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VEGETATION CHANGES AFTER DRAINAGE AND FERTILIZATION IN PINE MIRES

Kasvillisuuden muutokset rämeillä ojituksen ja lannoituksen jälkeen

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The effects of drainage and fertilization (both slowly and readily soluble fertilizers were included) on the above-ground biomass and cover of understorey vegetation were studied in two mires situated at Lammi, southern Finland, and at Ilomantsi, northern Karelia. Urea and especially micronutrients decreased the cover of *Sphagnum* species. Slowly soluble nitrogen also decreased the cover of *Sphagnum*, but not as efficiently. In fen site types the cover and biomass of *Vaccinium oxycoccos* and *Andromeda polifolia* increased strongly after fertilization. The greatest change in vegetation was caused by micronutrients given together with macronutrients. The cover and biomass of *Eriophorum vaginatum* and *Rubus chamaemorus* increased on all the fertilization plots probably because phosphorus was included in all the treatments. *Calluna vulgaris* and *Empetrum nigrum* benefited from the NPK fertilization on hummock sites.

Keywords: Apatite, biodiversity, biomass, biotite, peatland forestry, urea

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INTRODUCTION

The effect of drainage and fertilization on the production of stemwood has been rather intensively studied in Finnish peatland forestry. However, our knowledge of the primary production patterns of other components of the mire ecosystem is scarce and poorly documented (see, however, Reinikainen 1976, 1981, Paavilainen 1980, Vasander 1990, Finér 1992). The ecological role of a vigorous growth of tall dwarf shrubs may, for example, be great since they utilize a large proportion of the available nutrients, and may also inhibit the establishment of tree seedlings (Sarasto 1964, Sarasto & Seppälä 1977).

In treeless and sparsely forested bogs and fens the available nutrients are often accumulated in cottongrass (*Eriophorum vaginatum*) and dwarf birch (*Betula nana*) stands (Tamm 1954, Sarasto 1964, Päivänen 1970). The moss layer does not usually play a major role in nutrient accumulation (Jäppinen & Hotanen 1990), although it may have a considerable positive or negative effect on the establishment of tree seedlings in drained mires (e.g. Kaunisto & Päivänen 1985).

This study belongs to a project comparing the effects of slowly and readily soluble fertilizers on mire ecosystems (LaVaMe, Lindholm & Vasander 1988, Vasander & Lindholm 1991, 1992). The aim was to study the impact of drainage and different fertilization treatments on the understorey vegetation of southern boreal mires in southern Häme (Laaviosuo at Lammi) and northern Karelia (Ahvensalo at Ilomantsi). The change in the cover and above-ground dry mass of the plants on drained and drained and fertilized sites are compared.

MATERIAL AND METHODS

Laaviosuo at Lammi, southern Finland, was drained in February 1978 and the fertilization experiments were established in May 1978 (Reinikainen & Lindholm 1980). Kaurastensuo, a neighbouring similar undrained raised bog, was used as a control site. The vegetation in both raised bogs consists of hummocks and hollows at varying heights above the water table (Vasander 1979, 1982). The hummocks formed a site of the *Sphagnum fuscum* pine bog type, RaR, and the cottongrass hollows a site of the small-sedge bog type, LkN. This kind of complex site type is called ridge-hollow pine bog (KeR). As hollows cover a total of two-thirds of the area of the fertilization experiments at Laaviosuo the volume of the pine stand in undrained stage was only 3 m^3ha^{-1} (Vasander 1979, 1982). The uppermost two meters of peat on both mires is ombrotrophic *Sphagnum* peat (Tolonen 1987).

The dominant plant species on the high hummocks were the dwarf shrubs *Calluna vulgaris, Empetrum nigrum*, peat moss *Sphagnum fuscum* and some lichens *Cladina* spp. and *Cladonia* spp. *Rubus chamaemorus* and *Drosera rotundifolia* were the only herbs present. The dominant plant species in the field layer of the hollows were *Eriophorum vaginatum, Andromeda polifolia* and in the ground layer *Sphagnum angustifolium* and *S. balticum* (Vasander 1982).

Ahvensalo at Ilomantsi, eastern Finland, was drained for the first time by hand in the 1930s. The ditches were re-excavated for the first time in the 1950s, and again in 1968. Draining was rehabilitated in 1979. The fertilization experiment for the LaVaMe project was established in autumn 1979 (Kuusipalo & Vuorinen 1981). There are both readily and slowly soluble fertilizers as well as micronutrients added (Table 1).

The drained tall-sedge pine mire, where intermediate (lawn) level was the dominating plant community, is examined in this report. The dom-

Table 1. Design of the fertilization trial.

Taulukko 1. Lannoituskokeen eri käsittelyt.

Abbreviation	Fertilizer	Solubility	Kg/ha	Nutrients, kg/ha
O	–	–	–	–
AB	Apatite	Slowly	400	P54, K31, Ca178, Mg66
	Biotite	Slowly	570	
PK	Superphosphate	Readily	500	P44, K85, S60, Fe2
	Potassium chloride	Readily	170	Mg1, Na2
UAB	Urea	Readily	215	N100, P54, K31, Ca178
	Apatite	Slowly	400	Mg66
	Biotite	Slowly	570	
UABM	Urea	Readily	215	N100, P54, K31, B1.1
	Apatite	Slowly	400	Cu12.8, Mn5.5, Fe9.8
	Biotite	Slowly	570	Zn5.5, Mo1.4, Na0.7
	Micronutrients		100	
NFAB	Nitroform	Slowly	310	N118, P54, K31, Ca178
	Apatite	Slowly	400	Mg66
	Biotite	Slowly	570	

inant plant species in the field layer was *Eriophorum vaginatum* with *Carex magellanica, C. rostrata, C. pauciflora, Menyanthes trifoliata* and *Rubus chamaemorus*. The dwarf shrubs *Andromeda polifolia, Chamaedaphne calyculata, Vaccinium uliginosum,* and *V. oxycoccos* were also abundant. *Sphagnum angustifolium, S. magellanicum, Aulacomnium palustre* and *Polytrichum strictum* were abundant in the moss carpet (Kuusipalo 1982). There was no undrained control at Ahvensalo.

The vegetation analysis was based on cover estimation for each species. The study plots were 1 m^2 in area. The vegetation dry mass analysis was based on harvesting (Milner & Hughes 1968) the same plots at the time when the aboveground biomass of the plants was considered to be at a maximum. The size of the area harvested in the biomass analysis was 0.25 m^2. The sampling of mixed vegetation was based on weighed subsampling (Heikurainen 1951). Harvesting was done at Ahvensalo in 1982 and at Laaviosuo in 1984.

RESULTS

The cover of mosses decreased after fertilization. The change was most prominent in the hollows. The cover of *Sphagnum* species on the UABM plots was only 2%, the amount of other mosses being also only 20% (Fig. 1). The nitroform (slowly soluble nitrogen fertilizer) treatment also decreased the cover of *Sphagnum*, but the urea treatment had an even more drastic effect (Figs. 1–3). The carpet of dead *Sphagnum* was colonized by other mosses: *Polytrichum strictum* and *Pohlia nutans* at Laaviosuo, as well as *Pleurozium schreberi* and *Dicranum scoparium* at Ahvensalo.

The moss cover and the cover of litter were negatively correlated. The correlation was the most significant in the case of the hummocks at Laaviosuo ($r = -0.99$, $n = 7$, $p<0.001$). Mosses cannot grow through litter and, due to the annual deposition of litter, the moss protonemas are not able to colonize the litter carpet.

Eriophorum vaginatum was the species which benefited the most from fertilization. At Laaviosuo its cover increased in the hollows especially after the AB, UAB and UABM treatments. The increase in cover on the hummocks was highest on the PK plots (Figs. 1 and 2). At Ahvensalo *Eriophorum vaginatum* also increased especially after UAB fertilization (Fig. 3). Fertilization with the micronutrient mixture increased the cover of the dwarf shrubs *Androm-*

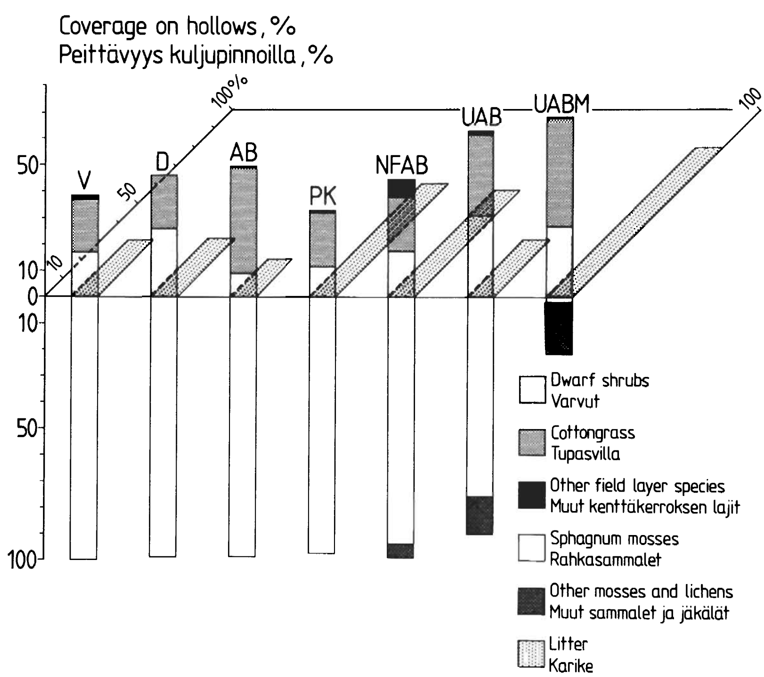

Fig. 1. Cover of different plant groups and litter in the hollows at Laaviosuo and Kaurastensuo (virgin bog). The letters on the columns denote the fertilization treatments. V = virgin bog, D = drained, unfertilized bog.

Kuva 1. Eri kasviryhmien ja karikkeen peittävyydet Laaviosuon ja Kaurastensuon (luonnontilainen suo) kuljupinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. V = luonnontilainen, D = ojitettu lannoittamaton suo.

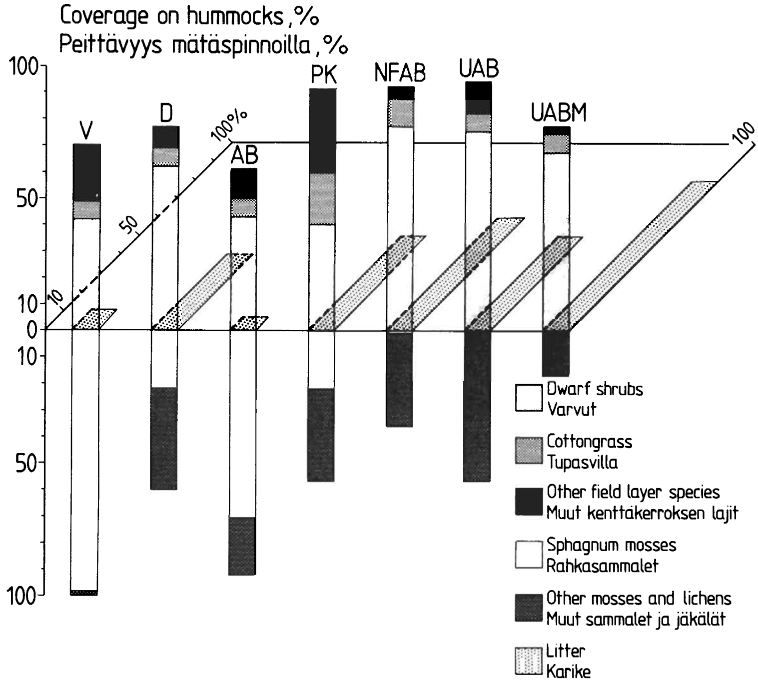

Fig. 2. Cover of different plant groups and litter on the hummocks at Laaviosuo and Kaurastensuo (virgin bog). The letters on the columns denote the fertilization treatments. V = virgin bog, D = drained, unfertilized bog.

Kuva 2. Eri kasviryhmien ja karikkeen peittävyydet Laaviosuon ja Kaurastensuon (luonnontilainen suo) mätäspinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. V = luonnontilainen, D = ojitettu lannoittamaton suo.

eda polifolia and *Vaccinium oxycoccos* at Ahvensalo, and also in the hollows at Laaviosuo. *Rubus chamaemorus* increased its cover on all

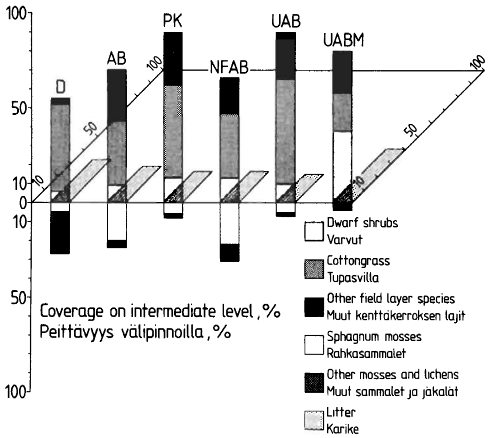

Fig. 3. Cover of different plant groups and litter on the intermediate levels at Ahvensalo. The letters on the columns denote the fertilization treatments. D = drained, unfertilized bog.

Kuva 3. Eri kasviryhmien ja karikkeen peittävyydet Ahvensalon sararämemuuttuman välipinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. D = ojitettu lannoittamaton suo.

the fertilization plots at Ahvensalo. At Laaviosuo it increased especially after NFAB fertilization (Figs. 1 and 3).

The above-ground biomass of the dwarf shrubs varied in the hollows between 40–190 g m^{-2}, and on the hummocks between 150–700 g m^{-2} (Figs. 4–6). The amount of dwarf shrubs increased the most on the UABM fertilization area where their total biomass at Laaviosuo was 118 g m^{-2} in the hollows. The proportion of *Andromeda polifolia* on these sites was 38% of the total biomass, and that of *Vaccinium oxycoccos* 59%. The above-ground biomass of *Vaccinium oxycoccos* was ten times greater on the UABM fertilization area at Laaviosuo compared with the undrained Kaurastensuo bog. There was also a clear difference when compared with the drained but not fertilized site at Laaviosuo, the biomass being three times greater on the fertilized site.

At Ahvensalo the dwarf shrub biomass was three times greater on the UABM fertilization plot as compared with the unfertilized, drained plot. The increase in *Andromeda polifolia* biomass was 12-fold, respectively (Fig. 6).

Drainage alone did not increase the biomass of *Eriophorum vaginatum* in the hollows. The *Eriophorum vaginatum* biomass increased over

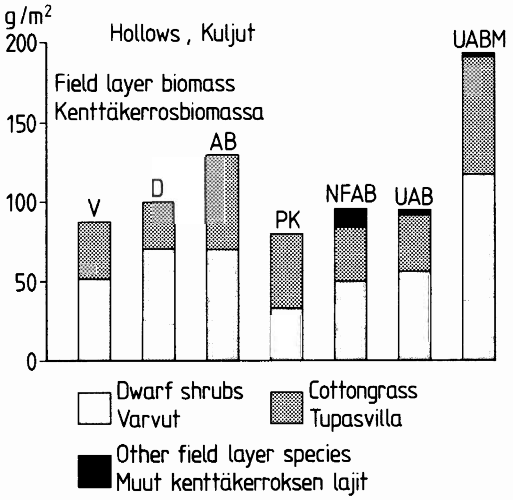

Fig. 4. Biomasses of different plant groups in the hollows at Laaviosuo and Kaurastensuo (virgin bog). The letters on the columns denote the fertilization treatments. V = virgin bog, D = drained, unfertilized bog.

Kuva 4. Kenttäkerroksen eri kasviryhmien biomassat Laaviosuon ja Kaurastensuon (luonnontilainen suo) kuljupinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. V = luonnontilainen, D = ojitettu lannoittamaton suo.

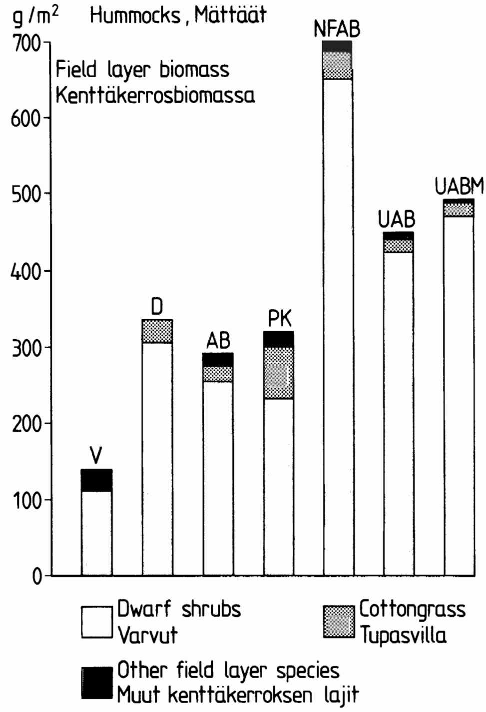

Fig. 5. Biomasses of different plant groups on the hummocks at Laaviosuo and Kaurastensuo (virgin bog). The letters on the columns denote the fertilization treatments. V = virgin bog, D = drained, unfertilized bog.

Kuva 5. Kenttäkerroksen eri kasviryhmien biomassat Laaviosuon ja Kaurastensuon (luonnontilainen suo) mätäspinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. V = luonnontilainen, D = ojitettu lannoittamaton suo.

twofold after PK fertilization compared to the unfertilized, drained site (Figs. 4–6). The AB fertilization increased the *Eriophorum vaginatum* biomass in the hollows at Laaviosuo, being finally about 1.5 times greater than that on the virgin site. After PK fertilization it was 1.3 times greater and after UABM fertilization double, respectively (Fig. 4).

The biomass of *Rubus chamaemorus* increased on all the fertilization plots at Ahvensalo (Fig. 6). It also spread to the hollows at Laaviosuo (Fig. 4).

The macronutrients N, P and K clearly increased the biomass of the dwarf shrubs *Calluna vulgaris* and *Empetrum nigrum.* This is evident from the results for the NFAB, UAB, and UABM fertilizations (Figs. 5 and 6). The dwarf shrubs on the NFAB fertilization plot were rather tall and hence their dry mass was high. The above-ground dry mass of *Calluna vulgaris* was 250 g m^{-2}, and that of *Empetrum nigrum* 340 g m^{-2} (Fig. 5).

Changes in total above-ground dry mass can only be calculated using the data from Ahvensalo as the mass of bryophytes was not determined at Laaviosuo. Compared with the drained, unfertilized area, the field layer biomass increased the most on the plots fertilized with UABM. As the ground layer dry mass usually decreased after fertilization the increase in total understorey biomass was at its highest 1.5-fold compared with the drained, unfertilized area (Table 2).

DISCUSSION

The results from Laaviosuo and Ahvensalo support the findings reported in other studies. Fer-

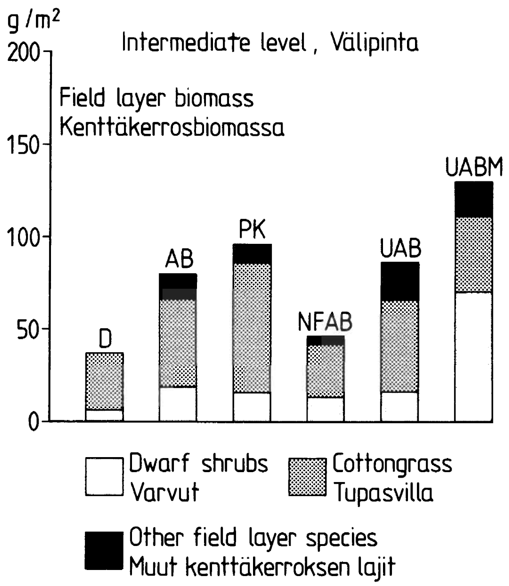

Fig. 6. Biomasses of different plant groups on the intermediate levels at Ahvensalo. The letters on the columns denote the fertilization treatments. D = drained, unfertilized bog.

Kuva 6. Kenttäkerroksen eri kasviryhmien biomassat Ahvensalon sararämemuuttuman välipinnoilla. Kirjaimet pylväiden yläreunassa viittaavat lannoituskäsittelyihin. D = ojitettu lannoittamaton suo.

tilizers, especially readily soluble ones, have been explained to produce salinity shock to *Sphagnum* (Sarasto 1961, Päivänen & Seppälä 1968, Mannerkoski 1970, Heikurainen & Laine 1976, Backéus 1980, Kuusipalo 1980, Vasander 1982). Micronutrient fertilization further diminished the amount of *Sphagnum* because the mosses surviving after fertilization were very etiolated. It was not possible to measure the biomass and production of *Sphagnum* at all at Ahvensalo owing to their poor condition (Jäppinen & Hotanen 1990).

Urea, micronutrients and readily soluble fertilizers also killed *Polytrichum strictum* at Ahvensalo. Micronutrients added seemed to be toxic to mosses probably due to their high heavy metal concentration (e.g. Simola 1977). The concentrations of Cu and Zn clearly increased in the surface peat at Ahvensalo after fertilization (Pasanen et al. 1983, Jäppinen 1987).

Drainage lowered the water table both in the hummocks and hollows (Lindholm & Markkula 1984), and affected the vegetation on both types of site. The total cover and biomass of the field layer increased after drainage and fertilization, partly due to the increase in growing space after the death of mosses, and partly due to the increase in nutrient availability due to deeper aerated surface peat layer. The change in biomass distribution after drainage is both quantitative and, what may be even more important, qualitative, i.e. the proportion of ground layer decreases and that of field layer increases (Vasander 1982, Reinikainen et al. 1984).

On hummocks and intermediate levels dwarf shrubs and *Rubus chamaemorus* increased their biomass after fertilization. At Ahvensalo all the fertilization treatments increased the cover and biomass of *Rubus chamaemorus*. Phosphorus obviously increases its leaf production (Saebo 1968, Kortesharju & Mäkinen 1986).

The height growth of dwarf shrubs increased after fertilization at the hummock level (Lindholm 1980, 1982). *Calluna vulgaris* and *Empetrum nigrum* increased their biomass on all the NPK plots. Heikurainen and Laine (1986) have

Table 2. The proportional change in field and ground layer biomasses at Ahvensalo. The drained unfertilized site is marked as 1, and the other sites are compared with it.

Taulukko 2. Kenttä- ja pohjakerroksen biomassojen suhteellinen muutos Ahvensalon sararämemuuttuman lannoitetuilla aloilla. Ojitettua lannoittamatonta suota on merkitty suhdeluvulla 1, johon lannoitettuja aloja on verrattu.

Layer – *Kerros*	Fertilization – *Lannoitus*				
	AB	PK	NFAB	UAB	UABM
Field layer – *Kenttäkerros*	2.2	2.6	1.3	2.3	3.5
Ground layer – *Pohjakerros*	1.2	0.4	1.6	0.7	0.1
Total – *Yhteensä*	1.5	1.0	1.5	1.1	1.1

also noted that NPK fertilization increases the height and vitality of dwarf shrubs and Mälkönen et al. (1982) noted that fertilization increases the cover of *Calluna vulgaris* in the long-term.

Andromeda polifolia and *Vaccinium oxycoccos*, increased their biomass on sites which had been fertilized with urea and micronutrients. Nitrogen is known to be essential for the growth of *Vaccinium oxycoccos* shoots (Vahrameeva 1982). Here micronutrients also increased the vegetative growth of shoots.

Eriophorum vaginatum benefited from fertilization in hollows and at intermediate levels. The species efficiently cycles the nutrients inside the tussock, and has a high capacity to absorb nutrients from the surrounding peat (Chapin et al. 1979). In southern Sweden its biomass increased ninefold two years after fertilization with phosphorus (Tamm 1954). In Finland PK and P fertilization has been noted to increase the vitality and cover of *Eriophorum vaginatum* (Päivänen & Seppälä 1968, Mannerkoski 1970, Päivänen 1970). NPK fertilization has been noted to affect the cover of *Eriophorum vaginatum* in proportion to the amount of fertilizer up to 1 000 kg/ha (Heikurainen & Laine 1976).

The relative increase in *Eriophorum vaginatum* after fertilization may be great in communities where the number of species in the virgin state is low and the species may colonize the free site due to the changed environmental conditions. Vasander (1982) found that the biomass of *Eriophorum vaginatum* in a *Carex limosa–Scheuchzeria palustris–Sphagnum majus* hollow (KuN) was 100-fold greater after drainage and NPK fertilization compared to the undrained hollows.

The influence of drainage and fertilization on the diversity of the field layer plant community is negative. Some dominant species, i.e. dwarf shrubs and cottongrass, increase their relative and absolute proportion. The difference between different vegetation units (e.g. hummocks and hollows) also decreases (Kuusipalo 1982, Vasander 1984). On the other hand, the diversity of the ground layer may even increase when there still survive original dominant mire species, and some forest moss species (e.g. *Pleurozium schreberi*) and colonists such as *Pohlia nutans* and *Marchantia polymorpha* are colonizing the site (Vasander 1987a, b).

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TIIVISTELMÄ:

KASVILLISUUDEN MUUTOKSET RÄMEILLÄ OJITUKSEN JA LANNOITUKSEN JÄLKEEN

Ojituksen ja lannoituksen (hidas- ja nopealiukoinen N, P ja K) vaikutuksia kenttä- ja pohjakerroskasvillisuuden peittävyyteen ja biomassaan tutkittiin ns. LaVaMe (Lannoituksen vaikutus metsäekosysteemiin)-lannoituskoejärjestelyn mukaisilla lannoitusaloilla Lammin Laaviosuon keidasrämeellä ja Ilomantsin Ahvensalon sararämemuuttumalla.

Peittävyys- ja biomassa-analyysit antoivat hyvin toisiaan vastaavia tuloksia. Urea- ja varsinkin hivenainelannoitus vähensi rahkasammalten määrää. Myös hidasliukoinen typpilannoitus (nitroform) vähensi rahkasammalten peittävyyttä, mutta ei kuitenkaan yhtä voimakkaasti kuin urea. Nevaisilla kasviyhdyskunnilla lannoituksesta hyötyivät pienikokoiset varvut (suokukka ja karpalo) sekä tupasvilla. Varvut lisäsivät biomassaosuuttaan etenkin kaikkia pääravinteita ja hivenainelannoitetta saaneilla aloilla. Tupasvillan ja lakan määrä kasvoi kaikilla lannoitealoilla.

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