Olive growth and photosynthesis under drought and application efficacy of alleviating products with different mode of action

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Abstract

Two years old self-rooted Chondrolia Chalkidikis olive trees (*Olea europaea* L.) were subjected to two irrigation regimes, i.e. the fully irrigated and the severely water stressed trees, previously treated with three alleviating products of different mode of action. The alleviating products were the osmolyte glycine betaine, the antioxidant Ambiol and the heat and irradiance reflecting kaolin clay particles. The effects of product application and water regime on shoot growth and trunk expansion, photosynthesis and leaf carbohydrates concentration were evaluated. Irrigated trees presented greater trunk expansion than drought stressed ones, while carbon assimilation rate, stomatal conductance and intrinsic water use efficiency were significantly reduced under drought stress. The opposite stood for intercellular CO_2 which was greatly increased under drought stress conditions. Drought stress resulted in elevated mannitol leaf concentration, while the application of kaolin clay particles resulted in sucrose concentration increase. Among the alleviating products tested in this experiment kaolin clay particles and glycine betaine had a slight positive effect on photosynthesis under drought stress conditions.

INTRODUCTION

The olive tree is mainly cultivated in areas with Mediterranean type climate, which is characterized by low rainfall, excessive heat load and high daily irradiance levels during the growing season. Such environmental conditions greatly influence the growth and productivity of crop plants, as they all exhibit additive and interactive effects on plant physiology (Diaz-Espejo et al., 2007). In order to ameliorate the negative effects of water stress in plants, various products have been used, such as glycine betaine, compound with known osmoregulatory action (Mäkelä et al., 1998), kaolin clay particles, which aims at alleviating heat load on leaves and fruits (Glenn and Puterka, 2005) and synthetic antioxidants like Ambiol (Darlington et al., 1996).In the present study the ameliorative effects of three exogenously applied substances (glycine betaine, kaolin clay particles and Ambiol) (ameliorating products) with distinctly different modes of action (osmoregulation, heat stress dissipation, antioxidative action respectively) is investigated against drought stress consequences.

MATERIALS AND METHODS

A total of eight plants, two years old, self rooted, olive plants cv. Chalkidikis grown in 20 L pots were used per treatment, arranged in a completely randomized design with four replications (two plants per replication). The experiment consisted of three treatments by spraying of various products (glycine betaine (Bluestim WP) – **B**, kaolin clay (Surround WP)– **S**, and Ambiol – **A**) and the control (**C**) (a total of four treatments) and two irrigation regimes, the fully irrigated trees and the drought stress ones. The products were applied at either their registered dose rate i.e. BlueStim WP at 500 g 100 L^{-1} and Surround WP at 5 kg 100 L^{-1}, or at a dose rate proved to be efficient in other crops i.e. Ambiol at 10 mg L^{-1} (Darlington et al., 1996). The control trees were sprayed with water. The drought stress period took place in August, during which only the well irrigated trees received enough water to hold soil wet, while drought stress trees did not receive any water at all, resulting in a soil suction value of -1.5 MPa. Ten days before the application of the products the plant height, the length of two marked shoots and the trunk width were measured. These parameters of plant growth were re-measured during the autumn, in order to assess cumulative growth. Fully expanded leaves were sampled at the end of the drought period and freeze dried till constant weight. Six carbohydrates were detected in olive leaves by HPLC with a refractive index detector. Net photosynthetic rate (Pn), stomatal conductance (gs) and intercellular CO_2 concentration (Ci) were measured using a Li-Cor 6200 portable photosynthesis system. The intrinsic water use efficiency (WUEi) was estimated as the ratio of A / gs. Data of growth parameters were analyzed as an one-way ANOVA while all other data were analyzed as a two-way ANOVA with the factors being the irrigation treatment and product application. The results are presented in tables and figures. For the figures, SEs were calculated from the residual variances.

RESULTS AND DISCUSSION

Drought stress had a significant negative effect on trunk expansion (Fig. 1). This reduction is in accordance with the literature, where significant reduction of growth rate has been reported, due mainly to the negative influence of water depletion on plant physiology and biochemistry (Ennajeh et al., 2006). Photosynthesis was also significantly affected by drought stress (Fig. 2). Carbon assimilation rate, gs and WUEi were significantly reduced under water stress, in accordance with the literature (Diaz-Espejo et al., 2007). The high Ci determined in the drought stressed trees could be directly connected to non-stomatal limitations, either through CO_2 diffusion and/or carboxylation efficiency limitations (Diaz-Espejo et al., 2007). Leaves treated with kaolin clay particles exhibited milder changes compared to those determined for the other treatments. It seems that kaolin clay particles protect to some extend the photosynthetic mechanism, probably through leaf temperature conservation at lower values (Glenn and Puterka, 2005). Mannitol increase under drought stress conditions has been reported by other researchers too, as a reaction of the plant to preserve cellular osmotic potential while the same has been observed also for sucrose (Ennajeh et al., 2006)(Fig. 3). The greater accumulation of mannitol in control drought stressed leaves, compared to that of the other treatments, could be an indicator of the level of stress the plant experienced, as in all other treatments, mannitol concentration under drought was lower, with the lowest being that of trees treated with kaolin clay particles. The same carbohydrate concentration scale was also observed with fructose concentration. The lower carbohydrate concentration under Ambiol, glycine betaine and kaolin clay particle treatments, could also be ascribed to carbohydrate continuous use in supporting plant growth. This becomes evident, concerning the greater shoot growth and plant height (except for Ambiol) increase under drought conditions, compared to control treatment.

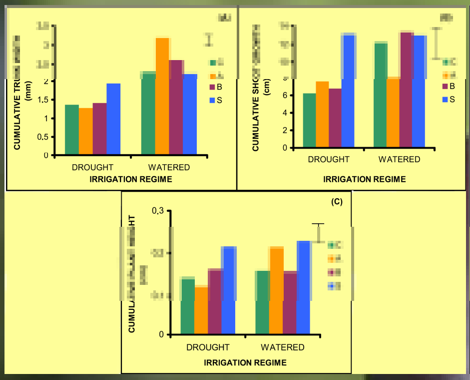

Figure 1. Effects of irrigation regime and treatments (C: control, B: glycine betaine, S: kaolin, A: Ambiol) on growth parameters during the drought stress period. The vertical bars are the SEs (n=4)

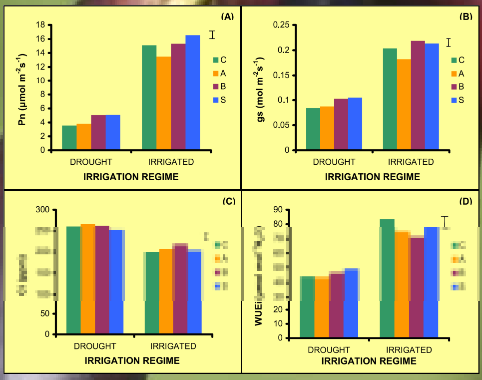

Figure 2. Effects of irrigation regime and treatments (C: control, B: glycine betaine, S: kaolin, A: Ambiol) on photosynthetic parameters during the drought stress period. The vertical bars are the SEs (n=4)

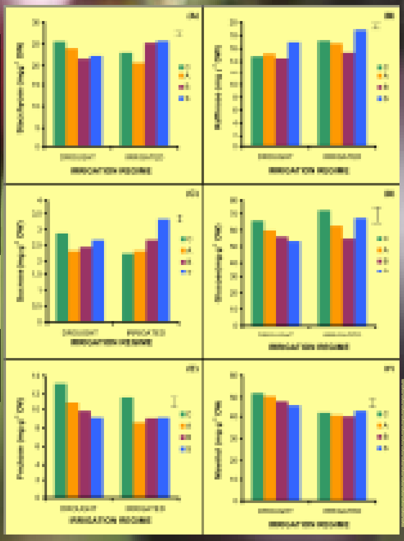

Figure 3. Effects of irrigation regime and treatments (C: control, B: glycine betaine, S: kaolin, A: Ambiol) on carbohydrate concentration during the drought stress period. The vertical bars are the SEs (n=4)

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