CANOPY UPTAKE OF ATMOSPHERIC NITROGEN AT A CONIFER FOREST: ENHANCED PHOTOCHEMICAL EFFICIENCY AND RELATIONS TO NET ECOSYSTEM CO_2 EXCHANGE

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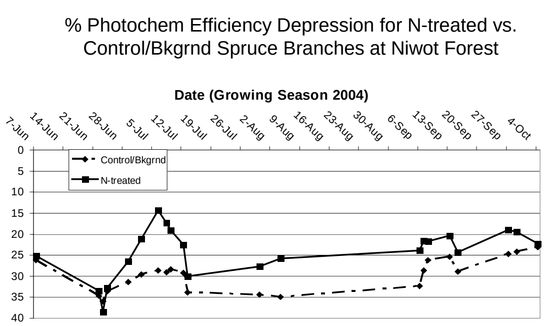
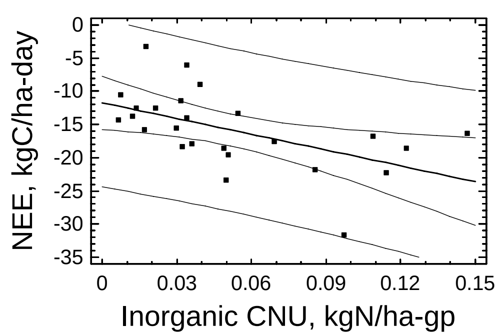
ABSTRACT
A field study at the Niwot conifer forest within the footprint of an AmeriFlux tower site used fluorometry (chlorophyll fluorescence) to identify a mechanism by which canopy uptake of atmospheric/anthropogenic N deposition may influence photosynthesis and net ecosystem exchange (NEE). Correlation of daytime NEE with canopy N uptake (CNU) had suggested a linkage. Strongly differing N additions were spray applied (simulating wet deposition) to spruce branches. Photochemical efficiency was markedly enhanced in N-treated branches under high light with a concomitant reduction in foliar photodamage and/or in PAR-induced foliar heat dissipation. Photosynthesis and NEE enhancement were statistically related to CNU.

Global carbon cycle modeling of the contribution that anthropogenic nitrogen (N) deposition makes to carbon sequestration generally assumes N deposition causes a proportional enhancement in carbon sequestration. Yet N deposition, especially at forests, may contribute to a wide range of ecosystem N cycling processes. Mechanisms that explain the influence of N deposition on photosynthesis, NEE, and/or carbon sequestration are lacking. Growing season N- and C-cycle studies at a Rocky Mountain (Niwot) conifer forest have been ongoing since 1999. Atmospheric wet plus dry deposition of, largely, anthropogenic N supplies half as much N as does soil/root derived N to the N demand by foliar new growth. Retention of deposited N by the canopy, or canopy N uptake (CNU), is high (>80%). Atmospheric N deposition (with CNU the majority of it) is, on a decadal time scale, the only significant source of new, available N at this (growth) N-limited forest. Photosynthesis at this site may, thus, be strongly influenced by CNU increments during the growing season. CNU data had been found to correlate well ($p<0.01$) with Niwot AmeriFlux daytime NEE data during the growing season.





To assess how this conifer canopy uptake of mainly anthropogenic N may be influencing growing season NEE a 2004 field study utilized foliar scale IRGA and fluorometry (chlorophyll fluorescence) measurements at Niwot spruce trees. N-treated and control branches on each of three spruce trees were sprayed with ion water solutions (enhanced NH_4^+ and NO_3^- vs. zero-N in solution with other ion concentrations at their mean natural precip. levels) to simulate strongly differing CNU applications. Background branches having no spray applications, to consider the influence of non-N ion solution water, were also studied.

Fluorometry provides PSII (site where water is split into molecular oxygen, electrons and protons) photochemical efficiency (ψ) data. See the left figure above for results. In this figure, daytime ψ values are compared with maximum ψ values (latter obtained pre-dawn when chlorophyll has fully relaxed) on a per branch basis. Percent depression of ψ values, from 0% depression predawn, across the 2004 growing season are shown for the N-treated branches and for control/background branches. (Control and background branch ψ data were not significantly different, confirming that the non-N ion solution water made no observable contribution to ψ.) The addition of N in simulated CNU reduced daytime depression in ψ substantially throughout the growing season; i.e., higher PSII photochemical efficiency was found for N-treated branches. This resulted from a total of 14 simulated wet deposition events, spaced about 6 days apart, during the first 2/3rds (approx.) of the time period shown in the left figure. Note that higher ψ, at times up to 20% greater, were found to prevail consistently for N-treated branches across the 4-month measurement period. Further, no cumulative influence was found. Rather, a short-term response in ψ was seen, keeping daytime ψ values consistently higher for N-treated branches.

These, and other fluorometry data to be presented, lead to the following argument: Canopy N uptake by conifer forest foliage may rapidly (several hours to a few days) enhance the photosynthetic apparatus of needles so that more PAR may be utilized for photosynthesis, and, perhaps, NEE as well as (ultimately) carbon sequestration. As a consequence, high light periods cause less foliar photodamage and also less PAR to be dissipated as heat from the foliage. IRGA data support this argument since V_{cmax} for N-treated branches was 15% greater than control and background branch V_{cmax} ($p<0.05$).

The figure on the right above shows Niwot daytime NEE data regressed against inorganic CNU for time periods from the end of one precip. event to the end of the ensuing precip. event. (These growing periods, gp in fig., are 3-4 days-long at the Niwot forest.) Inorganic CNU explicitly excludes uptake of organic N since it was observed that net canopy retention of organic N in precip. is essentially zero.) Data shown are for one entire growing season. Linear regression ($p=0.006$; statistically better than non-linear) resulted in 27% of daytime NEE variability explained by CNU. Multiple regression, considering over 20 parameters' data, showed CNU as the second most explanatory parameter after light (ppfd) with 22% of daytime NEE variability explained ($p<0.01$). With greater amounts of CNU, there is good statistical confirmation that daytime NEE during the growing season is enhanced.

Based on the combined flourometry, IRGA, and NEE vs. CNU results to date, a strong case is made for conifer canopy uptake of atmospheric N deposition contributing to enhanced NEE. Further, the fluorometry data argue for the mechanism by which this may occur being increased foliar photosynthetic apparatus and light utilization (high ψ). This, especially under high light conditions when, otherwise, foliar photodamage and excess light dissipation as heat would be more active. Ongoing field studies are attempting to quantify these linkages between atmospheric N deposition, CNU, ψ, NEE, and (ultimately) carbon sequestration.