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BLACK SPRUCE REPRODUCTION ON DISTURBED SOIL CONDITIONS

by
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INTRODUCTION

It is generally admitted that the pulpwood forests of the boreal region in Quebec reproduce satisfactorily after clear cutting.[2] In a number of associations (*Abieto-Piceetum* and *Hypno-Piceetum*), however, black spruce tends to be supplanted by balsam fir. In the *Kalmio-Piceetum* association, black spruce seedlings are poorly represented. Layering is abundant but its desirability is sometimes questionable because of evident slow growth and poor form.

During a visit to the Central Laurentian Section (B-3) north of the Quebec-Cochrane railway line and while travelling along a truck road, spruce was observed to be reproducing abundantly on the roadsides. This opening across the forest could be compared to strip clear cutting with soil scarification. The bulldozing of such a strip in 1947 resulted in breaking of the thick mantle and in some places covering it or mixing it with a more or less thick layer of mineral soil. In some instances the sand remained bare, in others it was colonized with mosses among which *Polytrichum commune* and *P. juniperinum* dominated. These two types of seedbed were then observed more closely as it seemed that spruce seedlings came in more frequently on moss-covered soil than on bare mineral soil.

EXPERIMENTAL PROCEDURE

A total of 2,855 milacre quadrats were taken irregularly between two points 25 miles apart. The quadrats were taken in series for short distances on both sides of the road. Presence or absence of spruce was noted in each of the quadrats but no count was made of the number of seedlings.

The following points were noted on the most promising specimen in each quadrat:

Age and height of the seedling.
Colour of the foliage.
Type and depth of rooting.
Presence of humus in mineral soil.

According to microrelief and texture plus depth of water table, the environment was defined as follows:

Seedbed:—moss-covered, mineral.
Soil moisture:—dry, fresh, moist, very moist.
Aspect:—warm (south and west exposures, and level terrain).
—cool (east and north exposures).
Textures:—sand, loamy sand, sandy loam.
Light intensity:—I (1- 30% in full sunlight)
II (31- 60% " " ")
III (61-100% " " ")

No actual measurement of these factors of the environment was made, only ocular observations.

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[1] Research Forester, Valcartier Forest Experiment Station, Valcartier, P.Q.

[2] Candy, R. H. 1951. Reproduction on cut-over and burned-over land in Canada. Canada, Dept. Resources and Development, Res. Note 92. 224 pp.

Analysis of the field notes showed that uniformity of sampling was not achieved owing to different interpretation by the various observers of certain site characteristics such as aspect and light, but in spite of these shortcomings, it is possible to present results of practical interest. In the analysis, chi-square tests were made to study the significance of difference in spruce stocking on the two seedbeds as affected by various environmental conditions. The tests were not performed when observations of these conditions were missing on the unstocked quadrats nor when comparisons were based on less than 100 quadrats.

THE AREA

The area investigated lies in Forest Section B-3 which is a flat sandy plateau on the height of land between the St. Maurice River and the rivers flowing north to James Bay.

The rocks are granite, gneisses, and schists of the Precambrian Shield, usually overlain with coarse-textured deposits. Lake shores, river banks and hills are sometimes of a finer texture and support mixed stands of white spruce, aspen, balsam fir and white birch of the *Abieto-Betuletum* association. Dry sandy soils where fire had destroyed the organic matter support jack pine of the *Cladonia-Pinetum* association. Black spruce appears in the understory. Poorly drained sandy soils are covered with black spruce of the *Kalmio-Piceetum* association. The stands surrounding the truck road belong mostly to the latter association.

OCCURRENCE OF SPRUCE ON THE TWO TYPES OF SEEDBED

The main fact revealed by the survey is the significantly greater percentage of quadrats stocked with spruce on the moss-covered than on the exposed mineral soil seedbed.

The oldest seedlings indicate that they were established in the year when the road was opened. Distance of seed trees from the road is about the same everywhere, that is, half a chain, and they are numerous since the forest has been left intact all along the road. Lack of reproduction cannot, therefore, be ascribed to seeding chance. Data at hand indicate that 874 and 1,981 quadrats were taken on bare mineral and moss-covered seedbeds respectively. Only 57 per cent of the mineral soil quadrats are stocked as compared with more than 90 per cent of the moss-covered quadrats. Analysis revealed that the proportion of stocked quadrats in the two main seedbeds was not due to chance; therefore, it was likely due to differences in the media. The chi-square value of 161 is too high a figure to be attributed to chance. Other analyses substantiated the statement, as will be shown presently.

SPRUCE ON SOILS OF VARIOUS MOISTURE CONDITIONS

From a consideration of texture, microrelief and water table, the environment was classified as dry, fresh, moist, and very moist. Spruce was found on these four conditions, but far more frequently on dry and fresh than on moist and very moist locations. Owing to the small number of quadrats in the latter case, the chi-square test was made for dry and fresh soils alone.

As shown in Table 1, per cent occurrence differs very little between *dry* and *fresh* soils on the same type of seedbed. It is evident that significance must not be attached to these differences. This does not apply if comparisons are established between similar moisture conditions on the two seedbeds. The chi-squares obtained indicate that the differences in stocking are not due to chance. The moss-covered soil is, therefore, more favourable to germination of spruce than bare mineral soil under all moisture conditions.

TABLE 1.—OCCURRENCE OF SPRUCE ACCORDING TO SEEDBED AND MOISTURE CONDITIONS

Moisture	Seedbed	
	Mineral	Moss-covered
	(Stocked quadrats %)*	
Dry	61	91
Fresh	60	91
Moist	34	89
Very Moist	50**	91

* Basis:—2,855 quadrats.
**Based on only 4 quadrats.

If moisture is of significance in the establishment of spruce, it must be inferred that soil moisture regime and moisture available in the seedbed are not necessarily the same thing.

ASPECT AND OCCURRENCE OF SPRUCE

Contributing to site differences is the exposure of the seedbed to direct or indirect sunlight with the relative soil temperature. Only one third of the quadrats have been observed for their aspect, that is, about one thousand, but they nevertheless reveal substantial differences of establishment.

TABLE 2.—OCCURRENCE OF SPRUCE ACCORDING TO TYPE OF SEEDBED AND ASPECT

Aspect	Seedbed	
	Mineral	Moss-covered
	(Stocked quadrats %)*	
Warm	35	94
Cool	47	94

* Basis:—938 quadrats.

In fact, Table 2 shows that there are fewer seedlings (some of course may have germinated and then died) on mineral than on moss-covered soils for both aspects. Survival percentages are 35 and 47 on the former, and 94 and 94 on the latter.

On moss-covered soil, warm and cool aspects are equally favourable for spruce, due probably to the protection afforded by the moss against evaporation from the surface soil. The nutritive level may also be responsible. As previously mentioned, the per cent stocking of spruce on moss-covered soil is significantly greater than that on mineral soil.

It has been stated that no significant differences were found in the stocking of spruce between dry and fresh soils, and this applies both to mineral and moss-covered seedbeds. Whether aspect is warm or cool on moss-covered soil seems to make no difference. Here again, the moss may be responsible. On bare sand, it seems, and it is logical so to think, that a cool aspect is more favourable than a warm one; and a fresh soil on a cool aspect will be more favourable than a dry soil, since moisture is retained better. This tends to be substantiated in Table 3.

TABLE 3.—OCCURRENCE OF SPRUCE ON TWO SEEDBEDS ACCORDING TO ASPECT AND SOIL MOISTURE CONDITIONS

Soil Moisture	Aspect			
	Warm		Cool	
	Seedbed		Seedbed	
	Mineral	Moss	Mineral	Moss
	(Stocked quadrats %)		(Stocked quadrats %)	
Dry	26	86	33	100
Fresh	46	94	54	98
Moist	—	—	—	60
Very moist	100*	100*	27	73

Basis:—938 quadrats.
* Only one quadrat observed.
— No quadrat of this condition.

LIGHT INTENSITY AND OCCURRENCE OF SPRUCE

From a consideration of the stocking level of seedlings in relation to light intensity, several interesting facts are revealed. Although the number of unstocked quadrats under the various light intensities was not always available, the distribution of spruce indicated a rather constant ratio between moss-covered and mineral soil under the three light conditions (Table 4). For a given seedbed a similar ratio holds, showing that most of the seedlings observed were growing under light intensity III, that is, 61 to 100 per cent full sunlight. Had sampling been less intensive, less weight would have been given to the ratios obtained. Partial sampling indicates that per cent stocking is higher in full sunlight.

TABLE 4.—PERCENTAGE DISTRIBUTION OF STOCKED QUADRATS ACCORDING TO LIGHT AND SEEDBED CONDITIONS

Seedbed	Light Intensity			
	I	II	III	All
Mineral	10	8	82	100
Moss	10	12	78	100

Basis:—2,141 quadrats.

There is no doubt, and this has been noticed by a number of observers, that even though seedlings benefit from reduced light at the time of germination, intensity must be high for rapid growth and survival. Even shade-bearers are subject to this law. Table 4 shows that 10 per cent of the stocked quadrats were found in reduced light. The majority of the seedlings were comparatively young and therefore small, and, if light remains the same, only a fraction of them will become dominant trees because of increased competition from their neighbours. To a lesser extent, seedlings in light intensity II will undergo the same difficulties.

HEALTH OF THE SEEDLINGS

The summer of 1954 was very wet; warm and sunny days were few. The previous season, 1953, had been very dry and warm. Before the field work was begun, a number of seedlings were observed to be chlorotic; it was believed that the 1953 season might in part be responsible. If soil is more or less favourable for the growth of the young seedlings, the first signs of abnormal behaviour, in the event of a dry season, are usually found on the foliage. Seedlings were therefore classed as green or yellow.[3] Table 5 shows the distribution of the seedlings on mineral and moss-covered soils according to colour. Chi-Square tests indicate that the proportion of green seedlings on moss-covered soil (97 per cent) is significantly higher than on mineral soil (86 per cent).

Distribution of green and yellow seedlings among the various classes of light and soil moisture is shown in Table 6. As expected, the highest percentage of chlorotic seedlings on mineral and moss-covered seedbed was found on dry soil under intense light. The two moisture regimes (dry, fresh) on the latter may differ much less than on bare mineral soil. Chlorosis is also slightly more pronounced on mineral than on moss-covered seedbed.

TABLE 5.—DISTRIBUTION OF THE STOCKED QUADRATS ACCORDING TO TYPE OF SEEDBED AND COLORATION OF THE SEEDLINGS

Seedbed	Coloration		
	Yellow (Per cent quadrats)	Green	Total
Mineral	14	86	100
Moss-covered	3	97	100

Basis:—2,141 quadrats.

[3] As in the other observations the best seedling on the quadrat was considered. Figures in Table 5 are the percentage of quadrats where that seedling was green or yellow.

TABLE 6.—PERCENTAGE OF QUADRATS WITH GREEN AND YELLOW SEEDLINGS ACCORDING TO LIGHT AND MOISTURE ON THE TWO SEEDBEDS

Seedbed and moisture conditions	Light							
	I		II		III		Total	
Mineral	Green	Yellow	Green	Yellow	Green	Yellow	Green	Yellow
Dry	7	1	4	—	33	11	44	12
Fresh	2	—	3	—	34	1	39	1
Moist	—	—	—	—	3	—	3	—
Very Moist	—	—	—	—	—	1	—	1
Total	9	1	7	—	70	13	86	14
Moss-covered								
Dry	6	—	4	—	16	1	26	1
Fresh	3	—	6	—	50	2	59	2
Moist	1	—	2	—	8	—	11	—
Very Moist	—	—	—	—	1	—	1	—
Total	10	—	12	—	75	3	97	3

Basis:—2,141 quadrats.

HEIGHT GROWTH OF THE SEEDLINGS

It is logical to think that the environment would be conducive to differential response of the seedling in height. Graphs 3 and 4 show that this is the case. There is a tendency for spruce to have a more rapid height growth on moss-covered soil than on bare mineral soil. Differences are not great but it must be recalled that the percentage of stocked quadrats is also much inferior on bare mineral soil. The seedlings which succeed in establishing themselves on this medium are probably well adapted. How long the effects will obtain is another question.

It is interesting to note that the seedling seems to thrive best on what was considered "fresh" mineral soil. In fact, it grows better on this condition than the seedling found on moss-covered seedbed. On the other hand, all moisture degrees are favourable on the latter.

DEPTH AND TYPE OF ROOTING

Much variation occurs in depth and type of rooting in spruce. It was noticeable, however, that rooting was more superficial on mineral soil, that is, an average depth of two inches. On moss-covered soil, rooting varied between two and six inches, with an average of three and a half inches.

On the latter seedbed, spruce had also a tendency to possess a better development and balanced root system. Although exceptions occurred, the seedling on bare soil sent roots in two or three directions whereas on the other type of seedbed, radii were more abundant and secondary and tertiary roots developed more abundantly. The total effect was apparently a better anchorage in the soil with a higher feeding ability.

DISCUSSION

The more favourable environment for black spruce reproduction with which *Polytrichum* mosses are associated is established beyond doubt. This is especially true if the mineral soil is coarse-textured. Why the moss has invaded here and not there is a matter for speculation. It may be pure chance or one or more environmental factors. It may be a fresh aspect, or the presence of organic matter or humus near the surface, or both. If pure chance, then the presence of moss creates a seedbed which is substantially better than that prevailing on mineral soil. The main effect would be to preserve moisture at the surface, a matter of great importance during the period of germination.

On the other hand, a thorough mixture of sand and humus is likely to be a better growing medium than sand alone, especially when germination of black spruce is considered. Apart from improving the physical properties of the soil, the nutrient level is surely higher than that of a coarse sand.

The favourable effect of *Polytrichum* on germination has been observed elsewhere. MacLean (Forestry Branch, Ottawa) stated that he had frequently observed in Ontario the association of *Polytrichum* with good stocking of black spruce seedlings. In New Brunswick, Place[4] found that low growths of *Polytrichum commune* form a good seedbed for spruce on dry sandy soils. Rank growth of the moss, however, proved to be very unfavourable.

Smith[5] found *Polytrichum* beneficial to white pine establishment on dry sites exposed to strong insolation. On other sites the moss would have a harmful effect owing to its too vigorous growth. On a *Viburnum-Oxalis* site in the Great Lakes-St. Lawrence region, the writer noticed that *Polytrichum* had invaded the surface soil one year after the removal of the organic layer. The mineral soil contained a fairly high percentage of humus. Whether this is a prerequisite for early colonizing by the moss is not known. When lifting spruce seedlings for examination of the roots, the presence of some humus in mixture with sand was frequently observed in moss-covered soil, whereas it was not noticeable in the other type of seedbed. Loss-on-ignition tests together with some experimental sowings in the area investigated would clarify this point.

SUMMARY

Black spruce reproduction was observed in the summer of 1954 along a truck road made in 1947 in Forest Section B-3, north of the Quebec-Cochrane railway. In a region where spruce regeneration by seed under undisturbed conditions is scanty, it was found to be satisfactory and rapid in the type of environment created by the opening of the road. Others had observed that the clearing of the roadsides had resulted in two main seedbeds, namely bare mineral soil and moss-covered soil. Spruce appeared more frequently on the latter type and it was decided to study to what extent this was true.

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[4] I.C.M. Place. 1955. Influence of seedbed conditions on the regeneration of spruce and balsam fir. Canada, Dept. Northern Affairs and National Resources, Forestry Branch, Bulletin 117, 87 pp.

[5] Connecticut Agr. Exp. Sta. Bull. 545, 1951.

The environmental conditions were studied by systematic observations in a series of milacre quadrats laid out irregularly between two points 25 miles apart. A total of 2,855 quadrats were taken. The results may be summarized as follows:

(1) Spruce is significantly more frequent on moss-covered soil than on mineral soil.

(2) The bulk of the seedlings were found on so-called dry and fresh situations, as defined by microrelief and soil texture.

(3) In moist situations, spruce is found much more often on moss-covered seedbeds. Reproduction is practically nil on mineral soil.

(4) If extreme cases of wetness are excepted, the essential differences in the two seedbeds do not lie directly in the moisture conditions of the soil. This is revealed by the fact that as many seedlings thrive in a dry soil as in a fresh soil. Percentages of frequency, however, are much higher on moss-covered sand than on bare sand.

(5) A cool aspect is more favourable than a warm aspect on mineral soil. Aspect makes no difference on a moss-covered soil. The fact that more quadrats on moss-covered soils were found on a cool aspect may be due to pure chance.

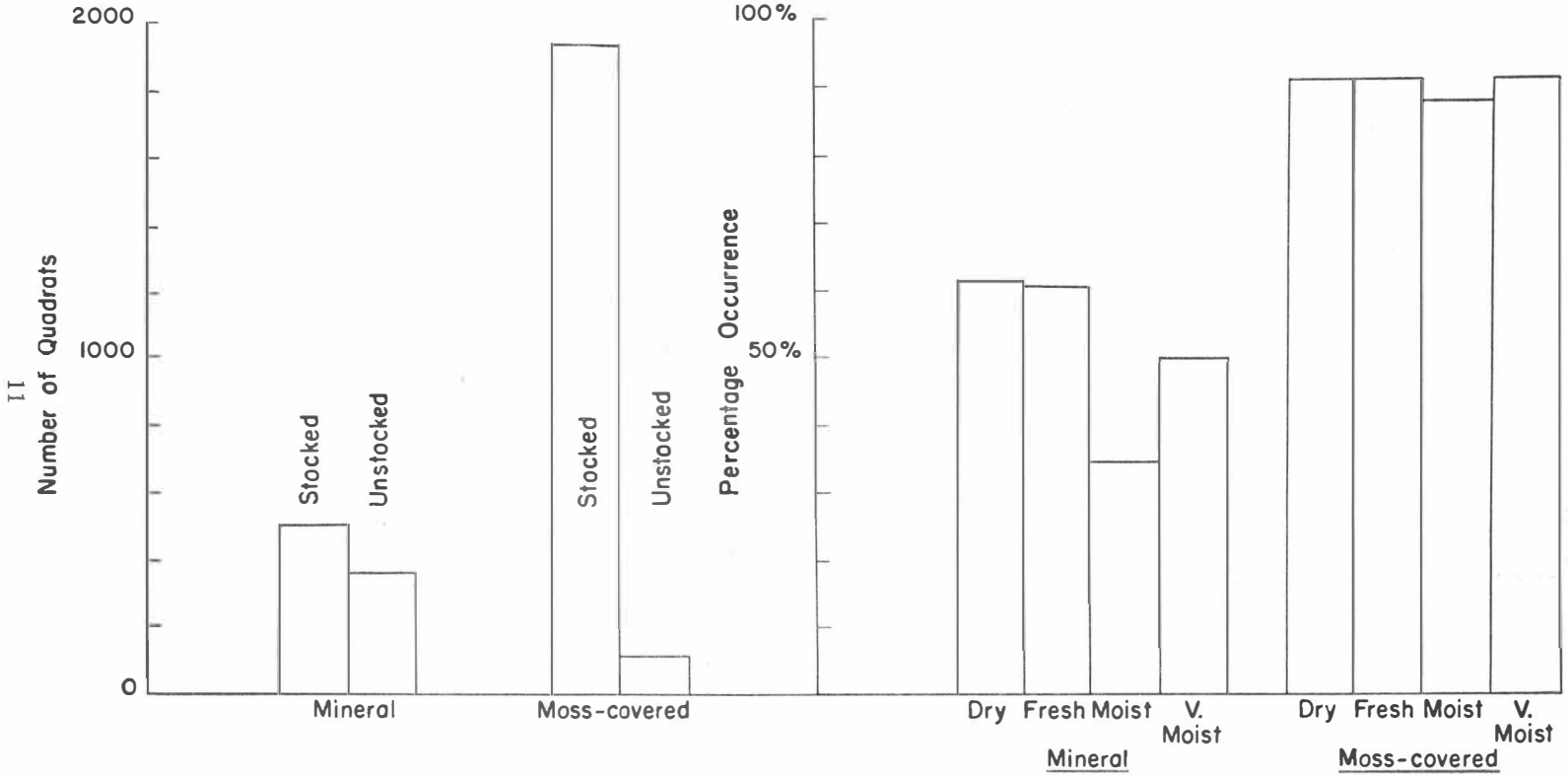


Figure 1A. Occurrence and absence of black spruce according to seedbed.

Figure 1B. Seedbed and moisture condition as affecting spruce establishment.

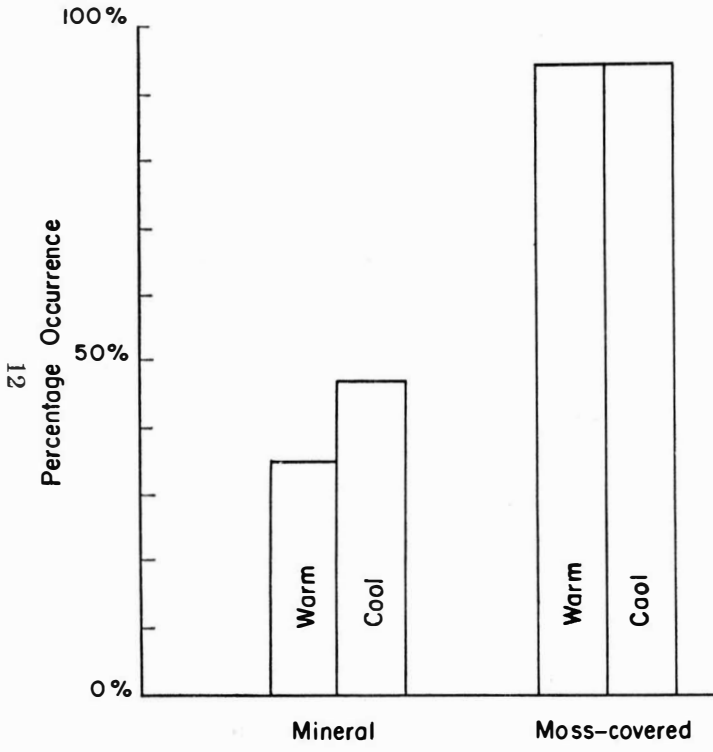


Figure 2A. Occurrence of spruce according to aspect and seedbed.

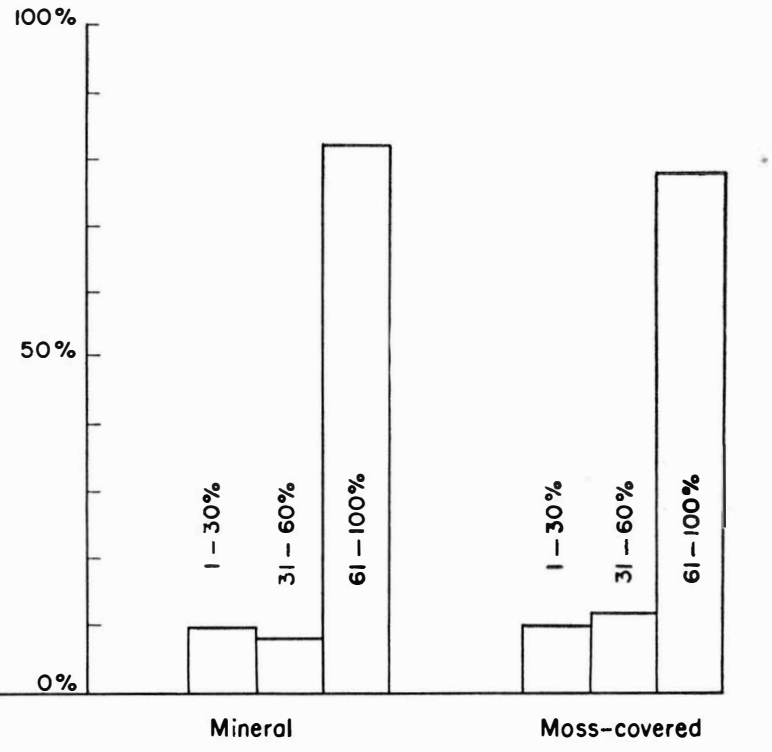
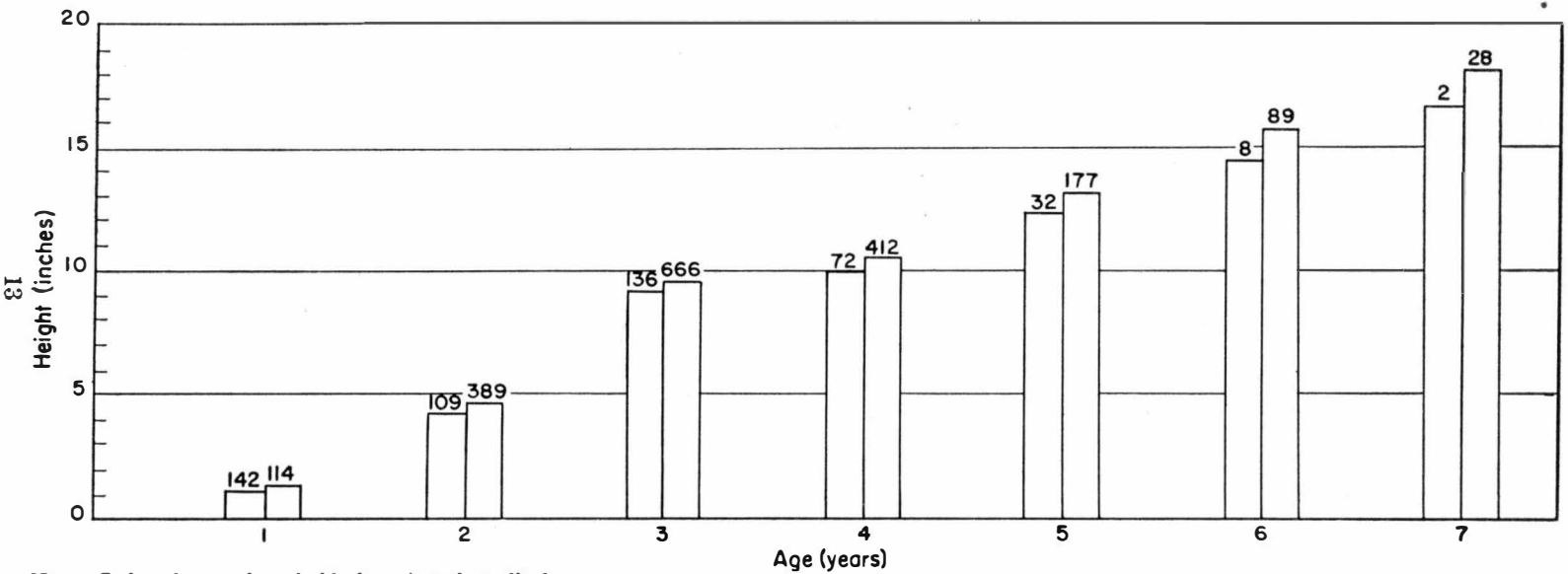
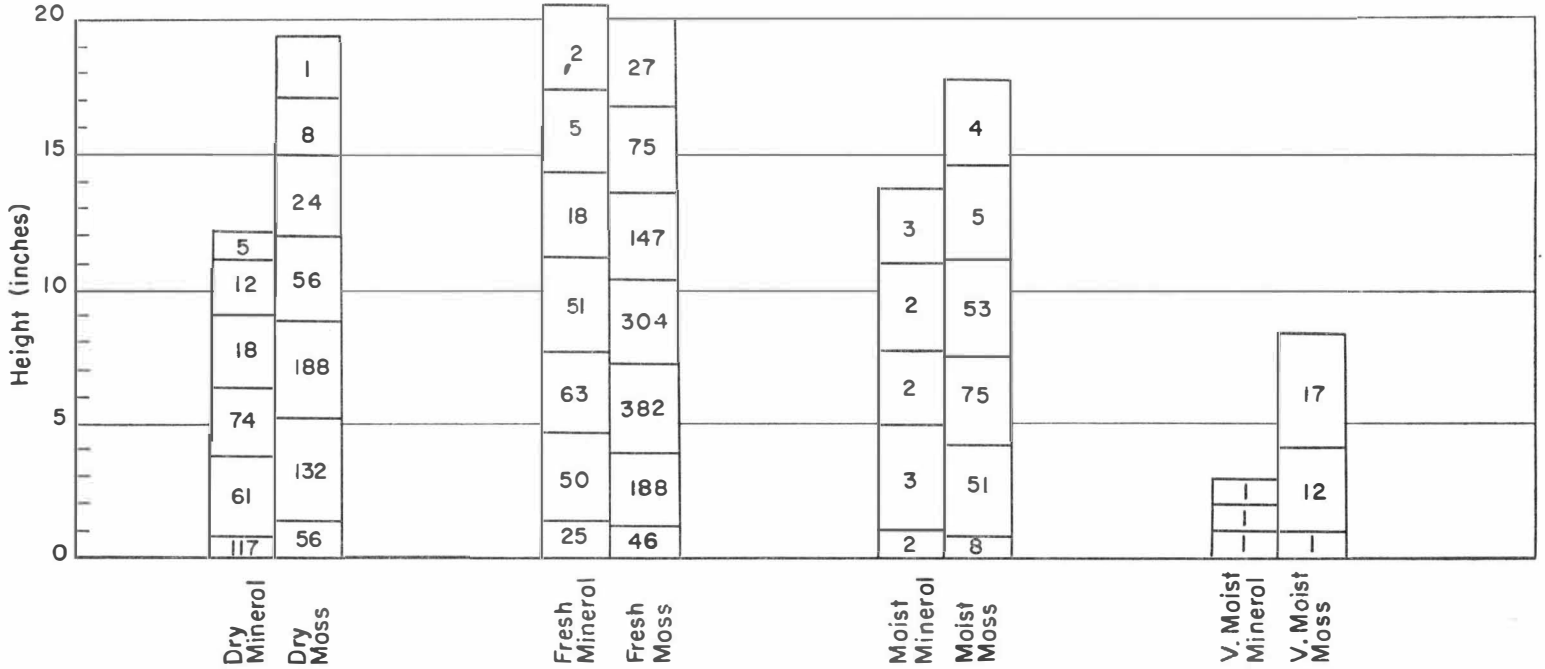


Figure 2B. Occurrence of spruce according to light and seedbed.



NOTE: Left column of each block—mineral seedbed.
Right column of each block—moss-covered seedbed.
Figures above columns—number of samples.

Figure 3. Height of spruce according to age and seedbed.



NOTE: Figures in blocks—number of sample seedlings.
Each horizontal line in blocks corresponds to one year of growth.

Figure 4. Height of spruce according to age, type of seedbed, and moisture condition.