EFFECT OF APPLICATION OF LIME AND FERTILIZERS ON CULTIVATED PEAT SOIL

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The effects of application of lime and fertilizers are usually estimated on the basis of the response of crops to these treatments, less attention is paid to their possible effects on the soil. There is a large mass of soil in a plough layer, and the soil is known to be fairly well buffered not only against changes in acidity, but also against changes in several other properties. Therefore, heavy applications of lime or fertilizers, and prolonged treatments may be needed before the changes are detectable with the common methods of soil analysis.

A few studies are published concerning the effect of phosphate fertilizers on peat soil of longterm field trials at Leteensuo Experiment Station in southern Finland. Annual application of superphosphate during a period of 35 years increased the content of mineral nitrogen and readily mobilizeable nitrogen in peat, the increase being the larger the heavier the treatment had been (Kaila 1958). Valdmaa (1958) found that the Ca content and the degree of Ca saturation of this soil increased, when the superphosphate doses were increased; also the quality of humic acids was improved. The studies on the phosphorus conditions showed that the higher annual applications had markedly increased the fractions of inorganic phosphorus and, particularly, the content of organic phosphorus (Kaila 1961).

In the present paper results are reported on the effect of lime or fertilizers on peat soil of two longterm field trials at Tohmajärvi Experiment Station in eastern Finland. The soil samples were kindly provided by the former director of the station. Mr. Jaakko Kivekäs, Lic. Agr.

Field trials

The first of the field trials was started in 1926 to study the effect of liming on a woody sedge peat soil. The object of the second trial, started in 1928, was to study the effect of nitrogen, phosphorus, and potassium fertilizers on a peat soil of same kind. In both cases, the soil was ameliorated in 1934 with 200 m^3 of clay per hectare. The soil samples were collected in September 1963, when the liming experiment had been run for 38 years and the fertilizing trial for 36 years.

In the liming experiment all plots were annually treated with 17.5 kg P/ha as superphosphate, and 66 kg K/ha as 40 % or 50 % potash fertilizer. In 1926, 1933, 1948, 1954, and 1957 finely ground limestone was applied in amounts of 0, 2000, 4000, or 6000 kg/ha. Thus, the total quantities of limestone in the experimental period were 0, 10, 20, or 30 tons per hectare, respectively. Yield results are not available, it is known, however; that in 1961 liming had only a slight effect on the yield of oats which was fairly high, or about 3500 kg grains/ha.

In the fertilizing experiment 15 kg N/ha as calcium nitrate, 22 kg P/ha as superphosphate, and 66 kg K/ha as 40 % or 50 % potash fertilizer were annually applied in all possible combinations. According to the information given by Mr. Kivekäs, phosphorus generally had a good effect, but also the response to potassium and even to nitrogen was not quite insignificant. As an example the following yields of oats in 1961 may be recorded.

Treatment	Grain yield	Straw yield
0	100	100
N	131	149
K	138	134
P	189	211
NK	151	181
NP	202	228
PK	206	239
NPK	215	247

The yields without fertilizers were rather poor, or less than 1700 kg grains/ha.

Soil samples and analytical methods

The samples were collected from the plough layer, 0 to 18 cm. Each of the replicate plots was represented by a sample composed of seven subsamples. The samples were air-dried and ground.

The pH was measured in 0.02 N $CaCl_2$ in the ratio of soil to solution of 1 to 2.5. The exchangeable cations were extracted with 1 N ammonium acetate at pH 7, Ca and Mg determined with a Perkin Elmer atomic absorption spectrophotometer 290, potassium and sodium with an EEL flame photometer, and H^+ by titration with NaOH. The cation exchange capacity and the base saturation were also estimated by the method of Teräsvuori (1959).

Inorganic phosphorus was fractionated by the method of Chang and Jackson (1957), and organic phosphorus estimated by the method of Kaila (1962). Also the phosphorus test Bray 1 (Bray and Kurtz 1945) and the sodium bicarbonate test (Olsen et al. 1954) were used.

The nitrogen conditions were studied by incubating samples of 20 g for three weeks under aerobic conditions at about field capacity in the room temperature. The ammonium and nitrate nitrogen of the incubated samples were extracted with 0.5 N K_2SO_4; NH_4-N was determined by steam distillation and NO_3-N by the phenol disulphonic acid method.

The results were treated by Duncan's new multiple range test (Duncan 1955). Values not marked by the same letter in the tables differ at the 5 per cent level.

Results

Effect of liming

The field was treated with clay 27 years before the soil samples were collected. Yet, it seems that the distribution of clay was not even when the sampling took place. The ash content of the samples which is largely due to the added clay, ranged in samples of the individual plots from 32 to 42 per cent. No significant difference occurred between the average values for the four different treatments. These were 36—38 per cent.

Table 1. Effect of liming on the pH-values, cation exchange capacity and base saturation.

$CaCO_3$ kg/ha	pH	NH_4OAc-method CEC me/100 g	BS %	Teräsvuori's method CEC me/100 g	BS %
0	4.4[a]	72.1[a]	43[a]	100[a]	35[a]
2000	4.5[a]	73.2[a]	46[a]	105[b]	37[a]
4000	4.8[b]	76.2[ab]	56[b]	111[bc]	48[b]
6000	5.0[c]	80.2[b]	61[c]	117[c]	53[c]

Results in Table 1 show that the lowest amount of lime has not decreased the acidity significantly, though there tends to be some increase both in the pH-value and the base saturation percentage. The effect of the higher applications is, however, quite distinct. It is of interest to note that liming has also increased the cation exchange capacity. According to the results obtained by Teräsvuori's method, this increase is significant even by the lowest amount of lime. Owing to the larger variation in the ammonium acetate values, first the highest application has significantly increased the cation exchange capacity. These two methods give results which are at different levels, but they agree in respect to the main tendency.

Table 2. Effect of liming on exchangeable cations.

$CaCO_3$ kg/ha	Ca^{++}	Mg^{++}	K^+ me/100 g	Na^+	H^+
0	29.2[a]	2.3[a]	0.34[b]	0.40[a]	40.9[b]
2000	30.9[a]	2.1[a]	0.34[b]	0.46[b]	38.7[b]
4000	39.3[b]	2.8[b]	0.27[a]	0.50[bc]	33.3[a]
6000	44.8[c]	3.3[c]	0.28[a]	0.54[c]	31.3[a]

The contents of exchangeable cations extracted by ammonium acetate at pH 7 are listed in Table 2. The increase in the calcium ions brought about by the heavier applications of lime appears to be higher than the corresponding decrease in the hydrogen ions. Also the content of exchangeable magnesium is increased by liming, probably, because the ground limestone used contained some dolomite. The content of exchangeable potassium, on the other hand, is lower in the plots treated with the higher amounts of lime than in the other plots. This may be attributed to a more intensive uptake of potassium by the crops from the former plots. A more effective washing out of potassium may also contribute to this result. The content of exchangeable sodium is somewhat higher than that of potassium, and it tends to increase with rate of liming.

No statistically significant effect of liming on the phosphorus conditions could be demonstrated because of the large variation in the results. The ammonium fluoride-soluble fraction of inorganic phosphorus tended to increase with liming, and the same direction was found also in the test values obtained by the Bray 1-method and the sodium bicarbonate method. It is likely that the crops have taken up more phosphorus from the plots with a higher pH, and thus decreased the amount of accumulating fertilizer phosphorus, particularly in the ammoniumfluoride-soluble fraction of these plots.

Results of the incubation experiments reported in Table 3, show no difference between the amounts of total mineral nitrogen found in the samples from the liming trial. The heaviest application of lime which decreased the acidity from pH 4.5 to pH 5.0 has been able to intensify the nitrification significantly. Thus, the content of ammonium nitrogen is in this plot distinctly lower and that of nitrate nitrogen distinctly higher than the corresponding values in the other plots. Even the pH level 4.8 seems to be too low to allow active nitrification to take place in this peat soil under laboratory conditions.

Table 3. Mineral nitrogen in the incubated samples from the liming experiment

$CaCO_3$ kg/ha	NH_4-N ppm	NO_3-N ppm	Total ppm
0	210[b]	30[a]	240[a]
2000	220[b]	30[a]	250[a]
4000	210[b]	40[a]	250[a]
6000	180[a]	80[b]	260[a]

Effect of fertilization

It seems that in the second field trial studied the distribution of clay is even more heterogeneous than in the first trial. The ash content of the individual samples ranged from 37 to 51 per cent, and the mean values for the various treatments from 40 to 47 per cent.

No statistically significant differences could be found in the acidity, cation exchange capacity, or base saturation percentage of the samples from the variously treated plots. The pH in $CaCl_2$ was 4.3—4.4, the CEC-value estimated by the method of Teräsvuori was about 94—105 me/100 g, and the base saturation ranged from 37 to 41 per cent.

Data in Table 4 show that the effect of fertilizers on the content of exchangeable bases is most distinct in respect to potassium. The content of exchangeable potassium is, of course,

Table 4. Exchangeable bases in the samples of the fertilizing experiment.

Treatment	Ca^{++}	Mg^{++}	K^{+}	Na^{+}
		me/100 g		
0	25.9[a]	3.7[ab]	0.26[a]	0.29[a]
N	28.9[a]	4.1[b]	0.21[a]	0.29[a]
P	26.6[a]	3.3[a]	0.21[a]	0.29[a]
K	24.3[a]	3.6[ab]	0.57[c]	0.35[bc]
NP	27.7[a]	3.3[a]	0.21[a]	0.32[ab]
NK	26.5[a]	3.8[ab]	0.54[c]	0.37[c]
PK	26.0[a]	3.5[ab]	0.30[b]	0.37[c]
NPK	27.5[a]	3.3[a]	0.31[b]	0.39[c]

lowest when no potassium was applied. It is highest in the plots (K and NK) which did not receive phosphorus in addition to potassium. This is in accordance with the information that in this trial application of phosphorus produced significant responses in yield: apparently, the uptake of fertilizer potassium is restricted, if phosphorus is not applied.

The content of exchangeable magnesium also tends to be lowest in the plots which received phosphorus, or in the plots which produced the highest yields. This, however, is less distinct than in regard to the exchangeable potassium in these samples. Exchangeable sodium tends to be higher in the plots treated with potassium than in the other ones. There is no significant difference in the content of exchangeable calcium in the samples of this trial.

Table 5. Phosphorus in the samples from the fertilizing experiment.
(Expressed as P ppm)

Treatment	Bray 1 test	Inorganic P extracted by NH_4F	$NaOH$	H_2SO_4
0	8.7[a]	57[a]	50[a]	111[a]
N	8.3[a]	53[a]	49[a]	99[a]
P	24.7[bc]	98[bc]	66[b]	126[b]
K	10.1[a]	56[a]	48[a]	111[a]
NP	19.4[b]	85[bc]	63[b]	123[b]
NK	10.6[a]	59[a]	52[a]	111[a]
PK	28.1[cd]	103[bc]	62[b]	115[ab]
NPK	30.5[d]	110[c]	72[b]	130[b]

The annual application of superphosphate is clearly reflected by the results of the phosphorus analyses in Table 5. Both the Bray 1 test values and the phosphorus content of the Chang and Jackson's fractions are higher in the plots which received phosphorus than in the other plots. The largest increases brought about by phosphate application are, as it is usual, in the ammonium fluoride soluble fraction. There is also statistically significant

Table 6. Mineral nitrogen in the incubated samples from the fertilizing experiment.

Treatment	NH_4-N ppm	NO_3-N ppm	Total ppm
0	140[a]	23[ab]	163[ab]
N	146[a]	31[b]	177[ab]
P	133[a]	24[ab]	157[ab]
K	176[c]	25[ab]	201[c]
NP	135[a]	28[ab]	163[ab]
NK	174[bc]	26[ab]	200[c]
PK	139[a]	16[a]	155[a]
NPK	152[ab]	27[ab]	179[bc]

increase in the acid soluble phosphorus in plots which got superphosphate. It is not likely that this would mean any accumulation of superphosphate phosphorus as secondary apatite: probably some iron bound phosphate is not dissolved by the alkali treatment and thus will get in the acid soluble fraction.

In the samples incubated under laboratory conditions, the highest amounts of mineral nitrogen are found in the soils of the plots K and NK. This is due to the high content of ammonium nitrogen in these samples. There are less differences in the content of nitrate nitrogen, only the soil of the N plots is richer in nitrate than the soil of the PK plots. The tendency of the soils from the plots treated with calcium nitrate to have a higher content of nitrate nitrogen than the other ones is not statistically significant. Relatively low amounts of ammonium nitrogen were accumulated in the soils of P, NP, PK and 0 plots. The low content of total mineral nitrogen found in the incubated samples from plots P and PK may be explained by the effective uptake of mobilized peat nitrogen by the crops growing vigorously because of the phosphorus application. The relatively large accumulation of exchangeable ammonium nitrogen in the soils of plots K and NK, on the other hand, might probably be connected by the fact that these soils contained rather high amounts of exchangeable potassium. This could mean that fixation of mineralized ammonium ions by clay in these amended soils would be less marked than in the soils of the plots with poorer potassium conditions.

Discussion

The effect of lime and fertilizers on the soil of these field trials is composed of the direct effect on the soil and of the indirect effect through the crops, their uptake of nutrients and the residues they left. Also the effect on the activity of micro-organisms has to be taken into account.

The results obtained by the common analytical methods used to study the samples from the fertilizing trial reveal the application of potassium and phosphorus; the contents of exchangeable potassium even point to a lower uptake of potassium when no phosphorus was applied. The treatment with calcium nitrate is far less distinctly detectable on the basis of the nitrate nitrogen content of the incubated samples. The application of ground limestone is demonstrable by the higher content of exchangeable calcium, the higher pH-value and base saturation percentage, although only when the amount added during the whole experimental period was at least 20 tons per hectare.

As a result of liming, statistically significant increase in the total cation exchange capacity is found. This increase brought about by the highest amount of limestone applied, 30 tons per hectare during the experimental period of 38 years, was about 11 per cent when the cation exchange capacity was determined by ammonium acetate at pH 7, and about 17 per cent, when results were obtained by Teräsvuori's method. It may be due to improvement in the quality of the humic matter, but it may also be connected with the cation exchange by clay. In both cases, the behaviour of sesquioxide complexes may play their role.

Apparently, the increase in the content of exchangeable magnesium by liming is to be attributed to the dolomite in the limestone, since it is likely that this not particularly heavy liming would increase the losses of magnesium and potassium by leaching as well as their availability to plants (Wiklander 1961). The lower content of exchangeable potassium in the samples from the plots which received the more effective treatment with lime is in accordance with this conception. On the other hand, the samples of the fertilizing trial did not give any hint of a more effective leaching of magnesium because of the application of potassium fertilizer. The effect of the various treatments on the content of exchangeable sodium in these soils is not quite easy to explain. It is likely that the potassium fertilizer contained also sodium.

It is of interest to note that in the fertilizing experiment the Bray 1 test value of the samples from the NPK plots is significantly higher than that from the P or NP plots. A similar tendency may be found also in the results of the fractionation of the inorganic phosphorus, but the differences are not statistically significant. It seems likely that the application of all the main nutrients, which obviously produced the largest yields, also allowed more intensive mobilization of phosphorus from the plant residues.

In the liming trial fairly high yields were obtained even without an application of nitrogen fertilizers. In the fertilizing trial nitrogen increased the yields to some extent. This is in agreement with the fact that markedly higher amounts of mineral nitrogen were found in the incubated samples of the former trial as compared with the samples of the latter one. This difference may be partly attributed to the higher content of organic matter in the soil of the liming trial. The analytical results indicate no superiority of the soil of this trial to that of the fertilizing trial in any other of the properties studied. Liming did not increase the amount of mineral nitrogen in the incubated samples, although it changed its distribution between the ammonium and nitrate nitrogen. The different fertilizer treatment again, resulted in significant differences in the amounts of accumulated mineral nitrogen, with a particularly high content in the samples from the plots K and NK and a low content in the plots PK and P. This result may be produced by the combined effect of several factors, such as the application of nitrogen fertilizer, the prevention of fixation of ammonium ions by clay by the presence of higher amounts of potassium, and a higher uptake of peat nitrogen when phosphate was applied.

The amounts of lime and fertilizers applied in these trials were moderate, and thus, in spite of the relatively long experimental period, their effects on the soil properties studied remain rather slight.

Summary

Soil samples were analysed from a long-term liming trial (38 years) and a fertilizing trial (36 years) on woody sedge peat soils at Tohmajärvi Experimental Station in eastern Finland.

Five applications of 4000 or 6000 kg/ha of ground limestone increased the soil pH from 4.4 to 4.8 or 5.0, respectively. The cation exchange capacity was increased from 72 me/ 100 g to 76 or 80 me/100 g, and the base saturation from 43 per cent to 56 or 61 per cent, respectively, if the exchangeable cations were extracted by ammonium acetate at pH 7. The relative increases in the cation exchange capacity and base saturation percentage were even higher when determined by the method of Teräsvuori. The contents of exchangeable calcium and magnesium were increased and that of potassium decreased by liming. A lower application of lime, five times 2000 kg/ha, did not cause statistically significant changes.

Owing to the large variation no significant effect of liming on the content of organic phosphorus or of various fractions of inorganic phosphorus in this soil could be detected. Liming did not increase the total amount of mineral nitrogen extracted by K_2SO_4-solution from the samples incubated under the labotatory conditions, but the highest application enhanced nitrification.

Annual applications of 22 kg P/ha as superphosphate, 66 kg K/ha as 40 % or 50 % potassium fertilizer, and 15 kg N/ha as calcium nitrate alone or in any combination did not change the acidity or the cation exchange capacity of the soil in the fertilizing trial. The application of superphosphate was detectable as higher Bray 1 test values and higher contents of inorganic phosphorus in various fractions. The content of exchangeable potassium was about 0.2 me/100 g in plots N, P, and NP, about 0.3 me/100 g in plots PK and NPK, and more than 0.5 me/100 g in plots K and NK. This is well in accordance with the significant response in yields produced by phosphate in this trial. The accumulation of mineral nitrogen in the samples incubated under the laboratory conditions was highest in soil from plots K and NK, and lowest in soil from the plots PK and P.

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SELOSTUS

KALKITUKSEN JA LANNOITUKSEN VAIKUTUKSESTA TURVEMAAHAN

ARMI KAILA ja RITVA RYTI

Yliopiston maanviljelyskemian laitos, Viikki

Tohmajärven Suoviljelyskoeaseman pitkäaikaisen kalkituskokeen ja n.s. täydellisen lannoituskokeen näytteitä analysoimalla tutkittiin kalkituksen ja kalkkisalpietari-, superfosfaatti- ja kalisuolalannoituksen vaikutusta mutasuoturpeen ominaisuuksiin.

Todettiin, että 38 vuoden kuluessa viidesti annetut kalkkikivijauhoerät, 4000 ja 6000 kg/ha, olivat nostaneet, ei vain pH-arvoa ja emäskyllästysastetta, vaan jossain määrin myös kationinvaihtokapasiteettia. Kalkitus ei lisännyt muhitetuista näytteistä neutraalisuolalla uutetun mineraalitypen kokonaismäärää, mutta voimakkaimmin kalkituissa maissa oli enemmän nitraattityppeä ja vähemmän ammoniumtyppeä kuin muissa. Suuren hajonnan takia ei voitu todeta kalkituksen vaikuttaneen merkitsevästi maan fosforin fraktioihin.

Lannoituskokeen näytteissä vuotuisen, 36 kertaa annetun lannoituksen vaikutus ilmeni selvästi sekä fosforin eri fraktioissa että vaihtuvan kaliumin määrissä. Merkitsevästi suuremmat vaihtuvan kaliumin pitoisuudet K- ja NK-jäsenissä PK- ja NPK-jäseniin verrattuna osoittivat kaliumin heikohkoa hyväksikäyttöä, ellei fosforin saantia oltu turvattu lannoituksella. Muhituksessa kertyneen mineraalitypen kohdalla oli selviä eroja eri koejäsenten välillä: K- ja NK-ruutujen näytteissä oli runsaimmin, PK- ja P-jäsenten näytteissä niukimmin neutraalisuolalla uuttuvaa mineraalityppeä.