DOE Final Technical Report

DOE Grant No. DE-FG02-98ER62680

Aspen-FACE (FACTS II) Decomposition Project

Title: Interacting CO₂ and O₃ effects on litter production, chemistry and decomposition in an aggrading northern forest ecosystem

PIs: Richard L. Lindroth and James G. Bockheim

Aug. 3, 2004

The overall purpose of this research was to evaluate the independent and interactive effects of elevated levels of CO₂ and O₃ on tree leaf litter quality and decomposition. This research was conducted at the Aspen FACE (Free Air CO₂ Enrichment) facility near Rhinelander, Wisconsin. This research comprised one facet of a larger project assessing how CO₂ and O₃ pollutants will alter carbon sequestration and nutrient cycling in north temperate forest ecosystems.

A 1-year decomposition experiment (begun 1998) consisted of four sub-experiments, addressing: 1) the effects of environmental differences incurred by the four fumigation treatments (control, +CO₂, +O₃, +CO₂+O₃) on mass losses in a common substrate; 2) substrate quality effects isolated from environmental variation in a common garden experiment; 3) assessment of substrate quality by environment interactions by replacing litter back into its native plot of origin; and 4) the effects of elevated temperature on mass loss dynamics in two target species (aspen and birch). Results from the first three experiments reveal that substrate quality (due to differences among fumigation treatments and plant species) can significantly alter litter decomposition rates, whereas the environment in which the litter decomposes has little to no impact (aside from temperature effects; see below). Overall, enriched CO₂, but not O₃, environments slowed decomposition of birch litter. The effects of CO₂ on aspen decomposition appeared to interact with temperature (below).

The fourth experiment was a passive temperature manipulation. The goal of this study was to assess whether the effects of temperature on decomposition varied from effects of substrate quality differences. Preliminary data analyses indicate that litter temperatures were 1.5 to 3.2 degrees higher in dark versus light-gray litter bags. These minor increases in temperature decreased time-to-95 % decay by one year in both species. Also, in the dark gray bags, we found that CO₂ was a strong driver of decomposition, especially for birch, and not for aspen; CO₂ enrichment retarded birch decomposition, but exerted no comparable effects on aspen at high temperature. At lower temperatures (i.e., litter in light-gray bags), elevated CO₂ strongly retarded mass losses in aspen and birch, especially when combined with O₃ exposure.

A 2-year decomposition experiment (begun 1999) was conducted to evaluate the impacts of elevated CO₂ and O₃ on long-term decomposition dynamics in aspen and birch leaf litter. The study again incorporated reciprocal transplantation of litterbags to separate substrate quality (litter chemistry) from environmental (fumigation treatment) effects. We monitored mass losses and changes in litter chemistry over 23 months. Mass loss rates (*k*-values) varied significantly among treatments and between tree species. For aspen, both CO₂ and O₃ retarded decay, and their effects were additive. Changes in loss rates were due primarily to shifts in litter chemical

composition rather than to changes in the environment in which decomposition occurred. For birch, elevated CO₂ and O₃ tended to hasten decomposition when administered independently, but failed to do so in combination. Accelerated birch decay was due to changes in both chemical composition and treatment environment. Differences in initial leaf litter quality were maintained between species and sustained for at least one year among fumigation treatments. Elevated C/N and lignin/N were sustained under CO₂ enrichment, and likely contributed to slower litter decay in aspen (elevated CO₂, elevated CO₂+O₃) and birch (elevated CO₂+O₃). Condensed tannins in aspen were initially higher under CO₂ enrichment, regardless of O₃ level. Starch was higher and lignin was lower initially in birch, which may explain why this species decayed as fast or faster under elevated CO₂ than under ambient conditions. *These results suggest that nutrient cycling dynamics of north temperate forest ecosystems will change under atmospheric conditions predicted for the future, and that the impacts of CO₂ and O₃ on litter decomposition will be species-specific.*

Aboveground estimates of litter production (2001, 2002) revealed that trees in elevated CO₂ produced more litter than did trees in other treatments. O₃ exposure did not significantly reduce cumulative litter production in either species, but did offset the increases in litter fall seen with CO₂ enrichment when the gases were added in combination. *These results indicate that in the future, ozone pollution may offset increases in plant growth and leaf litter production due to enriched CO₂.*

This project also contributed to the completion of several ancillary studies evaluating the impacts of CO₂ and O₃ on leaf chemistry and trophic interactions. We found, for example, that abundances and performance of leaf-feeding aphids differed among the different FACE treatments, and that these differences are due in part to fumigant effects on communities of insect natural enemies (predators and parasitoids).

Papers and other products delivered:

Journal articles:

Lindroth, R.L., B.J. Kopper, W.F.J. Parsons, J.G. Bockheim, D.F. Karnosky, G.R. Hendrey, K.S. Pregitzer, J. Isebrands, and J. Sober. 2001. Consequences of elevated carbon dioxide and ozone for foliar chemical composition and dynamics in trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). *Environmental Pollution* 115:395-404.

Parsons, W.F.J., B.J. Kopper, and R.L. Lindroth. 2003. Altered fine root chemistry of *Betula papyrifera* and *Acer saccharum* under elevated CO₂. *Canadian Journal of Forest Research* 33:842-846.

Percy, K.E., C.S. Awmack, R.L. Lindroth, M.E. Kubiske, B.J. Kopper, J.G. Isebrands, K.S. Pregitzer, G.R. Hendrey, R.E. Dickson, D.R. Zak, E. Oksanen, J. Sôber, R. Harrington, and D.F. Karnosky. 2002. Altered performance of forest pests under atmospheres enriched by CO₂ and O₃. *Nature* 420:403-407.

Karnosky, D.F., D.R. Zak, K.S. Pregitzer, C.S. Awmack, J.G. Bockheim, R.E. Dickson, G.R. Hendrey, G.E. Host, J.S. King, B.J. Kopper, E.L. Kruger, M.E. Kubiske, R.L. Lindroth, W.J. Mattson, E.P. McDonald, A. Noormets, E. Oksanen, W.F.J. Parsons, K.E. Percy, G.K. Podila, D.E. Riemenschneider, P. Sharma, R. Thakur, A. Sôber, J. Sôber, W.S. Jones, S. Anttonen, E. Vapaavuori, B. Mankovska, W. Heilman and J.G. Isebrands. 2003. Tropospheric O₃ moderates responses of temperate hardwood forests to elevated CO₂: a synthesis of molecular to ecosystem results from the Aspen FACE project. *Functional Ecology* 17:289-304.

Parsons, W.F.J., R.L. Lindroth, and J.G. Bockheim. 2004. Decomposition of *Betula papyrifera* litter under the independent and interactive effects of elevated CO₂ and O₃. *Global Change Biology* (in press).

Awmack, C.S., R. Harrington, and R.L. Lindroth. 2004. Individual performance does not predict aphid population responses to elevated atmospheric CO₂ or O₃. *Global Change Biology* (in press).

Technical Reports:

Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebles, D.R. Zak, R.L. Lindroth, S.C. Moser and M.L. Wilson. 2003. Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, MA, and Ecological Society of America, Washington, D.C.