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EFFECT OF FIRE ON THE AVAILABILITY OF NITROGEN AND GROWTH OF

BLACK SPRUCE (Picea mariana, Mill.) IN GASPE, QUEBEC

(Projects Q-79 and Q-102)

by

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(Picea mariana, Mill.) IN GASPE, QUEBEC^{1/}

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ABSTRACT

Visual symptoms of malnutrition associated with the unsatisfactory development of natural and planted black spruce seedlings in a 20-year old burn suggested low supply and uptake of nitrogen, phosphorus, and possibly other nutrients as the primarily adverse factors.

In order to test the hypothesis, both soil and foliage of the species there and in another climatic region were compared and the diagnosis was partially confirmed. Of the elements studied (K, Mg, Ca, P, Mn, Fe, and N) only nitrogen was found to be related to needle colour and poor leader growth.

Crushing of the nitrogen-rich Lecidea granulosa lichen crust, and its incorporation with the mineral soil is suggested as one means of improving soil fertility and promoting the development of future plantations.

INTRODUCTION

Many investigations have shown that forest fire causes changes in a number of site factors. Beaton (2), Glisic (7), and Malcom (16) report that soil degradation often occurs after fire. This view is questioned by Harper (8), particularly on soils where pure stands are grown. Heyward and Barnette (9), Hodgkins (10), and Ugglå (21) advance the idea that fire may sometimes stimulate growth by making available

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quantities of nutrients. Beaton (2) has shown that burning results in an increase in the pH and Tarrant (21) has found that pH decreases significantly with increasing time since burning. Of all the elements affected by fire, nitrogen is reported by Wilde (25) Kramer and Kozlowski (12) to be most greatly reduced.

The influence of fire on the fertility level of a site is undoubtedly variable. It is believed each burn must be considered as a different problem and that no general conclusions should be drawn since soil conditions prevailing after fire vary with the intensity of the fire, the nature of the parent material, and the site quality.

In 1941, over 200 square miles of standing timber were destroyed by a fire on the York River, in Quebec (Forest Section B.2). Twenty years later vegetation was still sparse and the humus layer wanting. The rare natural spruce seedlings found in this seedbed and also black spruce planted in 1958 and 1959 grow very slowly and have short yellowish needles. The whole situation points to a lack of nutrients, primarily of nitrogen and phosphorus, as suggested by the general appearance of the trees.

The purpose of this investigation was to learn the exact nature of the deficiency in order to determine the best way of improving the fertility of the York River burned area for future planting. Accordingly, physical and chemical properties of the soil and uptake of nutrients by natural and planted seedlings were studied along with the colour of the foliage and the current growth. The results were compared with those obtained from healthy and unhealthy nursery stock growing on soils of same texture as the York but in other localities.

MATERIALS AND METHODS

General

The study area located in the Gaspé Peninsula, 10 miles east of Murdochville, has soil conditions representative of roughly one third of the 200 square miles burned. Sparse vegetation consisting mostly of Vaccinium canadense (Kalm), Kalmia angustifolia (L.), Polytrichum commune (Hedw.) and a crust of Lecidua granulosa (Ehrh.) developed on the exposed mineral soil. MacArthur and Gagnon (15) found reproduction of softwood species a failure, with as few as 20 spruce and 10 fir seedlings per acre.

Suspecting that poor development of natural seedlings was due to low quality forest sites, one hundred 2-2 black spruce seedlings potted at Valcartier with nursery soil were planted in the study area in spring 1958, and their development followed. In order to compare survival and initial development of the 1958 potted seedlings with that of conventionally planted stock (2-2 black spruce), 12 plots of 100 trees each were planted in spring 1959. Three rows of four plots were established at 10 x 10 chain spacing on a uniform soil.

Field Procedure

Data were collected at the end of the 1961 growing season. Foliage colour was estimated in a manner similar to that described by White (24); colour variation occurring on individual trees was first graded from 1 to 4, from yellow to green, and four trees corresponding to these grades were excavated and used as standards of comparison on the study area. To compare methods of evaluation colour was also determined at mid-point of the crown by means of the Munsell Colour Chart for plant tissues.

Two trees were chosen at random from each of the twelve 100-tree plots for foliage sampling. Thirteen of the 24 sample trees were colour grade 1 and eleven were grade 2. The two colour grades were reduced to 10 trees each to permit comparison with other studies having only 10 sample trees. On each of the 10 foliage sample plots, 10 samples of the A₂, B₂ horizons and of the lichen crust were collected and used to make up a composite sample for each of the three layers.

Because of the small number of spruce wildings (20 per acre) in the study area, a random selection of specimens comparable in height to planted trees was impossible. Instead 10 comparable wildings were collected on or near each plot.

Each foliage sample consisted of current year needles collected from the terminal and from all the lateral shoots of the tree. Current leader growth of the selected seedlings was measured to the nearest tenth foot.

Laboratory Procedure

a) Soil analysis: Soil texture was determined by the Bouyoucos hydrometer method (3). The pH values were determined with a Beckman H2 potentiometer (glass electrodes) using a suspension of 1 part of soil to 1 part of distilled water. Exchangeable nutrients were extracted with a solution of 1N ammonium acetate adjusted to pH 7.0 (17) and subsequently determined separately as described by Wilde and Voigt (26) and Gagnon et al. (6). These nutrients included potassium, magnesium, calcium, manganese, and iron. Phosphorus was determined after extraction with .002N sulphuric acid at pH 3.0 using stannous chloride as the reducing agent (4). Nitrogen determinations were made by the Kjeldahl method (5).

b) Foliar analysis: Samples of needles, previously air-dried, were oven-dried for 24 hours at a temperature not exceeding 65°C and ground in a Wiley mill to pass a 40-mesh screen. Prior to analysis, the ground needles were again oven-dried for 12 hours at 65°C and one gram of material was submitted to oxidation by successive treatments with nitric acid (15N) and perchloric acid (72%), as recommended by Amiot and Bernier (1). Suitable aliquots of the clear liquid residue were taken for determination of various ions using the same method as for soil analysis.

RESULTS

The results of the analyses carried out on soil and foliar samples are presented in Tables 1 and 2. The measured fertility of the York River burn area is compared with that of the Valcartier nursery soil (Table 1). The assumed criteria of soil fertility (needle colour and leader length) are given with the corresponding measured concentration of nutrients in current year needles (Table 2.) The cations studied were not related to either needle colour or leader length either singly or when grouped. Nitrogen and phosphorus, assumed to be the prime cause of poor growth, are presented separately.

Results pertaining to the same species - black spruce - but in different localities are included in Tables 1 and 2 for comparison.

Soil Analysis (Table 1)

Soil texture of both the York River burn and Valcartier nursery was classified as sandy loam (22). The pH values from the burn are lower than those of the Valcartier nursery soil. The crust of lichen which covers most of the burn contains much more food material than the mineral soil collected from the A₂ and B₂ horizons. The exchangeable cations are greater in the mineral soil of the York River burn than in the Valcartier

nursery soil but the quantity of available phosphorus and the nitrogen percentage is much less.

Foliar Analysis (Table 2)

In the York River burn there is a gradation in leader length which parallels both the colour variation and the foliar concentration of nitrogen. Total cations, however, do not show any appreciable variation that could be related to either colour or leader growth. The phosphorous concentration in foliage is about the same in planted seedlings and wildings but it is higher in potted seedlings. The latter, moreover, concentrate in their needles significantly more nitrogen than the most chlorotic planted seedlings and slightly more than the least chlorotic ones. Wildings, although growing in the same soil as the planted trees, show better growth and concentrate in their needles more nitrogen.

For trees growing in remote localities with unlike climatic conditions, it is interesting to note the striking apparent relationship between growth and nitrogen percentage in needles.

Even though the data presented in Tables 1 and 2 are sufficient to demonstrate that on the York River burn visual symptoms of malnutrition in nitrogen and poor growth are associated with low supply and uptake of nitrogen, they do not, however, give a direct information as to the significance of this relationship for each group of data when needle colour grades are considered singly or combined. Such information may be obtained by establishing the linear regression equation of leader length on concentration of nitrogen in each condition and testing for significance by applying the "R" test (Table 3).

TABLE 3. Statistics pertaining to each sample regression line of leader length on needle N for the four growing conditions and needle colour grades singly and combined, in the York River burn.

Conditions	Needle colour grade	D.F.	Sample regression constant	Sample regression coefficient	"R" correlation coefficient
Planted	1	8	.105	.200	.150
Planted	2	8	.216	.213	.118
Planted/pots	3	8	-.457	1.902	.473
Wildings	4	8	-1.299	3.069	.630 *
All combined	-	38	-1.465	2.831	.689 **

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

DISCUSSION AND RECOMMENDATION

Soil Analysis (Table 1)

According to Wilde's standards (25) and data presented by Linteau (14) for the Boreal Forest Region, the soil texture in the York burn and in the Valcartier nursery is satisfactory for good development of seedlings, especially black spruce, but the pH values would appear to be below normal. Although the cation exchange in the mineral soil of the burn compares favourably with that of Valcartier, total phosphorus and nitrogen are much inferior. In fact, phosphorus is five times greater at Valcartier. The higher concentration of the element in the B₂, as compared with that in the A₂ horizon agrees with the findings of many workers. The low level of phosphorus (15 ppm) in the rooting zone of the planted trees is considered by Wilde (25) as unsatisfactory for most conifers.

Soil nitrogen content does not provide a reliable measure of available nitrogen, but it shows the range encountered in the soils studied. According to Wilde (25) the minimum content of nitrogen in the surface 6-in. layer of a planting site for black spruce would be .05% and the optimum for nursery soils would be 0.12%. Evidently, this range is likely to vary with climatic regions as Jenny (11) showed, yet the data for the York River burn are closer to the minimum found by Wilde (25), while the values for Valcartier would be higher than the optimum indicated by the same writer.

The crust formed by the lichen Lecidua granulosa is rich in exchangeable cations and in nitrogen. However, as it decomposes very slowly, it contributes little to the enrichment of the soil. An increase in the rate of its decomposition would be reflected by a greater quantity of exchangeable cations, total phosphorus and nitrogen in the A₂ horizon. It was first believed that this crust contained chemical agents inhibiting tree growth, but Marois and Bernier^{3/} have demonstrated that such was not the case. Furthermore, previous exploratory tests in vitro have shown an improvement in tree growth when the crust was broken and mixed with the mineral soil, and after one growing season no visual symptoms of malnutrition could be observed.

Foliar Analysis (Table 2)

In this experiment colour or leader length were not related to total cation content in spruce needles. Of the several elements

^{3/} Etude sur la revalorisation des aires incendiées de la Gaspésie. Thesis submitted to the Graduate School, Laval University, in April 1962. Unpublished.

investigated (K, Mg, Ca, Fe, Mn, P, and N) only nitrogen was found to vary with leader length and colour. The relationship found between leader length and nitrogen content agrees with the findings of Swan (19) and Weetman (23). Moreover, this relationship is clearer when colour is graded by comparison with selected standards than when estimated with the Munsell Chart. It is also more significant when all needle colour grades are combined (Table 3).

In spite of its greater discoloration, Valcartier nursery stock (fair growth) shows greater nitrogen concentration and better growth than trees of the York River burn. This is attributed to the very low uptake of calcium by Valcartier seedlings showing fair growth. Analysis has revealed that these trees from Valcartier contained in their needles as little as 890 ppm of calcium while needles collected from trees at York contained from 4,000 to 5,000 ppm of calcium.

The variation of phosphorus content in needles shown by the high standard errors of means is attributed to the high mobility of phosphorus in plant tissues. Greater concentration of this ion in the needles of potted seedlings as compared with planted seedlings or with wildings is presumably due to the influence of the potting soil. Examination of Scott's data (18) suggest that phosphorus values vary with site, and Leyton and Armson (13) have shown that growth can be related to the concentration of foliar phosphorus. However, the fact that concentration of phosphorus in black spruce needles does not vary with leader length, while needle nitrogen does, suggest that nitrogen rather than phosphorus is the growth limiting factor in the York River burn.

At first sight it would appear that deficiency of available nitrogen occurring in the burn and likely to occur in many similar burns overrun by Lecidea granulosa, could be easily corrected by the application of nitrogen fertilizers. But in these areas, there is no decomposable organic matter and, consequently, it is doubtful that such treatment would be of much benefit to the site unless frequent small doses were applied. In the light of the results obtained in this study and those found in vitro, we would favour the incorporation of the crust into the mineral soil as nitrogen fertilizer. The mixing of this crust, rich in organic matter, in mineral nutrients and in nitrogen, will favour its decomposition and, consequently, will favour site improvement more permanently by the slow release of nutrients and especially nitrogen.

SOMMAIRE

Nous basant sur certains symptômes de déficiences minérales, nous avons émis l'hypothèse que la faible croissance des jeunes épinettes noires et de celles plantées dans le brûlis de 1941 de la rivière York, était surtout attribuable à la carence de l'azote et du phosphore et peut-être aussi à d'autres éléments dans le sol et les tissus. L'hypothèse a été vérifiée et partiellement confirmée. De tous les éléments étudiés (K, Mg, Ca, P, Mn, Fe et N), seul l'azote est relié à la couleur des aiguilles et à la croissance de la flèche terminale. Cette relation cependant est beaucoup plus marquée lorsque la couleur est estimée à l'aide de comparaison avec des semis recueillis sur la place même de l'étude plutôt qu'avec la charte des couleurs de Munsell.

Les résultats de cette étude ont été comparés avec d'autres déjà obtenus avec l'épinette noire, ayant le même âge et croissant dans un sol de même texture, mais dans des régions climatiques différentes.

Même si le contenu minimum en azote d'un sol est susceptible de varier d'une région climatique à l'autre, il semblerait que la disponibilité de l'azote dans le brûlis de la rivière York est nettement insuffisante pour espérer le développement normal d'une plantation d'épinettes noires.

A la suite de travaux préliminaires faits en serre, nous avons constaté que le lichen Lecidea granulosa, riche en azote et qui recouvre en partie l'aire étudiée, favorisait la croissance des jeunes épinettes quand il était broyé et incorporé au sol minéral. On suggère donc, comme moyen d'amélioration du sol en vue de futures plantations, de broyer sur place ce lichen et de l'incorporer au sol.

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Table 1. Physical and chemical properties of the York River Burn and Valcartier nursery soils.

Location	Number of pooled samples	Mechanical Analysis		pH	Exchangeable cations ppm	Total phosphorus ppm	Total nitrogen %
		Sand %	Silt & Clay %				
YORK RIVER BURN							
* Crust	10	-	-	4.0	7340	30	.840
A ₂ horizon	10	60	40	3.9	311	4	.037
B ₂ horizon (root zone)	10	56	44	4.0	276	15	.073
VALCARTIER NURSERY (first 6-in. layer)							
Fair growth	10	51	49	4.6	57	80	.208
Good growth	10	51	49	4.8	143	83	.241

* A lichen called Lecidea granulosa (Ehfh.) appears as a hard crust developing in fairly large patches in open burned areas.

This crust covers most of the study area.

Table 2. Development and nutrient concentration of black spruce seedlings in various locations and conditions of the York burn,
Valcartier and elsewhere.

Locations and Conditions	No. of samples	Needle Colour			Age	Leader length (in.)	"t" values	Concentration of nutrients - dry weight basis				
		Grades	Colour	After Munsell Chart Colour				Total cations ppm	P ppm	"t" values	N %	"t" values
YORK RIVER BURN												
Planted	10	1	yellow	2.5GY 6/6 to 5.0GY 7/6	2-2+3	.34 [±] .05	1.0	12546	1555 [±] 90	.1	.65 [±] .04	4.0
Planted	10	2	yellowish	5.0GY 5/4 to 7.5GY 5/4	2-2+3	.41 [±] .05	3.8	12319	1570 [±] 112	3.1	.85 [±] .03	4.0
Planted in pots	10	3	greenish	7.5GY 5/6 to 7.5GY 6/6	2-2+4	1.20 [±] .20	3.2	11344	1970 [±] 57	4.2	.89 [±] .06	2.5
Wildings	10	4	green to greenish	7.5GY 5/4 to 7.5GY 6/6	7 to 14	1.92 [±] .09	12.8	12465	1590 [±] 70	4.0	1.04 [±] .01	6.3
VALCARTIER NURSERY												
Nursery stock (fair growth)	10	-	greenish yellow	7.5Y 7/8	2-2	5.8 [±] .30	3.1	8398 ^{2/}	1944 [±] 51	3.2	1.92 [±] .14	.9
Nursery stock (good growth)	10	-	green	10GY 6/4	2-2	7.44 [±] .40	-	10171	2220 [±] 69	-	2.08 [±] .12	-
ELSEWHERE (Que. and Ont.)												
Planted ^{1/}	6	-	-	-	2-2+3	5.25 [±] .10	-	-	2233	-	1.71	-

1/ For P 0.05, "t" 2.2; For P 0.01, "t" 3.2

1/ Data abstracted with permission, from interim results obtained by H.²D. Swan.

2/ Found to be deficient in calcium uptake.

