

EFFECTS OF CARBON DIOXIDE ENRICHMENT ON RESPONSE OF PITCH PINE GROWN AT DIFFERENT NUTRIENT LEVELS TO ALUMINUM

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The effect of elevated CO₂ on the response of pitch pine (*Pinus rigida*) to aluminum was determined in three experiments with different nutrient levels. During each experiment seedlings inoculated with the ectomycorrhizal fungus *Pisolithus tinctorius* were grown for 13 to 15 weeks in sand irrigated with a nutrient solution (pH 3.5) containing 0, 6.25, 12.5, or 25 mg/L Al (0, 0.232, 0.463, or 0.927 mM Al, respectively) in growth chambers fumigated with 350 (ambient) or 700 (elevated) μ L/L CO₂. The concentration of mineral elements in the nutrient solution of the experiment with the lowest concentration of nutrients (X) simulated that in the soil solution of a nutrient poor, sandy New Jersey Pine Barrens soil. Levels of nutrients in the two other experiments were approximately two (2X) or four (4X) times higher. Total biomass of seedlings at the higher nutrient levels was 19 percent (2X) and 172 percent (4X) higher than that at the lowest nutrient level. Growth at elevated CO₂ was significantly greater than growth at ambient CO₂ at the 2X (+24 percent) and 4X (+22 percent) nutrient levels but not at the X level. At the 2X and 4X nutrient levels, aluminum significantly reduced shoot growth (biomass, needle length) and root growth (biomass, lateral root length) at both CO₂ levels and there were no significant Al $\times$ CO₂ interactions. At the lowest nutrient level only root growth was significantly reduced by Al. Symptoms of Al toxicity in needles differed depending on nutrient level: X, needle chlorosis at 12.5 and 25 mg/L Al at both CO₂ levels; 2X, tip chlorosis at 25 mg/L Al at ambient CO₂ only; and 4X, no needle chlorosis in any treatment. At all nutrient levels without Al, seedlings growing at elevated CO₂ had greater numbers of mycorrhizal roots than seedlings growing at ambient CO₂. In the presence of Al, mycorrhizal roots had greater Al-induced modifications (decreased numbers of bifurcate mycorrhizal roots, increased numbers of dark, stunted root tips) at the 2X and 4X nutrient levels than at the X nutrient level, especially at ambient CO₂. The CO₂ concentration did not significantly affect Al concentration in roots or needles at either 2X or 4X nutrient levels (elemental analyses for X nutrient level not available at this time). Carbon dioxide fumigation had a minor influence on the nutrition of treated seedlings. The greatest effect of CO₂ on foliar concentration of mineral elements was at the 2X nutrient level; needles at elevated CO₂ had small but significantly higher concentrations of Ca, Mg, Fe, and B than needles at ambient CO₂. Generally, Al decreased the concentration of mineral elements in roots and needles of treated seedlings. At all nutrient levels, disruption of root meristem cells and the mycorrhizal fungal mantle surrounding the short roots increased as Al concentration increased. In treatments containing 12.5 or 25 mg/L Al, aluminum was detected by energy-dispersive x-ray microanalysis in outer root cells and in dead root cells embedded in the fungal mantle.

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