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CLIMATE CHANGE INFLUENCE TO THE PHOTOSYNTHESIS PRODUCTION, BIOLOGICAL AND PHYSIOLOGICAL PARAMETERS OF YOUNG OLIVE CULTIVARS*

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Abstract

The purpose of this study was to evaluate the effect of the combined water and the temperature stresses on young local olive cultivars (*Olea europaea* L. cvs 'Chemlali' and 'Zarrazi'). The experimentation was carried out following a split-plot design; the main plot units had a 3*3*2 factorial design with three controlled climatic, three irrigation treatments and two olive cultivars (Chemlali and Zarrazi).The volumetric water soil content, net photosynthesis production, stomatal conductance and apical growth were measured throughout the experimentation. We found that cultivar had insignificant effect on net photosynthetic production and stomatal conductance. Moreover, the irrigation was not proportional to the amount of change in net photosynthetic production and stomatal conductance. Likewise, the apical growth and the studied physiological parameters were dramatically dropped under heat stress regardless of the water treatment. Nevertheless, the severity of the decline was more intense in Chemlali cultivar (Apical growth dropped 40.39% and 42.18% for 100 and DI50, respectively for Zarrazi and dropped 42.18% and 46.87% for 100 and DI50, respectively for Chemlali).

Keywords: Olea europaea L., heat stress, deficit irrigation, photosynthetic, stomatal conductance

1. Introduction

Recent scientific research has concluded that the increased atmospheric concentration

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of greenhouse gases will have significant impacts on the Earth's climate in the coming decades. Assuming that no control policies of emission, the Intergovernmental Panel on Climate Change (IPCC) predicts that average global surface temperatures will increase by 2.8ºC on average during this century (Azaiez et al., 2011; Zhai and Zhuang, 2009). Arguably, Tunisia is among the most impact countries by these changes. In fact, the climate projections, based on the HADCM3 model, applied to the Tunisian case study show a rise in the temperature of 1.1°C by 2030, and 2.1°C in 2050 (Azaiez et al., 2011). The rainfall will decrease between 10% in the North and 30% for the South the same period. The South of the country is much more concerned (with temperature increases of 1.6°C). The predicted changes in temperatures and rainfall patterns and their associated impacts on water availability (groundwater will decrease by 28 %) and soil degradation are the most challenges to face (Azaiez et al., 2011). These changes will have drastic impacts on the whole system compounds including the olive sector. In fact, computation on water resources by sectors will make this precious liquid less available for olive grower as this sector is not as profitable as other sectors like tourism.

Thus, olive cultivars that have been cultivated for centuries in the region may be in jeopardy of not being able to adapt to these unwelcomed changes. In fact, genetic studies showed that local olive cultivars grown in the southern part of the country are very close (Abdelhamid et al., 2013; Belaj et al., 2002; Besnard et al., 2001). Therefore, extensive varietal study of the effect of climate change may not be necessary. Moreover, three olive cultivars (Chemlali, Zalmati and Zarrazi) dominate the olive sector in the south of Tunisia (Grati-Kamoun et al., 2006). In particular, Chemlali and Zalmati cultivars are very closely related to the point that some authors classified them as sub-cultivars. Hence, studying one cultivar is insufficient (Grati-Kamoun et al., 2006). Chemlali is more geographically distributed. Thus, beside Zarrazi cultivar, it was considered to conduct the experimentations. Future projections of climate suggest raise in temperature and decline in precipitation. Agronomically speaking these changes boils down to water and heat stresses.

The main objective of this study is to understand the physiological and biological effect of the combined water and temperature stresses on young olive trees (*Olea europaea* L. cvs 'Chemlali' and 'Zarrazi'). We specifically investigated the influence of two deficit irrigation treatments on net photosynthesis production, stomatal conductance and apical growth on young olive trees grown under three climatic conditions.

This work is divided in three main parts:

- Selection of the biological material and definition of the experimental conditions: In this study two local olive cultivars (*Olea europaea* L. cvs) 'Chemlali' and 'Zarrazi' was adopted. Also, three climatic conditions were applied. These conditions can be divided into controlled ones and uncontrolled. the two were controlled conditions were applied in order to simulate a state of heat stress and a state of non-stress. A third uncontrolled condition was applied in order to investigate the diurnal climatic fluctuation.
- Conducting the experimentations: during this step, the growing chambers and the olive-trees were checked regularly to avoid any inconvenience. Furthermore, the volumetric water soil content, net photosynthesis production, stomatal conductance and apical growth were measured regularly throughout the experimentation.
- Result analysis: analysis of results, drawing conclusion and formulation of recommendations for policy and decision makers in the olive tree sector in arid and semi-arid regions.

2. Materials and methods

One-year-old rooted cuttings of the olive cultivars *Olea europaea* L. cv. Chemlali and cv. Zarrazi were grown on 3L plastic pots containing freely drained light soil at a growth chamber at the arid region institute-Medenine-Tunisia. The experimentation was conducted following a split-plot design; the main plot units had a **3***3*2 factorial design with three controlled climatic conditions (Condition T25: RH= 70%, T = 25°C; Condition T35: RH= 70%, T = 35°C; Condition Tout: Outdoor, where temperature raged from 11°C to 23°C) [where T: temperature and RH: relative humidity]**,** Three irrigation treatments **(DI50:** 50% ETc, **DI75**: 75% ETc and **DI100**: 100% ETc) and two olive cultivars. Here, ETc: crop evapotranspiration. Climatic condition was the main factor. The split-plot units within each main plot consisted of three olive trees. Three irrigation treatments were applied with water amounts of 50% ETc, 75% ETc and 100% ETc, where ETc is the crop evapo-transpiration. Water and irrigation requirements were calculated using the ETc calculator software. Climatic data used as input for the softwear was provided by the national institute of meteorology. The crop coefficient (Kc) estimated from (Allen et al., 1998).

The volumetric water soil content was measured twice a day in 18 pots by time-domain reflecto-meter (TDR). The photosynthesis was measured using an LCI-SD portable photosynthesis system equipped with a broad leaf chamber (Analytical Development ComPany Ltd., England). Natural sunlight was used as a source of light and external air was used as a source of CO_2 (reference CO_2 was taken from the outside of the growth chamber). Measurements were taken every 30 minutes from sunrise to sunset on three olive-trees. These parameters were taken at a suitable angle for ambient light to penetrate up to the leaf chamber. The chamber was kept stable during measurements to avoid disturbance. Moreover, leaves were left for 3 min to acclimate leaf chamber before recording the data. Subsequently, the chamber was left open and away from trees for 3 min to acclimate before taking new measurements (Lee et al., 2016; Nada et al., 2015).

Apical growth was measured at the start and at the end of the experiment. The measurements were performed on all the studied trees.

A multi-factor analysis of variance (ANOVA) was used to examine the effect of cultivars, climatic conditions and irrigation treatments on all parameters studied. The differences between parameters were compared using Tukey's test calculated at $p < 0.01$. These analyses were performed using SPSS 16.0 statistical software for Windows (SPSS, Chicago, IL).

3. Results and discussion

The mean daily leaf photosynthetic production and stomatal conductance is shown in table 1. For those two parameters irrigation treatment and climatic condition were significant at a level of 0.01. No significant effect of cultivar on A and gs was showed. However, combined effects (cultivar*irrigation treatment, cultivar*climatic condition and cultivar*irrigation treatment*climatic condition) were significant. Similarities between cultivars were clear in all physiological results as they follow the same trend. Under all climatic conditions, both the two cultivars showed positive correlation between water availability and net photosynthetic production. Further investigation reveals that this correlation is disproportional. In fact, for trees grown in the most suitable condition (T25), the amount of irrigation decreased by 25% from 100% of ETc to 75% of ETc generated a reduction of 20.75% and 25.62 % for Zarrazi and Chemlali, respectively. In contrary, the decreasing of the irrigation amount from 75% of ETc to 50% of ETc reduced the photosynthetic production by 7.4% and 6.7% for Zarrazi and Chemlali, respectively.

Table 1. Means of daily net photosynthetic (µmol m^{-2} s^{-1}) production and stomatal conductance (mol m^{-2} s^{-1}) for irrigation treatments DI50, DI75 and DI100 and climatic conditions T25, T35 and OUT for the cultivars Zarrazi and Chemlali

		A *(µmol m^{-2} s^{-1})*		**Gs** *(mol m^{-2} s^{-1})*	
		ZARRAZI	**CHEMLALI**	**ZARRAZI**	**CHEMLALI**
DI100	**Tout**	13.42	12.25	0.09	0.07
	T25	15.21	14.01	0.12	0.09
	T35	9.09	8.13	0.08	0.06
DI75	**Tout**	10.76	9.18	0.05	0.04
	T25	12.05	10.41	0.06	0.05
	T35	6.85	5.78	0.04	0.03
DI50	**Tout**	10.04	8.40	0.04	0.03
	T25	11.16	9.71	0.05	0.04
	T35	6.25	5.18	0.04	0.03

Changes of net photosynthetic production and stomatal conductance are shown in Fig. 1. The irrigation treatments or the climatic conditions affected the pattern of the diurnal photosynthetic production. Thus, photosynthesis increased to reach its maximum in the morning and then it follows a slow decrease towards the end of the day. This trend is similar to that described for Mediterranean woody vegetation (Tenhunen, 1987). In fact, both climatic conditions and irrigation levels affected the minimum and maximum values of A and gs.

As shown in Table 1 and Fig. 1, photosynthetic production results were very similar to those of stomatal conductance. This may be even more noticeable when photosynthesis was plotted against stomatal conductance (Fig. 2). In fact, according Fig. 2, we showed good linear correlations between A and gs (r^2=0.61 and r^2=0.69 for Zarrazi and Chemlali, respectively) when control and stressed leaves were pooled together. On the other hand, we found better correlations (r^2=0.76 and r^2=0.83 for Zarrazi and Chemlali, respectively) between photosynthesis and stomatal conductance when climate conditions were uncontrolled (temperature and VPD were not fixed). Therefore, the VPD and the temperature are two crucial environmental factors that affect the stomatal behavior, the photosynthetic production and the diurnally shape of these two parameters. These conclusions were consistent with the findings of (Tenhunen, 1987) and (Tognetti et al., 1998) on Mediterranean trees and bushes.

Photosynthetic and stomatal conductance had the lowest correlation value when temperature was set to 35°c. This indicates that the decline in photosynthesis is not only due to the effect of water-stress. However, A was affected by temperature. At this high temperature photosynthesis was limited by RuBP (ribulose bisphosphate) regeneration rate by means of electron transport (Von Caemmerer, 2000; Bernacchi et al., 2001). However, outside measurements were conducted at January where mean temperature was about 16.75°C. This suggests that photosynthesis was affected by low temperature through limitation of RuBP (ribulose bisphosphate) carboxylation activity of the enzyme Rubisco (ribulose-1,5-bisphosphate carboxylase oxygenase) (Diaz-Espejo et al., 2006; Leegood et al., 2006). This elucidation explicates the better results noted in trees grown in chamber set at 25°c.

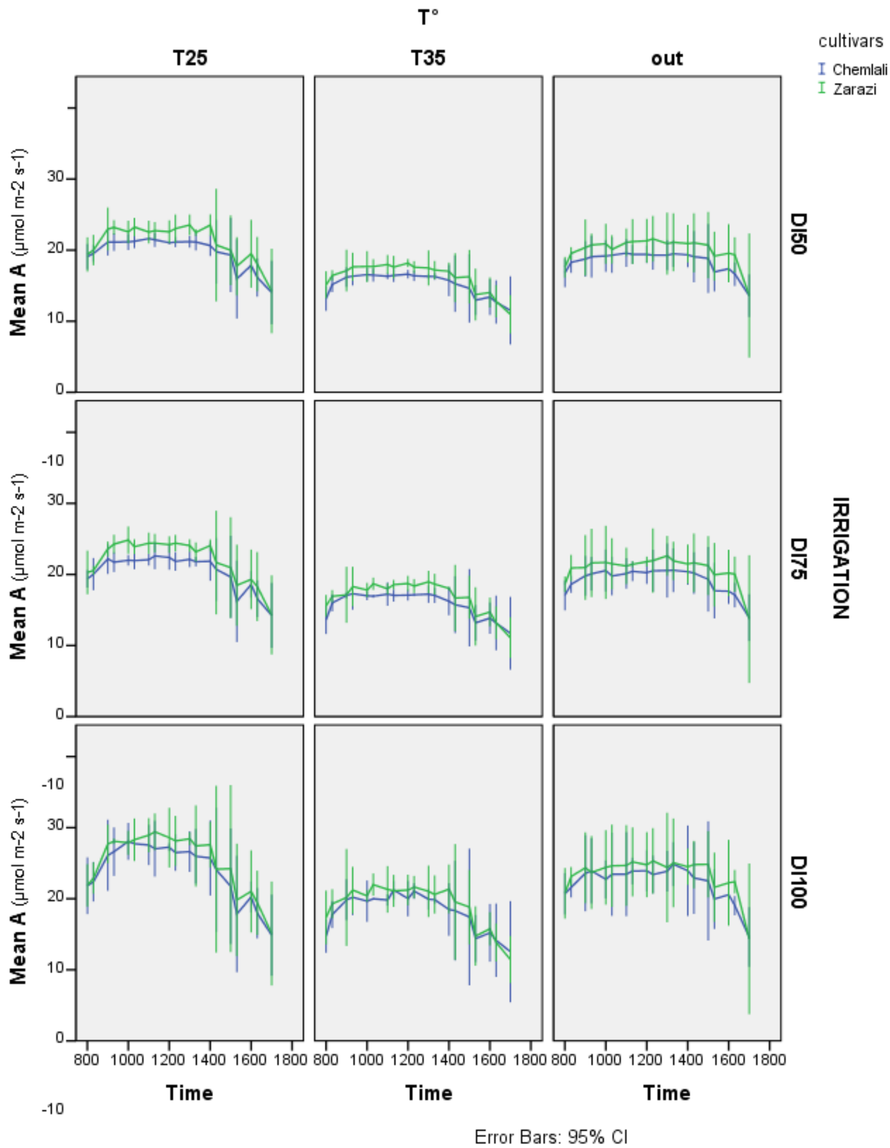

Fig. 1. Daily changes in net photosynthetic production (µmol m^{-2} s^{-1}) for irrigation treatments DI50, DI75 and DI100 and climatic conditions T25, T35 and OUT for the cultivars Zarrazi and Chemlali

Furthermore, in well-watered trees, the VPD explains the changes in gs twice as much more than water-stressed trees. This implies that olive trees are more sensitive to VPD changes when trees were not water stressed. Similar results were reported by Fernández et al. (1997) and Giorio et al. (1999) in olive-trees under field conditions (Giorio et al., 1999, Fernández et al., 1997). The visible decline of sensitivity of stomatal conductance to VPD in water stressed olives may be due to the principal effect of water deficits on the majority of the tree functions, including leaf gas exchange (Loreto et al., 2003; Moriana et al., 2002). Hence, water becomes the limiting factor in photosynthetic production through hydraulic and chemical mechanisms (Bongi et al., 1987; Jones, 1998; Wittig et al., 2007).

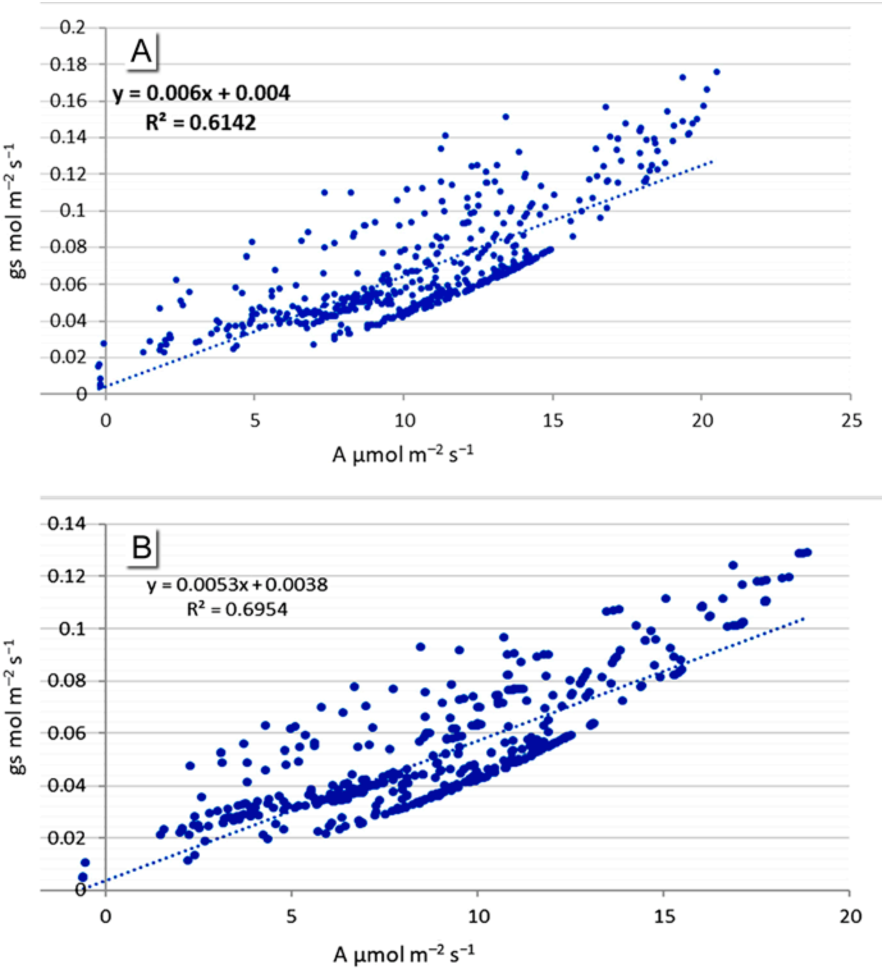

Fig. 2: The relationship between net photosynthetic production (µmol m^{-2} s^{-1}) and stomatal conductance (mol m^{-2} s^{-1}) for the combined irrigation treatments DI50, DI75 and DI100 and climatic conditions T25, T35 and OUT for the cultivars Zarrazi (A) and Chemlali (B)

Means of apical growth for Zarrazi and Chemlali cultivars are shown in Fig 3. The water treatment, climatic condition and cultivar parameters are all significants at level of 1%. Apical growth results are totally in concordance with leaf photosynthetic production and stomatal conductance. For all treatments and climatic conditions, the Zarrazi cultivar showed better apical growth results than Chemlali cultivar. Therefore, Zarrazi had better vegetative growth and photosynthetic performance than Chemlali cultivar. Nevertheless, the difference between these two cultivars was varied depending on the condition. In fact, when olives were well-watered but exposed to low temperatures, the difference in apical growth between cultivars was the smallest with a value of 0.36. This result could be explained by similar inactivation reaction to rubisco for both Chemlali and Zarrazi cultivars. However, when conditions were optimal (full irrigation and T25) the two cultivars showed the widest difference. This support that the Zarrazi is inheritably has better performance. However, when conditions are optimal (full irrigation and T25) cultivars showed the widest difference. This support that the Zarrazi had better performance.

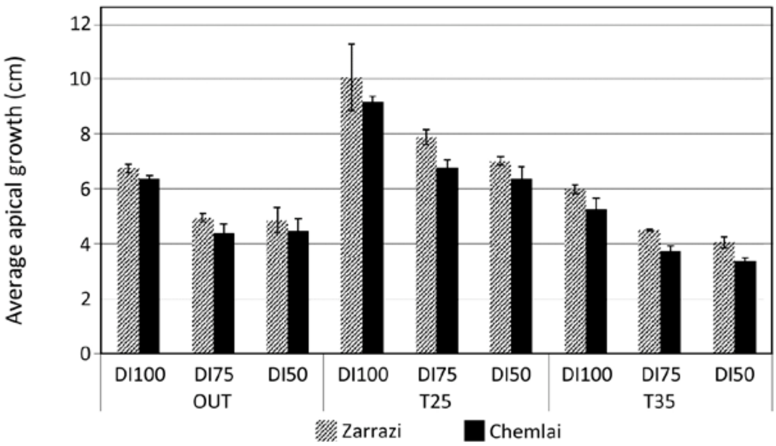

Fig. 3: Average apical growth (cm) of the two olive cultivars (Zarrazi and Chemlali) for irrigation treatments DI50, DI75 and DI100 and climatic conditions T25, T35 and OUT

The apical growth and the studied physiological parameters were dramatically dropped under heat stress regardless of the water treatment. Nevertheless, the intensity of the decline was more severe in Chemlali cultivar (Apical growth dropped 40.39% and 42.18% for 100 and DI50, respectively for Zarrazi and dropped 42.18% and 46.87% for 100 and DI50, respectively for Chemlali)

4. Conclusions

The results of the present work showed that cultivars did not affect significantly the photosynthetic production and the stomatal conductance. Likewise, the trend of daily changes of A and gs in both two studied cultivars were not affected by irrigation treatments or climatic condition. On the other hand, the amplitude of leaf photosynthetic production and stomatal conductance were influenced. Meanwhile, the amount of change in A and gs was disproportional to the irrigation dose. Which implies that irrigation even with small doses can improve simultaneously the CO_2 assimilation and the water efficiency in a magnified way.

Apical growth revealed that Zarrazi cultivar showed better results than Chemlali cultivar under all climatic and irrigation conditions. In addition, when trees were exposed to low temperature, the two studied cultivars showed similar decline in photosynthetic production. On the other hand, when olive trees were under heat stress better slightly results were noted in the Zarrazi cultivar.

Thus, Chemlali was more sensitive to the high temperature. Since, the majority of future climatic projections expect an increase in both mean and maximum temperature, it is advised to avoid this cultivar (Chemlali) in regions susceptive to heat stress in order to limit olive groove degradation and its impact on the environment (such as soil erosion and habitat loss).

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