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BRIEF COMMUNICATION

Effects of ammonia emission on epiphytic lichen vegetation

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SUMMARY

Lichen vegetation on oak was studied along two transects from a nature reserve with a low ammonia emission into an intensive animal husbandry area with high ammonia emission. Acidophytic species were dominant in the nature reserve, whereas nitrophytic species dominated in the agricultural area. Bark analysis showed the pH to be more important for species composition than the ammonium concentration. Ammonia emission favours nitrophytic species by raising the pH of oak bark, which is normally in the range 3·5–5·0. This phenomenon has been observed in many sites in The Netherlands, where it replaces earlier acidification by sulphur dioxide.

Key-words: ammonia, bark analysis, epiphytic lichens.

INTRODUCTION

In The Netherlands, many epiphytic lichen species became more common between 1970 and 1985 (de Bakker *et al.* 1987). This may be due to a decline in atmospheric sulphur dioxide (SO_2) concentrations (Rose & Hawksworth 1981). In particular, so-called 'nitrophytic' species have recovered more frequently than others. In areas with intensive animal husbandry, where much ammonia is emitted, the formerly dominant acidophytic species such as *Lecanora conizaeoides* Nyl. ex Crombie, *Evernia prunastri* (L.) Ach. and *Hypogymnia physodes* (L.) Nyl. are substituted by nitrophytic species of the genuses *Physcia*, *Xanthoria* and *Candelariella* (Anonymous 1988).

MATERIALS AND METHODS

In April 1986, lichen vegetation on wayside oaks was studied at 28 sampling stations along two transects in the Peel near Venray (Fig. 1). The transects ran from an agricultural area with a high level of ammonia emission (due to intensive animal husbandry) into the nature reserve 'Mariapeel', where ammonia emission is low. Ammonia emission within 600 m from each sampling station was estimated by multiplying the licensed number of cattle with a specific emission factor (van der Voet & Udo de Haes 1985). Bark samples were collected for analysis of pH, conductivity, NH_4^+ and NO_3^- concentrations (Table 1) according to de Bakker & van Dobben (1988).

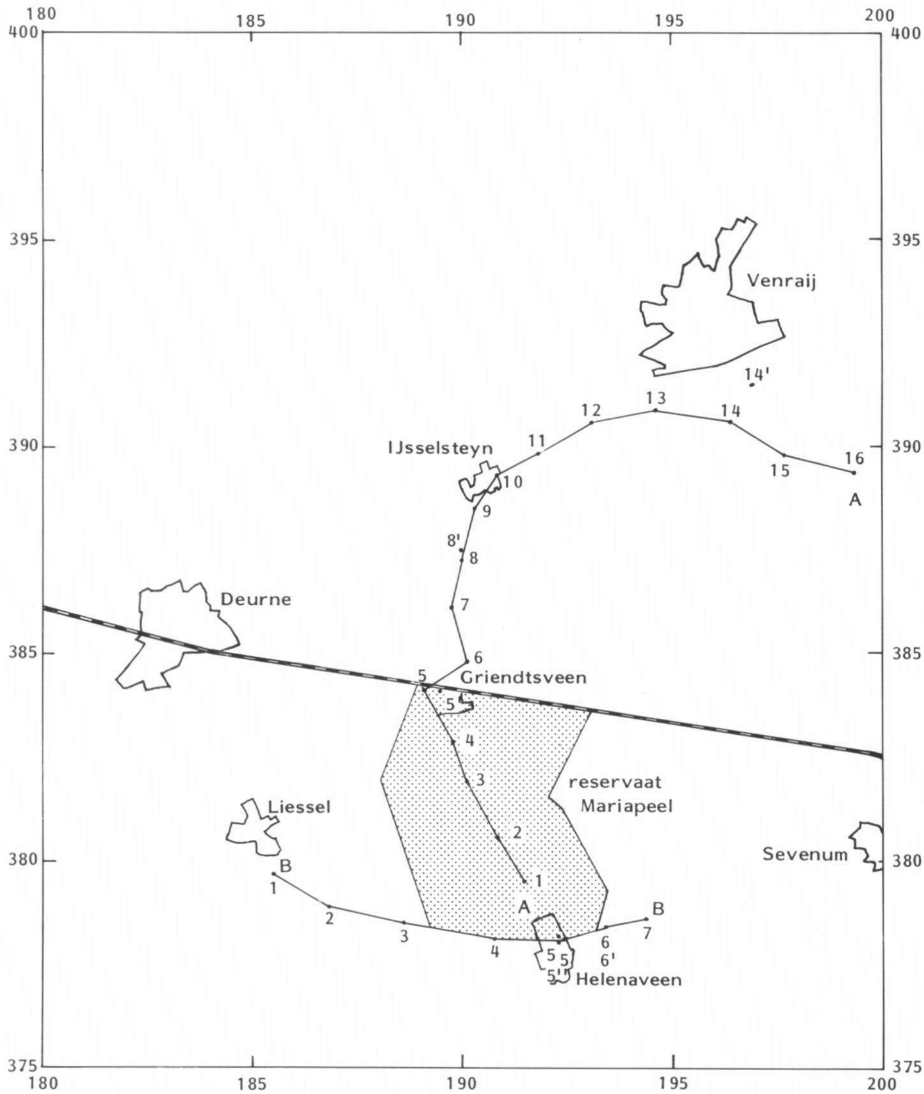

Fig. 1. Location of the sampling stations along two transects south of Venraij (The Netherlands)

RESULTS AND DISCUSSION

Epiphytic lichen vegetation in the agricultural area proved to be very different from that in the nature reserve (van Dobben 1987; de Bakker & van Dobben 1988). On oaks in the nature reserve acidophytic species dominated, whereas nitrophytic species were dominant in the agricultural area (Table 2).

Ammonia can affect lichens in two ways. It can raise bark pH or raise the ammonium concentration. Normally, the pH of an oak tree is 3·5–5·0. On tree bark ammonia causes a pH increase. Nitrification probably does not take place, because NO_3^- concentrations proved to be very low. Growing conditions for acidophytic species are detrimentally affected by a rise in bark pH, while they improve for nitrophytic species. There is some

Table 1. Code, location and estimated ammonia emission within 600 m, circumference of the tree and bark properties of the sampling stations

Code	Coordinates of Dutch triangulation *x* *y*	NH_3 emission (kg year^{-1})	Circumference (cm)	pH	*EC* (mS m^{-1})	[NH_4^+] (mg kg^{-1})	[NO_3^-] (mg kg^{-1})
A1	191·5/379·5	2427	200	4·50	14·0	9·7	0·03
A2	190·9/380·5	3049	220	4·71	12·5	8·2	0·01
A3	190·1/381·9	715	200	4·53	12·5	7·3	0·03
A4	189·8/382·8	0	210	4·14	8·9	4·0	0·02
A5a	189·5/384·1	0	260	4·31	21·2	13·5	0·01
A5	189·1/384·1	2171	180	4·73	14·1	6·4	0·03
A6	190·1/384·8	38234	120	5·02	14·7	2·7	0·01
A7	189·8/386·1	81680	120	5·55	18·6	7·0	0·03
A8	190·0/387·3	84116	130	5·32	22·4	4·4	0·03
A9	190·3/388·5	47427	130	5·11	16·8	1·5	0·01
A10	190·8/389·3	140072	140	4·50	18·0	1·9	0·03
A11	191·8/389·8	88724	100	5·53	22·5	3·0	0·03
A12	193·1/390·6	25109	260	5·26	16·6	12·5	0·05
A13	194·6/390·9	56763	240	5·49	15·4	9·3	0·03
A14	196·4/390·6	33776	200	5·28	19·8	13·7	0·04
A14a	196·9/391·5	33990	100	4·72	20·4	1·9	0·03
A15	197·7/389·8	56463	200	6·10	18·5	9·9	0·02
A16	199·3/389·4	78041	300	6·06	22·2	18·4	0·02
B1	185·5/379·7	14578	150	5·13	19·2	13·0	0·04
B2	186·8/378·9	28061	100	4·85	14·6	2·1	0·04
B3	188·6/378·5	30038	100	4·96	18·0	1·8	0·08
B4	190·8/378·1	9790	110	4·68	15·8	1·5	0·18
B5	192·3/378·2	1800	140	4·26	13·8	1·3	0·03
B5a	192·4/378·1	1800	230	*	*	*	*
B5b	192·3/378·0	4005	300	*	*	*	*
B6	193·4/378·4	4218	100	*	*	*	*
B6a	193·4/378·4	4218	100	4·79	17·6	2·6	0·03
B7	194·4/378·6	25008	100	4·73	14·9	1·9	0·02

pH = pH (H_2O), EC = electrical conductivity at 25°C, * = no analysis.

field evidence that ammonia is toxic for certain acidophytic species, but this is not taken into account here.

A permutation test on residual variances of means of species, as determined by Canonical Correspondence Analysis, was used to assess the importance of pH and ammonium to species composition (ter Braak 1987). pH was proved to have an effect on its own (P= 0·06), whereas NH_4^+ effects could only be detected after correction for pH (P=0·02).

pH is strongly correlated with NH_3 emission (P<0·01) whereas the ammonium concentration is not. NH_4^+ in bark samples is strongly correlated to the trunk periphery. A possible explanation for this is an increase in the roughness or adsorbing capacity of bark with age.

The number of nitrophytic species correlates significantly with bark pH but not with its NH_4^+ concentration. This suggests that the so-called 'nitrophytic' species need a high bark pH rather than a large supply of nitrogen. This view is supported by the high abundance

Table 2. Abundance of epiphytic lichens on oaks along two transects in the Peel. Each sampling station consisted of 10 trees. Species names are according to Brand *et al.* (1988)

	Nat.						Agr.												Agr.			Nat.				Agr.		
	A1	A2	A3	A4	A5	A5a	A6	A7	A8	A9	A10	A11	A12	A13	A14	A14a	A15	A16	B1	B2	B3	B4	B5	B5a	B5b	B6	B6a	B7
Acidophytic species																												
Evernia prunastri (L.) Ach.	5	3															2		1	3		3			1			
Hypogymnia physodes (L.) Nyl.	3		3	2																		3						
Lecanora aitema (Ach.) Hepp.																					1	2						
L. conizaeoides Nyl. ex Crombie	6	6	6	6	5	6																3	6	6	6			
L. pulicaris (Pers.) Ach.		1	3																					1				
L. symmicta (Ach.) Ach.	1			2													1											1
Lepraria incana (L.) Ach.	5	5	5	5	5	5							5	5			3							5	5			
Indifferent species																												
Bacidia arnoldiana Koerber								2																				
Buellia punctata (Hoffm.) Massal.	5	5	3		4	2	6	6	6	6	6	5	6	6	6	6	6	5	6	6	5	5		2	3	5	5	5
Cliostomum griffithii (Sm.) Coppins		3																										
L. chlarotera Nyl.								1					3	2			1		2		1							
L. expallens Ach.	2		2		2		3						3	3	3		3	3	5	3		3			2		3	
Lecidella elaeochroma (Ach.) Choisy							3	3	1	3	3	3				3					2	2						3
Lecidella spec.	2												3															

Parmelia acetabulum (Necker) Duby	2											2		2								
P. exasperatula Nyl.														2								
P. subaurifera Nyl.				1													1		3			
P. subrudecta Nyl.											1					1	1		1			
P. sulcata Nyl.		1	1	5		3	1	1	1	3	3	5		3		2	5	5	5	1	5	3
P. tiliacea (Hoffm.) Ach.														1								
Ramalina farinacea (L.) Ach.														2			1					
Nitrophytic species																						
Candelariella reflexa (Nyl.) Lettau																		1				
C. vitellina (Hoffm.) Mull. Arg.				2	3					3	2			3								3
L. dispersa (pers.) Sommerf.							5	5	5	5			5	3								6
L. hagenii auct.					6	6	6	6	6	3			6					3	3			6
L. muralis (Schreber) Rabenh.														3								1
Phaeophyscia orbicularis (Necker) Moberg					3	5	1	6	6	1		1	3					2	2			2
Physcia adscendens (Fr.) H. Olivier				3	6		3	5	5	5	3	1	3	1		3	3	5	5			
Ph. caesia (Hoffm.) Furnrohr				1	3	5	3	3	3	3	3	3	1	3		3	3	1	5			
Ph. dubia (Hoffm.) Lettau	1					2				5	3	3	2	5					5			
Ph. stellaris (L.) Nyl.									1													
Ph. tenella (Scop.) DC.			3	3	6	6	3	2	3	5	5	3	5	5	2	5		5	5	3	5	5
Physconia grisea (Lam.) Poelt.						1																
Xanthoria candelaria (L.) Th.Fr.										2	4		2	2				3				
X. parietina (L.) Th.Fr					1	1		3	3	3			3				1	1				
X. polycarpa (Hoffm.) Rieber				3	3		3	3	3	3			3	1		2	1	3	3			3

Abundances are according to a modified Tansley scale: 1 = one thallus only, 2 = on one tree only, 3 = rare, 4 = occasional, 5 = frequent and 6 = dominant. Nat. = Nature reserve, Agr. = Agricultural area.

of nitrophytic species near cement factories and along the coast, where the pH is high in the absence of an additional supply of nitrogen (Gilbert 1976). Of course nitrification following a pH increase remains a possibility, although in our samples we measured very low nitrate concentrations. Apparently more detailed studies into this area are needed before the name 'nitrophytic species' can be modified to 'neutrophytic species', as suggested by Du Rietz (1924).

From a nature conservation point of view, the expansion of nitrophytic species should not be welcomed too warmly. Many species with a narrow ecological range still have not recovered. In order to allow lichen vegetation to return to its normal state, the emission of both NH_3 and SO_2 should be further reduced.

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