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BRIEF COMMUNICATION

Influence of CO_2 on Stomatal Numbers

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Abstract. From nine different plant species grown at 1500 cm^3m^{-3} CO_2 five responded with a significant increase in stomatal numbers per mm^2 as compared with plants grown under normal air conditions. Within a collection of twelve french bean cultivars remarkable cultivar differences with regard to the CO_2 enhancement effect on stomatal numbers was found.

The rising CO_2 content of the atmosphere from a pre-industrial level of 280 cm^3m^{-3} to the current ambient level of 345 cm^3m^{-3} and the predicted further increase (Crane 1985, Trabalka and Reichle 1986) provoked an increasing number of papers on plant responses to changes in CO_2 concentration (Kimball 1983, Lemon 1983, Cure and Acock 1986). However, data about an influence of CO_2 on anatomical features as stomatal density or stomatal index are rather meagre.

Recently Woodward (1987) reported on a decrease in stomatal index as well as density with increasing CO_2 content. The experimental evidence for this statement was taken from comparisons of about 200 years old herbarium specimens with recent material and by growth chamber experiments at different CO_2 concentrations between 225 cm^3m^{-3} and 340 cm^3m^{-3} CO_2. For the comparison of herbarium material reconstructed changes in atmospheric CO_2 based on ice-core studies were included.

The results reported here are not directly comparable to Woodward's data because the plants were grown at 345 cm^3m^{-3} and 1500 cm^3m^{-3} CO_2, respectively. Nevertheless, they demonstrate that the response of plants to enhanced CO_2 concentrations with regard to stomatal density is much more complicated than could be deduced from the data of Woodward (1987).

The following species were investigated: *Phaseolus vulgaris* L. (12 cultivars), *Vicia faba* L. cv. Fribo, *Lycopersicon esculentum* L. cv. Bonner Beste, *Acer pseudoplatanus* L., *Triticum aestivum* L. cv. Carola, *Hordeum vulgare* L. cv. Trumpf, *Secale cereale* L. cv. Petka, *Avena sativa* L. cv. Solidor, *Zea mays* L. cv. Bema.

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TABLE 1

Leaf thickness and stomatal density of primary leaves of french bean cultivars grown at 1500 cm^3m^{-3} CO_2. The values are percentages in relation to the values at 345 cm^3m^{-3} which were taken as 100 %.

Cultivar	Stomatal density	Leaf thickness
Valja	141	138.5
Lusia	142	125.6
Rela	149	109.8
Dilana	135	136.6
Dowina	119	126.0
Esto	114	129.8
Berggold	149	118.6
Jutta	154	115.0
Karla	135	127.1
Ragalla	122	119.5
Comtesse	140	108.4
"Eisbohne"	135	115.5
x	136.3	122.5
S_x	3.60	2.81

The plants were grown in two growth chambers (KTLK 20000 VEB NEMA, GDR) in plastic pots with sandy soil. The light/dark cycle was 16:8 h with 20 °C in the light and 15 °C in the dark period. Photon fluence rate (400–700 nm) was 400 μmol $m^{-2}s^{-1}$.

One chamber was steadily flushed with atmospheric air (= control : 345 cm^3m^{-3} CO_2), the other was CO_2 enriched during the light period at a concentration of 1500 cm^3m^{-3} CO_2 and flushed with atmospheric air during the dark. All measurements were done with fully expanded leaves. Replicas from both surfaces of five leaves were made. From each replica stomata of five randomly chosen fields were counted at 250 fold magnification.

Stomatal density and leaf thickness of primary leaves were both statistically significantly increased at 1500 cm^3m^{-3} CO_2 in 12 French bean cultivars (Table 1).

However, the cultivar differences are remarkable. With regard to leaf thickness the enhancement reached from 108.4 % up to 136.5 % and for stomatal density from 114 % up to 154 %.

Even considering the much higher CO_2 concentration in our experiment than that of WOODWARD (1987) the controversial result required futher investigations. Therefore eight other species, among them 5 monocots and 3 dicots were included in this programme (Table 2).

From *Hordeum, Triticum, Avena* and *Secale* the penultimate leaf was used for analyses and the primary leaf from *Zea mays*. With *Vicia faba* and tomato it was the third leaf from the base and with *Acer* the second. The results are surprising in so far as in *Triticum, Avena, Secale* and *Vicia* no influence of high CO_2 concentrations on

TABLE 2

Response of stomatal density, leaf thickness and specific leaf mass to changes in CO_2 concentration. — Percentage values for 1500 cm^3m^{-3} (345 cm^3m^{-3} = 100 %)

Species	Stomatal density	Leaf thickness	Specific leaf mass
Hordeum vulgare L.	126.5 a	101.0	n.d.
Triticum aestivum L.	96.3	100.0	n.d.
Secale cereale L.	92.6	97.9	n.d.
Avena sativa L.	92.9	109.9	n.d.
Zea mays L.	143.9 a	111.7 a	n.d.
Vicia faba L	107.0	107.7 a	98.8
Lycopersicon esc. L.	155.6 a	117.7 a	216.6 a
Acer pseudoplatanus L.	154.6 a	114.8 a	148.9 a

a: indicates a significant difference from 100;
n.d.: not determined.

stomatal density was found. In *Hordeum, Zea, Lycopersicon* and *Acer* an increase comparable to that with *Phaseolus* and even somewhat higher was detected.

The matter is of potential ecological importance because of the influence of stomatal density on water use efficiency and the obvious difference between species in their response to a rising CO_2 content in the atmosphere. Therefore more detailed investigations with a taxonomic approach and at CO_2 concentrations which can be expected realistically for the near future are required.

The enhancement effect of CO_2 on leaf thickness (and specific leaf mass) in 5 of 9 species is not unexpected and in accordance with other results (HO 1977, THOMAS and HARVEY 1983).

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