The Influence of Fertilisers upon Microbial Activity in Peat

II. CALCIUM AND NITROGEN[1]

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Introduction

A LARGE proportion of some of the nutrients, especially nitrogen and phosphorus in certain peat types are unavailable to most crops. Peats are also characterised by having a low pH (Gorham, 1953), a high moisture content (Burke, 1967), a high carbon to nitrogen ratio and a relatively inert microbial population (Dickinson and Dooley, 1967). These features cause or lead to an extremely slow peat to plant nutrient cycling system.

The object of the present studies was to determine whether calcium and nitrogen had an effect on the microbial population in peat and, if so, whether this would increase the rate of peat decomposition and nutrient recycling.

Experimental Details

The peat used and the experimental methods were as previously outlined (Gardiner and Geoghegan, 1975). Calcium carbonate ($CaCO_3$) was added to the peat at rates equivalent to, 0 (Ca_0), 1500 (Ca_1), 3000 (Ca_2), 6000 (Ca_3), 7500 (Ca_4) and 10,000 (Ca_5) kilograms per hectare. After mixing with the $CaCO_3$ the peat was stored in jars in the laboratory and microbial activity was examined at intervals over an 80 day incubation period.

Results

1. *Effects of $CaCO_3$ addition on Peat Characteristics*

(a) Peat pH

The effect of added $CaCO_3$ on the acidity of the peat is shown in Table 1.

At all levels of added $CaCO_3$ the pH of the peat samples increased steadily over the first 4 weeks of incubation, but in most cases it dropped slightly thereafter. The highest pH of 7.50 was recorded

1. Part I: *Superphosphate and Ground Mineral Phosphate,* by J. J. Gardiner and M. J. Geoghegan, was published in *Irish Forestry,* Vol. 32, No. 1 (1975), pp. 50-59.
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TABLE 1

THE INFLUENCE OF $CaCO_3$ APPLIED AT VARIOUS RATES UPON THE pH (H_2O) OF CUT-OVER PEAT

	Days after Incubation							
Treatment	1	7	14	28	39	52	70	Mean
Ca_0	4.40	4.35	4.35	4.40	4.40	4.35	4.35	4.37
Ca_1	4.45	4.55	4.55	4.55	4.50	4.47	4.47	4.50
Ca_2	4.65	5.20	5.55	5.50	5.25	5.35	5.20	5.24
Ca_3	5.50	5.75	5.90	5.85	5.65	5.60	5.55	5.68
Ca_4	5.90	6.50	6.75	6.75	6.45	6.35	6.30	6.43
Ca_5	6.45	6.95	7.25	7.50	7.40	7.25	7.15	7.13
Mean	5.22	5.55	5.72	5.75	5.60	5.56	5.50	

L.S.D. (5%)=0.087

on the 28th day of incubation in the highest $CaCO_3$ treatment. After 70 days pH ranged from 4.35 in the untreated peat to 7.15 in the highest treatment.

(b) Concentration of NH_4–N

As shown in Figure 1 the addition of $CaCO_3$ to the peat led to a

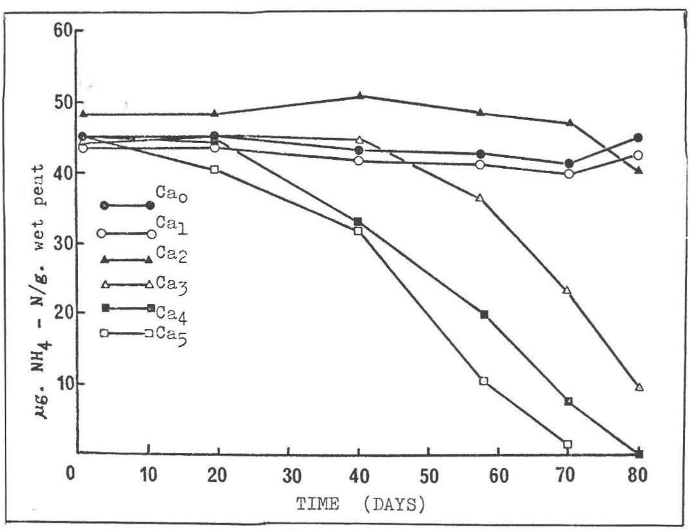

Figure 1
Amounts of NH_4–N in cut-over peat treated with various levels of $CaCO_3$.

decrease in the amount of NH_4–N in the peat at the three higher levels of application.

At the two highest rates of $CaCO_3$ addition the measured quantities of NH_4–N had reached zero by the 70th and 80th days after incubation compared with 45 microgram per gram wet peat in the untreated peat. However, at the three lower levels there was relatively no change in the concentration of NH_4–N over the period.

(c) Nitrification of NH_4–N

Figure 2 illustrates that nitrification of NH_4–N became evident in some of the treated peat samples after approximately 40 days. This would account for some of the loss of NH_4–N in Figure 1.

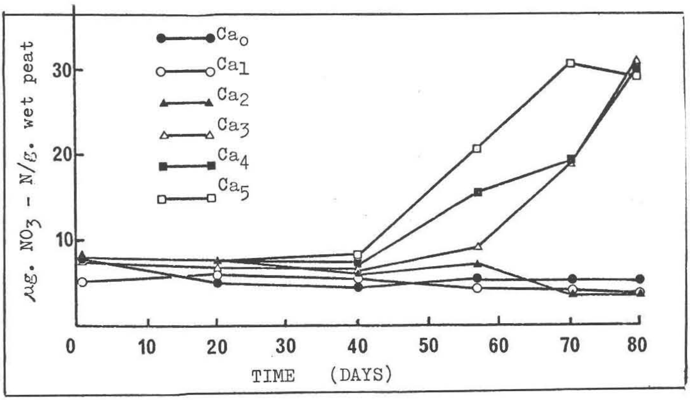

Figure 2

The effect of $CaCO_3$ on nitrification of native NH_4–N in peat.

(d) Total Mineral Nitrogen

A net decrease in total mineral nitrogen was apparent in most of the treated samples at the end of the incubation period. Table 2 shows that, while the total nitrogen concentration in the untreated peat was the same at the beginning and end of incubation, at the highest rate of $CaCO_3$ added, it had decreased from 52 to 29 microgram per g;am wet peat over the same period. This decrease was statistically significant at the three higher levels of $CaCO_3$ application.

(e) Bacterial and Fungal Population

Total bacteria were counted after 80 days incubation. Substantial increases were found in bacterial numbers but no such increases

TABLE 2

THE EFFECT OF $CaCO_3$ ON THE TOTAL K_2SO_4—EXTRACTABLE—NITROGEN IN PEAT. (NH_4–N+NO_3–N MICROGRAM PER GRAM WET PEAT)

Treatment	Time (Days) 1	20	40	57	70	80	
Cao	51	50	49	50	49	51	50.00
Ca_1	49	51	48	47	45	46	47.70
Ca_2	55	55	56	54	51	45	52.60
Ca_3	53	52	53	44	44	39	47.50
Ca_4	52	52	40	37	35	30	41.00
Ca_5	52	47	37	31	30	29	37.70
Mean	52.00	51.17	47.17	43.83	42.30	40.00	

L.S.D. (5%)=2.42

could be demonstrated in fungal numbers as is shown in Figure 3. The Ca_3, Ca_4 and Ca_5 treated peat samples had a significantly higher population of bacteria than the control peat.

Table 3 shows that nitrifying organisms were not present at detectable concentrations in untreated, cut-over peat or in the Ca_1

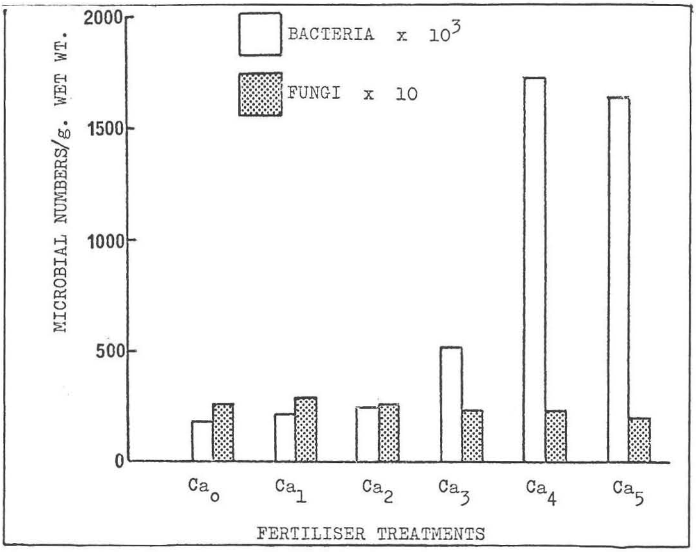

Figure 3
The influence of $CaCO_3$ upon microbial numbers in cut-over peat.

TABLE 3

THE M.P.N. OF *NITROSOMONAS* AND *NITROBACTER* (PER g. WET WEIGHT) PRESENT IN CUT-OVER PEAT 80 DAYS AFTER ADDITION OF $CaCO_3$ TO THE PEAT AT VARIOUS LEVELS

Treatment	Nitrosomonas spp.	95% Confidence Limits		Nitrobacter spp.	95% Confidence Limits	
		Upper	Lower		Upper	Lower
Ca_0	0	—	—	0	—	—
Ca_1	0	—	—	0	—	—
Ca_2	0	—	—	0	—	—
Ca_3	0	—	—	45	149	14
Ca_4	230	759	70	1300	4290	394
Ca_5	230	759	70	1300	4290	394

The factor for the 95% confidence limits is 3.3 (Cochran, 1950).

or Ca_2 treated peat samples. However, their presence in the other peat samples could be shown by the "Most Probable Numbers" method. (Cochran 1950) Nitrogen fixation by non-symbiotic nitrogen fixing micro-organisms could not be demonstrated under aerobic or anaerobicconditions.

(f) Rate of Oxygen Uptake

The rate of oxygen uptake by the peat samples was in all cases highest at the beginning of the experiment and as can be seen from Figure 4 the peat which had received the highest $CaCO_3$ application had the greatest rate of oxygen uptake at all times of testing.

Statistical analyses showed that there were significant differences between all of the peat samples in respect of rate of oxygen uptake at all times of testing. This indicates that microbial activity in peat is enhanced by even small additions of $CaCO_3$. Although some of

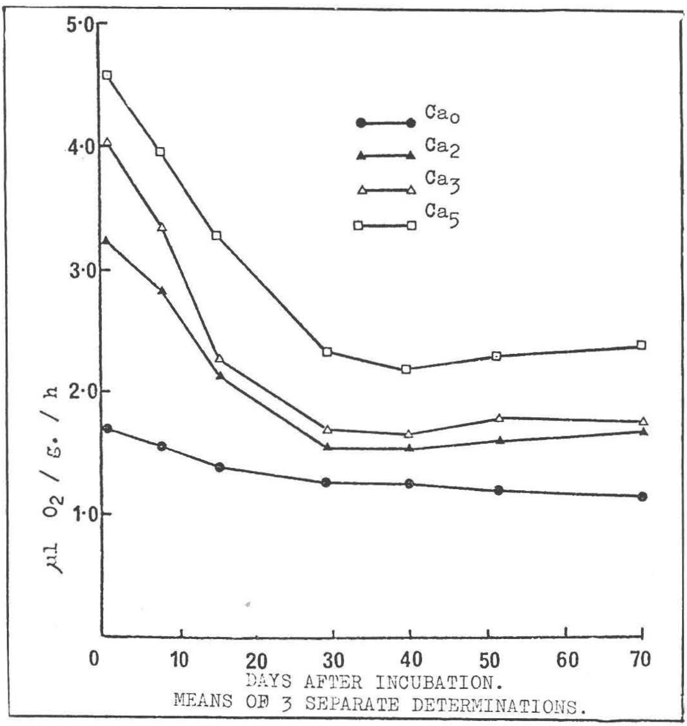

Figure 4
The effect of $CaCO_3$ on the rate of oxygen uptake by peat.

this oxygen may be used initially for non-biological reactions, Jackman (1960) has shown that carbon becomes more available when the peat pH is raised and Hu *et al* (1968) have found a good correlation in forest soils between the rate of soil respiration and the amount of water soluble carbon present.

In summary, these experiments show that the addition of $CaCO_3$ to peat leads to:

1. A decrease in the concentrations of NH_4–N and total mineral nitrogen in the peat.
2. An increase in the bacterial flora of the peat, but no corresponding increase in fungal numbers.
3. An increase in the rate of oxygen uptake by the peat.

These results indicate an increase in the rate of assimilation of carbon and nitrogen from the peat. However, it should be noted that this increase in the rate of decomposition of the peat has led to a net assimilation of available nitrogen.

2. *Effects of $CaCO_3$ and Mineral Nitrogen on Peat Characteristics*

In a second series of experiments ammonium sulphate $(NH_4)_2SO_4$ was applied to peat in combination with $CaCO_3$. The rates of

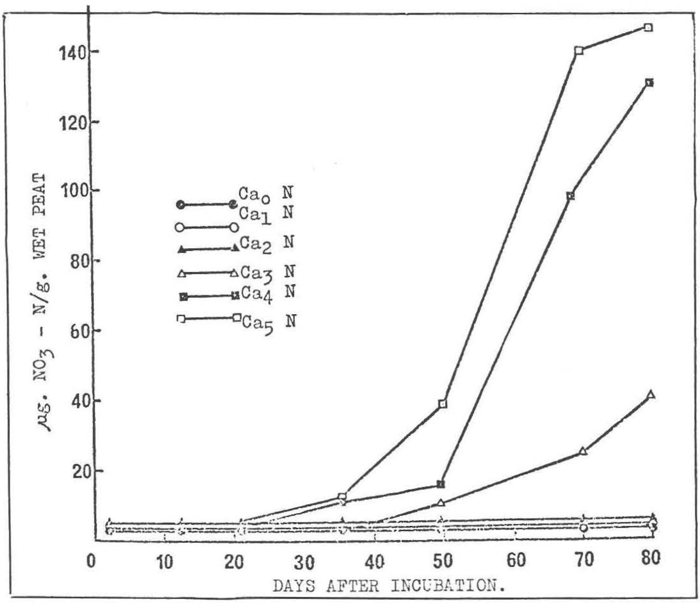

Figure 5
The influence of $CaCO_3$ upon the accumulation of NO_3–N in cut-over peat.

application of lime were as used in the previous experiment and nitrogen was applied at a rate of 200 micrograms per gram wet peat in each case. This is approximately equivalent to 730 kilograms of sulphate of ammonia per hectare.

3. *Effect of Calcium plus Nitrogen on Peat Characteristics*

(a) Peat pH

The pH of these peat samples followed much the same pattern as observed in the previous experiment, but the final pH levels were lower. This lowering of the pH was probably due to the more inten e nitrification of NH_4–N found in these samples.

(b) Concentrations of NH_4–N and NO_3–N

The variations in NH_4–N concentration and NO_3–N accumulation were similar to those already observed. As shown in Figure 5 there was little or no oxidation of NH_4–N prior to the 35th day of incubation but thereafter values for NO_3–N were much higher than where only $CaCO_3$ was added.

(c) Total Mineral Nitrogen

Again a decrease was observed in the total mineral nitrogen content of the incubated peat samples (Table 4). These losses of mineral nitrogen were in most cases significant at the 5% level.

TABLE 4

THE EFFECT OF $CaCO_3$ UPTON TOTAL K_2 SO_4—AVAILA'LE NITROGEN (NATIVE+ADDED) IN PEAT. (MICROGRAMS PER GRAM WET PEAT

Peat Treatment	Time (Days)							Mean
	1	14	21	35	49	69	80	
Ca_0 N	246	246	240	241	233	237	232	239.3
Ca_1 N	254	234	212	216	201	195	200	216.0
Ca_2 N	251	232	227	199	177	182	162	204.3
Ca_3 N	249	223	196	190	184	188	172	200.3
Ca_4 N	250	224	202	186	165	144	138	187.0
Ca_5 N	258	202	162	157	144	145	149	173.9
Mean	251.3	226.8	206.5	198.2	184.0	181.8	175.5	

L.S.D. (5%)=8.09

(d) Bacterial and Fungal Population

The decreases in mineral nitrogen were accompanied by large increases in the bacterial population as shown in Figure 6. However,

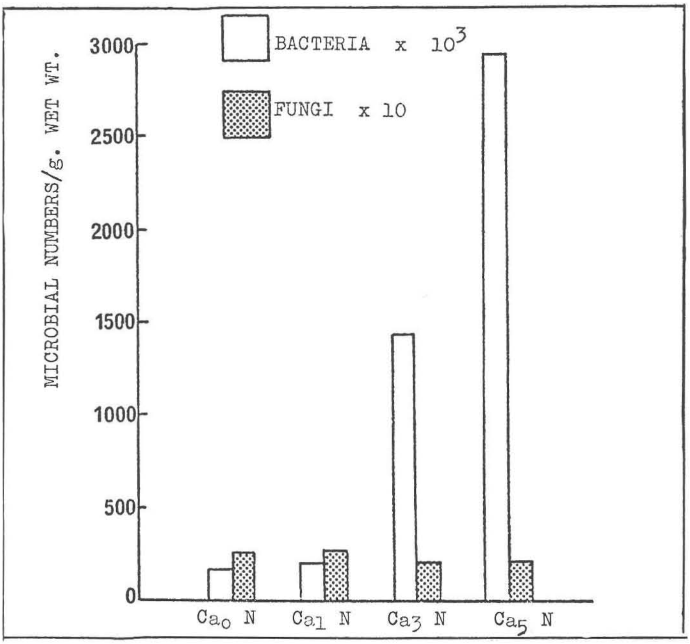

Figure 6
The influence of $CaCO_3$ plus added nitrogen upon microbial numbers in cut-over peat 80 days after treatment.

no statistically significant multiplication by the fungal flora could be shown. Table 5 shows that the concentrations of nitrifying organisms was very similar to that observed in the previous experiment. From these two experiments (Tables 3 and 5) it appears that *Nitrobacter* spp. are always more abundant in peat than *Nitrosomonas* spp.

This may account for the fact that nitrite nitrogen (NO_2–N) did not accumulate in any of the limed peat samples. The presence of active nitrogen fixing organisms could not be demonstrated by the Acetylene reduction technique.

(e) The Rate of Oxygen Uptake

The pattern of oxygen uptake by the treated peat samples as shown in Figure 7 was very similar to that already shown for the $CaCO_3$ treated peat. Statistical analysis of the results showed that the addition of nitrogen alone (i.e. the Ca_0 N treated sample) significantly depressed the rate of oxygen uptake from the 40th day of incubation to the termination of the experiment.

TABLE 5

THE EFFECT OF $CaCO_3$ PLUS ADDED NITROGEN UPON THE M.P.N. (PER g. WET WEIGHT) OF *NITROSOMONAS* AND *NITROBACTER* IN CUT-OVER PEAT 80 DAYS AFTER TREATMENT

Treatment	Nitrosomonas M.P.N.	95% Confidence Limits		Nitrobacter M.P.N.	95% Confidence Limits	
		Upper	Lower		Upper	Lower
Ca_0 N	0	—	—	0	—	—
Ca_1 N	0	—	—	0	—	—
Ca_2 N	0	—	—	0	—	—
Ca_3 N	40	12	132	78	23	257
Ca_4 N	1100	333	3630	3500	1061	11550
Ca_5 N	2800	848	9240	4300	1303	14190

The factor for the 95% confidence limits is 3.3 (Cochran, 1950).

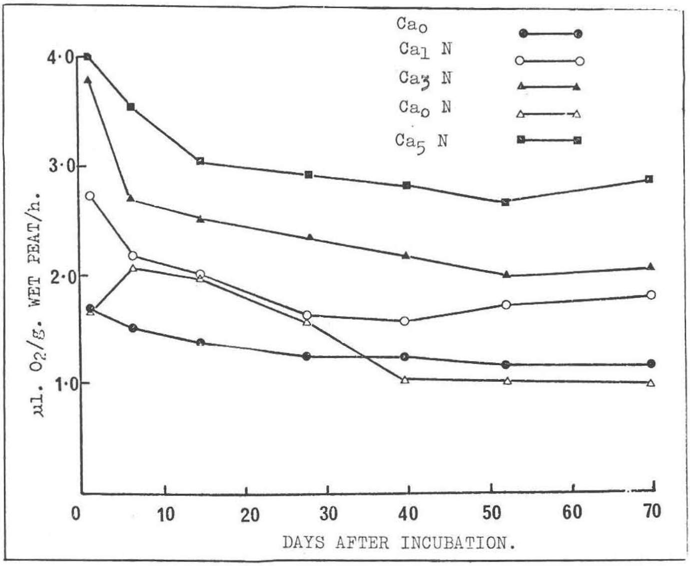

Figure 7
The influence of $CaCO_3$ plus nitrogen upon the rate of oxygen uptake by cut-over peat.

Comparisons also showed that the rate of oxygen uptake by the samples treated with lime plus nitrogen was significantly greater than that of the corresponding lime treatment, i.e. O_2 uptake by the Ca_3–N treated peat was greater than that of the Ca_3 treated peat and Ca_4 N $>$ Ca_4, Ca_5 N $>$ Ca_5.

These experiments again showed a stimulation of the microflora of peat following the addition of lime plus nitrogen to the peat. This stimulation resulted in the assimilation of mineral nitrogen from the peat.

However, this increased activity of microbial population took place only following liming of the peat. Fertilising of the peat with nitrogen alone, in the form of ammonium sulphate, significantly depressed the rate of oxygen uptake. It is doubtful if this depressed rate of activity was due to pH, since the difference in pH between the untreated and the nitrogen treated peat samples was very slight.

Discussion

It has frequently been proposed that the liming of organic residues, such as peat, would result in the release of mineral nitrogen (Kaila *et al,* 1953). This may apply to materials rich in available nitrogen (Waksman, 1929) but it appears from these studies that, an expanding microbial population must, initially at least, assimilate any mineral nitrogen available. This also seems to apply in field experiments. Dickson (1972) has reported that the addition of lime at planting to a Sitka spruce crop growing on peat resulted in a depression of leader growth and a decrease in nitrogen uptake by the trees lasting at least six years. It would, therefore, seem that tree roots cannot compete with an expanding microbial population for available nitrogen. Adams and Cornforth (1972) have also shown that the liming of Sitka spruce litter resulted in a decrease in nitrogen uptake by the crop. They conclude: "It is probable that the initial effect of lime in the field is to increase the rate of litter breakdown, cause assimilation of mineral nitrogen and decrease the uptake of nitrogen by the trees." Williams (1972) also found that lime in the absence of fertiliser nitrogen markedly stimulated the level of microbial activity and yet depressed the net production of mineral nitrogen. His experiments were carried out on pine humus.

Thus, results presented here, which are in accord with those of other laboratory and field trials, show that liming effectively promotes breakdown of peat and other acidic organic residues with a wide C : N ratio.

Nevertheless, it appears that the addition of lime to peat does not, in the short term, promote the rapid cycling of nutrients, particularly nitrogen, to trees growing on the peat. Nutrients become available to tree crops only after the needs of the microbial population are satisfied. These studies also indicate that, despite the provision adequate phosphorus and potassium, tree growth on peats may become limited by deficiency of available nitrogen, because phosphorus does not appear to stimulate microbial decomposition of the peat (Gardiner and Geoghegan, 1975). However, data available from laboratory and field experiments lead to the belief that if the acidity of peat is reduced by liming, and the initial nutrient requirements of the microbial population satisfied, then peat soils can be converted into productive forest soils, with regular recycling of nutrients to the tree crops.

In the absence of research data, one can only guess how long this conversion process will take or what fertiliser imputs will be necessary to promote this development. However, Dickson (1973) has reported that lime applied to peat in 1958, without addition of nitrogen, was beginning to influence uptake of nitrogen by Sitka spruce trees in 1972. With nitrogen addition this 15 year waiting period would surely have been shorter. In addition, O'Toole (1971) has shown that we can expect considerable release of nitrogen from cut-over peat after a period of cropping varying from 2–3 years on newly exposed fen peats, to a considerably longer period on

TABLE 7

FERTILISER USE/ACRE AT LULLYMORE

(Ref.: Lullymore; A Guide to Experiments, 1970)

Type of Bay	LIME (Ground Limestone)	PHOSPHORUS (Superphosphate)	POTASSIUM (Muriate of Potash)	NITROGEN (Calcium Ammonium) Nitrate 23% N.
New	2–10 tons†	15 cwts.	8 cwts.	6–20 cwts.*
2nd Year	—	8 cwts.	6 cwts.	2–20 cwts.*
"Old" Bays ... (maintenance rates)	—	4–8 cwts.*	3–6 cwts.*	2–20 cwts.*

†Based on pH determination.
*Varies according to the nutrient requirements of the crop.

Sphagnum peats. Three years after reclamation the latter investigator obtained a yield of 17 tons of onions per acre without addition of mineral nitrogen. The fact that this crop did not respond to dressings of mineral nitrogen indicates that its total nitrogen requirements were supplied by the peat. However, the fertiliser imputs necessary to bring about this enhanced nitrogen supply were extremely heavy by forestry standards (Table 7).

The results outlined show that addition of lime with or without nitrogen to samples of cut-over peat incubated in the laboratory brings about changes in some chemical and biological properties of the peat samples. If these changes occurred under field conditions they might result in rapid recycling of nutrients in coniferous forest ecosystems, especially those developed on peat.

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