SOME FACTORS AFFECTING RELEASE OF NITROGEN FROM MOR HUMUS UNDER DIFFERENT FOREST STANDS

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INTRODUCTION

The island of Newfoundland is located entirely within the Boreal Forest Region of Canada (Rowe, 1959) and its forests are composed mostly of balsam fir (*Abies balsamea* (L.) Mill) and black spruce (*Picea mariana* (Mill.) BSP). The soils under these stands are commonly nutrient-poor podzols with a severely leached Ae horizon. The organic mantle is generally a poorly-decomposed mor.

Mor humus often contains large amounts of nitrogen (Handley, 1954), an important nutrient for tree growth. However, because of the complex chemical nature of the various organic compounds (Harmsen and van Schreven, 1955) and because of the prevailing climatic conditions in Newfoundland, much of the nitrogen in the humus is not available to trees. It has been shown (Zöttl, 1960; Viro, 1963) that by adding fertilizers the breakdown of mor humus can be accelerated thus releasing nitrogen; rate of release is related to temperature (Mork, 1938).

In 1967, a research program was started in Newfoundland to determine if fertilizers could be used to increase forest productivity. As part of that program an incubation experiment was undertaken to determine (i) the amount of nitrogen contained in mor humus from stands of balsam fir and black spruce, (ii) whether the addition of various fertilizers affects the amount of nitrogen released, and (iii) whether temperature affects rate of release.

METHODS

During the summer of 1967, mor humus samples (L + F + H horizons) were collected from a semi-mature balsam fir stand near Deer Lake, a dense (3500 trees per acre) semi-mature black spruce stand near Springdale and an average (2400 trees per acre) semi-mature black spruce stand near Badger. The humus from the balsam fir stand was derived from herbaceous plants such as Clintonia borealis, Dryopteris spinulosa, Linnaea borealis, Maianthemum canadense, Trientalis borealis and from white birch (Betula papyrifera) and balsam fir. In the black spruce stands, the humus was derived from plants such as Kalmia angustifolia, Vaccinium spp., Hypnum crista-castrensis and Hylocomium splendens, in addition to black spruce. Some of the chemical properties of the samples are given in Table I.

Table I.

Chemical properties of the humus samples

Stand	Total nitrogen %	Available nitrogen %	Available nitrogen as % of Total N	Ash %	Cation Exchange Capacity me./100 g.	C/N Ratio	pH
Balsam fir	1.13	0.1077	9.5	23.0	73.2	39.8	4.2
Black spruce (Average)	0.79	0.0206	2.6	17.9	69.6	60.4	3.8
Black spruce (Dense)	0.59	0.0082	1.4	31.9	54.5	67.6	3.6

The humus from the balsam fir stand had the highest pH, the greatest amount of total and available nitrogen, the highest cation exchange capacity and the lowest carbon nitrogen ratio. The humus from the dense black spruce stand was poorest with respect to these characteristics and that from the average spruce stand was intermediate.

Samples were air-dried, crushed and passed through a 1 mm. sieve. Ten 150-gram lots of humus from each of the three stands sampled were placed in six-inch containers. Lime, monocalcium phosphate (MCP), lime plus MCP, and urea were each added to two of the pots. The remaining two pots were controls (no chemicals added). The chemicals (reagent grade) were added in amounts equivalent to 80 lbs. N, 20 lbs. P, and 2000 lbs. $CaCO_3$ per acre, based on an average of 35,600 lbs. of humus per acre in the three stands. Lime was added in powder form; urea and MCP were added as aqueous solutions. Samples were moistened to field capacity and pots covered with thin plastic to retard moisture loss. One set of pots for each stand was incubated at 54°F and the other set at 68°F for a period of 70 days. At 14-day intervals moisture loss was replenished by adding distilled water and then small samples (approximately 25 g.) were removed for analysis.

The pH of each sample was determined from a water saturated thin paste using a Beckman pH meter with glass and calomel electrode assembly. Extracts of the humus samples were made using 1 N KCl (pH 7.0) solution, and available nitrogen in these extracts was determined by alkaline steam distillation after adding Devarda Alloy (Bremner and Keeney, 1965).

RESULTS AND DISCUSSION

Changes in pH of the various samples as a result of the treatments are summarized in Table II. In most cases, after 70 days, there was a greater change in pH in samples incubated at 68°F than in samples incubated at 54°F. This is considered to be an indication of more rapid decomposition and greater release of bases at the higher temperature. Changes in pH in black spruce samples were greater than those in balsam fir samples. These results were to be expected, because the fir samples have a greater cation exchange capacity (Table I) and hence a greater buffering effect on pH.

Table II

Effect of temperature and fertilizer chemicals on pH of humus

Stand and Treatment	pH				
	Initial	Incubated at 54°F		Incubated at 68°F	
		14 days	70 days	14 days	70 days
Balsam fir:					
Control	4.2	4.2	4.2	4.2	4.3
MCP*	4.2	4.1	4.2	4.0	4.2
Lime	4.2	5.6	5.5	5.5	5.9
Lime & MCP	4.2	5.1	5.5	5.2	5.2
Urea	4.2	4.9	4.8	4.8	4.8
Black spruce (Average):					
Control	3.8	4.0	4.0	3.8	4.1
MCP	3.8	3.3	3.7	3.8	4.0
Lime	3.8	6.2	6.2	6.1	6.7
Lime & MCP	3.8	5.7	6.0	5.6	6.1
Urea	3.8	4.8	4.7	4.7	4.8
Black spruce (Dense):					
Control	3.6	3.5	3.6	3.5	3.8
MCP	3.6	3.5	3.6	3.6	3.7
lime	3.6	6.5	6.6	6.1	6.5
Lime & MCP	3.6	5.8	5.6	5.6	6.3
Urea	3.6	4.2	4.4	4.4	4.7

* MCP - Monocalcium Phosphate

Treatments listed in decreasing order of their effectiveness in increasing pH are as follows: lime, lime plus MCP, urea, control, MCP. Lime produced the greatest effect because it is a relatively strong base and was applied in large amounts. Urea has less influence because it was applied at a relatively low rate and because the ammonia produced during hydrolysis is a weak base. The MCP treatment showed less change than the control probably because it is a slightly acidic compound.

None of the fertilizer treatments increased the pH beyond 6.7 and under the conditions of this experiment it is unlikely that significant losses of nitrogen from volatilization have occurred. Although ammonia volatilizes readily from alkaline soils (Gasser, 1964), negligible quantities are lost from acid media[1] (Fried and Broeshart, 1967).

The amount of nitrogen released for the various treatments is shown in Table III. These data show that the rate of mineralization fluctuated in almost all samples, but no distinct pattern can be observed. Except for the two treatments involving lime with the black spruce samples, more nitrogen was released at 68°F than at 54°F. This indicates that, in general, decomposition is more rapid at higher temperatures. It has been shown (Waksman and Gerretson, 1931) that the synthesizing activity of microorganisms is favoured by lower temperatures and this phenomenon may also have contributed to the above results.

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[1]Bhure, N.D. 1970. Nitrogen losses by volatilization from urea applied to forest soils. Accepted for publication in Bi-monthly Research Notes.

Table III

Effect of different incubation temperatures and periods and fertilizer chemicals on the available nitrogen (mg.N/100 g. of soil)

Stand and Treatment	Available Nitrogen										
	Incubated at 54°F						Incubated at 68°F				
	Days of Incubation						Days of Incubation				
	0	14	28	42	56	70	14	28	42	56	70
Balsam fir:											
Control	107.7	122.3	148.6	148.5	152.4	154.3	141.0	140.5	142.3	158.9	160.1
MCP*	107.7	99.4	143.1	137.8	144.7	139.8	149.6	153.3	158.1	172.1	170.8
Lime	107.7	112.9	125.0	131.9	133.1	130.5	127.3	139.4	134.1	140.5	145.0
Lime & MCP	107.7	112.9	117.6	128.3	128.4	129.9	126.5	134.4	129.3	139.6	152.2
Urea	332.7	289.6	303.8	327.8	313.6	315.4	334.2	324.9	333.0	330.0	331.7
Black spruce (Average):											
Control	20.6	37.5	39.8	43.1	47.2	43.2	41.7	42.3	44.1	45.1	46.2
MCP	20.6	34.4	38.8	43.8	44.1	45.1	43.2	49.2	53.8	53.3	60.7
Lime	20.6	29.4	32.1	27.7	25.9	25.8	37.2	20.6	21.8	8.8	6.5
Lime & MCP	20.6	31.0	38.5	35.6	39.1	37.4	34.2	35.5	33.4	29.9	27.2
Urea	245.6	206.1	211.4	221.1	222.3	224.0	212.9	216.0	215.5	224.5	233.6
Black spruce (Dense):											
Control	8.2	3.9	4.0	5.1	4.0	6.2	6.2	3.1	6.9	12.7	19.4
MCP	8.2	3.1	6.3	3.5	4.7	3.4	4.6	3.9	9.4	13.6	22.1
Lime	8.2	3.7	4.2	2.3	3.4	5.2	3.5	4.2	1.2	1.8	1.6
Lime & MCP	8.2	5.5	6.7	5.4	4.9	6.1	4.6	2.1	1.5	2.4	2.1
Urea	233.2	90.5	88.0	99.7	114.8	116.8	123.4	148.5	162.0	168.0	164.0

*MCP - Monocalcium phosphate

Perhaps one of the most important results of this study is that when samples were incubated at 54°F and 68°F without the addition of chemicals the amount of available nitrogen was increased. Although the total available nitrogen was greater in the fir samples than in the spruce, the increase when expressed as a percent of the amount originally present was greater for the spruce than for the fir.

For most samples treated with urea the amount of available nitrogen decreased sharply during the first 14 day period but increased slowly and steadily from then onwards. At the conclusion of the experiment there was considerably more available nitrogen present in the urea treatment than in the control. However, in relation to the available nitrogen originally present all urea treatments showed a decrease over the entire 70 day period. The decrease was less than 10% for the balsam fir and average black spruce samples and from 30-50% for the dense black spruce samples. The greater immobilization of nitrogen in the latter samples is believed to be related to the high C/N ratios. Other workers have shown that under similar conditions available nitrogen from nitrogenous fertilizers is rapidly synthesized by mircoorganisms and chemically incorporated into complex compounds (Broadbent and Nakashima, 1967, Overrein, 1967).

The results of the MCP treatments were similar to those obtained for the controls. Increases in available nitrogen were 30 and 60% in the fir samples, 120 and 200% in the average black spruce samples, and -60 and 170% in the dense black spruce samples at incubation temperatures of 54°F and 68°F, respectively.

Lime treatments gave increases in available nitrogen of 20 and 40% in fir samples incubated at 54°F and 68°F and of 25% in the average black spruce samples incubated at 54°F, but these increases were less than those observed in the equivalent controls. Also, the lime treatments gave decreases of 70% in the average black spruce samples incubated at 68°F and of 40% and 75% in the dense black spruce samples incubated at 54°F and 68°F. No explanation for these latter results can be offered. However, it has been shown (Zöttl, 1960; Nommik, 1968) that the addition of lime to mor humus with high C/N ratios induces immobilization of nitrogen. It would appear from the results in Table III that immobilization occurs to a greater extent at 68°F than at 54°F.

The lime plus MCP treatment gave results intermediate between those for lime and for MCP. Increases in available nitrogen occurred in the balsam fir and average black spruce samples, and decreases occurred in the dense black spruce samples.

SILVICULTURAL IMPLICATIONS

The results of this investigation have shown (i) that the fir humus sample was relatively richer in available and total nitrogen than the black spruce samples, (ii) that incubation at 68°F released more nitrogen than incubation at 54°F, (iii) that the addition of monocalcium phosphate (MCP) and lime did not appreciably increase the amount of available nitrogen, and (iv) that the addition of urea provides much available nitrogen, especially in richer humus types.

From the results of this experiment it cannot be concluded that for any given site condition fir humus is always richer in available nitrogen than spruce humus, but studies are in progress to determine if real differences do exist. However, if in fact fir humus is always richer, then a fir component together with its associated ground vegetation, would improve nitrogen cycling on most sites.

Since more nitrogen becomes available at higher temperatures, careful consideration should be given to the growing of stands at densities that will allow enough solar radiation to reach the forest floor to maintain temperatures optimum for humus decomposition. Density may be controlled by planting at suitable spacings or by thinning at appropriate intervals and intensities. Maintenance of higher temperatures at ground level may also be achieved by favoring the development of a hardwood component in each stand. Intolerant hardwoods have more open crowns than conifers; besides, all hardwood litter is less resistant to decomposition than conifer litter.

Because much of the nitrogen in urea was immobilized when applied to humus with high carbon-nitrogen ratios, it follows that greater returns from fertilizing with urea will be obtained from more fertile sites with relatively low carbon-nitrogen ratios.

SUMMARY AND CONCLUSIONS

Humus samples from a balsam fir stand, a dense black spruce stand and an average black spruce stand were incubated for 70 days at 54°F and 68°F. Changes in pH and amount of nitrogen mineralized at periodic intervals after the addition of various fertilizer chemicals were measured. Results have shown that the humus from the balsam fir stand was richer in available nitrogen than that from black spruce stands. Addition of lime, lime plus monocalcium phosphate, urea and monocalcium phosphate raised the pH of almost all humus samples; lime produced the greatest increase while monocalcium phosphate produced the least. In no instance was the pH raised to more than 6.7.

Incubation at 68°F resulted in more nitrogen becoming available than at 54°F. Addition of lime and monocalcium phosphate did not appreciably increase the amount of available nitrogen. The addition of urea increased the supply of available nitrogen, especially in the fir humus samples. Therefore, greater returns from the application of urea fertilizer can be expected on richer sites. It is suggested that control of stand density and species composition can play an important role in maintaining optimum conditions for humus decomposition.

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