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OBSERVATIONS ON FACTORS INFLUENCING JACK PINE REPRODUCTION IN SASKATCHEWAN

by
J. S. Jameson

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Observations on Factors Influencing Jack Pine Reproduction in Saskatchewan

by

J. S. Jameson[1]

INTRODUCTION

Jack pine[2] ranges from Nova Scotia, Maine, central Quebec and the Lake States northwestward to the foothills of the Rocky Mountains in northeastern British Columbia and to the Mackenzie River valley in the Northwest Territories (Anon. 1956, Rudolf 1958). According to Rudolf (1958), to whom the reader is referred for a summary of its silvical characteristics, it also occurs locally in northern Illinois, northwestern Indiana, northern New York, Vermont, and New Hampshire. It occurs extensively throughout the forests of the Prairie Provinces and during the last few decades has become one of the region's most important commercial species.

A reconnaissance reproduction survey conducted throughout Canada from 1946 to 1948 revealed that areas from which jack pine had been cut were generally understocked (Candy 1951). As a result of this finding the Forestry Branch[3] undertook to study the effects of various environmental factors on the germination and early survival of jack pine. In Ontario the effects of shade, sunlight, watering, seedbed medium, and depth of sowing on germination were investigated (Farrar and Fraser 1953, Fraser and Farrar 1953a, Fraser and Farrar 1953b, and Fraser 1959). More recently Chrosciewicz (1959), after reviewing the North American literature on controlled burning, conducted several experiments in cut-over jack pine stands.

Studies in Manitoba of the results of slash disposal methods, scarification, and seeding have provided some suggestions as to suitable silvicultural techniques (Johnson 1955, Cayford 1958, Cayford 1959a, and Cayford 1959b). As part of the same program an exploratory field study of some of the more obvious factors influencing reproduction was undertaken in central Saskatchewan in 1954. This paper reports the results of that investigation.

DESCRIPTION OF STUDY AREA

Location

The 1954 study was confined to the Saskatchewan portion of the B.18a Mixedwood Forest Section (Rowe 1959). Field examinations were made in the Nisbet and Fort à la Corne Provincial Forests, and in the Northern Provincial Forest at Candle Lake, Montreal Lake, Big River and Meadow Lake (Figure 1). The descriptions that follow apply principally to the Saskatchewan portion of the B.18a section.

Climate

The regional climate is continental with a great annual range in temperatures and with only moderate precipitation. At Prince Albert the January mean temperature is −4°F and the July mean temperature 63°F. Average annual precipitation is 16.11 inches, 10.50 inches of which falls during the months of May to September inclusive (Boughner and Thomas 1948, Anon. 1952). There is an average annual moisture deficiency of four inches occurring in summer, usually after July 15 (Putnam 1952).

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[1] Forestry Officer, Forest Research Division, Manitoba-Saskatchewan District Office, Winnipeg, Manitoba.
[2] For list of botanical names of species mentioned in text, see Appendix I.
[3] Now the Department of Forestry.

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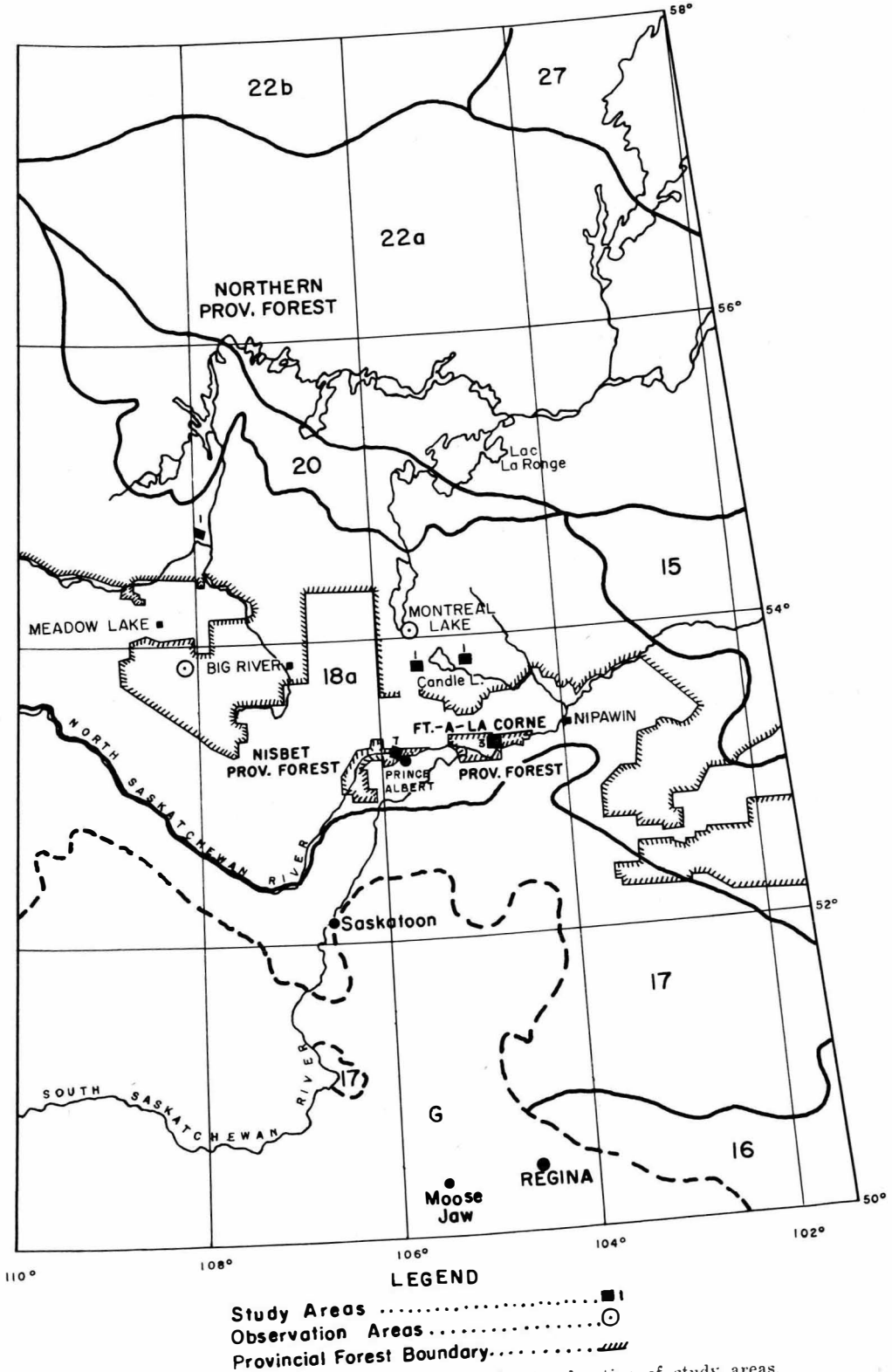

Figure 1. Map of central Saskatchewan showing location of study areas.

Forests

The characteristic forest is mixedwood occurring on moderately fresh to moderately moist loam to clay-loam sites, with trembling aspen and white spruce predominating. Jack pine most frequently occurs in pure stands on arid to fresh sandy sites and less frequently on moderately moist and moist sandy sites. On the latter it may occur in mixture with black spruce. On wet sites, black spruce predominates. Other species present in commercial quantities are balsam fir, balsam poplar, and white birch.

Topography, Soils and Sites[4]

Relief of the area is not extreme, except locally in the eastern part of the section. It is chiefly the result of pre-glacial erosion of the soft bedrock shales. Subsequent glaciation modified the landscape and the present topography is characterized by rolling morainic deposits on the uplands and smooth glacio-lacustrine deposits on the lowlands (Rowe 1959). The soil parent material is morainic till, outwash or alluvium.

Five jack pine site groups established on the basis of soil profile development, vegetation, and height/age relationship, were used for classifying the study areas.

Site Group A

These sites consist of dry to moderately moist, stony to stone-free, loam to clay-loam till soils on undulating to rolling topography. In general they may be recognized by well-developed grey-wooded profiles with leached A_2 horizons and blocky or nutty structured B horizons. In central and western Saskatchewan a podzol profile has developed on the well-leached A_2 horizon of the grey-wooded profile. A profile description of a typical moderately fresh silt-loam till soil is given in Appendix II.

The lesser vegetation consists of vigorous tall shrubs and herbs dominated by hazelnut, lungwort, alder and sarsaparilla. Dewberry and bunchberry also occur. On cool ecoclimates feather mosses are present.

Mixedwood stands of trembling aspen, balsam poplar, and white and black spruce are the most common. Jack pine, although it attains its best development on this site, is somewhat of an intruder and forms only a minor component. Occasionally pure stands of jack pine occur as a result of severe fire.

Residual dominant jack pine in a partially cut mixedwood stand at Candle Lake averaged 77 feet high at 87 years of age (corresponds to 58 feet at 50 years).

Site Group B

These sites consist of moist, coarse to fine sandy soils laid down as outwash plains, beach or terrace material, and loam to clay-loam soils of till or lacustrine origin. The topography is level to gently undulating.

On the sandy soils there is a strongly developed A_2 horizon and incipient mottling well up in the dark brown B horizon. The permanent water table occurs at about five feet. On the fine-textured soils the A_1 horizon is usually well developed and the A_2 poorly developed. The B horizon is usually blocky structured, the aggregates having the same dull colour outside as inside. Mottling occurs well up in the B horizon, although this characteristic is frequently inconspicuous in the clay-loam soils. The water table is usually perched.

The lesser vegetation is characterized by a feather moss cover, principally Schreber's moss. The shrub layer is frequently dense, with dry ground cranberry, Canada blueberry, and scattered Labrador tea occurring. Reed grass, bunchberry and twinflower are usually present in the herb layer.

Jack pine occurs in pure stands on the sandy soils and occasionally mixed with black spruce when the sites are interspersed with very moist to wet black

[4] Hills' (1952) basic site classification was used throughout this study and the fresh or standard moisture regime was designated as a 3. These were later grouped into five jack pine site groups as described, based on these and other field studies.

spruce sites. On the fine-textured soils jack pine also occurs in pure stands but more commonly with balsam fir, white spruce, trembling aspen, and balsam poplar.

Jack pine may be expected to reach a height slightly in excess of 45 feet at 50 years on these sites.

Site Group C

These are level to gently undulating sites, consisting of moderately fresh to moderately moist coarse to fine sands and sandy loam soils on glacial outwash, beach, washed till or alluvial deposits.

The sites are recognized by the presence of a slightly leached A_2 horizon and a yellowish brown B. The permanent water table is at six to nine feet. A description of a typical profile is given in Appendix III.

The lesser vegetation consists of bush honeysuckle, and various medium and low herbs. On cool ecoclimates feather mosses often carpet the ground.

Jack pine generally occurs in pure stands, but may frequently occur in mixture with white spruce, white birch, and trembling aspen. Black spruce is commonly associated with jack pine as an understorey when the sites are adjacent to or interspersed with black spruce lower slope or swamp sites.

These are fairly productive jack pine sites. Data for similar sites in south-eastern Manitoba showed that jack pine may be expected to reach somewhat in excess of 50 feet at 50 years.

Site Group D

These are perhaps the most common jack pine sites and comprise all dry sands, sandy loams and gravelly sands. The topography may be level to moderately rolling and the parent material is of glacial outwash, beach or terrace origin.

Soil profiles are weakly developed with little colour difference in the horizons. The B horizon may be slightly darker than the C horizon. The water table is usually beyond the reach of most tree roots. A description of a typical profile is given in Appendix IV.

There are several vegetation types associated with this site group. They include: *Arctostaphylos-Vaccinium; Festuca-Agropyron; Fragaria-Galium-Maianthemum;* and *Alnus crispa-Salix humilis-Rosa.* The first type is the most common and for practical purposes the remainder may be grouped as a Herb/Grass/Tall-Shrub type.

Jack pine usually occurs in pure stands and is probably the only species capable of forming well-stocked stands. Scrubby white birch and aspen sometimes occur.

Jack pine reaches a height of about 45 feet at 50 years.

Site Group E

These sites consist of arid to very dry coarse gravelly to medium sandy soils on level to undulating topography on glacial outwash, beach deposits, or aeolian deposits.

The soil profile development is barely discernible and the sites may be recognized by this feature. The permanent water table is well beyond the reach of most tree roots.

The ground vegetation consists principally of caribou moss with bearberry occurring in varying mixtures and degrees of abundance. The vegetation is referred to as the *Cladonia-Arctostaphylos* type.

Jack pine occurs in pure, open and semi-open stands. Other species do not usually invade, principally because the soils are too dry and too low in nutrients for them to survive. The cover type is therefore relatively permanent.

Jack pine reaches a height of about 35 feet at 50 years.

History

The stands examined were of fire origin as evidenced by their even-aged structure. Fire scars on living trees indicated that widespread fires had occurred

in the Nisbet and Fort à la Corne Provincial Forests in 1887, 1919 and 1937. Fire scars commonly occurred on living trees in other areas and were the result of recurring ground fires.

In the Nisbet and Fort à la Corne Provincial Forests and at Big River, Candle Lake, Montreal Lake and the Torch River in the Northern Provincial Forest, jack pine has been clear cut and partially cut for poles, ties and fuelwood. Up to about 1950, it was the policy to have the slash on the clear-cut areas piled and burned to reduce the fire hazard. The results varied from failure of reproduction in some areas to occasional moderate or better stocking. The results of partial cutting also varied, depending to a large extent upon site and composition of the original stand.

METHODS

A preliminary reconnaissance was made to determine prevailing conditions and to select sub-areas for study. Partially cut, clear-cut and burned-over jack pine and mixedwood stands, and when possible similar undisturbed stands, were examined. Detailed studies were made on square or rectangular one-fifth or one-tenth acre plots. Fifty-four plots were examined in 13 localities. Appendix V presents a summary of plot distribution by stand condition and cover type.

Trees and stumps were tallied by one-inch diameter classes. Ages were determined from increment borings and from stump sections. Heights of a number of dominant trees in undisturbed stands were measured. Habitat was described, biotic influences noted, and minor vegetation listed. A soil pit was dug on each plot, the soil profile described, and a site class assigned.

Reproduction[5] was tallied by six-inch height classes on 20 equally spaced milacre quadrats on each plot and the reasons for its presence or absence recorded in so far as they could be determined. Height and age data were collected for representative seedlings.

RESULTS

Availability of Seed

The closed cone habit, which appeared to be the chief factor limiting availability of seed from living trees, varied greatly with stand age. In mature stands few open cones were observed. In a 35-year-old stand in the Nisbet Provincial Forest, half the mature cones on 20 per cent of the trees had opened; although stand and habitat conditions were uniform the proportion of open cones varied greatly. On open-grown seven- to ten-year-old trees almost all mature cones were fully open. The occurrence of non-serotinous cones has been observed near the prairie border in Minnesota (Eyre and LeBarron 1944).

To further explore cone opening habits, 35 cones that had matured in 1954 were collected from each of six trees in a number of height classes on similar sites in the Nisbet Provincial Forest. The trees selected were all within semi-open stands. The cones were stored at about 70°F and 20 per cent relative humidity for five months. At the end of that period, 70 per cent of the cones from trees 10 feet or less in height (10 to 20 years old) had opened, while only one per cent of the cones from trees 20 feet or more in height (up to 55 years old) had opened.

An indication of the reproductive effectiveness of seed available from a 35-year-old stand in the Nisbet Provincial Forest was obtained by examining the reproduction on a seven-year-old cut over adjacent to and lying east of the stand. The area had been clear cut and the slash piled and burned. Five strips, each of 20 milacre quadrats, were laid out parallel to the edge of the stand and at distances of 0, 22.5, 45, 67.5 and 90 links from it. Per cent stockings, with the number of seedlings per acre in brackets, were respectively 55(700), 30(350), 25(400), 15(300), and 5(50). The presence of seedlings was attributed to seed available from the stand. The distribution of seedlings was probably a reflection of seed dissemination although exposure may have been a contributing factor.

[5] Reproduction is defined as stems not exceeding 0.5 in. diameter (outside bark) at b.h.

The closed cone habit does not normally place a serious limitation on availability of seed from slash. Eyre and LeBarron (1944) observed that one-half to two-thirds of the total seed supply may be dispersed from open cones on lopped and scattered slash. In this study nearly complete cone opening was observed to occur when slash was spread evenly in a layer not exceeding about six inches in depth, under conditions of favourable exposure. As cone height increased above six inches, cone opening tended to decrease.

Seedbed

Mineral soil seedbeds that had been prepared on sandy soils by scarification after cutting and by mechanical clearing of dense jack pine in strips were available for examination. They were moderately to well stocked[6] (Candy, 1951) (Table 1).

TABLE 1.—REPRODUCTION PER ACRE AND PER CENT STOCKING ON MINERAL SOIL SEEDBED, NISBET PROVINCIAL FOREST

Disturbance and year	Site group	Age of stand	No. of quadrats	Reproduction	
				Number per acre	Per cent stocking
Mechanically cleared strips 1949	E	35	20	1,500	65
Mechanically cleared strips 1949	D	45	23	870	61
Mechanically cleared strips 1949	C	65	33	2,515	64
Clear cut, scarified 1951	D	60	20	950	55
Clear cut, scarified 1951	D	60	20	3,500	60

NOTE: Seed supply for the cleared strips, especially in the older stands, was assumed to have come mainly from cones that were left on the ground after clearing.

Eighty-five per cent of all seedlings on scarified areas were located at the bottom of furrows where moisture and possibly temperature conditions were most favourable. In these positions they could be expected to be subject to smothering by accumulations of litter and eroded soil, but little evidence of smothering was seen.

Rate of seedling survival was found to be greater on scarified areas than on unscarified areas. Two groups of 45 newly germinated seedlings were marked on July 7 on D sites; one group was on scarified and the other on unscarified ground. In both instances stands had been clear cut. Seedlings were observed at intervals until September 15 and survival was as follows:

Period since germination	Scarified, no slash	Unscarified, slash under 6 inches
	(number)	(number)
One week—July 15	45	33
Three weeks—July 31	45	29
Ten weeks—Sept. 15	44	29

Slash burning provided patches of mineral seedbed and seedlings were almost always found around their perimeters. In their interiors, however, seedlings were usually absent owing to the destruction of seed.

[6]Candy's standards for stocking of reproduction are as follows:
Fully stocked....80 to 100 per cent of quadrats stocked
Well stocked....60 to 79 per cent of quadrats stocked
Moderately stocked....40 to 59 per cent of quadrats stocked
Understocked....20 to 39 per cent of quadrats stocked
Failure....less than 20 per cent of quadrats stocked

Slash

Depth of slash probably had a greater influence on survival than on germination, as recently germinated seedlings were found under various depths of slash. To examine survival under slash, 45 newly germinated seedlings were marked on July 7 on an area where slash was less than six inches in depth and the same number were marked on an area where slash was more than six inches (but less than 12 inches) in depth. Survival during the summer of 1954 was as follows:

Period since germination	Slash over six inches deep	Slash under six inches deep
	(number)	(number)
One week—July 15	8	33
Three weeks—July 31	1	29
Ten weeks—Sept. 15	1	29

Mortality was attributed principally to damping-off disease as a result of higher humidity under the deeper layer of slash. Smith (1951) in his studies of eastern white pine regeneration found that although germination under a dense layer of slash was satisfactory, almost 100 per cent mortality resulted, which he attributed largely to damping-off disease.

Aspect

Reproduction data from clear-cut areas in the Nisbet Provincial Forest were summarized by aspect. Other conditions were essentially uniform. Slash had been piled and burned. Reproduction was more abundant on eastern to northern aspects than on southern to western aspects or on approximately level areas (Table 2, Figure 2). It was also more abundant at a location on the lower portion of a northwest-facing slope than at one on the upper portion. The greater abundances recorded on eastern to northern aspects could possibly be attributed mainly to lower insolation temperatures and those on the lower northwest-facing slope to a lesser exposure to prevailing fine-weather summer winds (Anon. 1957).

TABLE 2.—SEEDLINGS PER ACRE AND PER CENT STOCKING IN CLEAR-CUT AND PARTIALLY CUT STANDS IN RELATION TO ASPECT, NISBET PROVINCIAL FOREST

No. of plots	No. of quadrats	Site group	Aspect	Year of cut	Reproduction		
					Per cent stocking	Number per acre	Disturbance
2	40	D	Level—Depr.	1946	8	75	Clear cut
1	20	D	S-SW	1947	10	100	" "
1	20	D	E	1943-46	70	1,150	" "
1	20	C	N	1943	35	550	" "
4	80	D	E-N	1943-48	62	1,950	" "
1	20	D	NW lower	1942	55	1,150	" "
1	20	E	NW upper	1942	15	200	" "
1	20	D	SW	1946	60	1,050	Partially cut
1	20	D	N	1950	0	0	" "

Figure 2. This D site on a five per cent northern aspect was clear cut in 1942. Reproduction numbered 1,150 per acre with 55 per cent stocking. Plot 5, Nisbet Provincial Forest.

Figure 3. This D site on a 15 per cent northern aspect was partially cut in 1940-41 and 1952-53. There was no reproduction in 1954. Plot 41, Fort à la Corne Provincial Forest.

The effects of aspect in partially cut stands differed from those in clear-cut stands. In two similar partially cut stands on similar sites in the Fort à la Corne Provincial Forest, stocking of reproduction was moderate on southern aspects but northern aspects were understocked (Table 2, Figure 3). In spite of partial shade, temperatures on southern aspects had obviously reached levels that produced cone opening; those on northern aspects apparently had not. Partial shade may have aided seedling survival on southern aspects. It has been shown elsewhere that partial shade not only increased germination of jack pine (Fraser and Farrar 1953a) but was also beneficial to planted seedlings (Anon. 1939).

Biotic Influences

Jack pine reproduction was found to be attacked by fungi and by several species of insects and mammals. These included: mistletoe broom (*Arceuthobium americanum* Nutt.), stem rusts (*Cronartium* spp.), jack pine budworm (*Choristoneura pinus* Free.), white pine weevil (*Pissodes strobi* (Peck)), pitch nodule maker (*Petrova albicapitana* (Busck)), and the snowshoe hare (*Lepus americanus phaenotus* (Allen)). With the exception of mistletoe broom and the snowshoe hare, damage by these organisms was slight and relatively unimportant.

Mistletoe broom, which was confined usually to the characteristically semi-open stands on E sites but was occasionally found in stands on C and D sites, influenced reproduction principally by inhibiting cone production on infested branches. This resulted in a large quantity of useless slash following logging. In one clear-cut area on an E site the slash contained practically no cones because of mistletoe, although depth of slash averaged more than six inches. Infected reproduction was largely confined to areas on which heavily infected stands occurred.

In uncut stands, and in a 12-year-old mixedwood stand of spruce, aspen and jack pine, reproduction had been severely girdled and browsed by the snowshoe hare. Although heavy damage probably occurs only at the peak of the hare cycle, about once every 10 years (Aldous 1947), it appears that this can be sufficient to prevent the development of advanced growth and to reduce the number of jack pine in mixed stands of reproduction. The form and vigour of damaged seedlings in the stands examined was so poor that their eventual development into sound, well-formed trees seemed unlikely.

Reproduction on Principal Sites

Germination and subsequent survival and growth of seedlings are dependent largely upon seedbed and vegetation, which in turn are expressions of site. The influences of site on jack pine reproduction, as determined by this study, are described by site groups.

Site Group A

Stands on these sites are primarily mixedwood, and partial cutting resulting in irregular stand openings has been the usual practice, as the aspen component has not been profitably marketable. In the partially cut stands examined a vigorous growth of aspen, shrubs and herbs had occupied the openings and jack pine reproduction was a failure. Residual stand and dense lesser vegetation tended not only to keep ground temperatures below the level required to open jack pine cones, but provided competition against which it was unlikely that jack pine seedlings could survive.

Site Group B

Clear cutting with lopping and scattering of slash produced variable results depending upon the lesser vegetation present. Stocking was moderate where the vegetation consisted of shallow feather moss and less than moderate where it consisted of deep feather moss or blueberry and Labrador tea. The latter was the most common vegetation encountered on these sites.

Under undisturbed stands reproduction was almost totally lacking except on rotting logs and exposed mineral soil, where white spruce usually, and balsam fir infrequently, were present. Thus successional development was toward a white-spruce/balsam-fir type. On sites adjacent to or interspersed with moist black spruce sites, black spruce reproduction commonly occurred.

Site Group C

Clear-cut and partially cut areas on which slash had been lopped and scattered after logging failed to reproduce although open cones were generally present on the slash, indicating that seed had been disseminated. The lack of reproduction was attributed to the abundance and aggressiveness of the lesser vegetation.

At Candle Lake in mature undisturbed jack pine stands adjacent to black spruce swamps, over 4,000 black spruce seedlings and layerings per acre were present, as well as occasional aspen suckers, but jack pine reproduction was lacking. It appeared that jack pine types on these sites would, if left undisturbed, be converted to black spruce or possibly scrubby aspen.

Site Group D

Clear cutting with lopping and scattering of slash resulted in less than moderate stocking in the Herb/Grass/Tall-Shrub type, apparently because of competition, as both open cones and recently germinated seedlings were found. In the *Arctostaphylos-Vaccinium* type, stocking of reproduction was usually moderate or better, depending largely upon the density of bearberry which, when it formed continuous cover, tended to prevent survival of cotyledonous seedlings.

In undisturbed stands reproduction was almost entirely lacking. In the stands examined deep needle litter doubtless contributed to poor seedbed conditions.

Fairly rapid invasion by black spruce occurred in stands near moist black spruce sites. In an 80-year-old undisturbed stand near Candle Lake there were about 1,800 black spruce seedlings per acre as against 100 jack pine, but it is unlikely that these poorer sites will produce good-quality spruce.

Site Group E

Where stands had been clear cut or partially cut and the slash lopped and scattered, stocking of reproduction was generally moderate or better. Exceptionally dense reproduction, in excess of 40,000 seedlings per acre, was found in the Nisbet Provincial Forest on an area clear cut in 1952 (Figure 4).

Wind damage in an overmature open stand on a calcareous sandy ridge resulted in a moderate stocking of reproduction as many cones on fallen trees had opened to provide seed. No other species were represented in the stand and therefore jack pine was virtually an edaphic climax on this particular location (Figure 5).

The characteristic ground vegetation on these sites, caribou moss and scattered bearberry, apparently did not offer serious competition to reproduction. Caribou moss apparently provides an excellent seedbed when precipitation is adequate, while bearberry provides some protection from the sun. Smith (1951) found that caribou moss made a favourable seedbed for eastern white pine, and that no advantage was gained by removing it. He also suggested that protection was necessary and could be provided by slash.

Figure 4. This E site was clear cut in 1952 and the slash lopped and thinly scattered. Reproduction numbered 40,000 one- and two-year-old seedlings per acre. Plot 29, Nisbet Provincial Forest.

Figure 5. Reproduction near crown of windfall. Site E, Candle Lake, Northern Provincial Forest.

Reproduction after Fire

Several recently burned jack pine areas were examined during the study. Following are brief descriptions of some of them.

At Candle Lake a fire in 1942 completely destroyed partially cut and undisturbed jack pine and mixedwood stands on A and B sites. Jack pine reproduction ranged from 500 to 26,000 per acre (Figure 6). White and black spruce and trembling aspen reproduction also occurred. Degree of humus destruction appeared to be a more important factor than original species representation in determining species representation in reproduction. On a plot on which the humus had been lightly burned, 10,000 trembling aspen and 8,100 jack pine per acre were found. On a nearby plot on a similar site on which the humus had been destroyed, 100 aspen and 21,000 jack pine per acre were found. Jack pine was represented in the original stand on the first plot but not on the second. On the first plot the rapidly growing trembling aspen had not only suppressed the jack pine seedlings, but had provided shelter for snowshoe hare, resulting in severe damage and mortality among the jack pine.

Figure 6. Thirteen-year-old jack pine as a result of a 1942 fire on an A site. Reproduction numbered 7,050 per acre and stocking was 100 per cent. Plot 48, Candle Lake, Northern Provincial Forest.

Fire in 1948 destroyed an old orchard-type jack pine stand on a C site near Big River. In 1954 the area was well stocked with reproduction.

On a C site about eight miles northwest of Big River a 70-year-old stand was partially cut in 1915 and an estimated residual stand of 60 trees per acre was destroyed by fire in 1941. The area supported an excellent stand of young jack pine when examined.

Kind, intensity, and time of fire all appeared to influence results. Kind and intensity of fire affected chiefly seed supply and nature of seedbed. Time, besides influencing the other two fire factors, determined the relationship of seeding to season. Spring and early summer fires would have tended to permit germination and hardening of seedlings before frost occurred. Saskatchewan fire records showed that most fires occurred by early summer.

Growth of Reproduction

The relationship of height of jack pine seedlings to site and stand disturbance, at one year, 10 years and 15 years of age, is shown in Figure 7. At 10 and 15 years of age height differences that suggested varying effects of site and disturbance were apparent. The greater average height of seedlings at 10 years of age on site D than on site C was attributed to less competition on the former. At 15 years the average height of seedlings was greater on site C, the richest site, than on sites D and E.

Seedlings on burned areas were taller than those on unscarified clear-cut areas, principally owing to less competition and possibly also to more moisture and available nutrients.

Data were not available on the effect of scarification on height growth. However, it was observed that seedlings appeared to be more vigorous on scarified than on unscarified ground.

DISCUSSION AND SILVICULTURAL RECOMMENDATIONS

It was apparent that cone opening in mature stands could not be expected to provide useful quantities of seed. Both for this reason and because of the intolerance of jack pine, advance growth could rarely be expected to provide an appreciable portion of stand replacement.

In general it was found that slash not deeper than about six inches resulted in cone opening and a reduction of seedling mortality from heat and drought. Moderate or higher stocking usually resulted when seedbed conditions were suitable. Deeper slash reduced seedling survival; therefore excess slash should be disposed of.

Under certain conditions a residual canopy provided protection against exposure of seedlings that more than offset any diminution of cone opening it may have caused.

Scarification was found to result in higher stocking and a higher rate of seedling survival. It should provide for early season germination and therefore should be done either in late autumn or in early spring, as soon as possible after cutting. Early season germination can be expected to minimize mortality resulting from early autumn frosts. It was found that seedlings germinating after September 1 were most susceptible to this type of damage (Zehngraff 1943).

The Athens plough appeared to be an effective scarifier on coarse textured soils. It required weighting for use over slash (Holt, Swan and Weetman 1956). On finer textured soils blade-type equipment may be required.

Techniques for using prescribed burning in jack pine silviculture have not been developed for the region, therefore the use of fire will not be included in the recommendations.

More specific treatment possibilities are discussed under the various site groups.

Site Group A

Because of the scarcity of jack pine on these sites and because of the difficulty of regenerating them to jack pine, it is recommended that silvicultural practices be directed to regenerating species better suited to them.

Site Groups B and C

Clear cutting on these sites followed by scarifying and slash scattering can be expected to provide a seed supply, a suitable seedbed, reduced competition, and a measure of protection against insolation and drought. Further protection may be desirable, particularly on exposed areas, and it is suggested that it be provided by clear cutting in one- to two-chain-wide north-south strips. The north-south orientation should provide for fairly uniform cone opening and effective protection against winds.

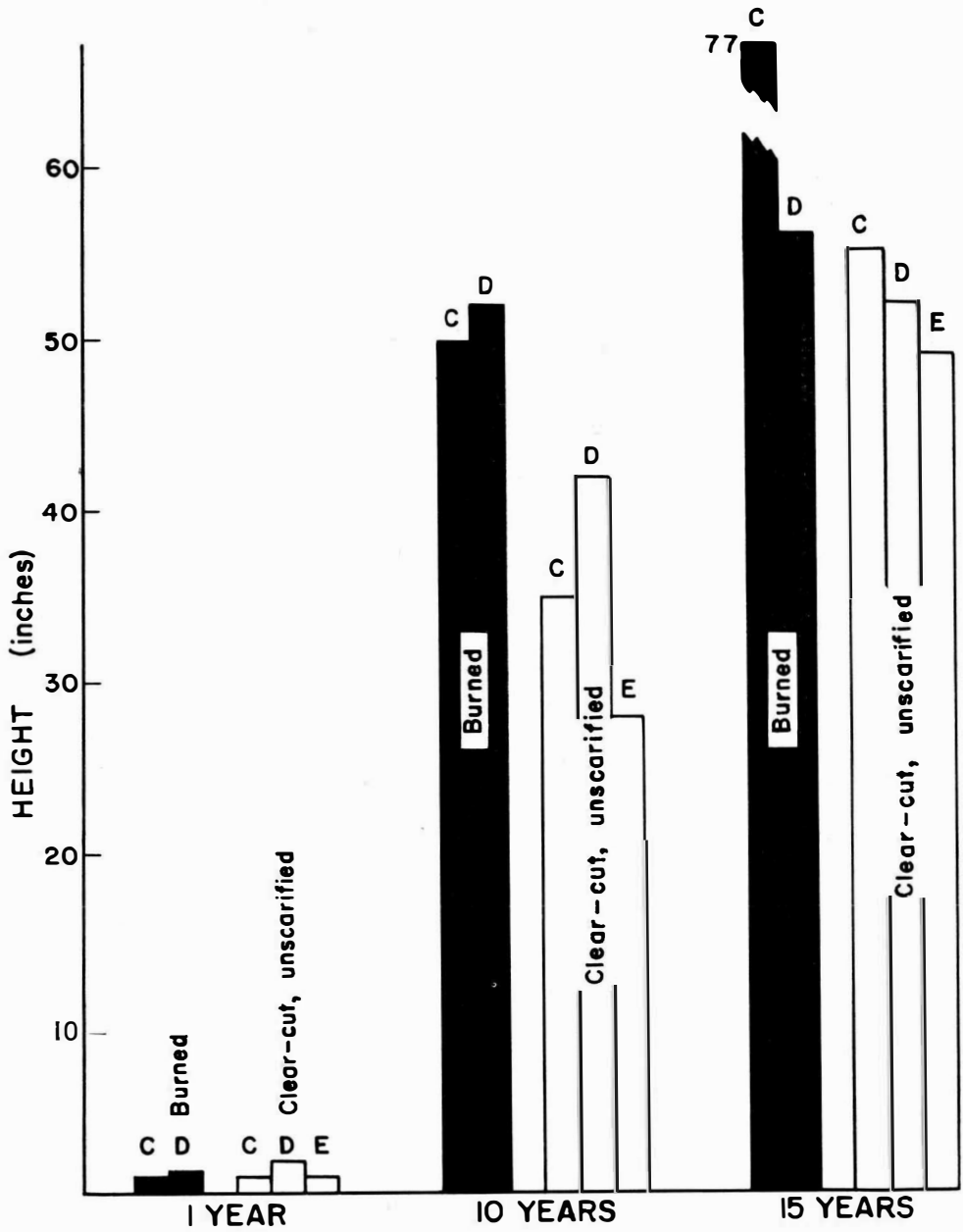

Figure 7. Height of jack pine seedlings in relation to age, site, and type of disturbance.

Site Groups D and E

The silvicultural practices suggested for these sites are discussed by topographic position, vegetation type, and aspect.

Level to Almost Level Areas

Herb/Grass/Tall-Shrub Type—Protection against wind and sun and the elimination of lesser vegetation was found to assist the establishment of reproduction. Clear cutting in one- to two-chain-wide north-south strips followed by scarification and slash scattering is recommended.

Arctostaphylos-Vaccinium Type—Stocking was obtained when there were sufficient openings in the lesser vegetation layer to allow germination and establishment of seedlings. The recommended procedure is similar to that described for the previous vegetation type. Scarification may be less intensive.

Cladonia-Arctostaphylos Type—Stocking of reproduction was found to be moderate without ground preparation because of the nature of the vegetation. Therefore cutting as for the two previous types without scarification is suggested.

Slopes

Southern to Western Aspects—Reproduction was a failure after clear cutting, principally because of exposure to sun and drying winds. Cone opening and germination were probably satisfactory, but because of the hot dry ecoclimate, there must have been a high proportion of seedling mortality. In partially cut stands stocking was generally moderate. Partial cutting, either uniform or in small patches, is therefore suggested on all three vegetation types. Slash should be lopped and scattered in the openings. On the Herb/Grass/Tall-Shrub and the *Arctostaphylos-Vaccinium* types scarification after cutting is recommended. On the *Cladonia-Arctostaphylos* type scarification should not be necessary.

Northern to Eastern Aspects—These aspects did not restock after partial cutting. The cooler and moister ecoclimates which prevailed on them encouraged the growth of dense herbaceous and shrub vegetation. Cone opening was inhibited by relatively low surface temperatures. Clear cutting followed by slash scattering and scarification is suggested.

Very steep northern aspects probably remain so cool that sufficient cone opening cannot be obtained under any conditions. Suggested treatment is to clear cut and plant, or to scarify and seed.

SUMMARY

A study of factors influencing jack pine reproduction was undertaken in the B.18a Mixedwood Section of Saskatchewan in 1954. Clear-cut, partially cut, burned, and undisturbed stands on several sites were examined. Temporary $\frac{1}{5}$-acre and $\frac{1}{10}$-acre plots were established to study the stands, and milacre quadrats to study the reproduction.

The serotinous habit was found to be less pronounced in young trees than in older trees. A large proportion of cones on slash were found open.

Mineral soil seedbeds were stocked when seed had been provided. On scarified areas reproduction occurred mainly at the bottom of furrows. Survival was better on mineral soil than on organic seedbeds.

Seed was released from and germinated under various depths of slash. Survival was much higher under a shallow than a deep slash layer.

Northern to eastern aspects after clear cutting and southwestern aspects after partial cutting produced higher stocking than northern aspects after partial cutting and southern to western aspects after clear cutting. Exposure of slope also affected stocking.

Infection with mistletoe reduced cone production; hares killed or severely retarded reproduction under canopies.

Sites influenced reproduction chiefly through the lesser vegetation they supported. On the more productive sites competition tended to prevent seedling survival. On sites of intermediate productivity, stocking was sometimes obtained without a treatment to improve seedbed and reduce competition. On the poor sites competition ceased to be an important factor while protection against heat and drought became more of a necessity. On all sites reproduction under well-stocked, mature, undisturbed stands was inadequate to provide stocking.

Restocking after fire was usual if cone-bearing jack pine had been present.

Variation of height growth with site and kind of stand disturbance was detected.

The possibilities of slash manipulation for seed supply and seedling shelter, of seedbed treatment for increased germination and seedling survival, and of the use of residual canopy in reducing exposure, are discussed briefly, and specific silvicultural treatments for different site groups are suggested.

GLOSSARY OF TERMS USED

Climax—the relatively stable stage of a succession of a plant community which continues to occupy an area as long as climate, history or soil conditions remain unchanged.

Climax, edaphic—a climax resulting from a relatively narrow edaphic control of the regional climate.

Edaphic—pertaining to the soil.

Regime, soil moisture (Hills 1950)—soil moisture regime refers to the fluctuation in levels of available moisture during a complete vegetation cycle (season).

Site (Syn. *habitat*)—habitat or site is defined by Nichols (1917) "as any unit area in which the combined influence of the various external factors which determine the ecological aspect of the vegetation is such as to produce an essentially uniform environment".

Succession—the change that takes place among and within plant communities, the cause of which may be external or internal.

Vegetation type—a plant community essentially uniform in general appearance, i.e. in floristic composition and structure.

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APPENDIX I

Common and Botanical Names of Plants Mentioned in Text

Aspen, trembling	*Populus tremuloides* (Michx.)
Birch, white	*Betula papyrifera* Marsh.
Fir, balsam	*Abies balsamea* (L.) Mill.
Pine, jack	*Pinus banksiana* Lamb.
Pine, white	*P. strobus* L.
Poplar, balsam	*Populus balsamifera* L.
Spruce, black	*Picea mariana* (Mill.) BSP.
Spruce, white	*P. glauca* (Moench) Voss
Alder, grey	*Alnus rugosa* (Du Roi) Spreng.
Bearberry	*Arctostaphylos uva-ursi* (L.) Spreng.
Blueberry, Canada	*Vaccinium myrtilloides* Michx.
Bunchberry	*Cornus canadensis* L.
Cranberry, dry ground	*Vaccinium vitis-idaea* L.
Dewberry	*Rubus pubescens* Raf.
Grass, reed	*Calamagrostis canadensis* (Michx.) Nutt.
Hazelnut	*Corylus cornuta* Marsh.
Honeysuckle, bush	*Diervilla lonicera* Mill.
Lungwort	*Mertensia paniculata* (Ait.) G. Don.
Moss, Caribou	*Cladonia* spp.
Moss, Schreber's	*Calliergonella schreberi* (Willd., Br. & Sch.) Grout
Sarsaparilla	*Aralia nudicaulis* L.
Tea, Labrador	*Ledum groenlandicum* Oedr.
Twinflower	*Linnaea borealis* L.

APPENDIX II

The following is a typical profile on a moderately fresh silt-loam stony till, site group A:—

O_0	: 0.5″-0.25″. Herbaceous litter, needles, and decaying wood.
O_{00}	: 0.25″-0.0″. Brown to black decomposed herbaceous litter and charcoal.
$A_{2(p)}$*	: 0.0″-2.5″. 10YR8/2.** White; loam to loamy sand; stony; medium platy structure; pH 5.4.
$B_{(p)}$	: 2.5″-6.0″. 10YR7/3. Very pale brown; loamy sand; stony; medium platy to slightly crumb structure; pH 5.1.
$C_{(p)}$	: 6.0″-10.0″. 10YR8/2. White; loamy sand; stony; medium platy structure; pH 5.2.
B_2	: 10.0″-17.0″. 10YR7/4. Very pale brown; silt loam to clay loam; medium blocky structure; darker on inside of aggregates than on outside; pH 5.6.
B_3	: 17.0″-24.0″. 10YR7/4. Very pale brown; silt loam to loam; very slightly stony; fine blocky structure; pH 5.8.
C	: 24.0″+. 10YR8/2. White; silt loam, slightly stony till; somewhat platy structure; pH 7.4.

* Podzol profile developed on grey-wooded profile.
** Munsell Colour Chart.

APPENDIX III

The following is a typical profile on a moderately fresh loamy sand, site group C:—

O_0 : 1.0″-0.0″. Needle and leaf litter—partly decomposed towards the mineral soil; charcoal present.

A_2 : 0.0″-9.0″. 10YR6/3. Pale brown; loamy sand; fine platy structure; pH 6.4.

A_3 : 9.0″-16.0″. 10YR6/3. Pale brown; loamy sand; fine platy structure; pH 6.3.

B_2 : 16.0″-28.0″. 10YR5/6. Yellowish brown; loamy sand; structureless; pH 6.2.

B_3 : 28.0″-38.0″. 10YR5/4. Yellowish brown; pH 6.3.

B_4 : 38.0″-54.0″. 10YR5/4. Yellowish brown; pH 6.2.

C : 54.0″+. 10YR6/3. Pale brown; loamy sand; slightly compacted structure; pH 5.6.

APPENDIX IV

The following is a typical profile on a dry sand, site group D:—

O_0 & O_{00} : 0.5″-0.0″. Needle litter and Caribou moss, partly decomposed towards the mineral soil.

A_1 : 0.0″-1.0″. 10YR2/2. Very dark brown; coarse loamy sand; fine crumb structure; pH 6.0.

A_2 : 1.0″-5.0″. 10YR6/4. Light yellowish brown; loamy coarse sand; structureless; pH 5.8.

B_2 : 5.0″-15.0″. 10YR5/4. Yellowish brown; loamy coarse sand; fine sub angular blocky structure; pH 5.6.

B_3 : 15.0″-30.0″. 10YR5/6. Yellowish brown; coarse sand; structureless; pH 5.4.

C_1 : 30.0″-40.0″. 10YR5/4. Yellowish brown; coarse to medium sand; structureless; pH 5.2.

C_2 : 40.0″+. 10YR6/4. Light yellowish brown; coarse sand; structureless; pH 6.3.

APPENDIX V

Distribution of Plots by Cover Type and Stand Condition

Type of disturbance	Age of stand or former stand	Years since disturbance	Number of plots			
			Cover type			
			jP	jP/bS	Mwd/jP	Total
1—Undisturbed	35	.....	4			4
2—Clear cut, slash burned	35	12	7			7
3—Ground fire, clear cut, slash burned.	28	7	1			1
Ground fire	35	.....	1			1
4—Clear cut, slash burned	49	6	6			6
slash lopped and scattered, scarified	49	6 & 2	1			1
5—Clear cut, slash burned	49	6 & 7	6			6
6—Ground fire	55	35	1			1
7—Clear cut, slash lopped and scattered	60	2	4			4
slash lopped and scattered scarified	60	2	1			1
8—Partially cut tops left	90	10	1		2	3
slash lopped and scattered	90	10	1			1
Undisturbed	90	.....	1			1
9—Partially cut, slash lopped and scattered	60–80	2	2			2
10—Partially cut, slash lopped and scattered	100	2	2			2
11—Partially cut slash lopped and scattered	90	2 & 14	1			1
tops left	90	2 & 14	1		1	2
Undisturbed	90	.....	1	1		2
12—Burned (once)	70	12	3	1	3	7
13—Burned (twice)	.....	15 & 35	1			1
Totals	.....	.....	46	2	6	54