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Effect of doubling atmospheric CO_2 concentration on growth, dry matter distribution and CO_2 exchange of 2 yr old sweet chestnut trees (*Castanea sativa* Mill.)

M. Mousseau[1] and H.Z. Enoch[2]

[1] *Ecologie Végétale, Bat. 362, Université Paris-Sud, 91405 Orsay Cedex, France, and*
[2] *Department of Agricultural Meteorology, Agricultural Research Organisation, The Volcani Center, Bet Dagan, Israel*

Introduction

The amount of CO_2 in the global atmosphere has increased about 25% during the last century. A doubling of the preindustrial CO_2 level and an increase of the global surface temperature of at least 2°C is expected in the next century (Clark, 1982).

The gas exchange and carbon storage capacity of forest trees may play an important role in regulating the global atmospheric CO_2 concentration. It is therefore important to describe and understand the behavior of tree species with regard to elevated atmospheric CO_2.

Materials and Methods

Two yr old sweet chestnut seedlings, obtained from a forest nursery, were potted in galvanized steel containers (25 cm in diameter, 50 cm deep) with 24 l of surface soil from a nearby chestnut forest. The plants were sorted according to size: 24 matched pairs were made from plants of similar heights and growth patterns. One set of plants was grown in the control growth chamber at ambiant CO_2 atmospheric concentration (350 ppm), the other set at twice that CO_2 concentration. CO_2 enrichment was maintained from 15 April to November.

The plants were grown in 2 permanently ventilated daylit growth chambers in a field at the University Campus in Orsay, France (48°N, 2°E). Atmospheric bulk air was blown into the enclosures from air-intakes placed 4 m above the ground. Pure CO_2 was supplied to the CO_2-enriched chamber by a steel tank containing 300 kg of compressed CO_2 (Carboxique Française).

The growth chambers had a ground area of 2 m^2, were 1 m high, made out of transparent polypropylene glued to aluminum frames. The aboveground part could be lifted off a base which was buried in the ground. The chambers' air throughflow was 4 $m^3 \cdot min^{-1}$. Plants were watered daily and nutrient granules were added on the 1st of June (0.75 g of N, 0.60 g of P_2O_3 and 1.1 g of K_2O per pot).

At the end of October, 8 matched pairs were harvested and their biomass distributions recorded.

Results

Leaf characteristics (Table I)

Prolonged CO_2 enrichment slightly reduced final mean leaf size, but enhanced leaf thickness. In the CO_2-enriched chestnut plants, stomatal density and stomatal index were not significantly different from the control.

Growth pattern (Table II)

The CO_2 enrichment seemed to shorten the time period over which the main branches grew. After the end of July, 62% of the enriched plants ceased growth as compared with 37% of the controls.

The early onset of yellowing and the stopped terminal bud growth indicates earlier senescence of the CO_2-enriched plants.

The final leaf area per plant, at the end of the growth period, was reduced by CO_2 enrichment. The pattern of growth through the vegetative development period showed a tendancy towards fewer leaves and lower leaf area per plant after June in the CO_2-enriched plants. Furthermore, the branch elongation (main branch + side shoots) was, during that period, 30% lower in the CO_2-enriched plants.

Dry matter partitioning (Table III)

Table III shows that the root biomass of CO_2-enriched plants was 69% heavier than roots of the control plants. The increase was statistically significant ($P > 95\%$). The shoot was 22% lighter ($P > 80\%$). Consequently, the shoot/root ratio was changed from 0.49 in the control to 0.23 in the CO_2-treated plants and total dry matter increased by 43% in the CO_2-enriched plot.

Table I. Effect of doubling the atmospheric CO_2 concentration on chestnut (*Castanea sativa* Mill.) leaves (mean ± SD).

	Control		*CO_2-enriched*	
Mean leaf area (cm^2)	29.4 ± 10.8	(a)	22.1 ± 7.3	(b)
Stomatal density (stomata/mm^2)	649 ± 94	(a)	597 ± 155	(a)
Stomatal index (%)	25	(a)	24	(a)
Specific leaf density ($g \cdot m^{-2}$)	70.2 ± 2	(a)	89.3 ± 21	(b)
Leaf thickness (μm)	129 ± 20	(a)	157 ± 21	(b)

Table II. Growth characteristics of CO_2-enriched trees, compared to controls (mean of 12 pairs ± SE).

Date	*Control*			*CO_2-enriched*		
	no. of leaves	*total leaf area (cm^2)*	*stem length (cm)*	*no. of leaves*	*total leaf area (cm^2)*	*stem length (cm)*
20 May	17.8 ± 3.3^a	344 ± 88^b	22.7 ± 5.9^c	20.2 ± 2.8^a	291 ± 54^b	21.3 ± 2.8^a
22 June	21.8 ± 4^a	535 ± 189^b	28.5 ± 5.6^c	24.9 ± 2.3^a	562 ± 58^b	28.7 ± 3.5^c
27 July	37.7 ± 4.9^a	885 ± 113	51.3 ± 7.6^c	30.5 ± 2.2^d	655 ± 46^e	35.1 ± 4.0^f
1 Sept.	39.6 ± 5.1^a	1166 ± 136^b	54.0 ± 7.6^c	34.6 ± 2.9^a	764 ± 72^d	40.6 ± 4.9^e

For each row of data, numbers with the same letters are not significantly different.

Table III. Dry matter distribution (*n* = 8) of CO_2-enriched chestnut trees.

	Control	*CO_2-enriched*	*Difference*	t	P[a]
Stem (g)	29.9 ± 13.5	23.2 ± 14	6.7 ± 5.0	1.33	80%
Root (g)	60.5 ± 34	105.9 ± 50	41.8 ± 16.8	2.70	95%
Total (g)	90.4 ± 36	129.1 ± 59	38.7 ± 20	1.68	80%
Stem/root	0.49 ± 0.14	0.23 ± 0.06	0.28 ± 0.04	3.59	99%

[a] *P* = probability for the difference to be significant is better than...

CO_2 exchange measurements

Towards the end of the first growth season (4 Sept.), 2 plants grown at 350 ppm were transferred into an airtight assimilation chamber where environmental conditions were controlled (22/15°C day–night, 15 h photoperiod, 50% RH). Whole plant photosynthesis at 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFD and dark respiration were measured after a 2 wk adaptation period as the slope of CO_2 concentration over time in the whole chamber (Gaudillère and Mousseau, 1989). During the two 1st 2 wk, the CO_2 concentration in the chamber was maintained at 330 ppm. It was then increased to 660 ppm for another 2 wk period. CO_2 enrichment increased net CO_2 uptake by about 20% during the day and decreased dark respiration so that the diurnal CO_2 balance was 28% greater for the CO_2-enriched plants (results not shown).

The 28% increase in daily carbon exchange was in approximate agreement with the 43% increase in total dry matter of CO_2-enriched chestnut plants observed in the growth measurements.

Discussion and Conclusion

Tree species may react differently to elevated levels of atmospheric CO_2. In chestnut trees, CO_2 fertilization was accompanied by a decrease in leaf area and a reduction in shoot growth, which is very unusual and may have resulted from the timing of the nutrient application. The accumulation of the carbon surplus was restricted to the root system.

These changes could have far reaching ecological consequences for tree growth of *Castanea* species under future elevated CO_2 levels.

References

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