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Reproductive Growth and Respiration in an Annual under Elevated CO₂

By

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K e y w o r d s : Elevated CO₂, respiration, reproductive yield, *Xanthium canadense*.

S u m m a r y

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We analyzed reproductive yield of an annual, *Xanthium canadense*, at elevated [CO₂] as the product of (1) the amount of plant photosynthesis, (2) relative allocation of photosynthates to reproduction and (3) photosynthate use efficiency in reproductive organs (reproductive yield per photosynthates allocated to the reproductive organ).

Plants were grown under ambient and elevated [CO₂] (360 and 700 µmol mol⁻¹) and were harvested periodically during the growing period. The rate of respiration was determined for each organ and the amount of photosynthates allocated to organs was obtained by summing biomass increase and respiratory consumption.

Reproductive yield increased with CO₂ enrichment by 9%, while plant dry mass increased by 16%. The amount of photosynthates assimilated in the growing period increased with CO₂ enrichment by 9%. However, because the relative allocation of photosynthates to the reproductive organ decreased with CO₂ enrichment by 7%, the increase in the amount of photosynthates allocated to the reproductive organ by elevated [CO₂] was small (+2%). Reproductive yield per photosynthates allocated to the reproductive organ was enhanced by elevated [CO₂] by 8%. These results indicate that respiratory consumption has a considerable effect on the response of reproductive yield to elevated [CO₂].

I n t r o d u c t i o n

Although the rate of photosynthesis is usually enhanced by elevated CO₂ concentration ([CO₂]), the enhancement is not always reflected on reproductive yield (final dry mass of reproductive organs) (KRAMER 1981, KIMBALL & al. 2002). Reproductive yield may be expressed as the product of (1) the amount of plant

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photosynthesis, (2) relative allocation of photosynthates to reproduction (RA_p) and (3) photosynthate use efficiency in reproductive organs (PUE, reproductive yield per unit photosynthate allocated to the reproductive organ). We analyzed the effect of elevated $[CO_2]$ on reproductive yield with reference to the effect on these three components in reproductive yield.

Material and Methods

Experimental design

Xanthium canadense Mill., a short-day summer annual, was employed for the experiment. After germination on 4 July, seedlings were transplanted into 1.5 L pots filled with washed river sand and were moved into four open top chambers (OTC, 2 x 2 x 2 m). Two OTCs were ventilated with ambient air (about $360 \mu\text{mol mol}^{-1}$, LC treatment) and the other two had $[CO_2]$ elevated to $700 \mu\text{mol mol}^{-1}$ by injecting pure CO_2 into ventilating air (HC treatment, see KINUGASA & al. 2003). In a preliminary study, we found no significant difference in the dry mass growth between chambers when plants were subjected to the same $[CO_2]$. Thus we assumed that there was no chamber effect on plant growth. Air and soil temperatures were monitored every 30 minutes. Mean monthly temperatures in OTCs decreased from 26.8°C in July to 7.3°C in November. Standard nutrient solution followed EPSTEIN 1972: N 16, P 2, K 6, Ca 4, S 1, and Mg 1 mmol L^{-1} , and 50 ml of 3/2 strength of the solution was added per pot every week.

By the end of the growing period (12 December), plants were harvested 10 times. On each harvest occasion, more than six plants were sampled. Harvested plants were separated into leaves, stems, roots, dead leaves, and reproductive organs. Leaf area was determined with a leaf area meter (Li-3100, Li-Cor, USA) and dry mass was determined after oven drying at 70°C for four days.

Respiration measurement

On every harvest occasion, the rate of dark respiration was determined for leaves, stems, roots, and reproductive organs after sunset until midnight. Plant materials were enclosed in a 1.7 L acrylic chamber and specific respiration rates (SRR) were determined at 25°C using an infrared gas analyzer (URA-107, Shimadzu, Japan). During the measurement, $[CO_2]$ in the chamber was maintained at around $360 \mu\text{mol mol}^{-1}$ for LC plants and $700 \mu\text{mol mol}^{-1}$ for HC plants, and temperature was maintained at around 25°C . Temperature dependence of SRR was determined for each organ every harvest occasion from the measurement of SRR at three temperatures covering the range of growth temperature at around the sampling date. Respiration expressed as CO_2 release was converted into dry mass with a conversion factor of 0.614, which is the molecular weight of one carbohydrate unit ($C_6H_{10}O_5$) divided by the molecular weight of six CO_2 molecules.

Maintenance respiration rate (μ) was determined for the reproductive organ as the y-intercept in the regression of SRR at 25°C on relative growth rate of the reproductive organ (two-component regression method, AMTHOR 1989).

The amount of respiration was calculated for each organ with dry mass growth and SRR at growing temperature. The amount of photosynthates allocated to each organ was estimated as the sum of dry mass and respiratory consumption. For more details, see KINUGASA & al. 2005.

Results and Discussion

Elevated $[CO_2]$ increased plant dry mass of *Xanthium canadense* by 16% at the end of the growing period, and the increase was larger than that in the reproductive yield (9%, Fig. 1A). Difference between plant mass and the reproductive yield in response to elevated $[CO_2]$ was also found in other studies (FARNSWORTH

& BAZZAZ 1995, JABLONSKI & al. 2002, KINUGASA & al. 2003).

The amount of plant photosynthesis in the growing period increased by 9% with CO₂ enrichment (Fig. 1B). However, because the relative allocation of photosynthates to the reproductive organ (RA_P) decreased with CO₂ enrichment by 7% (Table 1), the increase in the amount of photosynthates allocated to the reproductive organ was small (+2%). The decrease in RA_P resulted from the smaller increase in the amount of plant photosynthesis with CO₂ enrichment in the reproductive period (+5%) than in the vegetative period (+17%).

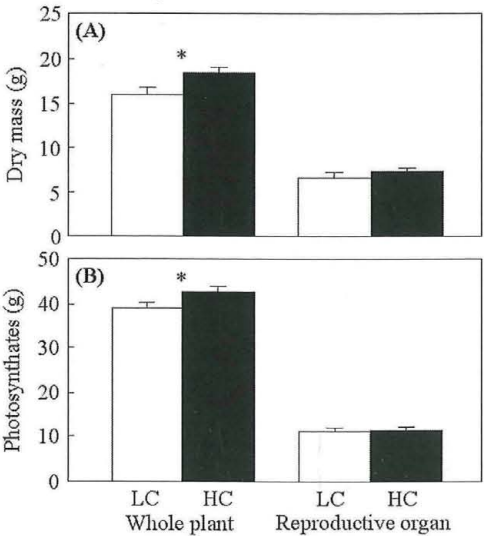


Fig. 1. Dry mass production (A) and the amount of photosynthates (B) in whole plant and in the reproductive organ in the growth of *Xanthium canadense*. Open columns, ambient [CO₂] (LC, 360 $\mu\text{mol mol}^{-1}$); closed columns, high [CO₂] (HC, 700 $\mu\text{mol mol}^{-1}$). Error bars, +1 SE ($n = 7$). * $P < 0.05$.

Table 1. Relative allocation of photosynthates to reproduction (RA_P) and photosynthate use efficiency in the reproductive organ (PUE, reproductive yield per photosynthates allocated to the reproductive organ). Means in ambient (LC, 360 $\mu\text{mol mol}^{-1}$) and high (HC, 700 $\mu\text{mol mol}^{-1}$) [CO₂] with SD in parentheses ($n = 7$) and relative stimulation by elevated [CO₂]. * and † indicate a significant difference between CO₂ treatments at $P < 0.05$ and $P < 0.1$, respectively (t -test).

	LC	HC	HC/LC
RA _P	0.29 (0.02)	0.27 (<0.01)	0.93†
PUE	0.58 (0.05)	0.63 (0.02)	1.08*

Photosynthate use efficiency in reproductive organs (PUE, reproductive yield per unit photosynthate allocated to the reproductive organ) was enhanced by elevated [CO₂] by 8% (Table 1). This enhancement in PUE was partly explained by

the decrease in maintenance respiration rate (μ) in the reproductive organ with CO₂ enrichment (-42%), though maintenance respiration was only a small fraction of total respiratory consumption in the reproductive organ (KINUGASA & al. 2005). The reduction in μ of the reproductive organ in *X. canadense* was associated with decreased N concentration ([N]) of the reproductive organ due to increased mass of capsules of low [N] by elevated [CO₂] (KINUGASA & al. 2003). Several authors reported that μ depends on tissue [N] (AMTHOR 1989, RYAN 1995, MAIER & al. 1998, AMTHOR 2000). Thus respiratory consumption considerably influenced the response of reproductive yield to elevated [CO₂].

A c k n o w l e d g m e n t s

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R e f e r e n c e s

- AMTHOR J.S. 1989. Respiration and crop productivity. - Springer-Verlag, New York.
- 2000. The McCree-de Wit-Penning de Vries-Thornley respiration paradigms: 30 years later. - *Annals of Botany* 86: 1-20.
- EPSTEIN E. 1972. Mineral nutrition of plants: principles and perspectives. - Wiley, New York.
- FARNSWORTH E.J. & BAZZAZ F.A. 1995. Inter- and intra-generic differences in growth, reproduction, and fitness of nine herbaceous annual species grown in elevated CO₂ environments. - *Oecologia* 104: 454-466.
- JABLONSKI L.M., WANG X.Z. & CURTIS P.S. 2002. Plant reproduction under elevated CO₂ conditions: a meta-analysis of reports on 79 crop and wild species. - *New Phytologist* 156: 9-26.
- KIMBALL B., KOBAYASHI K. & BINDI M. 2002. Responses of agricultural crops to free-air CO₂ enrichment. - *Advances in Agronomy* 77: 293-368.
- KINUGASA T., HIKOSAKA K. & HIROSE T. 2003. Reproductive allocation of an annual, *Xanthium canadense*, at an elevated carbon dioxide concentration. - *Oecologia* 137: 1-9.
- , — & — 2005. Respiration and reproductive effort in *Xanthium canadense*. - *Annals of Botany* (in press).
- KRAMER P.J. 1981. Carbon-dioxide concentration, photosynthesis, and dry-matter production. - *Bioscience* 31: 29-33.
- MAIER C.A., ZARNOCH S.J. & DOUGHERTY P.M. 1998. Effects of temperature and tissue nitrogen on dormant season stem and branch maintenance respiration in a young loblolly pine (*Pinus taeda*) plantation. - *Tree Physiology* 18: 11-20.
- RYAN M.G. 1995. Foliar maintenance respiration of sub-alpine and boreal trees and shrubs in relation to nitrogen-content. - *Plant Cell and Environment* 18: 765-772.

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