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Comparing Effects of Wood Ash and Commercial PK Fertiliser on the Nutrient Status and Stand Growth of Scots Pine on Drained Mires

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Because wood ash contains same main nutrients as commercial PK-fertilizers it may be an alternative to treat deficiencies of P and K, common in peatland stands. In this study, we compared the effects of wood ash and PK fertiliser on the volume growth and nutritional status of Scots pine stands. The data were collected from 4 field experiments established on drained mires in northern Finland. The living trees were measured in 1996 - 2001 to reconstruct the stand development back to the time of the fertilisation. Needle samples were taken when 15–20 years had passed from the fertilisation.

The rate and the magnitude of the growth response were in direct proportion with the thickness of the peat layer and the N-status of tree stand. With similar doses of phosphorus, PK-fertilisation increased stem volume growth faster than wood ash. The effect of ash became stronger when 15 years had elapsed from the treatment. On oligotrophic and shallow-peated sites, where the stand was suffering from the lack of usable nitrogen, PK fertiliser had no effect on tree growth, whereas the effect of ash seemed to become evident after ten year. Significant increases in foliar concentrations of phosphorus, potassium, and boron were observed 20 years after treatment in all of the PK and wood ash fertilised stands. Ash treatment increased also needle dry mass and PK treatment decreased zinc concentration in needles.

Keywords: drainage, nitrogen, nutrient status, phosphorus, peatland, peat thickness, *Pinus sylvestris* L., PK fertilizer, potassium, stand growth, wood ash.

Introduction

Deficiencies of mineralised phosphorus are common in Scots pine stands growing on drained thick-peated mires (e.g. Paarlahti and Karsisto 1968, Karsisto 1974, Kaunisto and Paavilainen 1988, Moilanen 1993, Paavilainen and Päivänen 1995). Moreover, originally sparsely stocked, wet and nitrogen-rich mires have developed potassium deficiencies that causes a growth reduction (Kaunisto and Tukeva 1984, Kaunisto 1989, Kaunisto 1992). Particularly on nutrient-poor sites and in northern climatic conditions, there is often also a simultaneous lack of nitrogen (Paarlahti *et al.* 1971, Kaunisto and Paavilainen 1977, Kaunisto 1977, 1982, 1987*a*, Paavilainen 1977, Penttilä 1984, Moilanen and Issakainen 1990, Moilanen 1993). In addition, the amounts of micronutrients — especially of boron — are low in peat, and this can induce growth disturbances in pines on fertile, drained mires (Veijalainen *et al.* 1984). On mires with a shallow peat layer less than 30–40 cm, the root-system reaches to the mineral soil, resulting in a better potassium status than on sites with a thicker peat layer (Saarinen 1997).

Approximately 1.7 million hectares of nutrient deficiencies and imbalances in Scots pine stands on drained peatlands have been successfully remedied by fertilisation in Finland during the past fifty years. On nitrogen-rich sites, P fertilisation with fabricated compound fertilisers may improve the phosphorus status of tree stand and increase growth for 20 – 30 years (Moilanen 1993, Silfverberg and Hartman 1999). The effects of water soluble K and N fertilisers are faster but of shorter duration than that of P fertilisation - only 10 to 20 years on nitrogen-rich sites (Kaunisto 1992, Moilanen and Issakainen 1990, Moilanen 1993, Kaunisto *et al.* 1999). PK compound fertilisers are recommended on nitrogen-rich sites, whereas NPK fertilisation is recommended on nitrogen-poor sites (e.g. Paavilainen 1972, Kaunisto 1977, Kaunisto 1982, Moilanen 1993, Paavilainen and Päivänen 1995, Silfverberg and Hartman 1999). However, the effect of N on nitrogen-poor sites remains considerably weak compared with the response to PK on nitrogen-rich sites (e.g. Moilanen 1993).

In Finland, wood ash is produced in heat and power plants that adjoin pulp mills and other large production plants with annual amounts exceeding 100 000 tonnes. In the late 1990's, nutrient recycling became current in Finnish forestry because of the requirements of the new environmental legislation and the new landfill directives (Korpilahti *et al.* 1999, Högbom and Nohrstedt 2001, Nilsson 2001). Practitioners of peatland forestry have an interest know to what extent wood ash functions as a soil improvement agent — and whether it is a suitable alternative or complement to commercial PK fertilisers.

It has been well documented that wood ash contains considerable amounts of mineral nutrients — especially phosphorus and potassium — usable for ground vegetation and tree stands (Silfverberg 1996). The fertilising effect of wood ash on Scots pine (*Pinus sylvestris* L.) growth on drained peatlands has been known for a long time (Lukkala 1955, Silfverberg and Huikari 1985, Ferm *et al.* 1992, Silfverberg 1996, Moilanen *et al.* 2002). Despite the positive effects of wood ash on drained mires, the use of ash in forest fertilisation has remained at a rather modest level (Korpilahti *et al.* 1999), and most of the ash produced has ended up in landfills.

The aim of this study was to compare the effects of wood ash and commercial PK fertiliser on the wood production and nutrient status of Scots pine on drained mires in northern Finland. We put forward a hypothesis that the response of a tree stand depends on — in addition to the fertilisation — the thickness and the nitrogen content of the peat substrate. Although the quantity of phosphorus would be the same, differences in e.g. the speed of element leaching suggested that the temporal responses (speed, timing and duration) of Scots pine to ash and PK were different.

Materials and methods

1. Experiments

The 4 field experiments used in this study were established on mires drained between 1961 and 1980 and located in the northern boreal coniferous zone in central and northern Finland, between the latitudes 63 ºN and 67 ºN (Table 1). Ditch spacing varied between 25 and 45 m. The sites represented fertility range from cotton-grass pine bogs (TR) to herb-rich birch-pine fens (RhSR) (site classification according to Laine and Vasander 1996). The average peat thickness varied from 30 to over 100 cm. The stands were at a sapling or pole stage when the experiments were set up, with the dominant height of 5–9 m. The dominant tree species in all stands was Scots pine (*Pinus sylvestris* L.) with a mixture (less than 15 % of stem volume) of pubescent birch (*Betula pubescens* Ehrh.) and Norway spruce (*Picea abies* Karst).

The wood ashes applied came from three thermal and electric power plants (Kajaani, Oulu, Sodankylä) (Table 2). The dust-like ash used originated mainly from wood or bark fuel, except the Kajaani ash, which consisted of a mixture of burned bark, peat and black liquor. The ash doses varied from 900 to 7 000 kg ha^{-1} dry weight. The main and micronutrient concentrations in the ashes were measured in the laboratory of Muhos Research Station (HCl-extraction, AAS (Halonen et al. 1983). The nutrient concentrations (e.g. phosphorus and potassium) varied considerably depending on the origin of the ash. However, the ash treatments contained more or less the same amounts of phosphorus and potassium as the PK fertiliser treatment (Table 2).

Table 1. Basic information on the experiments at the time of the establishment.

Experiment (number, name)	Coordinates (N, E)	Location (m a.s.l.)	Temperature sum (d.d.)	Site type [1)]	Peat depth (m)	Years of ditching	Stand volume (m^3 ha^{-1})
1. Lestijärvi 1/79	63°34', 24°42'	145	1056	TR-PsR	1,0+	1977	13
2. Kuhmo 1/80	64°17', 29°48'	175	972	PsR	0,3	1980	35
3. Sodankylä 1/79	67°03', 26°31'	215	823	VSR	1,0+	1977	8
4. Rovaniemi 1/80	66°21', 25°28'	80	943	VSR-RhSR	0,4	1961, -81	17

[1)] site types according to Laine and Vasander 1996.

Table 2. The treatments, ash sources, dosages, and nutrients amounts applied in the experiments.

Exp.	Treatment	Dosage, kg ha^{-1}	P	K	Ca	Zn	B
			Nutrients applied as elements, kg ha^{-1}				
1	Control						
1	PK fertiliser for peatlands	500	44	83	120	0	1,0
1	Bark ash (Oulu)	7000	28	77	644	5,2	1,0
1	Control						
2	PK fertiliser for peatlands	500	44	83	120	0	1,0
2	Bark ash-/ peat ash (Kajaani)	6000	30	50	1540	3,4	0,4
1	Control						
3	PK fertiliser for peatlands	500	44	83	120	0	1,0
3	Chip wood ash (Sodankylä)	2250	50	130	935	0,2	0,9
1	Control						
4	PK fertiliser for peatlands	500	44	83	120	0	1,0
4	Chip wood ash (Oulu)	900	27	45	284	0,7	0,4

The commercial fertiliser was a PK fertiliser for peatlands (8.7 % P, 16.6 % K, 0.2 % B) manufactured by Kemira Corporation. The PK fertiliser dosages (500 kg ha^{-1}) were equivalent to those of the present and past recommendations in forest practise in Finland (Paavilainen and Päivänen 1995).

The experimental lay-out followed the randomised block design with two to four replications. Unfertilised plots were included in each of the experiments as the third treatment. The size of the experimental plots varied from 0.10 to 0.17 hectares. The fertilisers were applied manually in summer or autumn in years 1979 - 1982 (Table 3).

Table 3. The points of time for tree stand measurements and for needle and peat samples, a = autumn, s = spring.

Experiment	Time of fertilisation	Treatments x replicates = plots	Stand measures	Needle samples	Peat samples
1	5-6/1979	4 x 3 = 12	a1997	3/1999	s1997
2	7/1981	4 x 2 = 8	a2001	3/2000	a1999
3	4/1981	4 x 3 = 12	a2000	4/2000	a1994
4	11/1982	4 x 2 = 8	a1997	1/1998	s1999

2. Measurements, samples and chemical analyses

The stand measurements and the foliar sampling were carried out between 1997 and 2001 (Table 3), when 15–20 years had elapsed since the fertilisation. For the tree stand measurements on each of the plots, either one (Rovaniemi) or two (Lestijärvi) measurement circles with a radius of 8–9 metres were marked, depending of the shape or size of the plot. In Kuhmo and Sodankylä, the tree stand was measured on the whole plot, excluding a 5 meter wide edge area. In the measurement areas, all trees (40–120 per plot) were counted by species and at breast-height (1.3 m) diameter classes (cm, minimum diameter class 5 cm). At each plot the heights (dm) and diameters at breast height (d1.3, mm) were measured from 15–30 randomly chosen pines. The height increments of the sample trees were focused on five-year periods prior to and after the fertilisation. Increment cores were extracted from breast height from each sample tree to determine the development of annual radial growth during the study period microscopically with the accuracy of 0.01 mm. The development of tree stand volume was calculated by using the taper curve and volume functions for Scots pine (Laasasenaho 1982).

To determine the site fertility of the experiments, peat samples were collected from the unfertilised plots (Table 3). One composite sample consisted of 5–10 subsamples, which were distributed uniformly over the plot excluding a 5 meters wide edge area. The living vegetation and undecomposed plant material of the peat cores were discarded from the analyses. The layers, 0–10 cm or 0–20 cm were separated into plastic bags and stored at -21 °C. After drying (at 70 °C for 48 hours) and weighing, the total N concentration was determined by the Kjeldahl method (Halonen *et al.* 1983).

Needle samples were taken from all experiments 15–20 years after fertilisation (Table 3). Current needles were collected from the sun-exposed upper whorls of 6 to 8 dominant trees per plot. The nitrogen concentrations were determined using the Kjeldahl method. After dry combustion and dissolving in hydrochloric acid, K concentrations were determined using an atomic absorption spectrophotometer (AAS-method, Hitachi 100-40). The concentrations of B were determined using the azomethine-H method, and those of P using the vanado-molybdate method as outlined by Halonen *et al.* (1983).

3. *Statistical analyses*

3.1. Annual growth by experiments

Two-way analysis of covariance was applied to test the effects of PK and wood ash treatment on the absolute annual volume growth of the tree stand separately for each experiment. The average pre-treatment volume growth of two years before fertilization was used as a covariate. The statistical significance of the differences between the treatments were analysed using Bonferron's paired t-test and showed in experimentwise results.

3.2. Periodic growth in all data

The stand growth response was studied also using all data by analysing the changes in the five-year periodic relative growth I_rel, which was calculated as follows:

$$IvRel_t = I\_v_t / I\_v_0 \qquad (1)$$

where $IvRel_t$ is the relative growth in a time period t (t = 1,…, 4), I v_t is the volume growth in t, and I_v_0 is the average stand volume growth of a two-year period before fertilisation.

Because of the hierarchical data structure, with repeated measurements of the same sample plots and several plots within each stand, the assumption of independence of observations was violated. Consequently, the following mixed ANOVA model with fixed and random parts was constructed. Logarithmic transformation was used to normalise the distribution of the response variable.

$$\ln(IvRel(t)) = a + X + Treatment + Period + Shp + TreatmentxPeriod + ShpxTreatment + ShpxPeriod + ShpxTreatmentxPeriod + u_{site} + v_{block} + e_{plot}(t) \qquad (2)$$

where: a = overall mean

X = vector of fixed plot (or experiment) level covariates (e.g., initial plot standing volume, m^3ha^{-1})

Treatment = fertilisation treatment (Control, PK, wood ash)

Period = categorical time effect referring to the 5-year growth periods (1, 2, … , 4)

Shp = categorical site effect referring to shal low-peated experiments (0/1)

u_{site} = random site effect (i.e., random variation among experiments)

v_{block} = random block effect (i.e., random variation among the blocks which were nested within the experiments)

$e_{plot}(t)$ = residual error (function of time, t)

In the residual error, the following first-order autocorrelation structure among the successive 5-year growth periods (nested within blocks and experiments) was assumed:

$$Cov\left(e_{plot}(t), e_{plot}(t-5)\right) = \begin{bmatrix} \mathrm{var}(e_{plot}(t)) & \mathrm{cov}(e_{plot}(t), e_{plot}(t-5)) \\ \mathrm{cov}(e_{plot}(t), e_{plot}(t-5)) & \mathrm{var}(e_{plot}(t-5)) \end{bmatrix} \qquad (3)$$

The fixed parameters, variances and covariances of the random effects were estimated simultaneously with a restricted maximum likelihood method (REML), using the Mixed procedure in SAS. For pair-wise comparisons, the Tukey's test was used.

3.3. Analysis of foliar nutrients and needle mass

Differences in the foliar nutrient concentrations and average needle mass at the end of the study period were tested with two-way analysis of variance model using all data. The statistical significance of the differences among the treatments were analysed using Tukey's paired t-test.

Results

1. *Stand volume growth responses*

The increase of absolute annual growth due to wood ash and commercial PK fertiliser was greatest on the thick-peated and nitrogen-rich sites in Lestijärvi and Sodankylä (the peat total N concentration 2,4 – 2,6 % of dry weight, and the foliar N concentration 12,3 – 12,8 mg g^{-1}). As the nitrogen status of the trees was good, both ash and PK increased the stand volume growth significantly already during the first five-year period (Figure 1). The response became stronger with time: after 20 years the growth of fertilised trees was more than double of that of the unfertilised trees (difference to control 1.5–2.5 $m^3ha^{-1}a^{-1}$). During the first years, PK treatment seemed to have a somewhat stronger, and during the last years, slightly weaker effect than wood ash, but the final differences in total stem volume were not statistically significant.

On the shallow-peated sites in Kuhmo and Rovaniemi – where the peat total N concentration varied between 1,2 – 2,6 % of dry weight - the effect of both fertilisation treatments was statistically insignificant (Figure 1). According to foliar analysis the nitrogen status of the trees was poor (foliar N concentration between 9,8 – 11,8 mg g^{-1}). However, on wood ash

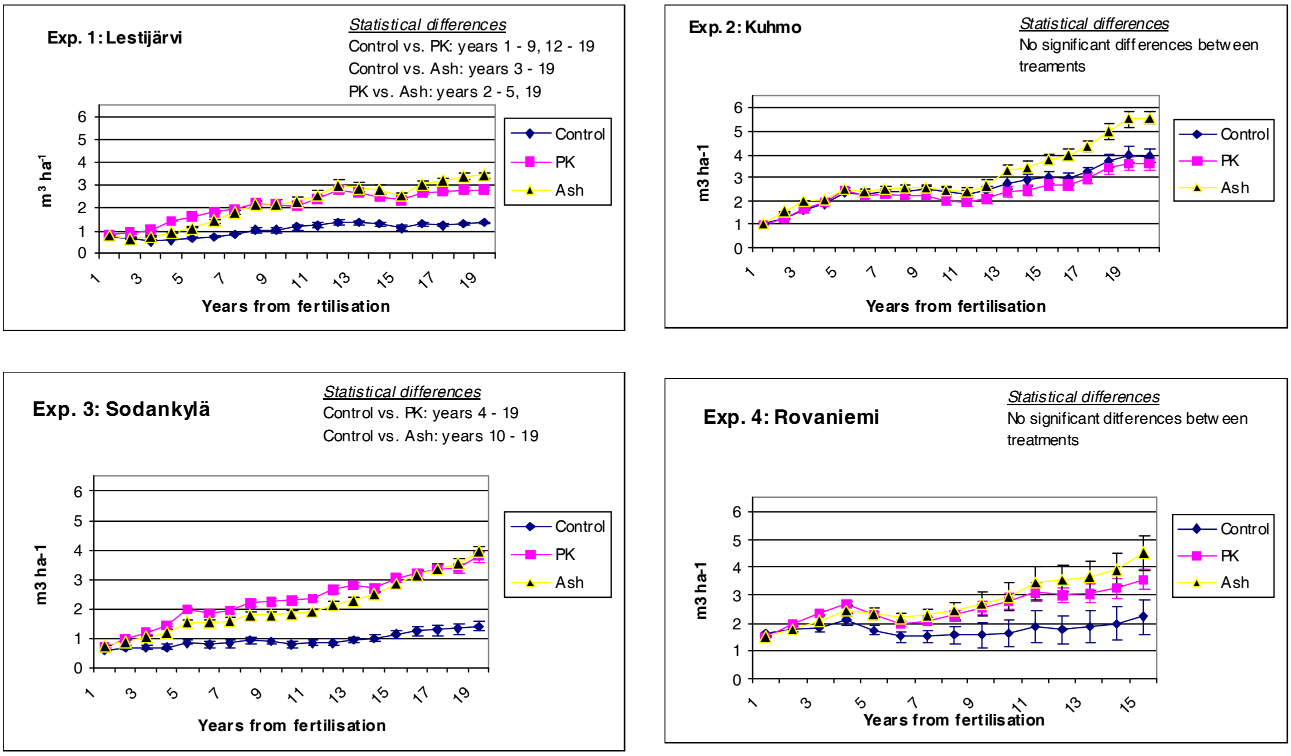

Figure 1. The annual development of stand growth after fertilizer application in the experiments 1 – 4, covariance adjusted values with standard errors of mean. Pair wise comparisons between the treatments have been made for each year and experiment (statistical difference: p-value < 0.05 in Bonferron's test).

plots the stand growth began to increase towards the end of the study period.

In the mixed ANOVA model comparing the relative stand growth among the fertilization treatments and the control, the initial differences in the stand volume had a significant influence on later growth. This was accounted for with a covariate referring to stand volume at the time of fertilisation (Vol_0) (Table 4). No other fixed plot or site level covariate (location /dd°C, peat N content) was significant. The fertilisation treatment and the time since fertilisation significantly influenced periodic relative growth. Significant interactions between time since fertilisation and peat thickness, as well as between fertilisation treatment and time were observed–suggesting that the temporal responses to treatment were different between the treatments. Second order interaction among peat thickness, fertilisation and time indicated varying temporal growth responses to the fertilisation treatments between thick-peated and shallow-peated sites.

Table 4. Model for the 5–20 year relative growth response to the PK and ash fertilisation treatments. The response variable is $\ln(IvRel_t)$.

Fixed part				
Factor	F-value	NumDF	DenDF	p-value
Vol_0	8.30	1	72	<0.0052
Treatment	17.84	2	72	<0.0001
Period	94.29	3	72	<0.0001
Shp*Period	12.47	3	72	<0.0001
Treatment*Period	2.75	6	72	0.0184
Shp*Treatment*Period	4.40	6	72	0.0008

Random part				
Variable	Estimate	s.e.	p-value	t-value
$Var(u_{site})$	0.0144	0.02995	0.315, n.s.	
$Var(v_{block})$	0.02243	0.01848	0.1124, n.s.	
$corr(e_{plot}(t), e_{plot}(t-5))$	0.5853	0.1145	<0.0001	
$var(e_{plot}(t))$	0.0311	0.00759	<0.0001	

Vol_0 = stand volume at time 0 yrs. (= when fertilised)
Treatment = control, wood ash, PK-fertilizer
Shp = shallow (< 40cm) peat thickness, site-level dummy

Random variation among the experiments as well as the block effect were insignificant. The autoregressive error term was highly significant. The positive correlation (r = 0.5853) indicated that higher growth in the former period was related to high growth of the next period (Table 4).

2. Foliar nutrient concentrations and needle mass

As regards the nutrient concentrations in pine needles, the deficiency limit for phosphorus has been considered to be 1.3–1.4 mg g^{-1}, for potassium, 3.5 mg g^{-1}, for nitrogen, 12 mg g^{-1} and for boron, 7 µg g^{-1} of dry weight (Paarlahti *et al.* 1971, Veijalainen *et al*. 1984, Reinikainen *et al.* 1998). The nitrogen concentrations in the needles were near or slightly under the deficiency level (Table 5). The unfertilised trees were suffering from a lack of phosphorus and potassium. Still 15-20 years after the fertilisation the most favourable nutrient status was found in the ash- and PK-fertilised stands. The concentrations of P, K, and B were significantly higher than the control values and clearly above the deficiency level. Moreover, wood ash had significantly increased the dry mass of the needles. PK fertiliser had lowered the needles' Zn concentration.

Table 5. Two-way ANOVA results for the nutrient concentrations of Scots pine needles 15–20 after fertilisation (mean values of four experiments). Differences between the values marked with same letters are not statistical within the period in Tukey's test (p > 0.05).

Nutrient	Control	PK	Ash
N, mg g^{-1}	12.3 a	11.9 a	11.7 a
P, mg g^{-1}	1.20 a	1.54 b	1.55 b
K, mg g^{-1}	3.62 a	4.07 b	4.06 b
Ca, mg g^{-1}	1.98 a	1.99 a	2.15 a
Zn, mg kg^{-1}	51 a	44 b	48 a
Cu, mg kg^{-1}	2,8 a	2.7 a	2.8 a
B, mg kg^{-1}	13.6 a	18.2 b	18.6 b
Dry mass of 100 needles, g	1.72 a	1.97ab	2.15 b

p-values of ANOVA :

Nutrient	Experiment	Treatment	Exp.*Treat.
N	0.000	0.219	0.315
P	0.566	0.000	0.089
K	0.000	0.016	0.202
Ca	0.000	0.138	0.248
Zn	0.001	0.029	0.125
Cu	0.000	0.525	0.423
B	0.000	0.014	0.206
Needle mass	0.000	0.008	0.158

Discussion and conclusions

Since wood ash is shown to be an alternative to commercial PK-fertilization (e.g. Silfverberg 1996, Silfverberg and Issakainen 2001), the comparison between the two treatments in terms of growth and foliar nutrient status was made in this study. Although the number of experiments in this study was limited to four, the data represented pine mires from a climatic transect, including wide range in site fertility and also variation in peat thickness. The data covered conditions in which phosphorus and potassium deficiencies are most likely to occur and PK-fertilization can be recommended in practical forestry. Consequently, we consider the data proper for comparing effects of PK and ash on tree growth on northern boreal drained peatlands.

According to the results of previous studies the magnitude of the response of tree stands after phosphorus-potassium fertilisation depends essentially on the total nitrogen content of the surface peat: the better the nitrogen status of the tree, the greater the growth increase due to PK fertilisation (e.g. Kaunisto 1982, 1987a, Moilanen 1993, Pietiläinen and Kaunisto 2003). In this study, peat and needle analyses showed that almost invariably, the site types differed as regards the nitrogen status of the stands. On sites with a thick peat layer (Lestijärvi, Sodankylä), the N/P-ratio in the needles was between 11 and 12, while on sites with shallow peat layers (Rovaniemi, Kuhmo), it remained at around 9. Sites with shallow peat layers (peat thickness < 40 cm) displayed poor or adequate nitrogen status of trees according to needle analyses (Pietiläinen and Kaunisto 2003); on the other hand, there was an excess of N in respect of the stand requirements on sites with thick peat layers. The thickness of peat — which often reflects its N-concentration (e.g. Moilanen 1993) — had a clear connection with fertiliser-induced increase in stand growth also in this study.

In studies on the afforestation of cut-away peatlands it has been observed that wood ash had a relatively strong effect - comparable with PK fertiliser - on the biomass production of Scots pine, downy birch, and willow stands (Kaunisto (1987*b*) and Hytönen and Kaunisto (1999)). However, Silfverberg and Issakainen (2001) noted that not even large amounts of ash increased height growth in pine stands on drained peatlands significantly more than a conventional PK fertilisation over 13–15 years. In this study, the comparison between ash and PK fertiliser is more appropriate because of the similar doses of phosphorus and potassium in ash and PK treatments. Moreover, the amounts of P and K were also comparable with those recommended for practical peatland forestry.

The effect of PK fertiliser on oligotrophic, nitrogen-poor site (Kuhmo) turned out to be very modest; a result which corroborates those previously published from oligotrophic pine mires (Ipatiev and Paavilainen 1975, Kaunisto 1977, 1985, Moilanen and Issakainen 1990, Moilanen 1993). The effect of wood ash emerged after 11-15 years, but the PK fertiliser did not have such an increasing effect over that time. On nitrogen-rich sites the stand volume growth increases obtained with wood ash and PK fertilisation were of the same magnitude as in previous studies in the same climatic conditions (e.g. Moilanen 1993).

During the first five-year period PK fertiliser increased volume growth more than wood ash. This might have been due to the fact that about 20 % of the phosphorus in the PK fertiliser was in the form of superphosphate, whose solubility and the initial effect on stand growth are known to be more rapid than with other sources of phosphorus (e.g. Nieminen and Jarva 2000). The effective duration of PK fertilisers might be limited by the exhaustion of potassium in the stands already after 10–20 years (Kaunisto 1989, Moilanen 1993). The effective duration of phosphorus — regardless of its form — is considerably longer (Moilanen 1993, Silfverberg and Hartman 1999).

After 15 years the growth on the ash-fertilised sites exceeded that of the PK-sites. Furthermore, unlike PK fertiliser, nitrogen-poor sites the effect of ash seemed to increase in strength over time, even in shallow-peated sites. The phosphorus in wood ash is slow-soluble (Steenari *et al*. 1999, Nieminen 2003), which together with the accelerating decomposition of organic material probably explains the long-term remedial effect of ash (see also Moilanen *et al*. 2002). It is likely that wood ash treatment will maintain growth at a higher level than PK treatment during the following years.

Both PK fertiliser and wood ash increased foliar P, K, and B concentrations and improved the nutrient status of tree stand at least for 20 years. As regards phosphorus, the status will most likely remain good for years or even decades still (Silfverberg 1996, Moilanen *et al*. 2002), but the status of the easily leachable potassium may be different, at least for PK fertilised trees (Ahti 1983, Kaunisto 1992, Silfverberg 1998). The effect of the water-soluble potassium chloride (KCl) in PK fertiliser has often been noted to last only 15–20 years (Kaunisto 1992, Moilanen 1993). As the fertilising effect begins to run out, stand growth is likely to become retarded by the lack of potassium, especially where using PK fertilisers, but also on ash-fertilised sites.

In conclusion, our results suggest that wood ash is a good alternative to commercial PK fertilizers in drained pine mires. Stand nutrient status and growth were enhanced over a longer period of time than with commercial PK fertilisers (having phosphorus as raw phosphate and potassium as KCl) on both nitrogen-rich and nitrogen poor sites.

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ВЛИЯНИЕ УДОБРЕНИЯ НА МИНЕРАЛЬНОЕ ПИТАНИЕ И РОСТ СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.) НА ОСУШЕННЫХ БОЛОТАХ – СРАВНЕНИЕ ДРЕВЕСНОЙ ЗОЛЫ И ФОСФОРНО-КАЛИЙНОГО УДОБРЕНИЯ ПРОМЫШЛЕННОГО ПРОИЗВОДСТВА

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Резюме

Дефицит минеральных питательных веществ ограничивает рост древостоя на осушенных торфяниках. За последние 50 лет в Финляндии было проведено удобрение заболоченных лесов в целом на территории 1,7 млн. га, что составляет около трети всех осушенных площадей. На богатых азотом болотах использовались в качестве подкормки фосфорно-калийные удобрения (ФК), а на бедных азотом болотах – азотно-фосфорно-калийные удобрения (АФК).

Тепловыми электростанциями и целлюлозными заводами ежегодно вырабатывается более 100 000 тонн древесной золы. Зола, как известно, содержит большое количество минеральных веществ, необходимых растениям, и снижает кислотность почвы на долгое время. Практическое лесоводство заинтересовано в информации о том, каким образом удобряющее действие древесной золы отличается от воздействия других видов подкормки. Важно также знать, в какой степени древесная зола может использоваться в качестве заменителя или добавки к удобрениям промышленного производства в поддержании питательной среды болотных лесов.

В ходе данного исследования изучалось различие воздействия древесной золы и фосфорно-калийных удобрений на примере четырёх различных по питательной среде участках болотного сосняка в Северной Финляндии. В качестве показателя эффективности подкормки использовались изменения, отмеченные в радиальном приросте древесины и изменения в содержании минеральных веществ в хвое деревьев.

Оба вида обработки заметно повляли на рост древостоя. В первые годы фосфорно-калийные удобрения ускоряли рост сосны больше, чем древесная зола. Позднее эти различия выравнивались и принимали обратный характер: спустя 15 лет с начала подкормки удобрениями и золой более быстрый прирост древесины отмечался на участках, где вносилась древесная зола.

Быстрота и интенсивность действия подкормки находились в прямой зависимости от толщины торфяного слоя, а также от концентрации азота в торфе и деревьях. При удовлетворительном или достаточном содержании азота, как древесная зола, так и фосфорно-калийные удобрения заметно усиливали рост сосен уже через пять лет. Со временем действие подкормки усиливалось, и через 20 лет прирост древесины обработанных удобрением сосен был уже в два раза больше, чем у сосен на сравнительном участке без внесения удобрения (разница в 1,5 – 2,5 мі на гаП№). И, наоборот, в болотных лесах с тонким торфяным слоем (глубина слоя < 30 см), где древостой страдает от недостатка азота, воздействие фосфорно-калийных удобрений было очень незначительно.

Действие обоих видов обработки на минеральный баланс деревьев продолжалось и 20 лет спустя. Содержание фосфора, калия и бора в хвое превышало дефицитный уровень, и было значительно выше, чем на сравнительных участках без подкормки. На основании результатов исследования можно сделать вывод, что древесная зола хорошо подходит для удобрения болотных лесов и является даже более приемлемым видом подкормки, чем традиционное фосфорно-калийное удобрение промышленного производства.

Ключевые слова: торфяники, глубина торфяного слоя, гидромелиорация, дефицит питательных веществ, азот, фосфор, калий, *Pinus sylvestris* L, прирост древесины, фосфорно-калийное удобрение, древесная зола.