

ELEVATED CO₂ COMPENSATES FOR WATER STRESS IN NORTHERN RED OAK

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Global climate change models predict decreased rainfall in association with elevated CO₂ in the western Lakes States region. Currently, the western edge of northern red oak (*Quercus rubra* L.) distribution coincides with the most xeric conditions of its ecological range. Decreased rainfall and water availability could alter ecological fitness and distribution. To better understand how climate change may affect this species, we are examining the interaction of CO₂ (400, 520, 700 ppm CO₂) with water stress (well-watered and water-stressed) on growth, and carbon and nitrogen metabolism of northern red oak seedlings through three flushes of development. In this report, we focus on growth, photosynthetic rate, and nitrogen responses to these stresses in three-flush seedlings.

Seedling biomass increased with increasing CO₂ and decreased with water stress. The water stress response was accompanied by a shift in relative biomass distribution from stems to roots; CO₂ did not alter the relative distribution among leaves, stems, and roots. As a consequence, shoot:root dry weight ratio was decreased by water stress but remained uniform across CO₂ treatments.

Photosynthetic rate generally increased with elevated growth CO₂ and decreased with water stress. The response to CO₂ under water stress was approximately linear; under well-watered conditions, photosynthetic rate plateaued at 520 ppm CO₂. Stomatal conductance decreased in well-watered seedlings with elevated CO₂. Although conductance was decreased by water stress, these seedlings did not respond to growth CO₂. Thus, an increased diffusional gradient for CO₂ into the mesophyll of these water-stressed seedlings would be expected with increasing growth CO₂.

Photosynthetic water-use efficiency was largely unaffected by water stress but increased with growth CO₂ to a plateau at 520 ppm. In contrast, photosynthetic nitrogen-use efficiency was decreased by water stress and the response to growth CO₂ differed between water stress regimes. In water-stressed seedlings, nitrogen-use efficiency plateaued at 520 ppm growth CO₂. However, in well-watered seedlings, efficiency increased to 520 ppm but decreased to 400 ppm levels at 700 ppm growth CO₂. Tissue nitrogen concentration was apparently involved in this decrease because photosynthetic rate did not drop to this extent.

Leaves and roots of water-stressed seedlings displayed a greater nitrogen concentration than did those of well-watered seedlings and increasing growth CO₂ generally decreased nitrogen concentrations in these tissues. In well-watered 700 ppm CO₂ grown three-flush seedlings, nitrogen concentrations in the leaves and roots were relatively low at 1.4 percent and 0.9 percent, respectively. We hypothesize that nitrogen supply was unable to meet biomass demands associated with 700 ppm growth CO₂ under well-watered conditions. Consistent with this hypothesis, between 400 and 700 ppm growth CO₂ seedling biomass increased twofold for well-watered seedlings and nearly threefold for water-stressed seedlings.

These physiological responses to the interaction between elevated CO₂ and water stress resulted in similar 3-flush seedlings grown at 400 ppm CO₂ under well-watered conditions and at 700 ppm CO₂ under water-stressed conditions. The biomass, nitrogen concentration and photosynthetic rate of these seedlings were similar. Thus, in northern red oak, elevated CO₂ compensated for water stress. However, several physiological measures differed in these seedlings suggesting mechanistic differences. For example, differences in shoot:root dry weight ratio suggested changes in root-shoot interactions; differences in water-use efficiency suggested changes in photosynthetic mechanisms among these treatments. We are currently collecting data to delineate some of these physiological mechanisms.

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