Peat Nitrogen Status and Its Effect on the Nutrition and Growth of Scots Pine (*Pinus sylvestris* L.) on an Afforested Mire

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The interrelationships between the peat total and mineral nitrogen concentrations at different times during the unfrozen period and the relationships between them and nitrogen, phosphorus, potassium and boron nutrition and growth of Scots pine (*Pinus sylvestris* L.) were studied on a drained, afforested and fertilised mire having a wide peat total nitrogen gradient (0.87% -2.91%) in eastern Finland. Three different fertilisation treatments were involved: PK, PKB and wood ash all with six replicates, chosen evenly along the nitrogen gradient. The highest mineral nitrogen concentrations were in the 0-5 cm peat layer. The main form was NH_4-N. It correlated closely with the total N concentrations at all sampling times but NO_3-N only occasionally. The concentrations decreased towards autumn. Stand growth responded similarly to different fertilisation treatments. Needle nitrogen concentrations and stand growth correlated closely positively with total peat N and Fe but negatively with the C/N ratio. Needle phosphorus correlated positively but boron negatively with peat total N.

Key words: Ammonium, boron, C/N ratio, mineralisation, mire, needle nutrients, nitrate, nitrogen, nutrition, peat, peatland, phosphorus, Scots pine, *Pinus sylvestris*, potassium, stand growth.

Introduction

On boreal forested peatlands stand growth increases from nitrogen poor dwarf shrub pine bogs and low sedge spruce swamps towards nitrogen rich pine and spruce mires (Huikari 1952, Heikurainen 1959b, 1960, Holmen 1964, Westman 1981, Keltikangas *et al.* 1986, Kaunisto & Paavilainen 1988). Holmen (1964) and Silfverberg & Huikari (1985) also found a positive relationship between the peat nitrogen concentrations and stand growth. Similarly, on afforested originally treeless mires pine growth increased along with the increasing gradient of the total peat nitrogen concentration (Kaunisto 1982, 1985 and 1987).

It seems, however, that very high peat nitrogen concentrations may lead to reduction in pine growth (Kaunisto 1987). This was attributed to excess nitrogen mineralisation and the consequent imbalance between nitrogen and some other nutrients leading to needle and bud damage during winter. Nitrogen mineralisation in different peat types and in the connection with different fertilisation or soil amelioration treatments has been studied especially in the British Isles by using different incubation methods (Gardiner 1975, Gardiner & Gegghegan 1975, Williams & Cooper 1979, Williams 1983, 1984, Williams & Wheatley 1988, 1992). Williams (1984) showed in an incubation experiment that the amount of mineral nitrogen correlated with the total peat nitrogen concentration. In peatland forests, however, the relationship between the mineral nitrogen and the peat total nitrogen concentration is more complicated, because, in addition to the total peat nitrogen concentration, the magnitude of nitrogen mineralisation depends also e.g. on water regime (Williams 1974, Williams & Wheatley 1988) and temperature (Kaunisto & Norlamo 1976) of the substratum.

The aim of the present study is, on an afforested mire with a wide gradient of peat total nitrogen concentration, to clarify 1) the relationships between the peat total and mineral nitrogen concentrations at different times during the unfrozen period, 2) the relationships between peat nitrogen and the nitrogen, phosphorus, potassium and boron nutrition of Scots pine, and 3) the relationship between peat total nitrogen concentrations and the growth of pine stands.

Material and methods

Site and treatments

The experimental area (Särkkä) is located (62° 45' N, 31° 00' E and 148 m a.s.l.) in the easternmost part of Finland (for more details see Kaunisto 1987, Hartman *et al.* 2001). This originally treeless mire was drained in 1970-71 with 40-metre ditch spacing and ploughed with a double mould board plough. Scots pine was sown on the spots in 1970 and 1971. All sowing spots were fertilised with a NPK multinutrient fertiliser for peatland forests (Suomaiden Y-lannos: (14-8-8) 30 g per spot (= 0.25 m^2).

A refertilisation experiment involving altogether 143 experimental plots was established in the area in 1981-82 (Kaunisto 1987). The treatments had been randomised inside three sites, two of which bordered each other and the third one, which was about three hundred metres apart but still in the same mire area. The sites differed in their vegetation and had a wide range of the total peat nitrogen concentration (Kaunisto 1987, Hartman *et al.* 2001). The present study involves 18 plots the mean total nitrogen concentrations of which varied in the 0-5 cm peat layer from one site to another as follows (classification according to Laine & Vasander 1990): Site 1, herb-rich fen (N 1.87-2.91%), Site 2, tall sedge/herb-rich fen (N 1.15-2.38 %) and Site 3, *Sphagnum fuscum*/low sedge bog (N 0.87-1.80%). The present study involves three different fertilisation treatments. Every treatment was replicated six times. The fertilisation treatments were (A) rock phosphate + KCl, (B) the same as A, added with fertiliser borate and copper oxide, and (C) wood ash, 5000 kg ha^{-1} (Kaunisto 1987). Accordingly, the amounts of nutrients applied were 45, 45 and 28 kg ha^{-1} for phosphorus, 78, 78 and 91 kg ha^{-1} for potassium, 0, 1.0 and 5.5 kg ha^{-1} for boron, and 0, 8.0 and x kg ha^{-1} for copper. Copper was not determined from wood ash. Wood ash contained 15 % of organic material. The plots inside each treatment were chosen to cover a wide and even total peat nitrogen gradient. The experimental plots measured mainly 40x40 m or 40x50 m each with no buffer zones between the fertilisation treatments. Ten-metre wide subplots for more intensive sampling were marked off across the strips leaving a 10-15 meter buffer zone to the next refertilisation treatment.

Sampling and analyses

Six pines in the middle of the plot parallel to and at least six metres from the ditch were selected for sampling on each plot in 1994 and another group of six pines in 1995. Needle samples were taken from the top third of the crown facing south of four trees at a time. The needles were sampled in the middle of August, September and October in 1994 and 1995 and also in the winter of 1996. Branches with current year needles were put into plastic bags and stored at -21°C. Needles were dried at 60°C and the dry weight determined after drying at 105°C for 24 hours. Nutrient analyses were performed with the methods routinely used at the Finnish Forest Research Institute (Halonen *et al.* 1983). Foliar nitrogen was analysed by the Kjeldahl method, potassium from ashed samples (at 550°C) with an atomic absorption spectrophotometer (Hitachi 100-40) and phosphorus and boron spectrophotometrically at Muhos Research Station.

The samples for the peat nutrient analyses were taken in June 1994 and in May, August, September and October 1995. Peat samples were taken from the edge of the area covered by the crown of each of the six sample trees. Four subsamples were taken from each subplot and pooled by 0-5, 5-10 and 10-20 cm layers at every sampling time and kept frozen (-20°C) until analysed. The total nitrogen concentration was analysed with the Leco CHN 2000 analyser at Parkano Research Station. NH_4-N was determined from 0.5 M KCl extract by distilling in an alkaline MgO solution and nitrate from the KCl extract by first removing NH_4-N with NaOH + distillation as free ammonia. The total phosphorus, potassium and iron concentrations were analysed. They were extracted with hydrochloric acid. Phosphorus was determined spectrophotometrically with the vanado-molybdate method and the other nutrients with an atomic absorption spectrophotometer (Hitachi 100-40) at Muhos research station.

Calculations

Calculations concerning the effects of fertilisation on the mineral nitrogen concentrations in peat and on the needle nutrient concentrations were done using the analysis of variance with repeated measures (BMDP software packing) and the relationship between the needle nutrient concentrations and the peat nitrogen status using correlation and linear regression analyses.

Results

Mineral nitrogen in peat

The average NH_4-N concentrations in the 0-20 cm peat layer were 16, 16, and 14 mg l^{-1} and the NO_3-N concentrations 2.6, 1.3, and 1.5 mg l^{-1} for PK, PKB and wood ash fertilised plots respectively. Fertilisation did not significantly affect the mineral nitrogen concentrations in any layer. The concentration of NH_4-N decreased quite clearly from the peat surface downwards in all treatments but the variation in the NO_3-N concentrations between different layers was quite inconsistent (Tab.1). The concentrations of NH_4-N were manifold compared with NO_3-N in all peat layers. The concentrations of both NH_4- and NO_3-N varied greatly during the growing season (Tab. 1). The highest mineral nitrogen concentrations were detected in the spring and there was a clearly decreasing trend from spring towards autumn. The differences were most pronounced and statistically significant in the two most superficial peat layers.

Table 1. Peat NH_4- and NO_3-N concentrations (mg l^{-1}) in different peat layers and sampling times (m/y = month/year) in 1994-1995. Analysis of variance with repeated measures (n = 90 for each layer).

Compound	Layer cm	Time, m/y 6/94	5/95	8/95	9/95	10/95	p
NH_4	0-5	24	42	23	24	11	0.000
	5-10	13	22	14	15	7	0.000
	10-20	7	9	8	7	5	0.432
	$\bar{x}$	15	24	15	15	8	
NO_3	0-5	0.1	9.7	2.0	1.3	1.0	0.044
	5-10	0.3	3.7	1.6	1.3	0.8	0.000
	10-20	0.3	5.5	1.0	1.2	1.0	0.012
	$\bar{x}$	0.2	6.3	1.5	1.3	0.9	

NH_4-N and the peat total nitrogen concentrations were in a close positive correlation in the 0-5 cm peat layer at every sampling time in 1995 (Fig. 1) and in all peat layers in the early summer sampling. However, in the 5-10 cm and 10-20 cm peat layers the correlations were rather weak or insignificant in late summer and in autumn. The concentrations of NO_3-N behaved quite differently from those of NH_4-N and were inconsistent along with the increasing total nitrogen concentration according to bivariate scatter plots. The correlation of NO_3-N with the peat total nitrogen concentration was significant in the 0-5 and 10-20 cm peat layers at the last sampling time (10/95, r = 0.436* and 0.548** respectively) and in the 5-10 cm layer (r = 0.648***) only in the early summer sampling. All the other correlations between NO_3-N and the peat total nitrogen concentrations were insignificant.

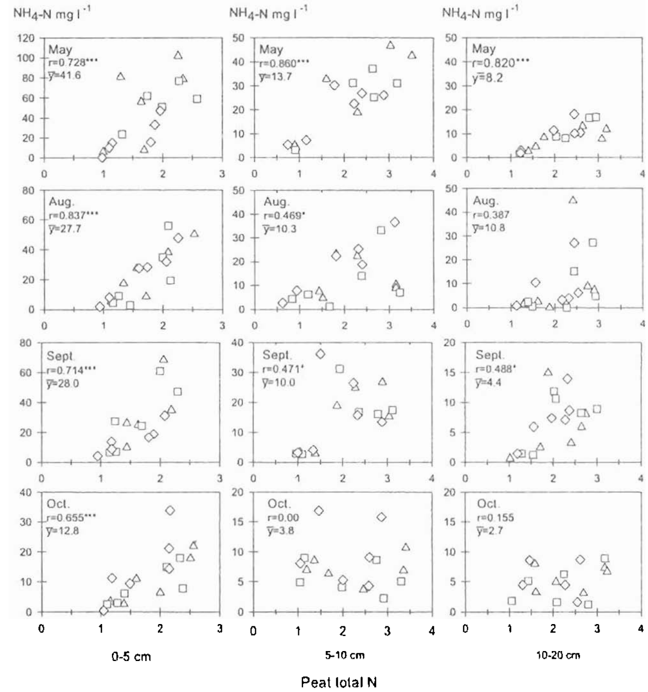


Figure 1. Correlations between the peat NH_4-N and total N concentrations in 0-5, 5-10 and 10-20 cm peat layers in 1995. Key: △ = PK, □ = P+Cu+PK, and ◇ = Wood ash fertilisation. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

The correlations between the mineral nitrogen concentrations and the C/N ratio in peat were calculated only for the autumn months. The correlations were negative but agreed quite well with the ones between the mineral nitrogen and peat total nitrogen concentrations.

Nutrition of trees

Analyses of variance with repeated measures were calculated to find out the effects of the different fertilisation treatments. In 1994 and 1995-96 the needle phosphorus concentrations on the ash fertilised plots were lower than in the other treatments but there were no significant differences in the potassium concentrations. The needle boron concentrations were lowest in the mere PK-fertilised trees and highest in the ash fertilised trees in both years. The boron concentrations in the needles decreased with PK fertiliser without boron to the critical deficiency level (5-7mg kg^{-1}, Reinikainen & Veijalainen 1983, Reinikainen *et al.* 1998) on average (Tab. 2). PK fertiliser containing boron as well as wood ash increased the boron concentrations in the needles to a satisfactory or good level (see also Kaunisto 1987).

Table 2. Effect of fertilisation on the needle N, P, K, B and ash concentrations. Analysis of variance with repeated measures. The figures are the means of the years 1994 and 1995-96. B as mg kg^{-1} and the others as mg g^{-1} (n = 54 in 1994 and 72 in 1995-96).

Year	Nutrient	Fertilisation			
		PK	PK+B+Cu	Ash	p
1994	N	15.0	16.2	14.8	0.327
	P	2.04	2.29	1.53	0.005
	K	4.58	5.64	5.20	0.143
	B	7.3	12.4	19.4	0.003
	Ash	19.4	22.4	22.2	0.202
1995 -96	N	12.8	12.5	11.7	0.040
	P	1.64	1.58	1.35	0.128
	K	3.94	4.10	3.99	0.873
	B	5.1	10.5	17.7	0.000
	Ash	17.6	18.2	19.1	0.278

The concentrations of the main nutrients were considerably lower in the needles of 1995 than in these of 1994 (Tab. 2). The nitrogen concentrations dropped from the optimum level (15.0-16.0 mg g^{-1}, Paarlahti et al. 1971, Kaunisto 1982) below the deficiency level, which indicates the need for nitrogen fertilisation (13.0 mg g^{-1}, Paarlahti et al. 1971) in 1995. Similarly, the foliar phosphorus concentrations dropped from an optimal nutritional level (1.60 mg g^{-1} Reinikainen et al. 1998) below it, and with wood ash even below the deficiency level. (1.40 mg g^{-1} Paarlahti et al. 1971). The needle potassium concentrations dropped close to or below the slight deficiency limit (4.0 mg g^{-1}) and in the control trees below the severe deficiency limit (3.5 mg g^{-1}, Paarlahti et al.1971, Sarjala & Kaunisto 1993).

The needle and peat total nitrogen concentrations of the 0-5 cm peat layer correlated positively, and quite closely with each other at all sampling times in 1994 and 1995 (Fig. 2). The correlations of the needle nitrogen with the peat total nitrogen concentrations were at their highest in the topmost 0-5 cm layer and decreased downwards, being at their lowest in the 10-20 cm layer (Fig. 2 and Tab. 3). The needle nitrogen concentrations correlated quite closely also with peat iron, especially with iron in the deepest layer (Tab. 3). The C/N ratio was determined only from the peat samples taken in the autumn of 1995. The correlations of the needle nitrogen concentrations with the C/N ratio were negative and slightly lower than these with peat total nitrogen (Fig. 3).

Similarly to the total peat nitrogen, the needle nitrogen concentrations correlated fairly closely also with the peat NH_4-N concentrations in the 0-5 cm peat layer in 1995 (Fig. 4). The same was also true with the correlations between needle nitrogen during dormancy in March 1996 and the NH_4-N concentrations in the

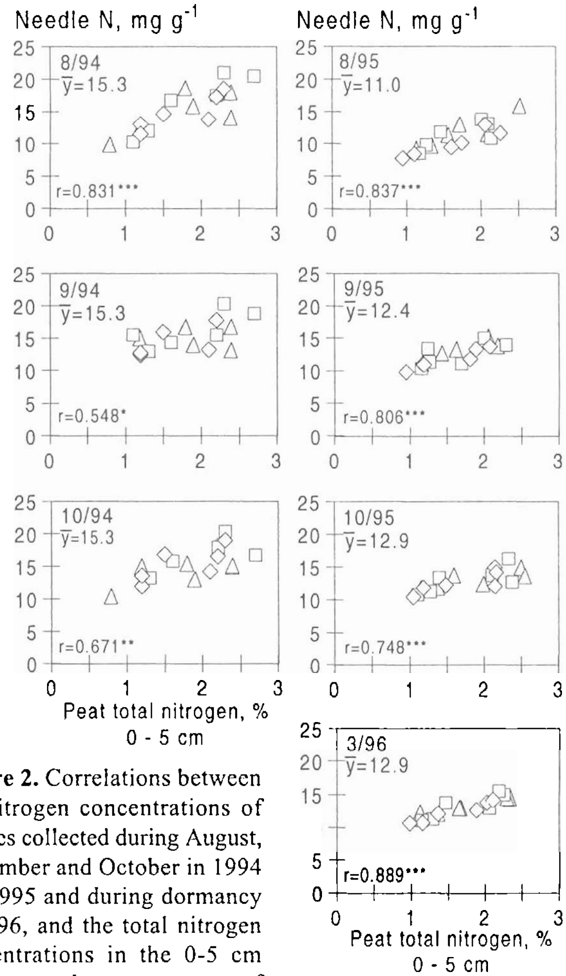


Figure 2. Correlations between the nitrogen concentrations of needles collected during August, September and October in 1994 and 1995 and during dormancy in 1996, and the total nitrogen concentrations in the 0-5 cm surface peat layer. y = mean of the needle nitrogen concentrations. At 3/96 needle sampling the mean of the peat N concentrations was used. Key as in Fig. 1.

Table 3. Correlations between the nitrogen concentrations of needles collected during August, September and October in 1994 and 1995 and during dormancy in 1996, and the total nitrogen and iron concentrations in different peat layers. At 3/96 needle sampling the means of the peat N and Fe concentrations in 1995 used. (n = 18). See also Fig. 2.

Time	Peat layer, cm				
	5-10	10-20	0-5	5-10	10-20
m/a	N	N	Fe	Fe	Fe
8/94	0.671**	0.574**	0.471	0.495*	0.692**
9/94	0.510*	0.458*	0.757***	0.720***	0.870***
10/94	0.566**	0.436	0.508*	0.538*	0.825***
8/95	0.787***	0.762***	0.562**	0.406	0.403
9/95	0.693***	0.510*	0.540*	0.474*	0.614**
10/95	0.748***	0.656**	0.695**	0.788***	0.825***
3/96	0.854***	0.794***	0.652**	0.745***	0.800***

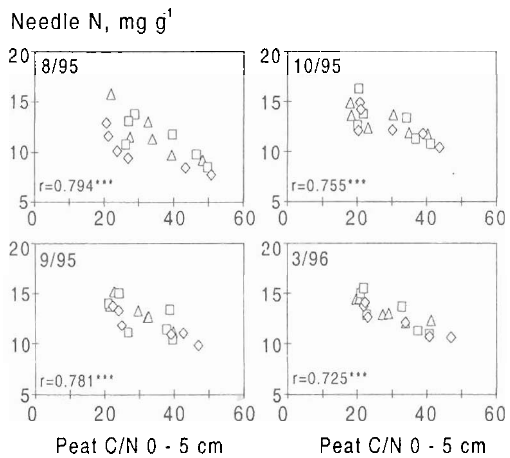


Figure 3. Correlations between the nitrogen concentrations of needles collected during August, September and October in 1995 and during dormancy in 1996, and the C/N ratio in the 0-5 cm peat layer. At 3/96 needle sampling the mean of the peat C/N ratios was used. Key as in Fig. 1

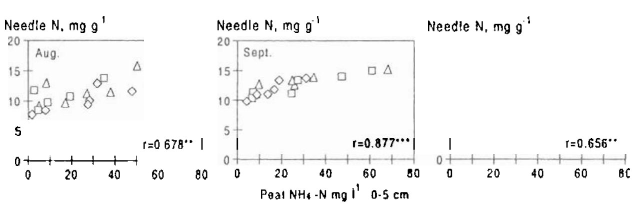


Figure 4. Correlations between the needle nitrogen and peat NH4-N concentrations in the 0-5 cm surface peat layer during August, September and October in 1995. Key as in Fig. 1.

0-5 cm peat layer analysed at different times during 1995 (Fig. 5). However, in most cases the correlations were considerably weaker between nitrogen in the needles and NH_4-N in the deeper peat layers.

The correlations of the needle phosphorus concentrations were positive but quite weak with the peat total nitrogen concentrations in the 0-5-cm peat layer (Fig. 6a), and even weaker with the nitrogen concentrations in the deeper peat layers. There were no correlations between the needle potassium and the peat total nitrogen concentrations (Fig. 6b). The needle boron concentrations correlated negatively with the peat total nitrogen concentrations at all sampling times and dropped to the critical boron level (5-7 mg g^{-1} Reinikainen & Veijalainen 1983, Veijalainen et al. 1984) in high peat total nitrogen concentrations (Fig. 7). This was shown especially clearly on the PK-fertilised plots, which had not received boron.

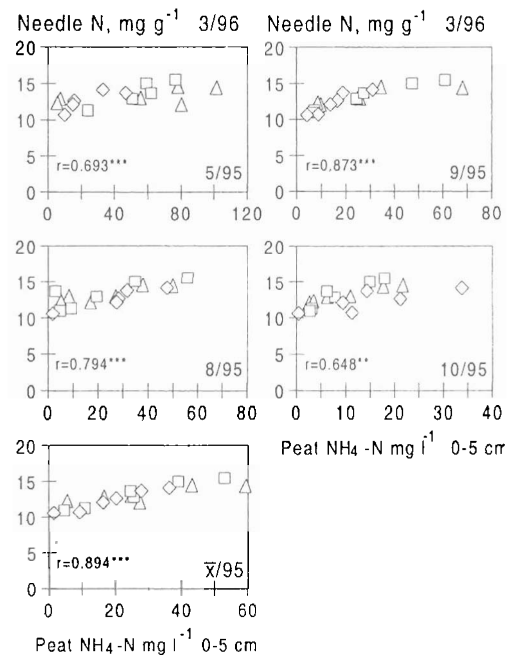
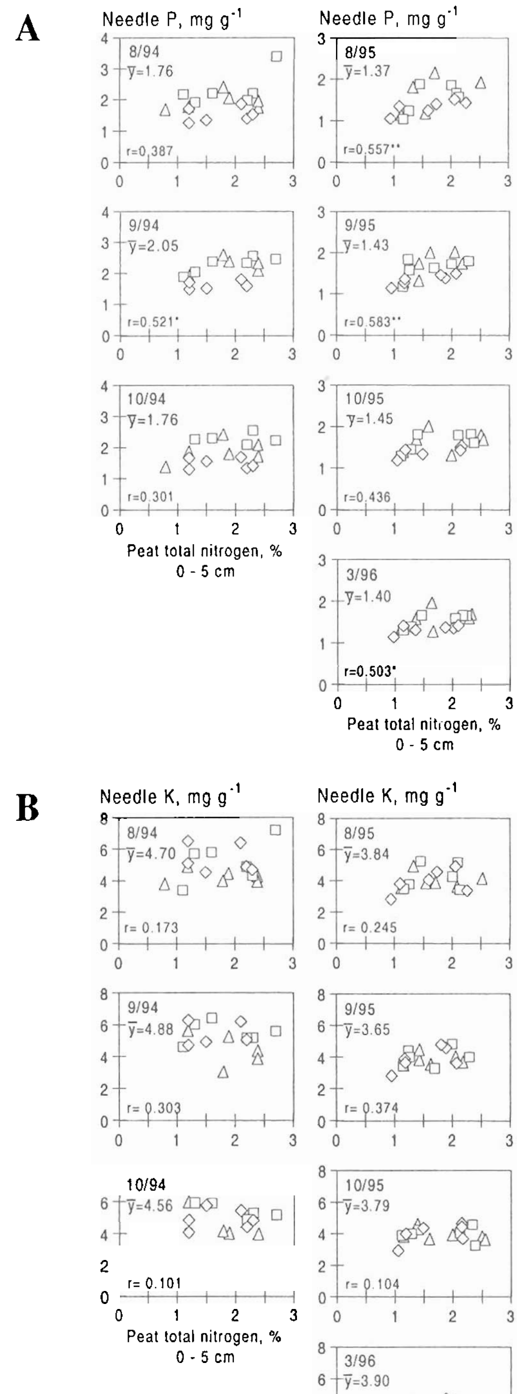


Figure 5. Correlations between the needle nitrogen concentrations collected in March 1996 and the peat NH4-N concentrations in the 0-5 cm surface peat layer sampled at different times in the previous year. Key as in Fig. 1.

Stand growth

There were no differences in stand charcteristics between the different fertilisation treatments but there was a strong positive correlation between them and the peat total nitrogen concentration in the 0-5 cm peat layer but a negative one between the stand characteristics and the peat C/N ratio in 1995 (Figs. 8 and 9). However, there seemed to be a slight reduction in the height increment at the highest peat total nitrogen concentrations. The correlations between the peat nitrogen concentration, C/N ratio and iron in all studied peat layers and the mean height and volume of the tree stands in 1994 are shown in Table 4. Both stand characteristics were in a strong positive correlation with both the nitrogen and iron concentration but in a strong negative correlation with the C/N ratio of all studied peat layers.

The variation in tree characteristics was explained quite similarly by the peat total nitrogen concentration in the 0-5 cm and 5-10 cm peat layers (Figs. 8 and 9, Tab. 4). The correlations between the peat total iron concentration and tree characteristics were similar or even higher than the correlations between the tree characteristics and peat nitrogen (Tab. 4). Contrary to the correlation of tree characteristics with nitrogen the correlation was closest with the iron concentrations of the deepest, 10- 20 cm, peat layer.



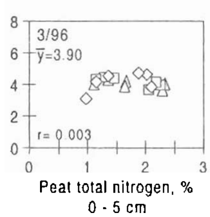
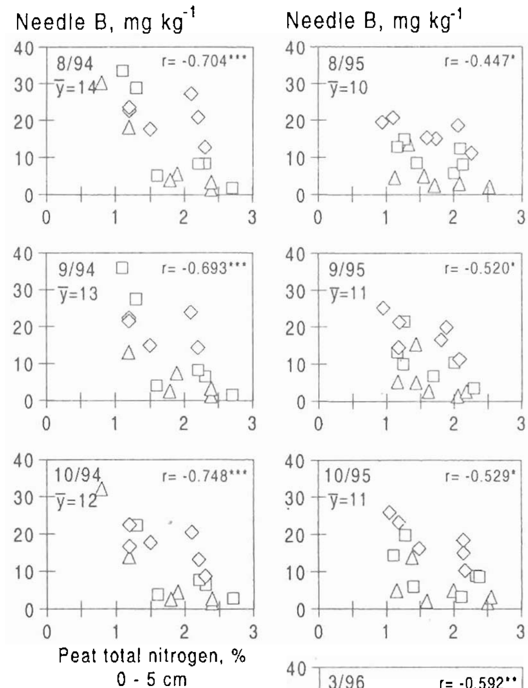


Figure 6. Correlations between the phosphorus and potassium concentrations of needles collected during August, September and October in 1994 and 1995 and during dormancy in 1996, and the total nitrogen concentrations in the 0-5 cm surface peat layer. y = means of the needle phosphorus and potassium concentrations. At 3/96 needle sampling the mean of the peat N concentrations was used. Key as in Fig. 1.



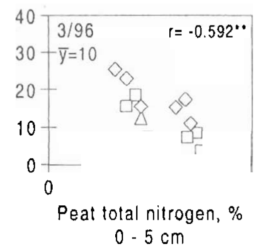


Figure 7. Correlations between the boron concentrations of needles collected during August, September and October in 1994 and 1995 and during dormancy in 1996, and the total nitrogen concentrations in the 0-5 cm surface peat layer. y = mean of the needle boron concentrations. At 3/96 needle sampling the mean of the peat N concentrations was used. Key as in Fig. 1.

Table 4. Correlation coefficients between some stand characteristics in 1994, and the C/N ratio and the total nitrogen and iron concentrations in different peat layers.

Measured quantity	Layer cm	Peat N	C/N	Fe
Height	0-5	0.779***	-0.806***	0.791***
	5-10	0.775***	-0.794***	0.788***
	10-20	0.712***	-0.735***	0.821***
Volume	0-5	0.879***	-0.877***	0.810***
	5-10	0.868***	-0.823***	0.802***
	10-20	0.873***	-0.812***	0.813***

Discussion

The results showed that in comparison to NH_4-N, NO_3-N had only a minor role in the amount of mineral nitrogen in peat. This agrees well with the results

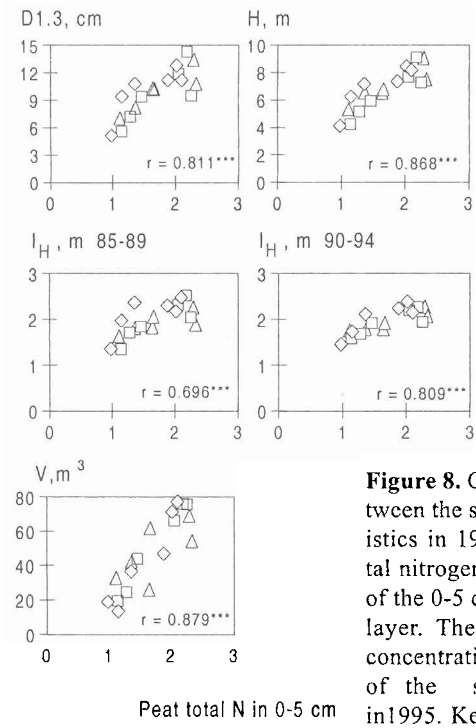


Figure 8. Correlations between the stand characteristics in 1995 and the total nitrogen concentration of the 0-5 cm surface peat layer. The peat nitrogen concentration is the mean of the samples taken in1995. Key as in Fig. 1.

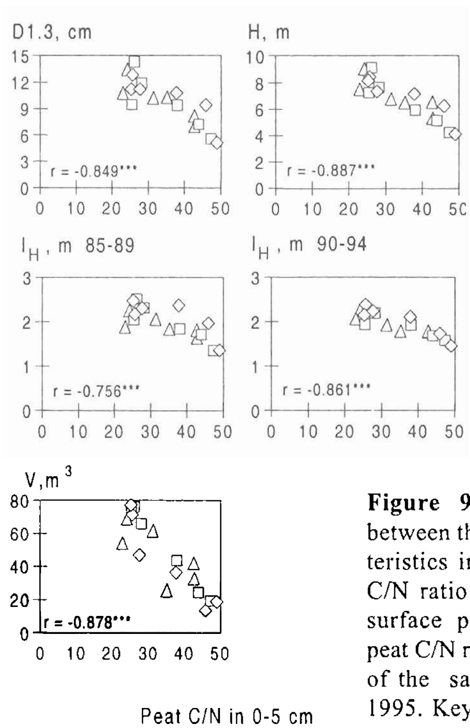


Figure 9. Correlations between the stand characteristics in 1995 and the C/N ratio of the 0-5 cm surface peat layer. The peat C/N ratio is the mean of the samples taken in 1995. Key as in Fig.1.

obtained in other studies (Gardiner 1975, Gardiner & Gegghegan 1975, Kaunisto & Norlamo 1976, Williams 1983, 1984). Nitrification is closely dependent on the pH of the substrate (Alexander 1961, Gardiner 1975) and its rate falls off markedly below pH 6.0 and becomes negligible below pH 5.0. In the present material pH, even in the surface peat of the ash fertilised plots, was only 4.8 and in the other treatments even lower, about 4.0 (see Hartman *et al.* 2001).

The results showed that the concentration of NH_4 in peat was closely related to the total nitrogen concentration of peat. This was coherent with the results of Williams (1984) The results also indicated that the most active part for nitrogen mineralisation was the surface peat. On the other hand, the fairly close correlation between NH_4-N and the peat total nitrogen concentrations in the deeper peat layers in spring implies that some nitrogen mineralisation had also occurred during winter as shown also by Williams & Wheatley (1992) or nitrogen was released from the dead and decaying microbial body as a consequence of the freezing and thawing of peat (Williams & Edwards 1993). The build up of NH_4-N into the lower layers was possibly also partly due to downward leaching of NH_4-N from the surface layer. The concentrations of NH_4-N decreased from spring towards autumn. This is accordance with the results obtained by Paavilainen (1980) on a dwarf shrub pine bog.

Needle nitrogen concentrations correlated most closely with both the peat total nitrogen and ammonium nitrogen (NH_4-N) concentrations in the 0-5 cm peat layer. This is quite understandable because the 0-5 cm layer was the most active part of peat in nitrogen mineralisation as shown above and because tree roots in peat soils are quite superficial (Heikurainen 1959a, Paavilainen 1966). Kaunisto (1982) and Lauhanen & Kaunisto (1999) also showed the importance of the nitrogen status of the surface peat in maintaining the nitrogen nutrition of trees.

The needle boron concentrations were in a close negative correlation with the total peat nitrogen concentration and dropped even to the deficiency level in high peat nitrogen concentrations (Reinikainen & Veijalainen 1983, Reinikainen *et al.* 1998). This was supposedly due to the dilution of boron in the needles (Smith 1962, Veijalainen 1977, Pietiläinen *et al.* 1996) because of more intensive tree growth along with the increasing peat nitrogen concentrations in the area. The needle phosphorus concentrations were lower in the wood ash fertilised than in the other trees. The reason supposedly is the poor quality of wood ash. The amount of phosphorus in wood ash was only about 2/3 of the phosphorus applied in the other fertilisation treatments even though the amount of wood ash was quite high. However, there were no differences in tree stand growth between the treatments.

The needle nitrogen, phosphorus and potassium concentrations were considerably lower in 1995 than in 1994. The temperature sums in 1994 and 1995 were quite similar in the area (1108 and 1151 d.d. respectively). The mean temperature in June 1994 was

13.1 °C, being under the 20-year average (13.7 °C). In July the mean temperature was 17.5 °C, being well above the average (15.8 °C). In 1995 the situation was quite the opposite. The mean temperature was 15.9 °C in June and only 13.9 °C in July. The low temperature in July may have hampered nitrogen and phosphorus mineralisation in peat and consequently nitrogen and phosphorus nutrition of trees. However, it is difficult to explain the low potassium concentrations in 1995, because potassium is not organically bound in peat and its availability is not dependent on microbial activity.

The total nitrogen concentration was a good indicator for the growth of tree stands. Breast height diameter and height more than doubled and the stand volume increased 3-4 fold along with the increasing peat total nitrogen concentration. This agrees well with the earlier results (Kaunisto 1982, 1985, 1987, Kaunisto and Paavilainen 1988). There were only slight differences in the correlations between the stand characteristics and the peat total nitrogen concentrations in the 0-5 or 5-10 cm peat layer. This differs somewhat from the earlier results by Kaunisto (1987) concerning the whole experiment where the 5-10 cm peat layer explained variation slightly better than the 0-5 cm layer. It seems that since the earlier results the decomposition of the surface peat has progressed and possibly decreased the variation in the peat total nitrogen concentration of the surface peat.

An interesting finding was that tree growth correlated as closely with the peat total iron as with the peat total nitrogen concentration. As reported before, the peat total nitrogen and iron concentrations and also the peat total phosphorus and iron concentrations were in a close positive correlation in this study area (Hartman *et al.* 2001), which explains the result.

The height growth of trees seemed to decline at the highest peat total nitrogen concentrations. The same phenomenon was seen already in the earlier results 3-4 years after refertilisation in the study involving the whole experiment, and especially so if fertilised with fertilisers containing nitrogen (Kaunisto 1987). It was assumed that high peat nitrogen concentrations caused excess nitrogen mineralisation and a consequent decrease in the frost resistance of trees on the most nitrogen-rich sites. Similar results have also been obtained when applying mere nitrogen even on quite nitrogen-poor peatland sites (Kaunisto & Paavilainen 1977). Aronsson (1980) found that frost hardiness of Scots pine decreased when the needle nitrogen concentrations exceeded 18 mg g^{-1}. In the present study the needle nitrogen concentrations were above that level on the most nitrogen-rich sites in October 1994.

Conclusions

The ammonium and nitrate nitrogen concentrations are highest in early summer and at their lowest in late autumn. Ammonium is the main inorganic form of nitrogen in peat and its highest concentrations are in the most superficial 0-5 cm peat layer. The ammonium and total nitrogen concentrations as well as the C/N ratio of the surface peat layer explain well the nitrogen nutrition of trees. The total nitrogen concentration of the surface peat is a good indicator of the growth of a tree stand. Trees are susceptible to boron deficiency on sites with high peat total nitrogen concentrations.

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СОСТОЯНИЕ ТОРФЯНОГО АЗОТА И ЕГО ВЛИЯНИЕ НА ПИТАНИЕ И РОСТ СОСНЫ (*PINUS SYLVESTRIS* L.) НА ОБЛЕСЕННОМ БОЛОТЕ

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Резюме

В данном исследовании изучено влияние азота на содержание питательных веществ в торфе, а также на питательные вещества в хвое и на рост древостоя сосны обыкновенной на удобренных, облесенных открытых болотах, где содержание азота в торфе особенно высокое.

В 1994, 1995 и 1996 году собраны материалы исследования в Сяркя Иломантся, где было проведено обширный опыт по внесению удобрений в Восточной Финляндии в 1981-82 годы (Каунисто 1987, участок обследования Хартман). Для исследования из множества опытных участков выбрали 18, которые представляли три разные вида обработки удобрениями, а именно: PK-, PKB и пепельное удобрение. Торфяные пробы брали в 1994 году весной, и1995 году осенью на глубине от 0-5 см 5-10 см и от 10-20 см. Пробы хвои брали в середине августа, сентября и октября в 1994 и 1995 годы, а также зимой 1996 года. Определялось содержание азота фосфора, калия и бора в хвое.

По всем пробным наборам больше всего минерального азота торфа содержалось в 0-5 см слое и почти без исключения во всех слоях в майских пробах его было больше, чем в сентябрских. Содержание аммиачного азота коррелировало стабильно с общим количеством азота торфа.

Содержание фосфора в хвое сосны, удобренной пеплом было ниже, чем в других. Удобряя PK, понижается боросодержание в хвое до грани недостаточности или ниже этого.

Содержание азота в хвое коррелировало стабильно с общим содержанием азота торфа, но негативно – с C/N. Найденая корреляция была наиболее высокой в слоях 0-5 см.

Содержание азота в хвое коррелирует также с содержанием железа в торфе, причем это наиболее выражено в глубоких слоях. Интенсивно, но негативно коррелирует содержание бора в хвое с содержанием общего азота торфа.

Прирост древостоя позитивно коррелирует с содержанием общего азота торфа и содержанием железа в торфе, и негативно – с индексом C/N торфа по всем уровням глубины. Объем древостоя на богатых азотом испытательных площадках был в 3-4 раза больше по сравнению с бедными азотом. Результаты подтверждают в предыдущих исследованиях найденную стабильную связь между общим содержанием азота в торфе и ростом древостоя.

Ключевые слова: аммоний, бор, C/N соотношение, минерализация, болото, питательные вещества, хвоя, нитраты, азот, питание, торф, фосфор, сосна обыкновенная *Pinus sylvestris*, прирост древостоя