GROWTH AND PHOTOSYNTHETIC RESPONSE OF DECIDUOUS TREE SAPLINGS IN A FREE AIR CO_2 ENRICHMENT SYSTEM

N. Eguchi[1], K. Karatsu[1], T. Ueda[2], R. Funada[3], K. Takagi[4], T. Hiura[4], K. Sasa[4], and T. Koike[4]

[1]*Graduate School of Environmental Science, Hokkaido University, Sapporo 060-0809, Japan; eguchi@fsc.hokudai.ac.jp*
[2]*Hokkaido DALTON, Sapporo 060-0808, Japan; ueda@hdalton.com*
[3]*Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu-Tokyo 183-8509, Japan; funada@cc.tuat.ac.jp*
[4] *Hokkaido University Forests, FSC, Sapporo 060-0809, Japan; tkoike@exfor.agr.hokudai.ac.jp*

ABSTRACT

We examined the photosynthetic and growth traits of two woody species (birch) that are dominant in northern Japan under elevated CO_2 concentration ([CO_2]), using a free air CO_2 enrichment (FACE) system. Our results suggest that it is necessary to consider not only leaf-level photosynthesis but also the entire plant physiology when using photosynthesis to evaluate the growth response of two birch saplings under elevated [CO_2].

INTRODUCTION

In northern Japan there are many forests dominated by early successional species, including *Betula platyphylla* var. *japonica* Hara (hereafter, *B. platyphylla*) and *B. maximowicziana* Regel. These species are characterized by high photosynthesis and growth rate [*Koike,* 1988]. An understanding of the photosynthetic and growth traits of these species under elevated CO_2 concentration ([CO_2]) would therefore permit an accurate evaluation of the future carbon sink capacity in northern Japan. We propose that the growth rate of these species increases at elevated [CO_2], following the change in photosynthetic capacity. To verify this hypothesis, we determined the growth and photosynthetic traits of these species under elevated [CO_2] using a free air CO_2 enrichment (FACE) system.

MATERIALS & METHODS

Our FACE system is located in Sapporo Experimental Forest, Hokkaido Univ, northern Japan (43˚06'N, 141˚20'E). There are six circular plots, 6m in diameter and 5m high; three circular plots are maintained at elevated CO_2, and the other three are ambient plots. [CO_2] in the FACE is aimed to be 500 µmol mol^{-1} (ambient + 130) during daytime. Since the response of plants under elevated [CO_2] depends on the soil nutrient conditions [*Eguchi et al*., 2004], two soil conditions were set up in each FACE, using brown forest soil and volcanic ash soil; both are typical in Japan. The nitrogen, phosphate, and potassium concentrations were higher in brown forest soil (data not shown). Two-year-old seedlings of *B. platyphylla* and *B. maximowicziana* were planted in May 2003 and grown for two years. The photosynthetic rate at light saturation level (P_{sat}) was determined each August by a LI-6400 system (Li-Cor, Lincoln, NE, USA). The stem volume, a parameter representing growth [D^2H: $(\text{diameter})^2 \times \text{height}$] was determined after growth had ceased on the end of each September. The total leaf area per sapling was also determined in September 2004. Differences in the effects of CO_2, of soil, and of the interaction between the two were evaluated by two-way analysis of variance (ANOVA). Differences were considered significant at $P < 0.05$, and 'tended to exist' at $P < 0.15$.

RESULTS & DISCUSSION

The results for P_{sat} and D^2H are shown in the Table. In 2003, P_{sat} for *B. platyphylla* tended to increase under elevated [CO_2]. The effect of [CO_2] was significant in brown forest soil. The stem volume of *B. platyphylla* displayed the same tendency. For *B. maximowicziana,* P_{sat} increased significantly under elevated [CO_2] in brown forest soil, but did not increase in volcanic ash soil. The stem volume of *B.*

maximowicziana also showed the same tendency. It follows that the change in photosynthetic capacity affects growth in both species. In 2004, P_{sat} for *B. platyphylla* did not increase under elevated [CO_2] in either soil, a phenomenon known as photosynthetic down-regulation, but the stem volume increased significantly. The change in photosynthetic capacity of *B. platyphylla* does not therefore clearly affect growth. The P_{sat} and stem volume values of *B. maximowicziana* showed a similar tendency in 2003, indicating that the change in photosynthetic capacity does affect the growth parameter. What factors caused the difference between *B. platyphylla* and *B. maximowicziana* in 2004? Since the change of growth is based on the total photosynthesis of the whole plant, this difference might be due to changes of the total leaf area per sapling (data not shown). In *B. platyphylla*, the total leaf area increased significantly in both soils. This implies that the increase in total leaf area compensated for the decrease in photosynthetic capacity, so that growth was enhanced overall. In contrast, *B. maximowicziana* did not show a significant increase in total leaf area, indicating that the leaf photosynthetic capacity directly regulates the growth parameter. *Hikosaka et al*. [2005] reported that the effect of elevated [CO_2] on growth is often much weaker than that predicted by the photosynthetic response. Our study suggests that, to evaluate changes in growth under [CO_2], it is necessary to look not only at the leaf photosynthetic capacity but also at the total leaf area of the whole plant.

Table 1. Photosynthetic Rate at Light Saturation Llevel (P_{sat}) and Stem Volume [D^2H: (Diameter)^2 × Height]

			brown forest soil		volcanic ash soil		*P*		
	sp.	year	ambient [CO_2]	elevated [CO_2]	ambient [CO_2]	elevated [CO_2]	[CO_2]	soil	[CO_2] × soil
P_{sat} (μmol m^{-1}s^{-1})	Bp	2003	8.49 (0.22)	12.27 (1.23)	11.50 (1.23)	12.67 (1.15)	0.06	NS	NS
		2004	7.90 (1.08)	8.29 (1.75)	6.68 (1.48)	7.33 (0.42)	NS	NS	NS
	Bm	2003	11.40 (0.27)	14.10 (0.40)	11.81 (0.53)	12.63 (0.74)	**	NS	0.10
		2004	7.17 (0.40)	9.73 (0.40)	7.17 (0.07)	7.89 (0.91)	*	0.12	0.12
D^2H(cm^3)	Bp	2003	15.98 (0.50)	44.13 (4.04)	25.32 (2.75)	28.08 (5.14)	**	NS	**
		2004	460.09 (26.96)	810.81 (138.93)	518.64 (22.89)	736.23 (64.31)	**	NS	NS
	Bm	2003	9.16 (0.88)	13.05 (1.29)	11.69 (1.54)	11.30 (1.11)	NS	NS	0.11
		2004	281.50 (11.49)	518.60 (5.72)	364.32 (76.73)	382.35 (64.35)	*	NS	0.06

n = 3 values of each parameter indicate the mean (S.E.). Statistical significance of CO_2 concentration ([CO_2]), soil condition and their interaction are determined by 2-way ANOVA. * denotes P<0.05, ** denotes P<0.01, NS denotes non-significant. Actual *P*-values are shown when 0.05<P<0.15. Bp = *Betula platyphylla* var. *japonica* Hara, Bm=*Betula maximowicziana* Regel. "ambient" indicates 370 μmol mol^{-1}, and "elevated" indicates 500 μmol mol^{-1}.

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