STAND AND SITE CONDITIONS ASSOCIATED WITH ABUNDANCE OF BLACK SPRUCE ADVANCE GROWTH IN THE NORTHERN CLAY SECTION OF ONTARIO

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ABSTRACT

Black spruce (*Picea mariana* [Mill.] B.S.P.) advance growth is most abundant in wet, poor site types--the CHAMAEDAPHNE, LEDUM, FEATHERMOSS-SPHAGNUM, ALNUS-HERB POOR, FEATHERMOSS-COARSE SOIL, FEATHERMOSS-FINE SOIL, and ALNUS-HERB RICH operational groups of the Forest Ecosystem Classification. Within operational groups and vegetation types there is considerable variation in advance growth stocking. Stand basal area explains a considerable portion of the variation in advance growth stocking, and, when combined with other variables in regression models, can be used to describe forest types in which black spruce advance growth is abundant. The annual height growth of advance growth under a canopy is slow, averaging 2.3 cm. Harvesting methods that help to preserve advance growth, and levels of advance growth required in the forest before cutting, are discussed.

RÉSUMÉ

La régénération préexistante de l'épinette noire (*Picea mariana* [Mill.] B.S.P.) s'observe surtout en milieux pauvres et humides où les conditions conviennent aux groupes d'exploitation suivants de la classification des écosystèmes forestieres: CHAMAEDAPHNE, LEDUM, MOUSSES HYPNACÉES-SPHAIGNES, AULNE ASSOCIÉ À UNE CARENCE EN HERBACÉES, MOUSSES HYPNACÉES-SOL GROSSIER, MOUSSES HYPNACÉES-SOL FIN, AULNE ASSOCIÉ À UNE ABONDANCE D'HERBACÉES. Le stock actuel de cette régénération varie considérablement à l'intérieur d'une groupe d'exploitation et d'un type de végétation. La surface terrière du peuplement permet d'expliquer une grande partie de la variation; combinée à d'autres variables, dans les modèles de régression, elle peut servir à décrire les types forestiers où la régénération préexistante de l'épinette noire est abondante. Sous le couvert forestier, la croissance annuelle en hauteur de cette régénération est lente, 2.3 cm en moyenne. L'auteur traite des méthodes de récolte qui aident à protéger la régénération préexistante et de l'intensité que celle-ci doit atteindre avant l'exécution de la coupe.

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INTRODUCTION

Black spruce (*Picea mariana* [Mill.] B.S.P.) advance growth is present in varying quantities throughout forests of the Northern Clay Section (B.4) of the Boreal Forest Region (Rowe 1972) in Ontario. In forests where it is abundant, advance growth has traditionally offered a ready source of regeneration following harvest. Even today, advance growth often forms part of the new crop on cutover black spruce lands, but is not depended upon as a source of regeneration, for two reasons: 1) it is often damaged or destroyed by harvesting; 2) stand conditions and site types where black spruce advance growth may be found in abundance have not been well defined.

PAST WORK

Foresters have a general knowledge of where black spruce advance growth is abundant. Virgo (1979) considered overmature black spruce stands that are in the process of breaking up as likely to contain considerable advance growth. Advance growth is generally more abundant in swamp forests than in drier upland forests (Bellefeuille 1935). In swamp forests, stand density appears to have a substantial influence on abundance of black spruce advance growth. In Minnesota, for example, stocking to black spruce advance growth decreased with increasing stand basal area (Schoenike and Schneider 1954), and in Saskatchewan, Benson (1973) found that stocking to black spruce advance growth decreased with increasing stand density and stand basal area. One reason for this was suggested by Stanek (1961). In dense, well stocked stands, black spruce undergoes rapid branch clearing, reducing the opportunity for layering. Dense brush can also reduce the opportunity for layering (Schoenike and Schneider 1954, Stanek 1961).

Schoenike and Schneider (1954) found that stand age did not affect the quantity of advance growth on Minnesota peatlands, but on uplands or shallow-peated sites in Quebec, black spruce advance growth appeared to be more abundant in old fire-origin stands than in younger ones (Hatcher 1963).

Low-density black spruce stands with high *Sphagnum* spp. moss cover (conditions conducive to layering) are most common on low-quality peatland sites. Thus, layering is common on many peatland sites (Stanek 1975). In Minnesota, Schoenike and Schneider (1954) found that advance growth was more common on poor sites than on good sites. Vincent and Haavisto (1967) reported that black spruce advance growth was more abundant on deep peats than on shallow peats.

The purpose of the investigation described in this report was to examine more closely the relationships between the abundance of black spruce advance growth and site and stand conditions, and to quantify these relationships. Knowledge of such relationships would aid forest managers in identifying which forest stands might contain sufficient advance growth to form the next crop following logging.

METHODS

Two separate data bases were used in the investigation: (i) Forest Ecosystem Classification (FEC) data, and (ii) Advance Growth Survey (AGS) data.

FEC Data

During the summer of 1980, 250 forest stands in the Northern Clay Section of Ontario were sampled as part of the data base for the Forest Ecosystem Classification (Jeglum et al. 1982, Jones et al. 1982, 1983). A portion of the information collected included 'regeneration' data; the stocking of 20 2-m x 2-m quadrats to regeneration of all tree species was recorded in each stand, for a total of 5000 quadrats. Other information recorded included stand basal area (BA) distinguished by species (recorded in DBH classes 2.5-9.9 cm, 10-14.9 cm, 15.0-19.9 cm, and individual 1-cm classes for diameters 20 cm or above); percentage crown cover of trees taller than 10 m by ocular estimate; percentage cover of feather mosses *(Pleurozium schreberi* (Brid.) Mitt., *Hylocomium splendens* (Hedw.) B.S.G., *Ptilium crista-castrensis* (Hedw.) De Not., and *Dicranum* spp.), *Sphagnum* spp. mosses, *Alnus rugosa* (Du Roi) Spreng., *Chamaedaphne calyculata* (L.) Moench, *Ledum groenlandicum* Oeder, shrubs other than the latter three, herbs, coniferous litter, deciduous litter, bare organic surface, grasses and sedges; peat depth and Of depth (or on mineral soils, organic matter depth and depth of the L + F layers); and age and height of dominant trees.

Two subsets of FEC data were used in the analysis. One subset included stands only from operational groups in which most stands were composed of at least 50% black spruce by BA (operational groups 4, 5, 8, 9, 11, 12, 13, 14). The second was a subset of these from operational groups that represent true peatlands (peat depth at least 40 cm--operational groups 11, 12, 13, 14) and transitional peatlands (peat depth less than 40 cm--operational groups 8 and 9).

AGS Data

In the summer of 1982, a separate survey was conducted to examine more closely black spruce advance growth and associated forest conditions. This survey was carried out in 30 peatland (peat depth at least 40 cm) or transitional peatland (peat depth 20-39 cm) stands in the Kapuskasing and Cochrane areas. These stands were all undisturbed and mature or overmature. The numbers of stands in each FEC operational group were as follows: OG8-1; OG9-4; OG11-6; OG12-7; OG13-7; and OG14-5.

In each stand 100 2-m x 2-m quadrats arranged in a 20-m x 20-m square plot were sampled, for a total of 3000 quadrats. In each quadrat the following information was collected: number of advance growth stems, distinguished by tree species and size class (0 to 9.9 cm tall, 10 to 49.9 cm tall, 50 to 199.9 cm tall, 200 cm tall to 2.5 cm DBH); proportion of the quadrat covered by *Sphagnum* spp. mosses, feather mosses *(P. schreberi, H. splendens, P. crista-castrensis,* and *Dicranum* spp.), coniferous litter, deciduous litter, bare organic surface, herbs, and grasses and sedges; the proportion of the quadrat covered by the visual projection to a horizontal plane of the foliage of *A. rugosa, L. groenlandicum,* and *C. calyculata.*

In each stand the following information was collected: BA distinguished by species for all trees above 2.5 cm DBH, taken with a wedge prism at five locations within each plot; peat depth, Of depth (Jones et al. 1983) or L + F thickness if a mineral soil taken at five locations within the plot; total height and breast-high age of five dominant trees within the plot; crown closure by moosehorn estimate at five locations within the plot; FEC vegetation type; and the height, condition, and previous 4 years' height growth of a sample of advance growth stems.

For the latter sample, two stems of advance growth were selected from each 20-cm height class up to 2 m. The current year's growth was not measured, because growth was not yet complete at the time of sampling.

Trees were classified as layerings if the bottom portion of the stem curved from the horizontal to the vertical. Occasional verification was made by identifying the layer connection. Vincent (1965) pointed out, however, that the stem form of seedlings in fast-growing *Sphagnum* is similar to the stem form of layerings. Conversely, fast-growing layerings may be mistaken for seedlings (Stanek 1968). The only certain methods of classifying the origins of advance growth are to identify the layer connection or to examine the root tissue microscopically (Stanek 1961).

Analysis

In the analysis, stocking refers to the proportion of 2-m x 2-m quadrats containing at least one advance growth stem; density is the number of advance growth stems per ha.

From the FEC data, average stocking to black spruce advance growth was calculated for each FEC vegetation type and operational group. For each vegetation type and operational group the range and standard deviation of stocking values was determined.

Simple correlation coefficients were determined between abundance of advance growth (stocking and density) and stand and site conditions for data from both the FEC and the AGS.

Multiple regression was used to relate black spruce advance growth abundance, calculated as stocking and density, to stand and site attributes.

A total of 409 advance growth stems was examined for height growth and condition. (This represented an average of fewer than 20 stems per plot since not all plots contained a complete range of advance growth size classes.) Average height increment was determined for each stem and tested for correlation with stem height, stand BA, and advance growth stocking. Average annual height increment was also determined for each stand, and one-way analysis of variance was used to determine if FEC vegetation type or operational group contributed to height increment variation. Proportions of layerings and seedlings were determined, as were the proportions of stems with single leaders, and stems displaying upright orientation. These proportions were also tested for correlation with stand BA and advance growth stocking.

RESULTS AND DISCUSSION

Abundance of Black Spruce Advance Growth in FEC Types

Stocking to black spruce advance growth for each FEC vegetation type is shown in Figure 1. FEC vegetation types and operational groups are described in Jones et al. (1983).

The highest stocking (94%) occurred in vegetation type 12 (within the CHAMAEDAPHNE operational group). In Figure 1 soil moisture regime is wettest at the bottom and driest at the top; sites on the left are generally floristically and nutritionally poorer than sites on the right (Jones et al. 1983). As conditions became either drier or richer, advance growth

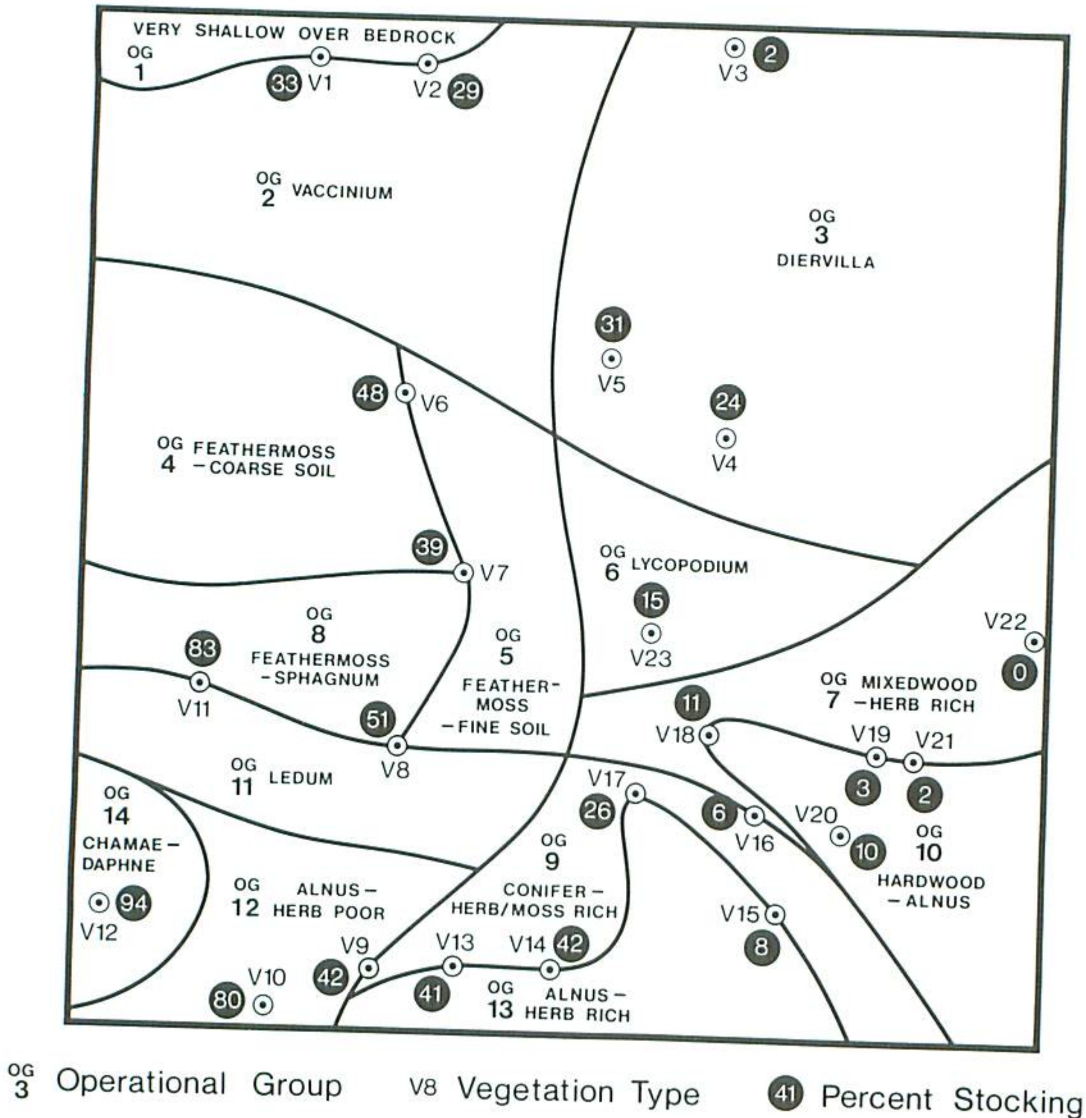

Figure 1. Mean percentage stocking to black spruce advance growth of FEC vegetation types. See Jones et al. (1983) for complete description of vegetation types.

stocking declined. Stocking values were high in vegetation type 11 (83%) and vegetation type 10 (80%), but all other vegetation types had stocking values of 51% or less. Of these remaining types, vegetation types 9, 13, 14, 8, 7, and 6 (with 42, 41, 42, 51, 39, and 48% stocking, respectively) displayed moderate stocking levels.

The FEC is also divided into operational groups (OGs) and mean stocking of black spruce advance growth was calculated for each group (Fig. 2). Highest stocking occurred in the CHAMAEDAPHNE group (94%), followed by the LEDUM group (69%), the FEATHERMOSS-SPHAGNUM group (60%), the ALNUS-HERB POOR group (50%), the FEATHERMOSS-COARSE SOIL group (48%), the FEATHERMOSS-FINE SOIL group (44%), and the ALNUS-HERB RICH group (43%). Stocking in all other groups averaged 31% or less.

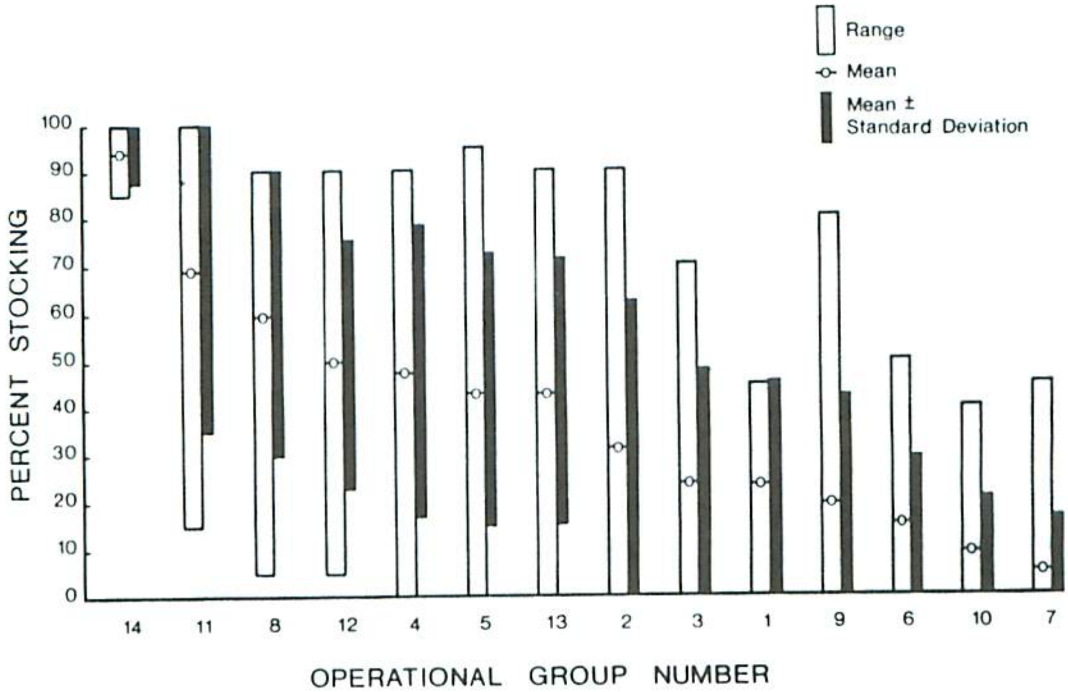

Figure 2. Mean, standard deviation, and range of percentage stocking to black spruce advance growth of FEC operational groups. See Jones et al. (1983) for complete description of operational groups. (OG 1 = VERY SHALLOW SOIL OVER BEDROCK; OG 2 = VACCINIUM; OG 3 = DIERVILLA; OG 4 = FEATHERMOSS-COARSE SOIL; OG 5 = FEATHERMOSS-FINE SOIL; OG 6 = LYCOPODIUM; OG 7 = MIXEDWOOD-HERB RICH; OG 8 = FEATHERMOSS-SPHAGNUM; OG 9 = CONIFER-HERB/MOSS RICH; OG 10 = HARDWOOD-ALNUS; OG 11 = LEDUM; OG 12 = ALNUS-HERB POOR; OG 13 = ALNUS-HERB RICH; OG 14 = CHAMAEDAPHNE).

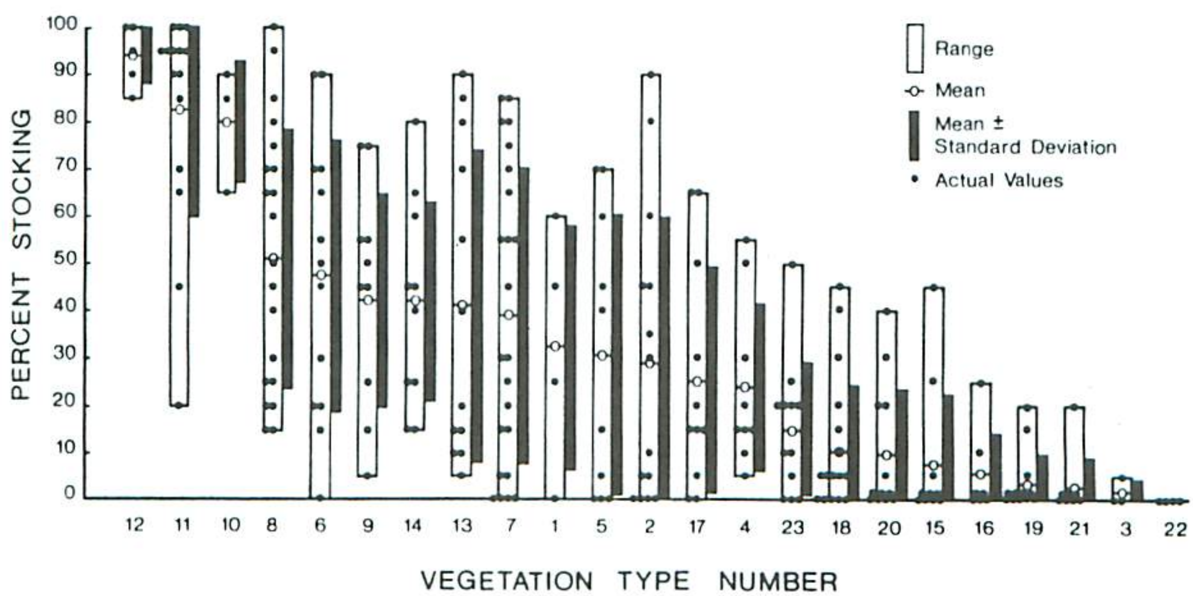

Figure 3. Mean, standard deviation, and range of percent stocking to black spruce advance growth of FEC vegetation types.

The stocking of black spruce in the FEC vegetation types and operational groups provides a good overview of where advance growth may be expected, but there is great variability of stocking values within individual operational groups and vegetation types (Fig. 2 and 3). The only vegetation types in which all stocking values were above 60% were types 12 and 10. In all other types either dispersion about the mean was great or mean stocking values were very low. It is evident that vegetation type by itself explains only a part of the variation in black spruce advance growth stocking.

Correlations

Significant correlations were obtained between black spruce stocking and density and a number of variables (Tables 1 and 2). Exact information on the density of advance growth was not available in the FEC data set; hence, FEC correlations are for stocking only.

The variable most strongly correlated with abundance of advance growth was stand BA. As stand BA increased, stocking and density of black spruce advance growth decreased. There are a number of possible reasons for this

Table 1. Stand and site conditions significantly correlated with stocking and density of black spruce advance growth - Advance Growth Survey.

	r	
Stand and site condition	Stocking	Density
Stand basal area	-.781**	-.776**
Maximum age	.568**	.561**
Leatherleaf cover	.563**	.495**
Herbaceous cover	-.559**	-.492**
Average age of dominants	.536**	.486**
Labrador tea cover	.533**	.558**
Crown cover	-.468**	-.486**
Age range of dominants	.463**	.490**
Average height of dominants	-.431*	-.473**
Alder cover	-.425*	-.467**
Of thickness[a]	.423*	.380*
Stocking to balsam fir advance growth	-.404*	-.432*
Coniferous litter cover	-.401*	-.340
Sphagnum moss cover	.370*	.371*
Proportion of black spruce in stand basal area	.367*	.267
Maximum tree height	-.359	-.387*
Peat depth[b]	.319	.374*

*significant at p = .05
**significant at p = .01
[a] L + F thickness on mineral soils
[b] Organic matter depth on mineral soils

Table 2. Stand and site conditions significantly correlated with stocking of black spruce advance growth - Forest Ecosystem Classification data (two subsets).

	r	
Stand and site condition	Black spruce-dominated operational groups (138 stands)	Peatland or transitional operational groups (94 stands)
Crown cover	-.451**	-.540**
Stand basal area	-.448**	-.575**
Average height of dominants	-.421**	-.535**
Labrador tea cover	.418**	.473**
Maximum tree height	-.411**	-.524**
Of thickness[a]	.379**	.481**
Sphagnum moss cover	.359**	.472**
Leatherleaf cover	.353**	.415**
Herbaceous cover	-.319**	-.441**
Stocking to balsam fir advance growth	-.321**	-.371**
Peat depth[b]	.297**	.384**
Proportion of black spruce in stand basal area	.244**	.402**
Deciduous litter cover	.211*	.262*
Bare organic surface cover	-.188*	-.171
Coniferous litter cover	-.211*	-.250*

*significant at p = .05
**significant at p = .01
[a] L + F thickness on mineral soils
[b] Organic matter depth on mineral soils

relationship. As stand BA increases, lower branches are less likely to persist, reducing the opportunity for layering. *Sphagnum* cover also showed a negative correlation with BA in both the AGS and the FEC data. Thus, as BA increases, the amount of medium conducive to layering or germination decreases. Finally, as stand BA increases, the amount of light available for the growth and survival of layerings or seedlings decreases.

In both data sets of the FEC, crown cover of trees taller than 10 m was significantly negatively correlated with stocking of advance growth. Crown cover and stand BA yielded similar correlation coefficients, and were well correlated between themselves, an indication that these two variables are different expressions of the same influence. Despite an inadequate sample of crown cover in the AGS (five 'moosehorn' estimates per plot), a significant negative correlation existed between stocking and density of black spruce advance growth on the one hand and crown cover on the other.

A number of other variables were also associated with the density and stocking of advance growth. In all cases, the percentage cover of

C. calyculata and *L. groenlandicum* were positively correlated with abundance of advance growth. These plants are common in the CHAMAEDAPHNE and LEDUM operational groups of the FEC, where advance growth is most abundant. Abundance of advance growth decreased with the percentage cover of herbaceous species, corresponding to the decrease in stocking of advance growth from the poor side to the rich side in the FEC (Fig. 1).

Abundance of black spruce advance growth was negatively correlated with the average height and maximum height of dominants in each of the data sets. In the range of stand ages observed in the FEC survey and in the AGS, stand height gives some indication of site quality. As is evident from Figure 1, the stocking of black spruce advance growth decreases on better sites, and this may account in part for why advance growth is less abundant in taller stands.

The thickness of the fibric layer (Of) in organic soils and the thickness of L + F layers on mineral soils was positively correlated with abundance of advance growth, as was percentage cover of *Sphagnum* spp. *Sphagnum* mosses are a good medium for germination and layering, and thicker Of layers are associated with increasing amounts of *Sphagnum*. In the AGS, density of black spruce advance growth was positively correlated with peat depth or organic matter depth, as was stocking in both FEC data sets.

In all data sets the abundance of black spruce advance growth was negatively correlated with stocking of balsam fir *(Abies balsamea* [L.] Mill.) advance growth. This is an indication of the differing ecological requirements of the two species, balsam fir being able to tolerate more shading than black spruce, but requiring a greater nutrient supply.

The proportion of black spruce in the stand BA was positively correlated with abundance of advance growth, a possible indication that the potential for layering or seeding decreases as the black spruce component of the stand decreases.

In all but the peatland FEC data, the amount of advance growth was negatively correlated with the cover of coniferous litter. Increasing amounts of coniferous litter may be an indication of increasing BA of conifers in the stand. In the FEC data for black spruce-dominated operational groups, stocking of advance growth was negatively correlated with bare organic surface cover and positively correlated with deciduous litter cover. It seems reasonable that as the cover of bare organic surface increases, the suitability for layering may decrease. Also, increasing cover of bare organic surface may be a reflection of greater basal area and greater shading. Deciduous litter from *L. groenlandicum* and *C. calyculata* might explain the positive correlation between deciduous litter and stocking, making it another expression of the correlation between the cover of these two species and stocking.

Several variables were correlated with the abundance of advance growth in the AGS but not in the FEC survey. Stocking and density of advance growth increased with the average age and maximum age of dominants, and also with the range in age of the dominants.

Stocking and density of black spruce were negatively correlated with alder *(Alnus* spp.) cover in the AGS data, but not in the FEC data. This relationship reflects the decreasing abundance of advance growth in the relatively richer *Alnus* types. Alder might also have a direct effect in lessening suitability for black spruce growth through shading. Shading might also encourage more rapid self-pruning of lower branches and thus reduce the opportunity for layering.

There were no contradictions between correlations obtained in the Advance Growth Survey data and in the FEC data, although correlations that were significant between certain variables in some data sets were not significant in other data sets. Over all, the correspondence between results from the two sources of information helps to confirm the relationships that were found.

Multiple Regression

Although the FEC vegetation types and operational groups provide a good overview of where black spruce advance growth can be expected, more precision is needed so that forest managers can decide whether or not to depend on advance growth for the regeneration of a particular site. Multiple regression equations developed from the AGS provide additional information for this decision.

Stocking of black spruce advance growth was used as the dependent variable to develop a model, by stepwise multiple regression, of the measured variables and some of their interactions.

The following model was obtained:

[1] $$S = -104.09 - .1481(BA^2) - .03325(A)x(BA) + 143.89(P) + 5.7504(BA)$$

ADJUSTED R^2 = 82.4; Sy.x = 11.56

S = % stocking to black spruce advance growth

BA = stand BA (m^2/ha)

A = % alder cover

P = proportion of stand BA consisting of black spruce

Since alder cover might be difficult to measure in some instances (for example from aerial photographs, or in the leafless condition), a model that omits this variable was also developed:

[2] $$S = -128.95 - .1254(BA^2) + 188.05(P) + 4.099(BA)$$

ADJUSTED R^2 = 72.2; Sy.x = 14.54

When density of black spruce advance growth was used as the dependent variable, the following equation was obtained, again by means of stepwise multiple regression:

[3] $$D = 32797 - 18.785(BA^2) - 406(A) + 261(L)$$

ADJUSTED R^2 = 75.9; Sy.x = 5754

D = density of black spruce advance growth (number/ha)

BA = stand BA (m^2/ha)

A = % alder cover

L = % *Ledum* cover

It is important to note that values for BA ranged from 14 m^2/ha to 39 m^2/ha, for alder from 0 to 35%, and for proportion of black spruce from .76 to 1.00. Prediction of stocking with these equations, using values outside these ranges, may yield anomalous results. Also, some combinations of independent variable values, such as high BA, high alder cover, and low black spruce proportion, were not sampled. The use of such combinations may also yield anomalous results.

FEC data from the peatland and transitional operational groups were fitted to the same independent variables that provided the best fit in Equation 1, yielding the following model (note that not all terms were significant):

[4] $S = 99.95 + .02039(BA^2) - .002080 (BA)x(A) + 21.84(P) - 2.738 (BA)$

ADJUSTED $R^2 = 37.5$; Sy.x = 26.95

S = % stocking to black spruce advance growth

BA = stand BA (m^2/ha)

A = % alder cover

P = proportion of stand BA consisting of black spruce

A better description of the data in the peatland and transitional operational groups of the FEC was provided by stepwise multiple regression:

[5] $S = 130.34 - 1.00(BA) - 3.41(H)$

ADJUSTED $R^2 = 43.6$; Sy.x = 25.59

S = % stocking to black spruce advance growth

BA = stand BA (m^2/ha)

H = average height of dominants in stand (m)

One possible reason that less variation was explained in the FEC data is that stocking was estimated from 20 quadrats in contrast with 100 in the AGS. With a mean stocking of 50%, 20 quadrats gives a 95% confidence interval of plus or minus 23%, while 100 quadrats gives a 95% confidence interval of plus or minus 10% (Freese 1962). Another possibility is that BA was estimated by a less exact technique in the FEC survey.

Equation 1, based on AGS data, and Equation 4, based on FEC peatland operational group data, both yield a relationship in which advance growth stocking declines with stand BA (Fig. 4 and 5). There are, however, differences between the equations. As an extreme example, with a stand BA of 25 m^2/ha and 0% alder cover in a peatland or transitional pure black spruce stand, Equation 1 yields a stocking value of 91%, while Equation 4 yields 66%, a difference of 25%. Most combinations of stand characteristics result in smaller differences between estimates of stocking provided by the two equations. When the most appropriate estimate is being chosen, it should be recalled that Equation 1 is based on a better fit of data, and that not all terms of Equation 4 are significant.

Growth and Condition of Advance Growth

The height growth of advance growth stems under a forest canopy is slow; the annual height increment of all stems averaged 2.3 cm (st. dev. = 1.29). The greatest individual annual increment observed was 16 cm. The greatest average annual increment of any stem over a 4-year period was 9.5 cm.

The average annual height increment was positively correlated with the total height of the stem (r = .34), negatively correlated with stand BA (r = -.26), and positively correlated with advance growth stocking (r = .20). The negative correlation with stand BA might indicate that height growth increased as more light became available. Although these correlations are statistically significant (p = .05), they account for only a small proportion of the variation in height increment of advance growth. Analyses of variance of the mean annual height increment of advance growth in each stand showed that neither vegetation type nor operational group contributed significantly to the variation in height increment.

Height increment values observed in this study were much lower than the prelogging mean periodic annual height increments of black spruce residuals observed by Johnstone (1978) in Alberta. These larger trees averaged about 8 to 10 cm in annual height growth. Site types were not specified in this study.

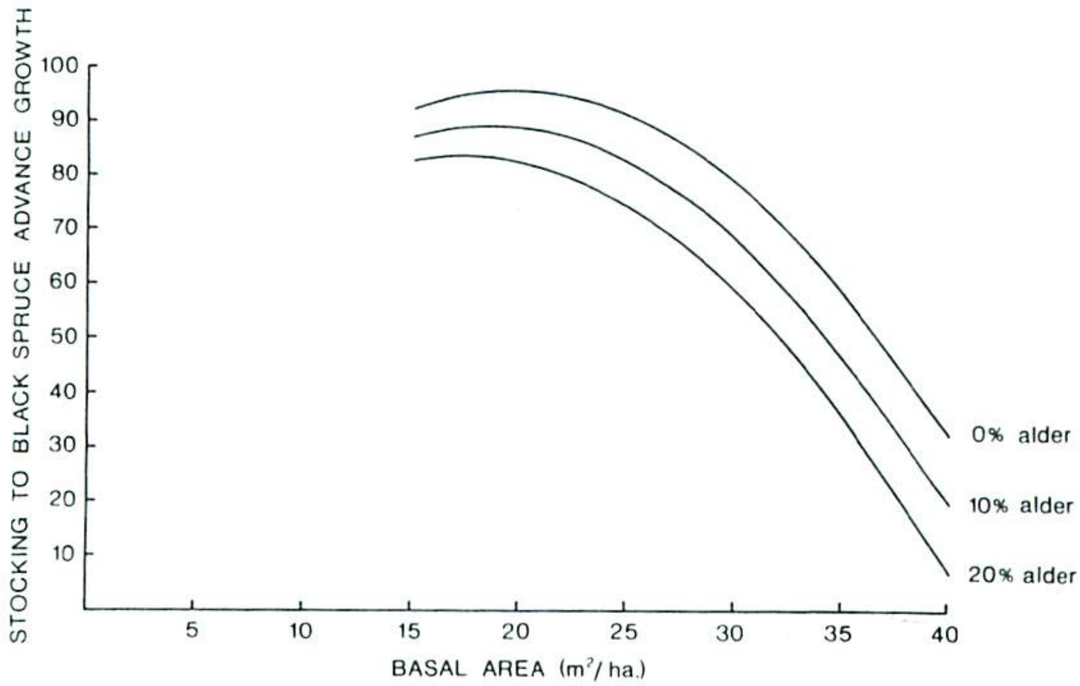

Figure 4. Stocking to black spruce advance growth in pure peatland black spruce stands related to stand BA and alder cover (from Equation 1).

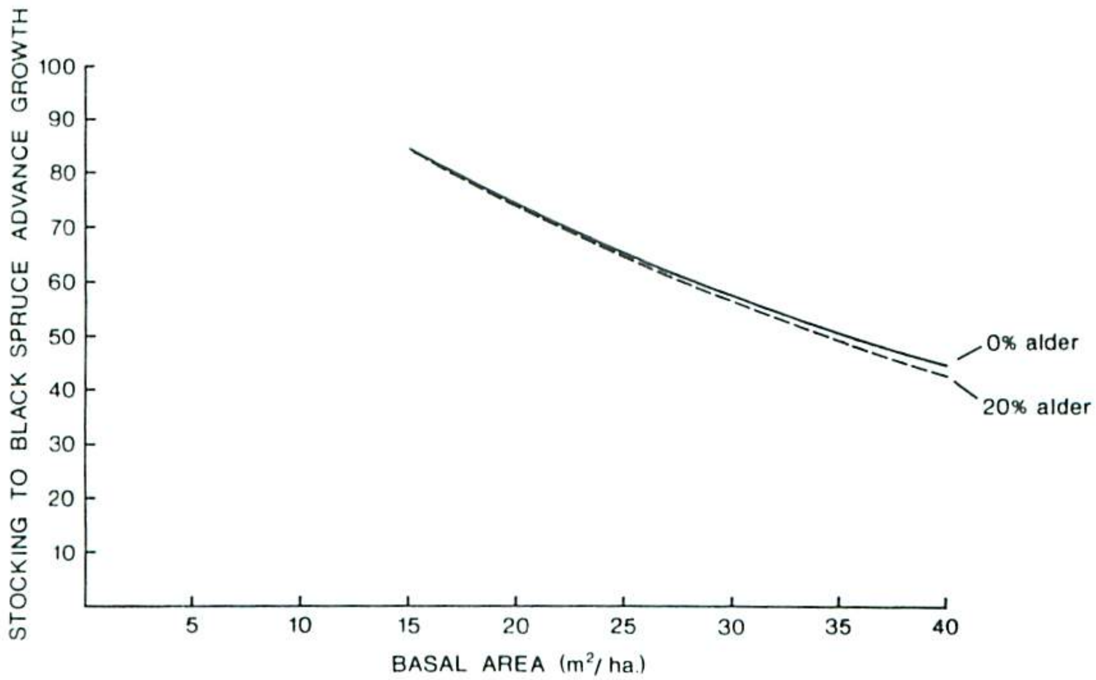

Figure 5. Stocking to black spruce advance growth in pure peatland black spruce stands related to stand BA and alder cover (from Equation 4).

An attempt was made to determine the proportions of layerings and seedlings in the subsample of advance growth stems in each stand of the AGS. Despite the potential for error in cursory classification of the origin of advance growth, the proportion of layerings observed in this study, 81%, is likely an adequate reflection of the true proportion.

To obtain an indication of quality, stems in the subsample of advance growth were examined to determine whether or not they possessed a clearly identifiable single leader, and whether or not the stem was oriented in an upright position. Over all, 86% of the stems had a single leader, and the proportion of stems with a single leader was higher in stands with high stocking of advance growth ($r = .70$), and higher in stands with lower basal area ($r = -.51$).

Fifty-five percent of the stems displayed an upright orientation. No significant correlations were obtained between proportion with upright orientation and BA or stocking of advance growth.

Management Implications

In stands where it is abundant, advance growth offers the possibility of a second tree crop being established immediately after the first crop has been harvested. Even if stands contain abundant advance growth, however, satisfactory regeneration following logging is not assured. It is essential that attention be paid during the logging operation to preserving the advance growth.

There has been little study of proportions of black spruce advance growth surviving different methods of harvesting, but some general recommendations on logging practices that will help to preserve advance growth can be made. Winter should be the preferred season of harvest, because snow helps to protect the advance growth from logging equipment. If the snow is deep, operators of logging machinery are more likely to reuse trails that have already been established in the snow. The result is that logging machinery travels over only a small portion of the cutover, and outside of this portion advance growth is largely undisturbed. In summer operations, operators should also be encouraged to reuse trails as often as possible. On peatland sites it might be necessary to equip machinery with wider tires or pads so that it does not become stuck or create deep ruts when a trail is being used a number of times.

Careful mechanical felling is probably preferable to felling by chainsaw, because a chainsaw operator generally must remove small growth for safety purposes. In forwarding, it is preferable to have the trees on a bunk off the ground rather than skidded on the ground so that advance growth will not be 'raked' by the load. It must be noted that mechanical felling and off-ground forwarding will be advantageous only if the machinery used can minimize travel over the cutover. Finally, full-tree logging should be preferred to tree-length or shortwood operations so that slash does not smother young growth.

Unfortunately, it is difficult to make recommendations on what levels of advance growth are required in the forest before cutting to ensure adequate regeneration following cutting. Survival of advance growth depends on the nature of the harvesting operation and season of harvest, and information is lacking for most methods of harvesting.

Some of the most complete information on reductions in density and stocking of spruce advance growth following logging is contained in a study by Frisque et al. (1978). A number of logging methods were sampled in this study, but the main method was chainsaw felling and rubber-tired skidder forwarding in the summer. This logging method would be expected to be relatively destructive of advance growth, and thus the reductions observed might have been more severe than could have been attained with other methods. In general, 75% of the precut density of spruce advance growth was destroyed by logging. Stocking of advance growth, however, decreased by only 21%.

If the 21% reduction value is used, then to obtain postcut stocking of 60% or better, precut stocking of about 80% or higher is needed. This precut level can be found reliably only in the CHAMAEDAPHNE operational group, which is generally unmerchantable. A precut stocking level of 80% is often, though not always, found in the LEDUM operational group, and somewhat less often in the FEATHERMOSS-SPHAGNUM, ALNUS-HERB POOR, FEATHERMOSS-COARSE SOIL, FEATHERMOSS-FINE SOIL, ALNUS-HERB RICH, and VACCINIUM operational groups.

Because black spruce advance growth can vary considerably within an FEC operational group or vegetation type, Equations 1 to 5 can be used to estimate more closely the advance growth stocking of a stand.

It must be emphasized that the 80% initial stocking value used in the above discussion is based on one study only (Frisque et al. 1978), which in turn was based mainly on one method of logging. Further research is needed to determine how applicable this value is.

A final concern is whether or not advance growth will develop suitably following logging. This concern is raised by its slow growth under a canopy (e.g., 2.3 cm per year in this study). Form is another part of this concern, since much advance growth is of layering origin.

Stanek (1968) found that in mature, natural black spruce stands, trees originating as layerings displayed a height growth pattern similar to that of trees originating as seedlings. Layerings had somewhat poorer form than seedlings, but in second-growth stands the form of most layerings was good. Vincent (1965) found that on 6- to 12-year-old cutovers the height growth of layerings and seedlings was similar. Johnstone (1978), studying the growth of black and white spruce *(Picea glauca* [Moench] Voss) layerings in Alberta following harvesting, concluded that advance growth would contribute to the future harvest.

Although past work is limited, it does indicate that advance growth might develop suitably following harvest. Further study of advance growth development is necessary.

CONCLUSIONS

This study helps to define site and stand conditions better where black spruce advance growth is abundant. Black spruce advance growth is most abundant on the wettest, most nutritionally and floristically poor site types, and becomes less abundant as sites become drier or richer.

Advance growth is most abundant in the CHAMAEDAPHNE operational group, is relatively abundant in the LEDUM operational group, and somewhat less abundant in the FEATHERMOSS-SPHAGNUM, ALNUS-HERB POOR, FEATHERMOSS-COARSE SOIL, FEATHERMOSS-FINE SOIL, and ALNUS-HERB RICH operational groups.

Because the abundance of black spruce advance growth is also related to stand attributes such as stand BA, stand composition, alder cover, *Ledum* cover, and stand height, regression models can be used to estimate advance growth levels in forest stands.

Height growth of advance growth under a forest canopy is slow, averaging 2.3 cm per year.

Harvesting in the winter, minimizing machinery travel over cutovers, careful mechanical felling, off-ground forwarding, and full-tree harvesting are recommended to reduce damage to advance growth during logging operations.

In the absence of better information, an 80% or greater precut stocking to black spruce advance growth is recommended to ensure satisfactory regeneration following harvesting.

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