Abstract

Atmospheric concentration of CO_2 is increasing, while its influence on plants is still not fully elucidated. Norway spruce (*Picea abies* L. Karst.) is an abundant conifer tree in European temperate and boreal forests, which behave as carbon sink in the global carbon cycle. The physiological response to elevated CO_2 concentration may be interconnected with changes in leaf anatomy and morphology. Needle structure is also determined by other factors in addition to CO_2 concentration, irradiance being the most important one. Thus, effect of irradiance was also included in our studies.

The effects of elevated CO_2 concentration and irradiance on Norway spruce needle structure were studied using new applications of well-established quantitative methods and novel methods enabling effective and unbiased analysis of needle structural traits. The General Procrustes analysis showed to be effective for needle shape on cross section comparison and the disector method proved to be suitable for chloroplast number estimates.

The influence of elevated CO_2 concentration and different irradiance on needle structure was studied at two hierarchical levels: At the level of needle morphology, irradiance was stronger morphogenic factor than elevated CO_2 concentration, while at the level of cell structure, the chloroplast density was enhanced by CO_2 concentration.

Irradiance microgradient within a shoot caused by needle self-shading was measured and shape differences among the needles within the same shoot were observed: Upper needles, i.e. needles growing from the upward side of the shoot, resembled sun needles by having larger cross-section area and less flat shape. However, the needle length was in counteraction as upper needles were rather shorter. Thus, needle volume differed following macroscale light gradient – needles from sun shoots had larger volume than needles from shade shoots regardless of their orientation on a shoot.

The main effect of elevated CO_2 concentration was stimulation of light-saturated CO_2 assimilation rate causing production of larger amount of starch in sun needles, which was accumulated in starch grains in chloroplasts. Larger starch grain area and starch areal density on cross section were observed in sun in comparison with those in shade needles in elevated CO_2 concentration. However, our observations may be influenced by the effect of the season on starch areal density under elevated CO_2 concentration.

In conclusion, anatomical studies contributed to integration of findings obtained by various types of analyses; thus, quantitative anatomy is inevitably important in the synthesis of knowledge how elevated CO_2 concentration may affect Norway spruce in the future.