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The response of herbaceous plants to elevated CO₂

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SUMMARY

The greenhouse effect is, at the moment, a subject of great public interest. One of the atmospheric gases, involved in this effect, and hence in the atmospheric temperature increase, is carbon dioxide (CO₂). The CO₂ concentration in the atmosphere has increased steadily from 280 ppm, around 1880, to 350 ppm, in 1995.

Given the increasing use of fossil fuels and the deforestation rate, a doubling of the atmospheric CO₂ concentration can be expected during the next century. This, in turn may lead to a temperature increase.

Green plants play a role in the above described scenario, because, with the help of the sunlight, they are able to fixate the CO₂ molecules into carbohydrates (sugars), which process is called photosynthesis.

The photosynthetic rate can be stimulated by an increase in the CO₂ concentration of the atmosphere, provided there are no other limitations to the process, such as a deficiency of nutrients or insufficient light intensity.

The products of the increased photosynthetic rate can be used by the plant as a C reserve, mostly in the form of starch, but they can also be used for extra growth.

The aim of this thesis is to unravel the common mechanisms behind the different growth responses of plants to elevated CO₂, using a model plant. This kind of knowledge may, in its turn, be used to gain insight into the future composition of natural vegetations and the behaviour of both wild and crop species.

Young plants of *Plantago major* ssp. *pleiosperma* (vegetative phase) were chosen as a "model plant", and cultivated in aerated nutrient solution. The plants were grown in climate chambers, with artificial light and constant air temperature and relative humidity. A CO₂ concentration of 350 $\mu\text{L.l}^{-1}$ was used to simulate ambient CO₂ concentration, and a concentration of 700 $\mu\text{L.l}^{-1}$ for elevated CO₂ concentration.

In the first experiments (Chapter 2) plant growth was stimulated by elevated CO₂. However, when plant growth was quantified as relative growth rate (RGR, the plants were in an exponential growth phase) it was revealed that stimulation of RGR was transient, lasting only the first 8 days after transfer of the plants to elevated CO₂. After this short period, the RGR of both ambient and elevated CO₂-grown plants showed the same values. Apparently, after exposure to elevated CO₂ for 8 days, the plants were no longer able to use the extra carbon input for extra growth.

Summary

During the development of the main shoot and when a certain plant size is reached, secondary shoots begin to form at the base of the main shoot. This occurred earlier in elevated CO₂-grown plants.

The RGR of the secondary shoots of plants grown at elevated CO₂ was still increased by the end of the long-term experiments, in contrast to the RGR of the whole plant. It was shown that at least part of the extra C input can be used for the extra growth of these new plant parts (Chapter 3).

Correction of the RGR data for differences in plant size due to a more rapid increase in plant weight at elevated CO₂ (ontogenetic drift) revealed that a great part of the effects, observed at elevated CO₂, could be explained by ontogenetic differences. However, residual, elevated CO₂-specific effects remained, namely the stimulation of root growth and metabolism, as indicated by an increased root weight ratio (RWR).

These last effects were further investigated in detail, at the physiological and molecular level (Chapter 4 and Chapter 5). Exposure of the plants to elevated CO₂ lead to:

- i) an increase in root respiration.
- ii) an increased nitrate reductase (NR) activity.
- iii) increased levels of NR mRNA.
- iv) increased root reduced nitrogen concentration.
- v) decreased shoot reduced nitrogen concentration.

It was discussed that these effects could have been initially caused by an increased soluble sugar concentration in the roots of the plants, exposed to elevated CO₂. At elevated CO₂, an increased flux of soluble sugars from the shoots to the roots would take place during the period of stimulation of RGR (8 days). It was proposed that the development of the secondary shoots (visible on day 6 at elevated CO₂) changed the sink:source balance in the plant and diverted the flux of soluble sugars from the roots to the new sinks. This event caused the stimulation of the RGR of the total plant to be transient.

In Chapter 6 (Fig. 1) a model of the proposed sequence of metabolic and morphological changes caused by elevated CO₂ is presented.

It can be concluded that, by a doubling of the atmospheric CO₂ concentration, plant species, which growth pattern includes the formation of new sinks at a certain stage of development, may have an advantage in relation to plant species with a more structured growth pattern, that does not include branching or tillering.

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