INTERACTIVE EFFECTS OF ATMOSPHERIC CO_2 AND NITROGEN NUTRITION ON COTTON GROWTH

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Abstract

As humanities continue to cause perturbation in the atmosphere, cotton crops in the 21st century are expected to grow in dramatically different environments than today. Currently, atmospheric carbon dioxide concentration is about 360 μL L^{-1}, and there is general agreement among climatic and atmospheric scientists that the atmospheric carbon dioxide could be in the range of 510 to 760 μL L^{-1} sometime in the middle or latter part of the 21st century. The rising levels of atmospheric carbon dioxide concentrations are expected to affect cotton growth and development. In this study, the influence of atmospheric carbon dioxide concentration and nitrogen nutrition on cotton growth and development was evaluated. Upland cotton (c.v. Nucot 33B) was seeded 6 May 1998 in one meter deep soil bins of temperature-controlled plant growth chambers in a nearly natural environment. Each chamber was filled with fine sand, and seeds were placed 10 cm apart in three 66-cm rows. Throughout the experiment, the temperature in the chambers was maintained at 30/22°C, day/night. During the whole season, two carbon dioxide treatments, 360 (ambient) and 720 µL L^{-1}, were applied during the daylight hours. A complete Hoagland's nutrient solution was applied daily to each growth chamber via a drip irrigation system. At initial flowering, 53 days after emergence, the units were leached with water, and one unit was supplied nutrients with no nitrogen in each of the carbon dioxide treatments while the other chambers were supplied with a complete Hoagland's nutrient solution. During the experimental period, canopy photosynthesis was measured by a mass balance approach. From the photosynthetic light responses curves, canopy light utilization efficiency and canopy conductance were estimated each day in all treatments. At weekly intervals, topmost fully expanded leaves were used to determine leaf N by micro-Kjedahl digestion. To obtain relationships between leaf nitrogen and the measured parameters, daily leaf N was required. Leaf N data from the weekly measurements were regressed on days after treatment to obtain daily leaf N data using curve fitting procedures.

A striking feature of the studies examining the influence of both ambient and elevated atmospheric CO_2 concentrations on cotton growth is that the N concentration in the leaves was decreased by 11% on a dry weight basis by CO_2-enrichment. These reductions occurred despite continuous application of relatively high rates of N and other nutrients. Lower concentrations of N in the foliage has potential implications in agriculture, affecting C/N ratios. Foliar nutrient status not only affects insect biology and feeding rates, but also soil biota. Also, litter decomposition and mineralization are expected to be slower and stubble retention longer.

Carbon dioxide enrichment significantly increased canopy photosynthesis and the response to elevated CO_2 sustained throughout the growing season. The relative photosynthetic response to elevated CO_2 (photosynthesis at 720/360 µL L^{-1} CO_2 calculated at 1200 µmol mol^{-1} photons by regressing daily canopy net photosynthesis as a function of solar radiation) was 29% more during the boll-filling period. Like in many C_3 plants, these higher photosynthetic responses to elevated CO_2 were primarily due to greater flux of carbon through the photoreductive cycle and suppressed photorespiration. Canopy photosynthetic nitrogen use efficiency was higher for plants grown in elevated CO_2, and the relative response was greater at low to medium leaf N levels than at optimum leaf N. The changes in physiological and biochemical processes appear to alter foliar N concentrations required for maximum photosynthetic rates (90% of the maximum) and thus the productivity of cotton. Critical N concentration in the leaves was 3.1% for the ambient atmospheric CO_2 conditions. Elevated atmospheric CO_2 concentration decreased this critical N by 21%.

Canopy conductance was lower at elevated CO_2 but increased linearly with increases in leaf N concentrations in both CO_2 treatments. Canopy light utilization efficiency was greater at elevated CO_2 compared to ambient conditions. The response to leaf N concentrations was not different at various N levels except at very low N concentrations.

In summary, as the atmospheric CO_2 rises, fertilizer requirements for growing cotton will need reassessment. The current critical foliar nutrient concentration may not be valid in the future climates. Critical concentrations of leaf N appear to vary with CO_2 environment and will need continuous reassessment as CO_2 in the atmosphere continues to rise due to human activity. The positive aspect of rising levels of atmospheric CO_2 is that photosynthesis and thus productivity and yield of cotton are likely to increase. This is good news to all cotton farmers. Also, the greater photosynthetic nitrogen use efficiency at low to medium leaf N concentration may benefit resource-poor economies more than resource-rich economies as atmospheric CO_2 continues to rise.

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