Vegetative Storage Proteins: Response to Atmospheric CO$_2$ Enrichment
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In a paper published in Tree Physiology, Maier et al. (2008) describe how a soil nitrogen fertilizer application affected upper-canopy needle morphology and gas exchange in approximately 20-meter-tall loblolly pine (Pinus taeda L.) trees previously exposed to elevated atmospheric CO₂ concentrations (200 ppm above ambient) for nine years at the Duke Forest FACE facility in Orange County, North Carolina, USA. This work revealed that during the tenth year of exposure to elevated CO₂, there was a strong enhancement (greater than 50%) of light-saturated net photosynthesis across all age classes of needles, but that the stimulation was 28% greater in current-year foliage than in one-year-old foliage. In addition, they report that current-year foliage incorporated the added nitrogen into photosynthetic components that increased the photosynthetic capacity of the current-year foliage, but that the one-year-old foliage tended to simply store extra nitrogen, which subsequently served as "an important source of nitrogen for the development of current-year foliage" via "efficient retranslocation of nitrogen from senescing one-year-old foliage to developing foliage."

These findings echo those observed several years earlier in sour orange tree (Citrus aurantium L.) foliage in an open-top chamber experiment conducted at Phoenix, Arizona, by Idso et al. (2001), where half of the trees they studied had been grown from the seedling stage for the prior six years in air that was continuously enriched with an extra 300 ppm of CO₂. In the seventh year of that study, the Arizona researchers identified three putative vegetative storage proteins located within amorphous material in the vacuoles of leaf mesophyll cells that was rerouted, "starting at about day 25 of the new year, into developing foliage on the new branch buds of the CO₂-enriched trees." They speculated that this phenomenon may have been "the key that allows the CO₂-enriched trees to temporarily stockpile the unusually large pool of nitrogen that is needed to support the large CO₂-induced increase in new-branch growth that is observed in the spring," citing the

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work of Idso et al. (2000), who had previously found that 24 days after new-branch emergence in the spring, "the new branches of the CO2-enriched trees were, on average, 4.4 times more massive than the new branches of the trees growing in ambient air," and that "the total new-branch tissue produced on the CO2-enriched trees to that point in time was over six times greater than that produced on the ambient-treatment trees."

If there is a common mechanism that links the results of the two groups, it could well revolve around the hypothesized vacuolar storage proteins Idso et al. (2001) identified in the sour orange tree foliage, since they detected immunologically-related proteins in a variety of other citrus species, but not in 20 different grasses, shrubs and trees growing in the Biosphere 2 facility near Oracle, Arizona. This possibility is deserving of further study; for if found to have merit, Idso et al. (2001) further speculated that the proteins in question "could possibly be genetically exploited to enhance the responses of other plant species to atmospheric CO2 enrichment," which could prove to be a valuable property of agriculturally-important plants in a high-CO2 world of the future.

In a third study that bears upon the topic (Erice et al., 2007²), 30-day-old nodulated alfalfa (Medicago sativa L.) plants were grown in two temperature-gradient greenhouses (one maintained at an atmospheric CO2 concentration of 350 ppm and the other at a concentration of 700 ppm) in pots recessed into the ground in an alfalfa field under conditions of ambient temperature (TA) and elevated temperature (TE = TA + 4°C) and well-watered (to field capacity) and water-stressed (50% field capacity) conditions for one month, after which a first cutting took place, plus for one additional month, after which a second cutting took place, and where after each cutting plant dry matter production was determined, while taproots were analyzed for vegetative storage protein contents.

At the time of first cutting, it was determined that the alfalfa plants had had their dry matter production boosted by an average of about 30% in the well-watered treatment (averaged across both temperature treatments) over the first growth period, but by only about 10% in the water-stressed treatment. At the time of the second cutting, however, it was found that the well-watered plants had experienced an average dry matter production increase on the order of 20% over the second growth period, while the plants in the water-stressed treatment had experienced a mean increase of fully 40%. In addition, Erice et al. report that over the first growth period "taproot vegetative storage protein content increased in response to drought and elevated CO2."

The researchers thus stated, in this regard, that "it has been demonstrated that nitrogen pools in alfalfa taproot, especially vegetative storage proteins, condition new regrowing shoots," and that appears to be what happened in their study. At the end of the first growth period, for example, the enhanced taproot vegetative storage protein content in the water-stressed and CO₂-enriched treatment may have been the reason why the elevated CO₂ was so effective in stimulating biomass production in the water-stressed treatment over the second growth period.

This finding is somewhat analogous to the observation of Idso et al. (2001), who found that nitrogen reabsorbed from second-year leaves of sour orange trees (which hold most of their leaves for a period of two years) during the process of senescence in the fall was stored over winter in much greater amounts in putative vegetative storage proteins in first-year leaves of CO₂-enriched trees than in first-year leaves of trees growing in ambient air, so that when the stored nitrogen was released in the spring to produce a flush of new leaves on the trees, leaf production on the CO₂-enriched trees vastly outpaced the production of new leaves on trees growing in ambient air. Taken together, the above observations hint at yet another of the manifold benefits of atmospheric CO₂ enrichment.

REFERENCES


Cover photo of alfalfa field by Microsoft.