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EASILY EXTRACTABLE NUTRIENTS IN THE SURFACE PEAT LAYER OF VIRGIN SEDGE-PINE SWAMPS

M. STARR and C. J. WESTMAN

SELOSTE:

HELPPOLIUKOISET KASVINRAVINTEET LUONNONTILAISTEN SARARÄMEIDEN PINTATURPEESSA

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This paper deals with the nutrient status of the surface peat layer from virgin sedge-pine swamps, its relationship to peatland site types and thus site productivity. More specifically, interest is focused upon easily extractable nutrients in the peat, variation in the different site types and also the geographic variation within the same site type.

When the results are expressed as concentration values, it appears, that only easily extractable Ca and Mg correspond to the productivity status of the peatland site types. Easily extractable N, P, and K levels in the herb rich sedge-pine swamps are generally lower than in the less productive ordinary sedge-pine swamps but are greater than in the small sedge-pine swamps, which are the least productive ones. The differences between the site types in all five nutrients become much clearer when the results are expressed in kilograms per hectare. The amounts of P, K, and Ca are significantly different between the site types, and the differences correspond to the productivity of the site types. For N and Mg, the differences are not as clear but a corresponding tendency can be seen. Further, it is shown that N and, to a lesser extent, P appear to comply with the hypothesis of an increase in nutrient availability in southern Finland.

1. INTRODUCTION

During the last two decades forest amelioration, primarily peatland drainage, has been of great importance in Finland. At present, about 4 million hectares of the total peatland area of some 9.6 million hectares, has been drained for forestry purposes. This enormous drainage activity has encouraged an intensive programme of research concerning peatlands and their utilization for forest production.

For timber production on drained peatlands it is of essential importance to know the virgin peatland site types and their potential post-drainage tree growth. The classification of peatlands in Finland for forestry purposes is based on the now classic work of CAJANDER (1913). Essentially, the classification is a phytosociological one; based on the species composition of the tree stand (if present) and on the ground vegetation. The site types — the taxonomic units — represent assemblages of species populations having a distinct tendency to concentrate at points along a vegetation continuum thus forming recognisable plant associations. These site types should relate to a pattern of habitats and environmental gradients.

Subsequent research, ranging from purely ecological studies to economic prognoses (eg. LUKKALA 1937, HEIKURAINEN 1959, KELTIKANGAS & SEPPÄLÄ 1966, HUIKARI & PAARLAHTI 1967, SEPPÄLÄ 1968, 1969, PAARLAHTI et al 1971), has thus sought to establish the nature of the site types. Much of the research has concentrated on the regulation of the water table which, of course, has been of primary interest when taking virgin peatlands into use for forestry purposes. Equally important has been the clarification of the potential post-drainage timber production from the different peatland site types. It can clearly be seen that, within climatological zones, the revival of growth after forest drainage is dependent upon the site type (LUKKALA 1929, 1937, 1951, HEIKURAINEN 1959, SEPPÄLÄ 1969).

Supposing that the site type fertility is principally determined by two gradients: a hydrological and a nutrient gradient (see HEIKURAINEN 1972 p. 438), it is possible to state that after drainage the hydrological gradient is optimized and so only the nutrient gradient remains to regulate post-drainage tree growth. It is of great importance when optimizing the nutrient gradient, through fertilization, to clarify the relationship between the nutrient status of the surface peat layer and the growth potential of the site types. The importance of the surface peat layer is verified by HEIKURAINEN (1955), PAAVILAINEN (1968) and PUUSTJÄRVI (1973), according to whom the surface peat type is shown to be well correlated with the site type and to contain the greatest part of the tree roots, both before and after drainage.

Several attempts have been made to clarify the relationship between the nutrient status of the surface peat and the virgin site type, and thus tree growth. For instance, VAHTERA (1955), who studied the chemical properties of the surface peat from 50 year old and younger forest ditching areas, established that there is a fairly good correlation between potential stand growth and surface peat pH as well as total content of nitrogen and calcium. However, a classification of peatlands based on chemical properties of the surface peat showed to be impossible.

Comparable results have been presented by HEIKURAINEN (1953), HOLMEN (1964), HAVERAAEN (1969) and VALK (1973). However, most studies have investigated only the total nutrient content of the peat. When studying the extractable (more or less plant-available) content the results have been more confusing. HOLMEN (1964) noted a tendency towards a negative correlation between ammonium lactate extractable phosphours and potassium, and tree stand characteristics; MANNERKOSKI (1973) also found a negative correlation between extractable potassium and phosphorus using an ammonium acetate extractant (pH 4.65), and stand characteristics. PAARLAHTI et al (1971) stated on the other hand, that peat nutrient analysis, based on either ammonium acetate (pH 4.65) extraction or treatment with hot 2-n HCl, explains very little of the stand growth after drainage.

The often weak and confusing relationships between peat nutrient status and stand productivity can be attributed to several possible causes. It must be remembered that the site type is the response to the whole environment and not to single, isolated environmental factors (see DICKSON 1962 p. 20 and HOLMEN 1964 p. 206). The effects of competition for soil nutrients by the ground vegetation may be quite significant. It has been shown that most of the nutrients added in forest fertilization treatments become bound up in the ground vegetation (HAVERAAEN 1967, PAAVILAINEN 1973, SARASTO & SEPPÄLÄ 1977). Fertilization experiments have also indicated, that the nutrient status of peat of the same origin may vary with the geographical location (ANTTINEN 1951, SALONEN 1958). One should also bear in mind, particularly when working with easily extractable fractions of nutrients, that the forest crop rotation period is considerable while the plant species used to classify the site types, having a much shorter growth cycle, can be compared to agricultural crops. Also, cation antagonism and interaction could significantly affect the relationships for some of the cations. For example, at high concentrations of calcium, exchangeable potassium may be replaced and leached away (BRADY 1974).

The research work cited indicates difficulties in predicting post-drainage stand growth using peat nutrient analysis and, particularly, the difficulties with easily extractable nutrients. The broad range of peatland site types result in an enormous variation in the peat due to the differences in hydrology and vegetation and thus, subsequently, the nutrient status of the site types. If however, the range of site types were restricted to, for instance the series of sedge-pine site types, it would then be possible to a great extent, to limit the variation that arises from differences in the physical properties of the peat. According to HEIKURAINEN (1972 p. 438) such a restriction would give the following series of site types: small sedge-pine swamp, ordinary sedge-pine swamp and herb rich sedge-pine swamp. These closely related series of site types are characterised by a steady increase in the site quality index, which indicates the potential postdrainage growth (HEIKURAINEN 1959 p. 227, 1972 p. 443). Thus, this restriction upon the range of site types offers the possibility of further development of peat nutrient analysis for the prediction of postdrainage stand growth and the necessity of forest fertilization.

The aims of this paper, are therefore, to examine the nature of the nutrient status of the surface peat layer from virgin sedge pine swamps, its relationship to peatland site types and thus site productivity. More specifically, interest is focused upon easily extractable nutrient content of the peat, variation in the different site types and also the geographical variation within the same site type.

The experimental design and field work were arranged and performed by Westman. The laboratory work in connection with this paper and the statistical treatment of the material were performed by Starr. The final compilation of this paper has been done in cooperation with both authors. The authors wish to express their acknowledgements to the Ministery of Education in Finland for granting Starr a scolarship, which financed his research work in Finland during years 1976—77. We also wish to express our acknowledgements to Kemira Foundation, which has supported Westman's research work for several years and thus made the preparation of this paper possible.

2. MATERIAL AND METHODS

2. 1 Material

The research material used is a part of a larger material sampled from a number of virgin sedge-pine swamps including: small sedge-pine swamps, ordinary sedge-pine swamps and herb rich sedge-pine swamps. The material covers most of Finland (60°N — 66° N and 22° E — 29° E); although many of the samples come from central and northern parts of the country where the frequency of peatland is especially high. Altogether 155 samples from 22 peatlands were sampled in years 1974 and 1975. All the samples were taken from peatlands in virgin condition. The field work was performed as follows. On the peatland fulfilling given criteria, a number of sampling quadrats (0.5 m^2) were randomly taken and from the centre of each a peat sample was extracted by means of a sample corer having a saw-toothed cutting edge. Effort was made to obtain an undisturbed sample. The sample was cut into 2 subsamples within the corer; one representing the 0—10 cm horizon and the other representing the 10—20 cm horizon. For the purposes of this paper, the data relates to the 10—20 cm horizon only. The two subsamples were immediately put into polythene bags and sealed with elastic bands. They were then taken back to the laboratory where they were frozen and stored. Generally, the time between sampling and freezing was not longer than 2—3 days, although in some cases, samples remained unfrozen for a period of 5 days. Taking into account the surrounding area, the peatland site type was determined for each sampling plot according to Heikurainen (1968). Frequency and percentage cover of plant species in the 0.5 m² sampling quadrat was determined as well as stand data and peat depth. In this study only the peatland site type has been used when grouping the material.

2. 2 Methods

The frozen samples were weighed and then oven dried in an aerated oven on metal trays at 30° C, when they were then milled using a hammer mill fitted with a 2 mm Ø bottom sieve; no other homogenization was performed. The dried and milled samples, which had a water content of about 10 %, were then stored in paper bags for future analysis.

For the purposes of this paper, the samples have been analysed for easily extractable nitrogen, phosphorus, potassium, calcium, and magnesium. The analysis was performed by extracting a 2 g sample with 200 ml of 0.05-n sulfuric acid. The peat-acid suspension was shaken in an automatic shaker for one hour and immediately filtered on a soft paper. From this extract were determined nitrogen (ammonium and, if present, nitrate) by steam distillation using Devardo's alloy and magnesium oxide as catalyts (Bremner 1965), phosphorus with the Molybenum blue method (Kaila 1955), potassium directly from the extract with a Flame Photometer, and calcium and magnesium from a 5 % lanthanum oxide buffered solution with an Atomic Absorption Spectrophotometer.

The total nutrient contents had been previously determined and are only presented here for reference. Total nitrogen was determined by the Kjeldahl method followed by steam distillation, and phosphorus, potassium, calcium, and magnesium by ashing a peat sample and dissolving the ash in hydrochloric acid acid, and then determining the nutrients principally as above. A peat: water suspension of 1: 2.5 was used to measure pH with a glass electrode; the ash content was determined by igniting a peat sample at 550° C, and the effective cation exchange capacity by extracting with 1-n potassium chloride and titrating the extract with sodium hyroxide for exhangeable acids and sodium EDTA for exchangeable bases.

2. 3 Statistical methods

To investigate the nutrient content in the different site types the chemical data, classified by site type, were subjected to a standard analysis of variance. The variance models for each nutrient in turn were then tested by the F-ratio and significant differences between pairs of mean values by a two-tailed t-test at the 5 % significance level. To enable an examination of the effect of regional climate upon site type nutrient levels, a two-way analysis of variance was performed, classifying the data both by site type and the Temperature Sum of the area. A value of 1000 d.d. was used to allocate the samples to either northern or southern Finland.

3. RESULTS AND DISCUSSION

3. 1 General properties of the research material

The general physical and chemical properties of the material: volume weight, ash content, pH, cation exchange capacity and total nutrient content of the peat, are presented in table 1. It is of certain intrest that the values seem to be well related to site type. There is a systematic increase in volume weight, ash content, pH and content of total N, P, Ca, and Mg from the small sedge-pine swamps through the ordinary sedge-pine swamps to the herb rich sedge-pine swamps. However, the variance models did not prove significant in all cases. In general the magnitude of nutrients in the peat is of same order as reported by Vahtera (1955). It is of interest, that the total cation exchange capacity seems to increase with decreasing trophic status, while the relative amount of exchangable bases, as could be expected, increases with increasing trophic status.

Table 1. The research material and its general physical and chemical properties.[1]
Taulukko 1. Tutkimusaineisto ja sen yleiset fysikaaliset ja kemialliset ominaisuudet.[1]

Site type *Suotyyppi*	Number of samples *Näytteiden määrä*	Volume weight *Tilavuuspaino* g/dm³	Ash content *Tuhkapitoisuus* %	Acidity *Happamuus* pH_{H_2O}	Cation exchange capacity *Kationivaihtokapasiteetti* Total *Totaali* m.e./100 g	Bases *Emäkset* %	Total content of nutrients *Kokonaisravinnepitoisuus* mg/g N	P	K	Ca	Mg
Herb rich sedge-pine swamp *Ruohoinen sararäme*	26	91.7±11.38	7.6±1.43	4.6	29.6±4.10	50.6	22.5±2.48	1.03±0.108	0.54±0.145	5.42±0.822	0.94±0.140
Ordinary sedge-pine swamp *Varsinainen sararäme*	86	54.8±5.68	5.1±0.66	4.3	36.1±1.63	44.1	16.0±1.17	0.77±0.056	0.79±0.094	3.38±0.352	0.72±0.073
Small sedge-pine swamp *Lyhytkortinen sararäme*	43	59.5±7.70	3.7±0.56	4.1	33.5±2.38	35.0	13.4±1.65	0.49±0.047	0.52±0.135	2.30±0.251	0.54±0.059

[1]) In the table are given mean values and the confidence values at the 5 % risk level.
Taulukossa on esitetty keskiarvot sekä niiden luotettavuusrajat 5 % riskitasolla.

3. 2 Easily ectractable nutrients

The easily extractable nutrient content for the whole material is presented, by site type, in figures 1—5. The mean values and their standard deviations are given in table 2. The site types are listed in order of their productivity status (descending order). It appears that only easily extractable Ca and Mg correspond to this series. Easily extractable N, P, and K levels in the herb rich sedge-pine swamps are generally lower than in the less productive ordinary sedge-pine swamps but are greater, as expected, in the small sedge-pine swamps the least productive of the site types in the study. The F-ratio's for the variance models were found to be significant at the 95 % level, or greater, with the exception of nitrogen. However, the t-tests for pairs of means between the site types were only significant in a limited number of cases, as indicated in table 2.

3. 21 Nitrogen

The easily extractable nitrogen content is poorly related to site type and thus, tree growth. The values also exhibit a wide range (fig. 1). Undoubtedly, the nitrogen values have been considerabely affected by both the sample collecting and processing and the time spent in dry storage before the analytical work could begin. Thus, the nitrogen values should be seen as relative values and not as an absolute measure of nitrogen availability in the peat. Nevertheless, it is known that little of the total nitrogen in the soil is readily soluble, most existing in organic forms with little mineralization (HEIKURAINEN 1964, NÖMMIK 1967 and WESTMAN 1974) The same conclusion can be drawn from this study where only some 5 % of the total nitrogen was in mineral form.

Since much of the nitrogen in peat is in organic forms, mineralization into easily

Table 2. Mean content and standard errors of 0.05-n H_2SO_4 extractable nutrients in the surface (10—20 cm) peat layer for the peatland site types studied. Results that differ statistically at the 5 % risk level are connected by brackets.

Taulukko 2. Pintaturpeen (10—20 cm) 0.05-n H_2SO_4 liukoisten ravinteiden keskimääräiset pitoisuudet sekä keskiarvon keskivirhe suotyypeittäin. Ne arvot, jotka tilastollisesti eroavat toisistaan 5 % riskitasolla on yhdistetty viivalla.

Site type *Suotyyppi*	0.05-n H_2SO_4 extractable nutrients, mg/100 g dry matter *0.05-n H_2SO_4 liukoiset ravinteet, mg/100 g kuiva-ainetta*				
	N	P	K	Ca	Mg
Herb rich sedge-pine swamp *Ruohoinen sararäme*	99.1±9.94	5.82±0.549	53.4±7.70	373.2±29.6	62.8±4.59
Ordinary sedge-pine swamp *Varsinainen sararäme*	103.7±6.89	7.17±0.304	65.4±3.90	232.3±12.8	49.8±2.87
Small sedge pine-swamp *Lyhytkortinen sararäme*	88.9±9.84	6.05±0.738	29.4±2.81	143.2± 8.92	35.9±2.24

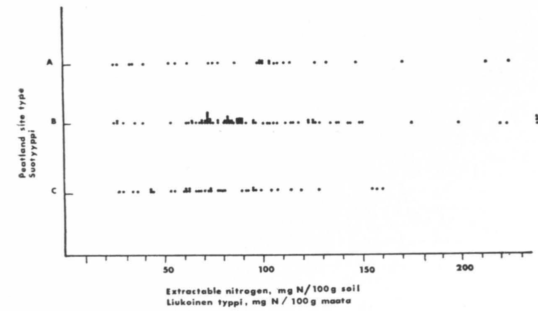

Figure 1. Extractable nitrogen content (mg/100 g)in the 10—20 cm peat layer from the peatlands studied (A: small sedge-pine swamps, B: ordinary sedge-pine swamps, C: herbrich sedge-pine swamps).

Kuva 1. Tutkittujen soiden pintaturpeen (10—20 cm) typpipitoisuus ilmaistuna milligrammoina sadassa grammassa turvetta (A: lyhytkortiset sararämeet, B: varsinaiset sararämeet, C: ruohoiset sararämeet).

soluble forms will be dependent upon the processes of decomposition (see ORLOV and IZVEKOV 1960) and hence the activities of the soil micro-organisms. Annual fluctuations of the soil micro-organism populations can, therefore, be expected to alter nitrogen mobilization levels (POPOVIC 1971). Further, the amounts of easily soluble nitrogen anticipated by the activities of the micro-organisms may be lower to uptake and multiplication of the micro organism populations themselves (ELLEN-BERG 1971). However, mycorrhizal activity may make good this loss by supplying available nitrogen, and phosphorus also, directly to the roots (PARKER 1962).

That the amounts of easily extractable nitrogen do not significantly differ between the site type does not imply that nitrogen is not a limiting factor determing the composition of the site type's vegetation. When present in small amounts, a nutrient will tend to be readily taken up by, and concentrated in, the vegetation (SAEBØ 1968). Although such a process has been shown to apply to manganese, phosphorus and potassium in particular (MALMER & SJÖRS 1955, MALMER 1958, 1962 a, 1962 b), it might also happen in the case of nitrogen.

3. 22 Phosphorus

The phosphorus content of peats is known to be very low, and even of this small content a very limited part is readily soluble (eg. KAILA 1956 a, 1958, 1959 and KIVINEN 1972). The small amounts of easily extractable phosphorus may of course be explained by leaching losses. However, the concentrations of phosphorus in mire waters is low (KAILA 1956 b) and, therefore, the washing out of phosphorus is probably not significant. Most of the phosphorus in peats is in organic forms and even when it does become mineralized it is readily refixed biologically or by iron and aluminium cations if present. KAILA (1956 b, 1958) reports that the availability of phosphorus in peats depends more on the degree of humification, sesquioxide content of the peat and the depth of peat layer sampled rather than the peat type. However, PUUSTJÄRVI (1973) concludes that bog type (site type) is reflected in the properties of the peat, including the degree of humification, and that peat type and bog type (site type) are closely related. Table 2 does show certain differences in the easily extractable phosphorus values between the site types. Easily extractable phosphorus levels in the ordinary sedge-pine swamps are significantly higher than in the small-sedge pine swamps but are also significantly higher than in the more fertile herb rich sedge-pine swamps. The smaller

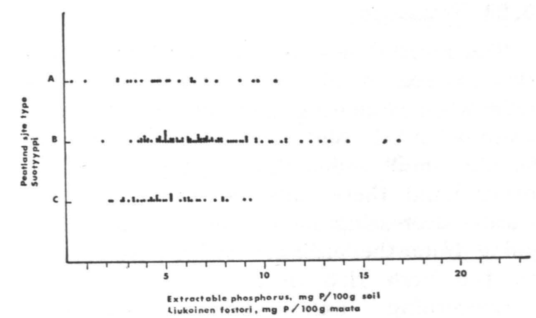

Figure 2. Extractable phosphorus content (mg/100 g)in the 10—20 cm peat layer from the peatlands studied (A: small sedge-pine swamps, B: ordinary sedge-pine swamps, C: herbrich sedge-pine swamps).

Kuva 2. Tutkittujen soiden pintaturpeen (10—20 cm) fosforipitoisuus ilmaistuna milligrammoina sadassa grammassa turvetta (A: lyhytkortiset sararämeet, B: varsinaiset sararämeet, C: ruohoiset sararämeet).

amounts of easily extractable phosphorus in the herb rich sedge-pine swamps could be attributed to a concentration in the more eutrophic vegetation, Such a process would explain the negative correlation between site type and soluble phosphorus found by HOLMEN (1964). However, the higher degree of humification (cf. table 1, volume weight) of the peat from the herb rich sedge-pine swamps and the presumably higher content of iron and aluminium in this peat type may have effected the results. On the other hand, the higher soluble phosphorus level associated with ordinary sedge-pine swamps could be related to the tendency of *Sphagnum-carex* peat, which is commonly formed in ordinary sedge-pine swamps, to supply plants with phosphorus better than do other peat types (KAILA 1958).

If one compares the amount of extractable phosphorus in peat to the total content of phosphorus (table 1) it can be seen, that the amount of mineral phosphorus is very low, only 5—10 %, depending on the site type. However, there is a clear tendency towards higher amounts of soluble phosphorus in the more fertile site types, which may indicate a higher mineralization rate in peats from these site types, and thus a better phosphorus economy.

3.23 Potassium

The results show a tendency towards increasing content of easily extractable potassium when comparing the ordinary sedge-pine swamps and the herb rich sedge-pine swamps to the small sedge-pine swamps. On the other hand there may be a tendency towards decreasing potassium content when going from the ordinary sedge-pine swamp to the herb rich one.

Concerning extractability, potassium presents the opposite case to nitrogen and phosphorus; most of the total potassium is in readily soluble forms. According to KIVINEN (1948) most of the potassium can be extracted with water and so leaching losses may be considerable. When comparing the readily extractable amount of potassium to the total amount of potassium in the peat it is of interest to note, that the extractability seems to increase with increasing trophic status. Almost all of the

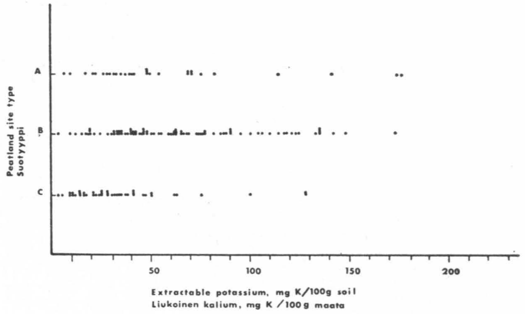

Figure 3. Extractable potassium content (mg/100 g)in the 10—20 cm peat layer from the peatlands studied (A: small sedge-pine swamps, B: ordinary sedge-pine swamps, C: herb-rich sedge-pine swamps).

Kuva 3. Tutkittujen soiden pintaturpeen (10—20 cm) kaliumpitoisuus ilmaistuna milligrammoina sadassa grammassa turvetta (A: lyhytkortiset sararämeet, B: varsinaiset sararämeet, C: ruohoiset sararämeet).

potassium is in extractable forms in the peat from the herb sedge-pine swamps, while only some 50 % is extractable in the small sedge-pine swamps. The ordinary sedge-pine swamps take an intermediate place.

The lower potassium levels overall compared with mineral soils, is due to the low mineral content of peats (see table 1). There is also a strong tendency for easily extractable potassium to concentrate in the living surface vegetation and, to a lesser extent, in the surface layers of peat (KAILA & KIVEKÄS 1956). Taking into account the sampling depth (10—20 cm), a greater ability of the eutrophic vegetation in the herb rich sedge-pine swamps to concentrate potassium would explain the lower amounts in this site type compared to the ordinary sedge-pine swamps. HOLMEN (1964) also found this negative tendency between site type and the available potassium. Another probable explanation for the decrease in potassium content would be the high solubility of potassium in the peat from the herb rich sedge-pine swamps due to a higher degree of peat humification. This fact together with a high calcium content (see below) has probably resulted in a large leaching loss of potassium from the herb

rich sedge-pine swamps. The time of sampling seems also to affect potassium levels. SHIKULA et al. (1972) found that sampling at the end of the season gave higher amounts of extractable (0.08 n CH_3COOH) potassium than in spring because of leaching losses during winter. The increasing scarcity of potassium with increasing depth, which is probably a subtle combination of both leaching losses and concentration by the vegetation, has been shown to limit tree growth (TAMM 1956, BINNS 1962).

3.24 Calcium and magnesium

Of the easily extractable cations studied, calcium, although exhibiting a wide variation, is generally the most abundant (cf. also KAILA & KIVEKÄS 1956, KIVINEN 1972). Not only are there significant differences in the easily extractable calcium fractions between the site types but also the differences correspond to the productivity series of the site types. Similar results have been obtained by VAHTERA (1955), HOLMEN (1964), KAILA & KIVEKÄS (1956). However, it is unlikely that calcium, or magnesium, act as tree growth limiting factors because they are so abundant; unlike phosphorus or potassium. In any case, relatively small amounts of calcium are required for plant growth; its importance lies in its physio-

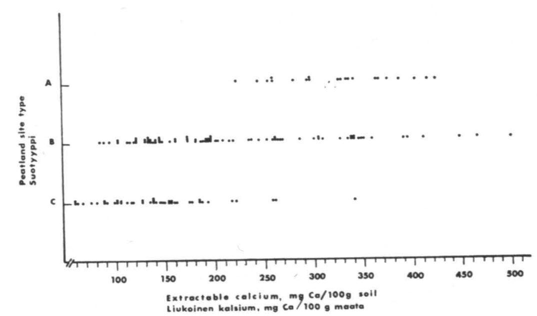

Figure 4. Extractable calcium content (mg/100 g)in the 10—20 cm peat layer from the peatlands studied (A: small sedge-pine swamps, B: ordinary sedge-pine swamps, C: herbrich sedge-pine swamps).

Kuva 4. Tutkittujen soiden pintaturpeen (10—20 cm) kalsiumpitoisuus ilmaistuna milligrammoina sadassa grammassa turvetta (A: lyhytkortiset sararämeet, B: varsinaiset sararämeet, C: ruohoiset sararämeet).

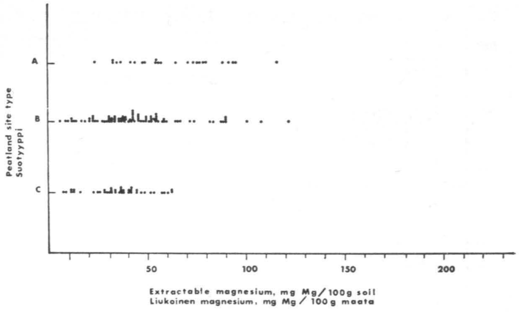

Figure 5. Extractable magnesium content (mg/100 g)in the 10—20 cm peat layer from the peatlands studied (A:small sedge-pine swamps, B: ordinary sedge-pine swamps, C: herb-rich sedge-pine swamps).

Kuva 5. Tutkittujen soiden pintaturpeen (10—20 cm) magnesiumpitoisuus ilmaistuna milligrammoina sadassa grammassa turvetta (A: lyhytkortiset sararämeet, B: varsinaiset sararämeet, C: ruohoiset sararämeet).

chemical properties. For instance, at high concentrations of calcium, potassium is replaced in the cation exchange sites by calcium ions. Although amounts are generally lower, magnesium exhibits a pattern clearly similar to calcium. The site types significantly differ in their content of easily extractable magnesium and in such a way as to relate to the productivity of the sites. Indeed the suitability of both calsium and magnesium to distinguish between phytosociologically determined site types has resulted in their use as indices for defining the trophic status of peatlands (e.g. CHAPMAN 1964).

The extractability of calcium and magnesium were found to be quite similar, being about 60—70 %.

3.3 Total amount of easily extractable nutrients

The results, when nutrient content is expressed in mg/100 g soil, do not take into account the differing volume weights of the peat samples. Therefore, if one is concerned with the availability of nutrients to the roots, the nutrient levels are not directly comparable since the amounts of

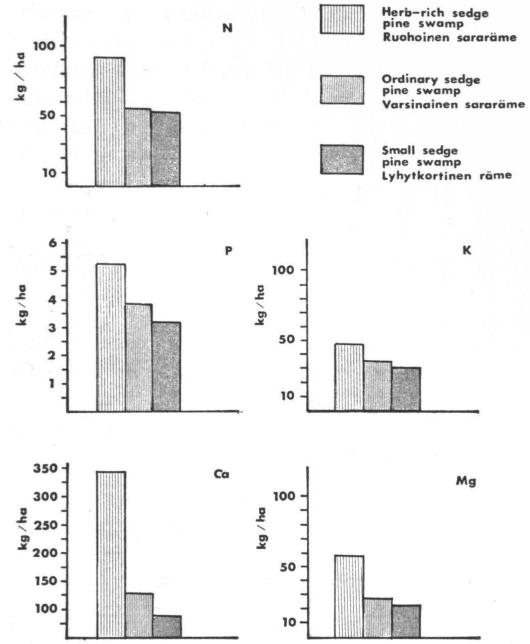

Figure 6. Total extractable amounts (kg/ha) of nitrogen, phosphorus, potassium, calcium, and magnesium in the 10—20 cm peat layer from the peatland site types studied.

Kuva 6. Tutkittujen sararämeiden pintaturpeen (10—20 cm) liukoisen typen, fosforin, kaliumin, kalsiumin ja magnesiumin kokonaismäärät ilmaistuina kilogrammoina hehtaaria kohti.

nutrients, expressed as mg/100 g, relate to different soil volumes. Thus, the extractable nutrient content, expressed in mg/100 g of soil, was converted into kilograms per hectare by using the volume weight (table 1). This is a basis that not only corresponds better to the natural conditions but also enables the nutrient status of the site types to be directly compared to figures for fertilizer applications.

The differences between the site types in all five nutrients become much clearer when the results are expressed in kg/ha. Figure 6 shows the mean total amount of each nutrient in kg/ha for each site type. An analysis of variance upon this data, showed that the amounts of phosphorus, potassium, and calcium were significantly different (5 %) between the site types, and that the differences corresponded to the productivity of the site types. Similar differences between herb rich sedge-pine swamps and ordinary sedge-pine swamps, and between herb rich sedge-pine swamps and small sedge-pine swamps also exist for nitrogen and magnesium. However, the differences between ordinary sedge-pine swamps and small seedge-pine swamps were only significant at the 10 % level for magnesium, and not at all significant for nitrogen.

For comparison, it can be mentioned that fertilizer applications for phosphorus are generally 40 kg/ha and for potassium 80 kg/ha. These figures are approximately 10 times and 2 times respectively, the easily soluble fractions for these nutrients.

3. 4. Geographical variation in the data

Since climatic conditions are more favourable in the south of Finland, one can hypothesize that decomposition and mineralization processes there are faster than they are in northern Finland. Therefore, one would expect the levels of easily soluble nutrients to be higher in southern Finland than in the north. On the other hand it is also possible that the same plant societies, in different climatic regions occur on peat types with a different nutrient status. Thus, for instance, herb rich sedge-pine swamps in north Finland could occur on peats with a higher total content of nitrogen and thus a higher ability to nitrogen mineralization than in south Finland.

An analysis of variance was performed to test the hypothesis that the content of extractable nutrients in the peat is higher in the south of Finland compared to the north. In all cases, the variance models proved to be highly significant (often reaching the 99 % level) when the data used to test the hypothesis was expressed in kg/ha. The results, when expressed in mg/100 g, were less convincing. Table 3 presents the mean contents in mg/100 g classified by site type and by north-south division. Nitrogen and, to a lesser extent, phosphorus appear to comply with the hypothesis of an increase in nutrient availability in southern Finland. Kivinen (1948) states also that soluble nitrogen levels are comparatively

Table 3. Mean content and standard errors of 0.05-n H_2SO_4 extractable nutrients in the surface (10—20 cm) peat layer for the peatland site types studied, when the material is presented separately for southern and northern Finland. Results that differ statistically at 5 % risk level are connected by brackets.

Taulukko 3. Pintaturpeen (10—20 cm) 0.05-n H_2SO_4 liukoisten ravinteiden keskimääräiset pitoisuudet sekä keskiarvon keskivirhe suotyyppeittäin kun aineisto on esitetty erikseen Etelä-Suomen ja Pohjois-Suomen osalta. Ne arvot, jotka tilastollisesti eroavat toisistaan 5 % riskitasolla on yhdistetty viivalla.

Site type *Suotyyppi*	0.05-n H_2SO_4 exctractable nutrients, mg/100 g dry matter *0.05-n H_2SO_4 liukoiset ravinteet, mg/100 g kuiva-ainetta*				
	N	P	K	Ca	Mg
	Southern Finland *Etelä-Suomi*				
Herbrich sedge-pine swamp *Ruohoinen sararäme*	116.2±10.9	5.78±0.68	48.9±15.0	337.4±18.9	58.0±4.78
Ordinary sedge-pine swamp *Varsinainen sararäme*	122.1±12.1	7.78±0.43	61.7±4.93	228.2±16.0	49.9±3.50
Small sedge-pine swamp *Lyhytkortinen sararäme*	107.1±12.1	5.70 0.46	22.5±3.51	147.9±12.5	44.9±2.56
	Northern Finland *Pohjois-Suomi*				
Herb-rich sedgepine swamp *Ruohoinen sararäme*	52.4±8.12	5.93±0.97	65.7±8.89	470.4±92.5	75.9±10.0
Ordinary sedge-pine swamp *Varsinainen sararäme*	85.3±5.54	6.55±0.42	69.1±6.01	236.3±20.0	49.7±4.58
Small sedge-pine swamp *Lyhytkortinen sararäme*	83.4±12.2	5.20±0.32	31.5±3.56	141.8±11.9	33.2±2.65

lower in the north of Finland. Both nitrogen and phosphorus occur in peat in mainly organic forms and therefore would tend to be more susceptible to any changes in nutrient availability brought about by climatic differences upon the decomposition and mineralization rates. The remaining nutrients: potassium, calcium and magnesium are frequently found in smaller amounts in southern Finland, although the differences in mg/100 g between the north and the south were found not to be significant. The preponderance of Aapa fens in northern Finland, which are dependent upon mineral soils as a source of nutrients (Minerotrophic), and Raised Bogs in southern Finland, which are dependent upon rainfall only (Ombrotrophic) for their nutrient supply, could account for the higher levels of potassium, calcium and magnesium indicated, in northern Finland.

However, it should be noted that the peatland site types studied are not very typical for either raised bogs or aapa fens; differences in the metal cation content of the peat may be more dependent on local differences in underlying mineral soil and flow of surface water than on geographic location.

4. CONCLUSIONS

The easily extractable nutrient content, as determined, is expected to be related to the nutrient levels generally available to plants. However, the amounts recorded do depend upon the type and strength of the extractant used which, as in this study, is arbitarily chosen. At best, the nutrients extracted represent a balance between the gross mineralization of the peat on one hand, and the uptake by roots and micro-organisms on the other hand. The problem is further exacerbated by the effect of seasonality upon these processes. In addition, because the forest stand forms such a major component of the site type association, many of the soil properties are due to the influence of the stand itself. Hence, the soil properties may be expected to vary with stand age, size and composition. However, virgin peatlands are considered to be stable climax communities (Heikurainen 1971) and therefore, the stand productivity may be attributed to intrinsic differences between the site types. Since the physical properties of the peat from the three site types chosen for study are quite similar, the differences between these particular site types can be expected to be in terms of their fertility.

In particular, easily extractable calcium and magnesium contents (mg/100 g) define site type productivity rather well. Although total nitrogen contents were found to relate significantly to site type and thus productivity (cf. Vahtera 1955; Heikurainen 1972), easily extractable nitrogen did not differ significantly between the site types. When the results were expressed in kg/ha, thus incorporating the variations of volume-weights in the samples, significant differences for potassium, phosphorus and calcium between all the site types were found. Differences between certain of the site types were noted for nitrogen also. The amount of easily extractable nutrients was also shown to be influenced by the geographic location of the site. It is suggested, that differences in soil temperature (Heikurainen 1964) causing differential decomposition rates between northern and southern Finland, limit the availability of the organically bound nutrients: nitrogen and phosphorus. Minerotrophic inputs of calcium, magnesium and potassium into the Aapa fens of northern Finland are suggested as the cause of the higher contents, in some cases, of these nutrients in northern Finland.

Unfortunately, the distribution of the sample sites is not even; it was particularly difficult to obtain a sufficient number of sample sites from the richer site types. The total number of herb rich sedge-pine swamps is 26, which only represents 17 % of the whole material. Nevertheless, the results from the material as presented do indicate certain relationships between site type and the nutrient availability of the peat. Evidently, forest productivity relates as much to the relative availability of nutrients as to the total nutrient contents of the peat. The results are noticeabily better if the data is expressed in kg/ha, rather than mg/100 g. Further research should be directed, therefore, towards perfecting the concepts of soil nutrient availability as related to forest growth and to refining techniques for its measurement.

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SELOSTE:

HELPPOLIUKOISET KASVINRAVINTEET LUONNONTILAISTEN SARARÄMEIDEN PINTATURPEESSA

Käsillä oleva tutkimus on osa laajempaa tutkimusta, jonka tavoitteena on tutkia luonnontilaisten sararämeiden pintaturpeen ravinteisuutta sekä ravinteisuuden ja pintakasvillisuuden välistä riippuvuussuhdetta. Tässä esitetyn osatutkimuksen tavoitteena oli tutkia helppoliukoisen typen, fosforin, kaliumin, kalsiumin ja magnesiumin pitoisuuksia luonnontilaisten sararämeiden pintaturpeessa ottaen huomioon myös maantieteellisen sijainnin mahdollisen vaikutuksen turpeen ravinteisuuteen.

Tutkimusaineisto käsittää kaikkiaan 155 näytettä 22 suoalueelta. Tutkittavat näytteet pyrittiin keräämään maata kattavasti; suurin osa näytteistä on kuitenkin peräisin Keski- ja Pohjois-Suomesta, jossa luonnontilaisia soita on vielä suhteellisen runsaasti. Näytteistä on yleisten fysikaalisten ja kemiallisten ominaisuuksien (tilavuuspaino, tuhkapitoisuus, kationinvaihtokapasiteetti ja totaaliravinnemäärät) lisäksi määritetty 0.05-n rikkihappoon liukeneva typpi, fosfori, kalium, kalsium ja magnesium. Nämä viimemainitut analyysitulokset muodostavat tutkimuksen varsinaisen aineiston.

Tutkimusaineiston yleiset fysikaaliset ja kemialliset ominaisuudet ilmenevät taulukosta 1.

Varsinainen tutkimusaineisto on suotyypeittäin esitetty frekvenssikuvina kuvioissa 1–5, joista käy ilmi, että helppoliukoisten kasvinravinteiden vaihtelu suotyypin sisällä on huomattava.

Taulukossa 2 on esitetty tutkittujen suotyyppien helppoliukoisten kasvinravinteiden keskimääräiset pitoisuudet (mg/100 g) sekä keskiarvojen keskihajonnat. Varianssianalyysin avulla voitiin todeta, että keskiarvojen väliset erot ovat merkitseviä 95% todennäköisyydellä. Parittainen t-testi sen sijaan osoitti, että keskiarvot eroavat vain muutamassa tapauksessa toisistaan (vrt. taulukko 2). Kun ravinnepitoisuudet (mg/100 g) muunnettiin absoluuttisiksi määriksi (kg/ha) saatiin tulokseksi, että fosfori-, kalium- ja kalsiummäärät turpeessa nousevat kun siirrytään lyhytkortisesta rämeestä varsinaiseen sararämeeseen ja edelleen ruohoiseen sararämeeseen. Erot ovat 5 % riskitasolla merkitseviä. Vastaavasti ruohoinen sararäme eroaa varsinaisesta sararämeestä ja lyhytkortisesta rämeestä typen ja magnesiumin suhteen (kuvio 6).

Varianssianalyysilla ja parittaisella t-testillä testattiin edelleen hypoteesia että saman suotyypin pintaturpeen liukoisten ravinteiden määrä on Etelä-Suomessa suurempi kuin Pohjois-Suomessa. Tulokset on esitetty taulukossa 3, joista ilmenee, että orgaanisesti sitoutuneita ravinteita, kuten typpeä ja fosforia, saattaa saman suotyypin turpeessa esiintyä runsaammin liukoisessa muodossa Etelä- kuin Pohjois-Suomessa.