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A Comparison of Impacts of N Deposition Applied as NH_3 or as NH_4Cl on Ombrotrophic Mire Vegetation

By

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Summary

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The impacts of increased N deposition (wet; NH_4^+ and dry; NH_3) on ombrotrophic mire vegetation were compared in a two-year dose-response study. Vegetation from an ombrotrophic mire in SE Scotland was exposed in open-top chambers to a range of wet N deposition at 0 (de-ionised water), 8, 16, 32, 64 & 128 kg N ha⁻¹ y⁻¹ applied as NH_4Cl and dry N deposition as gaseous NH_3 at concentrations of 2, 6, 20, 50 & 90 $\mu\text{g m}^{-3}$. N concentrations in the foliage of all species showed a significant linear increase in response to dose when N was applied as wet deposited NH_4^+ in both 1999 and 2000. Comparison of the linear regression for foliar N versus NH_4^+ and NH_3 in the dose-response relationships showed significant differences ($p < 0.05$) between the form of N applied and %N concentration for two species in 1999 (*C. vulgaris* and *P. commune*) but not in 2000. There was a significant increase in *C. vulgaris* shoot growth in the NH_3 treatments compared to NH_4^+ treatments when expressed per unit deposited N. Effects of nitrogen deposited as gaseous NH_3 are generally greater than those of wet deposited NH_4^+ on moorland species, when expressed per unit deposited N.

Introduction

Increases in both wet and dry N deposition have been reported throughout Europe in the past 30 years ('UNITED KINGDOM REVIEW' 1994). Enhanced N input

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to semi-natural lowland heaths has caused changes in species composition, stimulation of secondary environmental stresses such as drought, frost and insect infestations (AERTS 1989, CARROLL & al. 1999, POWER & al. 1998). Studies of enhanced N deposition on semi-natural communities such as ombrotrophic mires and moorland have generally reported effects of wet deposition as NH_4^+ and NO_3^- (GORDON & al. 1999, CARROLL & al. 1999). Although critical loads for N, set to protect these sensitive communities are 5-10 and 10-20 $\text{kg N ha}^{-1} \text{y}^{-1}$ respectively, the effects of increased dry N deposition as NH_3 or a comparison of NH_4^+ and NH_3 have not been widely reported (LEITH & al. 2001a).

In order to compare directly the effects of increased wet NH_4^+ deposition (expressed as $\text{kg N ha}^{-1} \text{y}^{-1}$) and dry NH_3 concentrations ($\mu\text{g m}^{-3}$) the deposition rates ($\text{kg N ha}^{-1} \text{y}^{-1}$) of NH_3 must be determined. To estimate NH_3 deposition, deposition velocities, canopy resistances and their dependence on ambient NH_3 concentrations must be known. Effects research to date has generally assumed that the dry deposition rate of NH_3 increases linearly with ambient NH_3 concentration, i.e. that deposition velocity is constant with increasing concentration. FLECHARD & FOWLER 1998 have shown that deposition velocity decreases as NH_3 concentration increases in the range 0.1-2.0 $\mu\text{g m}^{-3}$, due to chemical processes at the vegetation surface. However, this concentration range is not sufficiently wide to cover the range of NH_3 conditions in the UK where ambient concentrations close to point sources often exceed 10 $\mu\text{g m}^{-3}$.

In a 2-year open-top chamber (OTC) study, the effects of N form (NH_3 versus NH_4^+) on nutrient-limited, upland ombrotrophic mire vegetation (7 species) were compared in N dose-response experiments. The vegetation was exposed to a range of wet N deposition treatments (0-128 $\text{kg N ha}^{-1} \text{y}^{-1}$) applied as NH_4Cl and dry deposition as gaseous NH_3 at a range of concentrations (2-90 $\mu\text{g m}^{-3}$) for 2 field seasons (1999 and 2000). These concentrations are typical of gaseous NH_3 concentrations found in close proximity to intensive livestock units (FOWLER & al. 1998). Rates of NH_3 dry deposition were measured over a range of concentrations in a flux chamber to quantify inputs to the vegetation and the dependence of deposition rate on the NH_3 concentration.

Material and Methods

Measurements of NH_3 deposition velocities were made over ombrotrophic mire vegetation (identical to that used in the dose response experiment), using an additional OTC with a purpose built flux chamber. A full description of methods and results is given in LEITH & al. 2001b. This enabled deposition rates ($\text{kg N ha}^{-1} \text{y}^{-1}$) at a range of ambient NH_3 concentrations to be calculated. By applying the calculated deposition velocity to the measured NH_3 treatment concentrations the NH_3 deposition could be determined.

In the summer of 1998, a central square (1.75m x 1.75m; area = 3.06 m^2) in each of eleven OTC's was excavated to a depth of 50 cm. The excavated areas were then back-filled with peat and individual plants of seven species, *Calluna vulgaris* (L.) Hull, *Narthecium ossifragum* (L.) Hudson, *Potentilla erecta* (L.) Rauschel, *Deschampsia flexuosa* (L.) Beauv., *Eriophorum vaginatum* (L.), *Polytrichum commune* Hedw. and *Molinia caerulea* (L.) Moench from an ombrotrophic mire (30

going from the lowest and highest NH_4^+ treatments in 1999 and 2000 respectively. The decrease in % N concentration in the second year of treatment could be due to

Table 1. Linear regression analysis of foliar N with applied N as NH_4^+ or NH_3 in 1999 and 2000. The difference in response to NH_3 and NH_4^+ (*Prob.) was tested using a generalized linear regression model, where the slope and r^2 refer to mean values of 5(6) points. Data marked with an asterisk (*) are statistically significant at $p < 0.05$.

%N concentration	NH_4^+ (kg N ha ⁻¹ y ⁻¹)		NH_3 (kg N ha ⁻¹ y ⁻¹)		Prob. NH_4^+ Versus NH_3
	Slope	r^2	Slope	r^2	
1999					
<i>C. vulgaris</i>	0.004*	0.98	0.013*	0.96	0.003*
<i>M. caerulea</i>	0.006*	0.79	0.090	0.70	0.572
<i>E. vaginatum</i>	0.006*	0.91	0.001	0.01	0.314
<i>P. erecta</i>	0.011*	0.76	0.017	0.61	0.505
<i>D. flexuosa</i>	0.011*	0.90	0.022	0.61	0.116
<i>P. commune</i>	0.010*	0.93	0.033	0.86	0.007*
<i>N. ossifragum</i>	0.005*	0.78	0.008	0.43	0.536
2000					
<i>C. vulgaris</i>	0.004*	0.98	0.006*	0.89	0.106
<i>M. caerulea</i>	0.017*	0.88	0.004*	0.87	0.562
<i>E. vaginatum</i>	0.006*	0.96	0.005*	0.95	0.167
<i>P. erecta</i>	0.006*	0.71	0.008	0.91	0.530
<i>D. flexuosa</i>	0.011*	0.88	0.012*	0.96	0.716
<i>N. ossifragum</i>	0.007*	0.92	0.008*	0.93	0.542
<i>S. capillifolium</i>	0.010*	0.94	0.027*	0.91	0.068

growth dilution. PRINS & al. 1991 also found an increase in % N in *C. vulgaris* in response to increased NH_4^+ deposition. In the NH_3 treatment, only *C. vulgaris*, and *P. commune* showed a significant response to increasing N additions and also to the form of N applied (Table 1) in 1999. Both species exhibited greater N uptake when N was supplied as NH_3 rather than as NH_4^+ on a per unit N basis. A linear dose response relationship was also found by PITCAIRN & al. 1995, 1998 for a number of species including *C. vulgaris*. This dose response relationship found for both N forms is further support for the use of foliar N concentration as a bio-indicator of N deposition.

A significant relationship between % N and deposition was found for all species except *P. erecta* in the NH_3 treatments in 2000. This increase in foliar N concentration with increased NH_3 concentrations has been found in a number of species (FANGMEIER & al. 1994). It is not clear why this significant linear relationship was not found in 1999, but was present in the second year of treatment (2000) for *M. caerulea*, *E. vaginatum*, *D. flexuosa* and *N. ossifragum*. In contrast to 1999, none of the species in 2000 showed significant differences between the form of N applied and % N in the foliage.

Enhanced N deposition increased shoot extension in *C. vulgaris* in each year of N treatment. This is consistent with the results of CARROLL & al. 1999. Analysis of individual N treatment growth data found that Gompertz curves could be fitted to all individual treatment shoot elongation curves. There was a significant difference ($p < 0.001$) between the two N forms with NH_3 treatments increasing

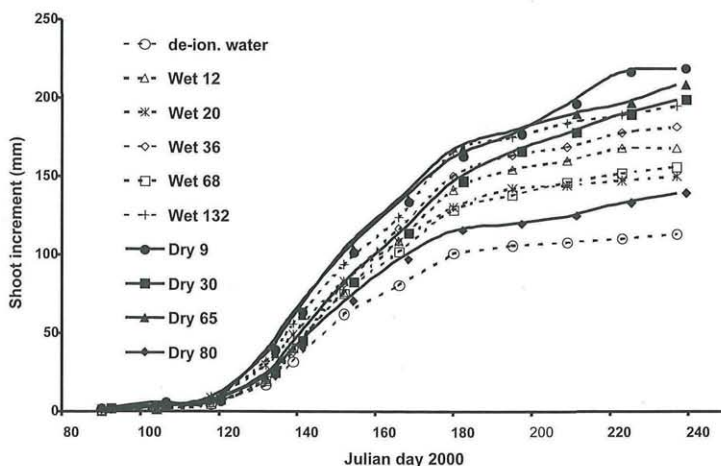


Fig. 1. Shoot extension of *C. vulgaris* shoot extension from April to September 2000. Numbers in legend refer to N deposition rate ($\text{kg N ha}^{-1} \text{y}^{-1}$).

shoot elongation compared to NH_4^+ treatments. This difference could be increased by excluding the high NH_3 treatment ($61 \text{ kg N ha}^{-1} \text{y}^{-1}$) and was not included as a separate component in the analysis, because shoot elongation was significantly decreased in this high NH_3 treatment. This could be attributed to changes in shoot morphology with increased lateral branching of the terminal shoot in the highest NH_3 treatments compared to other N treatments. Comparison of the dry weights of 3 cm length of *C. vulgaris* shoots showed a 35 % increase in weight in the highest NH_3 treatment compared to lowest. Generally, on an N input basis, N applied as dry NH_3 increased shoot extension more than wet NH_4^+ . The de-ionized water treatment had the smallest shoot extension compared to all the other N treatments irrespective of N form. This could be attributed to N deficiency as the foliar % N concentration decreased from 1.75 % in 1999 to 1.4 % in 2000.

This study has shown that NH_3 uptake is greater on a per unit of N deposited than NH_4^+ uptake and that the form of N applied influenced the assimilation of N and growth rates in *C. vulgaris*.

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