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_2 concentration and drought stress on the growth and some of the physiological processes of *Galenia pubescens*. Photosynthetic rate of plants increased under elevated CO_2 concentration, however drought caused significant reduction in net photosynthetic rate by (45% in 400 ppm CO_2) and (27% in 700 ppm CO_2) after five days simulating the drought treatment when compared with well-watered plants. Plants grown under elevated CO_2 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_2 concentration.

Keywords CO_2 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_2 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_2 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_2 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_2 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_2 chambers.

Setting-up CO_2 chambers and growth conditions Two identical *Steriudium e2400* model chambers were used for this experiment. Each chambers was set-up with a different CO_2 concentration. One of the chambers was set at an ambient atmospheric CO_2 concentration (400 ppm), simulating the present concentration of CO_2 in the atmosphere. The second chamber was placed at an elevated atmospheric CO_2 concentration (700 ppm), simulating the likely future concentration of atmospheric CO_2 (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_2 concentration of 400 ppm). Another 10 pots (randomly chosen) were placed into the other growth chamber (with a CO_2 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_2 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 (μmol CO_2 m^{-2} s^{-1}), transpiration rate (mmol H_2O m^{-2} s^{-1}) and stomatal conductance (gs; mol H_2O m^{-2} 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°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°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 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 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 CO_2 concentration and water availability of the net photosynthesis rate of *G. pubescens* seedlings at 60 days after the placement of plants in 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 CO_2 concentration recorded significantly ($F = 9.60$, $P < 0.05$) increases in the mean net photosynthesis rates on all recorded dates (21.3 μmol mol^{-1}) when compared to the plants in ambient atmospheric CO_2 concentration (13.3 μmol 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 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 CO_2 concentrations. However, the plants were significantly different between well-watered and drought treatments in producing dry biomass (data not shown). Similarly, elevated CO_2 concentration did not have a significant effect on root shoot ratio; however, data showed that the ratio was slightly decreased by increasing 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 CO_2 levels and water availability treatment. Dry leaf and dry shoot weight were also found not significantly affected by changing 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 CO_2 concentration. However, the number of branches per plant was significantly different under well-watered and drought treatments.

DISCUSSION

Elevated 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 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 CO_2 under well-watered conditions but not under drought. CO_2 concentration had no significant effects on the leaf, shoot, and root dry weight in either 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 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.

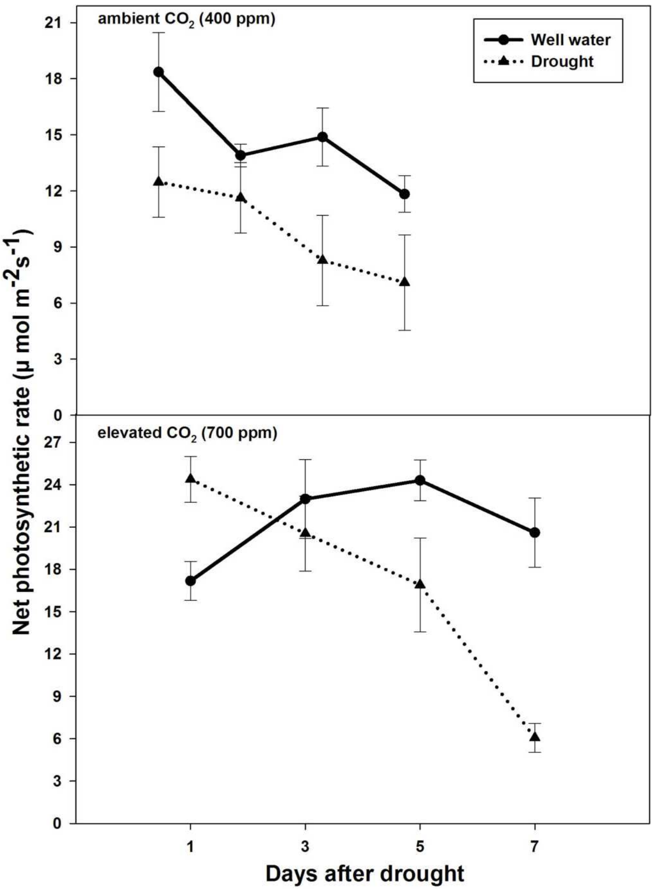

Figure 1. The effect of atmospheric CO_2 concentrations (a) ambient CO_2 (b) elevated CO_2 of the net photosynthetic rate (µmol $mol^{-2}s^{-1}$) of *G. pubescens* plants growing under well-watered and drought conditions. Vertical bars show standard errors of the mean from five replications.

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