GROWTH AND NUTRITION OF BLACK SPRUCE PLANTED ON CUTOVER UPLAND RAW HUMUS IN QUEBEC

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As part of a larger study of the nitrogen cycle in a stand of upland black spruce north of Baie Comeau, on the north shore of the St. Lawrence River, Quebec, a portion of the 65-year-old stand was clearcut (fig. 1) and planted with wilding trees (fig. 2) , 4 to 6 years of age, collected along the side of the road (Weetman, 1964, 1967).

The stand was known to be nitrogen deficient. The foliar nitrogen concentration in current needles sampled in the fall was less than one percent. This stand has responded in diameter and height growth to urea applications. It was anticipated that black spruce trees planted in the cutover would also be nitrogen deficient. In 1961, when these treatments were carried out, a phosphorus deficiency was also anticipated. However, our present knowledge of black spruce nutrition indicates that this is not the case.

Nitrogen deficiencies were anticipated on this site because it has a podzol profile in a deep outwash sand mixed with till and capped with four to six inches of mossy, fibrous and inactive raw humus. The C/N ratio of this humus is 55/1. It was thus originally anticipated that mineral nitrogen released by decomposition would be immobilized by microbial activity.

Figure 1.—65-year-old black spruce stand growing on deep outwash sand next to clearcut area, where wild seedlings were planted.

Figure 2.—Planted black spruce seedlings in thick raw humus. (Note cut stumps at right.)

1961 Field Study

Following cutting in 1961, groups of six wilding black spruce seedlings were used to test the effects of manually mixing the humus and mineral soil, of adding 400 pounds per acre of nitrogen as urea to 8-foot-square blocks plus 2.5 ounces of superphosphate placed in bands around each tree, and of the combinations of these two treatments, together with a control treatment of planting directly in the humus. Eighteen replications were used.

At the end of the first "year the survival rates on the soil and humus mixed treatments were 89 percent versus 65 percent in the control; the additions of urea and superphosphate had resulted in lower survival rates in all instances.

At the end of the second growing season, survival rates were less than 50 percent for all treatments except the soil and humus mixed, which was 68 percent. Many trees had died while in check; a few had been browsed.

Trees which had not received nitrogen and phosphorus grew about three to four inches in height during the two years 1962 and 1963 and were generally chlorotic and still in check. Fertilized trees grew about six inches during the same period and were deeper green and many had come out of check. The percentages of the total number of trees with greater than six inches of growth in 1962 and 1963 were:

Treatments	*Percent*
1. Control	4
2. Mixing mineral soil and humus	15
3. Urea plus superphosphate	45
4. (2) plus (3)	40

In 1964 and again in 1965, analyses of variance of the current leader lengths indicated that the treated trees had significantly longer leaders than the untreated trees in the control (fig. 3), but none of the differences between the three treatments were significant at the 5 percent level.

It thus appeared that the effect of the mixing of the soil and humus (equivalent to a type of soil scarification) was to increase the survival rate. The effect of the nitrogen and phosphorus additions was to bring the trees out of check sooner.

By the fall of 1966 all the surviving trees were very vigorous, healthy and had blue green needles. Foliar analyses on current needles collected in the

TABLE 1.—*Foliar nutrient contents of planted black spruce.*

[PERCENT]

Absolute levels		N	P	K	Mg	Ca
Range in the 4 treatments	1965	1.73–1.77	.25–.34	.29–.33	.05–.08	.33–.42
	1966	1.74–2.01	.29–.39	.46–.49	.10–.11	.37–.45
Suggested level for satisfactory growth in the field (Swan, 1967)		1.50	.17	.60	.10	.40
[PROPORTIONS]						
Proportions N = 100						
Range in the 4 treatments	1965	100	14–20	16–19	3–5	19–24
	1966	100	14–21	23–38	5–6	21–23
Optimum proportions, suggested by Ingestad (1966)		100	8–15	50–100	5–10	5–10

falls of 1965 and of 1966 (table 1) indicated very high nitrogen levels from trees in all treatments; even from trees which had received no nitrogen. These trees were growing mainly in the humus layer which, even after 5 years, showed little decomposition of needles and twigs, even though the layer of feather mosses *(Pleurozium schreberi, Hypnum cristacastrensis)* had died and partially decomposed. Phosphorus levels were also high, even in trees which had received no phosphorus. However, potassium levels were low in comparison to suggested values or proportions for better nutrition given by Swan (1967) and Ingestad (1966).

Greenhouse Study

In order to check on responsiveness of this site to the additions of ash elements either by simulated burning or by additions of chemical fertilizer, a separate study was conducted in the greenhouse.

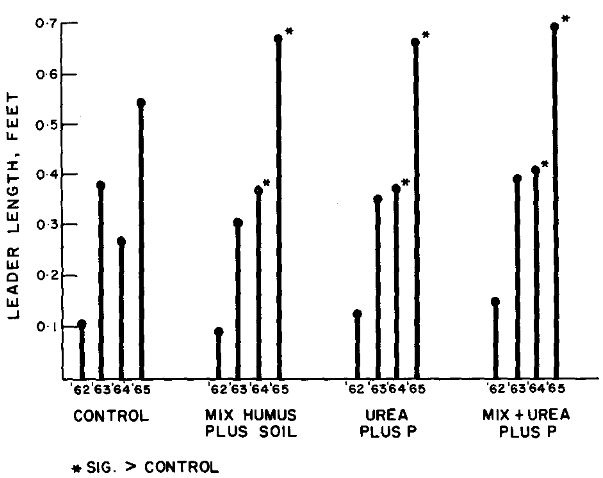

Figure 3.—Leader lengths of black spruce seedlings, by type of fertilizer treatment, for years 1962, 1963, 1964, and 1965.

Intact cores from the humus layer together with one to three inches of underlying mineral soil were placed into clear plastic tubes 1.75 inches in diameter. The tubes were sealed with tar at the base and placed in a constant temperature (48°F.) water bath. This temperature was found, in a separate study, to be the mean for the humus layer in the stand during the growing season.

Treatments, with 10 replications, involved nitrogen additions as urea, simulated burning by ashing and returning one-third and two-thirds of the humus, and fertilization with powdered chemicals or nutrient solutions. These were all carried out before placing one germinated black spruce seedling in each core.

The results (figs. 4 and 5) indicated a small, but not significant response in growth to either nitrogen additions or ash elements. However, the *combination of nitrogen and ash,* or the approximate major elements of the ash, *produced significantly greater growth* than any of the treatments involving additions of either nitrogen or ash alone.

The foliar analyses of the seedlings is given in table 2 as a proportion of nitrogen equal to 100. It can be seen that for these seedlings, almost entirely rooted in the humus layer, when the amount of only nitrogen added was increased from 100 to 400 lbs. per acre the proportional levels of the ash elements, particularly potassium, tended to be diluted. Further additions of humus ash or powdered chemical fertilizer tended to increase the proportions and particularly raised the proportional level of potassium to that suggested as optimum by Ingestad (1966).

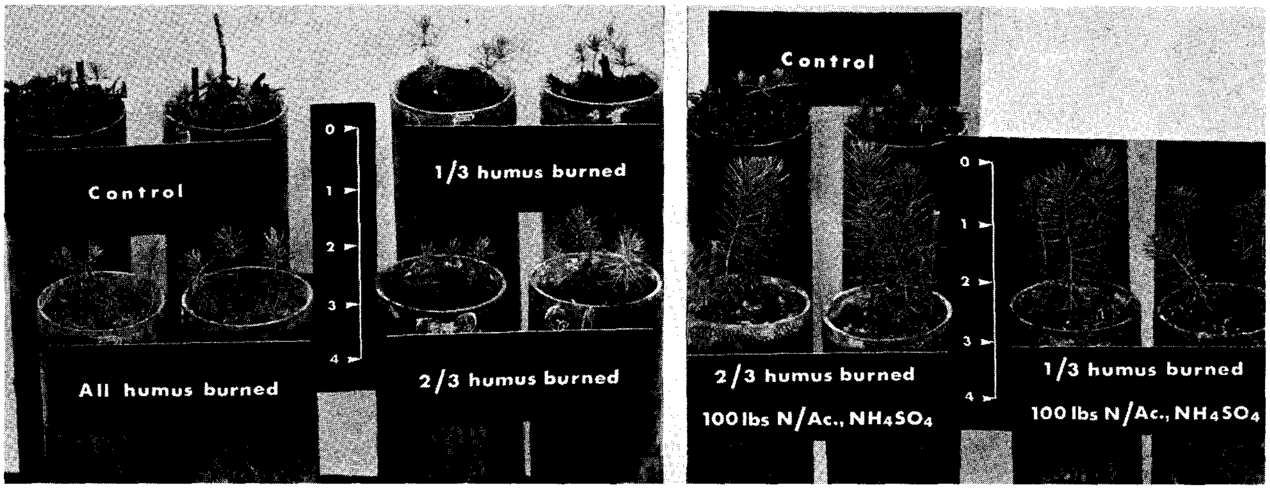

Figure 4.—Comparative growth of black spruce seedlings in cores of soil where humus has been partially and completely burned; without fertilizer at left, and with fertilizer at right. All seedlings 10 months old.

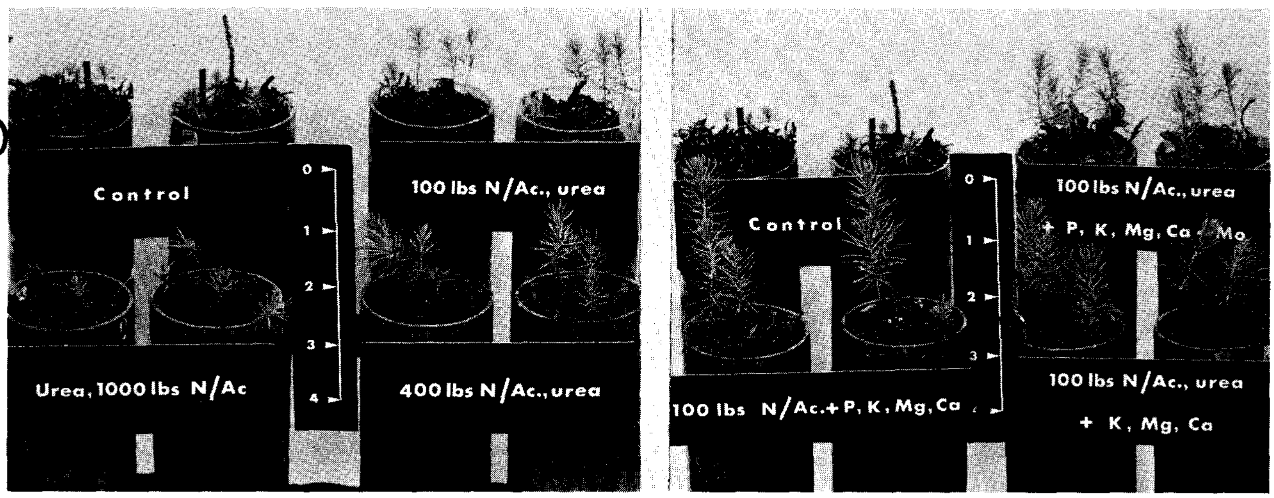

Figure 5.—Comparative growth of black spruce seedlings in cores of humus with various rates of fertilization. Response to nitrogen alone (in the form of urea), at left, even at heavy levels, was less than the response to moderate amounts of nitrogen plus the major elements in ash (from burning the humus), at right.

Discussion and Conclusions

These results indicate that in spite of a high C/N ratio in the humus layer, trees planted in this layer are not deficient in nitrogen, even though mature trees only a few yards away were found to be deficient. A separate study of the feather moss layer in the same stand (Weetman and Timer, 1967) has shown that it contains a large reserve of nitrogen. These feather mosses mineralize nitrogen readily upon decomposition (Bernier and Roberge, 1962). he planted trees must either have made use of this reserve or of the very limited reserve of mineral nitrogen found in the humus layer. (Roberge and Knowles, 1966).

Potassium appears to be in short supply if the trees are rooted only in the humus layer.

For best survival of planting stock on these upland cutovers, where the humus layer dries out very rapidly, some form of scarification to achieve a mixing of the humus and the mineral soil would be desirable.

If these sites are subjected to controlled burn-

TABLE 2.—*Foliar nutrient analysis of seedlings grown in cores in the greenhouse*

Treatment	% N	Proportions N = 100 P	K	Mg	Ca
100 lbs. N/Ac as urea	1.03	12	29	7	28
400 lbs. N/Ac as urea	1.79	5	14	3	10
100 lbs. N/Ac plus ash from one-third of the humus layer	0.75	26	48	11	41
100 lbs. N/Ac plus 300 lbs. K, 287 lbs. Mg and 380 lbs. Ca/Ac	1.59	7	57	14	27
Optimum proportions suggested by Ingestad (1966)	100	8–15	50–100	5–10	5–10

ing for site preparation and a portion of the humus layer is incinerated, ash fertilization from the burning should be supplemented by nitrogen additions to make up for the nitrogen lost in burning. Heavy burns which remove most of the humus layer, and therefore the bulk of the nitrogen, and promote loss of the ash elements by leaching, should be avoided.

It may be added that observations were made on clearcut areas, of various ages of upland black spruce in the same region, all with thick layers of inactive raw humus. It appears that if such areas are not promptly restocked, ericaceous heathland vegetation tends to become established. This makes any subsequent seeding and planting work very costly and difficult.

References

1. Bernier, B. and Roberge, M.
1962. Etude *in vitro* sur la mineralisation de l'azote organique dans les humus forestieres. 1. Influence de litieres forestieres. Fonds Rech. For. Univ. Laval Contrib. No. 9.

2. Ingestad, T.
1966. Experiments on constant internal nutrient concentrations. Proc. XVII Int. Hort. Congr. Aug. 1966.

3. Roberge, M. R. and Knowles, R.
1965. Available nitrogen in a black spruce humus ferti lized with urea. Woodl. Res. Index, Pulp Pap. Res. Inst. Can. No. 172.

4. Swan, H. S. D.
1967. Personal communication.

5. Weetman, G. F.
1967. Nitrogen deficient black spruce on raw humus soil in Northern Quebec. Response to thinning and urea treatments. Proc. Int. Union For. Res. Org. Sept. 1967, Munich.

6. Weetman, G. F.
1964. Clear cutting, planting, thinning and nitrogel. fertilization of a black spruce-feather moss site. Woodl. Res. Index, Pulp Pap. Res. Inst. Can., No. 156.

7. Weetman, G. F. and Timmer, V.
1967. Feather moss growth and nutrient content under upland black spruce. Woodl. Res. Index, Pulp Pap. Res. Inst. Can. No. 183.