112.6 ± 9.0 a
	Cambium	12.6 ± 1.1 NS	11.8 ± 1.6 NS	12,3 ± 0.9 NS
	Wood	472.7 ± 44.1 NS	481.2 ± 51.2 NS	488.6 ± 76.6 NS
Diameter of medullar parenchyma (µm)		708.1 ± 34.2 a	1032.8 ± 92.7 b	899.7 ± 148.5 ab
Diameter of shoot (mm)		2.92 ± 0.24 NS	3.35 ± 0.26 NS	3.38 ± 0.56 NS

Means followed by different letters within a row are significantly different at $P < 0.05$ (Student-Newman-Keul's). NS: Not significantly different. Each value is the mean of 15 repetitions per treatment.

tected by a fine cuticle, was not affected by the irrigation level. The suber, clearly distinguished from the phelloderm, has many layers of cells that have died around the phelloderm and plays a protective function in parenchymatous tissues (**Fig. 6**).

$T_{0\%\text{irrigation}}$ reduced the thickness of the phelloderm, cortical parenchyma, phloem and cambium by 17.2, 14.8, 33.4 and 38.6%, respectively and increased the sclerenchyma by 30.5%. At the same time, $T_{50\% \text{ irrigation}}$ reduced the thickness of the suber and medullary parenchyma by 13.6 and 25.4%, respectively while $T_{0\%\text{irrigation}}$ reduced the thickness of the wood by 15.5% (**Table 4**).

Anatomical study of the new shoot of apricot tree

The microscopic observation blades show protective tissues composed of a cuticle and an epidermis in the level of transverse sections of new shoots. Below the cuticle and epidermis, the peridermis is formed by the suber and the phelloderm which are very linked so that it is difficult to measure them separately. The chlorophyllous parenchyma, formed by chlorophyllous cells, is furnished with mineral inclusions. Cortical parenchyma supports tissues (**Fig. 7**).

Water conduits do not affect the thickness of the cuticle + epidermis, the sclerenchyma, cambium or wood, nor the diameter of the shoot (**Table 5**).

Compared to the control ($T_{100\% \text{ irrigation}}$), the thickness of the suber + phelloderm and cortical parenchyma was reduced by 20.2 and 23.9% for $T_{0\% \text{ irrigation}}$ and $T_{50\% \text{ irrigation}}$, respectively. The thickness of the phloem and the diameter of the medullar parenchyma were improved by moderate water stress ($T_{50\% \text{ irrigation}}$) (9.8 and 14.8%, respectively) but were reduced by 4.2 and 21.3%, respectively, when exposed to severe water stress ($T_{0\% \text{ irrigation}}$) (**Table 5**).

DISCUSSION

Compared to moderately or severely stressed, well irrigated apricot trees ($T_{100\% \text{ irrigation}}$) show a distinct epidermal print: a low SD and an important SA to the lower foliar face. Compared to control ($T_{100\% \text{ irrigation}}$), SD increased by 18 and 7% and SA dropped by 26 and 20%, respectively for $T_{0\% \text{ irrigation}}$ and $T_{50\% \text{ irrigation}}$. Gleen *et al.* (2000) noted that SD varied between 197 and 232 stomata/mm² of the lower leaf area (ventral) of the leaves of the peach (*Prunus persica*) trees.

Bosabalidis and Kofidis (2002) noted a 49.9 and 55.2% increase, respectively in SD of abaxial surface of leaves for two varieties of olive, 'Mastoidis' and 'Koroneiki' under water deficit. Similarly, olive plants grown under drought conditions (by withholding water during one month until the soil almost reached the wilting point) showed a significant increase in the number of stomata (Guerfel *et al.* 2009). Compared to irrigate regime, drought water regime increased stomatal density from 400 to 472 stomata/mm² and from 316 to 367 stomata/mm², respectively for 'Chemlali' and 'Chetoui' olive plants, whereas Bacelar *et al.* (2006) did not detect a significant difference in the thickness and foliar SD of plants under low water availability (plants received once per week only one-third of the water needed to maintain the soil at field capacity to simulate a moderate plant water stress) compared to well irrigated trees. Hsiao (2000) described the responses and adaptation of cultures exposed to moderate water stress in relation to the phases of growth of the expanding leaves: water stress affect leaf growth in case of limitation of leaf area index inducing photosynthesis and transpiration and consequently reduction of productivity par soil surface unit. The leaves of an apricot tree defend themselves against water deficit through an increase in the number of stomata and a reduction in stomatal size (**Fig. 1**).

Bownlee (2001) and Bacelar *et al.* (2006) indicated that, in response to a lack of water, during leaf development there is an adjustment of SD and that potassium is responsible for the turgescence of the guard cells which control the opening and closing of the ostiol.

The presence of inclusions with oils, tannin or phenols, in the leaves of apricot tree subjected to severe water stress characterizes the adaptation of apricot to a lack of water. Essential oils formed in olive and avocado trees grown under water stress (Chartzoulakis *et al.* 1999, 2002). The leaves of water-stressed olive trees contain more total phenols in stressed seedlings than in well-irrigated seedlings (Bacelar *et al.* 2006). The leaves of oak (*Quercus ilex*) leaves contain tannin, characterising this tree's adaptation to dryness (Bussotti *et al.* 2002). Moreover, Bussotti *et al.* (1995) observed a thickening of the mesophyll, especially of the spongy parenchyma, on the leaves of beech (*Fagus sylvatica* L.) grown in conditions of low moisture. Similary, White and Consuelo (2005) associate the variation in thickness of bean (*Phaseolus vulgaris* L.) leaves with leaf carbon assimilation in relation to water status. The ability of olive trees to adapt to water stress is indicated by variable proportions of conducting and support tissues of the petiole, allowing for their good development and functioning (Klich 2000). Thus, variation in thickness, such as a reduction in the thickness of the mesophyll and the palisade parenchyma of the lamina, the collenchyma and the sclerenchyma of the mid-vein and the xylem and cambium of the petiole (**Tables 1-3**) are a consequence of moderate and/or severe stress in apricot tree. The reduction in foliar tissues thickness is proportional to the intensity of the imposed water stress. Indeed, reduction mesophyll cell size is a major anatomical response in leaves of *Campylotropis polyantha* along a water stress gradient (Li *et al.* 2011).

Secondary growth of the stem of *Dolichos lablab* L. is related to the successive and eccentric formation of vascular rings in which small cambial segments are delimited by parenchymatous tissues, xylem and phloem (Rajput *et al.* 2006). For the apricot tree subjected to water stress, the anatomical variations observed on the transverse sections of mature branches and new shoot, affect the conductivity of the solutes through the xylem conducting vessels.

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