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Scientia Silvica Extension Series, Number 31, 2001

Vegetation and Soil Nutrient Properties of Black Spruce and Trembling Aspen Ecosystems in the Boreal Black and White Spruce Zone

Introduction

Changes in forest ecosystem vegetation also bring about changes to the associated soil. In order to maintain forest productivity, it is important to know the effects of tree species upon the soil, especially the influence of deciduous *versus* coniferous tree species. Many deciduous species increase pH, nitrogen, base saturation and/or accumulation of organic matter in the forest floor. The chemical properties of the forest floor may, in turn, influence the chemical properties of the underlying mineral soil. If a tree species significantly alters the soil, then silviculturists may consider crop rotation between deciduous and coniferous trees or growing mixed-species stands to maintain greater nutrient availability and maintain site productivity.

Trembling aspen (*Populus tremuloides*) and black spruce (*Picea mariana*) may occupy similar sites in the North American boreal forest. Shade-intolerant aspen is generally a seral species while shade-tolerant black spruce can be a seral species but also forms a major component in late successional stages. This study investigated differences in nitrogen-related soil properties between trembling aspen and black spruce stands on upland sites in the BWBS zone of northeastern BC. We asked two questions: (1) are the differences in soil nutrient properties manifested in both forest floor and mineral soil? (2) To what extent are these differences reflected in the floristic composition of understory vegetation?

Methods

We described vegetation and sampled the forest floor and top 30 cm of mineral soil in 40 spruce stands and 58 aspen stands. Vegetation was analyzed by tabular comparison and multivariate analysis, and soils were analyzed for acidity, total C, total N, mineralizable N, and extractable K, Ca, and Mg.

Results

Despite large differences in some forest floor measures between the two stand types, there were few differences between the associated mineral soils (Table 1, Figure 1). There were significant differences ($\alpha = 0.05$) in pH, total N, C:N ratio, mineralizable N, and extractable Ca, Mg, and K between the humus forms associated with the spruce stands compared to the aspen stands. The mineral soil associated with the spruce stands had lower pH and significantly lower concentrations of mineralizable N, extractable Mg and K. Significant differences in extractable bases could not be detected between the stands. This comparison suggests that aspen forest floors are richer in nutrients than spruce forest floors.

In view of profound differences in the forest floor nutrient properties between black spruce and trembling aspen stands, we expected analogous differences in understory vegetation. Non-parametric multidimensional scaling analysis showed no overlap in vegetation between the spruce and aspen stands (Figure 2). This pattern gives a convincing demonstration that the spruce and aspen stands have distinctly different flora and hence, represent different plant community types.

Although black spruce and aspen stands share a number of species that are characteristic of the boreal forest, they are distinguished from each other by a combination of several differential species (Table 2). The major differences include preponderance of mosses in spruce stands, and preponderance of shrubs, herbs and grasses in aspen stands. Compared to the moss-dominated understory in spruce stands, aspen stands support well-developed shrub and herb layers.

Table 1. Mean nutrient measures (standard error in parentheses) for humus form and the upper 30 cm of the mineral soil for black spruce stands (n = 40) and trembling aspen stands (n = 58) with the associated *p*-value for the t-test comparing spruce to aspen measures.

	Black spruce	**Trembling aspen**	**P-value**
Forest floor			
pH	4.34 (0.09)	5.37 (0.07)	<0.0001
Total C (%)	36.9 (1.67)	39.1 (0.55)	0.2146
Total N (%)	0.95 (0.03)	1.38 (0.03)	< 0.0001
C:N ratio	40.5 (2.6)	28.9 (0.5)	0.0001
Mineralizable N (ppm)	109.9 (9.5)	551.2 (27.5)	<0.0001
Extractable Ca (ppm)	1715 (271)	11734 (349)	<0.0001
Extractable Mg (ppm)	731 (85)	1342 (70)	<0.0001
Extractable K (ppm)	635 (33)	1287 (40)	<0.0001
∑(Ca, Mg, K) (ppm)	4755 (344)	14363 (412)	<0.0001
Mineral soil			
pH	4.79 (0.14)	5.27 (0.09)	0.0030
Total C (%)	1.38 (0.18)	1.44 (0.14)	0.8067
Total N (%)	0.08 (0.01)	0.09 (0.01)	0.4516
C:N ratio	16.5 (0.9)	16.0 (0.3)	0.6097
Mineralizable N (ppm)	8.6 (1.5)	15.9 (2.1)	0.0062
Extractable Ca (ppm)	874 (139)	994 (127)	0.5317
Extractable Mg (ppm)	238 (44)	131 (18)	0.0453
Extractable K (ppm)	46 (5)	75 (6)	0.0002
∑(Ca, Mg, K) (ppm)	1158 (179)	1211 (145)	0.8181

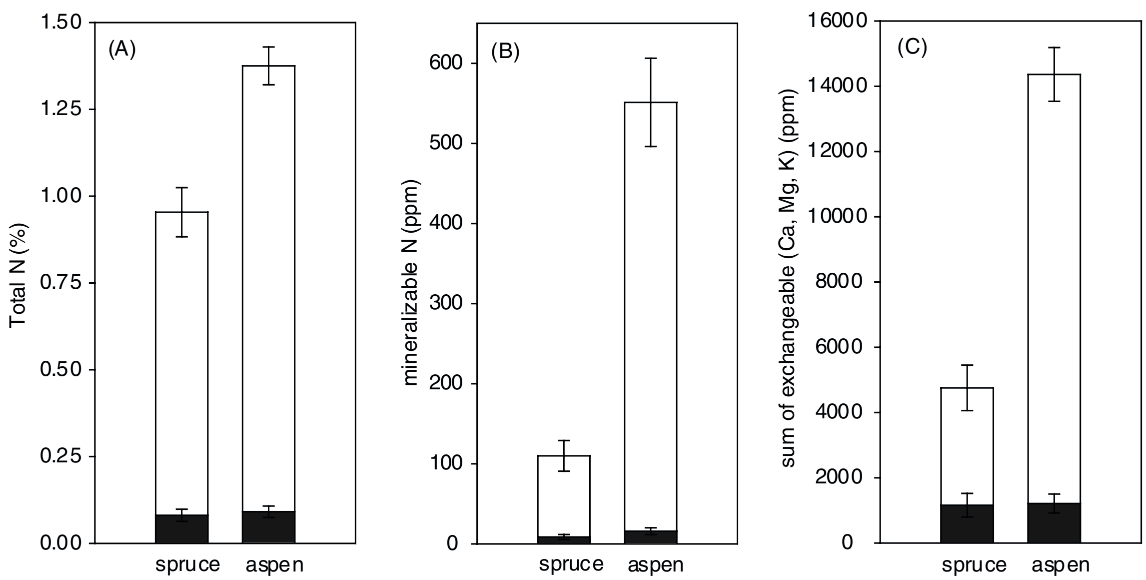

Figure 1. Concentrations of total N, mineralizable N, and sum of exchangeable cations (Ca, Mg, K) in the forest floors (white area) and in the upper 30 cm of the mineral horizons (shaded area) in black spruce stands (n = 40) versus trembling aspen stands (n = 58) on upland sites in the BWBS zone. Error bars represent 95% confidence intervals.

Table 2. Differentiated summary table indicating floristic differences between upland black spruce and trembling aspen stands in the BWBS zone of British Columbia. Only the species with presence class ≥III in one or both columns are given. Species presence class[1] and significance[2] for 40 black spruce and 58 aspen stands.

Plant species common to both spruce and aspen stands					Plant species occurring predominantly in spruce stands					Plant species occurring predominantly in aspen stands				
	Spruce		Aspen			Spruce		Aspen			Spruce		Aspen	
Cornus canadensis	**V**[1]	5[2]	**IV**	5	*Hylocomium splendens*	**V**	7	II	2	*Aster conspicuus*	I	t	**III**	4
Ledum groenlandicum	**IV**	5	**III**	5	*Peltigera aphthosa*	**III**	3	I	1	*Calamagrostis canadensis*	I	h	**IV**	3
Linnaea borealis	**IV**	4	**V**	3	*Picea mariana*	**V**	7	I	2	*Elymus innovatus*			**IV**	4
Petasites frigidus	**IV**	2	**IV**	3	*Pinus contorta*	**IV**	6	I	2	*Epilobium angustifolium*	**III**	+	**V**	4
Picea glauca	**III**	6	**IV**	4	*Pleurozium schreberi*	**V**	7	I	2	*Fragaria virginiana*	I	h	**III**	2
Vaccinium vitis-idaea	**IV**	5	**III**	3	*Ptilium crista-castrensis*	**IV**	6	I	h	*Galium boreale*	I	h	**III**	3
Viburnum edule	**III**	2	**III**	4						*Lathyrus ochroleucus*	I	+	**V**	3
Mertensia paniculata	**III**	+	II	2						*Maianthemum canadense*	I	h	**IV**	3
Orthilia secunda	**III**	+	II	1						*Populus tremuloides*	II	4	**V**	8
Shepherdia canadensis	II	3	**III**	4						*Pyrola asarifolia*	I	h	**III**	3
										Rosa acicularis	**III**	1	**V**	5
										Rubus pubescens	I	+	**III**	3
										Salix sp.			**IV**	4
										Spiraea betulifolia	I	t	**III**	2
										Vaccinium myrtilloides			**III**	5

[1] Presence is printed as presence class: I = 0 - 20%; II = 21 - 40%; III = 41 - 60%; = 61 - 80%; V = 81-100%; bold type indicates presence ≥ 41%.

[2] Mean cover is average cover value for ecosystem unit; scale used for cover values is the Domin-Krajina scale; percent cover ranges for symbols printed: t = 0.001 - 0.009; h = 0.010 - 0.099; + = 0.100 - 0.299; 1 = 0.300 - 0.499; 2 = 0.500 - 0.999; 3 = 1.000 - 1.999; 4 = 2.000 - 4.999; 5 =5.000 - 9.999; 6 =- 10.000 - 19.999; 7 =- 20.000 - 49.999; 8 = 50.000 - 69.999; 9 = 70.000 - 100.000.

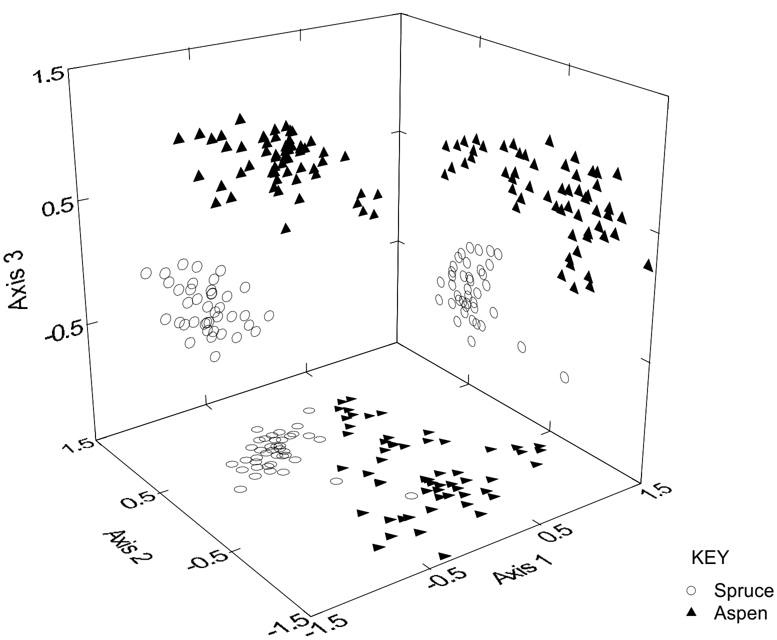

Figure 2. The distribution pattern of black spruce and trembling aspen stands along the first three axes of non-parametric multidimensional scaling ordination.

Discussion

Differences in forest floor chemistry between black spruce and aspen stands did not cause marked differences in the mineral soil. Except for pH and extractable K, forest floor has not modified nutrient properties of the mineral soil since the last stand-destroying event (> 50 years). Regardless of site differences, forest floors in aspen stands were richer than in spruce stands, particularly in nitrogen as indicated by a low C:N and high mineralizable N. In turn, aspen forest floors are expected to have a higher nitrogen mineralization rates as these increase with decreasing C:N. As differences in nutrient availability must result from differences in the type and decomposition rate of forest floor materials, they should be reflected in forest floor morphology and humus form.

Since both spruce and aspen stands occupy similar environments, humus formation must be influenced only by microclimatic conditions (temperature and moisture conditions in the forest understory) and chemical and physical characteristics of litter (including understory vegetation). These, in turn, determine the abundance and composition of flora and fauna in the forest floor. Using humus form classification, spruce stands had well developed Mor (Hemimor) humus forms which are characterized by incomplete decomposition and nutrient immobilization. A variety of Moder humus forms have developed in aspen stands. Moders have intermediate properties between Mors and Mulls. In contrast to Mors that form as a result of fungal decomposition, Moder and Mull formation result from soil fauna-mediated decomposition.

The common humus form in aspen stands was Lamimoder, although Mors also occurred rarely. In the lower humus form horizons there were many roots of aspen and herbaceous vegetation. Root distribution takes advantage of the humus layer since the main source of nutrients, warmest soil temperature, good aeration, and water availability occur just below the ground surface.

The ameliorating effect of aspen on the surface soil horizon is widely acknowledged. Nutritional studies of aspen-dominated ecosystems indicate that aspen takes up large quantities of nutrients and stores them in woody tissues and foliage. In contrast, black spruce is one of the few tree species well adapted to acid and nitrogen-deficient soils. White spruce, which is less tolerant of such conditions (more nutrient-demanding) and grows more productively with increasing nutrient availability, is found more frequently than black spruce regenerating in the understory of aspen stands (Table 2). Therefore, we attribute the differences in the patterns and processes in the forest floors to the influence of tree species and the understory vegetation that has developed in different microenvironments under spruce and aspen.

Conclusions

The major differences in nitrogen-related soil properties between black spruce and trembling aspen stands on upland sites in the montane boreal forest were detected in the forest floors. These differences were reflected in the floristic composition of understory vegetation and the types of humus forms. The forest floors in spruce stands were strongly acid, nitrogen- and base-poor, and exemplified by Mor humus forms, those in aspen stands were weakly acid, nitrogen- and base-rich, and exemplified by Moder humus forms. While ericaceous shrub and mosses were dominant in spruce stands, deciduous shrubs, herbs, and graminoids dominated the understory of aspen stands. We concluded that each study species has a strong effect on the forest floor but not on the underlying mineral soil.

Reference

G. J. Kayahara G.J., K. Klinka, P.V. Krestov, and H. Qian. 2000. Comparison of vegetation and soil nutrient properties between black spruce and trembling aspen ecosystems in the Boreal Black and White Spruce Zone of British Columbia Submitted for publication to Canadian Journal of Forest Research 00/11.

Scientia Silvica
is published by the Forest Sciences Department,
The University of British Columbia, ISSN 1209-952X

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