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Ecophysiological responses by loess grassland vegetation to elevated air CO_2 concentration in a miniFACE system

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ABSTRACT The experiment focused on the responses by loess grassland vegetation to elevated air CO_2 concentration (EC) with N as the second factor. Investigated responses include growth dynamics at stand (LAI) and at individual plant level (RGR). Leaf scale CO_2/H_2O gas exchange, shoot carbohydrate content, canopy surface temperatures and above ground dry matter production have also been measured. LAI has been slightly decreased by EC concentrations in both the high and low N treatments. RGR was lower in the monocots in the EC treatment than in the ambient, while similar growth depression was not found in the dicots. These results are in agreement with the dawn-evening carbohydrate pattern and CO_2 gas-exchange in the leaves of the same species. Canopy surface temperatures were higher during the day in the EC treatment than in the ambient with average difference of 1.5°C. The yield has not increased in the multi-species loess stands due to EC.
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KEY WORDS

carbohydrates
elevated CO_2
growth
LAI
canopy temperature

The aim of the research project was to assess the long-term impacts of elevated air CO_2 concentration on continental temperate xeric semi-natural loess grasslands. The combined effects of EC and nitrogen status on the structure, physiology, production (amount and quality) and primary functions of the grassland ecosystem (carbon and water fluxes) were assessed within the framework of the "Managing European Grasslands as a Sustainable Resource in a Changing Climate (MEGARICH)" EU IV R&D program.

Materials and Methods

Experimental material, vegetation and site description

The mini FACE experimental system was set up at the "Global Climate Change and Plants" Experimental Ecological Station is located at the Botanical Garden Szent István University (SzIE), Department of Botany and Plant Physiology (NETT) Gödöllő. Vegetation

Species with high abundance in the original loess grassland (Salvio-Festucetum rupicolae Zólyomi) are *Festuca rupicola, Dactylis glomerata*, *Brachypodium pinnatum*, *Filipendula vulgaris and Salvia nemorosa.* The total number of species at the start of the experiment was 52. The parent rock is sandy loess and loess with humus and nutrient-rich A layer.

Area where monoliths were excavated from has been selected as to represent the original grasslands' botanical composition. After excavation to a depth of 40 cm the monoliths have been transported to the mini FACE station in July 1998.

Exposure system

The mini FACE exposure system consists of twelve 1.6x1.6m square plots. Air supply rings (diameter of 1.5 m) have been put into the squares providing six control rings and six rings with EC. The sample area is a 0.8x0.8m square plot in the middle of each ring consisting of four 0.4x0.4 m monolith replicates.

Carbon dioxide concentration of air within the CO_2 enriched rings has been maintained at 600 $\mu mol.mol^{-1}$.

Leaf scale CO_2/H_2O gas-exchange was measured with an LCA2 (ADC, Hoddesdon, UK) gas analyser as described elsewhere (Tuba et al. 1996).

A camera in the infrared region (type MX4, Raytek) was used to measure canopy surface temperatures. The camera was fitted on a console describing a circular path at 2m height over the mini FACE plots. Necessary hardware and software was developed locally.

Estimates of leaf area index values were calculated by using paired incident-transmitted PAR data from a CEP80 sunfleck ceptometer (Decagon) at each occasion. Relative growth rates in individuals of the selected species (*Dactylis glomerata*, *Filipendula vulgaris)* have been calculated from successive (7 to 10 days) measurements of characteristic (length, width) shoot/leaf dimension in 7 to 10 replicates.

Determination of carbohydrates followed Dubois et al. (1956).

Results and Discussion

Above ground biomass

There were no statistically significant differences between the treatments in the total above ground biomass in neither of the investigated years. The phenomena might well been related to the observations on the counteracting responses of monocots and dicots in photosynthetic acclimation, carbohydrate patterns and relative growth rates and is in agreement with leaf area index dynamics (see below). Under good water supply conditions the CO_2xN interaction manifested in

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higher biomass in this treatment, while under drought conditions slight positive effect of EC on yield was seen, with no positive effect of N addition in either of the two CO_2 concentrations.

Leaf area index

In the present study, consistently smaller LAI values under EC have been estimated on the base of PAR transmittance. Decrease of leaf area index has been reported (Lutze and Gifford 1998), as well as no change in LAI under EC (Niklaus et al. 1999). The smaller starting LAI values in the EC rings could have been the result of smaller LAR and SLA values. This is consistent with the findings that atmospheric CO_2 enrichment results in a reduction in leaf area ratio caused by decreasing SLA in *Dactylis glomerata* (Harmens et al. 2000), smaller SLA at EC in *Lolium perenne* swards (Daepp et al. 2000) and also in the dicot *Urtica urens* (Mariott et al. 2001) early in the growth period all cases. These results are consistent with the smaller relative growth rates for the monocot *Dactylis glomerata* when grown under EC concentration, but not with that for the dicot Filipendula *vulgaris*. The long-term upward type of regulation in P_N in *Filipendula vulgaris* was accompanied with higher RGR under EC in this study. The smaller LAI under EC is therefore a compounded response by the multi-species stands mediated both by the above growth responses and the relative covers of the constituting species. Under mild water shortage, EC partly alleviated the drought effect as shown by the higher RGR of LAI accompanied with higher soil water content data in the CO_2 enriched rings in the initial stress period.

Canopy surface temperatures

Canopy surface temperature of the vegetation in the CO_2 enriched rings was higher than that in the ambient rings. Given the same size, physiognomy and physical environments of the rings these data suggest that decreased leaf conductance and transpiration were responsible for the temperature difference between the plots (*e.g.* Pintér et al. 2000). The resultant soil water conserving effect had probably contributed to the higher RGR of LAI under drought in the high CO_2 rings, showing lower LAI values than the control ones in the start of the growth period, prior to development of the drought stress.

Growth dynamics

In the main monocot species *Festuca rupicola* and *Dactylis glomerata* the relative growth rate was suppressed under EC as compared with data from the control rings, while RGR was similar in the dicot *Filipendula vulgaris*. This difference between the functional groups seems to be consistent with results from the carbohydrate and gas exchange patterns for the same species. The notion of sink-driven down-regulation in the monocot is also supported by the findings, that compounded leaves have much greater capacity for indeterminate growth than simple ones. Report by Stulen et al. (2000) regarding the growth strategy of a plant as the major factor in explaining differences in carbohydrate partitioning and magnitude of growth stimulation by EC is also in support of the above. The observed decrease of RGR in the early stages of development under EC can be attributed to decreased SLA Harmens et al (2000) and to N-content mediated down-regulation of net CO_2 uptake and therefore NAR.

Leaf scale gas-exchange

Down-regulation of net CO_2 assimilation (P_N) in *D. glomerata* leaves was accompanied by build-up of non-structural carbohydrates in leaves from plants grown at EC concentration. Dependence of the phenomena on leaf protein nitrogen was reported (Bunce 2000; Harmens et al. 2000). In *Dactylis glomerata* the role of sink-limitation is crucial, because the major sink in the case of this species is growth of vegetative organs. Sink activity can be controlled by appropriate scheduling of cuttings (Hakala et al. 1999), pointing to one of the grassland sward management possibilities regarding the fast growing grasses where significant sink activity is limited to shorter periods. The long-term upward regulation of P_N in the leaves of *Filipendula vulgaris* points to this species' ability to maintain the sink strength longer in the growth period. In addition to photosynthetic down-regulation, growth (RGR) was also suppressed in the monocot and this might have contributed to the decrease on the above ground production of the swards (Loiseau and Soussana 2000).

Non structural carbohydrates

Level of soluble sugars at dawn was lower at ambient than at EC concentration in leaves of *Dactylis glomerata*, while this pattern was the reverse in leaves of *Filipendula vulgaris*. These data refers to an enhanced sink activity in the dicot *Filipendula vulgaris* grown under EC ($P<1\%$). These trends are in agreement with the gas exchange data and relative growth rate data of the same species.

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