

## Investigations into the effects of elevated carbon dioxide and drought on the growth and physiology of carpet weed (*Galenia pubescens* Eckl. & Zeyh.)

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**Summary** The present study aimed to examine the interactive effects of elevated atmospheric CO<sub>2</sub> concentration and drought stress on the growth and some of the physiological processes of *Galenia pubescens*. Photosynthetic rate of plants increased under elevated CO<sub>2</sub> concentration, however drought caused significant reduction in net photosynthetic rate by (45% in 400 ppm CO<sub>2</sub>) and (27% in 700 ppm CO<sub>2</sub>) after five days simulating the drought treatment when compared with well-watered plants. Plants grown under elevated CO<sub>2</sub> level and well-watered produced a greater biomass (17.5 ± 0.5 g per plant) compared to the plants which were grown under the ambient CO<sub>2</sub> concentration.

**Keywords** CO<sub>2</sub> concentrations, drought, weeds.

### INTRODUCTION

Plant invasion can be developed or hindered as a result of numerous changes in the climate and ecological processes. Changes in climate include; change in precipitation pattern, a rise in temperature and CO<sub>2</sub> levels and deposition of nitrogenous material, and fire regime changes that can lead to changes in resource availability (Miri *et al.* 2012, Sheppard and Stanley 2014).

There has been a report that air CO<sub>2</sub> concentrations may be increased from the present-day 380 to 550 ppm by 2050 (Franks, 2013) and afterward to surpass 700 to 1000 ppm before the end of the 21st Century (Dietz and Stern 2009, IPCC 2015) This increase in atmospheric CO<sub>2</sub> concentration will affect plant growth in a variety of ways (Dukes 2011), as it can have a direct impact upon photosynthesis and metabolism (Plett *et al.* 2015).

The future potential of characteristics of *Galenia pubescens* under an elevated atmospheric CO<sub>2</sub> concentration and drought is unknown. Hence, the objective of this study was to assess the effects of elevated carbon dioxide and water availability on the physiology and growth on the exotic weed *G. pubescens* in order to improve management methods.

### MATERIALS AND METHODS

**Seedlings establishment** Mature *G. pubescens* seeds were collected from several populations of mature plants in the Werribee region (37° 49' 5.63" S, 144° 34' 58.77" E), and cleaned seeds were placed in an airtight container until use.

In the glasshouse twenty plastic pots (13 cm diameter and 13 cm high) were prepared as follows: for soil moisture movement and aeration, the sterilised industrial, seed-free sand soil was placed to a depth of 1 cm lined with paper towel. One kg of well-mixed dry sterilised soil was placed into each pot. On the top of each pot ten *G. pubescens* seeds were sown. Pots were labelled and placed into large white trays (44 × 36 × 7 cm) to facilitate watering from below, which ensured minimal disturbance of seeds and later, germinants. One month old *G. pubescens* seedlings (4–6 leaf growth stage), were thinned to one per pot and transferred to CO<sub>2</sub> chambers.

### Setting-up CO<sub>2</sub> chambers and growth conditions

Two identical *Steriodium e2400* model chambers were used for this experiment. Each chamber was set-up with a different CO<sub>2</sub> concentration. One of the chambers was set at an ambient atmospheric CO<sub>2</sub> concentration (400 ppm), simulating the present concentration of CO<sub>2</sub> in the atmosphere. The second chamber was placed at an elevated atmospheric CO<sub>2</sub> concentration (700 ppm), simulating the likely future concentration of atmospheric CO<sub>2</sub> (by the end of this century) as predicted in climate change scenarios (Franks 2013).

Thereafter, 10 pots (randomly chosen) were placed in one growth chamber (with a CO<sub>2</sub> concentration of 400 ppm). Another 10 pots (randomly chosen) were placed into the other growth chamber (with a CO<sub>2</sub> concentration of 700 ppm). All pots were watered to field capacity based on their need for water. One week prior to the taking of measurements in each CO<sub>2</sub> chamber, half of the plants from each chamber

(randomly chosen) were kept well-watered and the other half were allowed to dry out slowly until visible wilting occurred.

**Physiological parameters** The net photosynthetic rate ( $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ), transpiration rate ( $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ) and stomatal conductance ( $\text{gs; mol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ) were measured using a portable gas exchange system (Li-6400XT, Li-Cor, Lincoln, NE, USA), following methods described by Le *et al.* (2016). The water use efficiency (WUE), was determined by dividing the net photosynthetic rate value by the transpiration rate value (Shabbir *et al.* 2014).

**Plant biomass** After the completion of the trial, approximately at the end of the vegetative stage and the beginning of flowering, the following morphological parameters were measured: The number of branches that were present on each plant was recorded. Then the plants were harvested from the soil surface and the stems and leaves were separated and kept in labelled paper bags and oven dried at  $70^\circ\text{C}$  for 48 hours. The roots were removed from the soil and washed thoroughly, were put in labelled paper bags separately and oven dried at  $70^\circ\text{C}$  for 48 hours. The dry leaves were added to the dry branches, to determine individual dry biomass. The root/shoot ratio was measured by dividing the root dry weight to the branch dry weight.

**Data analysis** In order to statistically account for any potential influence of  $\text{CO}_2$  concentration and drought treatments on plant responses, a randomized complete design was used with two treatments and five replications. Data were analysed using a general linear model (GLM). The GLM was set up with two atmospheric  $\text{CO}_2$  concentrations, two irrigation levels and interaction as the main factor. An analysis was then undertaken using an adjusted sum of squares approach using 95.0% confidence intervals. A two-way analysis of variance tests was run for each trait separately to detect differences caused by each factor using the Statistix 8.1 Regd package. Means were compared by Tukey's test at a 5% level of probability.

## RESULTS

Figure 1 shows the effects of atmospheric  $\text{CO}_2$  concentration and water availability of the net photosynthesis rate of *G. pubescens* seedlings at 60 days after the placement of plants in  $\text{CO}_2$  chambers, and measurements were taken four times (48 hours were between each recorded date). It should be noted that the plants under elevated  $\text{CO}_2$  concentration recorded significantly ( $F = 9.60, P < 0.05$ ) increases in the mean

net photosynthesis rates on all recorded dates ( $21.3 \mu\text{mol mol}^{-1}$ ) when compared to the plants in ambient atmospheric  $\text{CO}_2$  concentration ( $13.3 \mu\text{mol mol}^{-1}$ ) under well-watered treatment. Whereas moisture stress significantly decreased the rate of net photosynthesis, the decrease was greater in plants that were grown under elevated  $\text{CO}_2$  conditions.

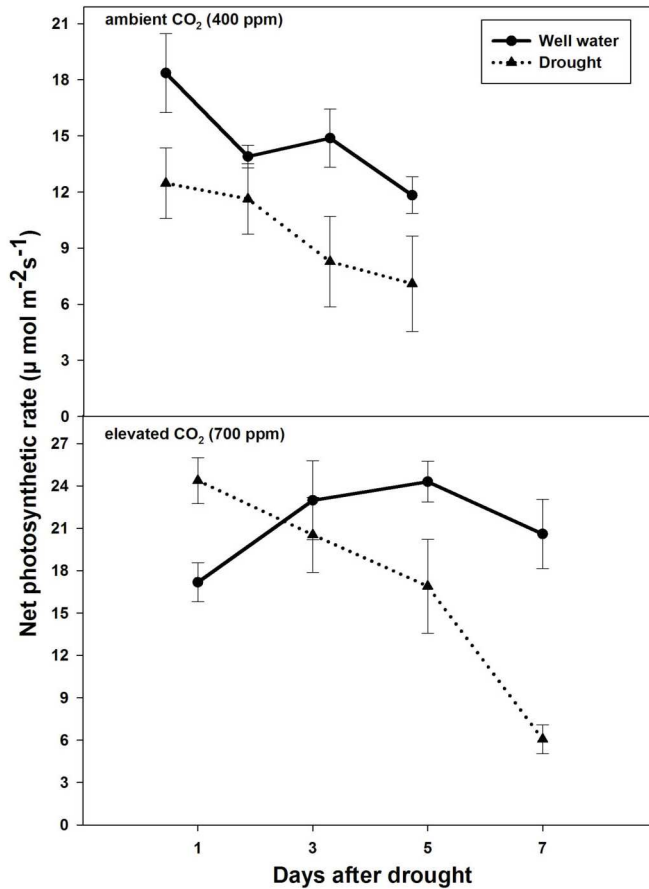
The *G. pubescens* plants were not significantly different ( $F = 1.68, P = 0.2132$ ) in their production of dry biomass by changing atmospheric  $\text{CO}_2$  concentrations. However, the plants were significantly different between well-watered and drought treatments in producing dry biomass (data not shown). Similarly, elevated  $\text{CO}_2$  concentration did not have a significant effect on root shoot ratio; however, data showed that the ratio was slightly decreased by increasing  $\text{CO}_2$  concentration in both well-watered and drought treatments. Regarding dry root weight, data showed no significant difference ( $F = 2.26, P = 0.152$ ) among plants under both  $\text{CO}_2$  levels and water availability treatment. Dry leaf and dry shoot weight were also found not significantly affected by changing  $\text{CO}_2$  levels; in contrast, water availability significantly affected dry leaf and dry shoot weight. The number of branches per plant was found not to be significantly affected by changing atmospheric  $\text{CO}_2$  concentration. However, the number of branches per plant was significantly different under well-watered and drought treatments.

## DISCUSSION

Elevated  $\text{CO}_2$  is beneficial for *G. pubescens* growth under well-watered conditions. The photosynthesis rate and the percentage of dry biomass were increased subsequently, whereas under drought conditions, elevated  $\text{CO}_2$  markedly showed reductions in the photosynthesis rate and dry biomass of the plants. Similar results were obtained by Erice *et al.* (2007), who reported that plant biomass increased under elevated  $\text{CO}_2$  under well-watered conditions but not under drought.  $\text{CO}_2$  concentration had no significant effects on the leaf, shoot, and root dry weight in either  $\text{CO}_2$  concentrations. These responses are in contrast with those of many herbaceous plants (Farrar and Williams 1991, Ziska 2002).

It can be concluded, that this study supported the view that the growth of *G. pubescens* will be significantly enhanced in a future climate with an enriched atmospheric  $\text{CO}_2$  concentration, producing taller plants with a greater biomass, and presumably with a higher seed output under well-watered conditions.

These changes will have important implications for management of this noxious weed in the future.



**Figure 1.** The effect of atmospheric CO<sub>2</sub> concentrations (a) ambient CO<sub>2</sub> (b) elevated CO<sub>2</sub> of the net photosynthetic rate ( $\mu\text{mol mol}^{-2}\text{s}^{-1}$ ) of *G. pubescens* plants growing under well-watered and drought conditions. Vertical bars show standard errors of the mean from five replications.

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