Effect of CO_2 enrichment on growth of faba beans at two levels of water supply

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Abstract. The occurrence of growth enhancement by increased CO_2 levels is well established under optimal conditions. A growth analysis study of faba beans, grown under two CO_2 levels (350 and 700 cm^3 m^{-3}) in combination with two levels of water supply, showed that the beneficial CO_2 effect is maintained when there is shortage of water. The effects of additional CO_2 and water were shown to be multiplicative.
Key words: CO_2 enrichment, water use efficiency, growth

Introduction. The favourable effect of CO_2 enrichment on growth of plants is well-established (Lemon, 1983).

There is far less evidence whether this growth enhancement is maintained under stress conditions. Gifford (1979) showed that in wheat waterstress does not eliminate the favourable CO_2 effect. In the study presented here the experimental basis for the interaction of CO_2 and water is broadened to faba bean (*Vicia faba*).

Material and methods. The plants were grown in pots with sand and were watered with a complete nutrient solution, including nitrate (Hoagland), twice a week, and with additional tap water at intermediate intervals for a treatment with high water supply. Excess water could escape from the bottom of the pots. Soil evaporation was prevented with a layer of plastic grains. Two greenhouse compartments, one for 350 cm^3 m^{-3} and one for 700 cm^3 m^{-3} of CO_2, were used in the period of 17 May - 31 August 1982. In 6 periodic harvests the plants were removed, 6 at a time for each treatment. The water stress treatment started after the third harvest in the beginning of July, by witholding additional tap water. A classic growth analysis was done with fresh and dry weights of leaves, stems, flowers, pods and roots as well as leaf area.

Results. After the initial phase, total dry matter (including roots) increased almost linearly with cumulative water consumption (Fig. 1). The water use efficiency, as expressed by the slope in this graph, was practically independent of waterstress, but it was improved by the CO_2 enrichment with more than 50 %.

By the time of the final harvest, loss of leaves caused a downward deviation from the linear relationship with water consumption. This loss was less under high CO_2,

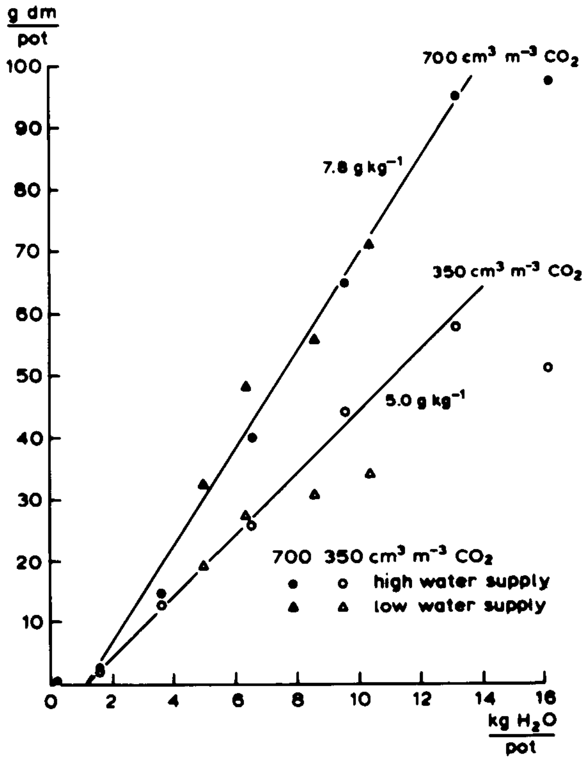

Fig. 1. Total dry matter of faba beans at subsequent harvests as a function of the cumulative water supply.

because of delayed senescence.

With a good water supply the final dry matter yield (averaged over the two CO_2 levels) was about 40 % higher than under water stress, and under double CO_2 the final dry matter (averaged over low and high water supply) was 97 % higher than under normal CO_2 (Table 1). As a result the best and the worst combination differed by almost a factor three in final weight, and it is concluded that the effects of increasing water supply and CO_2 supply appeared to be multiplicative. The large CO_2 effect was not only due to an enhanced growth rate (factor ≅ 1.6) mediated by increased photosynthesis, but also to a delayed senescence (factor ≅ 1.25). By

Table 1. Total dry matter of faba beans (g per pot) at final harvest at two levels of water and CO_2.

CO_2 levels	Levels of water supply	
	Low	High
350 $cm^3\ m^{-3}$	34.2	51.5
700 $cm^3\ m^{-3}$	71.4	97.9

a growth analysis these effects could also be shown in the time trend of the Unit Leaf Rate (ULR, net daily growth per leaf area). During the first month of growth ULR was about 1 mg cm^{-2} d^{-1} in both treatments, but in the high CO_2 treatment the leaf area index was larger. In the high CO_2 treatment the ULR started to decline about two weeks later than in the low CO_2 treatment. Good water supply had a similar but smaller effect.

The effects of water supply and of CO_2 supply on the morphology of leaves was different. Water supply increased both leaf area ratio (m^2 leaf area per kg plant weight) and leaf weight ratio (kg leaf weight per kg plant weight) without an effect on the dry matter percentage. CO_2 enrichment on the contrary diminished the leaf area ratio by about 10 %, notwithstanding an increase in leaf weight with 10 % of total plant weight. A much smaller specific leaf area (declining from about 300 to 180 cm^2 g^{-1}) under high CO_2 is the reason for this effect, partly caused by an increased dry matter percentage (from ≅ 15 to ≅ 20 %) in the leaves.

The fraction of root weight was initially 0.45, but in the linear growth phase (after harvest 3) it had reached a stable level of 0.25 (± 0.05) in all treatments. The water use efficiency in Fig. 1 is based on total dry matter, whereas transpiration coefficient is usually expressed as kg of water consumed per kg of shoot dry matter. With an observed root weight ratio of 0.25, the water use efficiencies are equivalent to transpiration coefficients of 270 and 170 in 350 and 700 cm^3 m^{-3} CO_2 respectively, independent of the level of water supply.

References

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