PHOTOSYNTHETICA 36 (4): 635-638, 1999

BRIEF COMMUNICATION

Interactions of elevated CO_2 concentration and drought stress on photosynthesis in *Eucalyptus cladocalyx* F. Muell.

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Abstract

Response of net photosynthetic rate (P_N), stomatal conductance (g_s), intercellular CO_2 concentration (c_i), and photosynthetic efficiency (F_v/F_m) of photosystem 2 (PS2) was assessed in *Eucalyptus cladocalyx* grown for long duration at 800 (C_{800}) or 380 (C_{380}) µmol mol^{-1} CO_2 concentration under sufficient water supply or under water stress. The well-watered plants at C_{800} showed a 2.2 fold enhancement of P_N without any change in g_s. Under both C_{800} and C_{380}, water stress decreased P_N and g_s significantly without any substantial reduction of c_i, suggesting that both stomatal and non-stomatal factors regulated P_N. However, the photosynthetic efficiency of PS2 was not altered.

Additional key words: chlorophyll fluorescence; intercellular CO_2 concentration; net photosynthetic rate; stomatal conductance; water stress.

The increase of CO_2 concentration in the atmosphere is predicted to be doubled in the middle of the next century resulting in an increase in temperature and water stress frequency. The raising of atmospheric CO_2 concentration can accelerate plant growth and could potentially increase plant and forest productivity (for review see Saralabai *et al.* 1997). The elevated CO_2 concentration enhanced P_N and water use efficiency also in tree species such as yellow poplar, sweetgum, sycamore, beech, and oak (Norby and O'Neill 1991, Tschaplinski *et al.* 1995, Beerling *et al.* 1996). However, water stress reduces productivity. The combined effect of elevated CO_2 concentration and drought on photosynthetic response of woody species is not clearly understood. In the present study the P_N, g_s, and chlorophyll (Chl) *a* fluorescence were measured

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Received 21 September 1998, *accepted* 17 December 1998.

Acknowledgements: The author thanks FAO, Italy for financial support for the training programme at the University of Melbourne, Australia, and Dr. Ian Woodrow, School of Botany, University of Melbourne, Australia for the facilities provided to carry out the work.

in *E. cladocalyx* under long term exposure to elevated CO_2 concentration with or without drought.

E. cladocalyx seedlings were raised in plastic containers (volume 6500 cm^3) containing perlite (seeds sown in December 1994) in two identical glasshouses supplied with NC (380 µmol mol^{-1}, C_{380}) or elevated CO_2 (800 µmol mol^{-1}, C_{800}) concentrations. The temperature was maintained at 25 °C and humidity at 50 %. The seedlings were grown in C_{380} or C_{800} for 7 months. They were watered twice a day (approximately 1000 cm^3 $plant^{-1}$ d^{-1}) with Hoagland's nutrient solution, and drought stress was induced on April 1995 in 50 % of the seedlings by reducing water supply (200 cm^3 $plant^{-1}$ d^{-1}) in both C_{380} and C_{800}. Six seedlings were maintained in each treatment. P_N, g_s, c_i, and leaf temperature were measured on mature leaves using *LICOR-6400* portable photosynthesis system (*Licor*, Lincoln, USA) under photosynthetically active radiation (PAR) of 1200 µmol m^{-2} s^{-1}. Chl *a* fluorescence induction kinetics were measured by using portable Chl fluorometer (*Hansatech*, King's Lynn, UK). The observations were taken 30 d after induction of water stress.

In *E. cladocalyx,* C_{800} under well-watered condition increased the P_N and c_i by 2.2 and 2.6 fold, respectively, when compared to those of C_{380} (Table 1). The increased P_N results from the improved competitive ability of CO_2 with respect to O_2 at the sites of carboxylation (Morison 1993). Enhanced P_N under elevated CO_2 has been reported for white oak, pine, sycamore, sweetgum, *Fagus crenata*, and *Ginkgo biloba* (Gunderson *et al.* 1993, Garcia *et al.* 1994, Liang *et al.* 1995, Tschaplinski *et al.* 1995). The doubling of atmospheric CO_2 concentration reduces g_s in many plant species (Morison 1987, Tschaplinski *et al.* 1995). On the other hand, in *E. cladocalyx* I did not find a significant variation in g_s at C_{800} under sufficient water supply (Table 1). Similarly Conroy *et al.* (1988), Bunce (1992), and Beerling *et al.* (1996) found that g_s was not reduced at elevated CO_2 in *Pinus radiata, Malus domestica, Quercus prinus,* and *Quercus robur.*

Table 1. Effect of ambient CO_2, C_{380} (380 µmol mol^{-1}) and elevated CO_2, C_{800} (800 µmol mol^{-1}) concentrations under drought on net photosynthetic rate, P_N [µmol(CO_2) m^{-2} s^{-1}], stomatal conductance, g_s [mol m^{-2} s^{-1}], intercellular CO_2 concentration, c_i [µmol(CO_2) mol^{-1}], leaf temperature, T_l [°C], and chlorophyll *a* fluorescence parameters (F_0, F_m, F_v, F_v/F_m) in *Eucalyptus cladocalyx*. Means ±SE, *n* = 6.

Parameter	C_{380} well-watered	water-stressed	C_{800} well-watered	water-stressed
P_N	13.2 ± 1.5	5.9 ± 0.8	29.5 ± 2.7	6.6 ± 1.1
g_s	0.14 ± 0.05	0.05 ± 0.01	0.18 ± 0.05	0.02 ± 0.01
c_i	187 ± 8	181 ± 6	492 ± 13	381 ± 15
T_l	25.7 ± 0.5	26.2 ± 0.2	25.5 ± 0.1	26.2 ± 0.1
F_0	440 ± 15	517 ± 23	399 ± 12	421 ± 20
F_m	2678 ± 28	3149 ± 33	2607 ± 25	2693 ± 16
F_v	2239 ± 23	2631 ± 12	2208 ± 37	2272 ± 29
F_v/F_m	0.83 ± 0.01	0.83 ± 0.01	0.84 ± 0.01	0.84 ± 0.01

Drought highly decreased P_N (by 55 % in C_{380} and 78 % in C_{800}) and g_s compared to well-watered plants in both the CO_2 concentrations, however, c_i was not substantially declined (Table 1). This is an agreement with the findings in sweetgum, *Fagus crenata*, *Ginkgo biloba*, and *Alnus firma* (Liang *et al.* 1995, Tschaplinski *et al.* 1995) and soybean (Huber *et al.* 1984). Both stomatal and non-stomatal factors may be involved in drought-induced reduction in P_N (Epron and Dreyer 1993). In drought the P_N and g_s at C_{380} were similar to those of C_{800} (Table 1). The elevated CO_2 did not compensate the effect of drought on reduction in P_N in *E. cladocalyx* which is in contrast to the findings of Tolley and Strain (1984, 1985) who reported that in sweetgum P_N in elevated CO_2 under drought was similar to well watered plants grown in ambient CO_2. In *E. cladocalyx* the amount of ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBPCO) in water-stressed and well-watered seedlings at C_{800} remained unchanged, while a marginal reduction was observed in water-stressed seedlings compared to those of well-watered at C_{380}. However, there was no significant difference in amount of RuBPCO in well-watered C_{800} and C_{380} seedlings (Palanisamy, unpublished), indicating that decrease of P_N in drought or enhancement of P_N at elevated CO_2 do not necessarily be due to RuBPCO amount (Campbell *et al.* 1988). The photosynthetic efficiency of PS2 (F_v/F_m) did not show any variation under C_{380} or C_{800} and in well-watered or water-stressed seedlings (Table 1) indicating that PS2 was not sensitive to these changes in environmental factors. This is consistent with the findings of Epron and Dreyer (1993) that in oak the photochemical efficiency of PS2 was not reduced under water stress.

Hence in *E. cladocalyx* increased atmospheric CO_2 concentration enhanced photosynthesis in well-watered condition. The interactions of elevated CO_2×drought affected P_N but not F_v/F_m.

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