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Effects of climate change scenarios on red and white Tempranillo grapevine (*Vitis vinifera* L.): Plant growth and grapes respond to a combination of elevated CO_2, temperature and drought

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Introduction

Carbon dioxide (CO_2) is the most important anthropogenic greenhouses gas. Its atmospheric concentration has increased from 280 in the pre-industrial era to ca. 389-400 µmol mol^{-1} air (ppm) and is expected to rise to ca. 700 ppm at the end of this century. An increasing drought in the agricultural areas and rising temperature (between 1.8 and 4.0 ºC by the year 2100) are also indirect effects of the increased CO_2 concentration (IPCC, 2007).

Grapevine growth is sensitive to direct environmental factors including water availability, temperature and CO_2. A general response to elevated CO_2 is an increased grapevine growth rate and yield (Bowes, 1993; Rogers et al., 1994; Bindi et al., 1996).

Nevertheless, the global effects of elevated CO_2, and its interaction with drought and elevated temperature, on red and white Tempranillo, which are important in the Spanish wine sector, still need further investigation.

Objective

The aim of the present work was to study the effect of several climate change scenarios (combinations of CO_2 concentration, temperature and water availability) on two Tempranillo grapevine varieties (red and white) in the vegetative and reproductive (grape yield) growth.

Temperature Gradient Greenhouses

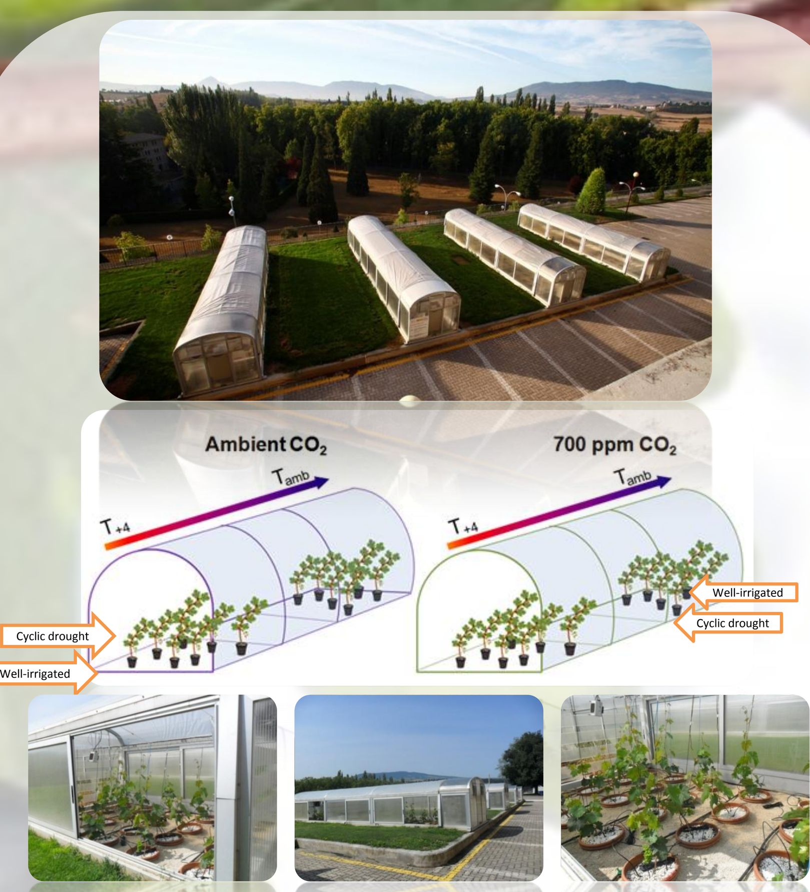


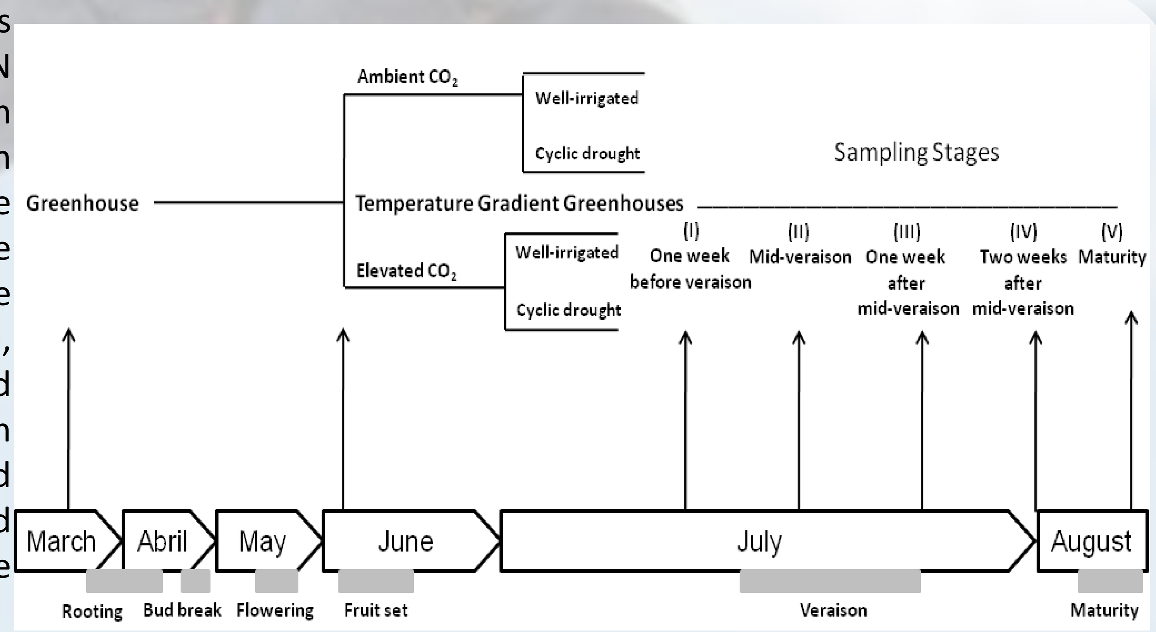
Figure 1. Four temperature gradient greenhouses were used for climate change simulation. Each greenhouse include three modules that has different temperature conditions (Ambient (T), Mid-term and Elevated (T+4ºC)).

Material and Methods

Grapevine fruit-bearing cuttings were exposed to ambient (ca. 400 ppm) or elevated CO_2 (ca. 700 ppm), combined with ambient (T) or elevated temperature (T + 4ºC) and two water regimes (optimum irrigation or cyclic drought) from fruit set to maturity in four temperature gradient greenhouses (**Figure 1**). Sampling was made at five phenological stages: (I) One week before veraison (equivalent to ca. 60 days after flowering), (II) Mid-veraison, (III) One week after mid-veraison, (IV) Two weeks after mid-veraison and (V) Maturity (21-23 ºBrix) (**Figure 2**).

Experimental Design

Figure 2. Fruit-bearing cuttings were developed, and a DECAGON water sensor was placed into each pot. Plants grew until fruit set in ambient conditions in the greenhouse. Then, they were transferred into four temperature gradient greenhouses (**Figure 1**), climate change simulation and current ambient conditions. In each greenhouse, plants were divided into two groups, well-irrigated and cyclic drought. Treatments were maintained until harvest time.



Results and Conclusions

Figure 3. Soil Volumetric Water Content (m^3 H_2O m^{-3} Soil) x 100

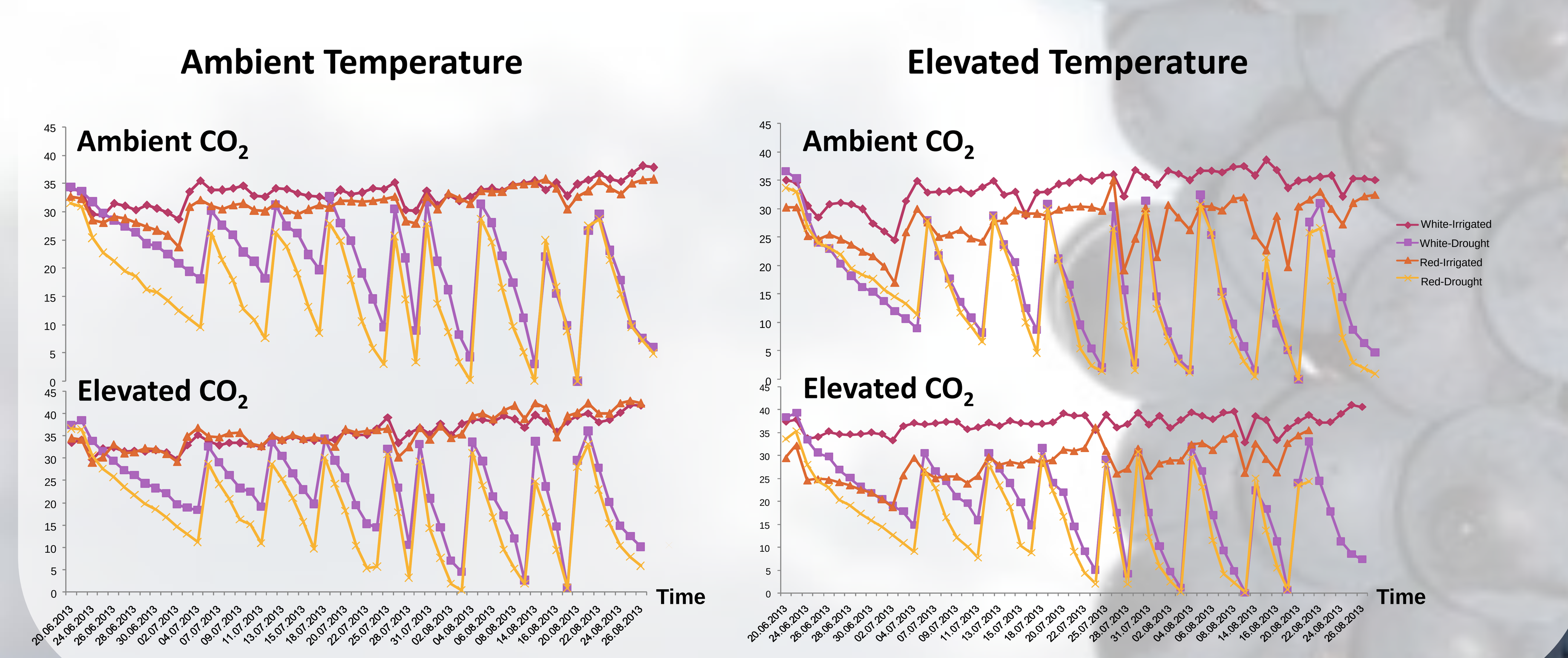
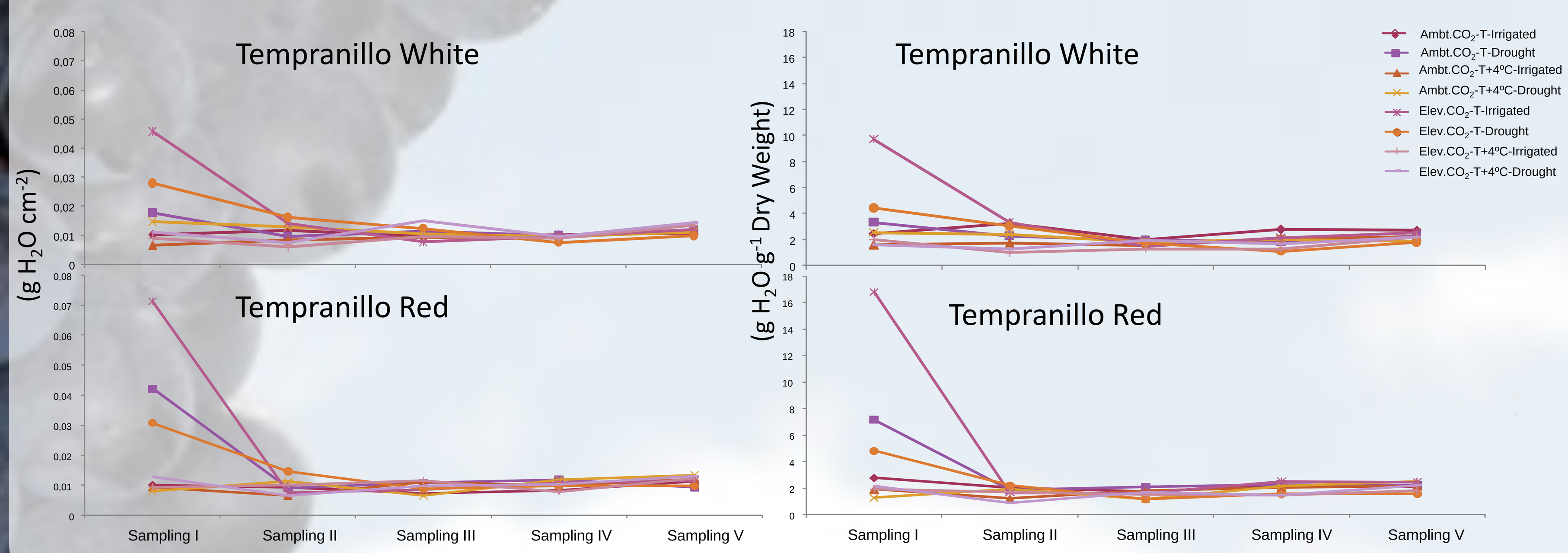


Figure 4. Leaf Water Content



Results showed that the red Tempranillo produces more leaf area and yield (berry bunch weight) than the white one (**Figures 5 and 6**). The increased growth and production of the red variety had as a consequence a higher water consumption and soil water depletion (**Figure 3**). Drought decreased leaf area in both varieties of all treatments (**Figure 6**). Leaf water content (expressed either per leaf area or per leaf dry weight) showed generally no remarkable differences in both varieties in any of the treatments. Only in the first sampling, some differences were observed; the elevated CO_2-well irrigated-ambient temperature treatment in both varieties had the highest leaf water contents (**Figure 4**). Elevated temperature reduced leaf area growth in both varieties of all treatments. Elevated CO_2 however tended to increase leaf area in all treatments (**Figure 6**). In summary, results indicate that climate change (elevated CO_2, elevated temperature and drought) affects red and white Tempranillo growth and yield.

Figure 5. Berry Bunch Weight (g plant^{-1})

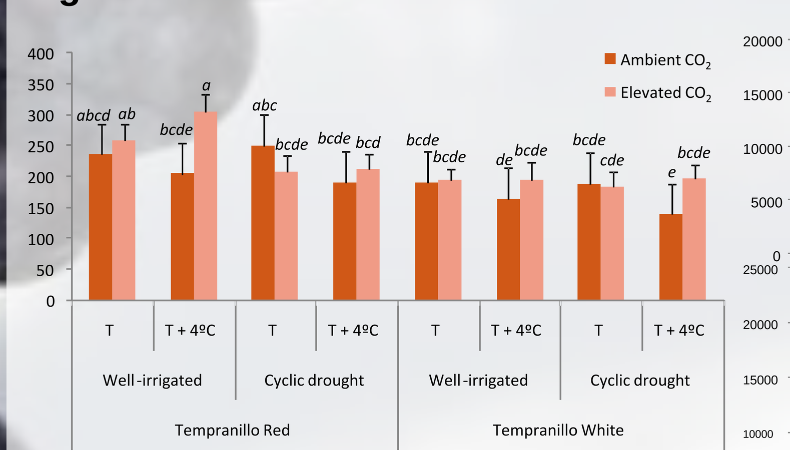
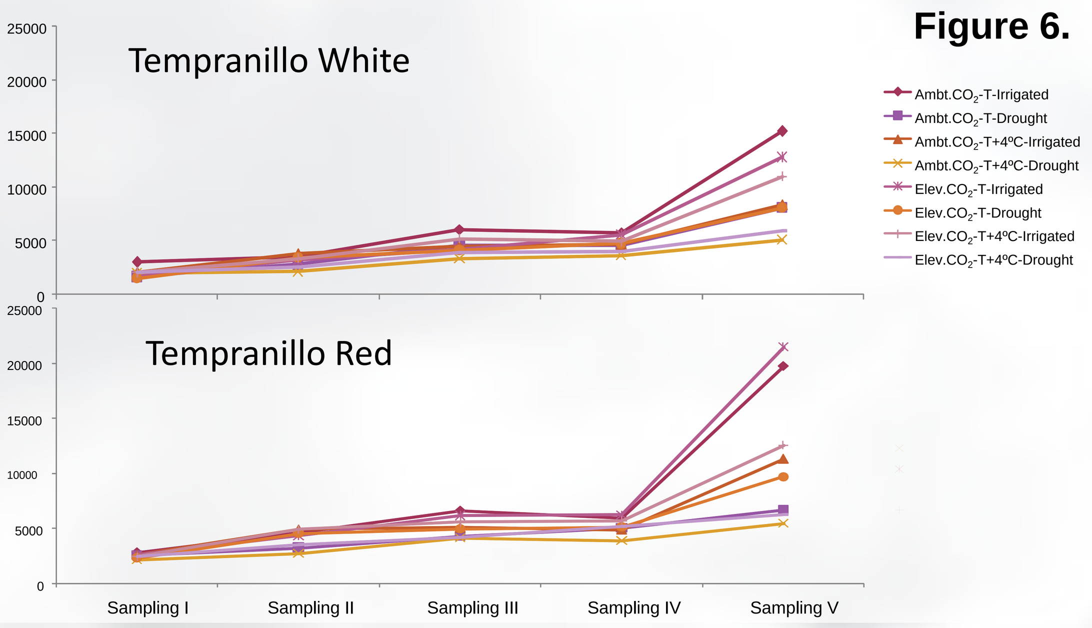


Figure 6. Leaf Area (cm^2 $plant^{-1}$)



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