Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

Canada

Alberta

The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

L'Entente comprend trois programmes: Reboisement; Recherche appliquée, transferts de connaissances techniques et relevé des occasions; et Information, évaluation et administration. Ces programmes sont gérés par un Bureau de direction conjoint, et mis en oeuvre par le Service canadien des forêts et le Service forestier de l'Alberta.

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MIXEDWOOD MANAGEMENT INFORMATION COMPENDIUM

Prepared by;
Canadian Forestry Service,

TABLE OF CONTENTS

(Table of Contents continued)

forestry report

CANADIAN FORESTRY SERVICE — NORTHERN FOREST RESEARCH CENTRE

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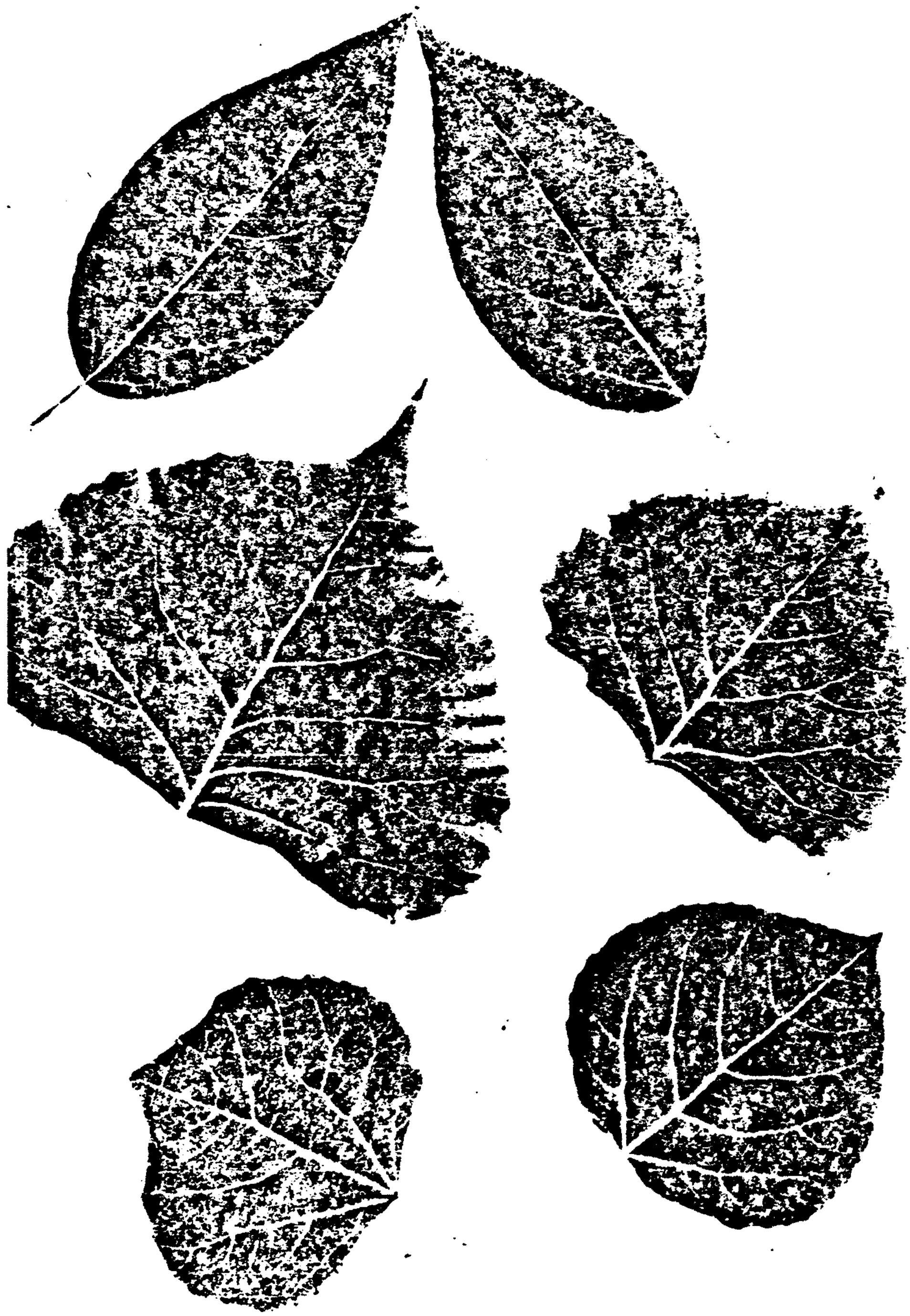

POPLARS in the Prairie Provinces

The story of poplars is an unusual tale – a rags to riches story. The poplar has gone from weed to valuable resource, because today this abundant species is being regarded by many as a possible source of newsprint, tissue, plywood and even livestock feed. Poplars provide choice winter and summer food for white-tailed deer and grouse, and the first prairie homes were built with and heated by poplar logs. Often considered a weed, the poplars of the Prairies are now facing a brighter future.

Poplars are fast-growing, short-lived trees supported by shallow, wide-spreading root systems. Aspen in particular propagates chiefly by means of suckers that arise from roots near the surface of the ground, a characteristic that is of great importance in the natural re-generation of poplar on cutover and burned-over areas. Other species sprout readily from stumps or shoots. This vegetative reproduction results in the development of large numbers of individuals of identical characteristics (clones) that may spread over 3 to 4 acres.

Besides being used by the wood-fibre industries, poplars are a familiar ornamental tree, and farm sites are made more attractive and protected from the sharp prairie winds by poplar shelterbelts.

This issue of FORESTRY REPORT is being devoted entirely to the familiar POPLARS of the prairie region, for if ever there was a tree that could boast of being a "true champion" of multiple use, it is the versatile poplar. In addition to serving a wide variety of man's needs, it provides home and food for wildlife, heals quickly our scarred landscape, and provides a brilliant splash of fall color to dazzle the eye.

Poplar Plantings on the Prairies

Tree planting on the plains of Canada was initiated by the then Forestry Branch, Canada Department of Interior, in 1901 for farm shelterbelts and uses other than forestry. A federal tree nursery was established at Indian Head in 1903 to produce and supply the deciduous and coniferous tree material for such plantings in the prairie region. A second federal nursery was established at Sutherland in 1913 to service the Northern areas of the prairies, but it was closed in 1966 to consolidate all operations at Indian Head.

Since 1909 the Indian Head and Sutherland nurseries in Saskatchewan have provided poplar material for 33,000 miles of plantings in the prairie region. Most of this material was utilized for farm shelterbelts (initially primarily in chinook areas), although 10% has been used in parks, conservation and urban developments. Annual demands for poplar gradually increased from 200,000 (Fig. 1) to over one million cuttings. However, demands declined from 1.3 million cuttings in 1929 to a low of about 100,000 cuttings in 1938 following planting failures due to periodic drought, disease and insect infestations. These adverse conditions decimated numerous poplar shelterbelts and nursery cutting beds. From the early 1940's until 1965 production and planting demands averaged about 250,000 plants. Production of superior clones and rooted cuttings increased planting demands in 1966 and 1967 to a high of 750,000 plants. Since 1969 with the development of mechanization and storage techniques only rooted cuttings have been produced to improve survival and development of prairie plantings. As a result demands continued to exceed production which has increased from 150,000 (1971) to 500,000 plants annually (1974). Nursery production problems have reduced available poplar material below the planting demand and production objective of one million rooted cuttings annually.

Research by nursery staff since 1948 has provided superior clones and equipment, propagation and storage techniques, controls for insects and diseases, and herbicidal and irrigation practices for expanding nursery production. Wider spacing for plantings were introduced in 1971 to improve survival of poplar in shelterbelts under climatic stresses.

Poplar material has also been provided for plantings in Alberta by the provincial nursery at Oliver since 1950. This material is utilized primarily for farm shelterbelts, and parks. From 1969 to 1973 material for 150 miles of plantings were planted in Alberta.

Some 200 clones, species and hybrids were collected or produced, and evaluations for performances (1, 2) initiated from 1948 to 1951.

Plantings to evaluate some 106 poplar clones for the prairie region were established in Manitoba, Saskatchewan and Alberta from 1965 to 1974. Although several of these plantings were initiated as co-operative studies with provincial and federal agencies, 21 were carried out by nursery staff (Fig. 2). Briefly these plantings have identified the most promising clones (Walker, Northwest, Saskatchewan, berolinensis, gelrica, tristis and cardeniensis). Severe winter injury in 1972-73 and 1973-74 of new poplar plantings, suggest that three clones were frost hardy.

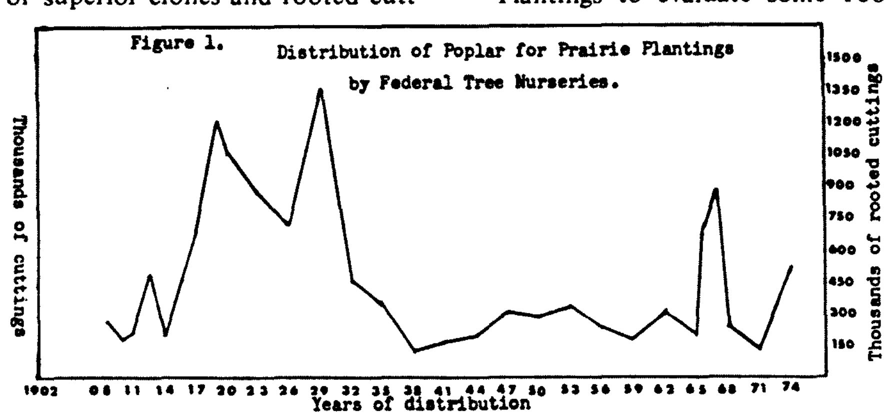

Fig. 2. Poplar regional test plantings of clones (1) Northwest, (2) gelrica, (3) Brooks, (4) Walker, (5) berolinensis

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The Familiar Poplar

Native poplar species in Canada are present in all parts of Alberta, Saskatchewan and Manitoba. Trembling aspen (Populus tremuloides Michx) and balsam poplar (P. balsamifera L.) are the most common poplars and occur throughout all three provinces. Although less common, the plains cottonwood (P. deltoides var. occidentalis Rydb.) grows throughout the Prairies. Largetooth aspen (P. grandidentata Michx) is limited to eastern Manitoba, whereas black cottonwood (P. trichocarpa Torr. and Gray) and narrowleaf cottonwood (P. angustifolia James) occur only in southwestern Alberta and southern Alberta and Saskatchewan respectively.

Sucker on aspen root

The poplars are intolerant pioneer species and will colonize a variety of habitats. The cottonwoods and balsam poplar prefer wet habitats including riverbanks and freshly exposed sandbars. The aspens will invade burns and cutovers on upland well-drained sites. The wetter depressions on these sites will tend to be occupied by balsam poplar.

Generally all the poplars are dioecious, i.e., male and female flowers occur on separate trees. Flowering usually starts at age 10 to 15. Regeneration by seed is more common with the cottonwoods and balsam poplar than the aspens, partly because of habitat characteristics.

Vegetative reproduction through root suckers is common with all the poplars. Stem cuttings of the cottonwoods and balsam poplars root readily. Rooting of aspen stem cuttings is almost nil. Some regeneration occurs through stump and root-collar sprouts, particularly with the cottonwoods and balsam poplar.

Of all the poplars on the Prairies the plains- and black Cottonwood probably grow to the largest size. They can reach a height of 100' or more and a stem diameter of several feet. Trembling aspen and balsam poplar are the most important species for the wood-using industry. The cottonwoods and their hybrids play an important role in the agricultural zone, where they are used for farm and amenity planting. ...

Wood Properties of Poplar

A number of economic reasons have been cited for the low level of utilization of the poplar resource. The central economic factor has been the ready availability of preferred softwood species which could be processed into the traditional wood products (lumber, pulp and plywood) at lower cost and with higher returns, than was possible with the poplars. A combination of two characteristics of the poplar resource: (1) the high proportion of relatively crooked, small diameter trees in natural stands and (2) the relatively high incidence of decay in mature stands, have largely contributed to the higher costs of processing poplars. However, with increasing demands for wood and fibre products and dwindling supplies of preferred species, a greater utilization of the poplar resource can be expected. Have the poplar species and principally trembling aspen the desired characteristics that will favor such increased utilization?

Because of the two above mentioned characteristics of the poplar resource, probably the greatest increase in utilization can be expected in fibre products such as pulp and paper, fibreboard and particleboard.

In pulping, poplar could be used either pure or in mixture with other species. Poplar kraft pulp is quite well suited for fine paper because of excellent sheet formation, high opacity, good bulk and good printability. Except for strength, it compares favorably with kraft pulps from softwoods (Table 1). The short fibre length of about 1.0 mm for poplar compared to 3.5-4.0 mm in most softwoods, and the lower proportion of tracheids in poplar are responsible for this lower strength. On the other hand, the high cellulose content, low lignin content, and ease of penetration by alkaline pulping liquors of poplars results in higher yields, lower alkali consumption, and faster pulping rates than for spruce at the same pulp lignin content.

Cont'd. Page 8

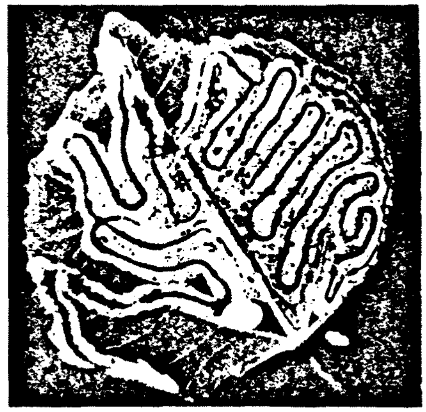
A wide variety of insects and mites feed on poplars. The Forest Insect and Disease Survey of the Canadian Forestry Service has records of at least 300 species of insects on living trembling aspen alone. Here we deal with some of the more important species attacking the catkins, leaves, branches, trunk, roots and causing the formation of galls on poplars especially trembling aspen.

The most common species damaging catkins are a micro moth, *Epinotia nisella* Clerk; a dagger

Malacosoma disstria

moth, *Anathix puta* (G. & R.) and weevils, *Dorytomus* spp. The larvae of the moths feed on buds or capsules of catkins and then on the developing leaves. The weevil bore into and consume the interior of the bud, stalk and main stem of catkins.

The largest group of insects feed on the leaves. Outbreaks of the forest tent caterpillar, *Malacosoma disstria* (Hbn.) and the large aspen tortrix, *Choristoneura conflictana* (Wlk.) have caused almost complete defoliation of trembling aspen in vast areas of the three Prairie Provinces for a number of years. The Bruce spanworm, *Operophtera bruceata* (Hulst) and the aspen twinleaf tier, *Enargia decolor* Wlk. have severely stripped the leaves of aspen in parts of Alberta. A leaf roller, *Pseudexentera oregonana* (Wlshm.) has caused serious damage to the



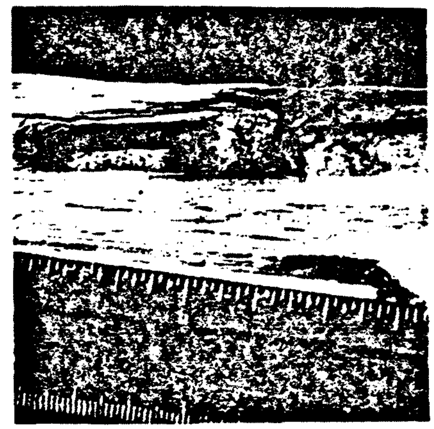
Phyllocnistis populiella

developing leaves. Unlike moths, which feed only on the foliage in the larval stage, the beetles consume the leaves in the larval and adult stages. Extensive damage has been caused by the aspen leaf beetle, *Chrysomela crotchi* Brown, the American aspen beetle, *Gonioctena americana* (Schaef.) and the gray willow-leaf beetle, *Pyrrhalta decora decora* (Say). Larvae of moths and beetles have also caused serious damage by feeding inside the leaf. The aspen leaf miner, *Phyllocnistis populiella* (Chambers) makes meandering mines in the upper and lower epidermis; the aspen blotch miner, *Lithocolletis salicifoliella* Chambers produces irregularly shaped blotches

Aceria parapopulion

by feeding on the mesophyll of the leaves; and the cottonwood leaf-mining beetle, *Zeugophora scutellaris* Suffr. attacks some of the hybrid poplars used as shelterbelts by mining the leaves in the larval stage and skeletonizing the leaves in the adult stage.

The most serious wood borer of aspen is the poplar borer, *Saperda calcarata* Say. Larvae of this beetle mine initially beneath the bark and then into the sapwood and heartwood. In small trees growing on poor sites, the poplar borer mine into the root and root collar. Damage by this insect degrades lumber and veneer and the tunnels serves as infection court for wood rotting fungi. The twigs and smaller branches are attacked by the twig borer, *Oberea schaumi* Lec. Trees weakened by natural factors such as defoliation, mechanical damage, wind



Saperda calcarata damage

breakage, etc. predisposes them to attacks by the bronze poplar borer, *Agrilus liragus* B. & B. and the ambrosia beetle, *Trypodendron retusum* (Lec.). The former produces zigzag galleries in the stem and branches and the latter bore into the woody tissues and feed on the ambrosia fungus, which stain the walls of their galleries.

Some of the insects and mites stimulate aspens to produce unsightly galls, which may persist on the trees for several years. The more common galls are caused by the poplar vagabond aphid, *Mordwilkoja*

# of POPLAR

vagabunda (Walsh) feeding on the leaf stipules; the poplar bud-gall mite, *Aceria parapopuli* (Keifer), attacking the new buds and newly unfolding leaves; and the poplar gall saperda, *Saperda inornata* Say tunnelling into twigs and small branches.

DEFECTS IN POPLAR:

Defects in poplar are receiving greater attention from natural resource managers, forest products users, nursery managers and urban and rural land owners as poplars are put to greater use. Defects may be caused by occasional epidemics of biological agents, but a more important and persistent cause is weather.

FROST INJURY

Night frost alternating with warm days during spring, fall and winter months causes a freeze-thaw condition that damages living tissues in the bark, leaf and sapwood of the tree. All species and hybrids are affected. Land form, night inversion temperature, alternate layers of cold and warm air, sudden invasion of cold or warm gusty winds, clearings, age and stand density influence the risk of frost damage. Defects in poplars caused by frost include girdling causing cankers and diebacks and growth deformities such as burls, brooms, leader proliferation and stunting. Other injury includes delay in growth and leafing out and interference with nutrient up-take and storage. What actually happens is the frost kills the tissues in localized parts of the stem and causes a weakening of the cells of the cambia around or below the killed portion. If the frost condition is such that the stem freezes all the way around or is girdled, dieback occurs but if the tissue on only one side of the stem is frozen a canker will form at that spot. It takes only two or three days for these symptoms to become visible. The cambia below the dieback and around the canker in the still-living part of the stem is damaged but not killed and subsequent growth of these tissues is abnormal. Shoot dieback results in growth proliferation on the lower living parts and gives rise to candelabra, forked leaders with narrow crotches and in extreme cases round crowns and a permanently stunted condition. Frost cankered stems can be very strong when vigorous burls and frost ribs form around and over the damaged parts in much the way as in spruce. Spruce burls are highly prized for decorative purposes such as lamp or gate posts but poplar burls are usually rough and unattractive.

Frost cankers and dieback in Russian Poplar showing damage and subsequent wind-breakage.

Gall and Rough Bark of Poplar:

The causal fungus *(Diplodia tumefaciens)* infects current and older woody stems including branches and main roots of all species of poplar and their hybrids. It can survive on a living host indefinitely. It does not kill the cambium but stimulates it to produce abnormally large amounts of inner bark and sapwood containing deformed cells. It's fruitifications produce water-dispersable conidia and air-dispersable ascospores. Infections result in galls or burl-like swellings that persist indefinitely on branches but not on the main stems where clearwood usually overgrows the tumors. Precautions to reduce infection include: planting poplar away from diseased trees, pruning and burning infected branches and removing severely infected trees.

Gall and rough bark caused by Diplodia tumefaciens

Septoria Canker and Leaf Spot

The causal fungus *(Septoria musiva* Pk.) infects and kills living cells in leaves and thin bark of nursery trees of most poplars except aspen. It is not perennial and renews itself by annual infections that result in a localized leaf spot and in a canker affected only after the cambium is killed. The fungus does not infect thick bark, nor cause economic losses in fully established ~~or~~ mature trees as once thought. The canker reduces the quality of the seedlings, rooted stock and whips utilized for cuttings. Infections occur during the short warm growing season and cease when cool nights and early frost effect an early leaf drop. The fungus overwinters on fallen and attached leaves and produces mature air-borne ascospores in the spring.

UTILIZATION of POPLAR[6]

The Resource

Interest in poplar as a commercially important species has existed across the prairies and, for that matter, in North America for some several decades, as match splints, lumber and lumber type products, peeler logs, pulpwood and fuelwood. More recently greater attention has been given poplar in the area of pulpwood and other fibre products such as flakeboard, particle board and similar products. Recent investigations have indicated that aspen fibre has a potential use in livestock diets.

Even greater consideration of poplar as a commercially important species, in league with spruce, pine and fir, is evidenced by the number of seminars, symposiums and conference held in the past ten years on the utilization of poplar.

In the prairie region of Canada (Manitoba, Saskatchewan and Alberta) recent forest inventories indicate a volume of 355 million cunits* of poplar. This volume includes both the trembling aspen and balsam poplar species. The percentage of balsam poplar included in this volume varies from province to province and ranges from 13 percent in Manitoba to approximately 20 percent in Alberta. It is included in this analysis because it is harvested commercially for various products and in varying amounts in each of the provinces.

The volume of poplar expressed in terms of annual allowable cut amounts to 6.2 million cunits.

Harvesting Levels

The harvest of poplar on the prairies is directed at the manufacture of conventionally or well-known primary wood products. Lumber, veneer, various types of particle board, flakeboard or wafer board, pulpwood in round and chip form and fuelwood. In past match splints were produced in Manitoba.

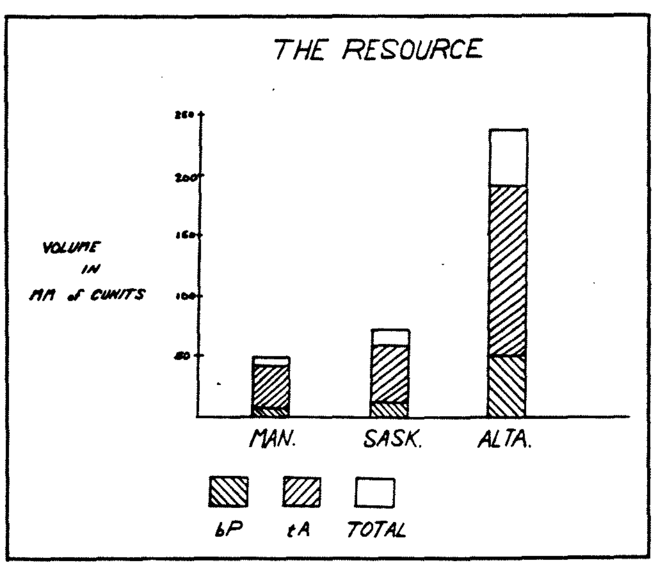
The current utilization level of the poplar resource in the prairie region is approximately 227,400 cunits annually. This amounts to about 3.7 percent of the annual allowable cut. Saskatchewan harvests the greatest volume of poplar of the three provinces (144,500 cunits), approximately triple that of Alberta and four times that of Manitoba.

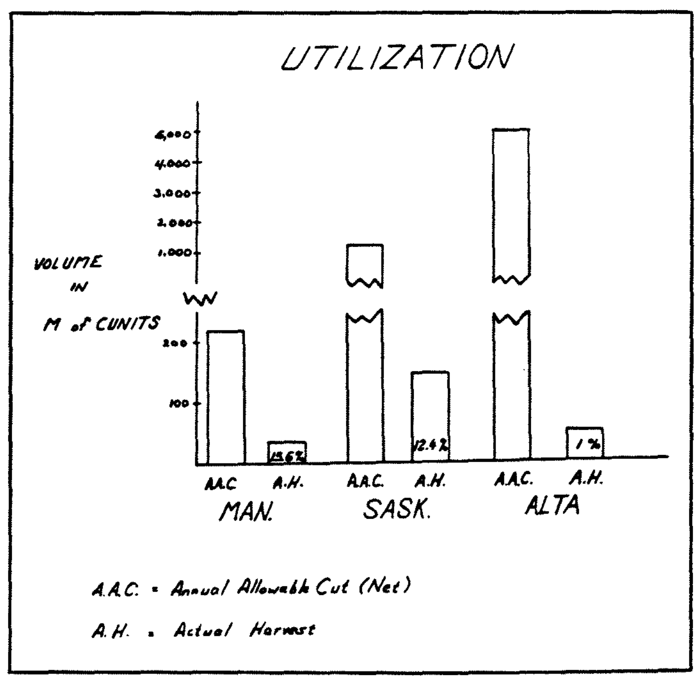
Secondary and tertiary manufacture of primary products include plywood, studs, poplar slugs, grain doors, furniture components and furniture, fish boxes and other containers, insulation material, various forms of exterior and interior sheathing pallets and sewer cribbing.

An aspect of utilization that should be considered is that pertaining to provincial policies in the management of poplar stands. Provincial policies in the past can be briefly summarized by saying that if a market existed producers were awarded volumes deemed necessary to meet the demand. The best quality trees were selected from stands over a two or three cut cycle. Only the best logs of each tree were used unless producers had markets for top and poorer quality logs.

The management trend today is towards complete utilization of

**A measure of wood, equal to 100 cubic feet of solid volume. One cunit equals about 1.17 cords.*





whole trees and stands. Poplar sites are reforested more easily and economically to an optimum level of stocking using a clear cut harvesting method. Logging equipment in the bush today aids the attainment of this objective.

Poplar Management policies on the prairies can be summarized thusly.

- Clear cutting of all poplar sites.
- Limiting the overall size of clear cuts and the management of poplar on an acreage basis.
- Utilization to minimum top diameters of four (4) inches inside bark.
- Utilization of individual logs containing up to 50 percent rot.
- Utilization of logs with external defects (crook, sweep, etc.)
- The integrated use of all species (coniferous and deciduous) in mixed wood stands.
- Cutting and operating plans prepared by producers, and approved by forest services, identifying the maximum but sustained utilization of poplar on their licence areas.
- Where applicable insistence on the development of manufacturing plants capable of using both deciduous and coniferous species.
- The utilization of trees in poplar stands to minimum stump diameters.
- Penalties for under cutting allowable cuts of poplar volumes set out in management areas plans and licences.
- The responsibility of producers to participate in active reforestation programs.
- Encouraging the use of poplar through the application of rates of dues that are slightly lower than those for coniferous species.

...

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FIGURES USED

Saskatchewan	balsam poplar	10.663.610 cunits)	69,115.500
	trembling aspen	58,451.890 cunits)	
Manitoba	balsam poplar	5.940.000 cunits)	46,097.142
	trembling aspen	40,157.142 cunits)	
Alberta	balsam poplar	48.000.000 cunits)	240,000.000
		192,000.000 cunits)	

	Allowable Cut	Actual Harvest
Saskatchewan	1,164,500 cunits	144,500 cunits
Manitoba	223,230 cunits	34.928 cunits
Alberta	4,800,00 cunits	48,000 cunits

Hybrid Poplars in the Forest Zone of Saskatchewan

The Northern Forest Research Centre obtained white, gray and trembling aspen hybrids from the Research Branch of the Ontario Ministry of Natural Resources in the spring of 1971, to test their adaptability to the harsh climate of central Saskatchewan.

Cuttings were rooted in pots and outplanted in the Prince Albert nursery, Saskatchewan. Although height growth was impressive during the first growing season (average of 27"), the current growth was not hardened off when first frost occurred in the fall and all plants were top-killed. In 1972 more cuttings of these hybrids were obtained and planted in the nursery. During the following winter all plants were completely killed, probably due to the lack of deep snow cover. It appears from this trial that hybrids of white, gray and trembling aspen, originating from Europe, Asia and North America, are not hardy in central Saskatchewan.

In 1971 and 1972 the Forestry Branch planted the following hybrid poplars developed for the Prairie Provinces on recent cut-over areas of MacMillan Bloedel Company Limited in Hudson Bay, Saskatchewan.

Saskatchewan poplar
Walker poplar.
Vernirubens poplar
Brooks No. 1
Trembling aspen (local)
Gelrica poplar
Dunlop poplar
Northwest poplar

Some of the planting sites were cultivated prior to planting. This preparation was beneficial for both survival and subsequent growth of the rooted cuttings, especially on the older cutovers. Where natural aspen suckering provided shelter, rabbits caused considerable damage to the planted material.

Based on preliminary observations by the Saskatchewan forestry branch, Northwest, Vernirubens, Saskatchewan and Walker showed best performance in terms of survival, hardiness and height growth. These results provide only early indications on the performance of hybrid poplars under forest conditions in Saskatchewan.

WOOD PROPERTIES cont'd.

TABLE 1. Major Wood, Pulping and Pulp Characterics[a]

Characteristic	Trembling Aspen	White Spruce
Specific gravity	105	100
Pulping rate	165	100
Alkali consumed	95	100
Pulp yield	125	100
Pulp strength[b]	70	100

a Relative to white spruce arbitrarily designated 100.

b An average factor based on tear factor, burst factor and breaking length.

Excessive amounts of cubical rots could seriously affect yield and quality of poplar kraft pulps. However, 10% white rot is probably acceptable. White rot is the common decay in poplar and only the advanced stages present a problem in pulping.

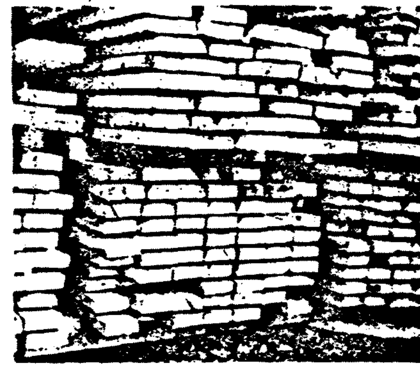
Poplar could be mixed with common softwoods in the kraft process up to a proportion by weight of 10% without any detectable decrease in strength properties. However, technical disadvantages would include the maintenance of a constant hardwood: softwood chip feed ratio, and selection of the most suitable pulping schedule to minimize the effects of different pulping rates. There might also be problems with customer acceptance of mixed hardwood-softwood kraft pulps. The mechanical pulps and specifically the chemi-mechanical pulp from poplar show excellent tear factors compared with white spruce and would find major outlets principally as newsprint, but also as magazine and book stock.

Fibreboards, a product of the mechanical pulping process, can be manufactured just as well or better from poplars as from softwoods because of their low density and good quality fibres. However, due to economic and market factors, the potential for greater use of poplars in fibreboards is somewhat limited at present.

The rapid growth rates in the particleboard industry, and the preference for relatively low-density species in particleboards, promises increased use of the poplar resource in these products. The good compressibility of poplars at low pressures results in a board with a smooth surface and adequate strength at low density. In Canada, waferboard has recently emerged as the fastest growing segment of the particleboard industry, and all existing and planned production is from poplar roundwood.

The potential for increasing poplar plywood production is not high because of inadequate supplies of high quality logs, and a number of production difficulties caused by tension wood, wet pockets, ring shake and soft cores.

Lumber production, particularly factory lumber, has been limited, because of high decay incidence and small diameter stands. Recovery for framing lumber is more promising.



Aspen lumber

Studies indicate that a satisfactory recovery of 2-inch construction lumber is attainable from at least 75% of the merchantable volume of most trembling aspen stands. In lumber strength, the "northern aspen" species group (including trembling and largetooth aspen, and balsam poplar) is similar to the "spruce-pine-fir" species group, and for many uses the two groups are interchangeable. Although the drying of poplar lumber presents some difficulties due to the presence of wet pockets, one commercial schedule has recently been developed, and further work is underway.

Because it lacks highly toxic extractives, poplar wood is quite susceptible to decay under conditions favoring fungal growth. However, indications are that, if properly dried, aspen will take preservatives equally well or better than most softwoods. Hence there exists the potential of using preservative-treated poplar in applications which require decay resistance.

Environment Canada | Environnement Canada
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forest management note

Note No. 1 **Northern Forest Research Centre** **Edmonton, Alberta**

SITE INDEX CURVES FOR ASPEN IN THE PRAIRIE PROVINCES

Site index (SI), the average height of dominant trees at a specified reference age, has been widely accepted and used to describe site quality and productivity of even-aged, single-species stands. Trembling aspen (*Populus tremuloides* Michx.) in Alberta, Saskatchewan, and Manitoba usually grows in such stands.

Although the extensive aspen resource in the B.18a Mixedwood Forest Section (Rowe 1972) generally has been unexploited in the past, its use is now increasing, and a need is emerging for information related to the growth, yield, and productivity of aspen stands. One specific need is for a common set of aspen SI curves for the mixedwood forests of western Canada in a form that would lend itself to computer processing.

Based on available data, the following equation was developed to express the relationship between dominant height, stand age, and SI:

$$H_{dom} = 11.2831X + 16.3545X^2 - 29.9919X^3 - 27.3295X^4 + (1.0 + 0.5131X - 1.8902X^2 + 2.4873X^3)SI$$

where $X = (\text{age} - 50)/100$

Using the above equation, height curves were calculated for ages 10 to 80 years for SI classes of 12, 14, 16, 18, 20, and 22 m at age 50; they are illustrated in Fig. 1. To estimate mean H_{dom} and age on a sample plot, three or four trees are usually sufficient if the plot is stocked primarily with one aspen clone or even with different clones of similar height growth characteristics (Steneker and Wall 1970). If several clones of different height growth characteristics are present, some proportional sampling scheme should be used to estimate H_{dom}. Having an estimate of present H_{dom} and age, future height can be found simply by following the curves to the desired age and reading the corresponding height.

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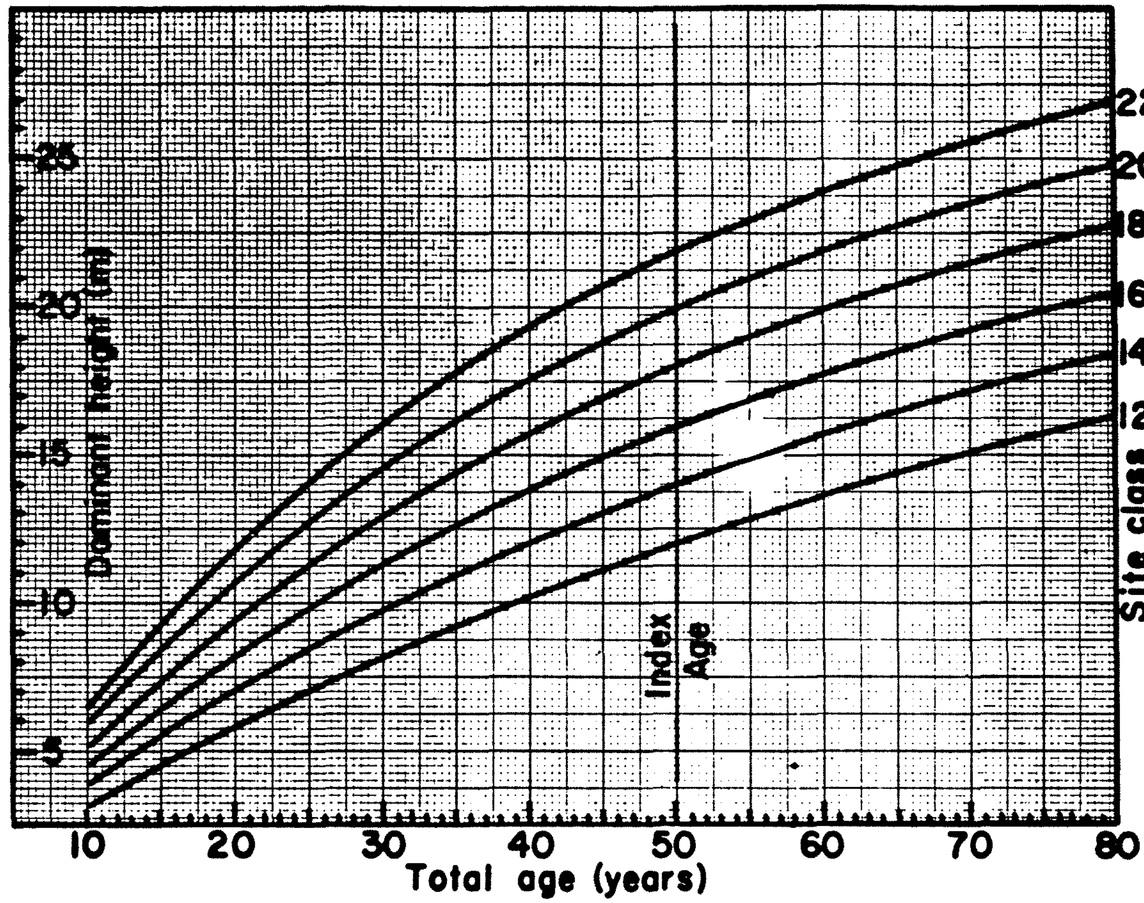

Figure 1. Site index curves for aspen.

DATA AND ANALYSIS

Site index curves may be prepared from measurements of height and age in a number of stands or from stem analysis of selected sample trees. An estimate of SI is available directly from the latter using measured height at reference age and also from projected heights from other ages.

Three sets of data were used to prepare the SI curves presented here:

1) values read from hand-drawn SI curves (plot data) in an unpublished report (CFS file A-9) on aspen growth and yield in central and northern Alberta,
2) values read from hand-drawn curves (plot data) published by Kirby *et al.* (1957),
3) from stem analysis of 30 suitable dominant aspen trees around 80 years of age sampled near Hudson Bay, Saskatchewan. Field sampling was done by the Aspenite Division of MacMillan-Bloedel Ltd., and laboratory analysis was by the CFS.

For deriving the present SI curves, an approach was used similar to that described by Johnson and Worthington (1963), Johnstone (1977), and others. Plotting all data revealed that the two sets of values read from the SI curves generally overlapped and were well within the midranges of the stem analysis data.

Linear regressions for each 5-year age interval were derived from these data using the form:

$$H_{dom} = a + b\ SI$$

Each value read from the SI curves represented many more source data points than the interpolated values from stem analysis. To allow for this, arbitrary weights were assigned: 3 to the Alberta and 4 to the Saskatchewan points. These weights were related inversely to the number of levels of SI curves (5 and 3, respectively) and hence to the number of values read. Thus the values from the two SI curves provided 27 data points compared to 29 points from the stem analyses (data from one tree was rejected).

To combine the above series of regressions, intercept values (a's) thus derived were fitted over age using polynomial models conditioned to zero at age 50. A 4th-degree polynomial provided a satisfactory fit:

$$a = 0.0 + 11.2831X + 16.3545X^2 - 29.9919X^3 - 27.3295X^4$$

where $X = (\text{age} - 50)/100$, $n = 16$, $R^2 = 0.999$

Similarly, b coefficients were fitted over age using polynomial models conditioned to equal 1.0 at age 50. The following model provided a satisfactory fit:

$$b = 1.0 + 0.5131X - 1.8902X^2 + 2.4873X^3$$

where $X = (\text{age} - 50)/100$, $n = 16$, $R^2 = 0.999$

Substituting the regressions for a and b into the general model ($H_{dom} = a + b\ SI$) resulted in this final SI equation:

$$H_{dom} = 11.2831X + 16.3545X^2 - 29.9919X^3 - 27.3295X^4 + (1.0 + 0.5131X - 1.8902X^2 + 2.4873X^3)SI$$

where $X = (\text{age} - 50)/100$

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GROWTH-DENSITY RELATIONS IN YOUNG ASPEN SUCKER STANDS

BY

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Bella, I.E. 1975. Growth-density relations in young aspen sucker stands. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-124.

ABSTRACT

Using diameter increment data from thinning experiments conducted in 3-, 5-, and 6-year old aspen (Populus tremuloides *Michx.) stands in the Mixedwood forests of Alberta and Saskatchewan, it was inferred that stand density has a significant effect on growth, and crowding may reduce by half the diameter increment of dominant and codominant trees at an age as early as 5 years. It is suggested that thinning, even at this early age, may be effective for improving diameter increment in similar stands.*

RESUME

Utilisant des données d'accroissement de diamètre par suite d'expériences d'éclaircies conduites en peuplements de Tremble, Populus tremuloides *Michx., de 3, 5 et 6 ans en forêt mixte en Alberta et en Saskatchewan, l'auteur conclut que la densité du peuplement influe significativement sur la croissance, et que le resserrement peut réduire de moitié l'accroissement du diamètre d'arbres dominants et codominants âgés d'aussi peu que 5 ans. L'auteur suggère donc d'éclaircir dès lors afin d'améliorer l'accroissement du diamètre en peuplements similaires.*

TABLE OF CONTENTS

INTRODUCTION

The utilization of our aspen resource has accelerated in the last decade and it is now of some economic importance. Its future is especially promising. This means the coming of age of aspen stand management, which requires related silvicultural knowledge. Growth and development trends of young stands that have become established after logging are of particular interest, first because there is a relative lack of such information on these stands, and secondly because here the manager has the opportunity to influence future stand development with very little or no additional cost by the way he conducts his logging operations in the parent stand.

A recent study (Bella and De Franceschi 1972) provided information on how logging practices influence the abundance of sucker regeneration and on the course of early stand development in terms of number of stems per acre. The present study evaluates the effect of density on tree growth in juvenile stands. This information can be of direct use to the forest manager, and it is also needed in research work aimed at improving growth and yield prediction techniques.

DESCRIPTION OF THE STUDY AREAS

The data for this analysis were taken from a thinning experiment in juvenile aspen stands *(Populus tremuloides* Michx.). At two localities, tree and stand data from permanent sample plots were obtained from stands treated at age 3 and 6 years (Hudson Bay, Sask.) and at 5 years (Slave Lake, Alberta).

The stands were growing on what were considered average sites for aspen at these locations. At establishment of the study, care was taken to minimize site variation. At Hudson Bay the soils were clay-loam with fresh to moist moisture regime; topography was flat and elevation about 300 m (1000 ft). At Slave Lake the soils were sandy silt-loam with fresh moisture regime. Topography was hilly and elevation about 600 m (2000 ft).

The stands were nearly pure aspen, with a sprinkling of balsam poplar *(P. balsamifera* L.). In Saskatchewan, the young stands originated after logging; in Alberta, after an extensive wild fire. The forests at both localities belong to the Mixedwood Section, B18a, of the Boreal Forest Region (Rowe 1972).

METHODS

The quickest way to obtain information on the effect of density on tree growth is through sampling untreated stands of different densities in the desired age group and sites using temporary sample plots. Tree size characteristics are then related to stand density using regression analysis. This approach, however, is unsuitable in aspen stands because the species' clonal habit can result in substantial differences in tree growth and size which tend to obscure density effects.

Growth-stand density information, however, can be obtained experimentally from thinning studies. This method has the drawback of providing information only at actual treatment levels (which are limited in number and yield discontinuous data) rather than over a wide range of density conditions. As well, relationships derived from data obtained in treated stands can be extrapolated to untreated stands only with caution.

The present analysis was based on the first 2-year increment data from strip and selection thinning experiments. The strip thinning left 3-m (10-ft) parallel residual strips between cut strips of 1.2, 1.8, 2.4, or 3.0 m (4, 6, 8, or 10 ft) width, which were to represent different thinning intensities. Selection thinning was done to .9 m (3 ft) and 1.2 m(4 ft) spacings. Figure 1 illustrates stand conditions and treatments at re-examination in the autumn of 1974.

Six 3 x 3 m (10 x 10 ft) plots were established for each treatment level and age group, including untreated controls, except at Slave Lake, where selection thinning intensities were replicated only three times (Table 1). There was a total of 120 plots. Data from two plots from the 5- and from the 6-year-old stands were later discarded because of damage, and in the 3-year-old stand the entire selection thinning treatment had to be abandoned because of extensive mortality from undetermined factors.

Measurements on the plots included a dbh tally of all trees to the nearest .25 cm (1/10 in.); those under breast height were counted. In addition, individual tree measurement data in dbh (to .01 cm) and height (to 3 cm or 0.1 ft) were obtained for 5-12 healthy dominant and codominant trees that had been tagged at plot establishment. Two of these were the largest aspen trees on the plot, while the remainder were selected from two 60-cm (2-ft) wide strips adjacent to the open edge after strip thinning. Tagged trees on the control plots were selected also in two similar strips on plot borders. On selectively thinned plots all residual trees were tagged.

Covariance techniques were used in the analysis. This means that trend lines of tree increment over initial tree size (i.e. diameter increment over dbh) were compared, rather than simply means of tree increment between different treatment (stand density) levels. Thus, initial differences in tree growth and dbh that might reflect clonal or micro-site variations were considered, and appropriate adjusted means calculated for treatment comparisons.

RESULTS AND DISCUSSION

Two-year diameter increment trends of the tagged dominant and codominant trees over initial diameter in 1972 are presented in Figure 2. They show first of all that increment was dependent on and increased with initial dbh, and secondly that the treatment resulted in significant differences between dbh increment trends (those shown are different at .05 level probability). In all three age classes increment was lowest in the control stand, higher in the strip thinned, and generally highest in the selectively thinned stands. No conclusive trends could be established for height increment.

In the 3- and 5-year-old stands, although the trends for different treatments were at different levels, there was no significant difference between their slopes (i.e. rate of increase) within an age group. This means that there was no real difference in absolute response in diameter increment between dominant and codominant trees of different sizes (dbh). Therefore, adjusted treatment means were calculated using a common slope.

In the 6-year-old stand there was no significant difference between increment trends after strip and selection thinning, so they were combined in a common regression line. The slope of this common line for treated stands and that of the control stands were not significantly different, so again adjusted means could be calculated using a common slope.

Adjusted diameter increment means of tagged trees by age and treatment are presented in Figure 3. The highest increase, 75%, occurred after selection thinning in the 5-year-old stand, while after strip thinning the increase was half as much, i.e., 37%. In the 6-year-old stand, the two thinning treatments combined resulted in nearly a 50% improvement in diameter increment. The least improvement in increment was 33%, which occurred in the 3-year-old stand after strip thinning.

The best growth and the best response to release occurred in the 5-year-old stand located at Slave Lake. The best growth occurred despite the fact that this stand had the highest density of the three stands studied. This high density however would explain the particularly good response to thinning treatment. The superior growth of aspen here seems to be related to environmental factors that make this region almost optimal for the development of this species.

Generally, these results indicate that there is already a substantial negative density effect on stem growth at around 5 years of age in dense aspen stands. Even at this early age, crowding may reduce diameter increment by as much as half of what it could be under more open stand conditions. This is inferred from accelerated diameter increment of up to 75% within two growing seasons, after a reduction of density by selection thinning to .9 m and 1.2 m (3 ft and 4 ft) spacings in dense young stands. It is very likely that in subsequent years there would be an even greater increase in diameter increment in the thinned stands, as it generally requires more than 2 years for the affected trees to take full advantage of increased growing space.

This conclusion is supported by the results of the study on the effect of logging practices on the development of new aspen stands (Bella and De Franceschi 1972), where juvenile stands with high initial density suffered heavy mortality in the first 5 years of their life. This also suggests overcrowding and density effects in these stands.

The response in tree growth was somewhat less pronounced after strip thinning because initially at least, only trees immediately adjacent to the open strip gained extra growing space, while those farther in the residual strip were hardly affected. In other words, this thinning creates unstocked areas in the cut strips, while leaving stand density unchanged in the residual strips.

Although this analysis is not intended to evaluate the effectiveness and relative merit of the two kinds of thinning treatment for improving tree growth in dense juvenile aspen stands, there is enough information here to say that even as early as 5 years of age, thinning treatments such as the above are effective for the purpose of improving diameter increment. However, additional measurement data are required for detailed evaluation.

ACKNOWLEDGEMENTS

The sample stands at Hudson Bay, Saskatchewan were located within the company limits of the Aspenite Division of MacMillan-Bloedel Ltd. Company personnel cooperated in locating suitable sample stands and also provided technical assistance in plot establishment and measurements. Mr. J. P. DeFranceschi, Forestry Research Technician, CFS, was in charge of field work and ran the statistical analyses required for this report.

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TABLE 1 STAND AND TREE STATISTICS AT STUDY ESTABLISHMENT IN 1972.

Stand Age (years)	Treatment	Number of Plots	Number of Trees[a] Average	Number of Trees[a] Minimum (per ha) (per acre)	Number of Trees[a] Maximum	Diameter at breast height[b] Average	Diameter at breast height[b] Minimum (cm) (inches)	Diameter at breast height[b] Maximum
3	Strip thinning	24	61,175	27,986	86,111	0.51	0.0	2.03
			24,757	11,326	34,848	0.20	0.0	1.2
	Selection thinning	12	59,381	41,979	72,118	0.61	0.0	2.29
			24,031	16,988	29,185	0.24	0.0	0.90
	Control	6	64,583	40,903	83,958	0.52	0.0	2.03
			26,136	16,553	33,977	0.20	0.0	0.8
5	Strip thinning	24	50,142	27,986	87,188	1.07	0.0	3.30
			20,292	11,326	35,284	0.42	0.0	1.3
	Selection thinning	6	46,105	23,680	74,271	1.22	0.0	2.79
			18,658	9,583	30,056	0.48	0.0	1.1
	Control	6	48,079	33,521	63,507	1.16	0.0	3.05
			19,457	14,375	25,700	0.46	0.0	1.2
6	Strip thinning	24	29,915	17,222	50,590	1.61	0.0	4.06
			12,106	6,970	20,473	0.63	0.0	1.6
	Selection thinning	12	34,086	22,604	47,361	1.58	0.0	3.30
			13,794	9,148	19,166	0.62	0.0	1.3
	Control	6	33,189	22,604	46,285	1.68	0.0	3.56
			13,431	9,148	18,731	0.66	0.0	1.4

a Includes all living aspen and poplar trees on plot.

b Trees less than 1.37 meters (4.5 feet) in height were given dbh=0.0.

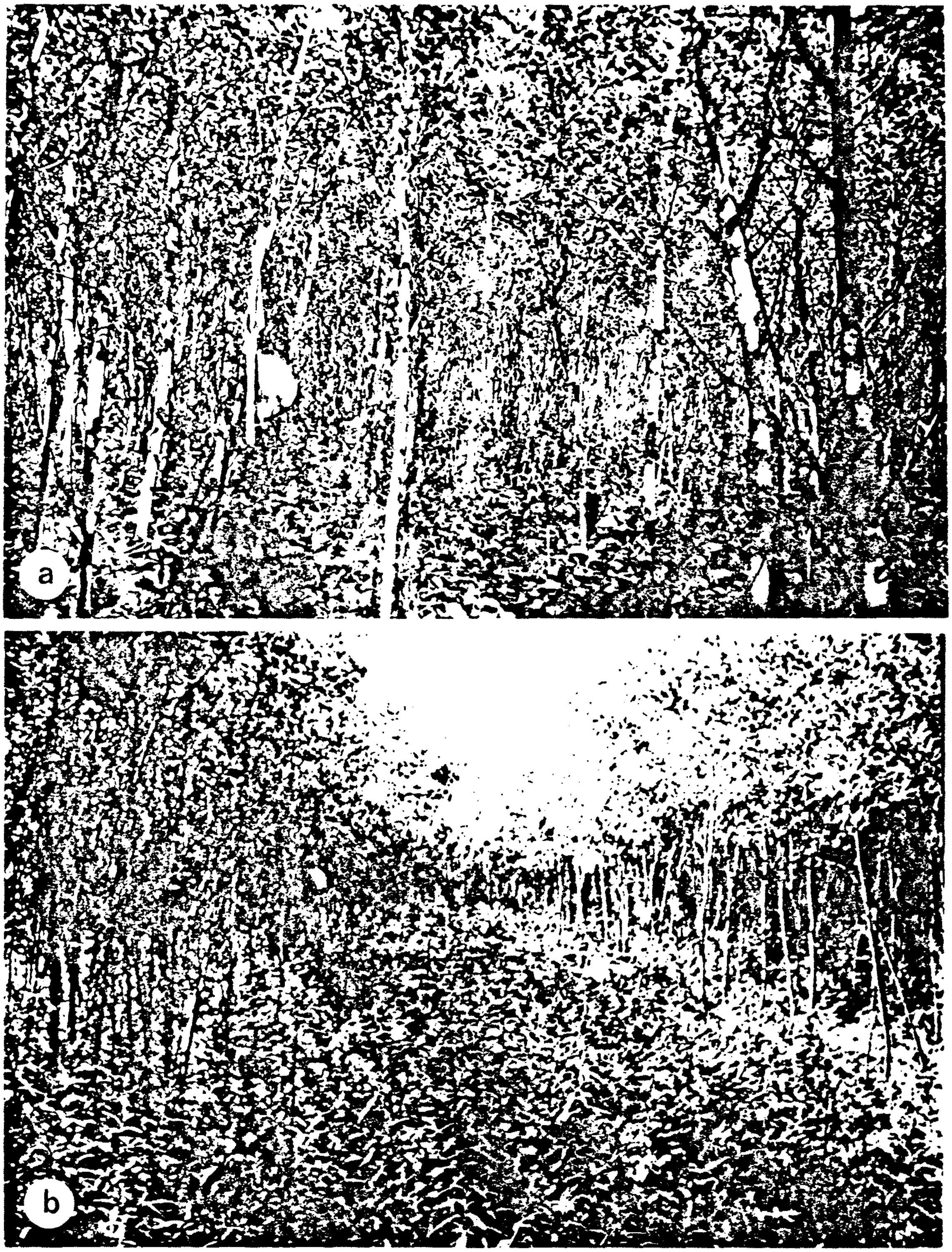

Figure 1. An 8-year-old aspen stand in Hudson Bay, Sask., treated 2 years earlier:

(a) selectively thinned to 1.2 m (4 ft) spacing,
(b) strip thinned, 3 m (10 ft) cut strips.

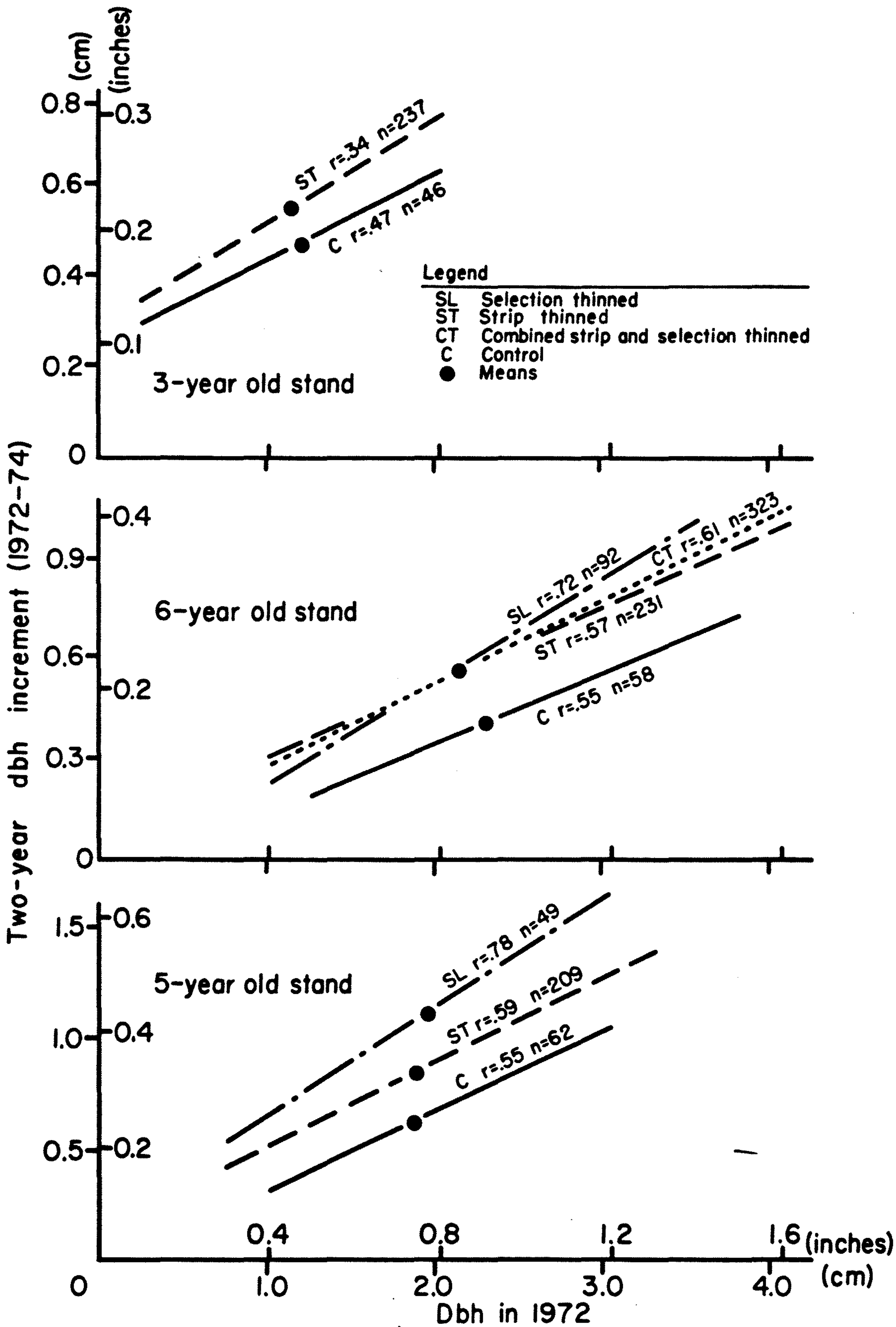

Figure 2. Diameter increment over diameter trends by treatment of dominant and codominant sample trees in 3-, 5-, and 6- year-old aspen stands.

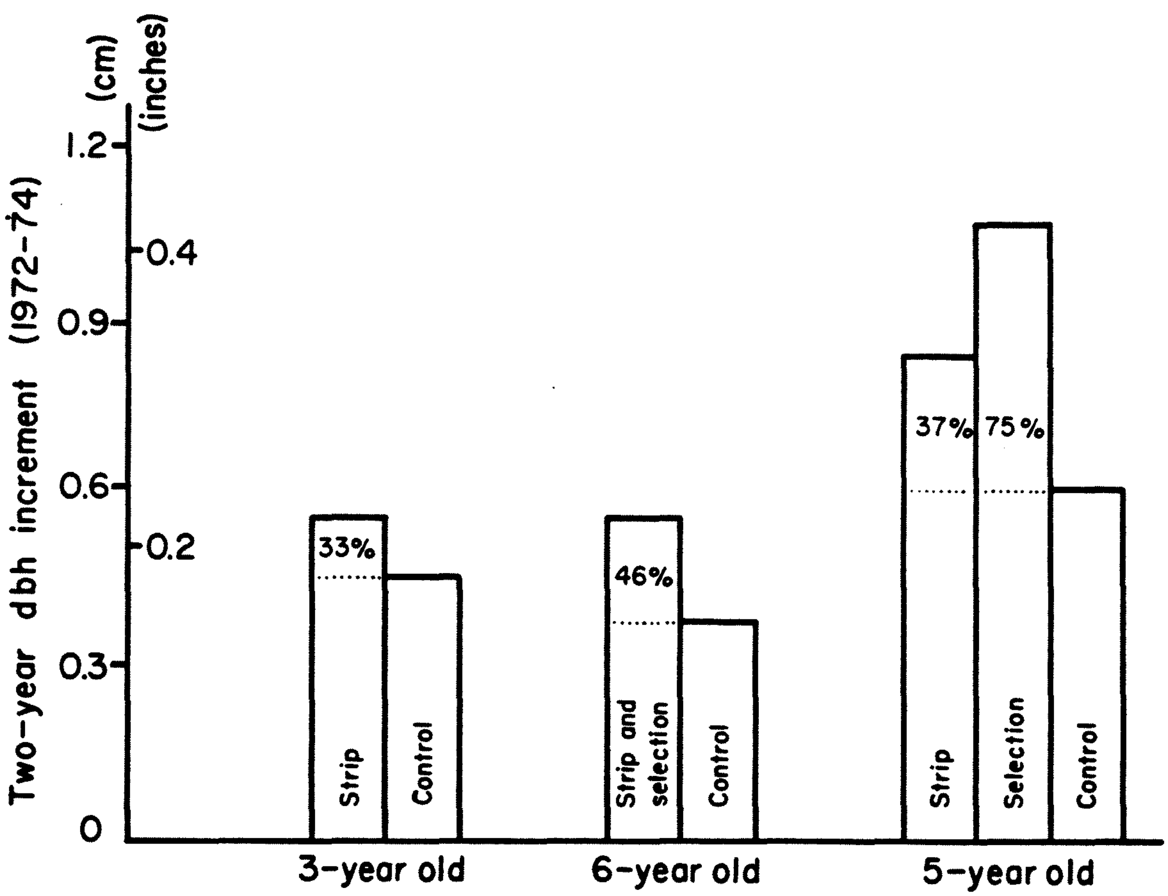

Figure 3. Diameter increment by treatment (adjusted means) of dominant and codominant sample trees in 3-, 5-, and 6-year-old aspen stands.

Interim Equations and Tables For the

YIELD OF FULLY STOCKED SPRUCE-POPLAR STANDS IN THE MIXEDWOOD FOREST SECTION OF ALBERTA

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Johnstone, W.D. 1977. Interim equations and tables for the yield of fully stocked spruce-poplar stands in the Mixedwood Forest Section of Alberta. Fish, Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-175

ABSTRACT

Least-square equations were derived to predict the yield of natural, fully stocked spruce-poplar stands of the Mixedwood Forest Section in Alberta from age and site productivity. The equations give reliable yield estimates, particularly for the softwood stand-component, over a wide range of age and site conditions. Yield estimates, in metric units, are tabulated for stands ranging in age from 20 to 140 years at 0.3 m growing on sites ranging from 12.5 to 25.0 m at 70 years stump age. The importance of considering both site quality and degree of utilization in managing mixedwood stands is discussed.

RESUME

L'auteur a dérivé des équations des moindres carrés pour prévoir le rendement des peuplements naturels entièrement remplis d'Epinette-Peuplier de la section Forêts mixtes de l'Alberta, du point de vue âge et productivité. Les équations fournissent des évaluations de rendement fiables, particulièrement chez les composantes des peuplements re résineux, couvrant une vaste gamme d'âges et de conditions de stations. Les estimations de rendement en unités métriques sont disposées en forme de tables pour les peuplements âgés de 20 à 140 ans à 0.3 m, croissant sur des stations variant entre 12.5 et 25.0 m, à l'âge d'exploitation 70 ans. L'auteur nous renseigne sur l'importance de considérer à la fois la qualité de la station et le degré d'utilisation dans l'aménagement des peuplements mixtes.

CONTENTS

INTRODUCTION

White spruce (*Picea glauca* (Moench) Voss) is the most prominent and commercially important conifer in Alberta. In 1972, this species made up about 45% of the gross merchantable volume of primary coniferous growing stock on productive crown forest land in Alberta and constituted 74.1% of Alberta's total sawmill production (Teskey and Smyth 1975). A large proportion of the province's white spruce inventory is located in the Mixedwood Forest Section (B18a) of the Boreal Forest Region (Rowe 1972) where the spruce-poplar is the dominant forest type. Stands in the spruce-poplar type are composed principally of white spruce interspersed with aspen (*Populus tremuloides* Michx.), but commonly contain some balsam poplar (*Populus balsamifera* L.) and white birch (*Betula papyrifera* Marsh.). These stands are most often of fire origin and therefore are usually even-aged.

With the continued expansion of Alberta's forest economy, there is an increasing need for reliable yield information upon which rational forest management planning can be based. The only yield information presently available for Alberta's spruce-poplar stands is that provided by MacLeod and Blyth (1955). Although this information has been useful in the past, it is available only in a tabular form that seriously limits its use in today's computerized inventory and planning systems.

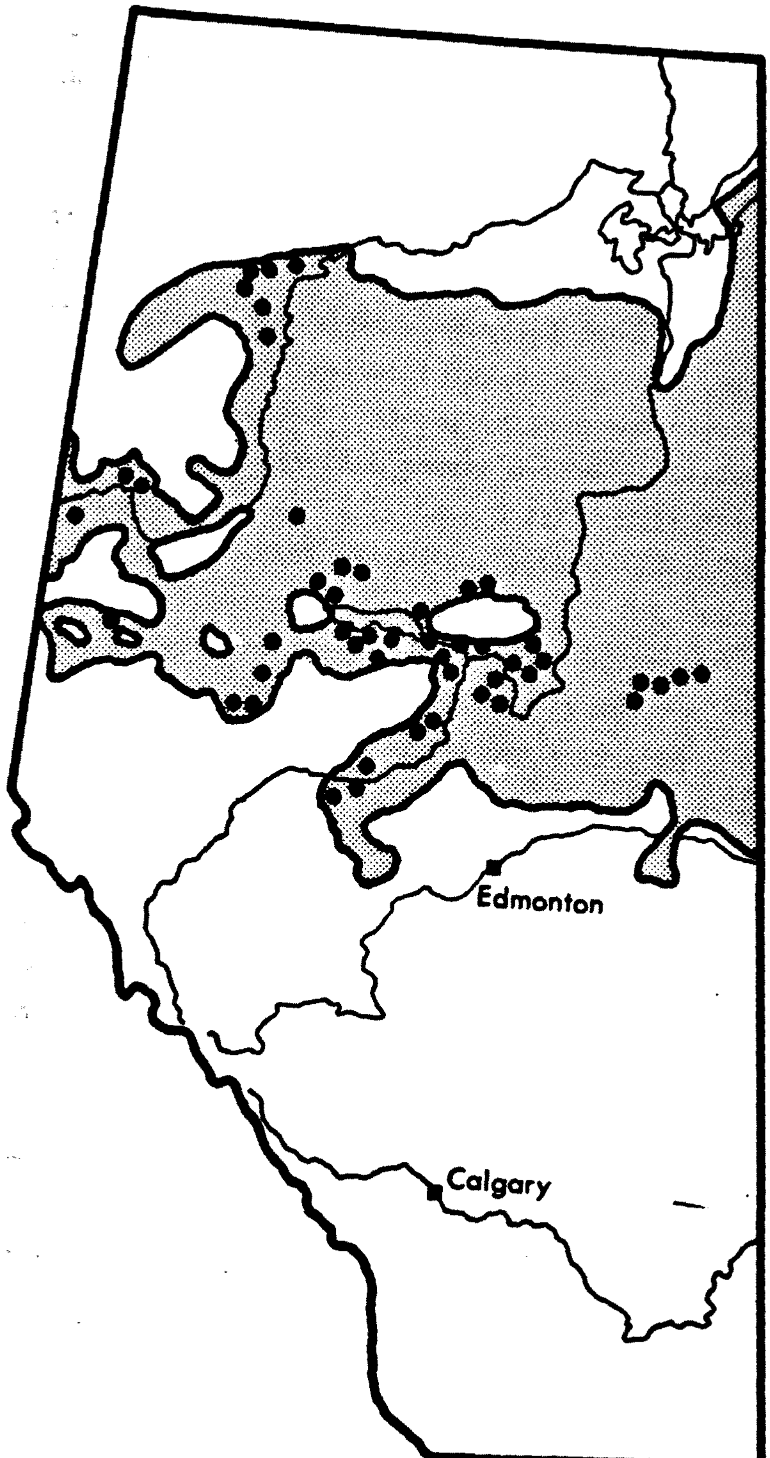
The purpose of this report is to present equations and tables in metric units for predicting the yield, to different merchantability limits, of fully stocked spruce-poplar stands in the Mixedwood Forest Section of Alberta's Boreal Forest Region. Although emphasis is placed upon the softwood component of these stands, an estimate of hardwood yield is also provided.

METHODS AND MATERIALS

SOURCES OF DATA

The basic data used in this study were obtained from 167 Canadian Forestry Service (CFS) plots plus 75 Alberta Forest Service (AFS) plots. All of the plots were established in spruce-poplar stands located within the Mixedwood Forest Section of Alberta's boreal forest (Fig. 1). The

Figure 1. Distribution of sample plots in the B18a (Mixedwood) Section of the Boreal Forest Region of Alberta



Each dot represents one or more sample plots used in this study.

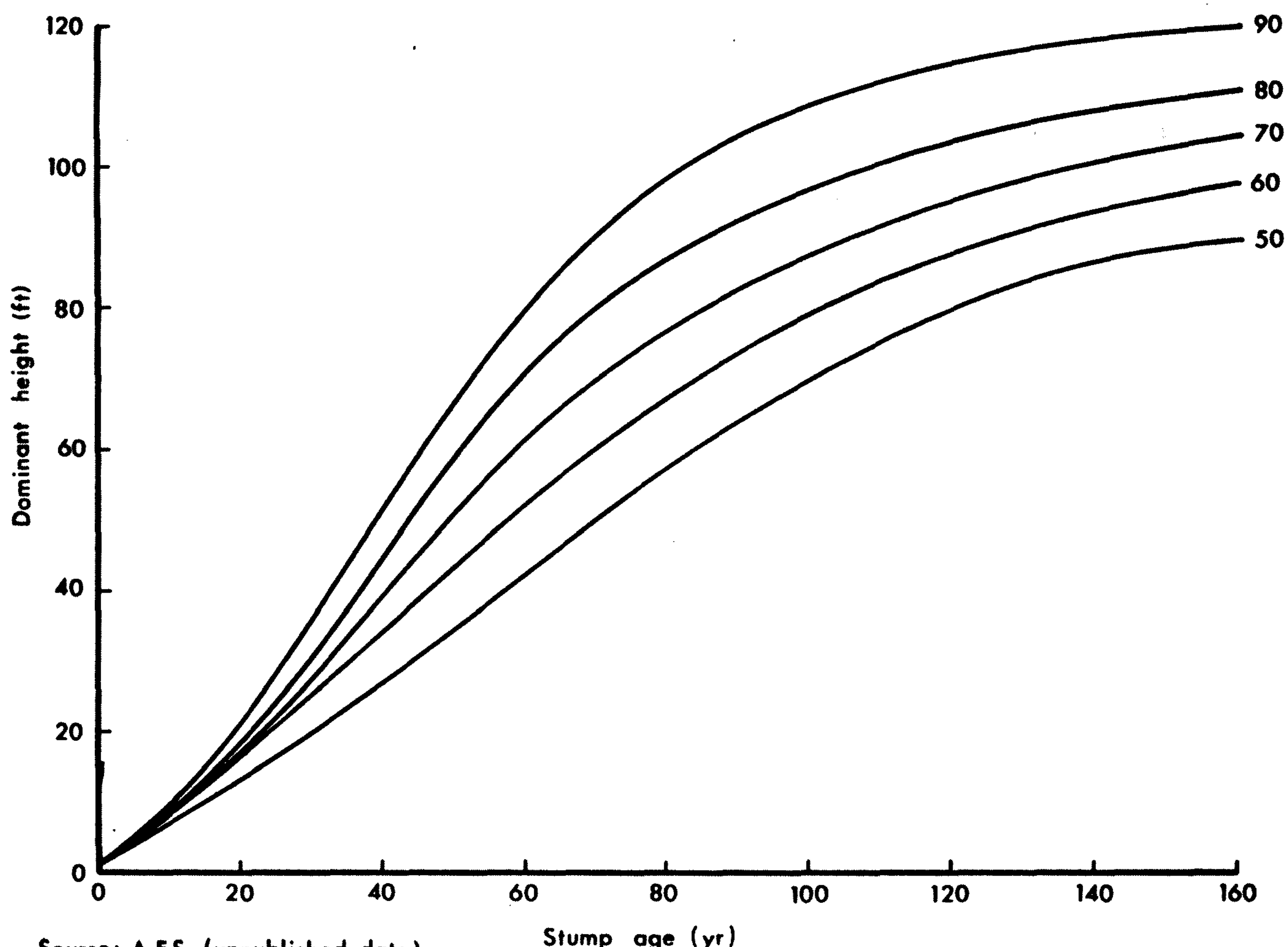
CFS plots, which varied in size (0.01 to 0.24 ha) and contained at least 100 trees in each, were located in fully stocked even-aged stands whose stump age varied from 16 to 146 years. The AFS plots varied in size from 0.08 to 0.20 ha and were located in "C" density (fully stocked) stands that varied from 59 to 123 years in stump age. All plots contained both white spruce and aspen, and some also contained a small component of balsam poplar, white birch, balsam fir (*Abies balsamea* (L.) Mill.), and/or black spruce (*Picea mariana* (Mill.) B.S.P.). None of the plots contained lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) or tamarack (*Larix laricina* (Du Roi) K. Koch).

A dbhob-tally by species was available for all plots. When possible, separate height-diameter curves were used for each species in each plot. Dominant height (h_{dom}) measurements of the spruce were available for all plots; a spruce site index (S) was assigned to each plot using AFS site index curves (Fig. 2). For the softwood component (white spruce, black spruce, and balsam fir) of each plot, the number of trees (N), basal area (G), arithmetic-mean diameter ($\bar{d}$), quadratic-mean diameter (dg: diameter of mean basal area), arithmetic-mean height ($\bar{h}$), Lorey's height (h_L: average height weighted by basal area), and average age (T) of the spruce at stump height (0.3 m) were determined. Individual tree volumes were calculated using Honer's (1967) equations (Appendix 1), based upon the following size and merchantability standards:

1. Total volume ($v_{1.5}$)--trees $\geq$ 1.5 cm dbhob and including stump and top volumes
2. Small roundwood volume ($v_{11.7}$)--trees $\geq$ 11.7 cm dbhob from a 0.3-m stump to a 7.6-cm dib top
3. Large roundwood volume ($v_{14.2}$)--trees $\geq$ 14.2 cm dbhob from a 0.3-m stump to a 10.2-cm dib top
4. Sawlog volume ($v_{21.8}$)--trees $\geq$ 21.8 cm dbhob from a 0.3-m stump to a 15.2-cm dib top

For the hardwood component (aspen, poplar, and birch), total volume, using the equations in Appendix 1, and basal area were determined. The means and variations of the various stand characteristics analyzed are presented in Table 1.

Figure 2. White spruce site index curves (index age 70 yr)



Source: A.F.S. (unpublished data)

Table 1. Summary of the stand characteristics of 242 sample plots of spruce-poplar stands in the Mixedwood Forest Section in Alberta's Boreal Forest Region

Stand characteristic		Mean	Standard deviation	Minimum value	Maximum value
Softwood component:					
S	(m @ 70 yr)	20.6	3.5	12.0	30.0
T	(yr)	81.5	30.9	16.0	146.0
h_{dom}	(m)	21.5	7.4	3.0	34.0
$\bar{h}$	(m)	14.7	5.8	3.1	26.6
h_L	(m)	18.6	6.8	3.1	30.1
$\bar{d}$	(cm)	15.8	7.4	2.5	35.9
dg	(cm)	17.4	8.0	2.5	37.9
N	(/ha)	1 524.5	1 245.1	163.0	6 919.0
G	(m^2/ha)	24.2	10.3	0.2	49.5
$V_{1.5}$	(m^3/ha)	205.2	113.8	0.3	510.3
$V_{11.7}$	(m^3/ha)	177.8	113.0	0.0	475.0
$V_{14.2}$	(m^3/ha)	163.3	112.2	0.0	460.8
$V_{21.8}$	(m^3/ha)	116.1	101.5	0.0	408.5
Hardwood component:					
$V_{1.5}$	(m^3/ha)	149.9	81.8	0.0	413.1
G	(m^2/ha)	17.1	8.4	0.0	41.3
Entire stand:					
$V_{1.5}$	(m^3/ha)	355.2	124.5	48.5	609.0

ANALYSIS

In a preliminary analysis, all of the yield characteristics for the softwood component were used as dependent variables, and site, age, and various transformations and interactions thereof were used as independent variables. This analysis indicated that many of the dependent variables could not be estimated with a high degree of certainty using only age and site. Further analysis indicated that the estimation of arithmetic-average and quadratic-mean diameters and basal area could be greatly improved by using Lorey's height as an independent variable in combination with site index and age. It was also found that all softwood volumes could be reliably estimated using softwood basal area and Lorey's height as independent variables. Because of the difficulty in reliably predicting number of stems, and in order to ensure agreement in the interrelationship between number of stems, quadratic-mean diameter, and basal area, it was decided to calculate number of stems from estimated basal area and estimated quadratic-mean diameter. Both hardwood basal area and volume correlated very poorly with all of the softwood stand characteristics, so regression equations for the hardwood portions of stands were not developed. However, because a fairly reliable equation could be developed to predict the total volume ($V_{1.5}$) of the entire stand (softwoods plus hardwoods), an estimate of hardwood total volume was obtained by subtracting estimated softwood total volume from the estimated total volume of the entire stand.

The following site index equation was derived by a separate analysis based upon the data presented in the AFS site index curves (Fig. 2):

$$h_{dom} = 1.6466X + 0.4189X^2 - 0.0417X^3 - 0.0066X^4 + 0.00076X^5 + (1.0 + 0.03788X - 0.03074X^2 + 0.00215X^3 + 0.00044X^4 - 0.000047X^5) \cdot S$$

Where: $X = (T-70)/10$

A detailed discussion of the derivation of this equation is presented in Appendix 2.

RESULTS

YIELD EQUATIONS AND TABLES

Least-square regression equations and their associated statistics for the various yield characteristics are presented in Table 2. Judged on the basis of their coefficients of determination (R^2) and standard errors of estimate ($s_{y \cdot x}$), these equations appear to provide highly reliable yield estimates, with the exception of basal area. In addition to developing yield tables, the stand-volume equations will provide quick, highly reliable estimates when used in conjunction with horizontal point sampling (p.p.s.), because estimates of both basal area (number of softwood trees tallied x the basal area factor) and Lorey's height (arithmetic-mean height of the tallied softwood trees) are readily available. In addition, because the same regression model was used, the stand-volume equations are additive, and consequently equations can be calculated to predict volume differences between merchantability limits merely by subtracting the corresponding regression coefficients (Johnstone 1976).

Yield estimates for fully stocked spruce-poplar stands from 20 to 140 years old and for a range of site productivities are presented in tabular form in Appendixes 3 to 8. These tables were developed using the yield equations in Table 2 and the site index equation derived in Appendix 2. For each table, dominant height, arithmetic-mean height, and Lorey's height were estimated for each age and site; then, arithmetic-mean diameter, quadratic-mean diameter, and basal area were estimated for each age, site, and corresponding estimated Lorey's height; next, number of stems was calculated from estimated basal area and quadratic-mean diameter. Finally, stand volumes were calculated from estimated Lorey's height and estimated basal area. As noted previously, the total hardwood volume was calculated by subtracting total softwood volume from the total stand volume.

Because predicted values of Lorey's height and/or basal area were used as independent variables in developing the yield table estimates, the standard errors of estimate of the base equations (Table 2) are not directly applicable to the tabular values. In order to obtain an indication of the precision of the estimates when predicted values are used,

Table 2. Yield equations for fully stocked spruce-aspen stands in the Mixedwood Forest Section of the Boreal Forest Region of Alberta

Softwood component:

$$\bar{h}\ (m) = 42.598 - 1.055T - 127.538\ Log_{10}T + 32.705T^{0.5} + 0.004(S \cdot T)$$

$n = 242 \qquad R^2 = 0.866 \qquad s_{y \cdot x} = 2.14$ m

$$h_L\ (m) = 94.559 + 0.290T - 73.413\ Log_{10}T - 59.260\ Log_{10}S + 5.717\ (S^{0.5} \cdot T^{0.5}) - 0.194\ (S^{0.5} \cdot T) - 0.230\ (S \cdot T^{0.5})$$

$n = 242 \qquad R^2 = 0.954 \qquad s_{y \cdot x} = 1.47$ m

$$\bar{d}\ (cm) = 0.560 - 0.155T^{0.75} + 8.293\ Log_{10}h_L + 0.040h_L^{\ 2} - 0.017(S \cdot h_L)$$

$n = 242 \qquad R^2 = 0.897 \qquad s_{y \cdot x} = 2.40$ cm

$$dg\ (cm) = 0.481 - 0.132T^{0.75} + 8.254\ Log_{10}h_L + 0.041h_L^{\ 2} - 0.015(S \cdot h_L)$$

$n = 242 \qquad R^2 = 0.927 \qquad s_{y \cdot x} = 2.18$ cm

$$G\ (m^2/ha) = -20.005 + 0.006(T \cdot S) + 36.886\ Log_{10}h_L - 0.029(S \cdot h_L)$$

$n = 242 \qquad R^2 = 0.612 \qquad s_{y \cdot x} = 6.46\ m^2/ha$

$$N\ (/ha) = G/(0.00007854\ dg^2)$$

$$V_{1.5}(m^3/ha) = -6.297 + 1.951G + 0.282h_L + 0.317(G \cdot h_L)$$

$n = 242 \qquad R^2 = 0.999 \qquad s_{y \cdot x} = 2.61\ m^3/ha$

$$V_{11.7}(m^3/ha) = -10.117 - 1.219G + 0.632h_L + 0.410(G \cdot h_L)$$

$n = 242 \qquad R^2 = 0.993 \qquad s_{y \cdot x} = 9.67\ m^3/ha$

$$V_{14.2}(m^3/ha) = -2.218 - 3.440G + 0.375h_L + 0.482(G \cdot h_L)$$

$n = 242 \qquad R^2 = 0.989 \qquad s_{y \cdot x} = 11.96\ m^3/ha$

$$V_{21.8}(m^3/ha) = 27.317 - 8.441G - 0.781h_L + 0.613(G \cdot h_L)$$

$n = 242 \qquad R^2 = 0.958 \qquad s_{y \cdot x} = 20.92\ m^3/ha$

Entire stand (softwood plus hardwood components):

$$V_{1.5}(m^3/ha) = 66.021 + 3.213G + 11.819h_L - 0.017(G \cdot h_L)$$

$n = 242 \qquad R^2 = 0.676 \qquad s_{y \cdot x} = 71.37\ m^3/ha$

two statistics, the aggregate difference (A.D.) and the mean absolute deviation (M.A.D.), were determined for each yield characteristic of the 242 plot observations using the following formulas:

$$\text{A.D.} = \frac{\Sigma\hat{Y} - \Sigma Y}{\Sigma\hat{Y}} \times 100\%$$

$$\text{M.A.D.} = \frac{\Sigma(|\hat{Y} - Y|)}{n}$$

Where: $\hat{Y}$ = estimated value of dependent variable

Y = observed value of dependent variable

n = number of observations

Aggregate differences and mean absolute deviations for the various yield characteristics are presented in Table 3. The small magnitude of the A.D.'s indicates that the estimates are essentially free from bias; howeven, the M.A.D.'s indicate that some loss of precision has resulted because predicted Lorey's height and/or predicted basal area were used as independent variables.

INCREMENT AND ROTATION

The results in Table 4 clearly demonstrate the direct effect of site productivity on mean annual increment (m.a.i.) and its inverse effect upon the age at which the m.a.i.'s culminate. Although basal area m.a.i. and the age at which it culminates are obviously affected by site productivity (Table 4), basal area appears to reach a uniform level of about 33.9 m^2/ha at 140 years on a range of sites (Appendixes 5 to 8). This may account for the low correlation ($r = 0.07$) observed between basal area and site index.

Rotation age is often selected to coincide with the age at which mean annual volume increment culminates, because at this age the stand will yield the maximum possible volume per acre per year. The results presented show that the more completely these mixedwood stands are utilized for small-sized material, the shorter will be the length of the rotation. On the other hand, if the stands are utilized for sawlog material, a long rotation (in excess of 145 years) should be anticipated, and only the better sites should be managed for this purpose.

Table 3. Aggregate differences (A.D.) and mean absolute deviations (M.A.D.) for 242 sample plots of spruce-poplar stands when predictions of Lorey's height and/or predicted basal area are used as independent variables

Yield characteristic	A.D. (%)	M.A.D. (±)
Softwood component:		
h_{dom}	-0.12	0.40 m
$\bar{h}$	0.00	1.76 m
h_L	0.00	1.14 m
$\bar{d}$	0.45	2.34 cm
dg	0.43	2.31 cm
N	2.24	509.57/ha
G	-0.26	5.12 m^2/ha
$V_{1.5}$	-0.11	43.79 m^3/ha
$V_{11.7}$	-0.04	39.06 m^3/ha
$V_{14.2}$	0.03	37.08 m^3/ha
$V_{21.8}$	0.28	32.64 m^3/ha
Hardwood component:		
$V_{1.5}$	0.03	61.50 m^3/ha
Entire stand:		
$V_{1.5}$	-0.05	53.94 m^3/ha

Table 4. Maximum mean annual increments[1] and the age at which they occur for the various stand characteristics of fully stocked spruce-aspen stands in the Mixedwood Forest Section of the Boreal Forest Region in Alberta[2]

Site Index	Softwood Component									
	G		$V_{1.5}$		$V_{11.7}$		$V_{14.2}$		$V_{21.8}$	
	m.a.i. (m^2/ha)	Age (yr)	m.a.i. (m^3/ha)	Age (yr)	m.a.i. (m^3/ha)	Age (yr)	m.a.i. (m^3/ha)	Age (yr)	m.a.i. (m^3/ha)	Age (yr)
12.5	.288	66	(2.02)	(155)	(1.88)	(192)	(1.82)	(208)	(-)	(>220)
15.0	.325	56	2.25	132	(2.09)	(165)	(2.03)	(179)	(1.74)	(202)
17.5	.357	49	2.46	117	(2.28)	(147)	(2.22)	(160)	(1.92)	(180)
20.0	.382	44	2.63	105	2.45	135	2.40	(147)	(2.08)	(165)
22.5	.403	40	2.75	97	2.59	126	2.53	137	(2.21)	(154)
25.0	.418	37	2.84	90	2.68	119	2.64	130	(2.32)	(146)

[1]M.a.i.'s determined by dividing estimated basal area and volumes by age

[2](Bracketed values are beyond range of tables (Appendixes 3-8))

Culmination of m.a.i. of the hardwood and the hardwood plus softwood components will occur much earlier than for the softwood component alone because the hardwoods are somewhat older than the softwoods, and the hardwoods--particularly aspen and poplar-exhibit a much faster juvenile growth rate than the softwoods.

DISCUSSION

The equations and tables presented provide yield estimates for fully stocked spruce-poplar stands in the Mixedwood Forest Section of Alberta. Emphasis is placed on the spruce component because of its current economic importance in the province. If used in conjunction with overstocked or understocked stands, an adjustment for stocking should be made, preferably based on volume.

The results demonstrate the importance of considering both site quality and degree of utilization in selecting rotation ages and making wood supply projections for mixedwood stands. The higher the degree of utilization of smaller trees, as well as stumps and tops, the shorter the length of rotation. Generally, the rotation ages observed agree with those suggested for spruce-aspen stands in Alberta by MacLeod and Blyth (1955) and in Saskatchewan by Kirby (1962). The results also suggest that only those stands growing on high-quality sites should be managed for sawlogs.

The equations and tables presented in this report are intended for interim use only. The inherent weaknesses in normal yield tables are widely recognized, and the range of the basic data was by no means all-encompassing. As the province's softwood allowable annual cut becomes more fully committed, the hardwood component of the mixedwood stands will no doubt become more important, as will the need for more sophisticated information on hardwood yields.

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APPENDIX 1. INDIVIDUAL TREE GROSS-VOLUME EQUATIONS (Honer 1967).

In the following equations d = dbhob (in.) and h = total tree height (ft).

1. White spruce[1]:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{1.440 + (342.175/h)}\right] \cdot 0.0283168$$

$$v_{11.7}\ (m^3) = v_{1.5} \cdot (0.9611 - 0.2456X - 0.6801X^2)$$

$$\text{Where: } X = \left(\frac{3.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{14.2}\ (m^3) = v_{1.5} \cdot (0.9611 - 0.2456X - 0.6801X^2$$

$$\text{Where: } X = \left(\frac{4.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{21.8}\ (m^3) = v_{1.5} \cdot (0.9611 - 0.2456X - 0.6801X^2)$$

$$\text{Where: } X = \left(\frac{6.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

2. Black spruce:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{1.588 + (333.364/h)}\right] \cdot 0.0283168$$

$$v_{11.7}\ (m^3) = v_{1.5} \cdot (0.9526 - 0.1027X - 0.8199X^2)$$

$$\text{Where: } X = \left(\frac{3.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{14.2}\ (m^3) = v_{1.5} \cdot (0.9526 - 0.1027X - 0.8199X^2)$$

$$\text{Where: } X = \left(\frac{4.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{21.8}\ (m^3) = v_{1.5} \cdot (0.9526 - 0.1027X - 0.8199X^2)$$

$$\text{Where: } X = \left(\frac{6.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

3. Balsam fir:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{2.139 + (301.634/h)}\right] \cdot 0.0283168$$

$$v_{11.7}\ (m^3) = v_{1.5} \cdot (0.9352 - 0.0395X - 0.8147X^2)$$

$$\text{Where: } X = \left(\frac{3.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{14.2}\ (m^3) = v_{1.5} \cdot (0.9352 - 0.0395X - 0.8147X^2)$$

$$\text{Where: } X = \left(\frac{4.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

$$v_{21.8}\ (m^3) = v_{1.5} \cdot (0.9352 - 0.0395X - 0.8147X^2)$$

$$\text{Where: } X = \left(\frac{6.0}{d}\right)^2 \cdot \left(1.0 + \frac{1.0}{h}\right)$$

4. Aspen[2]:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{-0.312 + (436.683/h)}\right] \cdot 0.0283168$$

5. Balsam poplar[2]:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{0.420 + (394.644/h)}\right] \cdot 0.0283168$$

6. White birch:

$$v_{1.5}\ (m^3) = \left[\frac{d^2}{2.222 + (300.373/h)}\right] \cdot 0.0283168$$

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[1]An indication of the allowances to be made to white spruce volumes for decay and cull are given by Nordin (1956) and Kabzems (1971).

[2]Decay losses for aspen and balsam poplar have been reported by Thomas *et al.* (1960).

APPENDIX 2. DERIVATION OF SITE INDEX EQUATION.

In this study the assessment of site productivity was based upon the site index curves shown in Fig. 2, for which there was no equation. It was deemed desirable, therefore, to develop an equation for future use based upon these curves. This equation was developed in the following manner:

1. Dominant height at 5-year age-intervals, from ages 20 to 140 were obtained for site index classes 50 to 90 from Fig. 2.
2. All height and site values were converted from feet to metres using the factor of 0.3048.
3. Using the following general model, a simple linear regression was derived with dominant height (h_{dom}) as the dependent variable and site index (S) as the independent variable for each 5-year age-interval (i):

$$h_{dom_{(i)}} = b_{0_{(i)}} + b_{1_{(i)}} S_{(i)}$$

4. The intercept values (b_0 regression coefficients) determined for each age-interval were then related to age using a least-square polynomial. The polynomial was conditioned to ensure that the intercept was equal to 0 when age was equal to 70 years (index age). A fifth-degree polynomial was required to satisfactorily fit the coefficients (Fig. 3). The derived polynomial is:

$$\hat{b}_0 = 0. + 1.6466X + 0.4189X^2 - 0.0417X^3$$
$$- 0.0066X^4 + 0.00076X^5$$

$n = 26 \quad R^2 = 0.999 \quad s_{y \cdot x} = 0.183$

Where: $X = (T - 70)/10$

5. Similarly, the slope values (b_1 regression coefficients) from each age-interval were related to age using a fifth-degree polynomial conditioned to equal 1.0 at index age (70 years). The following regression was derived and is shown in Fig. 4:

$$\hat{b}_1 = 1. + 0.03788X - 0.03074X^2 + 0.00215X^3$$
$$+ 0.00044X^4 - 0.000047X^5$$
$$n = 26 \qquad R^2 = 0.999 \qquad s_{y \cdot x} = 0.0098$$

6. Substituting the $\hat{b}_0$ polynomial for b_0 and $\hat{b}_1$ polynomial for b_1 in the general model (step 3) produces the following anamorphic site index equation:

$$h_{dom} = 1.6466X + 0.4189X^2 - 0.0417X^3 - 0.0066X^4 + 0.00076X^5$$
$$+ (1.0 + 0.03788X - 0.03074X^2 + 0.00215X^3 + 0.00044X^4$$
$$- 0.000047X^5) \cdot S$$
$$n = 128 \qquad \hat{R}^2 = 0.999^a \qquad \hat{s}_{y \cdot x} = 0.29 \text{ m}^b$$

Where: $X = (T - 70)/10$

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[a] $$\hat{R}^2 = \frac{SS_{total} - \hat{SS}_{residual}}{SS_{total}}$$

[b] $$\hat{s}_{y \cdot x} = \pm \sqrt{\frac{\hat{SS}_{residual}}{n - m - 1}}$$

Where: $\hat{SS}_{residual} = \Sigma(Y - \hat{Y})^2$

SS_{total} = sum of square of Y

Y = observed value of dependent variable

$\hat{Y}$ = estimated value of dependent variable

n = number of observations

m = number of independent variables

Figure 3. The relationship between stump age and the intercepts of the dominant height / site index regressions.

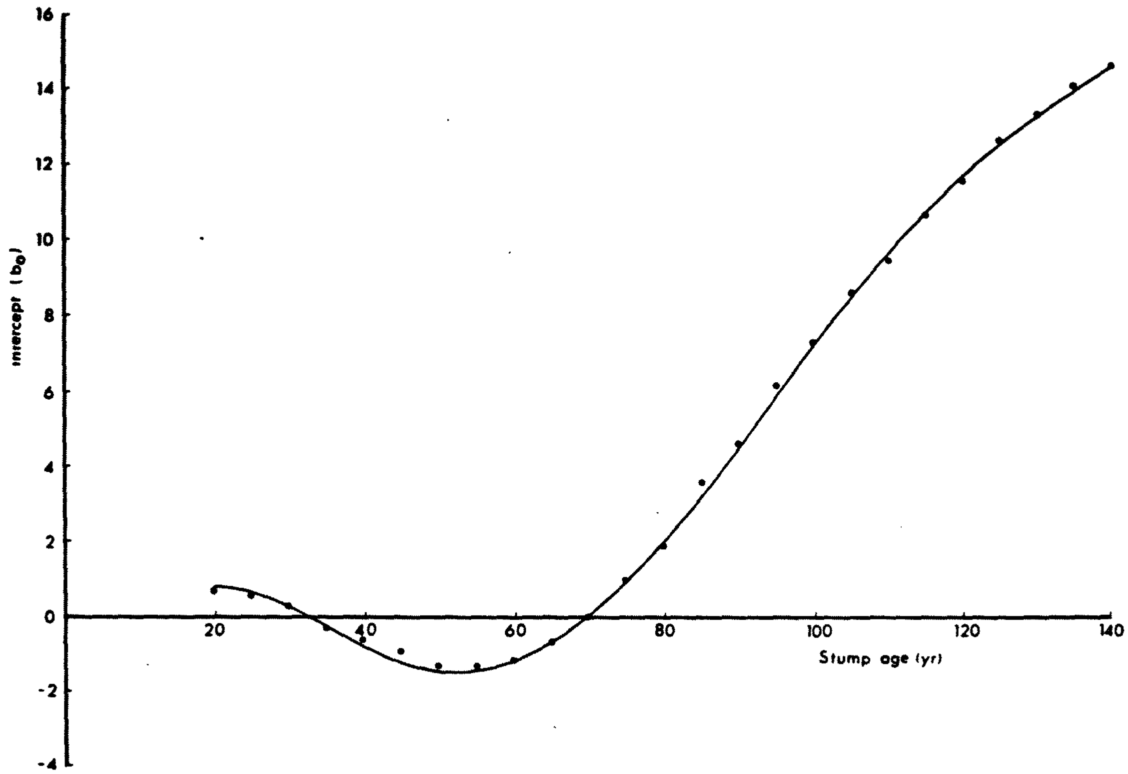
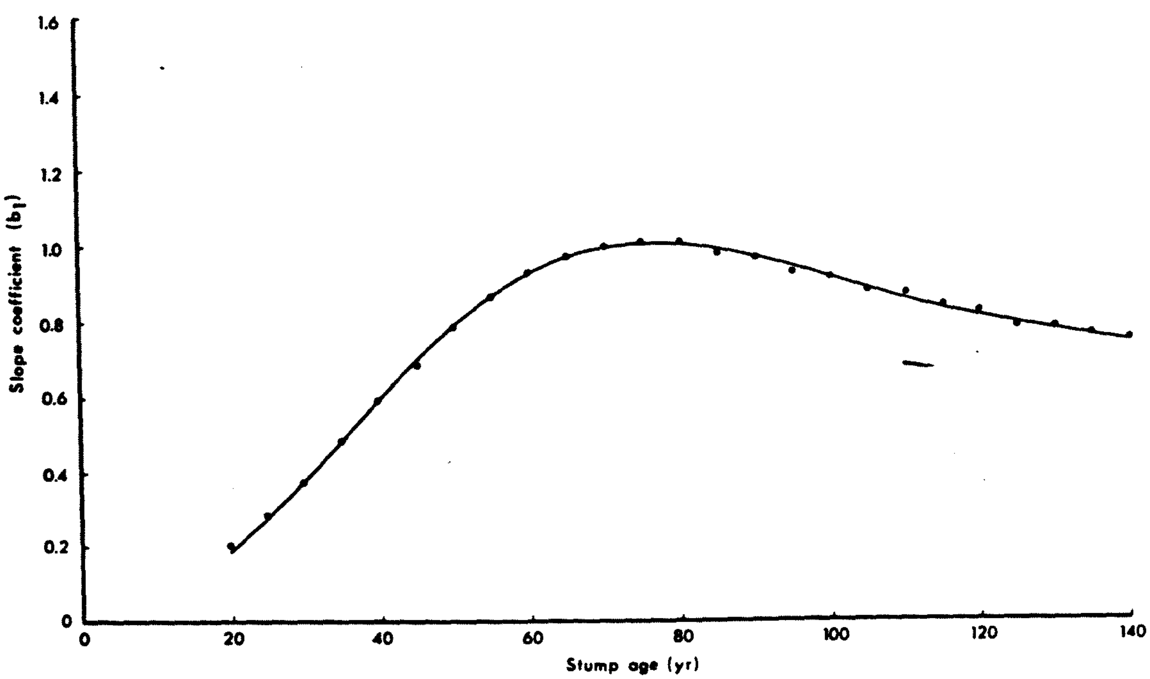


Figure 4. The relationship between stump age and the slope coefficients of the dominant height / site index regressions.



APPENDIX 3. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 12.5 (@ stump age 70 years)

SOFTWOOD COMPONENT, MAINLY SPRUCE												HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	Cubic-metre volume (ib) of trees with: dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	3.4	2.8	3.7	3.5	3.7	1.0	870	0.0	0.0	0.0	0.0	112.3	112.3
30	5.1	3.2	4.2	3.6	3.9	3.7	3159	7.1	0.0	0.0	0.0	120.3	127.4
40	6.7	4.9	5.8	4.5	4.9	9.0	4675	29.2	3.8	0.0	0.0	132.9	162.0
50	8.5	6.9	7.6	5.7	6.2	13.5	4424	55.0	20.5	3.9	0.0	142.9	197.9
60	10.4	8.8	9.6	7.0	7.7	17.2	3709	82.1	42.4	21.4	0.0	149.4	231.5
70	12.5	10.6	11.4	8.4	9.3	20.1	2997	109.3	67.1	43.9	0.0	152.8	262.1
80	14.6	12.0	13.2	9.9	10.9	22.6	2410	136.3	93.4	69.2	9.7	153.7	290.0
90	16.7	13.2	14.9	11.5	12.7	24.6	1956	162.7	120.2	96.1	33.3	152.8	315.5
100	18.7	14.1	16.5	13.2	14.4	26.4	1612	188.3	147.1	123.5	58.9	150.4	338.7
110	20.5	14.7	18.0	14.8	16.2	28.0	1352	213.1	173.6	151.0	85.6	146.9	360.0
120	21.9	15.1	19.3	16.5	18.0	29.4	1154	237.0	199.5	178.1	112.6	142.4	379.4
130	23.1	15.2	20.6	18.1	19.7	30.7	1003	259.9	224.7	204.6	139.5	137.3	397.2
140	24.1	15.2	21.7	19.6	21.4	31.9	886	282.0	249.0	230.4	166.0	131.5	413.5

APPENDIX 4. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 15.0 (@ stump age 70 years)

												HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
SOFTWOOD COMPONENT, MAINLY SPRUCE								Cubic-metre volume (ib) of trees with:					
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	3.9	3.0	3.7	3.4	3.7	1.2	1143	0.0	0.0	0.0	0.0	113.8	113.8
30	6.0	3.5	5.0	4.1	4.4	6.2	4031	16.9	0.0	0.0	0.0	127.1	144.1
40	8.2	5.3	7.0	5.3	5.8	11.8	4441	44.7	13.8	0.0	0.0	140.5	185.3
50	10.5	7.4	9.2	6.7	7.4	16.1	3750	74.9	37.1	17.6	0.0	149.6	224.4
60	12.8	9.4	11.4	8.3	9.2	19.4	2956	105.3	64.5	42.3	0.0	154.5	259.8
70	15.0	11.3	13.5	10.0	11.1	22.1	2305	135.3	93.9	70.7	13.1	156.3	291.6
80	17.2	12.8	15.4	11.9	13.0	24.3	1818	164.4	123.8	100.7	40.0	155.7	320.1
90	19.2	14.1	17.2	13.7	15.1	26.2	1465	192.4	153.5	131.3	69.0	153.4	345.8
100	21.0	15.1	18.8	15.6	17.1	27.8	1209	219.3	182.6	161.5	98.8	149.7	369.0
110	22.6	15.8	20.3	17.4	19.1	29.3	1021	245.0	210.7	191.1	128.6	144.9	389.8
120	24.0	16.3	21.6	19.2	21.0	30.6	883	269.5	237.7	219.7	157.8	139.2	408.7
130	25.1	16.5	22.8	20.9	22.8	31.9	779	292.8	263.6	247.2	186.2	132.9	425.1
140	26.0	16.6	23.9	22.4	24.5	33.0	700	315.0	288.2	273.4	213.5	126.0	441.1

APPENDIX 5. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 17.5 (@ stump age 70 years)

	SOFTWOOD COMPONENT, MAINLY SPRUCE											HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
								Cubic-metre volume (ib) of trees with:					
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	4.4	3.2	3.9	3.5	3.7	1.9	1791	1.0	0.0	0.0	0.0	117.3	118.3
30	7.0	3.8	5.8	4.5	4.9	8.3	4362	26.5	3.0	0.0	0.0	133.3	159.8
40	9.7	5.7	8.2	5.9	6.5	13.8	4089	58.8	24.7	8.1	0.0	146.7	205.5
50	12.5	7.9	10.7	7.6	8.4	17.8	3200	92.2	53.5	32.8	0.0	154.8	247.0
60	15.1	10.0	13.1	9.5	10.5	20.9	2413	125.1	85.2	63.1	9.0	158.6	283.7
70	17.5	12.0	15.4	11.5	12.7	23.3	1836	156.9	117.9	95.8	37.9	159.3	316.3
80	19.7	13.6	17.4	13.6	15.0	25.3	1433	187.4	150.3	129.1	69.6	157.8	345.2
90	21.6	15.0	19.2	15.7	17.3	27.0	1153	216.3	181.8	162.1	102.2	154.6	370.9
100	23.3	16.1	20.8	17.7	19.5	28.6	956	243.9	212.1	194.0	134.6	149.9	393.8
110	24.8	16.9	22.3	19.7	21.6	30.0	815	270.0	241.1	224.8	166.2	144.2	414.2
120	26.0	17.5	23.6	21.5	23.6	31.3	714	294.8	268.6	254.1	196.6	137.6	432.4
130	27.0	17.8	24.7	23.2	25.4	32.5	640	318.3	294.7	281.9	225.5	130.3	448.6
140	27.8	18.0	25.7	24.7	27.0	33.7	586	340.6	319.4	308.2	252.9	122.4	462.9

APPENDIX 6. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 20.0 (@ stump age 70 years)

SOFTWOOD COMPONENT, MAINLY SPRUCE												HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	Cubic-metre volume (ib) of trees with: dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	4.9	3.4	4.2	3.5	3.8	2.8	2485	4.1	0.0	0.0	0.0	120.0	124.1
30	7.9	4.1	6.5	4.8	5.3	9.9	4462	35.3	8.4	0.0	0.0	138.6	173.9
40	11.2	6.1	9.4	6.5	7.2	15.2	3754	71.0	35.5	17.5	0.0	151.9	222.9
50	14.4	8.4	12.1	8.4	9.3	18.9	2772	106.7	68.5	47.7	0.0	159.4	266.1
60	17.4	10.6	14.7	10.5	11.7	21.7	2022	141.2	103.3	82.2	27.9	162.6	303.8
70	20.0	12.7	17.0	12.8	14.2	23.9	1512	174.1	138.2	117.9	61.4	162.8	336.9
80	22.2	14.4	19.1	15.1	16.7	25.8	1173	205.1	172.0	153.2	96.2	160.8	365.9
90	24.1	15.9	20.9	17.4	19.2	27.4	945	234.5	204.5	187.5	131.0	157.0	391.5
100	25.6	17.1	22.5	19.5	21.6	28.8	790	262.3	235.5	220.4	164.8	151.7	414.1
110	26.9	18.0	24.0	21.6	23.7	30.2	681	288.6	264.8	251.6	197.2	145.3	434.0
120	28.0	18.7	25.2	23.4	25.7	31.5	605	313.5	292.5	281.1	228.0	137.9	451.4
130	29.0	19.1	26.2	25.0	27.5	32.7	551	337.1	318.6	308.9	257.0	129.6	466.7
140	29.7	19.4	27.1	26.4	29.0	33.9	514	359.4	343.1	335.0	284.0	120.7	480.1

APPENDIX 7. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 22.5 (@ stump age 70 years)

SOFTWOOD COMPONENT, MAINLY SPRUCE												HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	Cubic-metre volume (ib) of trees with: dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	5.4	3.6	4.4	3.6	3.9	3.7	3105	7.4	0.0	0.0	0.0	122.8	130.1
30	8.9	4.4	7.3	5.1	5.6	11.1	4477	42.9	14.0	1.2	0.0	143.3	186.2
40	12.7	6.5	10.4	6.9	7.7	16.1	3468	81.1	45.4	26.9	0.0	156.6	237.7
50	16.4	8.9	13.4	9.0	10.1	19.5	2443	118.4	81.5	61.4	11.9	163.8	282.2
60	19.7	11.2	16.0	11.4	12.7	22.1	1736	153.7	118.4	98.6	45.6	166.9	320.6
70	22.5	13.4	18.4	13.9	15.5	24.1	1283	186.9	154.5	136.1	82.0	167.1	353.9
80	24.7	15.2	20.6	16.4	18.2	25.8	993	218.1	189.0	172.6	118.8	164.9	383.0
90	26.5	16.8	22.4	18.8	20.8	27.3	804	247.6	221.9	207.4	154.6	160.8	408.3
100	27.9	18.1	24.0	21.0	23.2	28.7	677	275.4	253.0	240.6	189.0	155.1	430.4
110	29.1	19.1	25.4	23.0	25.4	30.1	592	301.7	282.4	271.9	221.7	148.0	449.7
120	30.1	19.9	26.5	24.8	27.4	31.4	533	326.6	310.0	301.4	252.3	139.8	466.4
130	30.9	20.4	27.5	26.3	29.0	32.7	494	350.2	336.0	329.0	281.0	130.6	480.8
140	31.6	20.8	28.3	27.5	30.3	34.0	470	372.6	360.3	354.7	307.4	120.5	493.1

APPENDIX 8. YIELD PER HECTARE OF FULLY STOCKED SPRUCE-ASPEN STANDS

Site index 25.0 (@ stump age 70 years)

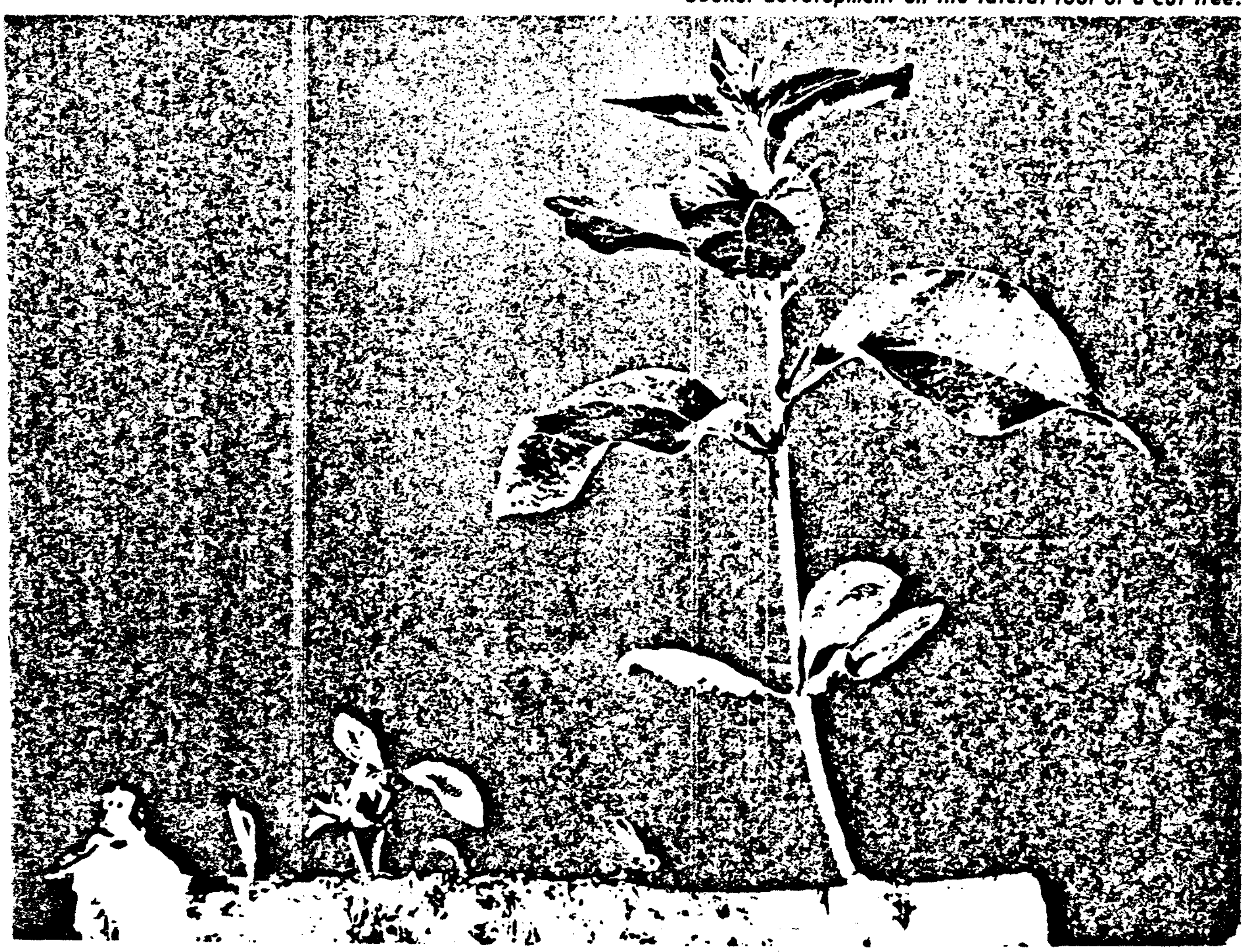
	SOFTWOOD COMPONENT, MAINLY SPRUCE											HDWD. COMP., MAINLY ASPEN	ENTIRE STAND
Stump age (yr)	Dom. height (m)	Mean height (m)	Lorey's height (m)	A. mean diam. (cm)	Q. mean diam. (cm)	Basal area (m^2)	No. of stems ≥1.5 cm	Cubic-metre volume (ib) of trees with: dbhob ≥1.5 cm	dbhob ≥11.7 cm	dbhob ≥14.2 cm	dbhob ≥21.8 cm	Volume (ib) ≥1.5 cm dbhob (m^3)	Volume (ib) ≥1.5 cm dbhob (m^3)
20	5.8	3.8	4.7	3.6	3.9	4.4	3641	10.4	0.0	0.0	0.0	125.4	135.8
30	9.8	4.7	7.9	5.2	5.8	11.9	4472	49.3	19.3	5.4	0.0	147.4	196.7
40	14.2	6.9	11.3	7.2	8.1	16.7	3238	89.2	54.1	35.7	0.0	161.0	250.2
50	18.4	9.4	14.5	9.5	10.7	19.8	2192	127.2	92.3	73.1	24.4	168.5	295.7
60	22.0	11.8	17.3	12.1	13.6	22.1	1525	162.7	130.3	112.1	61.1	171.9	334.5
70	25.0	14.1	19.7	14.7	16.5	24.0	1118	195.8	166.8	150.4	99.2	172.2	368.0
80	27.3	16.0	21.8	17.3	19.4	25.6	866	226.8	201.5	187.2	136.8	170.1	396.9
90	28.9	17.7	23.7	19.8	22.1	27.0	705	256.0	234.3	222.2	173.0	165.9	421.9
100	30.2	19.1	25.2	22.0	24.5	28.4	600	283.6	265.2	255.2	207.4	159.8	443.4
110	31.2	20.2	26.5	24.0	26.7	29.8	532	309.9	294.5	286.3	239.8	152.2	462.0
120	32.1	21.1	27.6	25.7	28.5	31.1	487	334.8	322.0	315.5	270.1	143.1	477.9
130	32.9	21.7	28.5	27.0	30.0	32.5	460	358.6	347.8	342.9	298.2	132.8	491.4
140	33.4	22.2	29.2	28.0	31.1	33.9	445	381.2	372.0	368.3	324.0	121.5	502.6

ASPEN CLONES
Their Significance and Recognition

Trembling aspen has a number of characteristics which differ from most other tree species: it grows on a wide variety of sites, has a short life span and usually reproduces by means of root suckers. A group of such suckers, having developed through repeated vegetative reproduction from the root system of a tree of seed origin, is called a CLONE, while individual trees making up the clone are called ramets. Most aspen stands consist of a mosaic of clones of varying size and form.

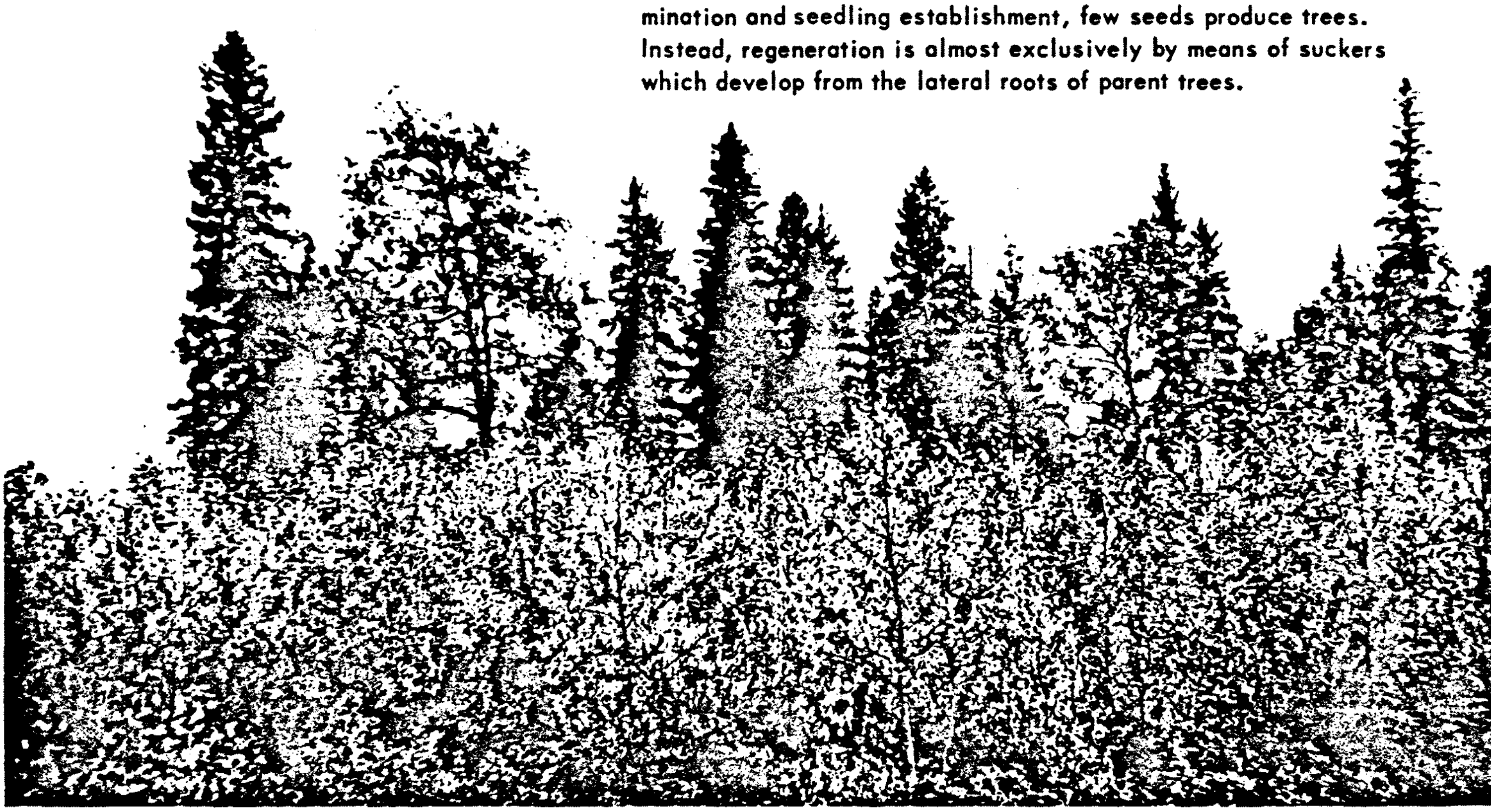
The aim of this brochure is to increase the general awareness of aspen clones among resource managers and naturalists and to point out ways in which such awareness can assist in the management and understanding of aspen stands. In addition, tree characteristics useful for the recognition of clones are described.

Sucker development on the lateral root of a cut tree.



Development of Clones

Trembling aspen[1] is a prolific seed producer as indicated by the snow-flurry-like quantities of seed released during the first weeks of June. However, due to the exacting requirements for germination and seedling establishment, few seeds produce trees. Instead, regeneration is almost exclusively by means of suckers which develop from the lateral roots of parent trees.



Abundant sucker regeneration following clear-cutting.

Removal of the parent trees by cutting or burning results in increased soil temperatures through exposure to direct sunlight, which in turn stimulates sucker growth. Removal of all trees simultaneously will result in an even-aged and fairly evenly spaced stand of suckers, while incomplete removal of the old stand will result in uneven sucker development with many large openings often leading to invasion by shrub species.

Suckers grow quickly during the first few years by drawing upon the extensive root system of their parent trees. These parent roots extend far into the soil and provide the young trees with an abundance of nutrients and moisture. The resulting initial growth rate of the suckers easily exceeds that of most other vegetation grown under similar conditions of climate and soil.

In all probability successive reproduction through suckering has been going on for centuries, so, while an individual tree in a clone may not live more than 100 to 150 years, the age of the clone to which it belongs could well date back several thousands of years.

[1]*Populus tremuloides* (Michx.)

By repeated suckering clones may eventually occupy large areas. In parkland communities, clones can encroach upon grassland vegetation, while in upland forest communities one clone can expand at the expense of others through better suckering ability and superior growth. Observations in several upland aspen stands in Manitoba have shown clone size to vary from a few yards (one or two trees representing a clone) to several acres.

Significance of Aspen Clones

In forest stands, each individual tree of seed origin has its own genetic make-up, and responds in its own particular way to prevailing environmental conditions. In trembling aspen stands of sucker origin the clone takes the place of the individual. Therefore, adverse conditions such as drought, early or late frost, attack by insects or disease, will tend to affect an entire clone similarly, while the effect on another clone exposed to the same conditions can be quite different.

Clones vary in size and generally overlap one another.

Since most aspen stands are of sucker origin, it is essential in the management of this species that the clonal growth habit be taken into consideration. The following discussion outlines areas where conventional practices, used in stands of seed origin, will lead to pitfalls when applied to aspen. Other approaches are suggested.

1 Stand Inventory and Site Productivity

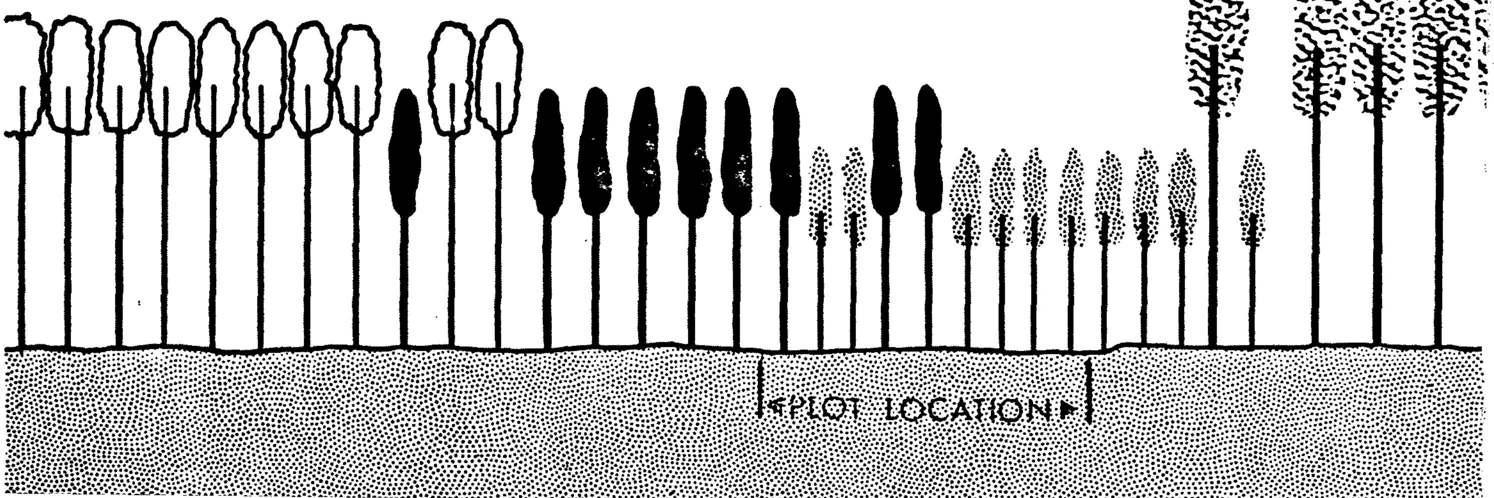
An accepted way of taking stand inventory and determining growth performance in relation to site in stands of seed origin is by calculating stand volume and average dominant height on small sample plots and relating these growth features to stand age. In aspen stands such plots may often contain only a single clone. Measurement of trees for height and diameter in such plots is, therefore, essentially the measurement of one individual. Therefore, a good estimate of volume and dominant height for the stand as a whole is not obtained, since all trees making up the clone within the sample plot exhibit a similar growth pattern. The full range of diameters and heights within the stand is therefore not sampled. Measurements confined to a single clone can either over, or under estimate productivity in terms of height by as much as 25 per cent and volume production by much greater percentages.

Measuring height and diameter in order to determine stand volume and tree growth.

Observations in some 30- to 40-year-old stands on the same site in Manitoba have shown height differences, between dominant trees of different clones, of up to 10 feet. Furthermore, it is possible that superior clones on a medium site may perform better than inferior clones on a good site.

Clearly, estimates of standing volume and site productivity should be based on the performance of five or more clones. A reliable estimate of stand growth is not likely to be obtained if only one or two clones are sampled. Since time often does not permit the identification and separation of clones, sampling along a transect should have the desired effect.

Plot location may lead to an over, or under estimation of stand volume and tree growth depending on clonal variation.



Fruiting bodies of Fomes igniarius are an indication of severe stem decay.

2 Estimation of Cull Losses

Cull studies in the past have shown extreme variation in decay within an age group. This variation has been so great that suggested rotation ages, based on average cull volumes at a given age, are frequently of questionable value. Recent examination of several stands have shown clones, heavily riddled with ***Fomes igniarius*** (the main trunk rot fungus in aspen) occurring beside clones practically free of the fungus.

Other indicators of stem quality, e.g., branchiness, burls, cankers, may vary from clone to clone in the same locality. It follows that the same precautions must be followed as in estimating stand volume and site productivity. In any locality several clones must be sampled. Since decay percentage between clones in mature stands can vary from 0 to as high as 80 per cent, somewhat more than the five or six clones stipulated before may be necessary to obtain a good estimate of cull. Transect sampling could also be used.

3 Selection of Superior Clones

Here the growth habit of clones offers a distinct advantage over stands of seed origin since:

(a) observation of the qualities of a clone is much easier when a number of individuals—rather than a single specimen—exhibit such qualities;

(b) features that are common to all individual trees of a clone are likely to be genetically rather than environmentally controlled, and will therefore tend to be retained when the selected material is propagated.

Selection will depend on the purpose for which the clones are required. It is possible to improve aspen as a source of pulp since interclonal variation in pulping properties, such as fibre length and strength, has been detected. Variation among clones in stem form, branching habit, natural pruning, bark characteristics and resistance to insects and diseases could be used in the selection for shelterbelts and recreational areas.

Knowledge of the clonal habit should find immediate application in the evaluation of the aspen resource, particularly with reference to estimates of productivity and quality of stands. The selection of superior native aspen stock is at present restricted by a lack of intensive management and by poorly developed methods of artificial propagation.

Male and female

Recognition of Clones

Clone recognition is based on the fact that trees within a clone have the same genetic make-up, and tend to show a similar response to a given environment, while trees from different clones generally will not.

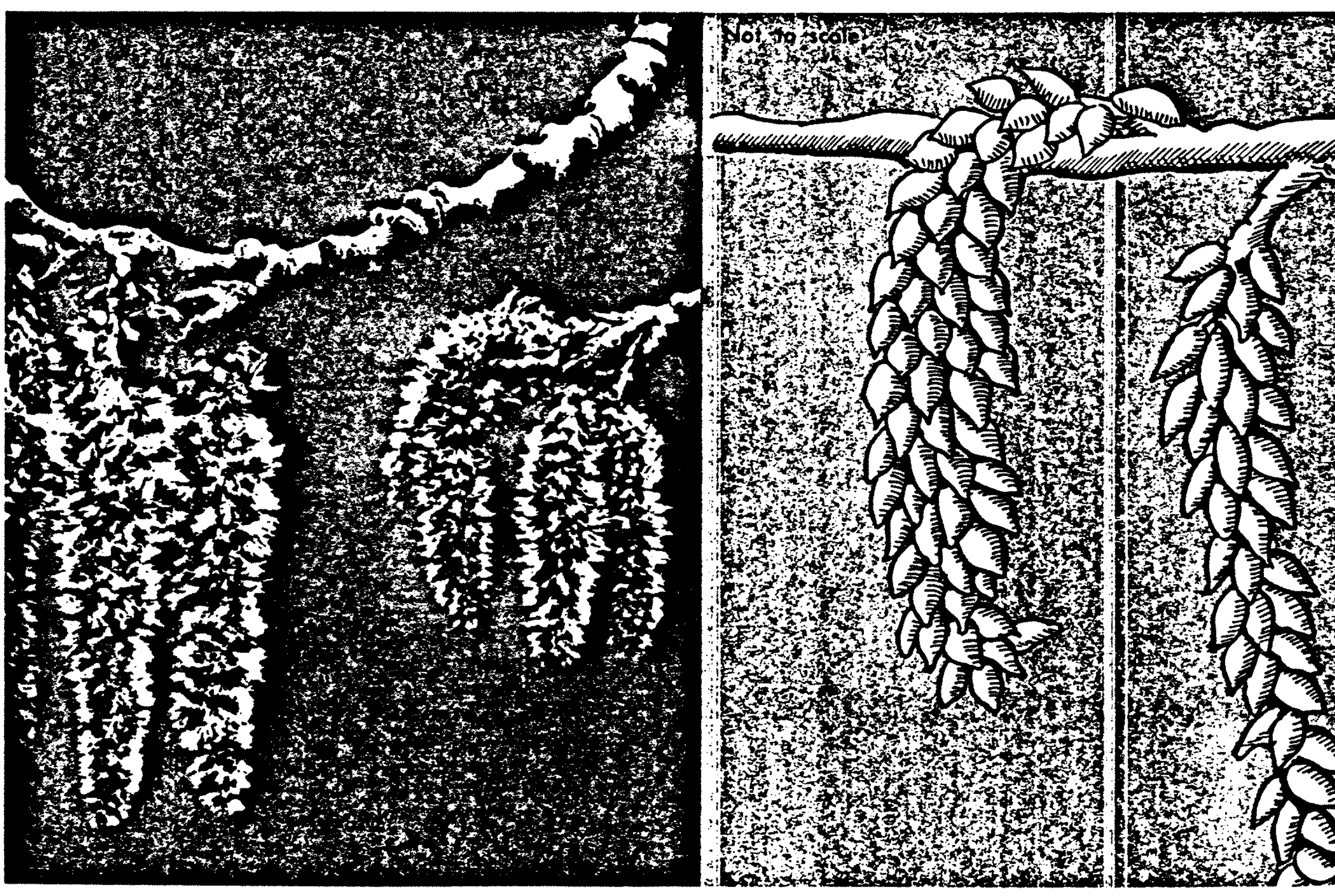
Following are a number of features and characteristics which can be used, by themselves or in combination, to distinguish between clones:

1 Flowering

Male and female flowers occur on separate clones. In the prairie provinces flowering occurs in late April and early May. All trees within a clone develop their flowers simultaneously, although clones themselves flower at different times. Observations in Manitoba have shown that male flowers appear before female flowers. Male and female flowers look very much alike from a distance and careful examination is required to distinguish between them.

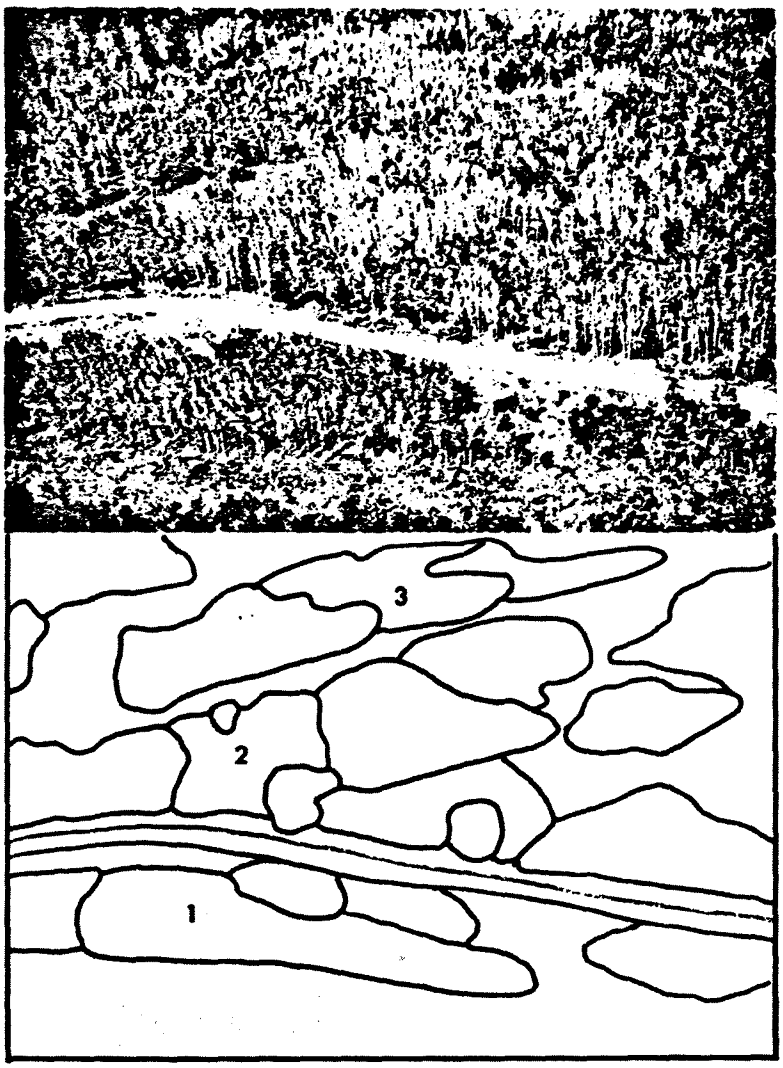
Female clones are most easily recognized during the latter stages of flowering before leaf flushing, when the fruits on the catkins give a green tinge to the tree crown. Male flowers have usually been shed by this time.

flowers and fruit of aspen.

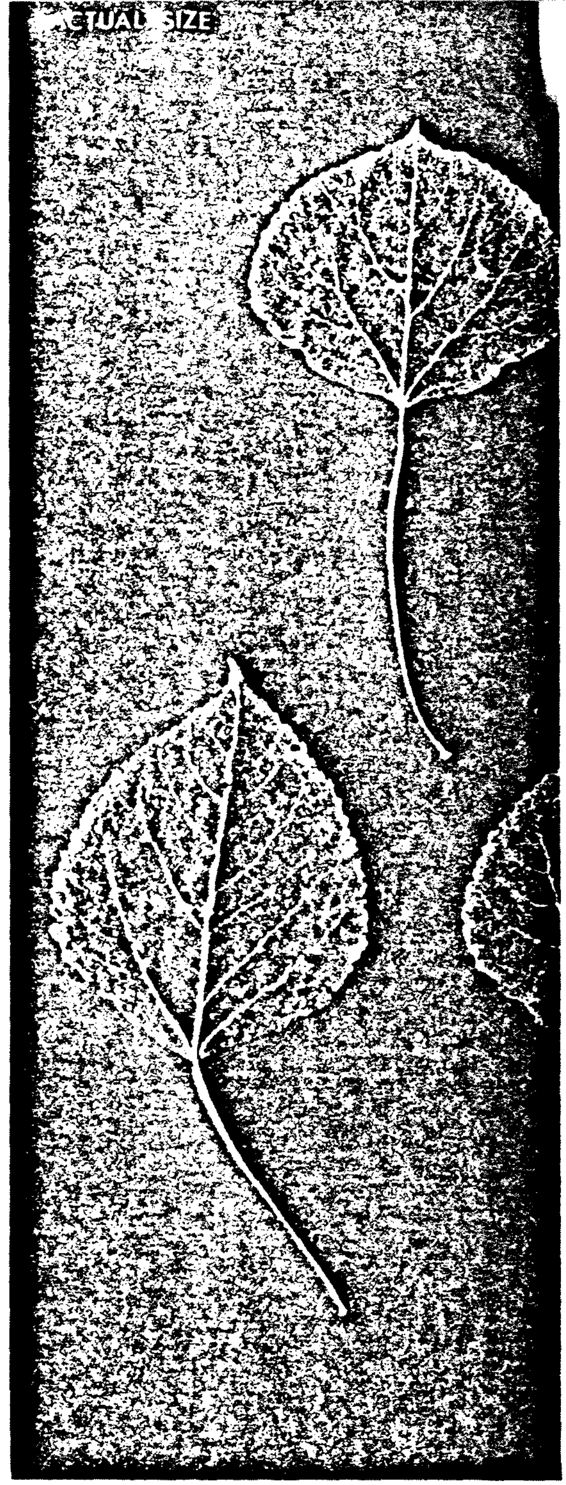


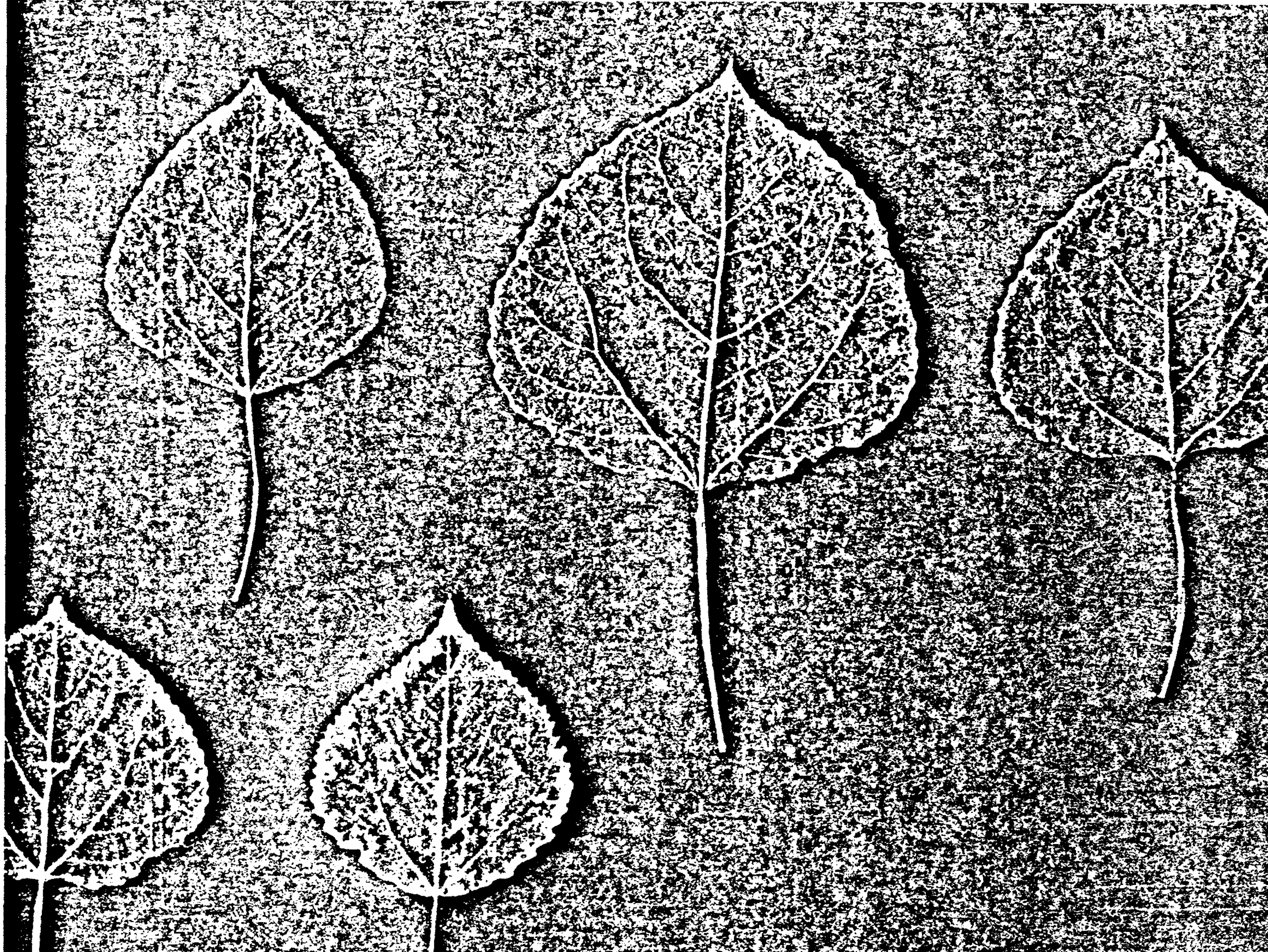
2. Leaf Flushing and Leaf Fall

Leaf flushing and leaf fall occur simultaneously for all trees within the clone. Earliest and latest flushing clones may be one to three weeks apart. This time interval results in stands exhibiting a patchwork appearance, which can again be observed in the autumn at the time of leaf discoloration and fall. The interval over which leaves of different clones fall may be several weeks.



Clones are readily distinguishable in the spring due to differences in time of leaf flushing.



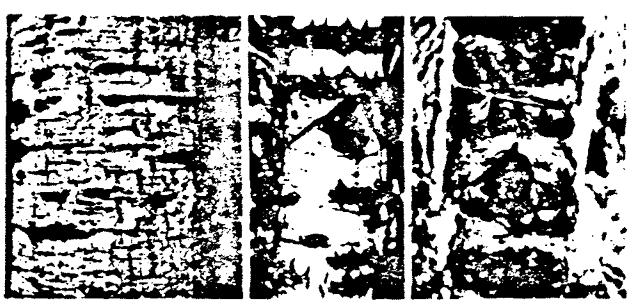


3 Leaf Shape

Leaves from different clones vary in size, blade width in relation to blade length, leaf base, petiole length, blade tip, number and size of teeth along the blade edge and the manner in which the leaf veins are arranged.

When foliage is used to distinguish between clones, only middle leaves on short (1" to 2") lateral shoots should be sampled, since they tend to exhibit a standard form.

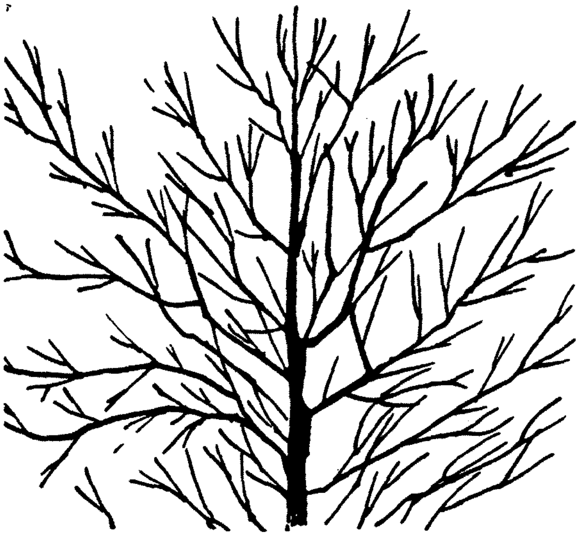
4 Bark Colour and Texture



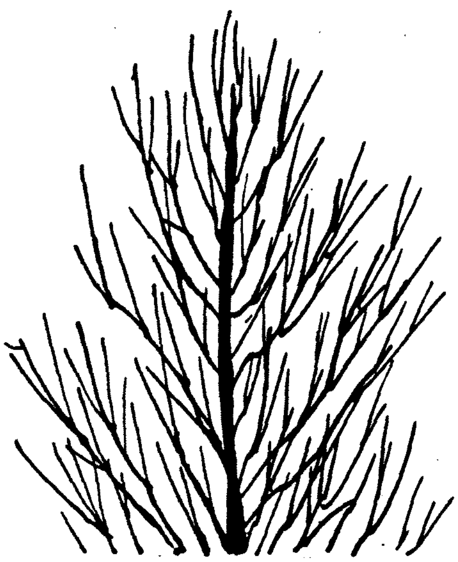
Considerable variation in bark colour and texture is noticeable between clones. Bark colour can range from near white and cream-coloured to greenish and grey, while shades of rust-brown and orange are occasionally observed. Bark can be thin and smooth or deeply furrowed while lenticels in the stem can show characteristic diamond shapes or be inconspicuous. When comparing trees, care should be taken to view stems always from the same direction, since the bark on one side of a stem is usually quite different from that on the opposite side.

5. Tree Form

Stem straightness, branchiness of the tree, degree of natural pruning and the angle between branches and the stem are other distinguishing features. An entire clone can often be distinguished, especially in parkland areas by a dome-shaped canopy pattern.



Clonal variation in tree crown and branching habit.



Clones can be identified more quickly in some stands than in others and is facilitated by practice. Although differences in leaf flushing and fall coloration are usually the most outstanding and useful features in identifying clones, it is not possible to list distinguishing features in order of importance. While two adjacent clones may be distinguished on the basis of leaf flushing, the most distinct difference between two other clones may be in the pattern of their bark or in their stem form.

A serious attempt to separate all clones within an area will require the observation of at least two sets of features. This often means two visits to the stand during the year. As an example: simultaneous leaf flushing of a group of trees may indicate one clone, although certain bark features may suggest the presence of more. To confirm, examine the leaves during the growing season.

When it is not necessary to distinguish each individual clone but merely to determine the extent of clonal variation and approximate clone size, one visit to the stand at any one time during the year should be sufficient.

Clone recognition is made easier by the fact that the individual trees within a clone are usually in close proximity to each other. Clones may occur as discrete "islands" within the stand, or trees from one clone may be intermixed with those of others.

Field observations have shown that with increasing stand age (e.g. stands 60 years old or over) clone recognition becomes

easier, since bark and crown features become more distinct.

In summary, there are no rules or identification keys for distinguishing one clone from another. However, with some practice identification of clones is possible in most cases.

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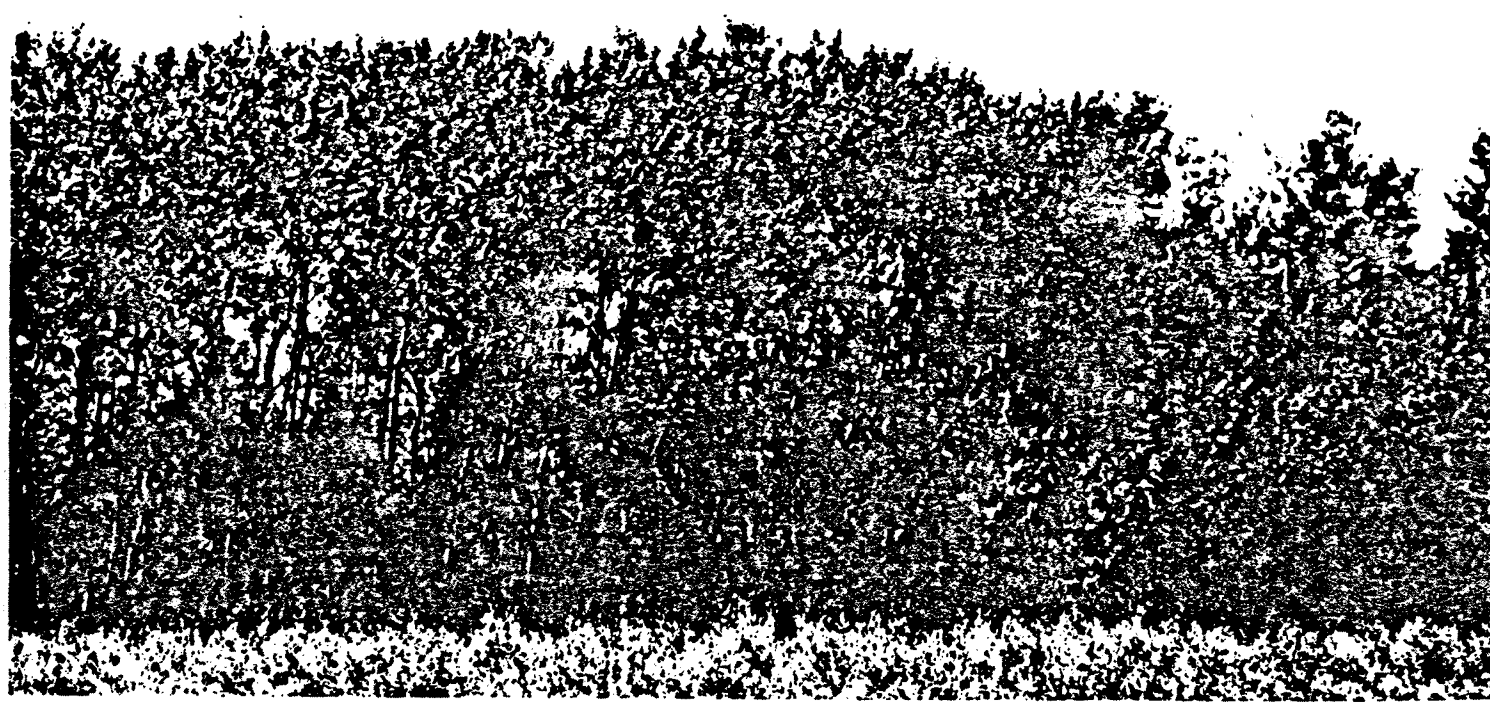
Dome-shaped canopy pattern of clones found in parkland areas.



Forest Research Branch

TEN-YEAR RESULTS OF THINNING 14-, 19- AND 23-YEAR-OLD ASPEN TO DIFFERENT SPACINGS

by

G. A. STENEKER

Sommaire en français

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CONTENTS

ABSTRACT

Ten-year results of thinning 14-, 19- and 23-year-old aspen stands to spacings of 8′ × 8′, 10′ × 10′ and 12′ × 12′ in the Riding Mountain National Park, Manitoba indicate that, with thinning to a 12 × 12-foot spacing, the rotation necessary for the production of veneer bolts will be shortened by about 10 years. Thinning to a 12 × 12-foot spacing resulted in the greatest board-foot volume.

Ten-Year Results of Thinning 14-, 19-, and 23-Year-Old Aspen to Different Spacings[1]

by

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INTRODUCTION

Aspen[3], present over large areas of Manitoba and Saskatchewan, is increasingly affected by decay organisms as it gets older, and its commercial value is greatly reduced by the resulting high proportion of defect in mature stands. Kirby, Bailey and Gilmour (1957) concluded from cull studies in Saskatchewan that aspen should be cut on a pathological rotation of 80 years. As untended stands of this age are normally deficient in sizes suitable for saw and veneer logs, thinning to increase the growth rate of individual trees has been suggested as a means of increasing saw and veneer log production.

Since the 1920's numerous thinning experiments in aspen have been conducted in the Lake States and in Canada. In some instances thinning showed promise, and in others it did not (Bickerstaff 1946, Zehngraff 1946 and 1949, Pike 1953, and Day 1958). Some of the less favourable results might be attributed to such causes as: thinning too lightly; thinning stands too old to respond; thinning stands on sites unfavourable for aspen; using thinning methods unsuitable to aspen.

A thinning experiment established in western Manitoba in 1950 would appear to have avoided most of the factors referred to above. Fourteen-, 19-, and 23-year-old aspen stands were thinned to spacings of 8′ × 8′, 10′ × 10′ and 12′ × 12′ on what may be considered good sites for aspen (Figures 1 and 2).

This report presents growth results to 1960.

LOCATION AND DESCRIPTION OF EXPERIMENTAL AREA

The experimental area is within the Riding Mountain National Park, which is located in the southeastern extremity of the B. 18a Forest Section (Rowe 1959).

A description of the selected stands, based on observations in 1950, is presented in Table 1.

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[3]For botanical names of plants mentioned, see Appendix 1.

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FIGURE 1. Thirty-three-year-old aspen, 1960. It was thinned to 12 × 12-foot spacing in 1950.

FIGURE 2. Thirty-three-year-old aspen, 1960—undisturbed.

TABLE 1. DESCRIPTION OF SELECTED STANDS—BASED ON OBSERVATIONS IN 1950

Factor	Stand description		
	Stand I	Stand II	Stand III
Age	14 years	19 years	23 years
Stand origin	clear cutting	burn	clear cutting
No. of trees per acre	6,000	2,400	2,200
Av. d.b.h.	1.4″	2.4″	2.9″
Av. dom. ht.	16′	25′	35′
Aspect	south	northwest	north
Slope	2%	2%	2%
Soil texture*	clay loam	clay loam	clay loam
Moisture**	fresh to mod. moist (3)	mod. fresh (2)	mod. moist to moist (4-5)
Tree species (Stand Composition based on number of trees)	pure apsen	aspen and 13% burr oak, green ash and balsam poplar	aspen and 8% burr oak, green ash and balsam poplar
Underbrush	hazelnut, cherry	hazelnut, cherry	hazelnut, cherry
Ground flora	dewberry wild strawberry rose	kidneyleaf violet wild strawberry rose	sarsparilla northern bedstraw snake root

*Detailed soil profile descriptions are given in Appendices II, III and IV.
**After Hills' classification, 1952.

METHODS

Within each stand permanent sample plots (with 30-foot surrounds) were laid out and thinned to spacings of 8′ × 8′, 10′ × 10′ and 12′ × 12′. Table 2 gives a summary of plots and treatments.

TABLE 2. SUMMARY OF PLOTS AND TREATMENTS

Treatment and Spacing	Number of plots		
	1/10-acre plots	1/5-acre plots	
	14-year-old	19-year-old	23-year-old
12′ × 12′	1	2	2
10′ × 10′	1	2	2
8′ × 8′	1	2	2
Control	1	2	2

Trees were tallied by one-inch diameter classes before thinning. Malformed and suppressed trees, and species other than aspen, were removed in thinning, along with sufficient intermediate trees to provide the prescribed spacing. Trees remaining after thinning were mapped and numbered, and diameter-at-breast-height was measured to the nearest one-tenth-inch; they were remeasured to the same accuracy in 1960. All trees on the thinned plots and about 10 per cent of all trees on the control plots were measured for height to the nearest foot in 1950 and 1960. Height diameter curves were constructed for each plot from both measurements. Stand tables for all plots before and after thinning in 1950 and in 1960 are given in Appendix IV.

Growth data for the replications in the 19- and 23-year-old stands have, because of their similarity, been grouped together.

Following an unavoidable destruction of plots in the 19-year-old stand in 1961, detailed growth analyses were made on some of the sample trees remaining on the various plots. Of the 1950 inch-class diameter groupings only the 3-inch class had sufficient residuals to give an adequate sample for analysis. Discs were cut from sample trees at breast height. At the radius of average diameter the yearly ring width over the last 20 years was measured with the aid of a vernier microscope.

RESULTS

Production of Large Trees

The various spacings had by 1960 not greatly influenced the production of large sized trees, although some trends were apparent (Table 3). In all stands in 1960 the number of trees in the two largest diameter classes was, with two exceptions, greater on thinned than on control plots. Number of trees 5 inches and over in the 14- and 19-year-old stands, and 7 inches and over in the 23-year-old stand, was greatest on plots thinned to an 8 × 8-foot spacing. However, initial differences in 1950 in diameter distribution between sample plots within the various stands may have favoured the 8 × 8-foot spacings to 1960. In the 19-year-old stand the number of trees 6 inches and over was greatest on plots thinned to a 12 × 12-foot spacing.

Diameter and Height Increment

Average diameters of the 200, 50 and 25 largest trees per acre in 1960 by treatment and stand, and their 10-year diameter increment (1950-1960), were computed (Table 4). Diameters in 1960 were, except in the 19-year-old stand, greater on the thinned than on the control plots, but differed little between thinned plots. However, 1950-1960 diameter increment, except for two instances, tended to be directly related to intensity of thinning. The effect of thinning was almost as evident on the 25 largest trees as on the 50 or 200 largest trees.

The large 1960 diameters on some of the plots could be attributed to diameter distribution before thinning.

TABLE 3. CUMULATIVE FREQUENCY DISTRIBUTION IN 1960 BY DIAMETER CLASSES, STANDS AND TREATMENTS

Treatment	Number of trees per acre											
	14-year-old (1950)				19-year-old (1950)				23-year-old (1950)			
	12′ × 12′	10′ × 10′	8′ × 8′	Control	12′ × 12′	10′ × 10′	8 × 8′	Control	12′ × 12	10′ × 10′	8′ × 8′	Control
D.b.h. class												
1	—	—	—	3,000	—	—	—	—	—	—	—	—
2	260	—	—	2,600	—	—	655	1,085	—	—	—	1,557
3	240	410	630	1,200	—	427	650	998	—	—	628	1,487
4	130	340	610	230	287	420	573	660	298	422	610	985
5	10	120	340	10	237	253	302	267	290	403	515	562
6	0	10	30	0	80	40	58	55	250	307	332	230
7	—	0	0	—	10	2	2	5	145	120	147	67
8	—	—	—	—	0	0	0	0	37	37	33	5
9	—	—	—	—	—	—	—	—	5	5	2	0
10	—	—	—	—	—	—	—	—	0	0	0	—

TABLE 4. AVERAGE D.B.H. OF 1960'S TWO HUNDRED, FIFTY AND TWENTY-FIVE LARGEST TREES PER ACRE IN 1950 AND 1960 AND DIAMETER INCREMENT, BY TREATMENT AND STANDS

Age in 1950	Treatment	Number of largest trees per acre: 200 D.b.h. 1960	200 D.b.h. 1950	200 Incr.	50 D.b.h. 1960	50 D.b.h. 1950	50 Incr.	25 D.b.h. 1960	25 D.b.h. 1950	25 Incr.	Incr. treatm. -Incr. control × 100 / Incr. control: 200	50	25
	12′ × 12′	4.7	2.0	2.7	5.3	2.3	3.0	—*	—	—	42%	30%	—
14 years	10′ × 10′	4.8	2.1	2.7	5.3	2.4	2.9	—*	—	—	42%	26%	—
	8′ × 8′	5.3	2.6	2.7	5.6	2.7	2.9	—*	—	—	42%	26%	—
	Control	4.0	2.1	1.9	4.6	2.3	2.3	—*	—	—	—	—	—
	12′ × 12′	5.5	3.0	2.5	6.1	3.3	2.8	6.4	3.6	2.8	56%	47%	40%
19 years	10′ × 10′	5.3	3.2	2.1	5.8	3.5	2.3	6.0	3.6	2.4	31%	21%	20%
	8′ × 8′	5.4	3.5	1.9	6.0	3.9	2.1	6.3	4.1	2.2	19%	10%	10%
	Control	5.4	3.8	1.6	6.1	4.2	1.9	6.3	4.3	2.0	—	—	—
	12′ × 12′	7.1	4.3	2.8	7.9	4.9	3.0	8.3	5.2	3.1	40%	30%	35%
23 years	10′ × 10′	6.9	4.2	2.7	7.9	4.8	3.1	8.3	5.0	3.3	35%	35%	43%
	8′ × 8′	7.0	4.6	2.4	7.8	5.3	2.5	8.2	5.5	2.7	20%	9%	17%
	Control	6.5	4.5	2.0	7.3	5.0	2.3	7.5	5.2	2.3	—	—	—

*Sample plots in the 14-year-old stand are 1/16-acre in size. Analysis of the largest 25 trees per acre would therefore involve 2 or 3 trees. This number was considered too small for analysis. Sample plots in other stands are 1/4-acre in size.

Figure 3 shows diameter increment (1950-1960) of all trees by treatments and 1-inch diameter classes. In all stands diameter increment rose with increased thinning intensity. Effect of thinning was most evident on trees in the smaller size classes. Little difference existed in diameter increment of trees in the largest diameter classes in the 23-year-old stand.

Yearly diameter increment of a number of sample trees in the 19-year-old stand is shown by treatment over a 20-year-period in Figure 4. After 1950, diameter increment for all treatments increased, the 12 × 12-foot spacing showing the most noticeable increase. By 1953 maximum rate of increment had been reached by all trees and a general decline occurred. However, trees on the thinned plots maintained a higher growth rate than those on the controls. Regression lines of diameter increment on years since thinning for trees on the heaviest thinned and control plots for the period 1953-1961 (1953 is year in which full effect of thinning was reached), have been superimposed on the graphs in Figure 4. The regression lines show that, although absolute difference in growth rate between thinned and control plots decreased somewhat, percentage difference increased from 1953 to 1961.

Height increment of dominant trees was not influenced by thinning.

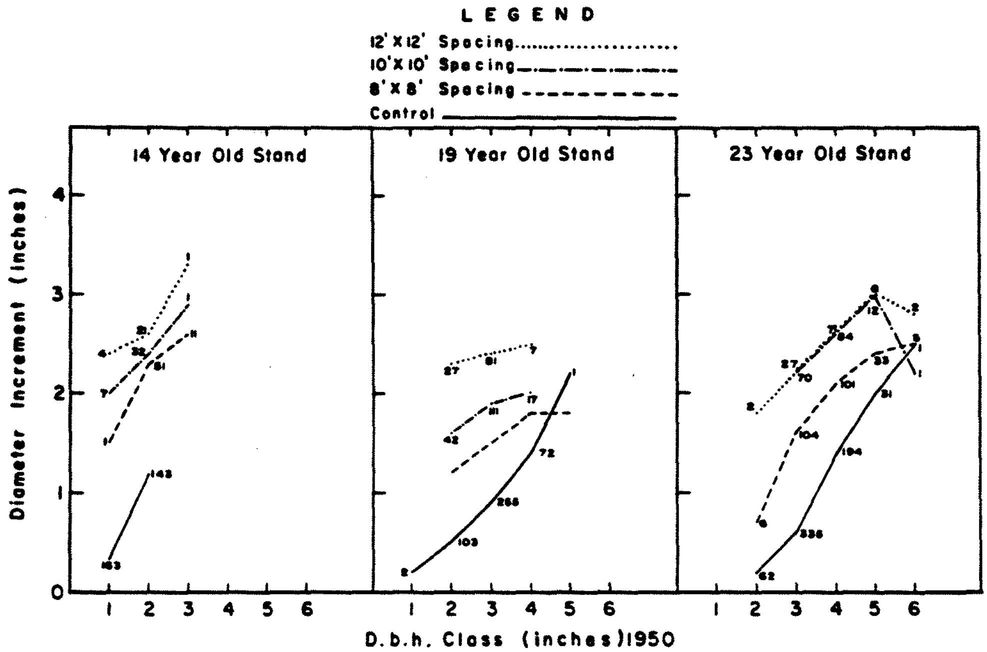

FIGURE 3. Periodic diameter increment by treatment and stands 1950-1960

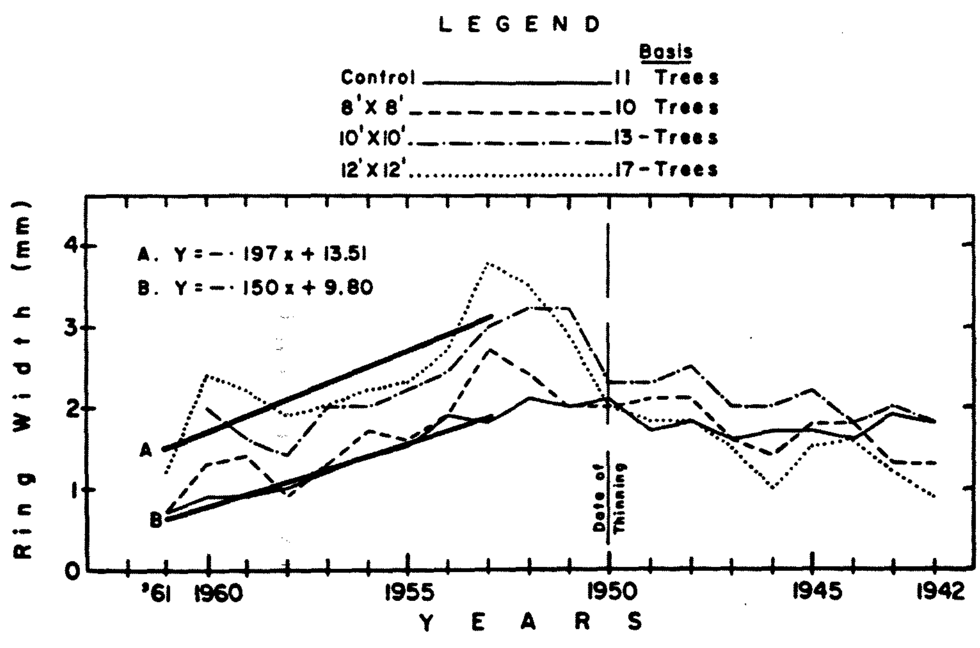

FIGURE 4. Yearly ring width at breast height from 1942 to 1961 by treatment of 3" trees (dominant and codominant in 1950) from the 19-year-old stand.

TABLE 5. STAND STATISTICS PER ACRE, 1950 AND 1960

Age in 1950	Treatment	No. of plots	No. of trees 1950 B.T.	No. of trees 1950 A.T.	No. of trees 1960	Basal area (sq. ft.) 1950 B.T.	Basal area (sq. ft.) 1950 A.T.	Basal area (sq. ft.) 1960	Total volume (cu. ft.)* 1950 B.T.	Total volume (cu. ft.)* 1950 A.T.	Total volume (cu. ft.)* 1960	Merchantable volume (cords)** 1950 B.T.	Merchantable volume (cords)** 1950 A.T.	Merchantable volume (cords)** 1960	Merchantable volume (bd. ft.)† 1950 B.T.	Merchantable volume (bd. ft.)† 1950 A.T.	Merchantable volume (bd. ft.)† 1960
14 years	12′ × 12′	1	5,970	300	260	70	6	29	907	83	459	0	0	3.7	0	0	0
	10′ × 10′	1	6,670	440	410	55	9	40	714	119	640	0	0	4.5	0	0	0
	8′ × 8′	1	5,270	680	630	71	20	75	988	296	1,424	0	0	13.4	0	0	0
	Control	1	6,050	--	3060	55	--	103	712	--	1,685	0	--	3.8	0	—	0
19 years	12′ × 12′	2	2,458	300	288	74	14	42	1,099	230	768	1.0	.2	8.0	0	0	0
	10′ × 10′	2	2,785	435	428	76	21	53	1,232	360	1,012	1.0	.6	10.0	0	0	0
	8′ × 8′	2	2,138	680	655	72	35	74	1,104	542	1,346	1.4	1.2	12.1	0	0	0
	Control	2	2,475	-	1,085	94	--	94	1,524	—	1,847	3.2	—	13.2	0	—	0
23 years	12′ × 12′	2	2,165	300	298	96	27	70	1,940	586	1,837	8.8	5.6	22.1	0	0	937
	10′ × 10′	2	2,448	435	422	90	34	88	1,930	729	2,284	6.2	5.6	26.8	0	0	870
	8′ × 8′	2	1,682	680	628	92	54	114	1,792	1110	2,969	9.0	8.3	35.5	0	0	821
	Control	2	2,610	--	1,557	129	—	162	2,668	—	4,142	15.1	—	40.4	0	—	135

*Interpolated volume tables. Canada, Department of Mines and Resources, Dom. For. Serv. Misc. Ser. No. 3. 1944.
**Peeled, 1-foot stump, 3-inch top diameter i.b. Volume, yield and stand tables for tree species in the Lake States. 1934. Univ. of Minn. A.E.S. Tech. Bull. No. 39. Page 30.
†1-foot stump; log length 12.6′ and 16.8′; top diameter 6.5″. Int. log rule (¼) (> 7.5″ d.b.h.) Form class volume tables (sec. ed.) 1948. Canada Dep't. of Mines and Resources, Dom. For. Serv. Table 203.

Stand in 1960

Stand statistics for 1950 before and after thinning and for 1960 are presented in Table 5. In 1960 only the 23-year-old stand supported trees sufficiently large (larger than 7.5 inches) to produce a board-foot volume. Thinning to a 12 × 12-foot spacing produced the greatest volume (937 bd. ft.) and no thinning produced the least (135 bd. ft.).

Basal area, total volume (cu. ft.) and cordwood volume in 1960 were, except in the 14-year-old stand, inversely related to intensity of thinning.

Nett and Gross Volume Increment and Mortality

Nett board-foot volume increment was greatest on plots thinned to a 12 × 12-foot spacing and least on the controls (Table 6). Net total volume (cu. ft.) and cordwood volume increment were for all stands greatest with an 8 × 8-foot spacing and, except for the 19-year-old stand, least with a 12 × 12-foot spacing.

TABLE 6. PERIODIC NETT AND GROSS VOLUME INCREMENT AND MORTALITY PER ACRE, 1950–1960.

Age in 1950	Treatment	Total volume (cu. ft.)			Merchantable volume (cords)			Merchantable volume (bd. ft.)		
		Nett inc.	Mort.	Gross inc.	Nett inc.	Mort.	Gross inc.	Nett inc.	Mort.	Gross inc.
14 years	12′ × 12′	376	49	425	3.7	.2	3.9	0	0	0
	10′ × 10′	521	24	545	4.5	.1	4.6	0	0	0
	8′ × 8′	1,128	36	1,164	13.4	.1	13.5	0	0	0
	Control	973	221	1,194	3.8	0	3.8	0	0	0
19 years	12′ × 12′	538	28	566	7.8	.3	8.1	0	0	0
	10′ × 10′	652	6	658	9.4	.02	9.4	0	0	0
	8′ × 8′	804	34	838	10.9	.2	11.1	0	0	0
	Control	323	357	680	10.0	.2	10.2	0	0	0
23 years	12′ × 12′	1,251	7	1,258	16.5	.07	16.6	937	0	937
	10′ × 10′	1,555	42	1,597	21.2	.5	21.7	870	0	870
	8′ × 8′	1,859	153	2,012	27.2	1.6	28.8	821	0	821
	Control	1,474	524	1,998	25.3	.8	26.1	135	0	135

Gross total volume increment showed a marked drop on those plots thinned to a spacing wider than 8 × 8 feet.

Mortality over the 10-year period on the control plots, especially among the smaller diameter classes, was in some instances as high as 50% by number of trees. Most trees on the thinned plots had their crowns relatively free from competition, and mortality was consequently greatly reduced.

DISCUSSION AND CONCLUSIONS

Results of aspen thinnings in Manitoba and Saskatchewan will most likely be evaluated in terms of increased production of material suitable for the manufacture of lumber and veneer for which certain size and quality standards must be met. Ten-year results of this experiment have shown that thinning produced a greater number of large sized trees to 1960 than no thinning. Furthermore the largest trees on the thinned plots were growing at a faster rate than the largest trees on the control plots. It is therefore likely that as a result of thinning veneer size material (minimum size: 11 inches d.b.h.) will be produced at an earlier age than would be the case with no thinning.

In order to make a conservative estimate of the rotation age at which veneer size material will be produced on the plots thinned to a 12 × 12-foot spacing in the 19-year-old stand, the assumptions are made that (1) Kirby's et al. (1957) projected growth rates for aspen apply to the growth rate of the largest trees on the controls and (2) a constant per cent difference (rather than slightly increasing difference as in Figure 4) in growth rate between the 12 × 12-foot thinned plots and control plots will be maintained in the future. Projected growth rate calculations for the 200, 50 and 25 largest trees on the 12 × 12-foot thinned plots revealed that these trees may produce veneer size material at an age of 48 years. On the control plots this material may be produced at an age of 58 years. Thinning to a 12 × 12-foot spacing will therefore have shortened the rotation by 10 years. If the same assumptions are made in the calculation of the projected growth rate of the largest trees in the other two stands, the rotation of these trees will also be shortened by about 10 years.

The three ages of stand in this study showed no difference in response to thinning. Where one non-commercial thinning is possible, early and heavy thinning would seem most advantageous. It would probably be cheaper, and also the growth advantage resulting from thinning would be better utilized, than if thinning were to be deferred. Thinning a 14-year-old stand to a 12 × 12-foot spacing will likely maintain the diameter increment at a high level for a long period of time, and a subsequent thinning can be delayed until such an operation will be commercial.

Greatest board-foot volume to 1960 was produced on plots thinned to a 12 × 12-foot spacing. However, volume differed little from that on plots thinned to a 10 × 10- and an 8 × 8-foot spacing. It cannot therefore be safely assumed that the widest spacing will continue to produce the greatest board-foot volume.

SUMMARY

In 1950, 14-, 19- and 23-year-old aspen stands were thinned to spacings of 8′ × 8′, 10′ × 10′ and 12′ × 12′ in the Riding Mountain National Park, Manitoba. An analysis of the growth to 1960 of 1960's 200, 50 and 25 largest trees per acre, by treatment and stand, showed that on plots thinned to a 12 × 12-foot spacing diameter increment of the largest trees was between 30 and 56 per cent greater than that of the largest trees on the controls. It was concluded that with thinning to a 12 × 12-foot spacing, the rotation necessary for the production of veneer bolts (assuming a minimum utilizable size of 11 inches d.b.h.) will be shortened by about 10 years.

Thinning to a 12 × 12-foot spacing resulted in the greatest board-foot volume; no thinning resulted in the greatest basal area and total volume (cu. ft.); and thinning to an 8 × 8-foot spacing resulted in the greatest cordwood volume.

Gross total volume increment dropped markedly at spacings wider than 8 × 8 feet. Mortality was noticeably reduced by thinning.

SOMMAIRE

En 1950, des peuplements de peupliers de 14, 19 et 23 ans ont été éclaircis à intervalles de 8 pieds sur 8, de 10 pieds sur 10 et 12 pieds sur 12 dans le parc national Riding Mountain, au Manitoba. Une analyse de la croissance, jusqu'en 1960, des 200, 50 et 25 plus gros arbres à l'acre en 1960, d'après le traitement reçu et le type de peuplement, a révélé que dans les places éclaircies à intervalles de 12 pieds sur 12, l'accroissement en diamètre des arbres les plus gros était de 30 à 56 p. 100 supérieur à celui des plus gros arbres des places témoins. L'auteur conclut que grâce aux coupes d'éclaircie à intervalles de 12 pieds sur 12, la rotation nécessaire pour la production de billes de placage, si l'on présume que les dimensions minima des billes utilisables sont de 11 pouces de diamètre à hauteur de poitrine, sera raccourcie d'environ dix ans.

Les coupes d'éclaircie à intervalles de 12 pieds sur 12 ont donné le plus fort volume de pieds mesure de planche, mais n'ont provoqué aucun accroissement de la surface terrière et du volume global (en pi. cu.); par ailleurs, les coupes d'éclaircie à intervalles de 8 pieds sur 8 ont donné le plus fort volume de bois de chauffage.

L'accroissement du volume global brut a sensiblement diminué à la suite des éclaircies à intervalles de plus de 8 pieds sur 8. De plus, les éclaircies ont enrayé notablement la mortalité.

APPENDIX I

Common and botanical names of plants mentioned in text.

Ash, green	*Fraxinus pennsylvanica* Marsh. var. *subintegerrina* (Vahl.) Fern.
Aspen, trembling	*Populus tremuloides* Michx.
Cherry	*Prunus* spp.
Oak, burr	*Quercus macrocarpa* Michx.
Poplar, balsam	*Populus balsamifera* L.
Dewberry	*Rubus pubescens* Raf.
Hazelnut	*Corylus cornuta* Marsh.
Kidneyleaf violet	*Viola renifolia* Gray (incl. var. *brainerdii* (Green) Fenn.)
Northern bedstraw	*Galium boreale* L.
Rose	*Rosa* sp.
Sarsaparilla	*Aralia nudicaulis* L.
Snake root	*Sanicula marilandica* L.
Wild strawberry	*Fragaria virginiana* Duchesne.

APPENDIX II

Soil Profile Description, 14-Year-Old Stand, Plots 9-12

Moisture regime 3, fresh.

		Accumulative depth
organic layers	L Depth ½″ F " 2″ H " 1″	3½″
Ahe horizon	Depth —3″ Texture —clay loam Structure—granular pH —6.5 Colour —very dark grey (10YR3/1)*	6½″
Bt horizon	Depth —11″ Texture —heavy clay Structure—blocky pH —6.7 Colour —dark brown (10YR3/3)	17½″
Bm horizon	Depth —6″ Texture —clay loam Structure—granular pH —7.4 Colour —grey brown (2.5Y 5/2) Free Ca present.	23½″
C horizon	Depth —8″+ Texture —clay loam Structure—granular pH —7.4+ Colour —grey brown (2.5Y 5/2) Water table below 31½″	31½″+

*Munsell Soil Color Charts, 1954 ed.
Munsell Color Company, Inc.
Baltimore 2, Maryland, U.S.A.

APPENDIX III

Soil Profile Description, 19-Year-Old Stand, Plots 13-20

Moisture regime 2, moderately fresh.

		Accumulative depth
organic layers	L Depth $\frac{1}{4}$" F " 1" H " $\frac{3}{4}$"	2"
Ahe horizon	Depth —4" Texture —loamy sand Structure—single grained to slightly granular pH —6.8 Colour —dark grey to reddish brown (5YR 3/1)	6"
Bt horizon	Depth —7" Texture —clay loam Structure—single grained to slightly granular pH —6.7 Colour —reddish brown (5YR 5/4)	13"
Bm horizon	Depth —9" Texture —silty clay loam Structure—single grained to slightly blocky pH —7.3 Colour —yellow brown (10YR 5/6) Free Ca present	22"
C horizon	Depth —7$\frac{1}{2}$" Texture —silty clay loam Structure—single grained to slightly blocky pH —7.4 Colour —yellow brown (10YR 5/6) Water table below 29$\frac{1}{2}$"	29$\frac{1}{2}$"

APPENDIX IV

Soil Profile Description, 23-Year-Old Stand, Plots 1-8

Moisture regime 4-5, moderately moist to moist

		Accumulative depth
organic layers	L Depth ¼" F " 1" H " 1"	2¼"
Ah horizon	Depth —2½" Texture —loamy fine sand Structure—single grained slightly platy pH —6.8 Colour --dark grey to black (10YR 3/1)	4¾"
Ae horizon	Depth —3½" Texture —loamy fine sand Structure—single grained slightly platy pH --6.8 Colour —grey brown (2.5 YR 5/2)	8¼"
Btg horizon	Depth —7" Texture —heavy clay Structure--granular to slightly blocky pH —6.8 Colour —grey brown (2.5 YR 5/2) Occurrence of gleying	15¼"
Cg horizon	Depth —15" Texture —alternate bands of silt and fine sand Structure—single grained to slightly granular pH —7.4 Colour —yellow brown (10YR 5/6) Occurrence of gleying Water table in June below 30"	30¼"

APPENDIX V

STAND TABLE, 1950 AND 1960

(number of trees per acre)

	14 years (1950)										
Treatment	12′ × 12′			10′ × 10′			8′ × 8′			Control	
Plot number	10			11			12			9	
D.b.h. class	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950	1960
1	3,630	20		5,400	30		3,050	490		4,580	460
2	2,330	270	20	1,250	400		1,980	190		1,470	1,400
3	10	10	110	20	10	70	240		20	—	970
4	—	—	120	—	—	220	—	—	270	—	220
5	—	—	10	—	—	110	—	—	310	—	10
6	—	—	—	—	—	10	—	—	30	—	—
7	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—
Total	5,970	300	260	6,670	440	410	5,270	680	630	6,050	3,060

APPENDIX V

STAND TABLE, 1950 AND 1960

(number of trees per acre)—continued

	19 years (1950)																					
Treatment	12′ × 12′						10′ × 10′						8′ × 8′						Control			
Plot number	13			14			17			18			15			16			19		20	
D.b.h. class	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950	1960	1950	1960
1	335	—	—	280	—	—	735	—	—	375	—	—	320	—	—	205	—	—	260	—	310	—
2	1,530	55	—	1,215	55	—	1,785	70	—	1,170	105	—	1,090	155	—	865	60	10	925	105	1,055	70
3	650	230	—	720	210	—	675	320	5	630	260	10	705	445	80	825	475	75	910	325	895	350
4	70	15	60	105	35	40	70	45	165	130	70	170	150	80	325	100	135	215	245	395	325	390
5	10	—	145	—	—	170	—	—	215	—	—	210	5	—	190	10	10	300	5	210	15	215
6	—	—	70	—	—	70	—	—	40	—	—	35	—	—	65	—	—	45	—	45	5	55
7	—	—	10	—	—	10	—	—	—	—	—	5	—	—	—	—	—	5	—	—	—	10
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	2,595	300	285	2,320	300	290	3,265	435	425	2,305	435	430	2,270	680	660	2,005	680	650	2,345	1,080	2,605	1,090

APPENDIX V

STAND TABLE, 1950 AND 1960

(number of trees per acre)—concluded

	23 years (1950)																					
Treatment	12′ × 12′						10′ × 10′						8′ × 8′						Control			
Plot number	1			2			3			4			5			6			7		8	
D.b.h. class	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950 B.T.	1950 A.T.	1960	1950	1960	1950	1960
1	260	—	—	95	—	—	170	—	—	75	—	—	75	—	—	70	—	—	145	—	165	—
2	910	—	—	675	—	—	1,190	—	—	960	—	—	495	15	—	415	—	—	765	50	865	90
3	810	55	—	790	75	—	950	140	—	920	165	—	655	240	25	750	280	10	925	460	1,070	545
4	340	205	—	300	140	15	265	225	25	260	240	15	345	295	70	305	285	120	530	390	545	455
5	40	35	35	95	75	45	70	70	70	30	25	120	120	120	170	105	100	195	110	330	85	335
6	5	5	120	10	10	90	—	—	200	5	5	175	10	10	205	20	15	165	15	155	—	170
7	—	—	115	—	—	100	—	—	60	—	—	105	—	—	100	—	—	130	—	70	—	55
8	—	—	20	—	—	45	—	—	60	—	—	5	—	—	45	—	—	15	—	10	—	—
9	—	—	10	—	—	—	—	—	10	—	—	—	—	—	—	—	—	5	—	—		—
Total	2,365	300	300	1,965	300	295	2,645	435	425	2,250	435	420	1,700	680	615	1,665	680	640	2,490	1,465	2,730	1,650

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THINNING OF TREMBLING ASPEN
(*POPULUS TREMULOIDES* MICHAUX) IN MANITOBA

BY

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Steneker, G.A. 1974. Thinning of Trembling Aspen *(Populus tremuloides* Michaux) in Manitoba. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-122.

ABSTRACT

Results of thinning trials in 11-, 14-, and 23-year-old trembling aspen stands in Manitoba 23 and 21 years later show that individual tree growth was markedly increased by thinning. By thinning up to 12 ft x 12 ft (3.6 x 3.6 m) spacing, the time required for trees to reach an average dbh of 9 in. (23 cm) can be reduced by about 20 years.

Although thinning to increase fibre production is not economical, thinning to produce sawlogs might pay, provided that precommercial thinnings could be carried out cheaply at the age of about 10 years.

RESUME

Les résultats d'essais d'éclaircie, effectués au Manitoba dans des peuplements de peupliers faux-tremble âgés de 11 et 14 et 23 ans, indiquent une augmentation significative dans l'accroissement des arbres. L'auteur rapporte que des éclaircies suffisantes pour produire des écartements de 12' x 12' (3.6 x 3.6 m) réduisent d'environ 20 ans l'âge normalement requis pour atteindre un dhp moyen de 9" (23 cm).

L'auteur croit que les éclaircies en vue d'accroître la production de fibres ne sont pas rentables. Par contre, pour produire des grumes, on pourrait effectuer des éclaircies, pourvu qu'elles soient faites à peu de frais lorsque le peuplement est âgé d'environ 10 ans.

TABLE OF CONTENTS

INTRODUCTION

Trembling aspen (*Populus tremuloides* Michaux) is one of the most abundant commercial tree species in the Prairie Provinces. By volume it accounts for about 13%, 30%, and 50% of the total forest resource in Manitoba, Saskatchewan, and Alberta, respectively (Gill 1960, Saskatchewan Department of Natural Resources 1959, Alberta Department of Lands and Forests 1961). Utilization of the species, however, particularly for lumber, has been very limited. One important reason for this is the high incidence of decay with advancing age (Gill 1960, Kirby et al. 1957, Thomas 1968).

The present minimum acceptable tree size for sawlogs is an 8-in. (20-cm) stump and 5-in. (13-cm) top; these dimensions are not reached until the stand is 60-70 years old. At that age 25% or more of the merchantable volume may have been lost through decay. If minimum commercial size can be reached at an age of 40 or 50 years by an increase in individual tree growth through thinning, decay losses could be kept at about 10-15%.

In 1948 and 1950 two thinning trials were initiated in Manitoba in 11-, 14-, and 23-year-old aspen stands with the objective to evaluate the effect of thinning on 1) individual tree growth and subsequent merchantable volume production, and 2) mean annual total cubic foot volume increment and production.

This report presents results to 1971. Intermediate results of the two trials were reported previously (Steneker 1964, 1966; Steneker and Jarvis 1966).

LOCATION AND DESCRIPTION OF STUDY AREAS

The study areas are located in the Turtle Mountain Forest Reserve and Riding Mountain National Park. Both areas are within the B18a Mixedwood Forest Section (Rowe 1972). The soils are grey-black and grey-wooded Luvisols, developed on calcareous till. Soil texture ranges from loam to clay loam. Species occurring in small amounts with the aspen are balsam poplar (*Populus balsamifera* L.), bur oak (*Quercus macrocarpa* Michaux), elm (*Ulmus americana* L.) and green ash (*Fraxinus pennsylvanica* Marsh. var. *subintegerrina* (Vahl.) Fern).

At Turtle Mountain Forest Reserve an 11-year-old aspen stand was selected for study. The number of trees per acre ranged from 3,000 to 4,000 (7,400-9,900 trees per ha), average diameter at breast height (dbh) was 2 in. (5 cm), and average height of dominant trees ranged from 19 to 26 ft (5.8-7.9 m).

At Riding Mountain National Park 14- and 23-year-old aspen stands were selected. Specifications for the 14-year-old stand were 6,000 trees per acre (14,800 trees per ha), 1.4 in. (3.6 cm) average dbh, and 19-25 ft (5.8-7.6 m) average dominant height; and for the 23-year-old stand were 2,200 trees per acre (5,400 trees per ha), 2.9 in. (7.4 cm) dbh and 41-44 ft (12.5-13.4 m) dominant height.

METHODS

Within each selected stand a series of 0.2-acre (0.08-ha) permanent sample plots were established and subjected to the following thinning regimes:

Initial treatment	Number of sample plots (0.2 acre)[a] stand age (years)		
	11 in 1948	14 in 1950	23 in 1950
12' x 12' spacing (3.6 m)		1	2[b]
10' x 10' " (3.0 m)		1	2[b]
8' x 8 ' " (2.4 m)		1[b]	2[b]
7' x 7' " (2.1 m)	1[b]		
5' x 5' " (1.5 m)	1[b]		
20' strip thinning (6 m)	1		
Control	1	1	2

[a] Plot size in the 14-year-old stand was 0.1 acre (0.04 ha).
[b] Plots subsequently thinned in 1965.

Thinning to spacing was approximate. Residuals were left as evenly distributed as possible while leaving the required number of trees per plot. The 20-ft (6-m) strip thinning in the 11-year-old stand involved the removal of all trees in 20-ft wide strips with the strips 20 ft apart.

The objective of the thinning in 1965 was to maintain the increased growth rate that resulted from the first thinning. Thinning intensities in 1965 were based on other aspen thinning results on the prairies (Steneker and Jarvis 1966), which indicated the required basal area levels for maximum net basal and total cubic foot volume increment at various ages (Table 1). By 1965 these levels of stocking had either been reached or surpassed on the more lightly thinned plots (Tables 2 and 3).

In the 1965 thinning the 7 ft x 7 ft and 5 ft x 5 ft thinned plots in the 11-year-old stand (28 years old in 1965) were thinned back

TABLE 1. Average basal area of undisturbed upland aspen stands in Manitoba and Saskatchewan and basal area per acre giving maximum basal area increment, by age (After Steneker and Jarvis 1966)

Stand age (years)	Basal area of undisturbed stands (sq ft)	Basal area giving maximum b. a. increment (sq ft)
10	44	28
20	86	48
30	104	67
40	114	84
50	122	101

to 53 and 60 sq ft (4.8 and 5.4 m^2) respectively. The 8 ft x 8 ft thinned plot in the 14-year-old stand (29 years old in 1965) was thinned back to 63 sq ft (5.7 m^2), and the 8 ft x 8 ft, 10 ft x 10 ft and 12 ft x 12 ft thinned plots in the oldest stand (38 years old in 1965) were thinned back to 90, 78 and 58 sq ft (8.1, 7.0, and 5.2 m^2) respectively. Stand statistics per acre for all plots to 1971 are given in Tables 2 and 3.

Most stems removed in the 1965 thinnings were 4 in. (10 cm) dbh or larger and it is assumed that this thinning paid for itself.

RESULTS

VOLUME INCREMENT

In all three stands plot data showed considerable differences in net mean annual total cubic foot volume increment (MAI) before thinning (Figure 1), presumably the result of site differences between plots and/or genetic differences between trees of different plots. However, treatment effects were still apparent.

TABLE 2. Stand Data Per Acre to 1971 for Sample Plots at Turtle Mountain

	Number of trees at age							Basal area (sq ft) at age							Total volume (cu ft)[a] at age						
	11		16	23	28		34	11		16	23	28		34	11		16	23	28		34
eatment	BT	AT			BT	AT		BT	AT			BT	AT		BT	AT			BT	AT	
' x 7'	3,085	805	740	680	585	230	225	62	16	47	81	101	53	78	951	248	821	1,798	2,442	1,349	2,139
' x 5'	3,280	1,470	1,430	1,125	855	335	335	54	32	73	107	114	60	86	800	474	1,322	2,328	2,770	1,509	2,271
0' strips	4,240	2,260	1,905	1,440	930	930	730	65	33	55	82	90	90	98	937	475	879	1,612	1,849	1,849	2,216
ontrol[b]	2,740	2,740	2,240	1,425	980	980	845	44	44	71	88	98	98	110	655	655	1,256	1,877	2,326	2,326	2,768
ontrol	60	60	65	55	50	50	55	15	15	19	22	24	24	28	238	238	343	596	720	720	641

Interpolated volume tables 1944. Dominion Forest Service, Miscellaneous Series #3.

The control plot contained some trees other than aspen.

TABLE 3. Stand Data per Acre to 1971 for Sample Plots at Riding Mountain

Treatment	Number of trees at age						Basal area (sq ft) at age						Total volume (cu ft)[a] at age					
	23		33	38		44	23		33	38		44	23		33	38		44
	BT	AT		BT	AT		BT	AT		BT	AT		BT	AT		BT	AT	
12' x 12'	2,365	300	300	290	190	190	97	26	71	87	59	87	1,986	580	1,873	2,455	1,662	2,738
12' x 12'	1,965	300	295	280	190	190	95	28	69	80	58	80	1,895	593	1,801	2,141	1,554	2,330
10' x 10'	2,645	435	425	405	270	265	106	36	93	105	77	104	2,065	765	2,408	2,861	2,133	3,112
10' x 10'	2,250	435	420	400	320	310	75	33	84	96	80	103	1,796	693	2,160	2,530	2,100	2,964
8' x 8'	1,700	680	615	530	370	350	92	56	114	114	89	107	1,793	1,132	2,964	3,087	2,389	2,997
8' x 8'	1,665	680	640	575	400	380	92	53	115	119	91	112	1,792	1,087	2,974	3,175	2,458	3,061
Control	2,490	2,490	1,470	1,090	1,090	865	127	127	159	164	164	177	2,706	2,706	4,069	4,562	4,562	5,351
Control	2,730	2,730	1,650	1,110	1,110	955	131	131	166	159	159	178	2,631	2,631	4,214	4,191	4,191	5,127
							Stand age											
	14		24	29		35	14		24	29		35	14		24	29		35
12' x 12'	5,970	300	260	250	250	240	70	6	29	40	40	58	907	83	459	729	729	1,242
10' x 10'	6,670	440	410	350	350	340	55	9	40	46	46	62	714	119	640	803	803	1,290
8' x 8'	5,270	680	630	560	400	400	71	20	75	85	62	84	990	296	1,424	1,767	1,311	2,001
Control	6,050	6,050	3,060	2,050	2,050	1,540	55	55	103	104	104	111	712	712	1,685	1,914	1,914	2,263

[a] Interpolated volume tables 1944. Dominion Forest Service, Miscellaneous Series #3.

Data to 1971 for the Turtle Mountain stand (Fig. 1a) show that MAI (based on standing volume + thinnings) was not much affected by treatment except for the strip thinning, which resulted in a marked increment drop, presumably because of incomplete utilization of the site. The control plot did show a drop in increment during the last few years due to high tree mortality. Although thinning to 7 ft x 7 ft at age 11 (residual basal area of 17 sq ft or 1.4 m^2) caused a slight drop in increment, subsequent increment was comparable to the other plots. Culmination of MAI on the control plot appears to have occurred by age 30, whereas MAI for the two thinned plots may still not have maximized by age 34.

In the youngest Riding Mountain stand (Fig. 1b) thinning to 10 ft x 10 ft and 12 ft x 12 ft at age 14 caused a marked drop in MAI. Under these regimes basal areas per acre were reduced to 9 and 6 sq ft (0.8 and 0.5 m^2) respectively. At that age residual stocking was too low to attain all the potential volume increment. The effect of thinning on these plots was still apparent 15 years after treatment, although by 1971 at age 35 MAI approached that on the control plot. Culmination of MAI on the control plot appears to have occurred at age 25. On the thinned plots no distinct culmination of MAI could as yet be observed by age 35.

The older stand at Riding Mountain (thinned at age 23) showed little difference in MAI between thinned plots (Fig. 1c). Although a drop in increment occurred after thinning to a 12 ft x 12 ft spacing, by age 44 in 1971 MAI on all thinned plots was quite similar. Culmination of MAI on the control plots occurred at age 30. However, by age 44 no maximum increment value was yet apparent on the thinned plots.

Although the oldest (44-year-old) stand had produced the greatest amount of material 8 in. (20 cm) dbh and larger, no prediction could be made at what age MAI for this material would culminate. MAI to age 33 ranged from 12 cu ft (0.3 m^3) for the 12 ft x 12 ft thinning to 1.5 cu ft (0.04 m^3) for the control plots and at age 44 from 60 cu ft (1.7 m^3) to 42 cu ft (1.2 m^3) respectively. Substantial further increases in increment before culmination are indicated.

VOLUME PRODUCTION

Total cubic foot volume production data (standing volume + thinning) to 1971 (Table 4) still reflect initial standing volumes at time of treatment (Table 3). Consequently, the effect of thinning is obscured. However, some differences in production can be attributed to treatment. The 44-year-old stand at Riding Mountain shows a slightly higher production to 1971 following the 10 ft x 10 ft than the 12 ft x 12 ft thinning (4,819 to 4,578 cu ft or 135 to 128 m^3), although initial volumes in 1950 were comparable. The 35-year-old stand at Riding Mountain showed a loss in total production as a result of thinning to 10 ft x 10 ft and 12 ft x 12 ft, although judging from Fig. 1, production losses may disappear within a few years. Strip thinning caused a marked drop in production, whereas thinning to 5 ft x 5 ft and 7 ft x 7 ft resulted in production gains of almost 15%.

Production to 1971 of material 4 in. (10 cm) dbh and larger, as with total production, does not show any clear treatment effect except for reduced production after strip thinning.

Production to 1971 of material 8 in. (20 cm) dbh and larger reflects the effect of thinning on diameter increment. In the 44-year-old

TABLE 4. Volume Production (Cu Ft) Including Thinnings to 1971 by Stands and Treatments

Stand age in 1971	Treatment	Number of plots	Volume (cu ft)		
			Total	≥4" dbh	≥8" dbh
44	12' x 12'	2	4,578	3,537	2,618
	10' x 10'	2	4,819	3,680	2,472
	8' x 8'	2	4,420	3,826	1,874
	Control	2	5,239	5,214	1,820
35	12' x 12'	1	2,066	1,242	248
	10' x 10'	1	1,885	1,290	-
	8' x 8'	1	3,151	2,451	-
	Control	1	2,263	1,514	-
34	7' x 7'	1	3,935	3,268	1,604
	5' x 5'	1	3,859	3,452	811
	20' strips	1	2,678	2,102	207
	Control	1	3,409	3,260	780

stand, production had increased by about 45% from 1,820 to 2,618 cu ft (51 to 73 m^3). The two younger stands also showed increases, although an insufficient number of trees had passed the 8-in. (20-cm) diameter limit to make meaningful comparisons.

DIAMETER INCREMENT

Thinning increased the diameter increment of all residual trees regardless of size. For illustration, tree increment data for the older Riding Mountain stand have been presented (Figure 2).

Strip thinning did not produce any apparent stimulation of diameter increment, even in those trees close to the edge (Figure 3).

Figure 4 shows the average diameter of selected dominant trees in two stands from the time of treatment to 1971. Trees with an average dbh of 4 in. (10 cm) in 1950 in the 23-year-old stand at Riding Mountain, thinned to a spacing of 12 ft x 12 ft, reached an average dbh of 9 in. (23 cm) in 1971 at age 44. Similar-sized dominants on the control plots reached an average dbh of 6.4 in. (16 cm). If growth trends for the unthinned plots were projected at current rates, these trees would not reach an average of 9 in. (23 cm) dbh until an age of about 65, or 20 years later.

Increment trends for the Turtle Mountain stand also indicate a difference of about 20 years between trees reaching an average of 9 in. (23 cm) dbh on thinned and control plots. The difference of 20 years, particularly for the Riding Mountain stand, is conservative because it is assumed that the unthinned trees will maintain their growth rate over the next 20 years.

DISCUSSION AND CONCLUSIONS

Although results are confounded by differences between plots in initial stand volume and tree size, and although there were few or no replications, some general conclusions can be drawn:

1. Mean annual total volume increment (MAI) in the unthinned stands culminated at age 25 to 30. Thinning appears to prolong culmination age by a few years.

2. Thinning stimulated the diameter increment of all tree sizes, confirming results by Zehngraff (1949) and Zasada (1952).

3. Thinning to 12 ft x 12 ft spacing in the 23-year-old stand and to 10 ft x 10 ft and 12 ft x 12 ft spacings in the 14-year-old stand was too severe and caused marked losses in MAI and subsequent losses in total cubic foot volume production to ages 44 and 35 respectively.

4. Cubic foot volume production of material 8 in. (20 cm) dbh and larger was markedly increased by thinning.

If the anticipated end product from poplar stands is fibre or pulp, thinnings would be unjustified. Gain in fibre production will be in the form of anticipated mortality. This material will generally be of small size and low value and its removal will be uneconomical.

If the objective of thinning is to produce large-sized trees for lumber in a shorter period of time, thinning could be given consideration. The initial cost of thinning must then be recovered through a final gain in merchantable volume. Present growth data indicate a 45% gain in production of material 8 in. (20 cm) dbh and larger to age 44. Diameter increment data further suggest that an average diameter of dominant trees of 9 in. (23 cm) will be obtained at least 20 years sooner on the thinned than on the control plots.

Recent experience with precommercial thinning (Bella 1974) would indicate that aspen stands 10 years or under could be thinned relatively quickly using a brush saw. Cost per acre would depend on stand age, tree size, and stand density, but would likely be under 8 man-hours per acre. Trees could be thinned to a spacing of at least 10 ft x 10 ft on average sites and 12 ft x 12 ft on good sites. In Bella's study (1974), tree increment subsequent to thinning maintained itself well and the beneficial effect of the second thinning on residual trees was not marked. Therefore, subsequent thinnings should only be considered if they can pay for themselves, possibly at an age of about 35 years.

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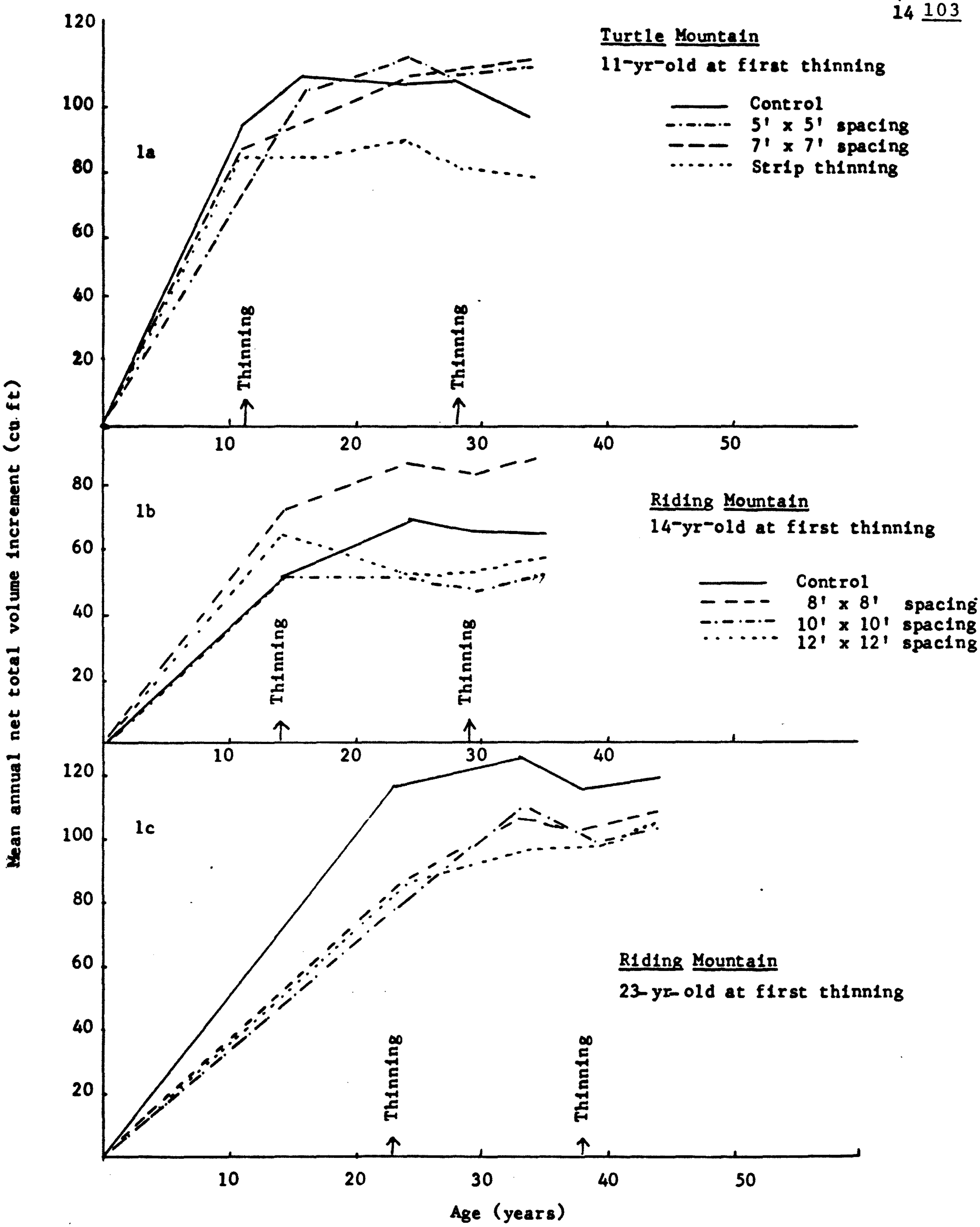

FIGURE 1. Mean annual net total volume (cu ft) increment in relation to age and treatment for the stands at Turtle Mountain and Riding Mountain.

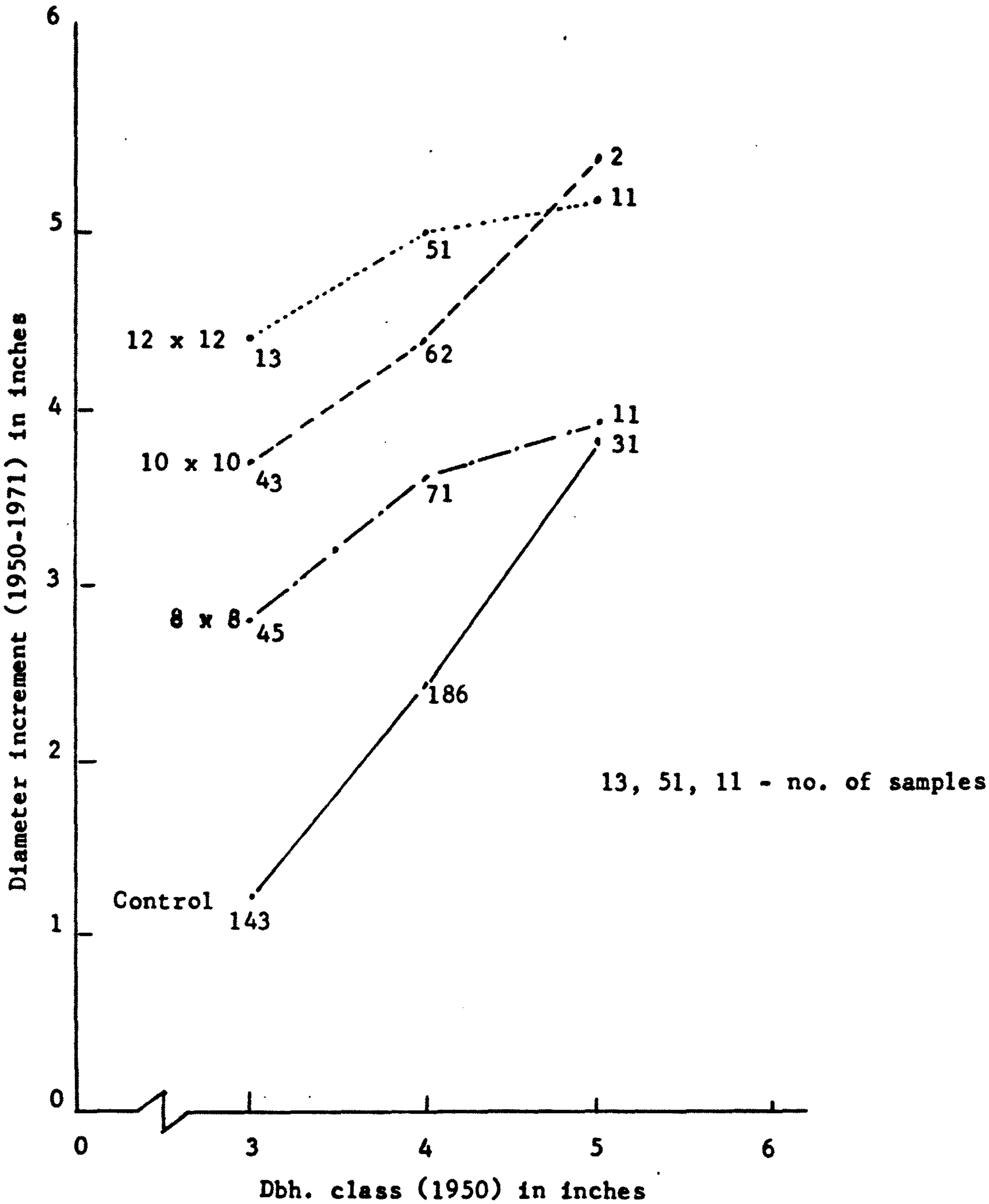

FIGURE 2. Diameter increment (1950-1971) in relation to dbh class in 1950 after thinning to different spacings in the 23-year-old aspen stand at Riding Mountain National Park.

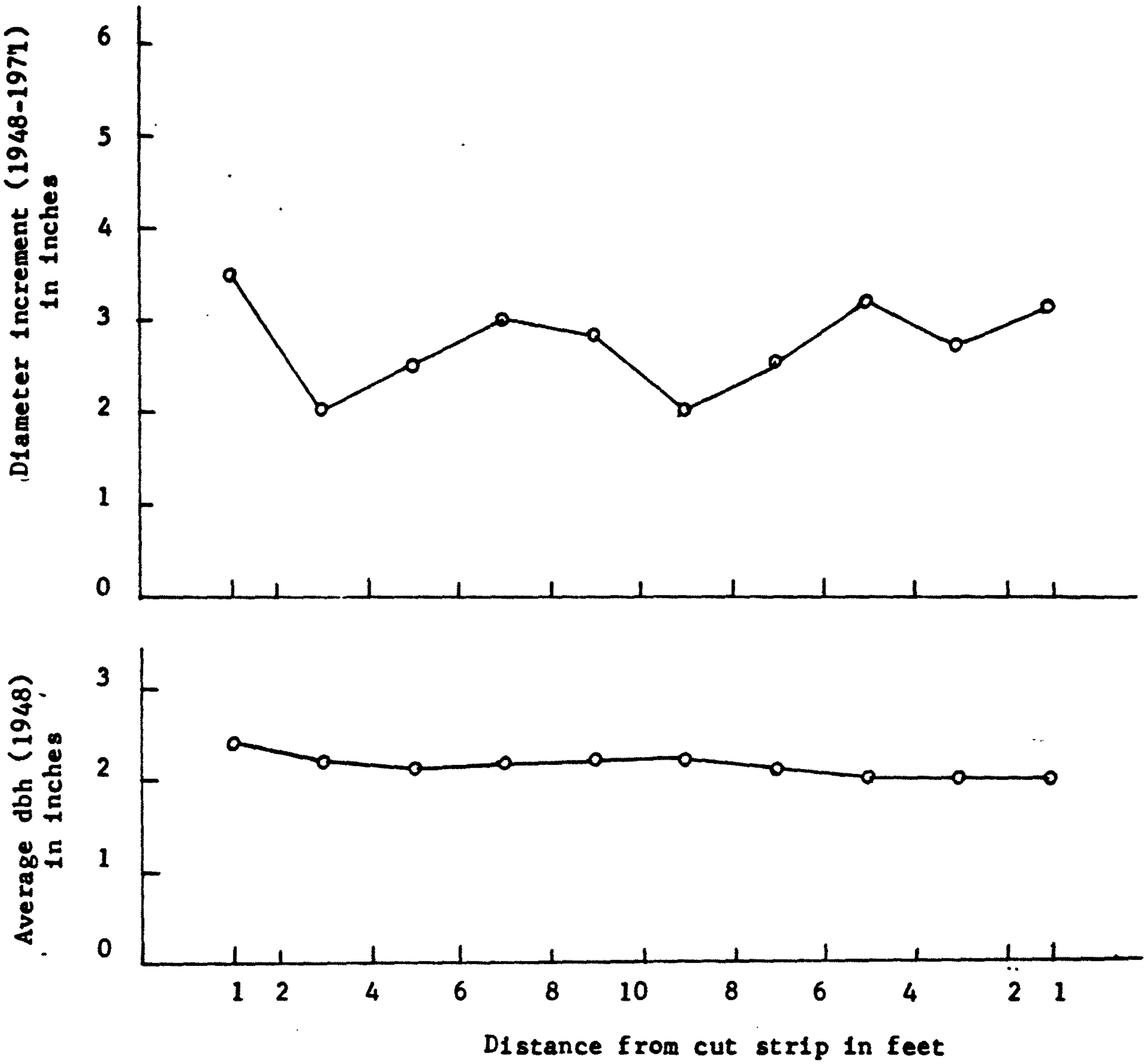

FIGURE 3. Initial diameter at breast height in 1948 and diameter increment (1948-1971) of trees across a 20-foot strip on the strip-thinned plot at Turtle Mountain Forest Reserve.

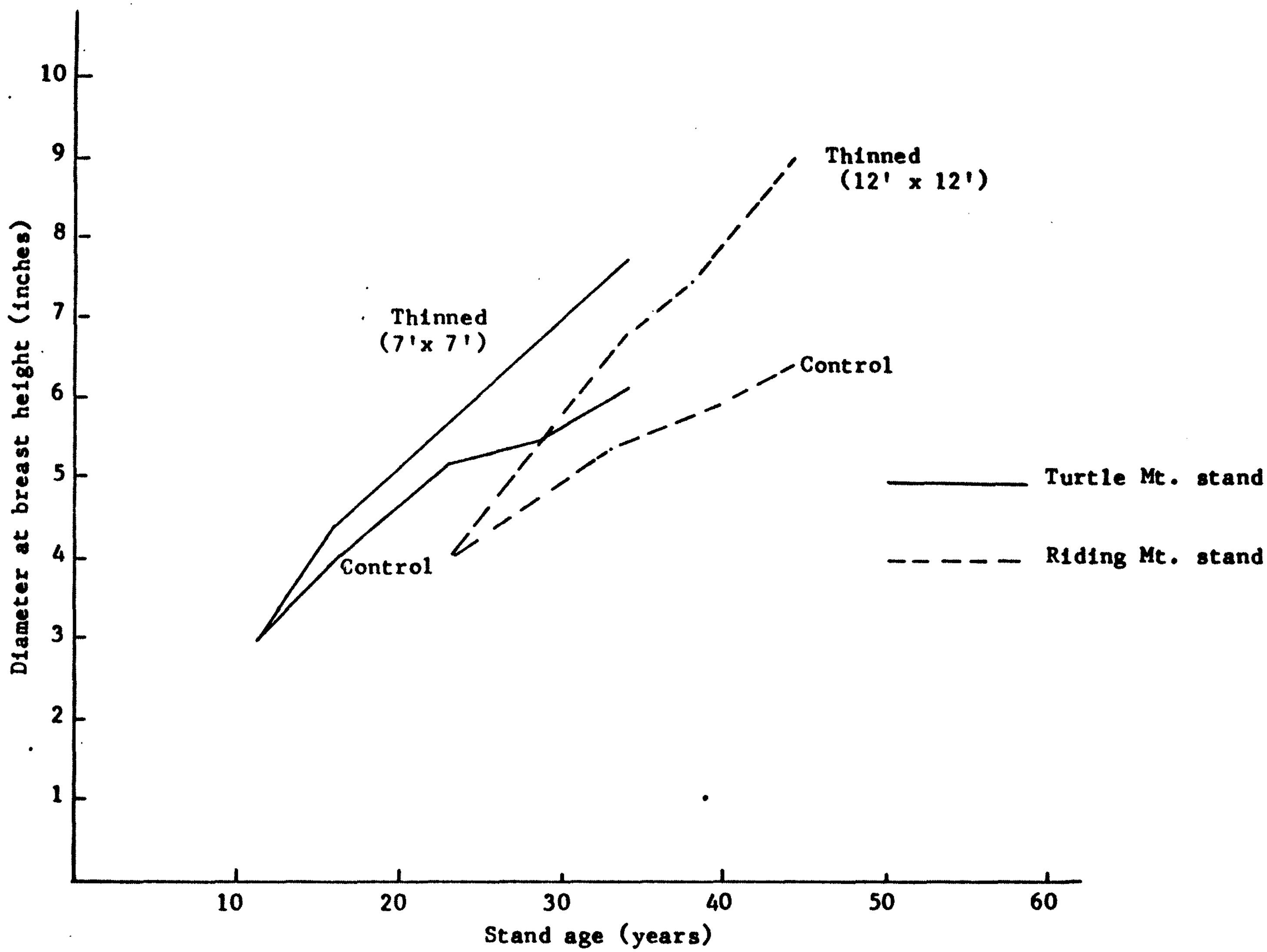

FIGURE 4. Average diameter at breast height of dominant trees to 1971 on thinned and control plots at Riding Mountain and Turtle Mountain.

THINNING IN TREMBLING ASPEN STANDS MANITOBA AND SASKATCHEWAN

by

G. A. Steneker and J. M. Jarvis

Sommaire en français

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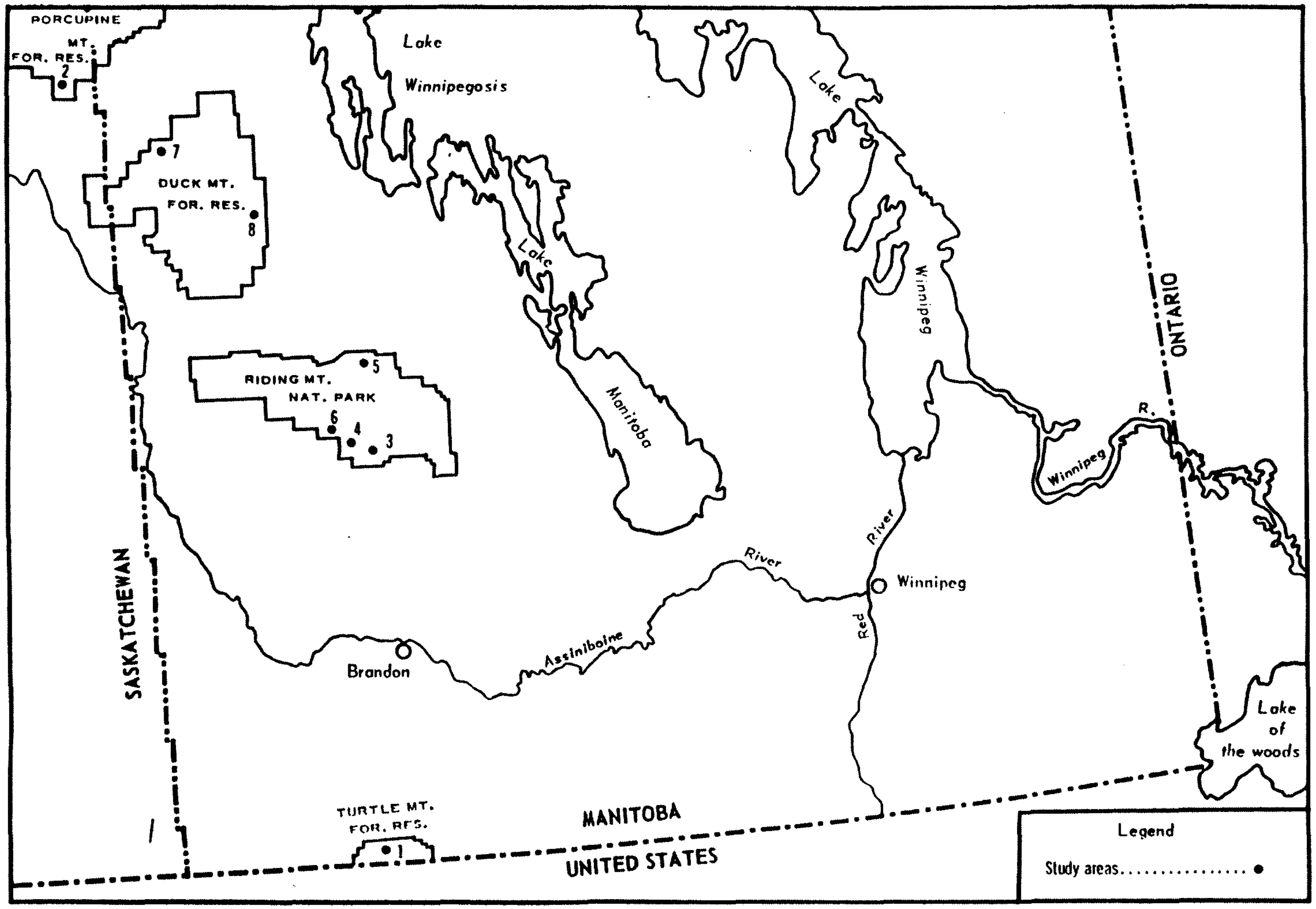
ABSTRACT

Results of eight thinning experiments in trembling aspen (*Populus tremuloides* Michx.) have been pooled, chiefly for the purpose of developing tentative thinning regimes for the eastern plains area of Canada.

Thinning regimes to age 40 were developed, and they indicate that total volume production can be increased by as much as 25 per cent by thinning at 5-year intervals. Under a heavy thinning schedule, crop trees at age 40 can be expected to average 8.0 inches in diameter at breast height as compared to 6.0 inches in unthinned stands.

Maximum net periodic total volume increments for 10-, 20-, 30-, 40-, and 50-year-old stands were achieved at about 30, 50, 65, 85 and 100 square feet basal area per acre respectively.

CONTENTS



Location of study areas

Thinning in Trembling Aspen Stands Manitoba and Saskatchewan

by

G. A. STENEKER and J. M. JARVIS[1]

INTRODUCTION

Trembling aspen (*Populus tremuloides* Michx.) is one of the most abundant commercial tree species in Manitoba and Saskatchewan. Recent inventory records show that hardwood stands, primarily aspen, in these two provinces occupy respectively a little more than one-tenth and about one-third of the productive forest land. The volume of trembling aspen in Manitoba and Saskatchewan is over 2.1 and 3.5 billion cubic feet respectively (Anon. 1959 and Gill 1960). The species is adaptable to a wide variety of sites and has an enormous capacity to regenerate, so is likely to remain one of the region's most abundant trees.

Trembling aspen has a high susceptibility to decay[2]. Although gross volumes of fully stocked aspen stands (80-100 years) in Manitoba and Saskatchewan compare favourably with those of fully stocked coniferous stands of the same age, very little can be utilized because of rot. Trembling aspen must be cut before it reaches maturity (Gill 1960) and it has been reported that in Saskatchewan rotation age on most sites should not exceed 80 years (Kirby *et al.* 1957). At this rotation many trees in natural stands are still too small to be utilized for veneer and lumber. As a result potential merchantable volume is greatly curtailed.

At present very little trembling aspen in Manitoba and Saskatchewan is utilized. During the 1940's and 1950's the average annual cut was about 12 to 19 million fbm, respectively (Anon. 1940 to 1961 and Anon. 1942 to 1959). Economic surveys (Anon. 1956) indicate, however, that the demand for trembling aspen for use in newsprint, corrugated board, hardboard, insulating board, plywood and lumber, will increase considerably. Just recently two waferboard mills, one at Hudson Bay, Saskatchewan, and one at Sprague, Manitoba, each capable of utilizing about 20,000 cords of trembling aspen per year have been constructed. Further evidence of increasing utilization is seen in the pulpwood production figures for the Lake States. Trembling aspen pulpwood production in Michigan, Wisconsin and Minnesota has increased from 486,000 cords in 1949 to 1,708,000 cords in 1959 (Horn 1960, 1964).

Foreseeing the time when trembling aspen will be in great demand, and being aware of the effect that decay has on natural stands, the Department of Forestry, as early as 1926 began thinning studies in trembling aspen stands. Between then and 1951 a total of eight experiments were undertaken in Manitoba and Saskatchewan. Although the purpose of each was to determine stocking levels necessary for maximum volume production and maximum diameter growth, thinning specifications differed between experiments. In some studies stands were thinned to specific spacings and in others to specific basal areas or specific stand density indices. In some experiments stands were re-thinned at periodic intervals whereas in others only one thinning was made. Furthermore, periods between remeasurements differed for the various experiments.

[1]Research Officers, Department of Forestry of Canada, Manitoba-Saskatchewan Region, Winnipeg, Manitoba.

[2]Black, R. L. and P. S. Kristapovich 1954. Decay of trembling aspen in Manitoba and eastern Saskatchewan. Canada, Dept. Agri., Sci. Serv., For. Biol. Div., For. Path. Lab. Saskatoon. Unpub. Interim Rep.

This paper combines the results of all eight experiments. To facilitate comparisons thinning intensity for each study has been expressed in terms of basal area immediately after treatment. Results are based on data from individual studies in some instances and on combined data from several or all studies in others[3]. The reader is reminded that because of differences in experimental methods the combined data express only general trends and it is on these general trends that the hypothetical thinning schedules, presented later, are based.

LOCATION AND DESCRIPTION OF STUDY AREAS

The study areas are located in the Turtle Mountain, Duck Mountain and Porcupine Mountain Forest Reserves, and in the Riding Mountain National Park (Frontispiece). All are in the Mixedwood Forest Section of the Boreal Forest Region (Rowe 1959).

The study areas have a dry continental climate. Mean January and July temperatures, except in the Turtle Mountain, are approximately −3°F and 64°F respectively (Turtle Mountain 2°F and 67°F). Frost free periods average 80 days (Turtle Mountain 100 days). Annual precipitation is about 18 inches, of which 7 inches falls during May, June and July (Turtle Mountain 18 inches and 8 inches) (Anon. 1960a).

Representative trembling aspen stands, ranging in age from 11 to 45 years were selected for study. All had originated after fire or cutting. Pertinent stand data are given in Table 1.

[3]Basic data for individual studies may be obtained on short-term loan by writing to the Regional Director, Department of Forestry of Canada, Winnipeg, Manitoba.

TABLE 1. STAND AND SITE DATA OF STUDY AREAS.

Study	Location	Stand age at establishment	Number of trees per acre B.T.*	Average d.b.h. (") B.T.*	Height (') of dom. trees B.T.*	Stand origin	Physiographic Site
1	Turtle Mt. Forest Reserve	11	3400	1.7	22	Clear-cut	Non telluric mesic clay-loam till.
2	Porcupine Mt. Forest Reserve	14	3400	1.8	24-34	Burn	Non telluric mesic clay-loam till.
3	Riding Mt. National Park	14	6000	1.4	20	Clear-cut	Non telluric mesic clay-loam till.
4	"	19	2600	2.4	27-33	Burn	Non telluric mesic silty clay-loam till.
5	"	23	2200	2.9	41	Clear-cut	Telluric mesic silty clay-loam till.
6	"	30	1600	3.5	49	Burn	Non telluric mesic clay-loam till.
7	Duck Mt. Forest Reserve	35	1800	3.3	46	Burn	Non telluric mesic clay-loam till.
8	"	45	1000	4.8	49-56	Burn	Non telluric mesic glacio-fluvial clays and gravel.

*Before thinning.

Seven areas are located on mesic sites[4] on gently rolling terrain; the other (study 5) is on a somewhat moist site and has a telluric moisture supply. Soils belong to the Grey Wooded Great Group of the Podzolic Order (Anon. 1960b). Parent materials on seven areas are clay loam tills; on one area (study 8) they are glacio-fluvial clays and gravels (Table 1).

METHODS

Methods of thinning must take into account the silvical characteristics of the species. Trembling aspen is a highly intolerant species, and unless trees can maintain their position in the upper canopy they quickly become suppressed and die. Consequently in all studies thinning was done to favour dominant and codominant trees whenever possible.

Treatments, including thinning to specific spacings, specific basal areas and specific stand density indices (Reineke 1933), were carried out on permanent sample plots (ranging in size from 0.1 to 1.0 acre) and their surrounds. In six of the studies stands were thinned once; in studies 2 and 6 they were thinned more than once (Table 2). Axes and saws were used for felling. In some studies felled trees were left on the plots but in other studies they were removed.

In all but two studies (6 and 7) residual trees were numbered and mapped. Diameter at breast height of all trees before and after thinning and at remeasurement was tallied to the nearest one-tenth inch. In some studies every tree was measured for height at each remeasurement; in others only some of the trees were measured.

In 1961 some of the sample plots belonging to study 4 were partially destroyed. Since the plots, as such, could no longer add useful information to the experiment, stem analysis studies were made on a number of the residual trees.

RESULTS

Individual Tree Increment

Diameter

All studies showed that the diameter increment of individual trees increased as competition (expressed in terms of residual basal area per acre immediately after thinning) was reduced. All size classes were affected. Larger trees maintained a higher increment than smaller ones, although the latter showed a greater percentage response. These findings are illustrated below by data from specific studies.

Annual diameter increment for the 25 and 200 largest trees per acre between 1951 and 1962 for study 2 (14-year-old stand first thinned in 1951) is shown in Figure 1. Rate of growth increased as intensity of thinning increased; however, for the 25 largest trees growth rate levelled off at about 45 square feet of residual basal area per acre. For given levels of stocking the 25 largest trees grew faster than the 200 largest.

Differences in 10-year diameter increment (1950-1960) between trees on control and thinned plots for study 5 (23-year-old stand thinned in 1950) show that thinning stimulated the growth of all size classes (Figure 2). Large trees maintained a higher growth rate than smaller ones but per cent increase was less. The increment of residual trees was not significantly increased when basal area per acre was reduced below 34 square feet. This supports the trends shown in Figure 1.

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[4]Sites with adequate moisture for optimum development of mesophytic plants throughout the growing season.

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TABLE 2. SUMMARY OF THINNING TREATMENTS.

Study	No. of Sample plots	Plot Size (acres)	Date of establishment	Date of remeasurement	Stand age at establishment	Thinning Method	Intensity of thinning
1	4	0.2	1948	1953, 1960	11	Regular spacing	Control, no thinning—2 plots Treatment, 5′ x 5′—1 plot, 7′ x 7′—1 plot
2	14	0.2	1951	1957, 1962	14	Thinning to fixed S.D.I. in 1951, 1957 and 1962	Control, no thinning—2 plots Treatment, thinned to and maintained at 120, 100, 80, 70, 60 and 50% of S.D.I. of control in 1951—2 plots to each intensity.
3	4	0.1	1950	1960	14	Regular spacing	Control no thinning—1 plot Treatment 8′ x 8′—1 plot, 10′ x 10′—1 plot, 12′ x 12′—1 plot
4	8	0.2	1950	1960	19	Regular spacing	Control, no thinning—2 plots Treatment, 8′ x 8′—2 plots, 10′ x 10′—2 plots, 12′ x 12′—2 plots
5	8	0.2	1950	1960	23	Regular spacing	Control, no thinning—2 plots Treatment, 8′ x 8′—2 plots, 10′ x 10′—2 plots, 12′ x 12′—2 plots
6	3	1.0	1926	1940, 1945, 1950 & 1960	30	Thinned to fixed basal area in 1926 & 1940	Control, no thinning—1 plot Treatment, 14% b.a.cut in 1926 and 23% in 1940—1 plot, 24% b.a. cut in 1926 and 33% cut in 1940—1 plot
7	3	1.0	1926	1946 1960	35	Thinned to fixed basal area	Control, no thinning—1 plot Treatment, 30% b.a. cut—1 plot, 36% b.a. cut—1 plot
8	3	0.5	1937	1946	45	Thinned to fixed basal area	Control, no thinning—1 plot Treatment, 25% b.a. cut—1 plot, 50% b.a. cut—1 plot

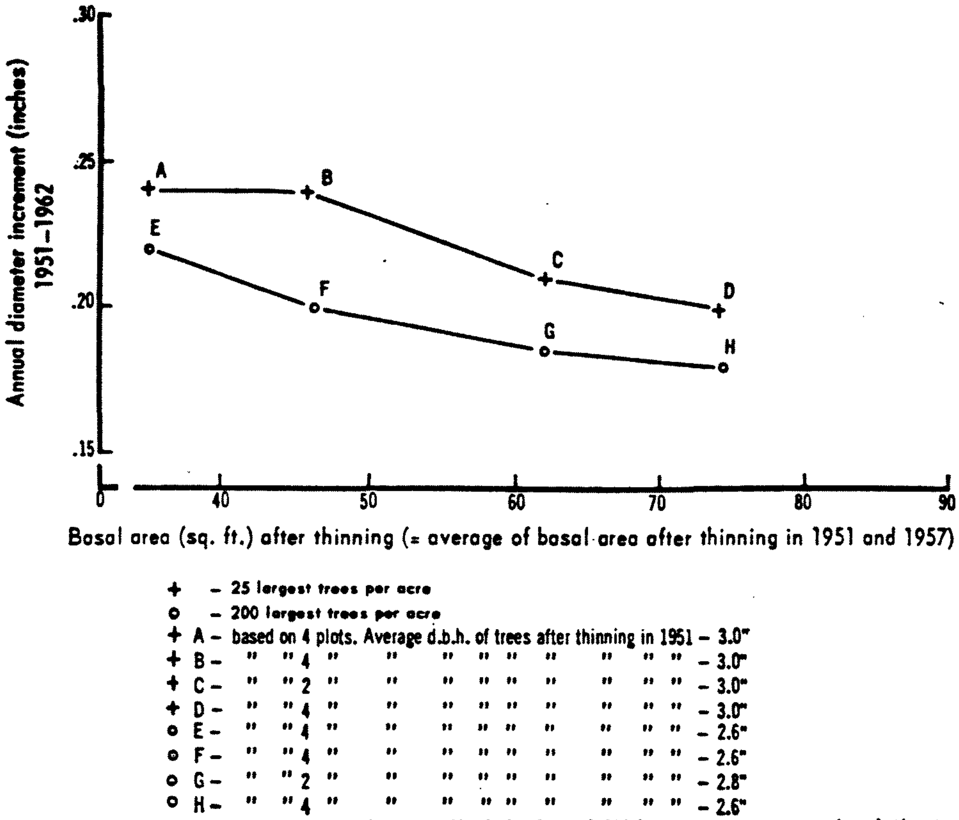

FIGURE 1. Annual diameter increment (1951-1962) of the 25 and 200 largest trees per acre in relation to the residual basal area per acre. Study 2—14-year-old stand, thinned in 1951 and 1957.

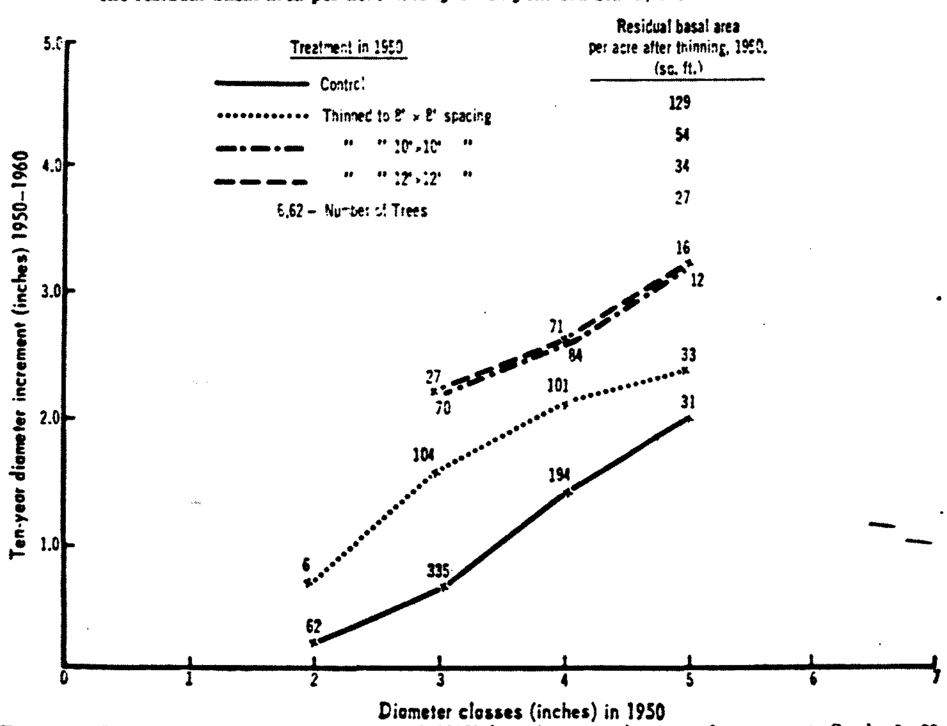

FIGURE 2. Ten-year diameter increment (1950-1960) by diameter classes and treatment. Study 5—23-year-old stand, thinned in 1950.

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Growth ring analysis of a number of dominant and codominant trees from study 5 (19-year-old stand thinned in 1950) provided a measure of year-by-year diameter increment over the period 1942-1961. Three years after thinning, maximum increment had been reached with all treatments, then a general decline occurred (Figure 3). However, trees on treated plots maintained a higher increment than trees on control plots. Furthermore, heaviest thinning provided the highest increment.

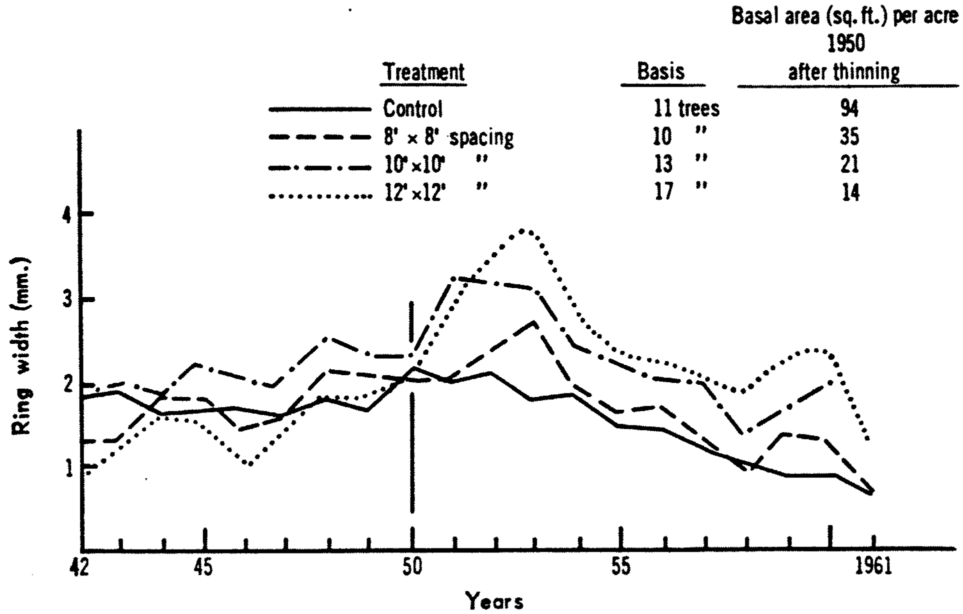


FIGURE 3. Annual radial increment (1942–1961) dominant and co-dominant trees (all trees 3 inches d.b.h. in 1950). Study 4—19-year-old stand thinned in 1950.

The lasting effect of thinning is illustrated also by Table 3. The diameter increment of the 50 largest trees on the thinned plots of study 7 (35-year-old stand thinned in 1926) was greater than that of the largest trees on the control during both remeasurement periods (1926 to 1946) and (1946 to 1960).

TABLE 3. TOTAL BASAL AREA PER ACRE AFTER THINNING AND AVERAGE DIAMETER AND DIAMETER INCREMENT OF THE 50 LARGEST TREES, STUDY 7, 35-YEAR-OLD STAND IN 1926.

Treatment	Basal area after thinning 1926 (sq. ft.)	Average diameter 50 largest trees			Diameter increment 50 largest trees			
					Periodic		Annual	
		1926	1946	1960	'26-'46	'46-'60	'26-'46	'46-'60
Control	106	6.6	8.9	10.5	2.3	1.6	.12	.11
Thinned (30% b.a.cut)	74	6.5	9.1	10.8	2.6	1.7	.13	.12
Thinned (36% b.a.cut)	65	5.9	9.1	11.0	3.2	1.9	.16	.14

Basal area

The average periodic annual basal area increment for the 200 largest trees per acre (all studies) in relation to residual basal area per acre by 10-year age groups is shown in Figure 4. As the data for all age groups (except study 5) fall in one band it may be inferred that age has had little influence on the basal area increment of the 200 largest trees. Therefore the younger trees (small d.b.h.) increased in diameter at a faster rate than older trees (large d.b.h.) for given residual basal areas. The data show also that the basal area increment of the 200 largest trees is inversely related to residual basal area per acre.

The high increment shown by the 20-29 year age group (study 5) has been attributed to site (Table 1).

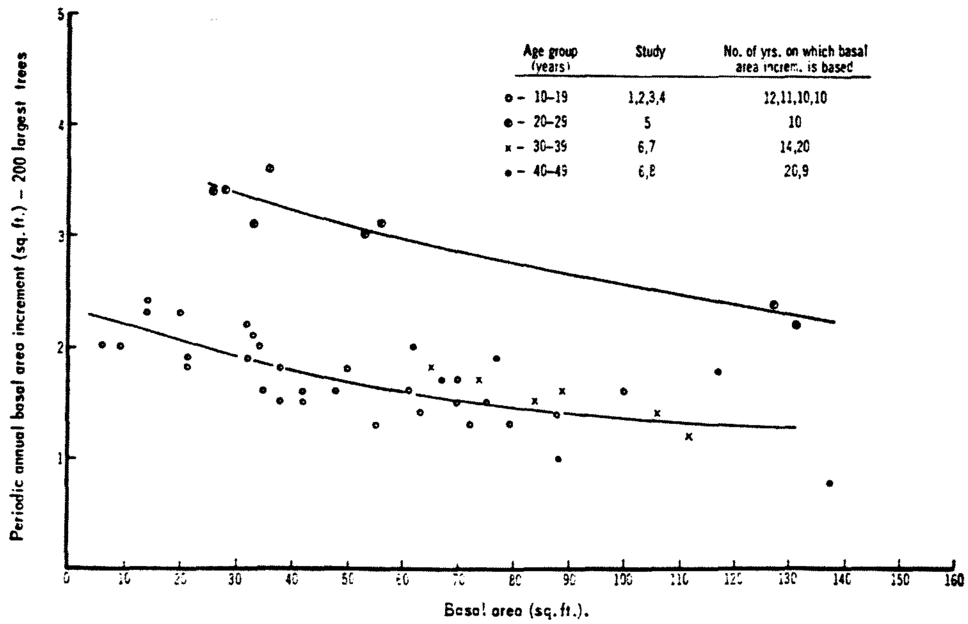


FIGURE 4. Periodic annual basal area increment of the 200 largest trees per acre related to residual basal area per acre (by 10-year age groups)—all studies.

Height

All studies have indicated that height increment was not affected by thinning. Data from study 5 (23-year-old stand thinned in 1950) are given in Table 4. Height increment of the 100 largest trees per acre between 1950 and 1960 on thinned and control plots was about the same.

TABLE 4. TEN-YEAR HEIGHT INCREMENT OF THE 100 LARGEST TREES PER ACRE. STUDY 5, 23-YEAR-OLD STAND, THINNED IN 1950.

Treatment	Height increment (feet) 1950-1960
12′ x 12′ spacing	13
10′ x 10′ "	13
8′ x 8′ "	14
Control	13

Stand Increment per Acre

Basal area

Results indicate that within certain wide limits basal area increment (and furthermore volume increment) is influenced very little by density of stocking. Data from study 5 are presented which show net and gross periodic basal area increment at various levels of stocking (Figure 5). The data for gross basal area increment (curve A) indicate very little change at residual densities between 60 and about 130 square feet. The slight drop in increment which does occur at the higher densities is attributed to the effect of overly dense stocking which has probably resulted in some stagnation of growth. The marked drop in basal area increment with residual basal areas below 50 square feet is attributed to inadequate use of the site by residual trees. Similar growth trends have been presented by Möller *et al.* (1954) for Norway spruce and beech. He showed that only at density levels of less than 50 per cent of normal was there any significant reduction in basal area and volume increment.

The loss in periodic basal area increment due to mortality is shown also in Figure 5. It is the difference between the gross and net periodic basal area increment curves (A and B). As can be seen mortality increases at the higher density levels.

The net basal area increment curve (B) in Figure 5 indicates that for this particular stand (23 years old) 50 to 60 square feet per acre was about the optimum basal area for maximum future per acre production. At this density level mortality was relatively low and individual trees had adequate growing space. Furthermore, density was high enough to prevent loss in increment due to inadequate stocking.

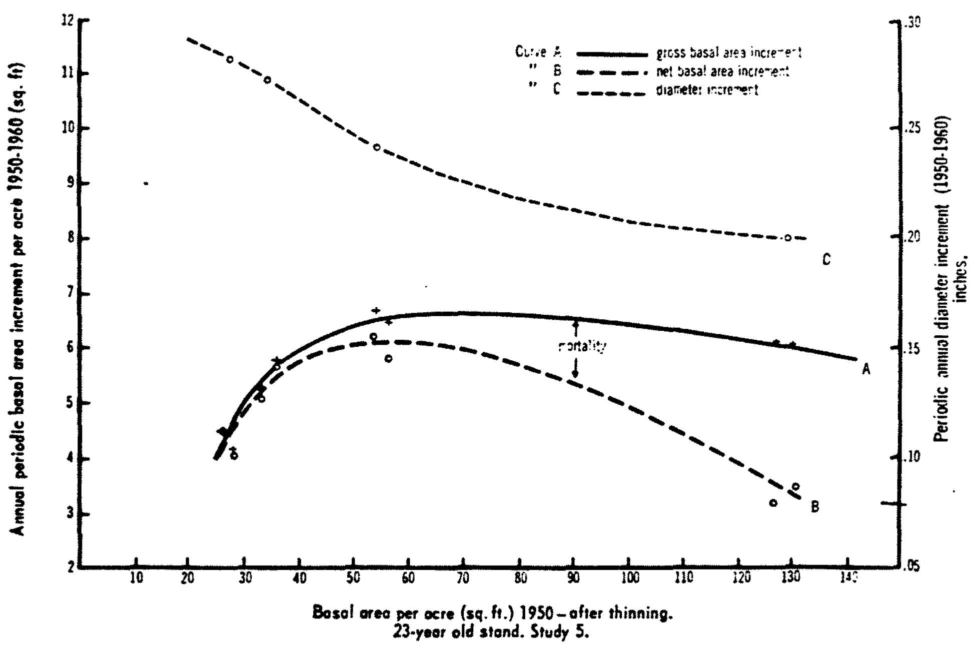


FIGURE 5. Annual periodic net and gross basal area increments and annual periodic diameter increment of the 200 largest trees per acre related to residual basal area after thinning in 1950. Study 5—23-year-old stand.

Curves of net basal area increment are presented for all studies in Figure 6. They show optimum basal area levels for maximum periodic net increment. As stands increase in age optimum basal area levels also increase.

The basal area of undisturbed stands (Appendix I) and the basal area at which maximum periodic net basal area increment occurred (Figure 6) have been related to age. Curved values at 10-year intervals are presented in Table 5. The data show that the basal area of untreated stands can be reduced, depending on age, by between 36 per cent (age 10) and 17 per cent (age 50) without any marked loss in increment. These findings support those by Assman (1961) for Norway spruce. He found that with increasing age the optimum degree of stocking approaches the normal or maximum stocking. Smithers (1954) found also that the basal area of 40- to 80-year-old red and white pine stands could be reduced up to 30 per cent at 10-year intervals without a substantial loss in gross basal area increment.

Basal area development on all thinned plots (study 5 excluded) in relation to the average basal area of all control plots (Appendix I) is shown in Figure 7. In the young age classes (10-30 years) rate of increment, as indicated by the slope of the straight lines, is greater than that for older stands (30 years and over). Figures 6 and 7 show that for a given age increment has been higher with intermediate residual basal areas than with either low or high residual basal areas.

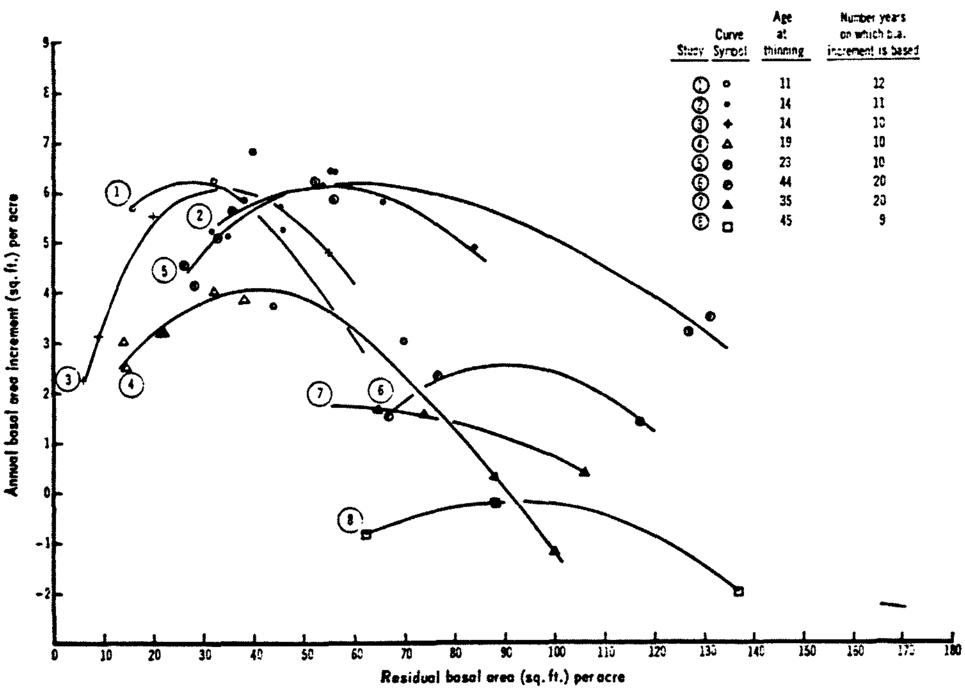


FIGURE 6. Periodic annual net basal area increment related to residual basal area after thinning, all studies.

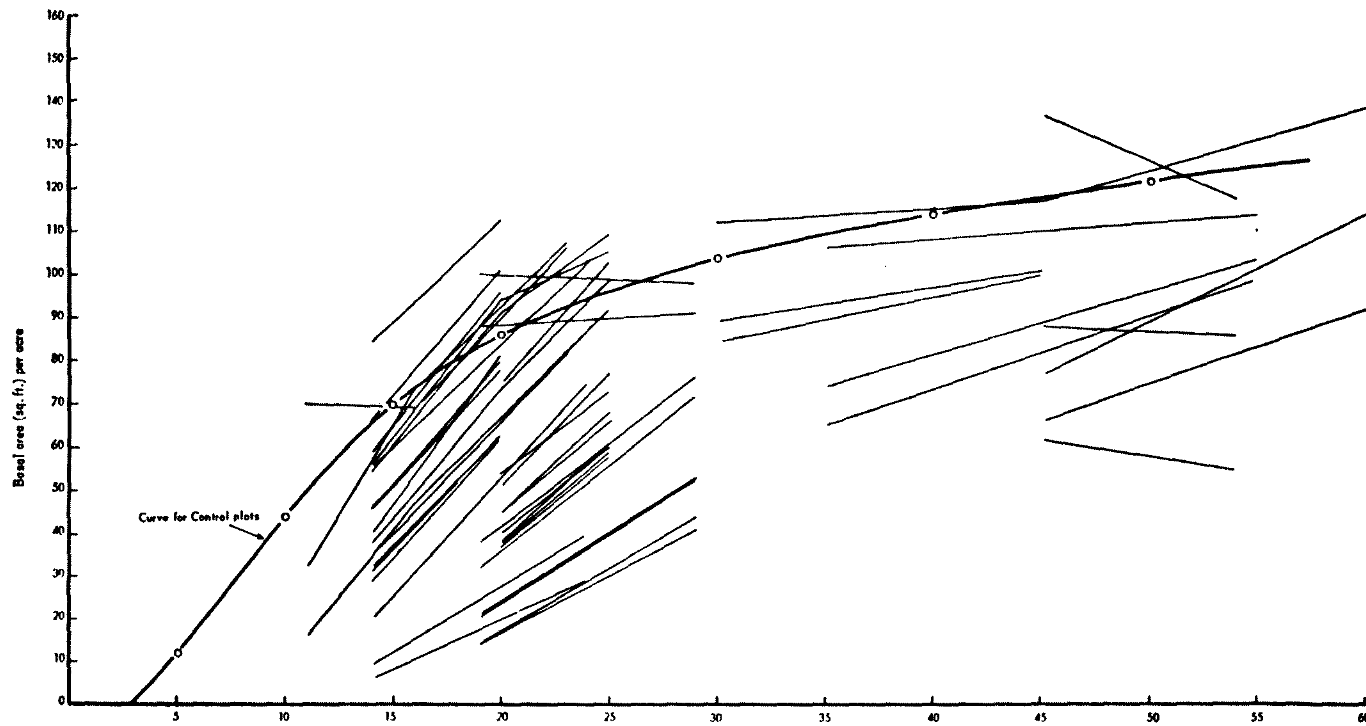


FIGURE 7. Average basal area per acre of control plots and individual thinned plots over age. All studies except No. 5.

TABLE 5. BASAL AREA PER ACRE OF UNDISTURBED STANDS AND BASAL AREA PER ACRE AT WHICH MAXIMUM BASAL AREA INCREMENT OCCURRED IN THINNED STANDS, BY AGE.

Age	Basal area of undisturbed stand (sq. ft.)	Basal area producing max. net basal area increment	
		(sq. ft.)	As per cent of basal area or undisturbed stands
10	44	28	64
20	86	48	56
30	104	67	60
40	114	84	74
50	122	101	83

Total volume

Periodic net annual volume increment per acre showed a similar trend to that of periodic net annual basal area increment; that is, above and below certain basal areas net volume increment was reduced. This relationship is illustrated with data from study 5 (23-year-old stand thinned in 1950) in Figure 8. Maximum net annual increments (basal area and volume) occurred at a residual basal area of about 60 square feet per acre.

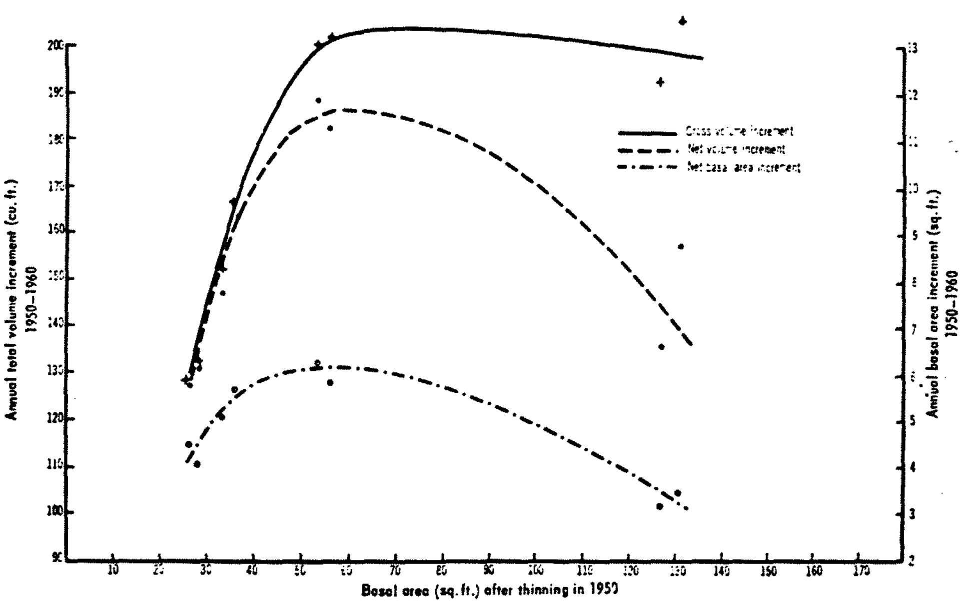


FIGURE 8. Periodic annual net and gross total volume increment and net basal area increment per acre related to basal area per acre after thinning. Study 5—23-year-old stand thinned in 1950.

Within a range of about 60 to 130 square feet per acre, gross annual volume increment between 1950 and 1960 remained at about 200 cubic feet per acre. Below 60 square feet, gross annual volume increment dropped abruptly. This again is in agreement with Möller *et al.* (1954) (see above).

TABLE 6. NET MERCHANTABLE VOLUME PRODUCTION RELATED TO THINNING INTENSITY AND PERIOD SINCE THINNING.

Study number	Initial stand age	No. of years between establishment and last remeasurement	Basal area after thinning (% of control)	Basal area necessary to give max. net total volume increment (% of control)	Merchantable volume production/acre			
					cords[3] Trees ⩾ 4" d.b.h.		board feet[4] Trees ⩾ 8" d.b.h.	
					Control	Thinned	Control	Thinned
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
1	11	12	28 and 56	63	19	20 and 23	[5]	[5]
2	14	11	52 to 150	61	8	7 to 13	[5]	[5]
3	14	10	10 to 36	61	4	3 to 4	[5]	[5]
4	19	10	25 to 37	58	13	8 to 12	[5]	[5]
5	23	10	21 to 42	59	40	25 to 36	135	821 to 937
6	30	34	{ 75 and 80[1] 57 and 65[2]	65 } 78 }	54	56	8997	10966
7	35	20	60 and 70	70	34	36 and 36	2688	3116 and 3698
8	45	9	45 and 65	78	39	31 and 32	859	363 and 1386

[1]Thinned in 1926.
[2]Thinned in 1940.
[3]Volume of peeled stem above 1-foot stump to a 3-inch top-diameter inside bark. Table 17 Univ. of Minn. Tech. Bull. No. 39. 1934.
[4]Stump height 1-foot; log lengths 12.6 and 16.8 feet; top diameter to 6.5 inches. Table 203, Form Class Volume Tables, Canada Dept. Mines and Resources, 1948.
[5]Trees not large enough to contain board foot volumes.

By thinning this 23-year-old stand to about 60 square feet of basal area in 1950, approximately 90 per cent of the potential increment was realized during the following 10 years. However, by thinning to 25 square feet or by not thinning in 1950 only about 65 and 70 per cent of the potential increment were realized during the same period. The lower net increment on the heavily thinned plots was the result of inadequate stocking; on the unthinned plots it was the result of greater mortality.

For some species, gross volume increment declines at excessively high densities as a result of stagnation (Braathe 1957, Smithers 1957). There is slight evidence of this in Figure 8.

Merchantable volume

The effects of thinning on merchantable volume production are illustrated in Table 6. When consideration is given to the intensity of thinning actually achieved (column 4), it is apparent that on some plots stocking after thinning was lower than that necessary for maximum volume increment, which resulted in a loss in cordwood production. On other plots residual basal area after thinning approximated that necessary for maximum volume increment and cordwood production was increased slightly.

Only four studies had trees large enough to contain board foot volumes. On each thinned plot except one for study 8 production was increased by thinning. The low board foot production on the one thinned plot in study 8 has been attributed to the fact that it supported smaller trees before thinning than the control.

Relationship Between Diameter and Basal Area Increment

The relationship between the diameter increment of individual trees and basal area increment per acre is illustrated in Figure 5. Curve C shows the periodic annual diameter increment of the 200 largest trees per acre at basal area levels which vary from 28 to 130 square feet per acre. With a residual basal area of 60 square feet (which provides maximum periodic net basal area increment), only 44 per cent (or .035 inches) of the observed total increase in annual diameter increment had taken place. An additional reduction to 28 square feet provided for the remaining 56 per cent. In other words the greatest observed diameter increment was obtained at the expense of basal area increment per acre.

Mortality

Trembling aspen is an intolerant species and as a result mortality among the smaller trees is very high. An illustration of this is given in Table 7 which records the per cent mortality by size classes on the unthinned plots of study 3 (14-year-old stand). The greatest part of the mortality occurred among the smallest trees. Since all stands were thinned from below, mortality was reduced in proportion to the intensity of the thinning, as indicated by Figure 8.

TABLE 7. MORTALITY (NO. OF TREES) BY DIAMETER CLASSES UNDISTURBED PLOTS (1951-1962) STUDY 3, 14-YEAR-OLD STAND.

D.b.h. class 1951	Mortality 1951-1962 (per cent)
1	86
2	25
3	12
Weighted average	52

DISCUSSION AND APPLICATION OF RESULTS

Thinning has two important aims: (a) to maximize volume production and (b) to increase and possibly maximize the growth rate of residual trees. Unfortunately it is not possible to create conditions by means of thinning which will achieve both (a) and (b) simultaneously to the fullest extent. As has been shown earlier, only a portion of the possible increase in diameter increment of individual trees is obtained at basal area levels necessary for maximum periodic net basal area and volume increment.

Whether thinning is undertaken to maximize volume production or to maximize diameter increment on individual trees the greatest benefits will occur if treatment is done when the trees are capable of achieving their fastest growth rate. For the stands studied this occurred up to about 20 years of age. Since young trees are capable of faster growth than older ones it follows that thinning (in terms of per cent basal area removed) can be heavier in young stands than in older ones.

None of the studies were designed to compare the effects of site on response to thinning. However, it has been shown that trees on telluric sites are capable of faster growth than trees on other sites. Therefore, in a thinning program these sites should normally be treated first.

Based on basal area data for all studies, six thinning regimes (Figures 9 and 10) have been set up to show probable stand development to age 40. Data were too scanty to extend the regimes further. Regimes are labelled, light, moderate and heavy for convenience. Those in Figure 9 are based on a 5-year cutting cycle while those in Figure 10 are based on a 10-year cycle. Thinning intensity for the moderate regimes was chosen so the standing basal area half-way

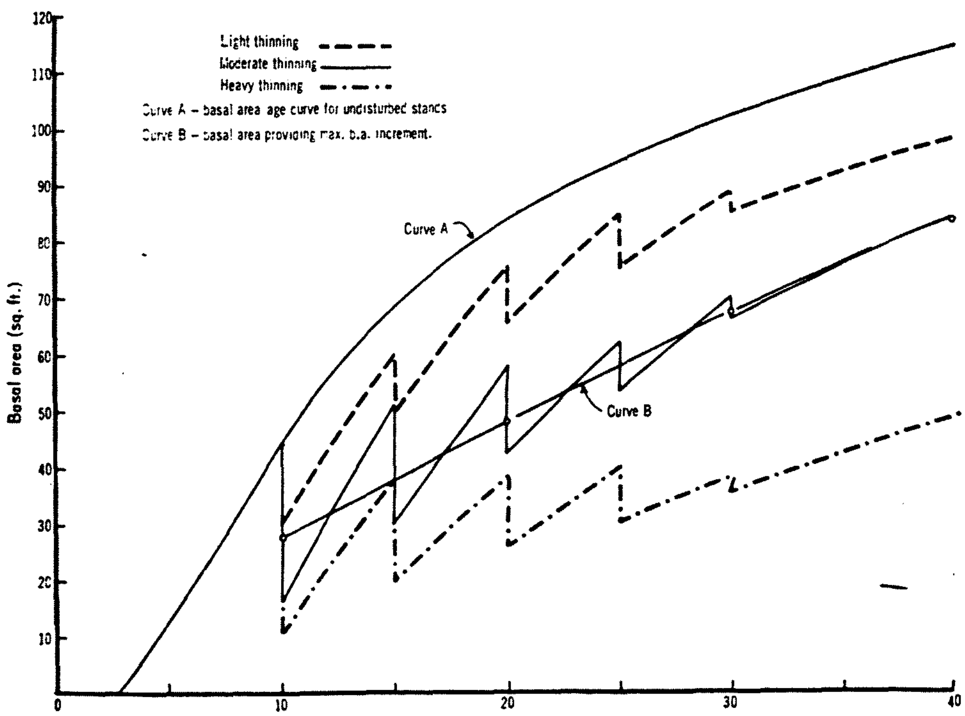


FIGURE 9. Relationship between basal area per acre and age for undisturbed stands and light, moderate and heavy thinning schedules, 5-year cycle.

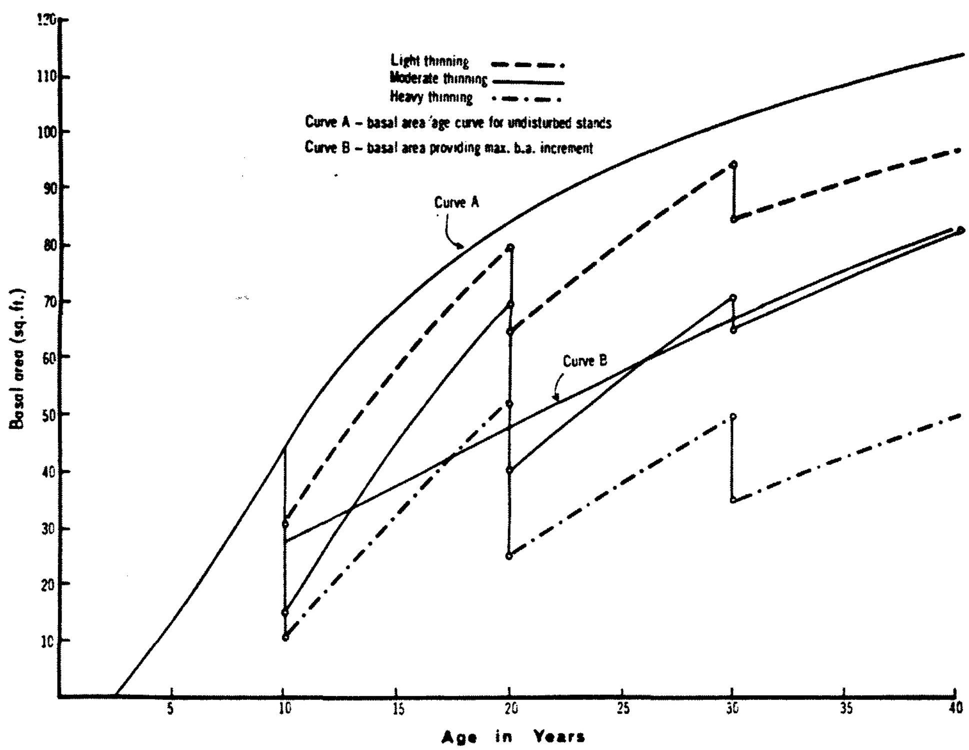


FIGURE 10. Relationship between basal area per acre and age for undisturbed stands and light, moderate and heavy thinning schedules, 10-year cycle.

between two consecutive thinnings would approximate that found to give maximum periodic net basal area increment (Table 5). The light and heavy regimes were chosen arbitrarily. The curves showing development of untreated stands were taken from Appendix I.

Total basal area, total volume, cordwood volume and average breast-height diameter of the 200 largest trees per acre at various ages, for all regimes, are presented in Table 8. Data for the untreated stands were derived from Appendices I to IV. For the treated stands, cordwood and total volumes shown are interpolated values derived from individual plot data (all studies). Data for average breast height diameter of the 200 largest trees were obtained by interpolation using Figure 4 and the data contained in Appendix IV.

Total basal area production at 40 years (for both 5- and 10-year cutting cycles) ranked in descending order by thinning intensity is: (1) moderate thinning, (2) light thinning, (3) heavy thinning, and (4) control. Total volume yield at 40 years ranked in the same manner is: (1) light thinning, (2) moderate thinning, (3) control, and (4) heavy thinning. As can be seen, light and moderate thinnings can be expected to produce greater basal area and total volume yields than either heavy thinning or no thinning.

Cordwood production at age 40, for both 5- and 10-year cutting cycles ranked in descending order by thinning intensity is: (1) control, (2) moderate and light thinning, and (3) heavy thinning. At age 25 production is higher for thinned stands than for unthinned stands. This may be explained by the fact that cordwood includes only material 4 inches in diameter at breast height and up. Therefore, because of increased diameter growth of trees in the thinned stands they reach the minimum diameter sooner than trees in unthinned stands. However,

TABLE 8. YIELD PER ACRE THINNED AND UNTHINNED TREMBLING ASPEN STANDS.

Age	Basal area (sq. ft.)		Total volume[1] (cu. ft.)		Cordwood[1]		D.b.h. 200 largest	
	Standing	Thinning	Standing	Thinning	Standing	Thinning[2]		
			No thinning					
10	44	0	400	0	0	—	2.0	*Yield at age 40*
15	68	0	1,000	0	0	—	2.8	B.A. = 114 sq. ft.
20	84	0	1,500	0	3	—	3.6	Total volume =2,650 cu. ft.
25	94	0	1,900	0	9	—	4.3	Cordwood = 30 cords
30	102	0	2,200	0	16	—	5.0	
40	114	0	2,650	0	30	—	6.0	
			Light thinning (5-year cycle)					
10	30	14	260	140	0	—	2.0	*Yield at age 40*
15	50	10	650	110	0	—	3.2	B.A. = 147 sq. ft.
20	65	11	1,060	200	3.5	—	4.2	Total volume = 3,375 cu. ft.
25	75	10	1,460	225	10	—	5.0	Cordwood = 27 cords
30	85	4	1,885	100	15	—	5.6	
40	98		2,600		27	—	6.6	
			Moderate thinning (5-year cycle)					
10	16	28	130	270	0	—	2.0	*Yield at age 40*
15	30	21	370	280	0	—	3.1	B.A. = 162 sq. ft.
20	42	16	650	290	4	—	4.2	Total volume = 3,305 cu. ft.
25	53	9	970	190	14	—	5.2	Cordwood = 28 cords
30	66	4	1,400	100	19.5	—	6.1	
40	84		2,175		28		7.3	
			Heavy thinning (5-year cycle)					
10	10	34	70	330	0	—	2.0	*Yield at age 40*
15	20	18	240	235	0	—	3.2	B.A. = 127 sq. ft.
20	25	13	370	215	4.5	—	4.4	Total volume = 2,195 cu. ft.
25	30	10	510	190	11	—	5.5	Cordwood = 21 cords
30	35	3	685	65	13.5	—	6.6	
40	49		1,160		21		8.2	
			Light thinning (10-year cycle)					
10	30	14	260	140	0	—	2.0	*Yield to age 40*
20	65	15	1,065	275	3	—	3.9	B.A. = 136 sq. ft.
30	85	10	1,885	265	16.5	—	5.2	Total volume = 3,180 cu. ft.
40	97		2,500		27		6.2	Cordwood = 27 cords
			Moderate thinning (10-year cycle)					
10	15	29	120	280	0	—	2.0	*Yield to age 40*
20	40	30	620	540	3	—	4.1	B.A. = 147 sq. ft.
30	65	6	1,380	150	17	—	5.8	Total volume = 3,090 cu. ft.
40	82		2,120		27		7.0	Cordwood = 27 cords
			Heavy thinning (10-year cycle)					
10	10	34	70	330	0	—	2.0	*Yield to age 40*
20	25	27	370	465	4	—	4.3	B.A. = 126 sq. ft.
30	35	15	685	315	15	—	6.3	Total volume = 2,310 cu. ft.
40	50		1,200		23		7.8	Cordwood = 23 cords

[1]Total volume and cordwood values are interpolated.
[2]Thinning from below, no cordwood volume removed.

when the unthinned stands reach the 4-inch minimum, cordwood yields increase rapidly because of the greater number of trees. It should be noted that material removed as thinnings is not of cordwood size.

The effect of thinning on board foot production is still unknown since most stands were too young to produce board foot volumes (Appendix V). However, the beneficial effect of thinning on tree increment has been demonstrated. Heavy thinning at 5- and 10-year intervals should produce crop trees with an average diameter of about 8 inches at 40 years of age as compared to 6 inches for similar trees in unthinned stands.

CONCLUSIONS

If all sized material could be used, total volume production to age 40 could be increased by about 25 per cent with light to moderate thinning at 5-year intervals. To achieve this, stands would have to be maintained at densities between 15 square feet per acre at age 10 and 85 square feet at age 40. For the stands on which the thinning regimes were based this would have meant a reduction in basal area of between 65 and 75 per cent (Table 5).

Thinning has little effect on cordwood production to age 40, mostly because the material removed is not of cordwood size (minimum diameter at breast height 4 inches). If thinnings have to meet this minimum size, treatments will have to be postponed until stands are about 30 to 40 years of age, when volumes will be between 15 and 30 cords per acre. For maximum cordwood growth of residual trees, density should be varied from about 65 square feet per acre at age 30 to about 100 square feet per acre at age 50.

If thinning is carried out for lumber (board measure) production, stands will have to be maintained at basal areas well below those optimum for total volume or cordwood production.

SUMMARY

Between 1926 and 1951 eight thinning studies, comprising 47 sample plots ranging in size from 0.1 to 1.0 acres, were established in 11- to 45-year-old trembling aspen stands in Manitoba and Saskatchewan. Thinning was carried out to specific spacings, specific basal areas and specific stand density indices.

Within the range of basal areas created by thinning, diameter increment of individual trees (both large and small trees) increased as intensity of thinning increased. The most severe thinnings left basal areas that were about 15 per cent of those of untreated stands.

Greatest net basal area and total volume increment for 10-, 20-, 30-, 40-, and 50-year-old stands occurred at residual basal area levels of 28, 48, 67, 84 and 101 square feet per acre, respectively.

There was a marked difference of growth rate between sites; response to thinning on the best site followed a similar trend to that on the other sites.

Data suggest that thinning should be initiated before the age of 20 years to be most beneficial to further stand development.

Six thinning regimes were prepared, describing stand development for various cutting intensities up to an age of 40 years. These regimes suggest that gains in total volume production of up to 25 per cent may be obtained at an age of 40 years by moderate thinning at 5-year intervals.

Thinning for cordwood production is recommended only when thinning material can be utilized. This is expected to be at an age between 30 to 40 years when stands will contain between 15 and 30 cords per acre.

Sufficient data were not available to predict the effect of thinning on board foot production. However, up to the age of 40 years crop trees in stands under a heavy thinning schedule can be expected to average 8 inches d.b.h. as compared to 6 inches in untreated stands.

SOMMAIRE

De 1926 à 1951, on a procédé à huit éclaircies expérimentales dans 47 placeaux dont la superficie variait de 0.1 à 1 acre, établis dans des peuplements de peupliers faux-trembles de 11 à 45 ans, au Manitoba et en Saskatchewan. Les coupes d'éclaircie ont été faites selon des indices déterminés d'espacement, de surface terrière et de densité de peuplement.

Dans la marge des surfaces terrières obtenues à la suite des coupes d'éclaircie, la croissance en diamètre de tous les arbres (gros et petits) a été accélérée en proportion directe de l'intensité des coupes d'éclaircie. Les coupes d'éclaircie les plus intensives laissaient des surfaces terrières égales à environ 15 p. 100 des surfaces terrières occupées dans les peuplements laissés intacts.

L'accroissement le plus élevé du volume total des arbres et la plus grande surface terrière nette, dans les peuplements de 10, 20, 30, 40 et 50 ans, ont été constatés dans les placeaux dont la surface terrière après les coupes d'éclaircie était respectivement de 28, 48, 67, 84 et 101 pieds carrés à l'acre.

L'allure de croissance des arbres était sensiblement différente d'une station à l'autre; les coupes d'éclaircie ont eu un effet bienfaisant aussi bien dans les meilleures stations que dans les autres.

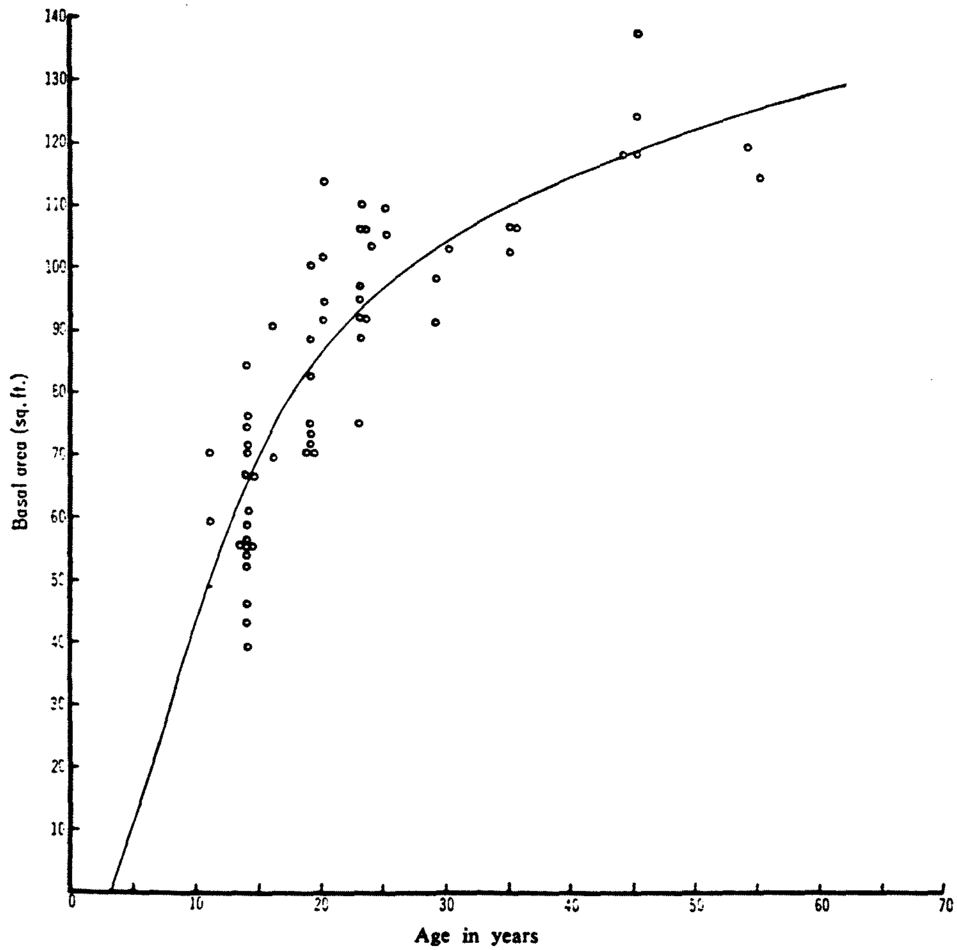
D'après les données recueillies au cours de l'étude, les coupes d'éclaircie devraient commencer avant que les peuplements n'atteignent leur vingtième année, afin de favoriser au mieux la croissance des arbres. Six régimes de coupes d'éclaircie ont été préparés, d'après la croissance des peuplements qui avaient subi des coupes d'éclaircie d'intensité variable, jusqu'à 40 ans d'âge. D'après ces régimes, il est possible d'obtenir des gains de volume total de l'ordre de 25 p. 100 à 40 ans, grâce à des coupes d'éclaircie modérées faites tous les 5 ans.

Les coupes d'éclaircie en vue de favoriser la production de bois à pâte ne devraient se faire que lorsqu'on peut utiliser les bois provenant de ces coupes. Cette condition sera probablement remplie lorsque les peuplements auront de 30 à 40 ans, alors qu'ils pourront produire de 15 à 30 cordes à l'acre.

Les données recueillies ne permettent pas de déterminer l'effet des coupes d'éclaircie sur la production de bois d'œuvre. On a toutefois pu établir que dans les peuplements de 40 ans soumis à des coupes d'éclaircie intensives, le d.h.p. moyen des arbres atteint 8 pouces, alors que dans les peuplements laissés intacts il ne dépasse pas 6 pouces.

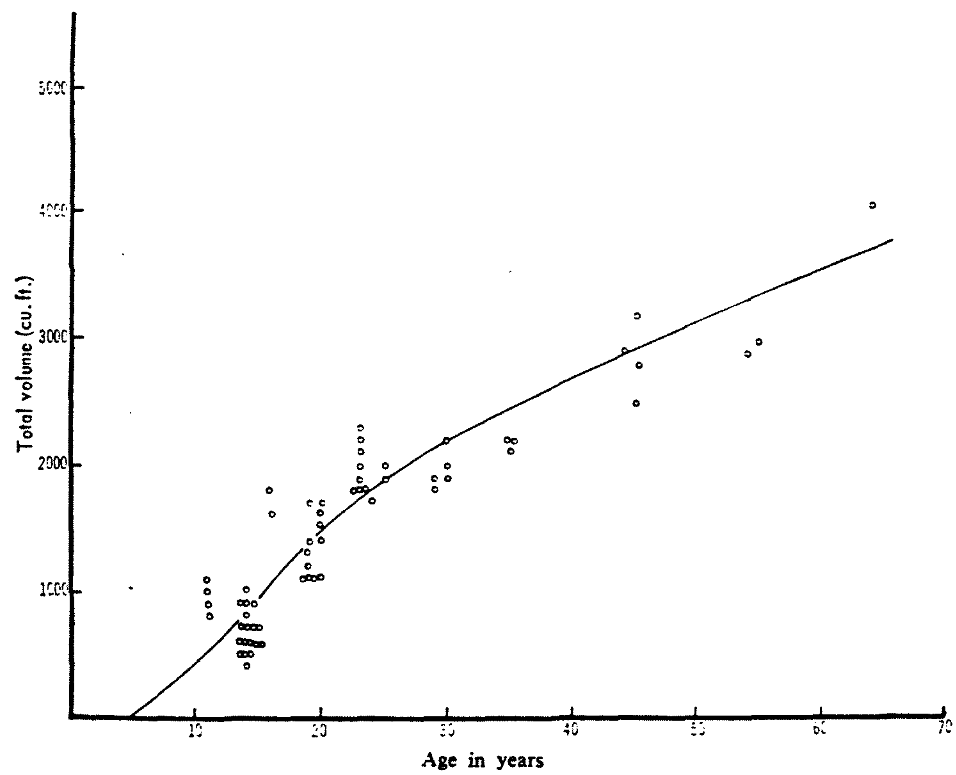
APPENDIX I

Relationship between basal area and age of untreated stands.
Basis: Control plots from all studies.



APPENDIX II

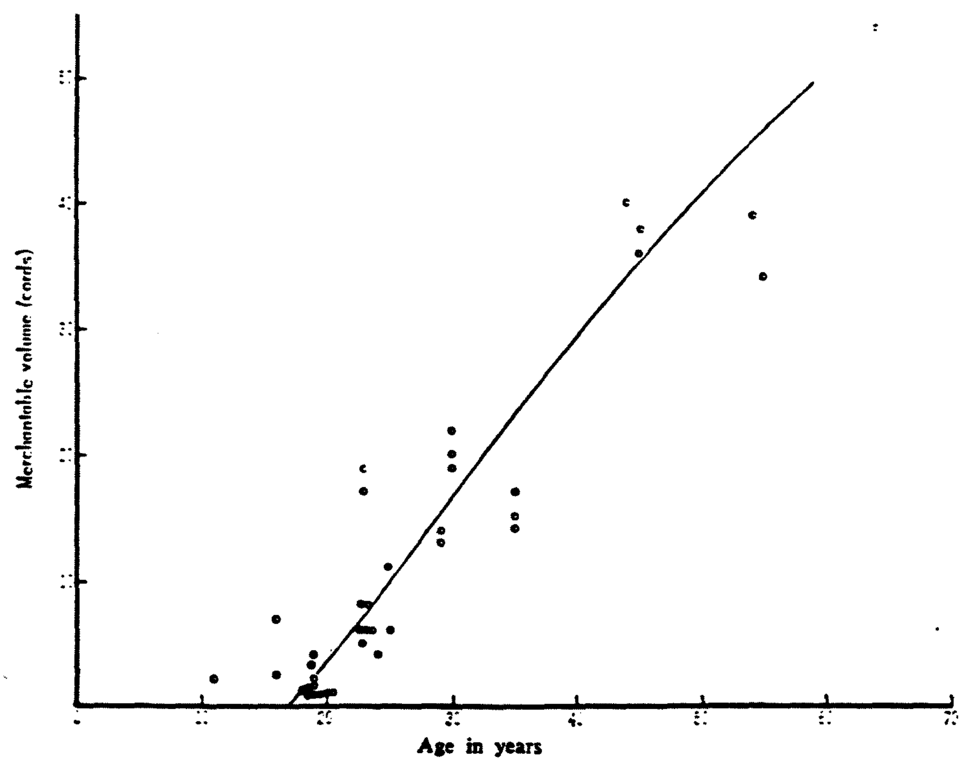
Relationship between total volume and age of untreated stands.
Basis: Control plots from all studies.



APPENDIX III

Relationship between cordwood merchantable volume and age of untreated stands.

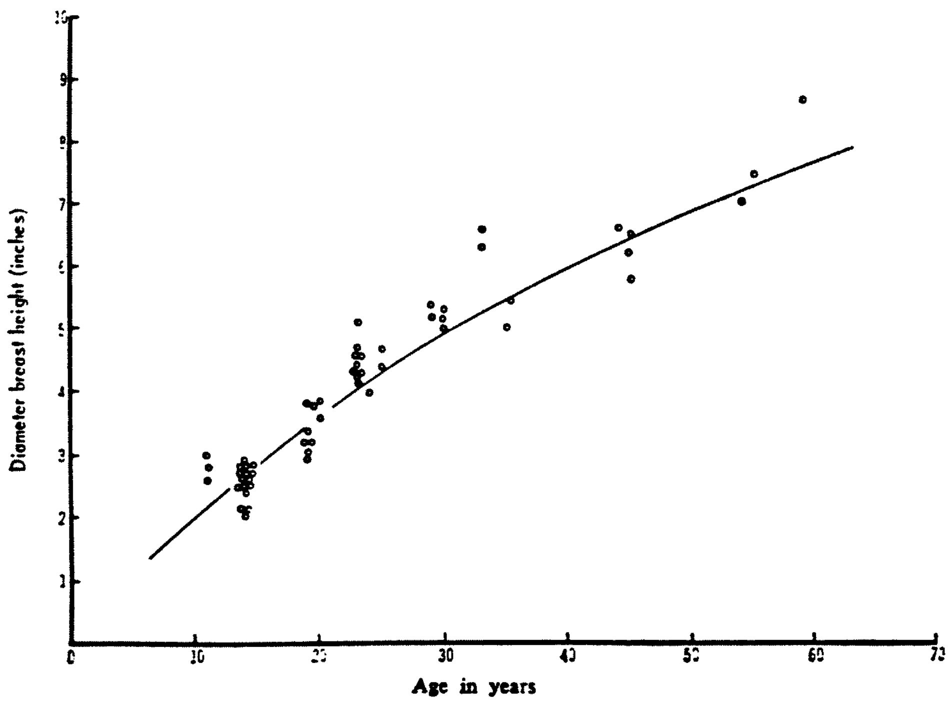
Basis: Control plots from all studies.



APPENDIX IV

Relationship between the breast height diameter of the 200 largest trees per acre and age of untreated stands.

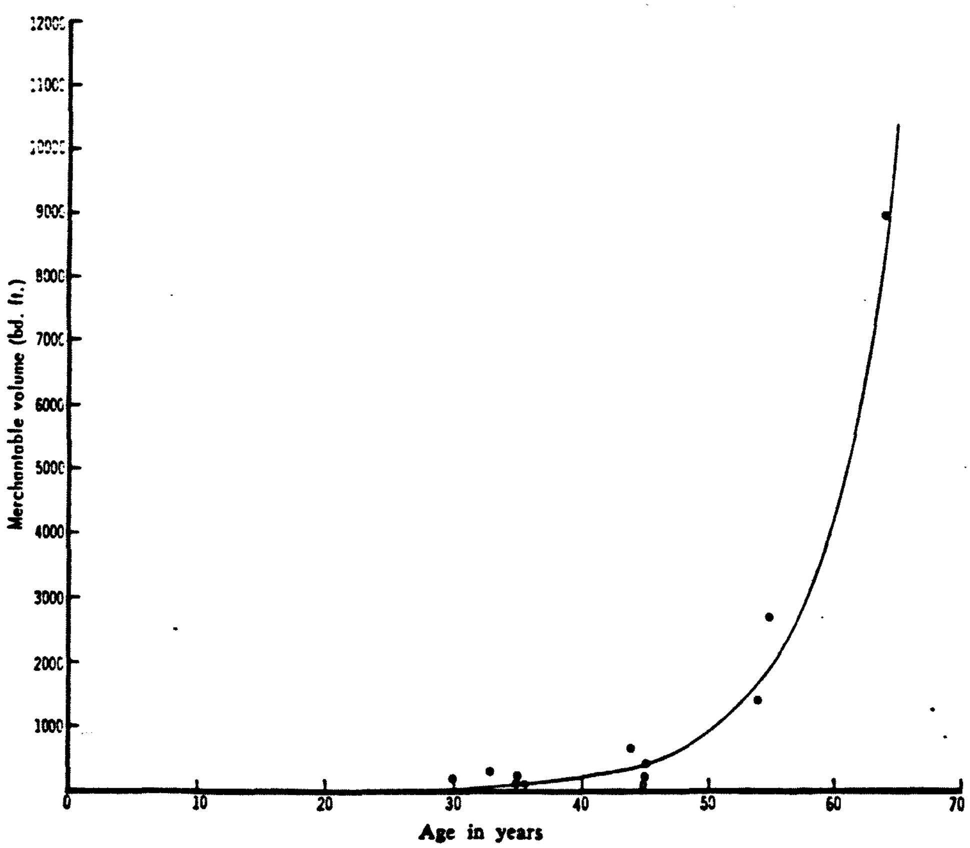
Basis: Control plots from all studies.



APPENDIX V

Relationship between board foot merchantable volume and age of untreated stands.

Basis: Control plots from all studies.



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PARTIAL CUTTING WITH SCARIFICATION IN ALBERTA SPRUCE-ASPEN STANDS

by

J. C. Lees

Sommaire en français

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TABLE OF CONTENTS

62527-7—2

Partial Cutting with Scarification in Alberta Spruce-Aspen Stand[1]

by

J. C. Lees[2]

SUMMARY

In 1952 a study was begun in 110-year-old spruce-aspen stands in the B–18a section of Alberta's mixed-wood to investigate scarification for white spruce regeneration before and after partial cutting to four residual stand densities: *a*) control, *b*) heavy, *c*) medium, and *d*) light.

Scarification was carried out using a TD9 tractor with a 9-foot straight blade. Three seedbed types were compared: *a*) scarified, *b*) mounded, and *c*) undisturbed.

Germination and survival of spruce seedlings were tallied on sub-samples of 4,000 quarter milliacre quadrats between June 1956 and November 1957 and 400 scarified quadrats in 1959. Windfall and mortality, and residual stand growth were measured in 1959 on forty half-acre plots.

It was found that:—

a) Only the scarified seedbed permitted satisfactory establishment of spruce regeneration and remained receptive for five years.

b) Regeneration establishment was not affected significantly by residual stand density or time of scarification.

c) Mortality and windfall were slight, occurring mainly in stems damaged by either scarification or logging.

d) Growth rates for spruce were good considering the age of the stands, and a valuable recruitment to the merchantable size class (7 inches d.b.h.) was noted.
Growth of aspen was poor, many stems being overmature and decadent.

e) The success of partial cutting with scarification is sufficient to recommend its further use in the Mixed-wood Section.

INTRODUCTION

In 1950, partial cutting of white spruce (*Picea glauca*) with tree marking was introduced in the B–18a Section of Northern Alberta by the provincial Department of Lands and Forests. It replaced cutting to breast height diameter limits of 14 to 20 inches. The initial felling under the new system was to provide enough merchantable stems to allow economical logging and at the same time to leave a residual stand for seed supply and conditions suitable for germination and establishment of white spruce seedlings. Only the spruce was considered merchantable and aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*)

[1] Department of Forestry, Forest Research Branch Contribution No. 502
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were left unmarked. In essence this was a two-cut uniform shelterwood. Private industry agreed to the method on a trial basis and it has subsequently been adopted.

In 1952, work[1] was begun by the Forest Research Branch to examine the system of partial cutting with individual tree marking, and to assess white spruce regeneration following scarification. Four residual stand densities were studied including three degrees of marking and an uncut control. Scarification was tested as a seedbed treatment both before and after logging. This report gives the results of examinations made in 1959.

EXPERIMENTAL AREA

The study area is about 25 miles east of Lesser Slave Lake in the B-18a Mixed-wood section of the Boreal Forest region (Rowe 1959) (Figure 1). The terrain is gently rolling with distinct ridges and long slopes. Grassy sloughs and seasonal streams occur in the lower areas. Soils are Grey Wooded with profiles in well-drained positions showing a characteristic leached A_e horizon and a dark brown-grey crumbly Bt horizon over a calcareous parent material. Textures range from sands and sandy loams on the ridges and slopes to heavy clays in the depressions. Humus accumulations vary from two to three inches on the ridges to more than one foot in the poorly drained bottomland.

A white spruce-aspen forest of fire origin occurs on the upland sites with balsam poplar, black spruce (*Picea mariana*), and larch (*Larix laricina*) on the lowland sites and muskegs. Mixtures tend to be by species groups rather than individual stems. Occasional white birch (*Betula papyrifera*) and jack pine (*Pinus banksiana*) are present.

The white spruce on the study areas was vigorous and sound and had an average age of 110 years. Diameter range at breast height was from 9 to 16 inches. The aspen was slightly older and decadent. Spruce volumes per acre were commonly 12,000 f.b.m. with 8,000 f.b.m. per acre of aspen and poplar. There was an understorey of about 600 aspen suckers per acre of one to two inches breast-height diameter and some suppressed spruce of three to five inches breast-height diameter that had originated after ground fires in 1904. Advance growth included 100 to 200 white spruce 1 to 4 feet high. Milliacre stocking to spruce reproduction in the area before any treatment amounted to 10 to 15 per cent. Tables of advance growth stocking are presented in Appendix I.

Ground cover beneath the spruce was mainly feather mosses and scattered herbs. Where aspen was the chief component of the stand, minor vegetation was abundant and included tall shrubs such as rose and high-bush cranberry. Moist sites were typically grassy under white spruce-aspen. This created severe competition for tree seedlings.

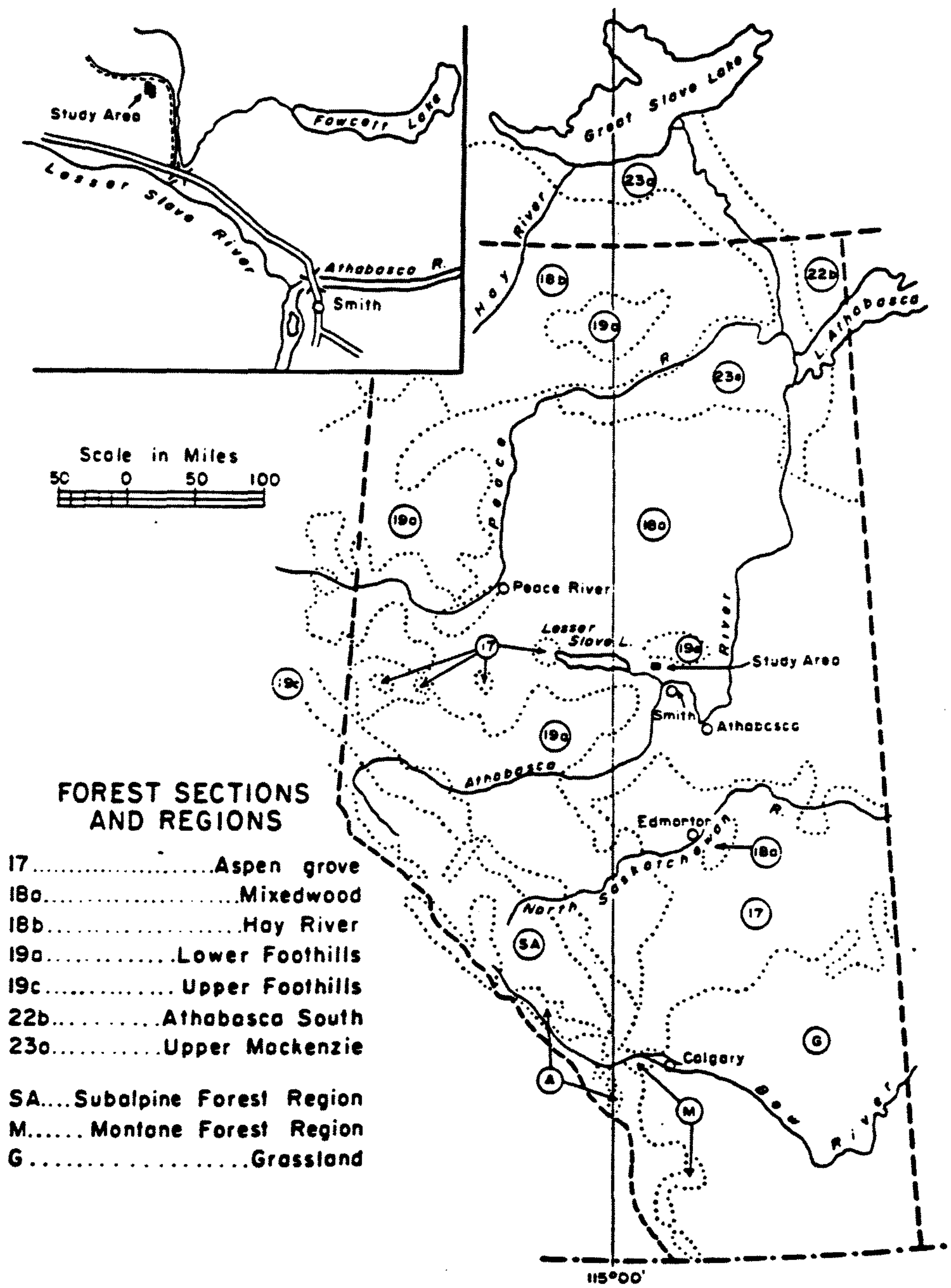
METHODS

The experimental design, covering 20 acres of forest, provided for four intensities of main stand treatment, three seedbed treatments, and two variations in the timing of the seedbed treatments.

[1] Research Project A-22.

FIGURE I.

STUDY AREA LOCATION



Partial Fellings

The stands were marked for cutting to provide three densities of residual spruce; an uncut control was also preserved. In no treatment was aspen or balsam poplar cut, nor was any spruce cut which was under 7 inches in diameter at breast height. The treatments were as follows:

1. Control—no logging
2. Heavy residual—leaving 8,000 f.b.m. spruce per acre. On the average 5,400 f.b.m. per acre was removed.
3. Medium residual—leaving 5,000 f.b.m. spruce per acre. On the average 3,900 f.b.m. per acre was removed.
4. Light residual—leaving 2,000 f.b.m. spruce per acre. On the average 5,600 f.b.m. per acre was removed.

The experimental layout is shown in Figure 2. The four felling treatments were randomly assigned to 40 half-acre plots combined into five uniform blocks. Within each block, two plots received the same treatment, thus providing a total of 10 replications of each treatment.

The original stand volumes of spruce were not uniform and practically the same volume was removed from the light residual treatment area as from the heavy residual (Appendix II). Since the aspen and balsam poplar were unmerchantable and left standing, the treatment affected only the spruce component of the stand volume. Residual stand density depended therefore, to some extent, on the distribution of the uncut hardwoods. In the summer of 1952, horses were employed to log the treated areas using short log lengths resulting in negligible damage to the residual trees.

Seedbed Treatment

On each half-acre plot two strips were scarified before logging (June and July 1952) and two after logging (September 1952) as shown in Figure 3. More complete scarification would have been possible particularly in the lighter residual stand densities, but treatment was limited to four strips to prevent excess damage to residual trees in the denser stands. Some small spruce were destroyed and roots of several large residual trees were exposed and scarred.

A TD9 tractor with a 9-foot straight blade was used. It proved to be easily manoeuvrable and capable of scarification after logging despite the slash. Alternate lowering and raising of the blade produced spots approximately 8 by 5 feet, scarified to mineral soil.

Following scarification, three distinct types of seedbed were available for comparison:

1. Scarified—mineral soil exposed.
2. Mounded—litter, humus and mineral soil dumped by the blade at the end of each patch.
3. Undisturbed.

ASSESSMENT

Regeneration

On each half-acre plot one hundred quarter-milliacre quadrats were established to sample regeneration on the scarified, mounded, and undisturbed

FIGURE 2

DESIGN OF EXPERIMENT

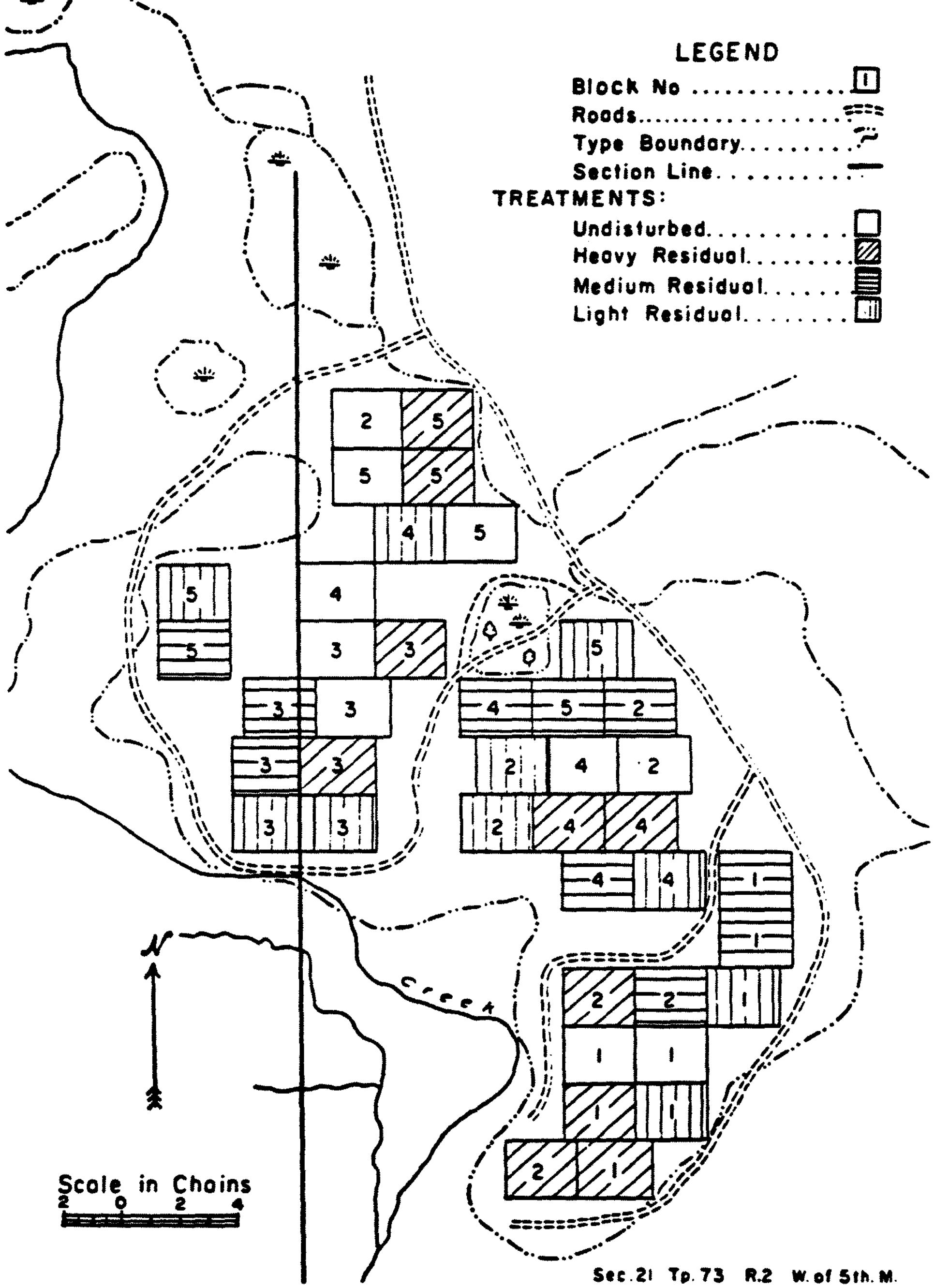
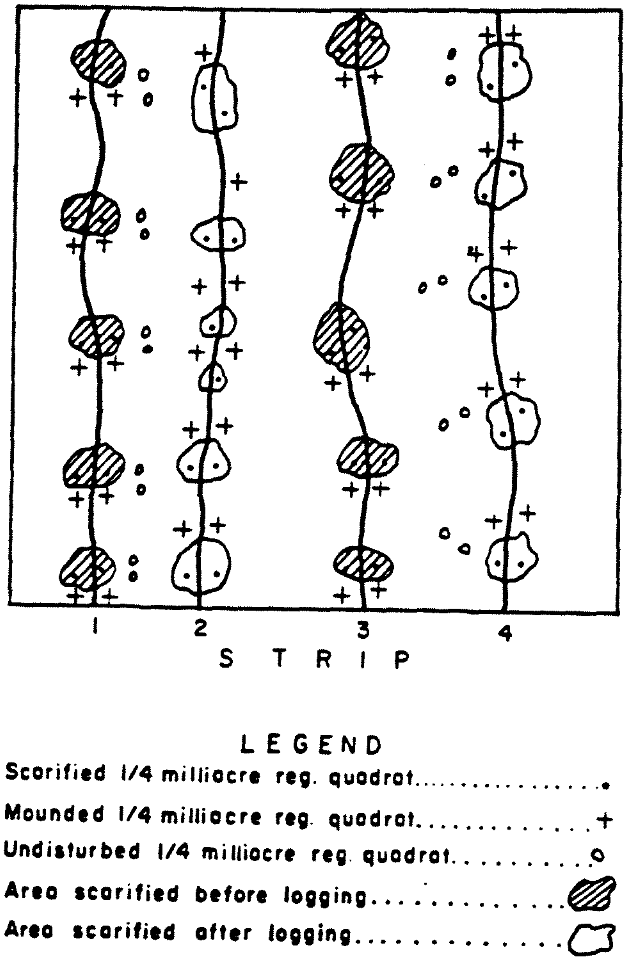


FIGURE 3
THE LAYOUT OF SCARIFICATION STRIPS
AND THE
ONE HUNDRED 1/4 MILLIACRE REGENERATION QUADRATS
ON THE 1/2 ACRE PLOTS



(control) ground (Figure 3). This resulted in a total of 4,000 quadrats of which 1600 were on scarified, 1600 on mounded and 800 on undisturbed ground.

There was no appreciable spruce seed crop in the area until 1955 and regeneration was assessed first in 1956 and 1957 when a stratified sample of 500 quadrats was used to record bi-weekly seedling germination and mortality throughout the growing seasons. Results were analysed and a report was published (Smithers 1959). In 1959, four years after the first seedlings appeared, 400 scarified quadrats were measured to determine whether the earlier stocking to spruce had been maintained and if the regeneration was firmly established.

Residual Stand

All trees, 0.5 inches in diameter at breast height and over, were tallied on each of the 40 half-acre plots before and after cutting. Six trees per plot were tagged and measured for height/diameter studies. Dead trees standing and down were tallied in 1953, 1954, and 1956 and the cause of mortality was noted when this could be determined.

In 1959, a complete tally was made of all living trees and of all dead trees since 1956. Radial growth was measured from increment cores on ten dominant and co-dominant spruce per plot and the original tagged trees were remeasured.

RESULTS

Regeneration

Smithers (1959) found that up to 1956 there was no significant difference in either number of spruce germinants or per cent stocking to spruce between blocks, times of scarification or between cutting treatments. As only the effect of the scarification treatment was significant, the data for all blocks and times of scarification are combined in Table 1. Scarified spots with mineral soil exposed provided a consistently better seedbed than either the mounded or undisturbed conditions. The level of stocking on scarified ground is acceptable.

In 1959 the average milliacre stocking to spruce regeneration on scarified areas remained high at 75 per cent and did not vary between stand densities. Quadrats were stocked mainly with 4- to 5-year-old seedlings up to 6 inches in height, which were survivors from the earliest seedling catch in 1956. Apparently, overwinter and second season mortality had been low; survival had been aided by favourable rainfall in the spring and summer of 1957. A few younger seedlings, 2- to 3-years old, had subsequently seeded in.

By 1959, encroachment of vegetation on the scarified ground was severe and the seedbed could no longer be classed as receptive. Spruce seedlings were most vigorous where the canopy was open and they were suppressed under dense spruce. Other regeneration on the scarified spots, particularly in the more open stands, included white birch and aspen.

Residual Stand Development

Stand volumes and growth for the period 1952 to 1959 are given in Table 2. Between 1952 and 1959 the spruce component on the treated areas had a net volume increment per acre which ranged from 151 to 371 cubic feet, while on the uncut control, the amount was 245 cubic feet. Although the period between measurements is short, some release of individual trees is evident in the merchantable sizes of residual spruce; recruitment to the 7-inch diameter class is a substantial contribution to the merchantable volume increment. Examination of increment cores showed that the growth rate of the residual stems throughout the treatment areas was sustained while growth on control areas decreased.

The aspen showed little increment and on the control area there was a decrement. However, the volume of the hardwood component was relatively stable between 1952 and 1959. Losses owing to mortality in the old decadent trees were offset by increment in younger vigorous stems.

Treatment produced difference in per cent diameter increment. Table 3 shows that values for diameter increment in per cent, obtained by Schneider's

TABLE 1. PER CENT STOCKING TO SPRUCE SEEDLINGS ON SCARIFIED, MOUNDED AND UNDISTURBED SEEDBEDS

Date	June, 1956 (500 Quadrats)						Sept. 1956 (4,000 Quadrats)						June 1957 (500 Quadrats)						Nov. 1957 (500 Quadrats)						July 1959 (400 Quadrats)					
	Scarified		Mounded		Undisturbed		Scarified		Mounded		Undisturbed		Scarified		Mounded		Undisturbed		Scarified		Mounded		Undisturbed		Scarified		Mounded		Undisturbed	
Treatment	¼*	1**	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1	¼	1
Uncut	36	83	4	14	0	0	27	71	2	7	0	0	24	68	2	7	0	0	22	63	2	7	0	0	21	61	—	—	—	—
Heavy	26	71	0	0	0	0	18	55	0	0	0	0	16	50	0	0	0	0	16	50	0	0	0	0	30	78	—	—	—	—
Medium	22	63	6	21	4	14	18	55	2	7	2	7	16	50	2	7	2	7	16	50	2	7	0	0	33	80	—	—	—	—
Light	32	79	4	14	0	0	26	71	4	14	0	0	26	71	0	0	0	0	20	59	0	0	0	0	35	82	—	—	—	—

* ¼ — ¼ milliacre stocking (as measured)
** 1 — milliacre stocking (after Grant 1951).

formula[1] for dominant and co-dominant stems, were highest in the light residual stands. Spruce height growth amounted to half a foot per year with no variation between treatments.

TABLE 2.—VOLUME AND GROWTH PER ACRE
(Total Volume in Cubic Feet)

Treatment	Species	Number of stems 1959	Volume 1952 before cut	Volume 1952 after cut	Volume 1959	Net increment 1952–59	Mortality 1952–59	Gross increment 1952–59	Net volume increment /ac /year	Recruitment to 7" dbh class 1952–59
Control....	wS	207	—	3187	3432	245	92	337	35	96
	Hwd	122	—	2077	2033	−44	142	98	—	—
	Total	329	—	5264	5465	201	234	435	—	—
Heavy Residual...	wS	164	3377	2066	2437	371	76	447	53	68
	Hwd	110	2023	1907	1922	15	144	159	—	—
	Total	274	5103	3973	4359	386	220	606	—	—
Medium Residual.	wS	160	2410	1420	1666	246	49	295	35	72
	Hwd	151	2301	2181	2219	39	184	223	—	—
	Total	311	4711	3601	3885	285	233	518	—	—
Light Residual...	wS	116	2069	740	891	151	30	181	22	65
	Hwd	175	2363	2321	2374	54	268	322	—	—
	Total	291	4432	3061	3265	205	298	503	—	—

TABLE 3.—DIAMETER AND HEIGHT INCREMENT 1952-1959 DOMINANT AND CO-DOMINANT WHITE SPRUCE

Residual Stand	Average d.b.h. 1959	Diameter increment 1952–1959	Average dominant height 1959	Average annual height growth 1952–1959
	(inches)	(per cent)	(feet)	(feet)
Control..............................	13.9	1.96	83.0	0.6
Heavy..............................	13.6	1.87	85.7	0.6
Medium..............................	12.8	2.25	79.1	0.6
Light..............................	11.3	2.83	69.5	0.5

Mortality figures are presented in Table 4 for the periods 1952 to 1956 and 1956 to 1959. Spruce mortality was noticeably light. It occurred mainly in stems damaged by either scarification or logging; windfall was negligible. The 1 to 6 inch diameter class was most affected. Average annual figures show that mortality volume was slightly higher in the initial period because of damage to some large stems and possibly due to insolation and shock of release. Aspen, on the other hand, showed an increasing mortality trend as the larger stems disappeared from the overwood. This left residuals relatively free from insect attack and disease.

[1] $P = \frac{400}{nD}$ value P = diameter increment in per cent
D = present diameter breast height over bark in inches.
n = number of rings in the last inch of radius.
Schneider's formula

TABLE 4.—MORTALITY

Treatment — Species		Average Annual Mortality Per Acre					
		1952-56		1956-59		Total	
		Number of Stems	Total Volume Cu. Ft.	Number of Stems	Total Volume Cu. Ft.	Number of Stems	Total Volume Cu. Ft.
Control	wS	1	9	1	14	2	23
	Hwd.	1	10	2	25	3	35
	Total	2	19	3	39	5	58
Heavy Res.	wS	1	11	1	8	2	19
	Hwd.	1	14	1	22	2	36
	Total	2	25	2	30	4	55
Medium Res.	wS	1	8	1	4	2	12
	Hwd.	1	10	1	36	2	46
	Total	2	18	2	40	4	58
Light Res.	wS	1	4	1	4	2	8
	Hwd.	1	31	2	36	3	67
	Total	2	35	3	40	5	75

DISCUSSION AND APPLICATION

Treatment of the stands proved successful in providing an overhead spruce seed source and shelter for the seedlings during the establishment period. The mineral soil seedbed produced by scarification remained receptive to seed at least up to 1957. This resulted in good stocking to spruce on scarified spots compared with failure on the mounded and undisturbed seedbeds. Because the superficial layer of moss and litter dries out too quickly to provide a suitable medium for germination and survival, regeneration on undisturbed areas failed. Likewise, the moisture levels of the loose, structureless mineral soil on the mounded seedbeds were apparently too low to support regeneration.

Although good spruce seed crops are infrequent, occurring about once every seven years, the increase in stocking of spruce seedlings between 1957 and 1959 suggests that there may be a light seedfall at more frequent intervals. However, as the period during which scarified ground remains receptive to seed (about 5 years) may be shorter than the intervals between adequate seed crops, scarification in partial cut stands should be synchronized with good seed years; otherwise some artificial seeding or planting may be necessary to obtain adequate regeneration. The advantages of scarification shown to date in trials in the area are considered sufficient to warrant inclusion of scarification as a standard procedure in regeneration silviculture in spruce-aspen stands.

The residual spruce remained vigorous and healthy. Height and diameter growth of dominant and co-dominant stems has been satisfactory considering the advanced age of the stands. There has been recruitment to the merchantable seven-inch diameter size class. Mortality has been light and windfall negligible.

Several points are noteworthy with respect to application of the results. Since current marking practice provides for removal of less than 50 per cent spruce by volume, the resulting residual stands most closely resemble medium to heavy residual stands on the experimental area. Results of this study suggest, however, that up to 70 per cent spruce by volume can safely be removed in partial cutting provided the residual stems are vigorous and healthy.

Rotation age and the end product of stand treatment depend on the level of silviculture which it is economical to practice. Within the framework of the present sawlog economy, regeneration and growth data from this experiment indicate that present cutting and regeneration practices are producing good results for the amount of effort expended. If age class distribution was satisfactory, the first cutting could be made when stands are about 75 years of age. Improved growth would result in the residual stems during the ensuing regeneration period. If defective and poorly formed trees could be removed, well-spaced desirable parent trees would be left. Scarification could then follow, and timing of removal felling would depend on regeneration status and residual stand growth.

Damage to residual stems during felling and scarification operations can be minimized through education, supervision of operators and the layout of well-planned extraction routes. The selection of appropriate logging equipment and methods is important and would vary with the density of the stand. It is preferable to scarify after rather than before logging; tractors are more easily manoeuvred and slash is seldom a hindrance. For removal fellings, winter logging is preferable as snow lends some protection to seedlings and thus minimizes damage.

Under more intensive management, greater advantage could be taken of the production potential of sites and stands. For example, under a pulpwood economy, which would allow the use of hardwoods, two 60-year rotations of hardwood and one 120-year rotation of spruce could be realized. Only selected spruce crop trees would be allowed to grow to full rotation age for sawtimber. The remainder would be removed as pulpwood in a series of thinnings and regeneration fellings. Higher yields might also justify the cost of artificial regeneration to achieve more rapid restocking.

SOMMAIRE

Une étude a été entreprise en 1952 dans des peuplements d'épinettes et de peupliers faux-trembles âgés de 110 ans dans la section B-18a des bois mixtes d'Alberta aux fins d'étudier l'effet de la scarification sur la régénération de l'épinette blanche, avant et après une coupe partielle visant à obtenir quatre densités différentes de peuplement résiduel, soit: *a*) densité témoin, *b*) forte densité, *c*) densité moyenne, *d*) faible densité.

La scarification a été effectuée au moyen d'un tracteur TD9 muni d'une lame droite de 9 pieds. On a fait la comparaison de trois types de planches à semis: *a*) planches scarifiées, *b*) planches en comble, *c*) planches non remuées.

On a enregistré la germination et la survivance des semis d'épinette dans des sous-échantillons de 4000 quadrats d'un quart de milliacre chacun entre juin 1956 et novembre 1957, et dans 400 quadrats scarifiés en 1959. On a aussi mesuré, en 1959, le chablis, la mortalité et la croissance du peuplement résiduel dans 40 places d'une demi-acre.

On a découvert que:

a) Seule la planche à semis scarifiée permettait l'établissement satisfaisant de la régénération d'épinette et demeurait en état de réceptivité pendant cinq années.

b) L'établissement de la régénération n'était pas modifié de façon importante par la densité du peuplement résiduel ou par l'époque à laquelle la scarification fut effectuée.

c) La mortalité et le chablis étaient faibles et se produisaient surtout dans le cas des tiges endommagées par la scarification ou par l'exploitation.

d) Les taux de croissance de l'épinette étaient bons, compte tenu de l'âge des peuplements, et un apport précieux à la classe de grosseur marchande (7 pouces de diamètre à hauteur de poitrine) a été enregistré. La croissance du peuplier faux-tremble a été médiocre, plusieurs tiges ayant passé l'âge d'exploitabilité et étant en état de décadence.

e) Le succès de la coupe partielle avec scarification est suffisant pour en recommander la continuation dans la section des bois mixtes.

APPENDICES

Appendix I

ADVANCE GROWTH—1952

No. of Stems Per Acre

Before Cutting

Ht. Ft.	Control				Heavy Residual				Medium Residual				Light Residual			
	wS	tA	bPo	wB	wS	tA	bPo	wB	wS	tA	bPo	wB	wS	tA	bPo	wB
1	36	130	35	8	31	135	44	12	50	84	19	10	102	74	26	25
2	30	204	44	38	30	299	56	36	50	278	56	26	58	215	49	61
3	19	194	64	21	26	231	49	25	56	237	41	27	29	288	48	119
4	8	143	53	4	15	161	36	11	34	155	47	21	14	239	36	90
5	2	36	27	—	5	34	24	—	19	32	33	1	4	93	17	13
6	—	31	18	1	6	30	14	—	14	20	14	3	3	58	17	13
7	1	33	34	2	1	22	14	4	1	23	15	3	1	42	18	7
8	—	19	26	—	1	17	4	—	1	27	15	—	—	57	18	2
9	—	11	14	—	—	10	6	—	—	8	8	—	—	24	12	2
10	—	3	2	—	—	2	1	—	—	2	4	—	—	10	2	—
Total	96	804	317	74	115	941	248	88	225	866	252	91	211	1,100	243	332

After Cutting

Ht. Ft.	Control wS	Control tA	Control bPo	Control wB	Heavy wS	Heavy tA	Heavy bPo	Heavy wB	Medium wS	Medium tA	Medium bPo	Medium wB	Light wS	Light tA	Light bPo	Light wB
1	19	102	19	1	15	81	27	4	24	76	8	2	38	53	17	10
2	27	173	27	11	12	143	220	11	19	118	25	15	34	110	17	12
3	6	121	37	14	4	119	29	11	22	108	19	12	11	137	18	28
4	6	67	28	5	3	58	13	8	16	54	14	6	7	91	20	27
5	4	27	13	1	3	21	9	4	9	35	12	—	4	38	6	7
6	—	26	13	4	—	15	5	2	5	10	13	1	1	11	7	1
7	—	19	22	—	7	17	5	1	1	14	3	1	4	13	3	1
8	2	20	13	—	2	34	4	—	—	8	4	1	—	10	3	1
9	—	12	8	—	—	2	1	—	—	4	3	—	—	4	3	—
10	—	—	5	—	—	2	1	—	—	3	2	—	—	2	3	—
Total	64	567	185	36	46	492	314	41	96	430	103	38	99	469	97	87

Appendix II

VOLUME PER ACRE—SUMMARY

		Total Cubic Foot Volume				Board Foot Volume			
		Control	Heavy Res.	Medium Res.	Light Res.	Control	Heavy Res.	Medium Res.	Light Res.
Before Cutting	wS.	3,090	3,377	2,410	2,069	11,914	13,285	8,965	7,866
	Hwd.	1,990	2,026	2,301	2,363	7,017	7,351	7,738	8,228
	All Spp.	5,080	5,403	4,711	4,432	18,931	20,636	16,703	16,094
Removed by Cutting	wS.	—	1,311	990	1,328	—	5,418	3,972	4,715
	Hwd.	—	119	138	42	—	418	476	16
	All Spp.	—	1,430	1,128	1,370	—	5,836	4,448	4,731
After Cutting	wS.	3,090	2,066	1,420	741	11,914	7,867	4,993	3,151
	Hwd.	1,990	1,907	2,163	2,321	7,017	6,933	7,262	8,212
	All Supp.	5,080	3,973	3,583	3,062	18,931	14,800	12,255	11,363

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Scientific and Technical Articles/ Articles scientifiques et techniques

Logging Practices and Subsequent Development of Aspen Stands in East-Central Saskatchewan

by

I.E. Bella[1]

Abstract

A study was started in 1965 to quantify the effect of logging variables on initial sucker stand density and subsequent development of aspen (*Populus tremuloides* Michx.). The study found excellent stocking and density of sucker regeneration after both summer and winter logging of 70- to 80-year-old stands in east-central Saskatchewan. Logging slash on the ground reduced suckering but the density of regeneration even with heavy slash cover was similar to that found in fire-origin stands. Winter logging resulted in more uniform and less dense sucker regeneration. Large initial differences in stand density diminished to a 30% range or less by 5 years of age. This suggests that flexibility may be exercised in harvest scheduling and method of logging.

Résumé

On a entrepris en 1965 une étude visant à quantifier les effets des variables d'exploitation forestière sur la densité initiale des peuplements en drageonnement et le développement ultérieur de peuplier paux-tremble (*Populus tremuloides* Michx.). On a constaté un excellent matériel relatif de régénération après les coupes d'été et d'hiver pratiquées dans des peuplements de 70 à 80 ans. La présence des rémanents sur le sol a réduit le drageonnement mais la densité du matériel régénéré était semblable à celle des peuplements créés par suite d'incendies, malgré la forte couverture de rémanents. Les coupes d'hiver ont donné lieu à une régénération plus uniforme par drageonnement moins dense. Les fortes différences initiales de densité de peuplement ont été ramenées à 30% ou moins avant que le matériel atteigne 5 ans. Cela porte à croire qu'on pourrait assouplir le calendrier et les méthodes d'exploitation.

Introduction

Over 40% of Canada's immense aspen (*Populus tremuloides* Michx.) resource (nearly 2 billion m^3) is in the Prairie Provinces. Although only little of the annual allowable cut (AAC) of aspen is now harvested, utilization is rising and with it the need for information about silvicultural management of this species.

Adequate regeneration after logging is fundamental to responsible forest management. Regeneration is easily attained for aspen because it reproduces readily from root suckers after the parent stand is logged or killed by fire (Farmer 1962; Schier and Smith 1979; Steneker 1974). The abundance of suckers depends mainly on logging practices such as the number of trees left standing, the amount of logging slash, equipment used, and the season of harvesting.

This study was started in 1965 to quantify the effect of these logging variables on initial sucker stand density and subsequent development. Bella and DeFranceschi (1972) summarized results of the study up to 6 years after logging. This current paper describes growth and stand development trends to 17 years after logging.

Study Area and Method

The study was conducted about 35 km south of Hudson Bay, Saskatchewan, in the Mixedwood Section (B.18a) of the Boreal Forest Region (Rowe 1972). Topography is flat to gently rolling, the soils are clay loam, and the site is moist. The original aspen stands at the time of logging were 70-80 years old and also contained a few balsam poplar (*Populus balsamifera* L.) and black spruce (*Picea mariana* (Mill.) B.S.P.). Shrub cover was relatively sparse.

The clear-cut, which left only the odd balsam poplar and black spruce, was done in two seasons: winter (March) 1966 and mid-summer (July) 1967 with chain saws and wheeled skidders. Within the two cut blocks, each over 10 ha in size, a rectangular area of 1.5 ha was sampled near the centre of cut so that shading by the adjacent stand was not a factor.

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Along line transects 20 m apart, sample quadrats 2m² in size (1.0 X 2.0 m) were established every 40 m in August 1966 in the winter cut (400 quadrats) and in September 1967 in the summer cut (526 quadrats). Slash conditions on each quadrat were recorded at establishment as: (1) limbs only, (2) logs only, (3) limbs and logs, and (4) no slash. Logs were unmerchantable material only and even the heaviest slash condition (class 3) resulted in only partial shading of the ground. On reexamination in the autumns of 1967, 1969, and 1971 and in May 1983, data recorded included number of suckers and height of the tallest tree per species.

Results and Discussion

Initial sucker density after the first growing season was about twice as high after a summer cut (even exceeding 200 000 per ha) as after a winter cut (Fig. 1 and 2). The greatest number of suckers occurred with no slash cover and the numbers generally declined as the amount of slash increased. The greatest difference in number of suckers between summer and winter cuts occurred where no slash was present. Average sucker density differed more both relatively and absolutely with slash condition after summer cutting than after winter cutting. Variation in sucker density was also greater after the summer cut.

Slash shades the ground and thus inhabits soil warming and suckering (Maini and Horton 1966). The presence of foliage on limbs after summer logging probably amplified the shading effect and the differences in sucker densities between slash condition classes (Fig. 1); however, this greater shading effect seemed to be more than offset by the destruction of ground vegetation and disturbance of the humus layer during summer logging, which results in higher soil and root temperatures and promotes root suckering (Maini and Horton 1966; Steneker 1974). In contrast, winter logging causes relatively little disturbance or related soil warming.

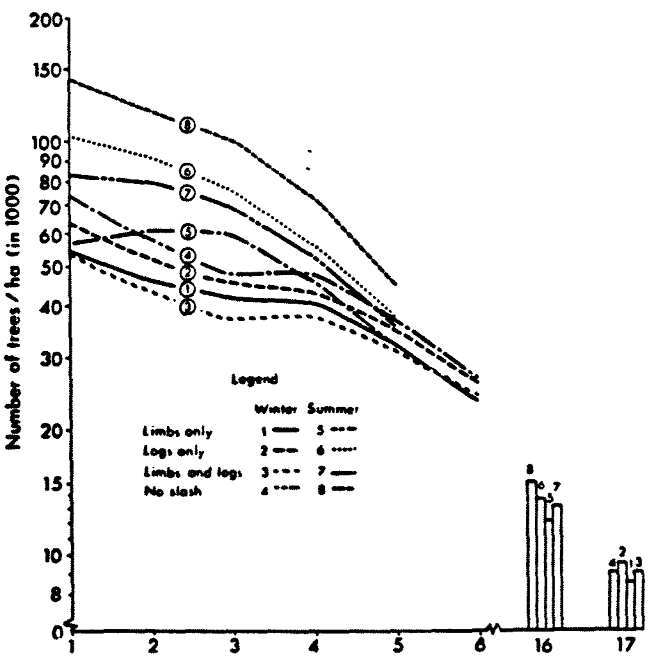

Figure 1. Number of trees per hectare by slash conditions for summer and winter cuts.

The large initial differences in stand density owing to season of cut and slash conditions had diminished to a range of 30% or less five years after cutting (Fig. 1). The same

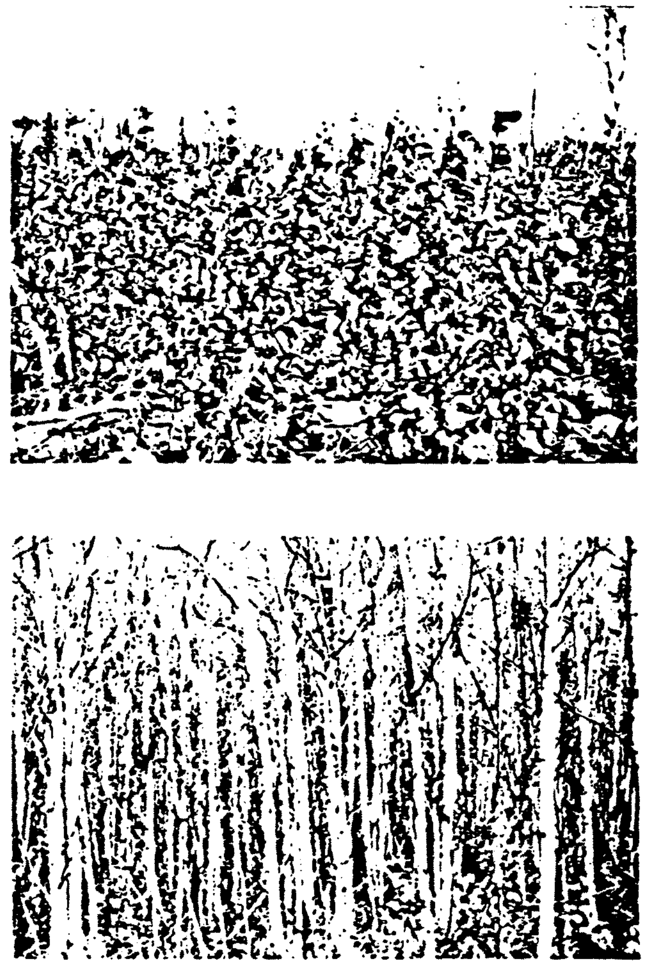

Figure 2. (a) First year growth of suckers after summer logging aspen.
(b) A 17-year-old aspen stand

relative range of densities remained to ages of 16 and 17 years. By this time, stand density differences due to slash conditions virtually disappeared on winter-logged areas. After summer logging, however, slight differences remained between two extreme treatments. The ranking order of treatments also remained the same in terms of sucker density.

Height growth of the largest suckers per quadrat (2 m²) was slightly greater in the first growing season after winter cut than after summer cut. This was probably owing to the difference in the length of the first growing season, which was considerably shorter after summer logging. Another factor that likely had some influence was the nutrient level of the root systems; these were obviously somewhat depleted after summer logging. The difference in height growth of the largest suckers persisted to the last measurement (age 16 for summer and 17 for winter logging; Fig 3). Height growth was consistently best under the slash condition class "Logs Only" regardless of season of logging, and was significantly better ($P < 0.05$) than those under slash condition classes "Limbs and Logs" and "Limbs Only" after summer logging.

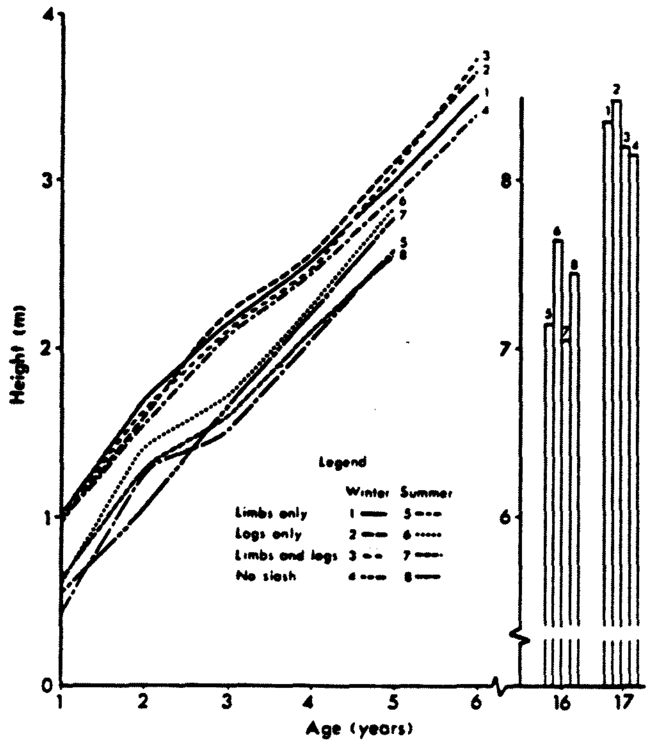

Figure 3. Average height of tallest aspen per quadrat by slash conditions.

To find out whether the densities and thus expected yield of these stands are similar to those of fire origin, values for height and number of trees per hectare were extrapolated to age 20 and compared with appropriate yield tables for aspen in Saskatchewan (Kirby *et al.* 1957). On the basis of height, these stands would fall in the "Good Site" quality class for which these yield tables show 5500 trees/ha, a value well below even the most conservative extrapolated values for the study stands. This suggests more than adequate sucker regeneration under any of the logging and slash conditions studied.

In conclusion, excellent stocking (nearly 100% based on 2-m² quadrats one year after logging) and more than adequate density of sucker regeneration after both summer and winter logging indicate that flexibility can be exercised in harvest scheduling in aspen stands. Although logging slash will reduce suckering, the density of regeneration will be more than adequate even with heavy slash cover. This means that full tree logging is not a prerequisite for adequate aspen regeneration because the slash left following conventional logging had no major effect on aspen stocking and stand density after the initial 5-year period. Winter logging results in more uniform and less dense regeneration and thus may be favored over summer logging. Other considerations, however, such as access, possible soil compaction, and the presence of shrub cover, may be important in scheduling harvest. For example, summer logging may be advantageous in stands with heavy shrub cover that would be destroyed by logging and thus reduce competition for the aspen suckers. On wetter sites with clay soils, winter logging facilitates harvesting and prevents soil compaction that can result in unstocked patches or reduced growth of suckers.

Acknowledgements

This study was established by R.M. Waldron, then with the Forest Research Branch, Canada Department of Forestry, Winnipeg, Manitoba. The staff of MacMillan Bloedel Ltd. at Hudson Bay, Saskatchewan has contributed in all phases of the fieldwork, and Robert Brooks provided the two photos for this paper.

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Forest Research Branch

A TEST OF HARVEST CUTTING METHODS IN ALBERTA'S SPRUCE-ASPEN FOREST

by

J. C. LEES

Sommaire en français

DEPARTMENT OF FORESTRY PUBLICATION NO. 1042

1964

Abstract

Eight harvest cutting methods, ranging from clear-cut to individual tree selection plus an uncut control were applied in 1950 and 1951 to a 150-acre experimental block of white spruce-trembling aspen stands in the B-18a Mixedwood Section of Alberta. Limited trials of hand scarification were carried out in each cutting area.

This report deals with the regeneration and stand growth results following a 10-year remeasurement in 1961. The selection cutting method, in effect a two-cut shelterwood system, resulted in highest stand growth rate, low mortality and best regeneration status.

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CONTENTS

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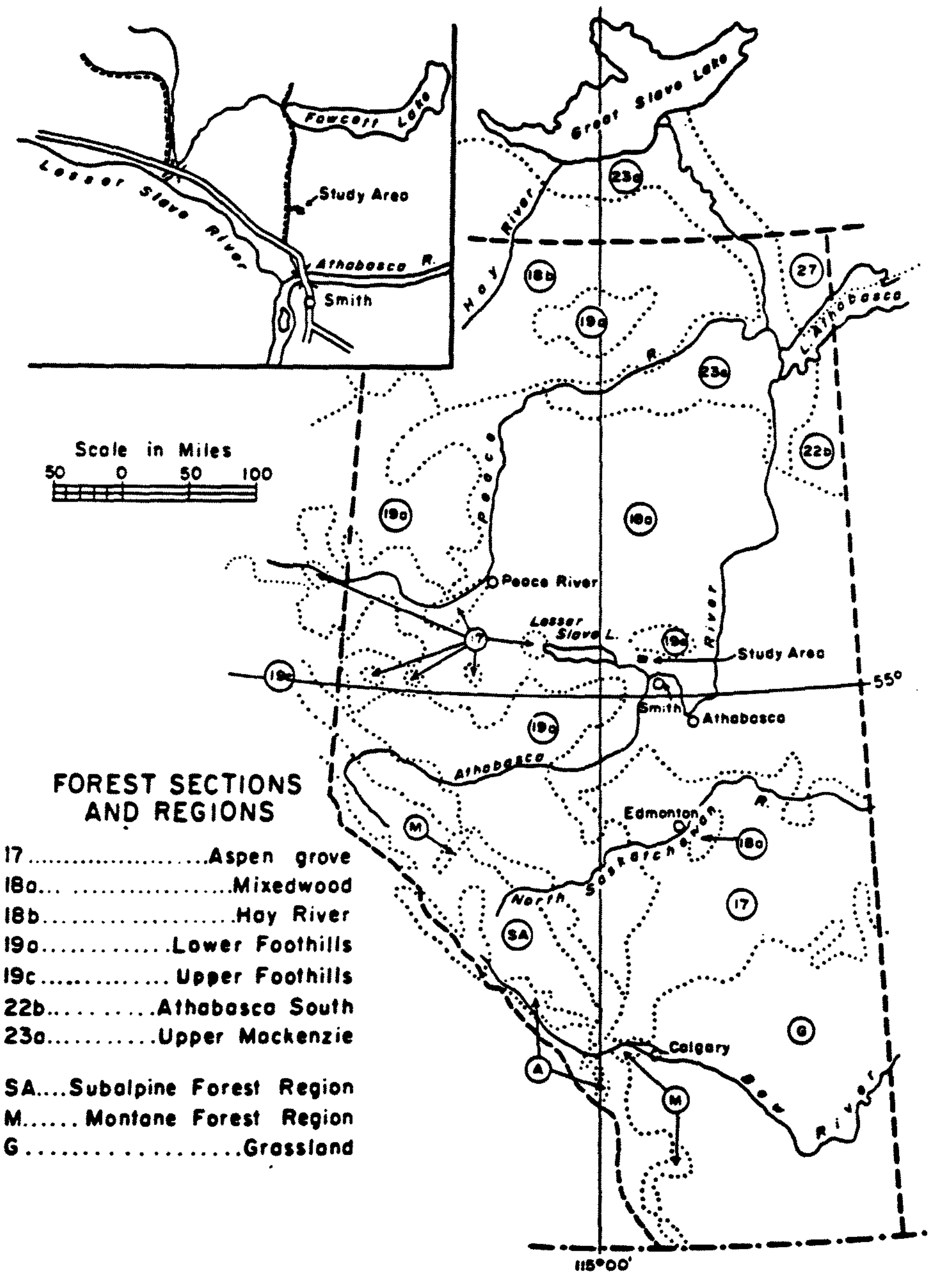
STUDY AREA LOCATION



Frontispiece. Study area location

A TEST OF HARVEST CUTTING METHODS IN ALBERTA'S SPRUCE-ASPEN FOREST[1]

by

J. C. Lees[2]

INTRODUCTION

Diameter limit cutting of white spruce to 14 inches diameter at breast height in the B-18a Mixedwood Section of Alberta has left patchy stands with groups of the unmerchantable hardwoods and undersize white spruce. Regeneration of spruce under these residual stand conditions is unsatisfactory.

Management practice in the region tended towards the introduction of partial cutting, and in 1950, a research project was initiated by J. Quaite[3] to develop suitable harvest cutting methods designed to promote maximum yield and satisfactory regeneration in spruce-aspen stands, and preferably based on individual tree marking.

It was decided to investigate eight harvest cutting treatments including clear-cutting and single tree selection to cover as wide a range of conditions as possible. On this basis the project was established in co-operation with the Alberta Department of Lands and Forests, and Swanson Lumber Company, Edmonton. The Forest Research Branch was responsible for experimental design, tree marking, supervision of cutting and assessment of results. A 150-acre Special Timber Permit area was approved and cutting was completed in the fall of 1951.

Experimental Area

The study area lies in the B-18a Mixedwood Section of the Boreal Forest Region (Rowe 1959) and is a few miles south of Fawcett Lake on the Smith-Fawcett Lake West End road (Frontispiece). Altitude is 2,100 feet with drainage to the north and west. The terrain is gently rolling with a series of distinct ridges. Nowhere does the slope exceed 5 per cent. The soils are grey wooded with a characteristic leached A_e horizon and a dark brown grey crumbly B_t horizon over a calcareous parent material. Textures range from sands and silts to heavy clays in depressions. A layer of humus varying from 2 to 3 inches on ridges to more than one foot in wet bottomland overlies the soil profile. For much of the year the water table is above mineral soil in depressions.

The forest is white spruce (*Picea glauca* (Moench), Voss) and aspen (*Populus tremuloides* Michx.), of fire origin. On the wetter sites black poplar (*Populus balsamifera* L.) replaces the aspen. Occasional white birch (*Betula papyrifera* Marsh.), black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.) and larch (*Larix laricina* (DuRoi) K. Koch) are found throughout the stands. Very moist to wet sites tend to support pure spruce stands. A forest profile[4] is shown in Figure 1. The soils on the well drained tills resemble the Braeburn soils, the depressional podzols resemble the Snipe soils and the ponded stratified material resembles the Kathleen series as described by Odynsky, Wynnyk and Newton (1956). The spruce on the study area averages 105 years

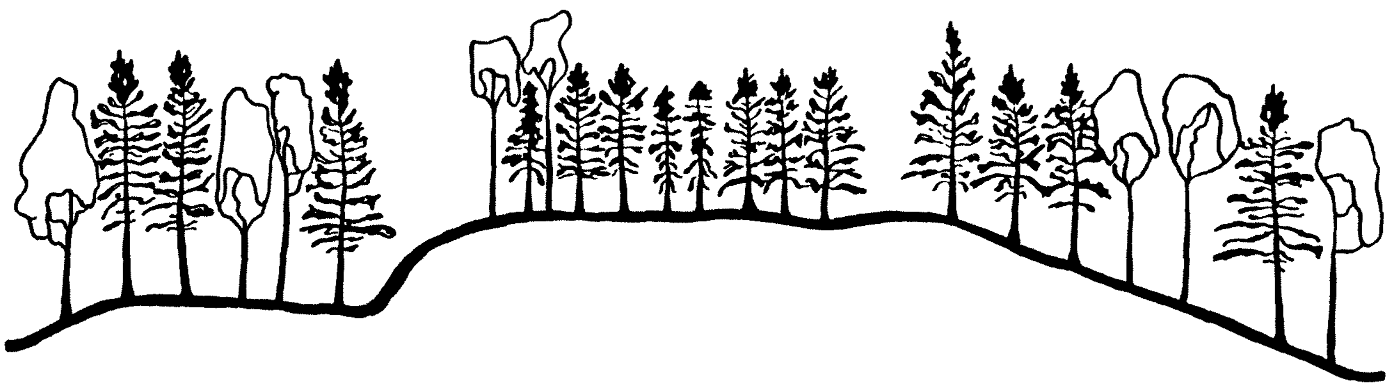
[1]Department of Forestry, Canada, Forest Research Branch, Contribution No. 569.
[2]Research Officer Department of Forestry, Calgary, Alberta.
[3]Formerly, Research Officer Department of Forestry, Calgary, Alberta.
[4]Information for physiographic sites follows Duffy (1959) "An evaluation of forest site in the Mixedwood Section of Alberta" Forest Research Branch. Unpub. Ms.

FOREST PROFILE

(Not to Scale)

PONDED MATERIAL | GLACIAL TILLS

"KATHLEEN" SOIL	"SNIPE" SOIL	"BRAEBURN" SOIL
Moisture Regime 2-6	**Moisture Regime 4-6**	**Moisture Regime 2-3**
White spruce – aspen White spruce 84-90 feet at 80 years.	White spruce - black spruce White spruce 80 feet at 80 years	White spruce – aspen - balsam poplar White spruce 90 feet at 80 years



Devil's club – fern – grass 2 ins. fibrous matted humus over 10-12 ins. raw organic matter Stratified stone-free sands silts and clays	Shrub – horsetail – moss 3-12 ins. humus and black raw organic matter poorly drained clay looms and clays	Shrub - herb - grass - moss 2-4 ins. humus fresh clay looms and loam

Figure 1. Forest profile

and is vigorous and sound. Diameter at breast height currently ranges from 6 to 20 inches and dominant height from 80 to 100 feet. The aspen is slightly older and is rather decadent. Before cutting, stand volumes were 25,000 f.b.m. per acre comprising approximately 18,000 f.b.m. of spruce and 7,000 f.b.m. of hardwood. An understorey of aspen suckers of 1 to 2 inches diameter breast height developed after cutting.

Ground cover[5] beneath the patches of residual spruce consists mainly of feather mosses, *Hylocomium*, *Pleurozium*, and *Hypnum* spp., and scattered herbs such as bunchberry, *Cornus canadensis* L., twin-flower, *Linnaea borealis* var. *americana*, (Forbes.) Rehd., and stinging nettle, *Urtica gracilis* Ait. Where aspen is the chief stand component, ground vegetation is abundant and includes tall shrubs such as rose, *Rosa acicularis* Lindl., high-bush cranberry, *Viburnum trilobum* Marsh, currant, *Ribes lacustre* (Pers.) Poir., and sarsaparilla, *Aralia nudicaulis* L. Blue-joint grass, *Calamagrostis canadensis* (Michx.) Beauv., dominates the moist sites.

METHODS

Felling Treatments

All spruce to be cut was marked. The eight felling treatments were:

A. Control—no disturbance.

B. Heavy residual—leaving 8,500 f.b.m. spruce per acre. Marking removed 47 per cent of spruce by volume.

C. Medium residual—leaving 5,500 f.b.m. spruce per acre. Marking removed 69 per cent of spruce by volume.

D. Light residual—leaving 4,500 f.b.m. spruce per acre. Marking removed 63 per cent of spruce by volume.

E. Selection—leaving only spruce which showed good growth potentialities—The treatment resulted in 67 per cent removal by volume. It was, in effect, a shelterwood cut based on individual tree marking.

F. Diameter limit—removing all spruce 14 inches in diameter and over at a 12-inch stump height. This treatment resulted in 61 per cent removal of spruce by volume.

G. Seed tree—Six seed trees per acre were selected and left. All other spruce over 6 inches in diameter at breast height were removed—96 per cent of spruce by volume was removed.

H. Clearcut—removing all spruce over 6 inches diameter at breast height. Since there was a diameter limit, the treatment resulted in 96 per cent removal by volume.

A summary of the board foot volumes removed by cutting[6] is presented in Table 1.

The aspen was unmerchantable because of local market conditions and a high incidence of decay in hardwoods and was left standing. Logging was carried out in the summer and fall of 1951 using crawler tractors hauling short log lengths. Road location was carried out by the research officer-in-charge.

Treatment Layout

Within the 150-acre study area, twenty-four 4/10-acre patches were selected and the eight felling treatments were randomly assigned giving three replications. A surround, approximately 1½ chains wide, was treated in the same manner as

[5]Nomenclature for shrubs, herbs, and grasses follows Moss (1959), "Flora of Alberta". Univ. of Toronto Press.
Nomenclature for mosses follows Conrad (1944). "How to know the mosses" Brown Co. Iowa.
[6]Board feet, Scribner's rule, trees 7 inches d.b.h. and over.

TABLE 1. SUMMARY OF BOARD FOOT VOLUMES PER ACRE.

Treatment	Volume Before Cutting	Cut Volume	Volume After Cutting		Volume 1961	
	White spruce	White spruce	White spruce	Hardwoods	White spruce	Hardwoods
Control	16,410	—	16,410	5,710	19,860	6,320
Heavy Residual	14,540	6,860	7,680	4,020	10,880	4,980
Medium Residual	15,040	10,340	5,500	4,200	6,320	4,690
Light Residual	10,780	6,770	4,010	6,240	5,220	5,890
Selection	11,740	7,910	3,830	6,240	5,040	6,390
Diameter Limit	10,150	6,220	3,930	5,150	6,420	6,140
Seed Tree	12,610	12,050	580	3,710	840	3,400
Clear Cut	9,430	9,060	370	3,490	460	3,820

the patch. On those portions of the area outside the plots and surrounds, a diameter limit of 14 inches at 12-inch stump height was imposed. Each 4/10-acre patch was sub-divided into four 1-chain-square sample plots for measurement. The layout of the cutting areas and sample plots is shown in Figure 2.

Seedbed Treatment

Since spruce advance growth[7] was not adequate before logging, a limited test of hand scarification to expose a mineral soil seedbed for regeneration was included in the treatment. It was intended also to study differences in seedling survival on scarified seedbeds under the various residual stands.

Eight scarification plots approximately 5 by 5 feet, together with one control, were placed just outside the boundary of each 4/10-acre patch. The distribution of the scarified spots about the plots 53 to 56 is shown in Figure 2. Scarification consisted of removing the humus with a shovel or hoe to expose mineral soil.

Assessment

Regeneration

Regeneration was tallied in 1952 and 1954 and the results published, (Quaite, 1956). In 1960 the regeneration on the hand scarified and control plots was remeasured and in 1961 a one-chain grid of 16 milliacre quadrats was used to determine the regeneration status on the whole of each treatment area. Quality, vigour, and height of the tallest seedling of each species were assessed on each quadrat.

Stand growth and development

All stems on the 96 plots were tallied in 1951 and 1952 before and after logging. Approximately six dominant and co-dominant trees per plot were selected and tagged for height/diameter studies at that time. Standing and down-dead trees were axe-blazed and tallied in 1952, 1953 and 1954 to establish periodic mortality. In 1961, ten years following logging, a diameter tally of all trees was made; height, diameter and diameter increment at breast height for the ten years before and after logging, were remeasured on the tagged trees. Mortality and windfall were tallied on all plots.

[7]Advance growth—seedlings established before cutting.
Regeneration—seedlings established after cutting.

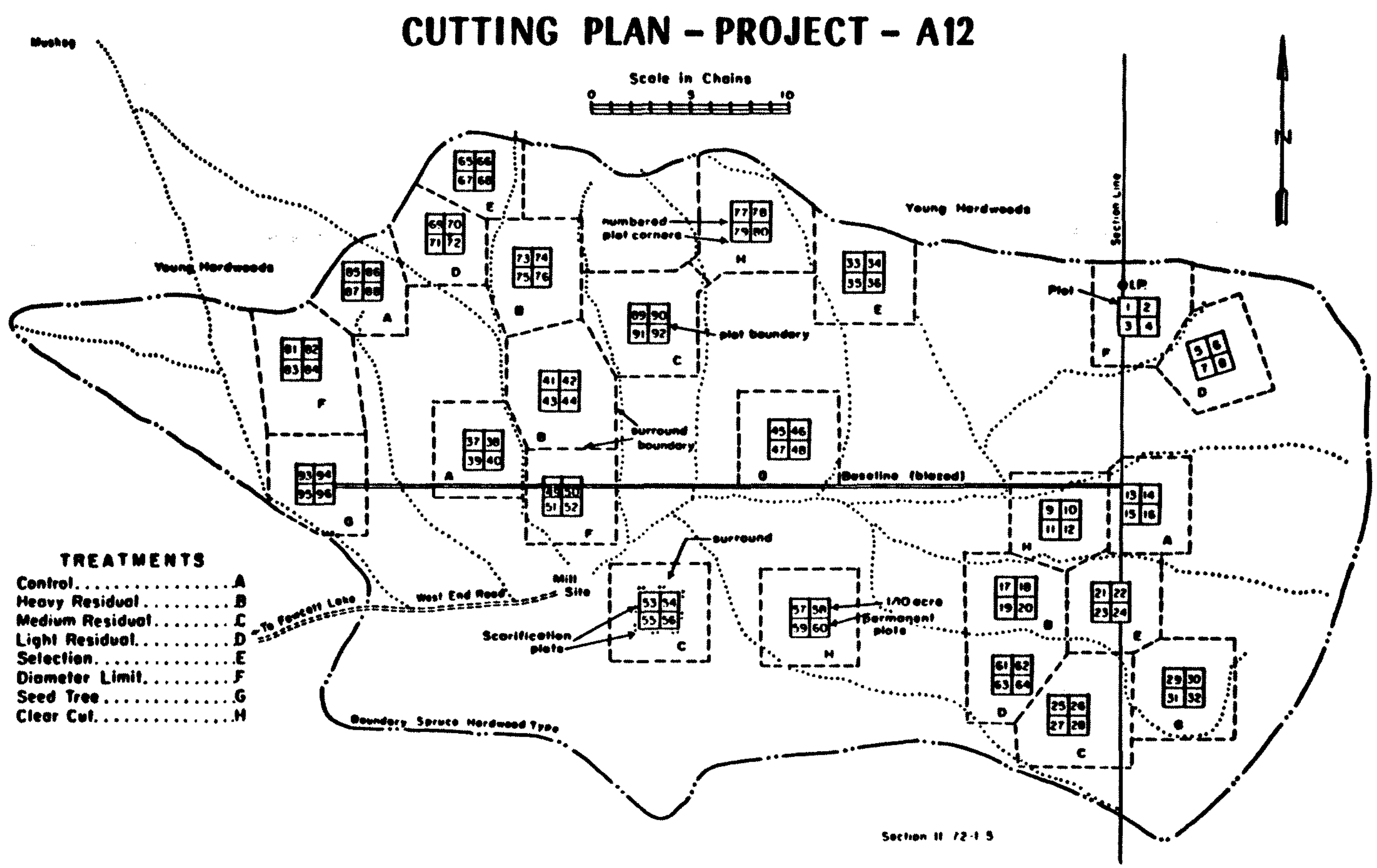


Figure 2. Cutting plan project—A12

RESULTS

Regeneration

The stocking to white spruce regeneration in 1960 for the hand-scarified and control plots is given in Table 2. Analysis of variance (Table 3) shows that there was no significant difference between cutting treatments; only the effect of seedbed treatment was significant. Seedling establishment was consistently better on scarified spots than on controls. High values for per cent stocking in both 1954 and 1960 arise from the fact that scarified spots were completely exposed to mineral soil. The figures are, however, not representative of the stocking which might result from extensive scarification of a large area where the mineral soil exposure is intermittent and amounts to 20 to 30 per cent. Spruce seedlings on the area originated mainly from a 1951 seed crop. There was further seeding-in following a light seed crop in 1955 (Lees, 1963). Good survival may be attributed to wet summers in 1952, 1953 and 1954 (Quaite, 1956).

Scarified spots which were not stocked to spruce generally showed signs of flooding. Twenty per cent of scarified spots were so affected. To a great extent this is because the method of scarifying left distinct five-foot-square basins of various depths up to one foot. Some flooding might be attributed to a rise in the water table after heavy cutting, but flooding occurs on wet sites under all treatments.

TABLE 2. WHITE SPRUCE REGENERATION STOCKING ON HAND-SCARIFIED AND UNSCARIFIED ¼ MILLIACRE QUADRATS, 1954 and 1960.

(Basis—24 permanent ¼ milliacre quadrats per treatment.)

Treatment	Scarified		Unscarified	
	1954 per cent	1960 per cent	1954 per cent	1960 per cent
Control	88	61	—	5
Heavy Residual	67	50	17	13
Medium Residual	66	52	25	23
Light Residual	75	70	13	6
Selection	75	54	17	30
Diameter Limit	83	82	17	12
Seed Tree	79	71	17	7
Clear cut	75	59	—	—

TABLE 3. ANALYSIS OF VARIANCE FOR PERCENTAGE* OF QUADRATS STOCKED WITH WHITE SPRUCE SEEDLINGS, 1960.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Main Plots				
Blocks	2	1,883.4	941.7	7.23 **
Cutting Method	7	1,570.5	224.3	1.72 N.S.
Error	14	1,824.0	130.3	
Subplots				
Seedbed (T)	1	18,443.6	18,443.6	127.7 **
T X Cutting Method	7	2,165.8	309.4	2.14 N.S.
Subplot Error	16	2,309.6	144.4	
Total	47	28,196.9		

*Percentages were transformed into angles

Table 4 gives the per cent stocking of tree species for each treatment as assessed in the 1961 survey. The survey did not include any of the small scarified spots. Although regeneration stocking is everywhere below a satisfactory level, it is interesting to note the levels with undisturbed ground conditions. Stocking to spruce under the selection cutting treatment is highest at 30 per cent by milliacre quadrats. Figures for the other treatments range from 10 to 23 per cent. It was observed that seedlings occurred mainly on rotten wood, old logging trails and areas disturbed by logging, as is the case throughout this region.

TABLE 4. REGENERATION STATUS BY FELLING TREATMENT, 1961 SURVEY.

(Basis—48 temporary milliacre quadrats per treatment.)

Treatment	White Spruce		Trembling aspen		Balsam poplar		White birch	
	Stocking per cent	No. per acre	Stocking per cent	No. per acre	Stocking per cent	No. per acre	Stocking per cent	No. per acre
Control	12	300	22	550	12	300	—	—
Heavy Residual	10	260	35	990	16	410	6	350
Medium Residual	17	420	38	1,190	19	590	8	410
Light Residual	21	720	35	890	6	160	6	160
Selection	30	930	38	1,190	25	750	21	850
Diameter Limit	19	1,040	63	1,560	21	650	15	810
Seed Tree	23	570	40	990	13	310	23	700
Clearcut	15	490	46	1,650	21	520	29	1,100

A summary of the vigour and quality of the tallest seedlings on each quadrat is given in Table 5. The spruce seedlings are well established and fall mainly within classes I and II in both vigour and quality under all treatments. Height growth is best on the selection treatment areas. The tallest spruce on the stocked quadrats average 8 inches. Aspen and black poplar reach their best development under diameter limit cutting while white birch is most vigorous on the seed-tree and clear-cut areas and is almost absent on control areas. Average height of tallest hardwood regeneration ranges from 6.5 to 8.5 feet throughout the area.

Residual Stand Growth and Development

Table 6 shows the volume growth, mortality, and recruitment to the merchantable 7-inch diameter class in the residual stands for each treatment. Per cent volume growth and net volume increment were best under the selection cutting treatment. Gross increment was slightly higher in the heavy residual stands, 575 cubic feet per acre, than under selection treatment, 558 cubic feet per acre, but stand volume in 1951 after cutting was 3,200 cubic feet per acre in heavy residual stands and only 1,484 cubic feet per acre under selection treatment. Thus total volume production under the selection treatment was considerably higher. The light residual stands had lowest gross increment with 276 cubic feet per acre although number of stems and stand volume in 1951 were almost identical to that of the selection stands. This is the result of the marking under these treatments producing different diameter distributions, as strict diameter limit cutting removed those large residual stems which are preserved in the selection treatment. The selection treatment too, showed the greatest recruitment to the merchantable size classes.

Diameter increment values in Table 7 show that there has been only a slight increase in growth rate during the past ten years compared to the ten-year period before cutting. Individual stem increment was highest on the clear-cut and seed-tree areas and lowest on control and heavy residual areas.

TABLE 5. SUMMARY OF VIGOUR* AND QUALITY OF TALLEST SEEDLINGS BY TREATMENT 1961 SURVEY**

(Total Number of Seedlings)

Treatment	White spruce							Trembling aspen							Balsam poplar						White birch					
	Average height	Vigour			Quality			Average height	Vigour			Quality			Vigour			Quality			Vigour			Quality		
	inches	I	II	III	I	II	III	feet	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Control	3.0	1	4	1	3	3	—	8	2	5	4	2	3	6	1	4	1	2	3	1	—	—	—	—	—	—
Heavy Residual	1.8	3	2	—	4	1	—	7	4	11	2	1	11	5	1	3	4	1	4	3	2	1	—	2	1	—
Medium Residual	5.5	3	5	—	6	2	—	7	9	9	—	7	9	2	3	5	1	5	3	1	3	1	—	2	2	—
Light Residual	6.2	4	6	—	7	3	—	7	8	4	5	3	11	3	1	2	—	2	1	—	3	—	—	1	2	—
Selection	8.2	7	6	1	8	4	2	7	9	7	2	4	9	5	2	7	3	1	6	5	7	2	1	3	4	3
Diameter Limit	4.5	3	6	—	7	2	—	7	8	15	7	5	17	8	4	2	4	3	5	2	5	2	—	4	3	—
Seed Tree	2.2	6	5	—	9	2	—	7	10	6	3	10	6	3	3	2	1	4	1	1	9	2	—	5	6	—
Clearcut	5.5	4	3	—	5	1	1	8	11	9	2	5	13	4	3	7	—	6	3	1	11	3	—	11	2	1

*Vigour: I Dense foliage, good colour—dominant crown
II Foliage not very dense—crown slightly overtopped
III Scanty foliage, poor colour— crown completely overtopped

**Quality: I Good form, well formed crown—straight stem
II Fair form, poorly formed crown—crooked stem
III Poor form, no definite main stem, course branching

TABLE 6. ESTIMATE OF STAND VOLUME INCREMENT AND MORTALITY PER ACRE BY FELLING TREATMENT

(Total Volume in Cubic Feet)

Treatment	Species	Volume Removed By Cutting	Volume After Cutting 1951	Basal area 1961 sq. feet	Volume 1961	Number of stems 1961	Net Volume Increment 1951-61	Volume of Mortality 1951-61	Gross Volume Increment 1951-61	Net Volume Increment ac/year	Recruitment to 7" d.b.h.		Per Cent Volume Increment
											No. of Stems	Cubic Feet	
Control	wS	—	4,883	163	5,650	455	707	144	911	77	28	202	1.7
	Hwd.		1,424	49	1,432	68	8	26	34				
	Total		6,307	212	7,082	523	775	170	945				
Heavy Residual	wS	1,619	3,201	108	3,513	327	312	262	574	31	20	146	1.6
	Hwd.		1,020	41	1,184	99	164	15	179				
	Total		4,221	149	4,697	426	476	277	753				
Medium Residual	wS	2,432	1,849	67	1,908	176	59	247	306	6	13	81	1.5
	Hwd.		1,142	37	1,107	63	−35	121	86				
	Total		2,991	104	3,015	239	24	368	392				
Light Residual	wS	1,759	1,543	65	1,764	247	221	55	276	22	13	82	1.6
	Hwd.		1,700	53	1,508	110	−192	311	119				
	Total		3,243	118	3,272	357	29	366	395				
Selection	wS	1,843	1,484	66	1,963	207	479	79	558	48	27	168	3.1
	Hwd.		1,661	56	1,636	130	−25	428	403				
	Total		3,145	122	3,599	337	454	507	961				
Diameter Limit	wS	1,565	1,658	70	1,841	328	183	304	487	18	18	113	2.6
	Hwd.		1,618	62	1,776	586	158	246	404				
	Total		3,276	132	3,617	914	341	550	891				
Seed Tree	wS	3,373	453	19	439	93	−14	130	116	—	15	89	2.3
	Hwd.		1,018	35	885	796	−133	371	238				
	Total		1,471	54	1,324	889	−147	501	354				
Clear Cut	wS	2,751	368	13	283	67	−85	108	23	—	8	49	0.6
	Hwd.		967	34	997	210	30	105	135				
	Total		1,335	47	1,280	277	−55	213	158				

TABLE 7. WHITE SPRUCE DIAMETER INCREMENT 1941 TO 1951 AND 1951 TO 1961

Treatment	Average Diameter inches 1961	Diameter Increment Per Cent*	
		1941-51	1951-61
Control	9.9	0.62	0.62
Heavy Residual	9.2	0.82	0.93
Medium Residual	10.1	0.92	1.12
Light Residual	9.0	0.99	1.21
Selection	9.4	1.06	1.13
Diameter Limit	8.3	1.24	1.34
Seed Tree	7.0	1.04	1.77
Clear-cut	5.9	1.24	2.78

*Pressler's formula

$$p = \frac{200}{n} \cdot \frac{(D-d)}{(D+d)}$$

where p = increment per cent
D = present diameter
d = diameter "n" years ago
n = number of years in one period

Mortality

Mortality and windfall were noticeably light throughout the study area. Mortality figures are presented in Table 8 for the periods 1951 to 1956 and 1956 to 1961. Higher mortality of spruce in the earlier period may be attributed to logging damage and the shock of release. Many small stems succumbed in the first five years. Control area figures show a trend of increasing mortality.

TABLE 8. PERIODIC MORTALITY BY TREATMENT

Treatment	Species	Mortality per Acre			
		1951-1956		1956-1961	
		Number of Stems	Total Volume Cubic Feet	Number of Stems	Total Volume Cubic Feet
Control	wS	13	56	21	89
	Hwd.	4	14	1	11
	Total	17	70	22	100
Heavy Residual	wS	35	158	13	104
	Hwd.	1	15	—	—
	Total	36	173	13	104
Medium Residual	wS	21	140	14	107
	Hwd.	7	38	6	82
	Total	28	178	20	179
Light Residual	wS	16	33	4	22
	Hwd.	13	130	12	182
	Total	29	163	16	204
Selection	wS	13	67	3	12
	Hwd.	7	101	11	326
	Total	20	168	14	338
Diameter Limit	wS	41	245	8	60
	Hwd.	14	116	15	130
	Total	55	361	23	190
Seed Tree	wS	24	87	4	42
	Hwd.	19	223	15	149
	Total	43	310	19	191
Clearcut	wS	23	83	6	25
	Hwd.	3	6	10	99
	Total	26	89	16	124

Height/diameter relationships were affected by top break and whipping damage. Height decrement was common under all treatments. As a result, height/diameter curves for 1961 were often lower than for previous measurement. Top break may be attributed to snow and ice damage. Occasional unseasonal heavy snowfalls have been reported in the area in May and June. May, 1962, is a recent example where top damage in spruce was widespread. Many spruce stems in those patches to the west of the area also appeared to have been affected by insect attack about seven years ago. This confirms the suspected spread of infestation by spruce bark beetles (*Ips perturbatus*) from sawmill waste to living stems in 1952, reported by Quaite[8]. The sawmill waste was subsequently burned and no further damage was noted.

DISCUSSION

The most valuable stand treatment is that which produces the largest volume of merchantable timber at the earliest age. Thus a stand producing 7,000 f.b.m. per acre at age 70 may be as valuable as one producing 10,000 f.b.m. per acre at age 110. This is particularly true where there are stand establishment costs which must be compounded to the end of the rotation.

Provided that stem spacing is not limiting, no improvement fellings will alter appreciably the total volume production of the stand in a given rotation. Nevertheless, treatments such as the partial cutting methods used in this experiment, especially when applied at an earlier age while the stand is growing vigorously, should improve the quality of the timber and make a large part of the volume production available at an earlier date. Merchantable volume production may thus be increased.

If the advantages of increased yield of high quality stems can be coupled with adequate regeneration of the commercially important species, then a treatment is worthy of application.

The treatments in this study have met with some measure of success. Lack of uniformity in the stands before and after treatment and site variation precluded clear comparisons, but certain effects should be noted. Strict diameter limit cutting, for example, produced average regeneration stocking compared to other treatments and despite its inherent weakness of poor residual stem distribution, there was good recruitment of small stems to the 7-inch diameter breast height merchantable size class. Little difference in growth and regeneration was recorded between the heavy, medium, and light residual stand densities. The few stems remaining on the seed tree and clear-cut areas, together with marginal stands, supplied sufficient seed to stock the scarified spots. Survival of spruce regeneration on seed tree and clear-cut areas is, however, problematical. Vegetation, especial grasses, is rank, and there is a dense young stand of aspen and poplar suckers c. 1 to 2 inches in diameter and 6 to 15 feet in height. The various partial cutting treatments have only occasional groups of aspen suckers and vegetation is less dense.

The selection treatment is more outstanding and is worthy of further examination. Average diameter of spruce following cutting was 8.6 inches at breast height compared with only 6 inches under diameter limit cutting. Despite this somewhat restrictive marking, the cut produced about 8,000 f.b.m. per acre, as much as the volumes removed from other treatments, and total volume production is among the highest when current stand volume is added to this figure. The high volume increment, 3.16 per cent, shows that the residual stand is growing most vigorously of all treatment plots. This is in part because the marking

[8]Establishment Report: Experimental Cutting of white spruce in a mixedwood stand in Northern Alberta. Canada Department of Northern Affairs and National Resources, Forestry Branch, Forest Research Division.

left a preponderance of vigorous stems (Quaite 1953)* and is not the result of release alone. Recruitment to the 7-inch diameter breast height class is the highest of all cut stands and spruce regeneration stocking is also highest. Spruce seedlings are tallest. Mortality is next to lowest of all stands. In contrast, the uncut control stands are decreasing in growth and would be better removed and replaced.

The selection treatment as applied in this study is not the true selection system of classical silvicultural working. It is in fact a 2-cut uniform shelterwood system, with the introduction of more intensive marking than had previously been envisaged in the region. The first cut involves removal of at least 65 per cent spruce board foot volume and 44 per cent by basal area leaving 62 square feet basal area per acre. Marking ensures that only those stems are left which show good growth potentialities. Scarification to provide a receptive seedbed should follow the first cut. Timing of the removal cutting will depend on residual stand growth and regeneration status. The method embodies the following advantages:

(1) Site protection.
(2) Seed supply from selected vigorous parent trees.
(3) Shelter for establishing seedlings.
(4) It inhibits colonization by intolerant species.
(5) It permits valuable recruitment to merchantable size within the residual stand.
(6) There is accelerated growth on crop trees.
(7) It increases the value of the stand.
(8) Seeding may be induced by increased insolation following the first cut.

Although the other partial fellings provided these advantages to varying degrees, the more intensive marking system leaving a preponderance of vigorous stems provided benefits which justify the extra care necessary. The results corroborate those of another study in the same area where four residual stand densities were examined following partial cutting of marked stems and seedbed scarification (Lees, 1963). The system is being adopted in the region by the Alberta Department of Lands and Forests and the first fellings using tree marking were made in conjunction with this study. Further investigation is now required of removal cutting.

FUTURE WORK

Remeasurement is scheduled for 1971 at which time the residual stems will be removed. Results will be available at that time of total volume production for each treatment.

Because the initial scarification of the various treatment areas was limited to particular spots, regeneration stocking to white spruce nowhere exceeds 30 per cent. Since it is planned to remove the overstorey within the next ten years, treatment to restock the areas to spruce is now due. It is planned to scarify the whole experimental area with a medium size tractor and a toothed blade. The work will coincide with a good seed year. Following scarification, a tally will be made of all trees uprooted or damaged by the equipment.

One hundred per cent enumeration will precede cutting. Following final clear cutting in 1971, regeneration will be assessed for each treatment area.

*Experimental cutting of white spruce in a mixedwood stand in Northern Alberta. Canada Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Research Division. Progress Reports.

SUMMARY

A research project was initiated in 1951 in 95-year-old spruce-aspen stands, in the Mixedwood Section of Alberta's boreal forest, to develop suitable harvest cutting methods designed to promote maximum yield and satisfactory regeneration of spruce. It was planned to develop a tree marking system for partial cutting in the region, but treatment also included clear-cut and seed tree areas. There was an uncut control.

Seedlings were tallied in 1952, 1954 and 1960 on specific scarified spots. In 1961 the regeneration status on the whole 150-acre study area was assessed. Growth was measured in the residual stands in 1961 and windfall and mortality were assessed in 1952, 1953, 1954 and 1961.

It was found that:—

(a) A bare mineral soil seedbed prepared by scarification provided a receptive medium for spruce seedling establishment under all harvest cuttings.

(b) Seedling survival did not vary between treatments.

(c) Overall regeneration establishment including unscarified conditions was unsatisfactory and an extensive scarification of the area is planned before final felling in 1971.

(d) Mortality and windfall in the residual stands was slight, occurring mainly in stems damaged by logging.

(e) Individual tree growth rates improved following cutting with the best in the lightest residual stands.

(f) "Selection" cutting which was in fact a two-cut shelterwood system provided highest stand growth rates, low mortality and the best regeneration.

(g) The spruce responded to release under all partial cutting treatments and provided a valuable recruitment to the seven-inch diameter breast height merchantable size class.

(h) The more intensive marking carried out under the "selection" treatment resulted in improved quality growing stock which will provide high yield at the final felling.

A two-cut uniform shelterwood system with the first cut removing 65 per cent spruce board foot volume is recommended for trial in the region followed by scarification to determine on which sites it is best adapted. Marking will ensure that only those stems are left which have good growth potentialities.

Further research is planned in assessment of regeneration status and total volume production under each treatment. Final removal fellings will be made in 1971 at which time total volume production and regeneration will be assessed for each treatment.

SOMMAIRE

Un projet de recherche a été entrepris en 1951 dans des peuplements d'épinette et de peuplier âgés de 95 ans dans la section des bois mêlés de la forêt boréale de l'Alberta, afin de mettre au point des méthodes de coupe destinées à favoriser le rendement maximum et une reproduction satisfaisante de l'épinette. On a voulu élaborer une méthode de marquage en vue d'effectuer une coupe partielle dans la région, mais le traitement comprenait également des étendues coupées à blanc et des étendues pourvues de porte-graines. On a également établi une place témoin.

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Les semis ont été dénombrés en 1952, 1954 et 1960 à des endroits précis qui avaient été scarifiés. En 1961, on a fait une estimation de la reproduction dans l'ensemble de l'aire d'étude de 150 acres. La croissance a été déterminée dans les peuplements résiduels en 1961, tandis que les chablis et les sujets morts étaient dénombrés en 1952, 1953, 1954 et 1961.

On a constaté les faits suivants:

a) Un terrain de germination à sol minéral dénudé et scarifié constitue un milieu propice à la reproduction des semis d'épinette dans toutes les étendues exploitées.

b) La survivance des semis n'a pas varié d'un traitement à l'autre.

c) La reproduction était en général peu satisfaisante, y compris aux endroits non scarifiés, et on projette de recourir à une scarification poussée de la place avant la dernière coupe en 1971.

d) Les sujets morts et les chablis étaient peu nombreux dans les peuplements résiduels et il s'agissait principalement de tiges endommagées lors de la coupe.

e) Les taux de croissance des arbres se sont améliorés par suite de la coupe et les taux les plus élevés ont été relevés dans les peuplements résiduels les plus clairs.

f) La coupe de jardinage qui, de fait, est une méthode qui comporte deux coupes de l'essence d'abri, a donné les taux de croissance du peuplement les plus élevés, la plus faible mortalité et la meilleure reproduction.

g) L'épinette a réagi à toutes les coupes partielles de dégagement, lesquelles ont permis d'augmenter le nombre de sujets de la classe de bois marchand mesurant sept pouces de diamètre à hauteur de poitrine.

h) Le marquage plus intensif exécuté en vertu du traitement de jardinage a amélioré la qualité du volume sur pied, ce qui donnera un rendement élevé lors de la dernière coupe.

On recommande de mettre à l'essai dans la région une méthode uniforme de deux coupes de l'essence d'abri, dont la première fournirait 65 p. 100 du volume en pieds mesure de planche d'épinette et serait suivie de scarification, afin de déterminer dans quelles places elle convient le mieux. Le marquage permettrait de conserver uniquement les sujets affichant les meilleures tendances de croissance.

D'autres recherches projetées permettront de déterminer l'état de la reproduction et le volume global de la coupe à la suite de chaque traitement. Les dernières coupes seront effectuées en 1971 et à ce moment-là, on pourra déterminer le volume global, le volume de la coupe et celui de la reproduction à la suite de chaque traitement.

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RELEASE OF WHITE SPRUCE FROM ASPEN COMPETITION IN ALBERTA'S SPRUCE-ASPEN FOREST

by
J. C. LEES

Sommaire en français

DEPARTMENT OF FORESTRY PUBLICATION NO. 1163
1966

ABSTRACT

Ten-year remeasurement of white spruce stems released from aspen competition in Alberta's spruce-aspen forest indicated that over a wide diameter and age range, growth of spruce increased significantly after treatment. Trees above a 5-inch breast height diameter limit increased in mean merchantable cubic foot volume by 20-40 per cent. Release of spruce from aspen competition should be carried out before the spruce grows into the aspen overstorey. Poisoning cut aspen stumps with ammonium sulphamate prevents regrowth of aspen suckers and sprouts.

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CONTENTS

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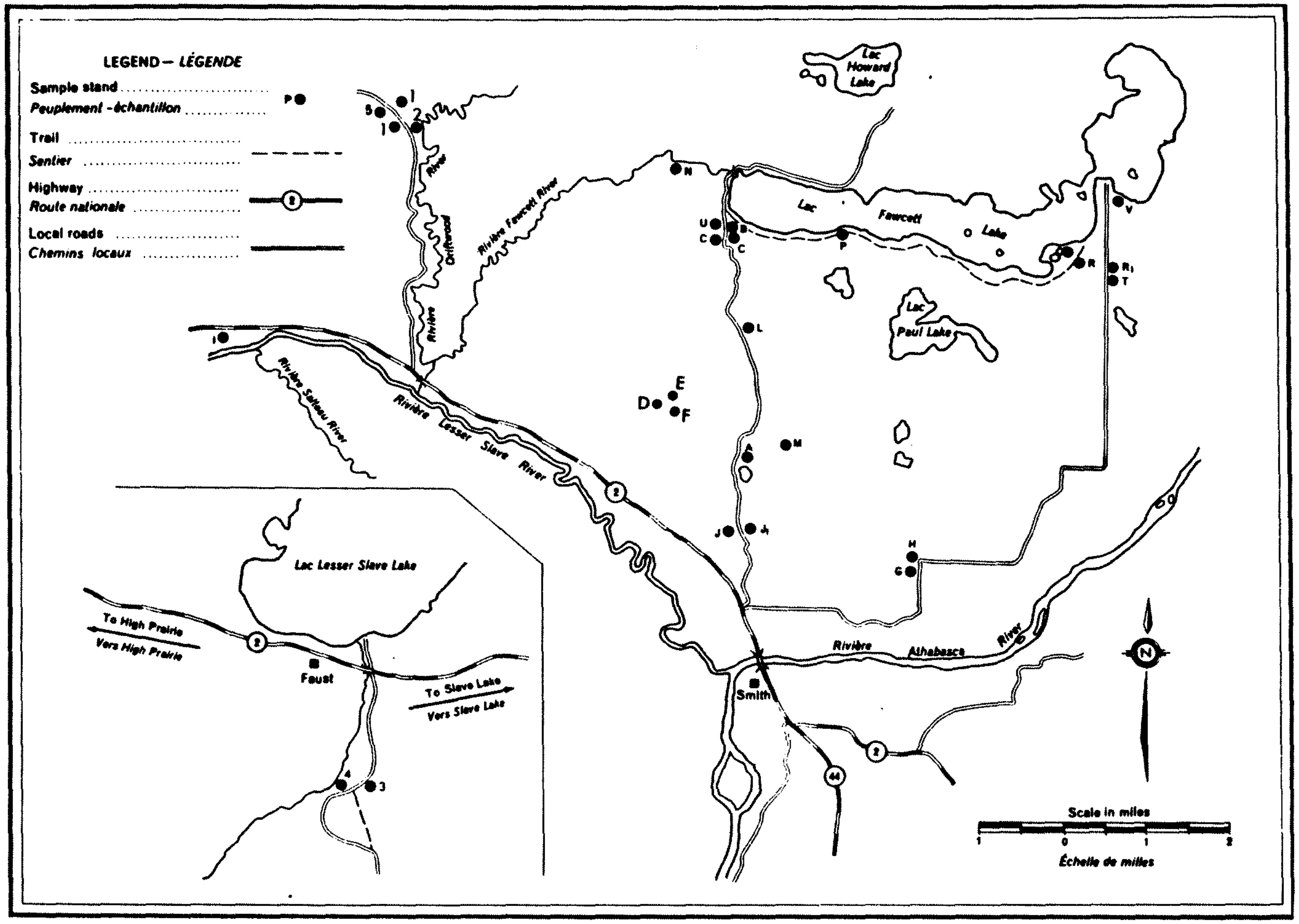

FRONTISPIECE. Sample stand locations
FRONTISPICE. *Localisation des peuplements-échantillons*

Release of White Spruce from Aspen Competition in Alberta's Spruce-Aspen Forest

by

J. C. LEES[1]

INTRODUCTION

Two-storied stands are typical of the spruce-aspen forest in Alberta. The aspen, a vigorous pioneer species, forms the overstorey for most of the natural rotation of the stands. When 55 to 75 years old the spruce grows through the overstorey as the older aspen goes into an increasingly decadent stage. During this stage mechanical damage to spruce crowns is a factor added to competition for crown space and root space. Recent studies from Manitoba (Steneker 1963) illustrate that the spruce at age 50 shows a definite response to release over a wide diameter range and that a valuable increase in merchantable spruce volume results. However, it is not known how early competition for the commercially important spruce begins, or how late the spruce will respond to release from aspen. This report deals with the results of a release study, initiated by J. Quaite[2] in 1951. Selected spruce stems under an aspen canopy were released and control stems were selected. Remeasurement in 1956 was carried out by G. Ontkean[2] (Ontkean and Smithers, 1959). The current remeasurement was carried out by the writer in 1962.

DESCRIPTION OF THE AREA

Location

Spruce-aspen stands of varying age were selected for this study within a 30-mile radius of Smith, Alberta, 55° 10′N. 114° 01′ W., in the B-18a Mixedwood Section of the Boreal Forest Region (Rowe 1959). Sample stand locations are shown in the Frontispiece. The terrain is gently rolling. There are distinct low ridges and wide shallow depressions with grassy sloughs and seasonal water-courses. Physiography derives from extensive glacial deposits, lacustrine deposits from the Lesser Slave Lake basin, and from the recent river action in the Athabasca, Lesser Slave, Salteau and Fawcett river drainages.

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[2] Formerly, Research Officer, Department of Forestry of Canada, Calgary, Alberta.

Forest

The forest is white spruce (*Picea glauca* (Moench), Voss) and aspen (*Populus tremuloides* Michx.), of fire origin. Balsam poplar (*Populus balsamifera* L.) and black spruce (*Picea mariana* (Mill.) BSP) occur with white spruce and aspen on depressions. Occasional white birch (*Betula papyrifera* Marsh.), jack pine (*Pinus banksiana* Lamb.) and larch (*Larix laricina* (Du Roi) K. Koch) are found throughout the stands. In the sample stands selected for this study, aspen was the main stand component and was generally 10 to 20 years older than the understorey.

Soils

Soil textures range from stony sandy loams to heavy clays. Ridges and upper slopes are well drained. A shallow gley horizon prevails in the depressions. A layer of raw humus varying from 2 to 3 inches on upland soils to more than one foot on wet bottomland overlies the soil profile. The soils on well-drained glacial tills resemble Braeburn soils and have a well-defined leached A_e layer and a dark brown clayey B_t horizon over a calcareous parent material; depressional podzolic soils with heavy clay B_t horizon, and gleying often close to the surface, resemble the Snipe soils; and the ponded stratified silts and clays resemble the Kathleen series as described by Odynsky, Wynnyk and Newton (1952).

Sample Stands

Brief descriptions of the sample stands are presented in Table 1.

Table 1. Sample stand description

Tableau 1. Description du peuplement étudié*

Stand *Peuplement*	Average age (1962) White sp. *Âge moyen en 1962 Épinette blanche*	Aspen *Peuplier faux-tr.*	Parent material *Roche-mère*	Soil texture *Texture du sol*	Drainage *Égouttement*
A.........	45	56	Lacustrine	Silty Clay	Moderate
B.........	45	56	Till, Fresh	Clay Loam	Moderate
C.........	45	56	Till, Moist	Clay	Mod./Slow
G.........	25	30	Till, Moist	Clay	Slow
H.........	35	40	Till, Fresh	Clay Loam	Moderate
I.........	45	56	Recent Alluvium	Silt	Mod./Rapid
J.........	45	56	Waterwashed Till	Sandy Loam	Mod./Rapid
L.........	15	20	Lacustrine	Sandy Silt	Mod./Rapid
M.........	45	56	Waterwashed Till	Sandy Loam	Mod./Rapid
N.........	65	85	Recent Alluvium	Silt	Moderate
P.........	15	20	Till, Fresh	Clay Loam	Moderate
Q.........	35	43	Till, Moist	Clay	Mod./Slow
T.........	35	43	Till, Fresh	Clay Loam	Moderate
U.........	75	99	Till, Fresh	Clay Loam	Moderate
V.........	45	56	Till, Fresh	Clay Loam	Moderate
1.........	65	77	Till, Moist	Clay Loam	Moderate
2.........	35	44	Till, Fresh	Clay Loam	Mod./Rapid
3.........	55	63	Recent Alluvium/ Till (variable)	Silt/Clay Loam	Mod./Slow
4.........	25	39	Till, Moist	Clay Loam	Moderate
5.........	65	81	Till, Moist	Clay Loam	Moderate

* Termes descriptifs employés dans le tableau. Clay: *argile;* Clay Loam: *limon argileux;* Lacustrine: *lacustre;* Moderate: *modéré;* Mod./Rapid: *modéré à rapide;* Mod./Slow: *modéré à lent;* Recent Alluvium: *alluvions récentes;* Sandy Loam: *limon sableux;* Sandy Silt: *limon siliceux fin;* Silt/Clay Loam: *limon argileux;* Silt: *limon;* Silty Clay: *argile limoneuse;* Slow: *lent;* Till, Fresh: *till frais;* Till, Moist: *till humide;* Till (variable): *till variable;* Waterwashed Till: *till lessivé.*

METHODS

In 25 stands a total of 333 spruce stems were individually released from aspen competition and 323 were left as controls covering the same age and diameter range.

The following treatment was carried out in 1951 and 1952:

> Individual spruce trees having only aspen competition were subjectively selected and all competition within a radius of twice the crown width of the treated spruce trees was removed by cutting. A minimum radius of 8 feet regardless of crown width was applied. To prevent aspen suckering and root competition, all aspen stumps were treated with "ammate" crystals, (ammonium sulphamate).
>
> In each stand, control trees comparable to the treated spruce in d.b.h., age, and height were selected. Spruce sample trees were tagged, d.b.h. and total height were measured. Below 0.8 inches d.b.h. only height measurements were taken. All aspen and other species within a radius of twice the crown width of each spruce sample tree were mapped and their diameter and height recorded. The treated stands were segregated into three broad site classes; good, medium, and poor, as defined by site index curves (MacLeod and Blyth, 1955) for spruce.
>
> good—80 feet at 80 years
> medium—70 feet at 80 years
> poor—60 feet at 80 years.

A spruce sample tree is shown in Figures 1 and 2 before and after release.

Results of the 1956 remeasurement showed that all ages and diameters of spruce had responded to release but no differences were revealed between site index classes. It was then decided to reclassify the stands on a physiographic site basis using the classification developed for the region by J. Quaite.[1]

By 1962 many of the stands had been lost to road construction and fire. However, a total of 461 stems were located in 20 stands and remeasured that year. The distribution of the treated stems by age and diameter classes is shown in Tables 2A and 2B. Distribution of control stems was almost identical—235 treated and 226 control stems were measured. The data for 10 years' growth were processed using IBM data cards and diameter and height increment of released and control trees were analysed using "t" tests[2].

Table 2A. Distribution of treated spruce sample trees by age and 2" classes—1952

Tableau 2A. Répartition d'épinettes-échantillons traitées, par classes d'âge et par classes de diamètre de 2"—1952

Age Class — *Classe d'âge*	2 inch breast height diameter classes — *Classes de 2 pouces de diamètre à hauteur de poitrine*								Grand total
	<0.8"	1–2	3–4	5–6	7–8	9–10	11–12	13–14	
0–10	21								
10–20	43								
20–30	71	26	5						
30–40	46	46	14						
40–50			3	4	6	6	1		
50–60			1	8	15	8	3		
60–70					2	2	1	1	
Total	181	72	23	12	23	16	5	1	333

[1] Quaite, J. 1953. The evaluation of site in the Mixedwood Section of Northern Alberta. Canada, Department of Resources and Development, Forestry Branch. Unpubl. MS.

[2] Analysis of data using appropriate "t" tests was carried out by T. G. Honer and the staff of the Data Processing Unit, Department of Forestry of Canada, Ottawa.

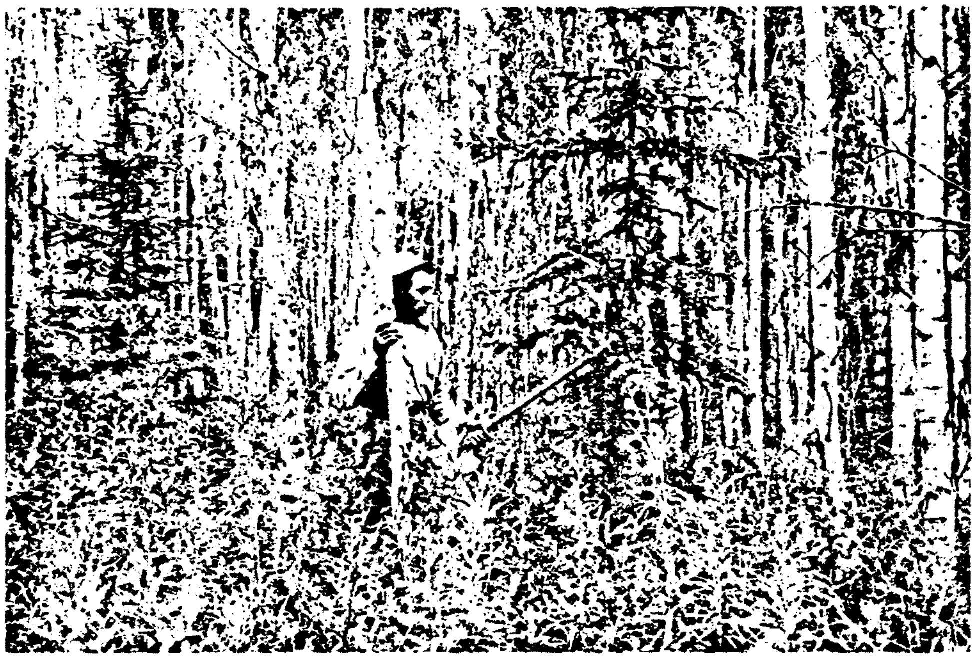

FIGURE 1. Spruce sample tree before release
Échantillon d'épinette, avant dégagement

FIGURE 2. Spruce sample tree after release
Échantillon d'épinette, après dégagement

Table 2B. Distribution of treated spruce sample trees by age and 2" classes—1962

Tableau 2B. Répartition d'épinettes-échantillons traitées, par classes d'âge et par classes de diamètre de 2"—1962

Age class — *Classe d'âge*	2 inch breast height diameter classes — *Classes de 2 pouces de diamètre à hauteur de poitrine*										Grand total
	<0.8"	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	
0-10........	14	8	1								
11-20........	18	19	3	3							
21-30........	14	20	17	9							
31-40........	2	17	21	14	3						
41-50........					1	1	3	4	1		
51-60........				1	1	5	8	11	3	1	
61-70........					1	2	7	2			
Total........	48	64	42	27	6	8	18	17	4	1	235

RESULTS

Curves of average annual diameter increment for treated and control stems are shown in Figure 3 for the periods 1952-56 and 1957-62. The effect of release on diameter increment has been sustained over the second five-year period. The differences between released and control stem values are significant at the 5 per cent probability level. Periodic diameter increment values for the 1962 remeasurement were plotted over the logarithm (base 10) of breast height diameter and the straight line regressions for released and control stems were developed using the weighted means for each diameter class. The regressions are presented in Figure 4. The difference between released and control stem regressions is distinct and the equations will be used in future comparisons.

Mean values of diameter increment are presented for each diameter class in Table 3 and for each age class in Table 4. The results of the "t" tests are indicated in these tables and they substantiate the trends observed in the graphical presentation. These values include all sites. In Figure 5 curves of diameter increment per cent are presented by age classes. Pressler's formula gives growth per cent based on the mid-period diameter. The greatest release occurs in the 20 to 40 year age class.

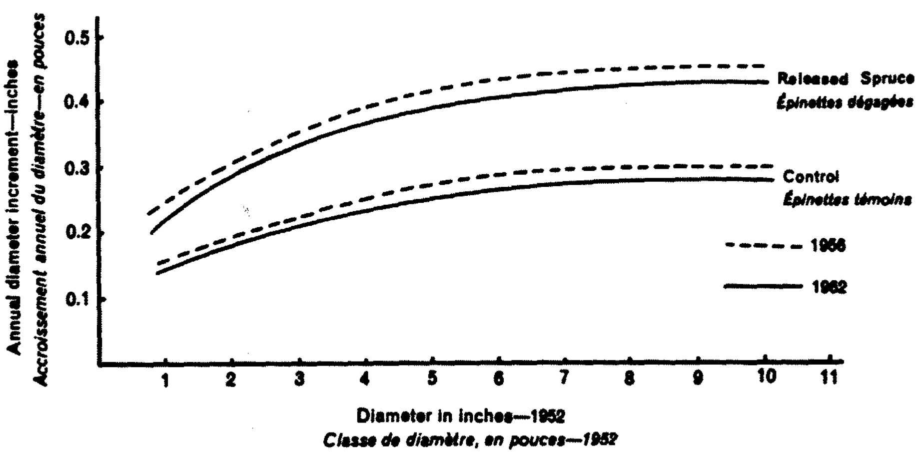

FIGURE 3. Average annual diameter increment 1952-1956 and 1957-1962 (sites and age classes combined)
Accroissement annuel moyen du diamètre, 1952-1956 et 1957-1962 (stations et classes d'âge combinées)

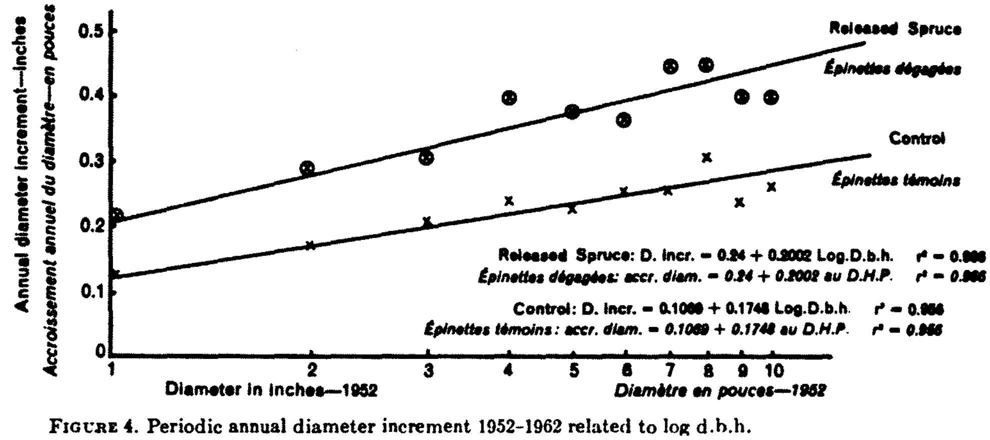

FIGURE 4. Periodic annual diameter increment 1952-1962 related to log d.b.h.
Accroissement périodique annuel du diamètre, 1952-1962, par rapport au D.H.P. de la bille

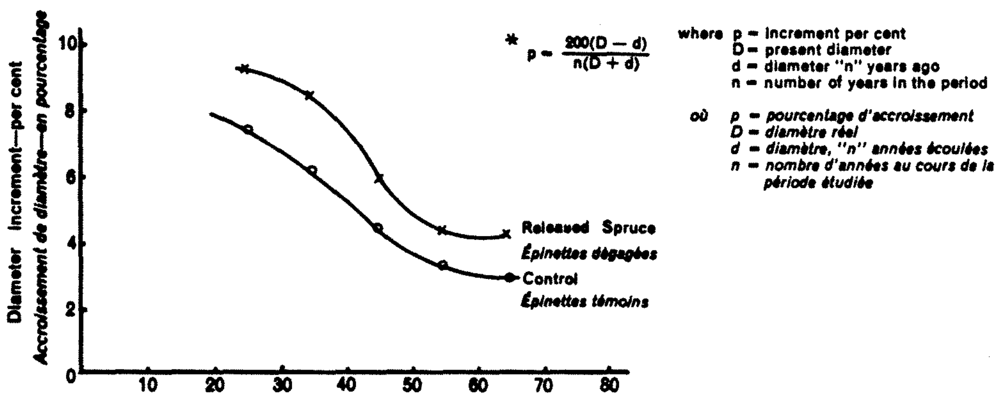

FIGURE 5. Diameter increment per cent 1962 (Pressler's Formula)*
*Pourcentage d'accroissement de diamètre, 1962 (d'après la formule Pressler)**

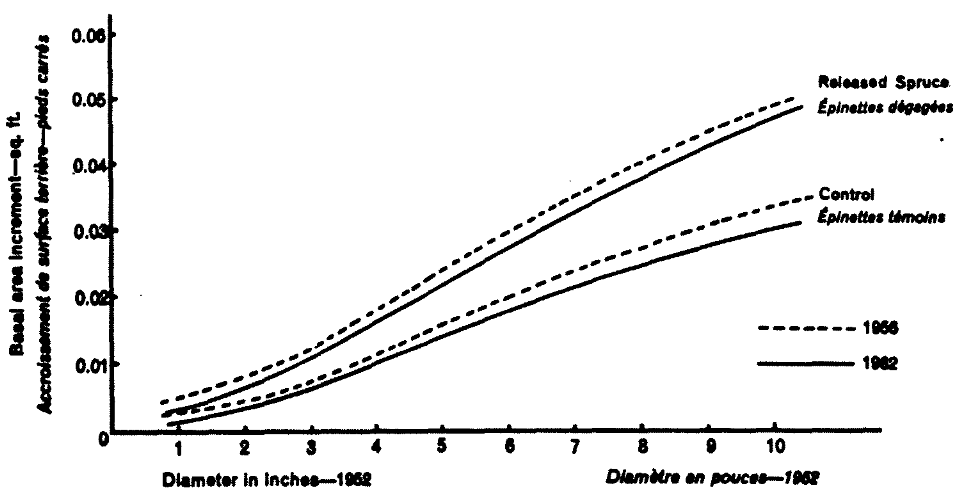

FIGURE 6. Average annual basal area increment 1952-1956 and 1957-1962
Accroissement annuel moyen de surface terrière, 1952-1956 et 1957-1962

Table 3. Mean annual diameter and height increment for treated and control stems by diameter classes

Tableau 3. Accroissement annuel moyen en diamètre et en hauteur des tiges traitées et des tiges témoins, par classes de diamètre

Diameter class — *Classe de diamètre*	Diameter increment in inches — *Accroissement de diamètre en pouces*: Treated — *Tiges traitées*		Control — *Tiges témoins*	Height increment in feet — *Accroissement de hauteur en pieds*: Treated — *Tiges traitées*		Control — *Tiges témoins*
1	0.23	*	0.14	1.27	*	0.87
2	0.27	*	0.17	1.35	*	1.06
3	0.29	*	0.19	1.66	*	0.97
4	0.40	*	0.24	1.54	*	0.38
5	0.39	*	0.23	1.50	*	1.20
6	0.37	*	0.26	1.71	N.S.	1.08
7	0.44	*	0.26	1.56	N.S.	1.20
8	0.44	*	0.32	1.38	N.S.	0.85
9	0.40	*	0.24	1.21	N.S.	0.99
10	0.39	N.S.	0.26	1.38	*	0.80

* Difference is significant at P=0.05
La différence est significative au seuil de P=0.05

N.S. Difference is not significant at P=0.05
La différence n'est pas significative au seuil de P=0.05

Curves of average annual basal area increment by diameter classes are presented in Figure 6 for the periods 1952-56 and 1957-62. There is a slight decrease in basal area increment in the second five-year period.

Average periodic annual height increment by age classes is shown in Figure 7. Weighted mean values are shown. Greatest release occurs in the 30 to 50 year age range. Beyond 50 years of age there is greater variation within the treated and control values. Tables 3 and 4 show that height differences in the diameter range 6 to 9 inches and age class 50 to 60 years are not significant. This is the result of extensive top damage to the spruce because of whipping by competing aspen and snow and ice damage. In 1962, 18 per cent of released and 22 per cent of control stems showed top damage, and at the time of measurement a few released spruce had been bent to the ground by a recent (May) snowstorm.

Table 4. Mean annual diameter and height increment for treated and control stems by age classes

Tableau 4. Accroissement annuel moyen en diamètre et en hauteur des tiges traitées et des tiges témoins, par classes d'âge

Age class — *Classe d'âge*	Diameter increment in inches — *Accroissement de diamètre en pouces*: Treated — *Tiges traitées*		Control — *Tiges témoins*	Height increment in feet — *Accroissement de hauteur en pieds*: Treated — *Tiges traitées*		Control — *Tiges témoins*
20–30	0.27	*	0.18	0.94	*	0.62
30–40	0.26	*	0.16	1.18	*	0.82
40–50	0.35	*	0.22	1.37	*	0.87
50–60	0.42	*	0.28	1.42	N.S.	1.24
60–70	0.39	*	0.25	1.34	*	0.84

* Difference is significant at P=0.05
La différence est significative au seuil de P=0.05

N.S. Difference is not significant at P=0.05
La différence n'est pas significative au seuil de P=0.05

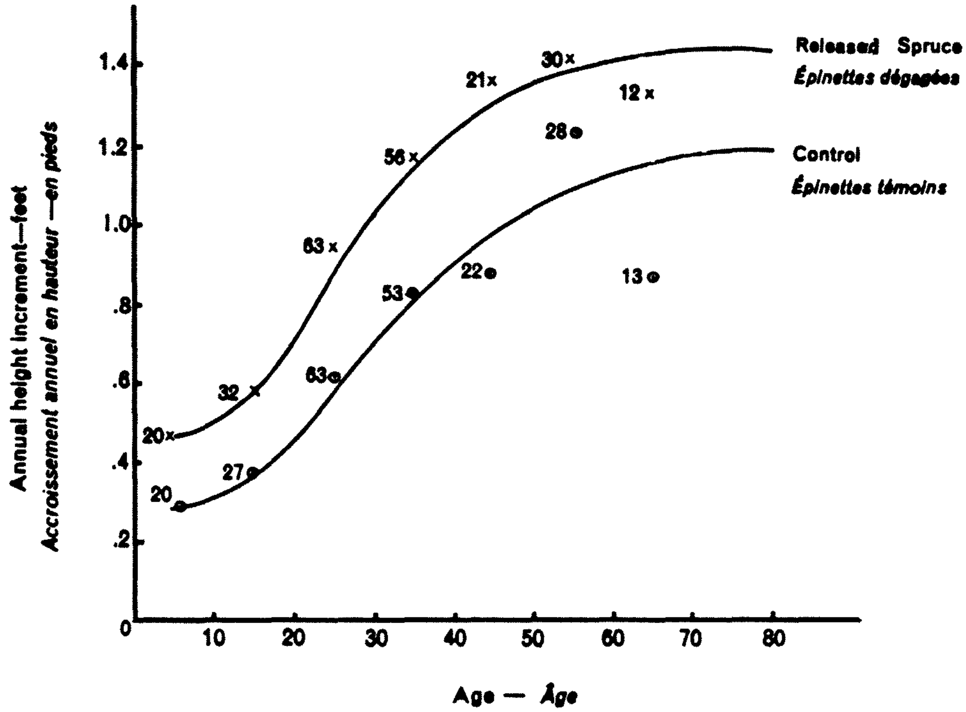

FIGURE 7. Periodic annual height increment 1952-1962
Accroissement périodique annuel en hauteur, 1952-1962

Table 5 shows mean merchantable cubic foot volume (Anon. 1962) for four of the stands in the older age classes. The merchantable volumes are presented to illustrate the value of the treatment to stems 5" d.b.h. and over in increased productivity. Mean volumes of released stems are from 20 to 40 per cent higher than control stems.

Table 5. Mean merchantable cubic foot volume, trees over 5" d.b.h.

Tableau 5. Volume moyen du bois marchand en pieds cubes—arbres au-dessus de 5" D.H.P.

Age — *Âge*	Stand — *Peuplement*	Number of stems — *Nombre de* Released — *tiges dégagées*	Control — *tiges témoins*	Volume per tree (cubic feet) — *Volume (en pieds cubes)* Released — *par arbre dégagé*	Control — *par arbre témoin*
50	3	12	11	19.3	15.7
60	1	8	7	30.3	21.7
60	N	11	13	26.7	15.2
70	U	13	13	18.9	14.7

Ontkean and Smithers (1959) reported that no significant trends could be established by graphical analysis with age or site index. The stands were therefore reclassified on a physiographic basis recognizing 6 types as shown in Table 6.

Table 6. Physiographic site types

Tableau 6. Conditions physiographiques des stations

Physiographic site *Stations physiographiques*	Parent material* *Roche-mère***	Soil texture *Texture du sol*	Moisture status *Teneur en humidité*	Productivity class* *Classe de fertilité***	No. of released stems *Nombre de tiges dégagées*	Index height at 80 years *Hauteur habituelle à 80 ans*
1.........	Recent alluvium *Alluvions récentes*	Sands and silts *Limons et sables*	Fresh-Moist *Frais à humide*	I	20	95
2.........	Till fresh *Till frais*	Clay loams *Limons argileux*	Fresh *Frais*	I	93	90
3.........	Waterwashed till *Till lessivé*	Sandy loams *Limons sableux*	Fresh *Frais*	I	7	87
4.........	Alluvium till (variable) *Till d'alluvion (variable)*	Silts and clay loams *Limons et limons argileux*	Moist-Wet *Humide à mouillé*	I	10	84
5.........	Lucustrine *Lacustre*	Clays *Argiles*	Moist-Somewhat wet *Humide à quelque peu mouillé*	II	23	84
6.........	Till moist *Till humide*	Clays *Argiles*	Moist *Humide*	II	84	84

* Classification follows Duffy (1965). A Forest Land Classification for the Mixedwood Section of Alberta. Dept. Forestry Can. Publication No. 1128

** *Classification d'après Duffy (1965).* A Forest Land Classification for the Mixedwood Section of Alberta. *Min. des Forêts, Can. Publication nº 1128*

Separate empirical diameter growth curves were developed for each type. Unfortunately not all diameter classes were represented on all sites. However it was quite clear that for trees of given size there was no significant difference in diameter growth between the sites sampled. There are no extremes included in the sample and index height at 80 years for spruce ranges from 84 to 95 feet. Soil textures do not vary a great deal among the stands sampled and are mainly clay loams and clays. More than half of the sites in the region occur on glacial tills and most of the remainder occur on lacustrine deposits of the ancient Lesser Slave Lake basin. The site data were not analysed further.

Aspen Poisoning

Ammonium sulphamate was applied in V-notches in the cut aspen stumps, in crystalline form, around the treated stems. Quaite (1953) reported that this was effective in inhibiting aspen sprouting and suckering within the treated circle and in killing additional standing stems on the circle perimeter. The treated areas re-examined in 1962 were still remarkably clear of aspen suckers although a stand of smaller stems 3 to 4 years old seemed to be quite vigorous and healthy. Among the small spruce of less than one inch in diameter this was sufficient to provide serious competition. It is doubtful if release of such small spruce stems is worthwhile unless repeated treatments could be given.

DISCUSSION

The results of this study indicate that release of individual spruce stems from aspen competition will be successful on all the sites which were sampled and that the treatment will be widely applicable in the study region.

The treatment which was used suggests a method of thinning which emphasizes crown space and the relative crown position of the spruce and aspen stand components. Variation between individual stems within sample stands illustrates the need for treatment of single spruce crop trees rather than whole stands since each tree requires individual and different treatment based on crown characteristics. During the period when the spruce grows up through the hardwood overstorey, top damage from whipping is extensive. Height growth is checked and several years height growth may be lost.

The 10-year remeasurement shows that the effect of treatment is still favourable. However, in 1962 the crowns of many of the spruce crop trees were in contact with those of competing aspen and further release is warranted within the next five-year period.

At present the very small spruce stems up to 3 feet high which were treated are suffering from heavy and repeated browsing and from ground vegetation competition. These should not be treated in future thinnings unless more frequent release can be given.

The release of the oldest stems in this study bears out the experience of other workers (Cayford 1957, Steneker 1963) who note the ability of mature spruce to respond to release. Thinning in stands more than 70 years old is not recommended. However partial cutting from a commercial standpoint will lead to a valuable increase in growth of residual stems and an increase in merchantable volume production from the stands. These findings agree with results from associated studies of harvest cutting methods where partial cutting resulted in increased growth of residual spruce (Lees, 1963, 1964). The most valuable age and diameter range for release of spruce from aspen competition indicated by this study is 20 to 40 years and 3 to 5 inch d.b.h. classes.

It is recommended that stump poisoning of the cut aspen competition be carried out at the time of release treatment.

Economics did not feature in the current study. The decision to carry out the suggested treatment which may be biologically sound must depend on what is economically feasible. It may be possible to thin these stands twice to obtain best development; once in the range 20 to 40 years and again in the 40 to 60 age range. This would greatly increase the yield of quality spruce lumber and would prevent the crucial period of competition when the spruce is co-dominant with the aspen. However, thinning of the aspen cannot be considered an economic hardwood improvement treatment as long as the vast areas of pure aspen in the region remain unexploited. Nevertheless, it will always be worthwhile to remove as many poor and diseased aspen stems as possible in the release of spruce. It may be economical to poison or girdle the aspen if it is unmerchantable.

The results of this study closely parallel those in Saskatchewan. Growth rates are higher in Alberta but the effect of release may be more pronounced in the Saskatchewan studies. All studies indicate that the aspen overstorey in immature spruce-aspen stands inhibits the height and diameter growth and lowers the quality of the spruce. It is agreed that the release of the spruce is justified before it becomes co-dominant with aspen.

SUMMARY

Removal of competing aspen within twice the crown width of spruce crop trees in spruce-aspen stands resulted in a marked increase in height and diameter growth of the spruce. Poisoning of the cut aspen stumps with ammonium sulphamate (ammate) prevented suckering and sprouting of the aspen for several years. Release was effective over a wide range of ages and diameters on all sites sampled. These represent the most extensive and commonly occurring fresh to moist sites with predominantly clay loam and clay soil textures. Results agree with those of parallel release studies in Manitoba and Saskatchewan within the same forest section. It is recommended that release of spruce be carried out before spruce and aspen crowns are co-dominant.

SOMMAIRE

Cette publication porte sur le dégagement de l'épinette blanche, au milieu de peupliers faux-trembles concurrentiels, dans un peuplement mélangé d'épinette et de peuplier faux-tremble de l'Alberta. Dans un peuplement mélangé d'épinette et de peuplier faux-tremble, on a effectué une coupe de nettoiement des peupliers faux-trembles concurrentiels dans un espace correspondant à deux fois la largeur de la cime des épinettes de récolte; cette coupe a amené une augmentation sensible de la croissance des épinettes, en hauteur et en diamètre. L'empoisonnement des souches des peupliers faux-trembles, au moyen de sulfamate d'ammonium (ou ammate), a empêché le drageonnement et le bourgeonnement des peupliers faux-trembles pendant plusieurs années. Ce dégagement s'est révélé efficace pour un grand nombre d'épinettes d'âge et de diamètre variés dans toutes les stations échantillonnées; ces dernières comprenaient toute la gamme des types forestiers, de frais à humides, les plus répandus et les plus communs, et dont le sol était en majeure partie composé de limon argileux ou d'argile. Les résultats de cette expérience concordent avec ceux qu'on a obtenus au cours d'expériences analogues pratiquées au Manitoba et en Saskatchewan dans la même zone forestière. L'auteur recommande de pratiquer de telles coupes avant que les cimes d'épinette et de peuplier faux-tremble deviennent co-dominantes.

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O.D.C. 174.7 (Picea glauca)

CANADA
DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

GROWTH OF WHITE SPRUCE FOLLOWING RELEASE FROM TREMBLING ASPEN

by

G. A. Steneker

Sommaire en français

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GROWTH OF WHITE SPRUCE FOLLOWING RELEASE FROM TREMBLING ASPEN

by

G. A. Steneker


LEGEND
location of study area
SASKATCHEWAN
MANITOBA
Northern
Coniferous
Forest
Mixedwood
Section
Big River
Montreal L.
Candle L.
PRINCE ALBERT
Aspen
Grove
Bertwell
Reserve
Lake Winnipeg
Lake Manitoba
Riding Mtn
REGINA
BRANDON
Prairie
U.S.A.

ABSTRACT

Experimental release cuttings to favour white spruce in 15- to 60-year-old white spruce-trembling aspen stands have shown that diameter increment and in certain instances height increment of the spruce was doubled; merchantable volume production per acre was, on the average, increased by about 60 per cent. These findings are of special interest in the Prairie Provinces, where the spruce-aspen cover type forms the principal source of white spruce.

ACKNOWLEDGEMENTS

I wish to acknowledge the previous work by J. H. Cayford, R. M. Waldron and J. M. Jarvis of the Department of Forestry and Rural Development. Their interim results on the study were essential to the preparation of this paper.

CONTENTS

GROWTH OF WHITE SPRUCE FOLLOWING RELEASE FROM TREMBLING ASPEN

by

G.A. Steneker[1]

INTRODUCTION

White spruce (*Picea glauca* (Moench) Voss) normally grows in association with trembling aspen (*Populus tremuloides* Michx.) in the B18a Mixedwood Forest Section (Rowe 1959) of Manitoba and Saskatchewan. Admixtures of balsam poplar (*Populus balsamifera* L.) and black spruce (*Picea mariana* (Mill.) BSP.) may occur also on the moist sites. Aspen usually forms the upper canopy in immature stands, thereby suppressing the spruce and exposing it to mechanical injury (Kittredge and Gevorkiantz 1929). The growth rate of spruce is therefore often impaired and much of its potential volume is lost (Kagis 1952, Kabzems 1952, Cayford 1957).

Experimental improvement cuttings, to favour the white spruce component of mixedwood stands in Manitoba, were first carried out by the Department of Forestry and Rural Development in 1936 (Steneker 1963). Later, between 1951 and 1954, a series of eight experimental release cuttings were made in 15- to 60-year-old stands in Manitoba and Saskatchewan, to determine the effects of partial and complete removal of the aspen upon the development of the white spruce understorey.

This publication presents the 10-year growth results of these latter experimental release cuttings. Information is presented on the effect of various levels of aspen and white spruce stocking upon subsequent diameter, basal area and volume increment of the white spruce.

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STUDY AREAS

Location and Stand Description

The experimental areas are located within stands typical of the Mixedwood Forest Section at Riding Mountain, Manitoba, and Reserve, Bertwell, Candle Lake, Montreal Lake and Big River, Saskatchewan (Frontispiece). Data on age, diameter and height are given in Table 1. All stands originated following fire. On some of the moist sites balsam poplar and black

TABLE 1. AGE, AVERAGE DIAMETER AND HEIGHT OF WHITE SPRUCE AND ASPEN AT TIME OF TREATMENT

Study area	Date of establishment	Age*		Av. d.b.h. (inches)		Av. height (feet)	
		wS	tA	wS	tA	wS	tA
Bertwell	1951	10-25	25-30	1.2	3.6	11	44
Riding Mountain	1954	20-35	25-40	1.2	4.2	11	45
Big River Nursery	1953	15-25	20-40	2.2	3.3	15	41
Montreal Lake	1953	20-35	25-35	2.6	4.1	20	52
Candle Lake (1)	1953	15-40	45-60	2.0	5.5	15	55
Candle Lake (2)	1953	15-50	50-60	2.3	6.3	17	54
Big River	1953	35-50	55-60	3.1	5.7	28	60
Reserve	1951	25-60	50-60	4.4	6.4	28	65

*Age at 1 foot above ground.

spruce occur as component species. The profile of the stand at Bertwell (Figure 1) illustrates the typical variation in stand structure and composition in the various study areas. It shows the irregular spatial distribution of the spruce; the wide range in size classes of the spruce; and different conditions under which individual spruce trees are growing, from completely suppressed to relatively free growing.

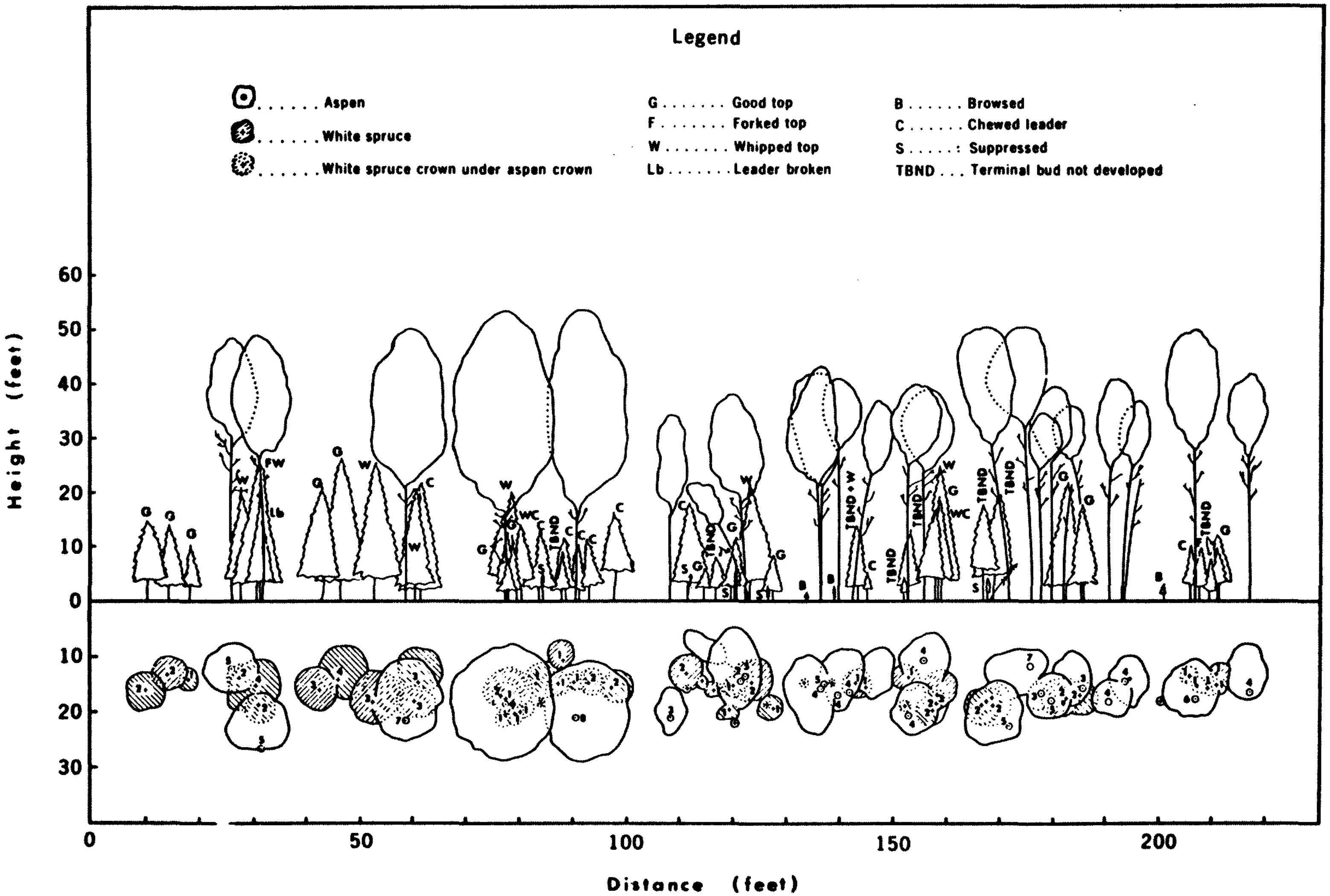

Figure 1. *Profile and plan sketch, uncut portion of stand at Bertwell Saskatchewan 1961. Number on plan view indicates diameter of tree.*

Site Information

Site conditions are similar on the various study areas. The topography is flat to gently rolling and the soils are well drained. Parent soil materials are glacial tills, and vary in texture from silty clay loams to clay loams. However at Montreal Lake soils have been influenced by water, as the profiles show bands of silt and sand over the till. Grey wooded soils have developed in all areas except Bertwell; there, degrading black or dark grey wooded soils predominate, indicating that at one time grasses were the predominant vegetation. Representative soil profile and drainage types are described in Appendix I.

METHODS

Growth data were obtained from 1/10-acre permanent sample plots. Two plots were chosen at each location as controls and two for release from which all aspen were removed from the plots and surrounds. Two additional plots were chosen at both Bertwell and Reserve for partial release from which 50 per cent of the aspen were removed by systematically cutting every other stem.

All spruces were tagged and the height and breast height diameter of all trees were measured during the year of release and 5 and 10 years after release. A number of ring counts were made to establish the range in age of the aspen and spruce in each stand (Table 1).

Plots were classified as to relative moisture status and soil texture (Hills 1952), and soil profiles were described. Increment borings at breast height were made on the spruce during the 10-year remeasurement at three study locations to analyse and compare year by year radial increment of individual spruce trees on release and on control plots.

RESULTS

Diameter Increment

Removing the aspen overstorey increased periodic diameter increment of white spruce in all diameter classes. Released trees grew between 40 (Candle Lake, area 2) and 200 per cent (Big River Nursery) faster than trees on the control plots. This wide variation in response is attributed primarily to

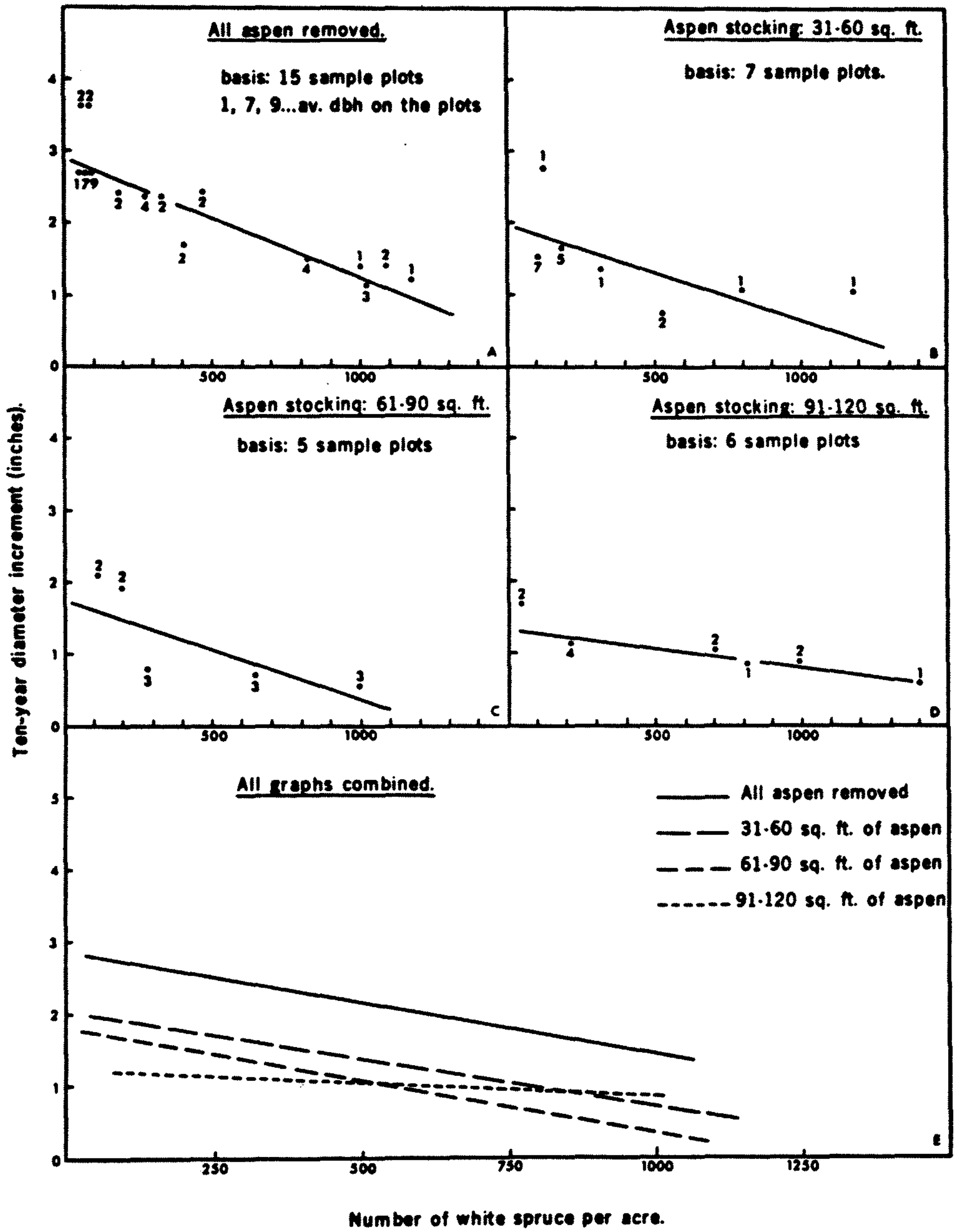

Figure 2. *Ten-year diameter increment of white spruce related to number of residual spruce per acre at four density classes of aspen.*

differences in stocking levels of spruce between release and control plots within areas (Appendix II), and to variation in the spatial distribution of spruce within plots. The effect of spatial distribution of the spruce upon its periodic diameter increment is typified by data from the Riding Mountain plots. Average 10-year diameter increment of the 1-inch unreleased spruce was 0.5 inches with individual tree increments ranging from less than 0.1 to 1.2 inches; released spruce of this size class had an average increment of 1.2 inches with individual tree increment ranging from 0.1 to 2.7 inches. Therefore, with diameter increment rounded off to the nearest 1/10 inch, the effect of release on some "released" trees could not be observed. Usually such trees were severely suppressed by neighbouring spruce.

To illustrate the effect of aspen overstorey density on white spruce growth, periodic increment data for spruce from all studies have been stratified by four levels of aspen stocking (Figure 2). This graph shows that the diameter increment of white spruce is inversely related to the overhead aspen stocking and that complete release resulted in 100 per cent increase in increment. Initial stand diameter breast height had apparently little or no influence on subsequent increment (Figure 2A).

The effect of age upon response was not determined owing to the variation in the age of spruce within individual stands (Table 1). However, as tree diameter tends to vary directly with tree age, and as initial diameter showed no relationship to response to release, it may be assumed that age, within the range examined, had little or no influence on the subsequent diameter increment of the spruce.

The year-by-year increment over a 20-year period for a number of released and unreleased spruce at Riding Mountain, Big River Nursery and Montreal Lake is shown in Figure 3. White spruce responded to treatment immediately and a maximum growth rate was reached after 3 years. During the following 6 to 7 years diameter increment declined, but remained well above the growth rate of the unreleased trees. Although a sufficient period has not elapsed to establish the complete growth pattern, indications are that the released trees will maintain a faster growth rate than the unreleased trees for some time to come.

Height Increment

The removal of the aspen overstorey resulted, on the average, in an increase in height increment of the spruce. However, in contrast to diameter increment, increases in height

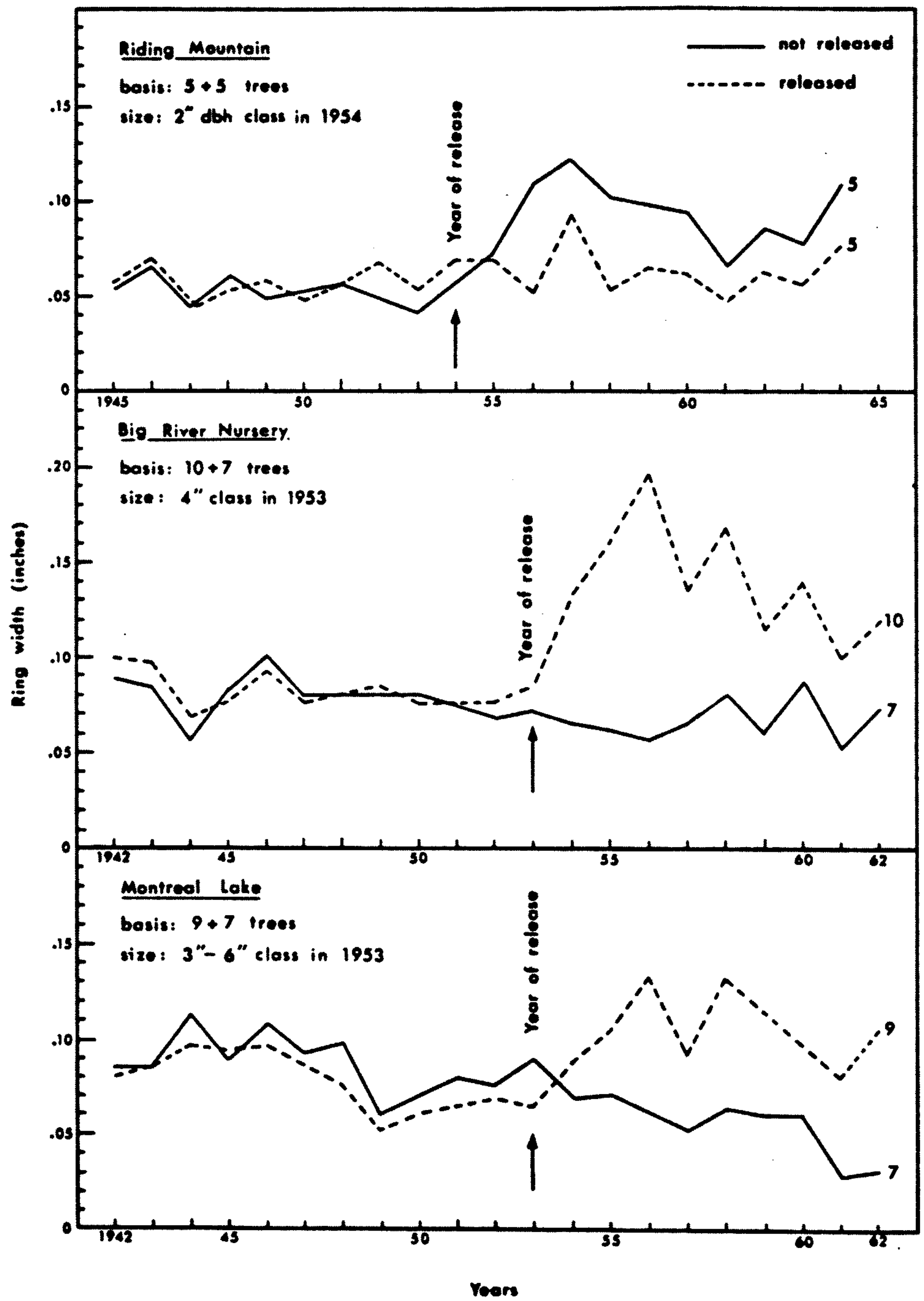

Figure 3. *Annual radial growth over a 20-year period for released and unreleased white spruce at Riding Mountain, Big River Nursery and Montreal Lake based on largest size classes of the spruce component at each area.*

Note:

Figure 3 - P. 7 - Graph for Riding Mountain. Solid line should be broken and broken line should be solid.

increment did not occur consistently in all areas; e.g., at Riding Mountain and Candle Lake (area 2) height increment was about the same for trees on the release and control plots.

Response in height increment to release is directly related to stand structure. To illustrate this, trees on the control plots at Big River were stratified into three growth condition classes, and the increment of trees within these classes was compared to that of the white spruce on release plots. The classes are designated as suppressed (spruce which have their crowns directly underneath a crown from the upper canopy, or are suppressed by other spruce), whipped (spruce, which have their crowns within the upper canopy crowns and receive mechanical injury), and free growing (spruce although overtopped, having growing space available above their crown). The data show (Figure 4) that the height increment of the "free growing" spruce is almost as rapid as that of the completely released spruce, whereas the increment of the "suppressed" and "whipped" trees is about half that of the released spruce. The Big River data therefore indicate that the inconsistency in average height increment between the various study areas is due to the distribution of spruce trees within the suppressed whipped, and free growing classes at each location.

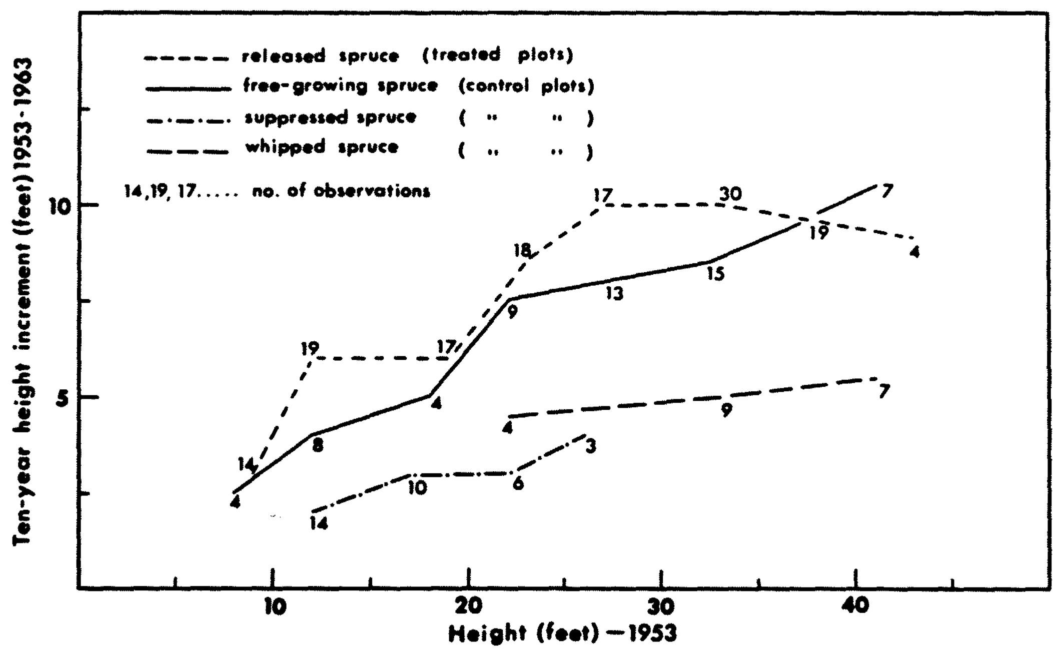

Figure 4. *Ten-year height increment by height classes for released, suppressed, whipped and free-growing spruce at Big River.*

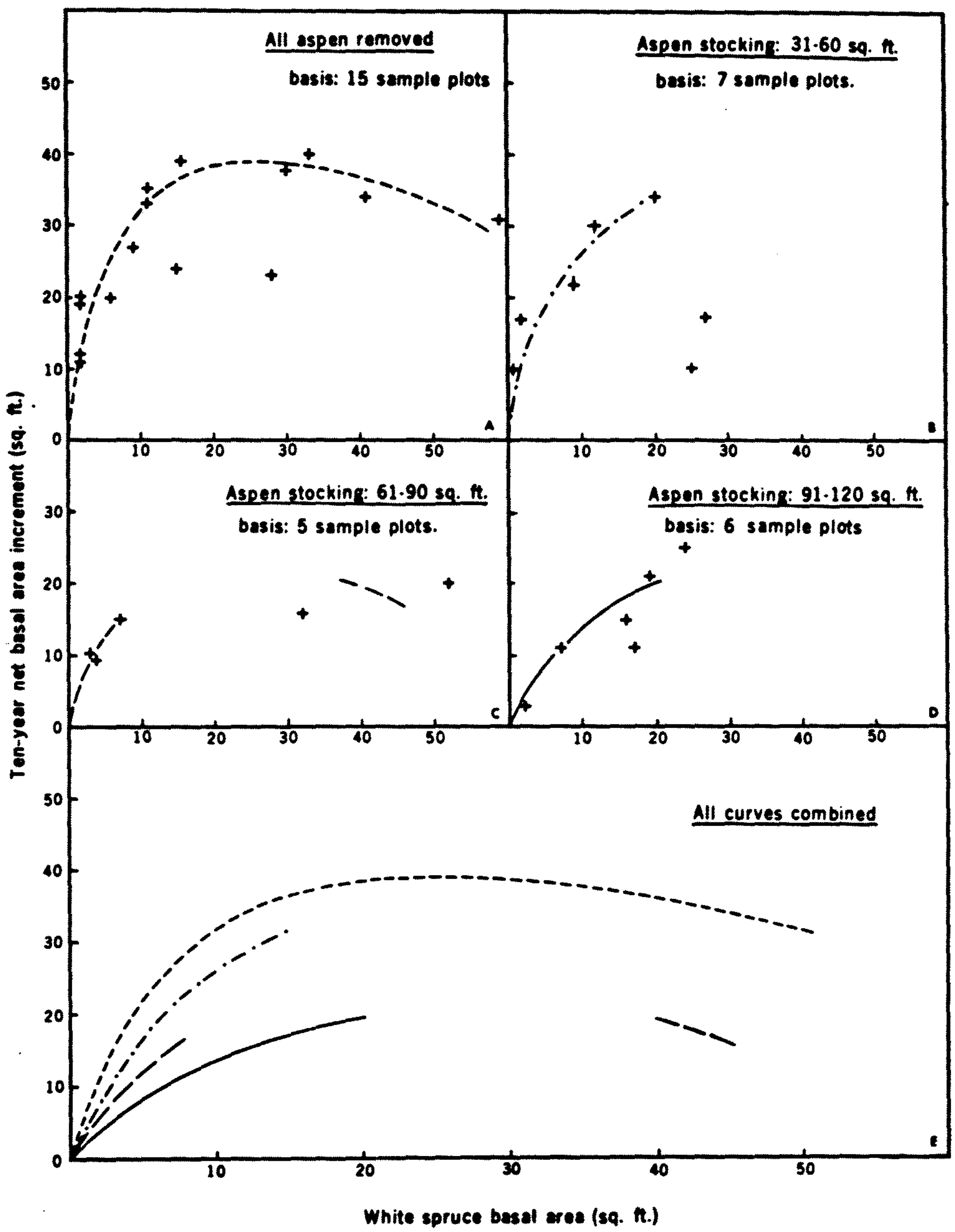

Figure 5. *Periodic net basal area increment per acre of white spruce related to residual basal area per acre of white spruce at four density classes of aspen (free hand curves).*

Basal Area and Total Volume Increment

Figure 5 shows the relationship between periodic net white spruce basal area increment and residual spruce basal area for plots with different aspen densities. Net increment of spruce was inversely related to the amount of aspen stocking. Over the 10-year period since treatment it reached a maximum of about 20 sq. ft. an acre on plots with an aspen stocking between 90 and 120 sq. ft. an acre and a maximum of about 40 sq. ft. an acre on release plots. On four sample plots (Figure 5A and B) increment was extremely low. This appears to be related to uneven spruce distribution since as much as 75 per cent of the total number of spruce trees on each plot were located on half the plot.

Total periodic volume increment of spruce showed a similar relationship as basal area increment with residual white spruce and aspen stocking. Net volume increment was as much as 50 per cent lower on the control than on the release plots because of aspen competition.

Merchantable Volume Production

The insufficient number of trees with breast height diameter of 8 inches and over on the control and release plots did not allow an assessment of the effect of release in terms of board foot volume production, so merchantable volume production has been expressed in cords only. A valid assessment of the effect of release on cordwood production can only be made if, at time of release, the tree-size or number-of-trees relationship between the control and release plots was comparable. Therefore the number of spruce trees on the release and control plots was related to the spruce basal area per acre. Figure 6 shows that at specific spruce basal area levels the tree-size or number-of-trees relationship was similar between control and release plots. Figure 6A shows the number of spruce per acre for all plots was related to spruce basal area per acre at time of release. Although within-area variation existed, on the average, basal area and number of trees per acre on the control and release plots were the same. In Figure 6B the cordwood production 10 years after release is related to white spruce basal area at time of release. The lines, significantly different at the 1 per cent level, indicate that on the average spruce cordwood production was about 60 per cent greater on the release plots than on the controls.

Mortality and Condition of Spruce after Release

Spruce mortality by number of trees during the 10-year

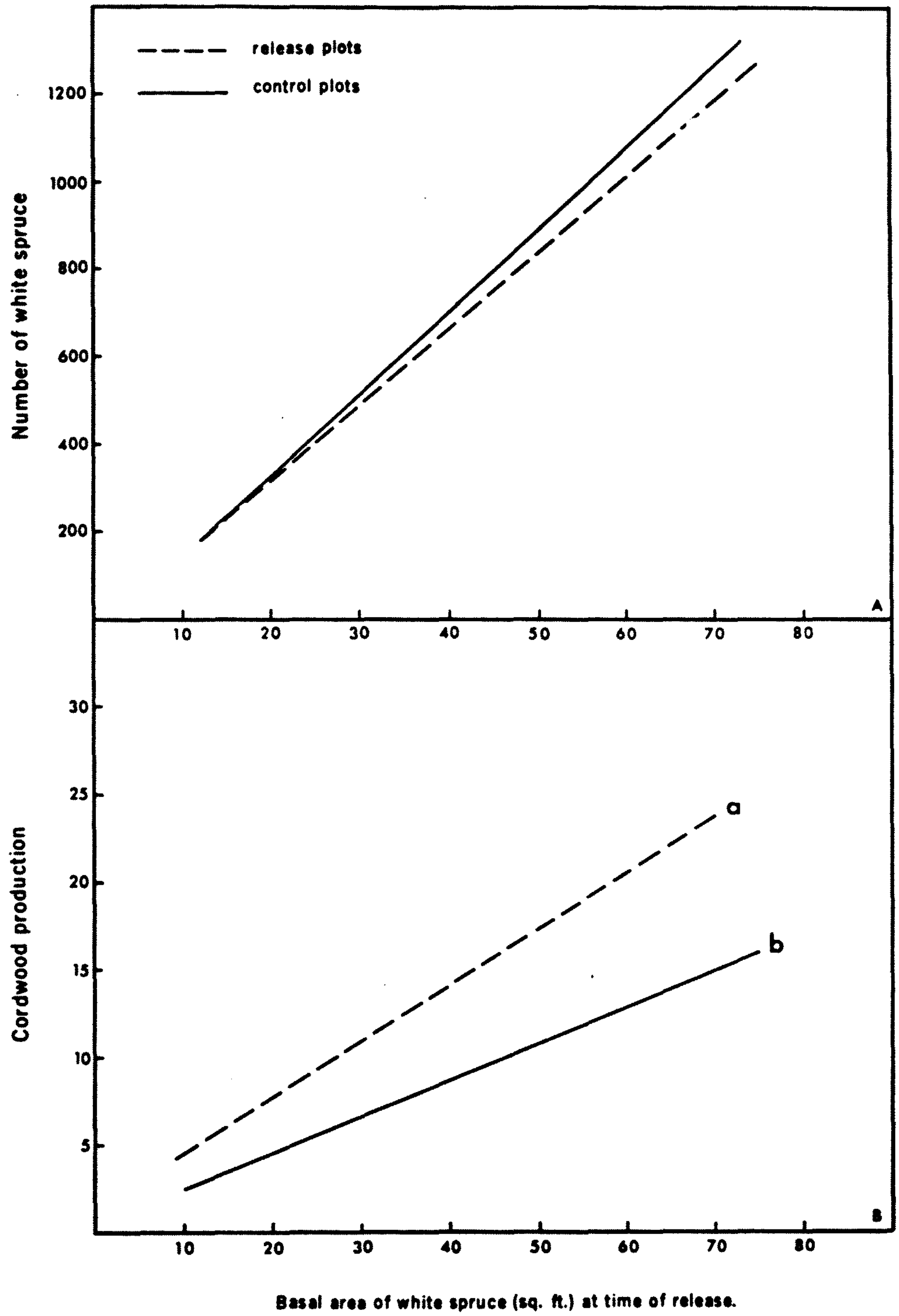

Figure 6. *Relationship between basal area and number of trees per acre of white spruce on control and release plots at time of release (A), and basal area and cordwood production 10 years after release (B). Difference between a and b significant at 1 per cent level.*

period after treatment ranged up to 12 and 30 per cent on the release and control plots respectively. In terms of total volume, percentages were 5 and 18, indicating that mortality generally occurred in the smaller diameter classes. Unexpectedly high spruce mortality at Big River was caused by porcupine girdling. The leaders of released trees at some localities showed evidence of damage by squirrels, weevils (possibly *Pissodes strobi* (Peck)) and frost; this damage was not related to release and most trees have recovered.

DISCUSSION AND CONCLUSIONS

In intermediate aged mixedwood stands, diameter increment of white spruce of all size classes can be increased up to 100 per cent by removal of the trembling aspen overstorey. Response to release in terms of height growth will be most noticeable on trees which have their crowns in direct contact with and immediately below those of aspen. In these conditions trees can be expected to double their height growth when released. The combined effect of release on diameter and height increment may result in increases in merchantable volume production of about 60 per cent an acre.

In Manitoba and Saskatchewan about 30 per cent of the B18a Forest Section consists of intermediate-aged white spruce-trembling aspen stands, which will form the principal source of white spruce in the future. The increasing demand for aspen in the two provinces should make release cutting operations more feasible. The aspen could be clearcut when it reaches commercial size at about 60 years of age, when 40 cords an acre can be expected. Where markets permit, thinning of the spruce could be carried out at the same time. Released from overhead and lateral suppression, the residual spruce is greatly stimulated and reaches sawlog size in a much shorter time than unreleased spruce. A harvest cut could be made at a rotation age of 100 to 120 years, removing spruce sawlogs and another aspen pulpwood crop, since in all probability a good stand of aspen suckers would have sprung up after the first cut. Killing aspen by aerial spraying may be considered in localities where the aspen cannot be utilized. This method has given good results in the Lake States as an economic means of disposing of undesirable hardwoods (Arend 1959).

SUMMARY

Ten-year growth results of eight experimental release

cuttings to favour white spruce in spruce-aspen stands, ranging in age from 15 to 60 years, have shown that:

a) Diameter increment of spruce can be doubled by removing the aspen canopy.

b) Height increment of spruce under immediate overhead suppression and in physical contact with the aspen crowns, can be doubled by release.

c) The combined stimulus to height and diameter increment from release can increase merchantable volume production of spruce by about 60 per cent.

The findings are discussed relative to the commonly occurring white spruce-aspen cover type in Manitoba and Saskatchewan, the principal source of white spruce, and the developing aspen-using industries in these provinces.

SOMMAIRE

L'auteur rapporte dans le présent mémoire les effets qu'ont produits huit coupes expérimentales d'éclaircies sur la croissance de l'épinette blanche au sein de peuplements mélangés d'épinette blanche et de peuplier faux-tremble dont l'âge variait de 15 à 60 ans. Les voici:

a) L'accroissement en diamètre des épinettes blanches a pu doubler par l'enlèvement du couvert des peupliers faux-trembles.

b) Du même coup, l'accroissement en hauteur des épinettes doubla lorsque celles-ci étaient auparavant étouffées ou serrées de près par les peupliers.

c) Un tel accroissement en diamètre et en hauteur peut signifier une production de volume marchand accrue d'environ 60 p. 100.

L'auteur commente les résultats obtenus au regard d'un certain type de peuplement mêlé d'épinette blanche et de peuplier faux-tremble que l'on voit communément au Manitoba et en Saskatchewan. En ces deux provinces, ce type particulier de peuplement fournit à peu près tout le bois marchand d'épinette blanche et l'on s'occupe actuellement d'augmenter l'utilisation industrielle du peuplier qui s'y trouve.

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APPENDIX I

SOIL PROFILE DESCRIPTIONS

Fresh Site	Horizon	Description
(Orthic Grey Wooded)	L - H	Horizon consisting of litter, fermenting and decomposed plant material. 1/2 - 3 inches in depth.
	A_h	Dark coloured horizon containing organic material. From a trace to 1 inch in depth. About 5.8 pH.
	A_e	Light brown eluvial (leached) horizon 3 - 6 inches in depth. pH about 5.9.
	AB	Transitional horizon between A and B. Usually only a trace in depth.
	B_t	Brown illuvial horizon, fairly hard, compact blocky structured. 12 - 24 inches in depth. About 6.8 pH.
	C	Parent material. 10 inches or more in depth. About 7.4 pH.
Moderately Fresh Site		Profile fairly well developed but shallower than the maximum on fresh sites.
Moderately Moist Site		Profile strongly developed. A_h usually present, A_e darker than on fresh sites, less colour contrast between inside and outside of aggregates of B horizon, incipient gley at bottom of the B or top of the C.
Moist Site		Profile strongly developed, A_h well developed, A_e shallow and dark in colour, no colour contrast between inside and outside of aggregates of B horizon, gley present in the B horizon.

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APPENDIX II

STAND DATA PER ACRE - all plots

Treatment	Plot #	No. of trees[1] R wS	No. of trees R tA	No. of trees [R + 10][2] wS	No. of trees [R + 10] tA	Basal area (sq.ft.) R wS	Basal area R tA	Basal area [R + 10] wS	Basal area [R + 10] tA	Total volume[3] (cu.ft.) R wS	Total volume R tA	Total volume [R + 10] wS	Total volume [R + 10] tA	Merch. volume (cords) R wS[4]	Merch. volume R tA[5]	Merch. volume [R + 10] wS	Merch. volume [R + 10] tA	Mortality in 10 yrs. Basal area wS	Mortality Basal area tA	Mortality Total Volume wS	Mortality Total Volume tA
Bertwell																					
Control	1	810	720	1260	500	9	60	31	78	71	1242	346	1726	0	12	0	19	0	14	0	282
Control	4	1190	830	2060	740	12	50	42	83	92	989	460	1744	0	7	0.2	16	0	2	0	21
50% hwds cut	2	330	780	1370	720	2	52	19	89	15	1038	172	2164	0	8	0	24	0	2	0	44
50% hwds cut	5	130	900	1000	760	0.7	53	11	85	4	1050	90	2057	0	8	0	22	0	5	0	95
100% hwds cut	3	70	-	770	-	0.7	-	20	-	5	-	180	-	0	-	0.4	-	0	-	0	-
100% hwds cut	6	100	-	870	-	0.5	-	21	-	3	-	186	-	0	-	0	-	0	-	0	-
Riding Mountain																					
Control	19	840	1900	950	1010	7	120	18	127	37	4110	164	3084	0	27	0	36	2	35	18	1078
Control	21	2370	1410	1820	850	16	100	31	98	144	2114	296	2187	0	19	0	24	3	20	21	308
100% hwds cut	20	1190	-	1450	-	11	-	44	-	80	-	443	-	0	-	0.8	-	0.5	-	4	-
100% hwds cut	22	1000	-	1430	-	9	-	36	-	72	-	355	-	0	-	0.4	-	0.4	-	3	-
Big River Nursery																					
Control	14	1110	1490	1320	990	24	107	50	139	194	1913	686	3696	0	21	0.8	42	0	12	0	265
100% hwds cut	13	340	-	420	-	11	-	46	-	110	-	683	-	0.2	-	6	-	0	-	0	-
Montreal Lake																					
Control	16	520	750	630	840	20	50	54	77	198	1220	1130	2028	0.8	12	10	23	0.9	5	9	119
Control	17	260	1020	360	1250	7	72	21	105	87	1783	355	2971	0.2	18	3	35	1	8	12	169
100% hwds cut	15	190	-	490	-	6	-	26	-	66	-	342	-	0.2	-	2	-	0	-	0	-
100% hwds cut	18	400	-	550	-	15	-	39	-	173	-	558	-	0.8	-	4	-	2	-	16	-
Candle Lake - area 1																					
Control	1	110	590	110	n.d.[6]	4	84	13	n.d.	41	2128	183	n.d.	0	26	2	n.d.	0.1	n.d.	1	n.d.
Control	3	170	700	170	n.d.	3	84	13	n.d.	29	2143	171	n.d.	0	26	1	n.d.	0	n.d.	0	n.d.
100% hwds cut	2	60	-	70	-	2	-	12	-	16	-	185	-	0	-	2	-	0	-	0	-
100% hwds cut	4	80	-	80	-	1	-	13	-	11	-	175	-	0	-	2	-	0	-	0	-
Candle Lake - area 2																					
Control	5	690	470	950	n.d.	19	103	40	n.d.	204	2713	555	n.d.	0.2	33	2	n.d.	2	n.d.	25	n.d.
Control	7	690	460	n.d.	n.d.	17	92	n.d.	n.d.	186	2419	n.d.	n.d.	0	29	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
100% hwds cut	6	1070	-	1290	-	33	-	73	-	387	-	977	-	0.8	-	5	-	4	-	58	-
100% hwds cut	8	460	-	530	-	16	-	55	-	167	-	658	-	0	-	7	-	0.5	-	5	-
Big River																					
Control	9	990	540	900	470	52	80	72	97	828	2253	1391	2848	4	27	11	34	2	16	17	466
Control	11	640	510	620	450	32	82	48	103	428	2319	852	3421	0.8	24	6	43	0.3	11	2	298
100% hwds cut	10	1010	-	720	-	60	-	92	-	989	-	1783	-	4	-	17	-	14	-	211	-
100% hwds cut	12	840	-	800	-	41	-	75	-	610	-	1404	-	2	-	13	-	15	-	249	-
Reserve																					
Control	1	210	410	210	370	17	105	28	115	261	3063	464	3706	1	38	4	46	0	7	0	209
Control	4	40	400	60	320	2	111	5	123	36	3244	81	4042	0.4	38	0.7	48	0	12	0	320
50% hwds cut	2	190	210	190	170	27	44	43	52	452	1244	866	1505	5	15	9	18	1	4	22	108
50% hwds cut	6	110	230	110	200	25	43	35	47	442	1172	742	1319	5	14	8	16	0.9	6	12	179
100% hwds cut	3	280	-	280	-	30	-	68	-	472	-	1323	-	4	-	14	-	0	-	0	-
100% hwds cut	5	100	-	90	-	28	-	51	-	499	-	1157	-	5	-	13	-	1	-	19	-

[1] Ingrowth has occurred in the spruce since treatment.
[2] R, [R + 10] - Time of release and 10 years after release.
[3] Interpolated Volume Tables 1941, Canada, Dept. Mines and Resources, Lands, Parks and Forests Branch. Dom. For. Serv., Misc. Series 3.
[4] Peeled - 1 ft. stump, 3-inch top ib. Formclass Volume Tables. Table 177.,1948, Canada, Dept. Mines and Resources.
[5] Peeled - 1 ft. stump, 3-inch top ib. 1934. Volume, Yield and Stand Tables for tree species in the Lake States. Univ. Minn. Tech. Bull. 39.
[6] The aspen and spruce on some plots at Candle Lake received wind damage during the 10-year period.

NATURAL REGENERATION OF WHITE SPRUCE UNDER SPRUCE-ASPEN SHELTERWOOD, B-18a FOREST SECTION, ALBERTA

by
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Résumé en français

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ABSTRACT

This report examines growth and survival of white spruce seedlings after scarification under a spruce-aspen shelterwood. In 1959, nine 10-acre plots were scarified with a 10-foot, six-toothed bulldozer blade. Three site groups were sampled - dry upland, moist transition, and wet bottomland.

Scarification produced a receptive seedbed and the residual stand provided an adequate natural seed supply. White spruce regeneration status was raised from 12% mean milliacre stocking in 1959 to 43% in 1963, with 44% stocking on dry, 47% on moist, and 38% on wet sites. Failure of regeneration because of seedbed flooding was common on wet sites, but only 10% of scarified spots on moist sites were affected. Initial seedling mortality was high and was most severe overwinter. Survival improved after the first two growing seasons. Vegetative competition affected seedling height growth on all sites. Mineral soil was the most productive seedbed on scarified areas and rotten wood on undisturbed areas.

RÉSUMÉ

L'auteur analyse la croissance et la survie des semis d'Épinette blanche (*Picea glauca*) après certaines opérations de scarifiage en peuplement d'abri composé d'Épinettes et de Trembles (*Populus tremuloides*). En 1959, neuf lopins de 10 acres ont été scarifiés au bulldozer muni d'une lame à six dents. Trois groupes de stations ont été échantillonnés: collines sèches, stations de transition humides et basses terres très humides.

Le scarifiage rendit le sol propice à la régénération et le peuplement résiduel fournit suffisamment de graines. Le reboisement des Épinettes blanches passa de 12% par milli-acre, en moyenne (en 1959), à 43% en 1963 (i.e. 44% en terrain sec, 47% en lieu humide et 38% en sol très humide). En terrain bas et très humide, la régénération allait souvent mal parce que les graines et puis les semis étaient noyés; cependant, seulement 10% du sol scarifié était inondé dans les stations intermédiaires (humides). Le taux de mortalité des tout jeunes semis s'avérait élevé, surtout pendant le premier hiver. Le taux de survie augmenta après deux saisons de croissance. La croissance en hauteur des semis était partout retardée par la végétation concurrente. C'est le sol minéral qui constituait le milieu le plus propice en terrain scarifié, et le bois pourri en terrain laissé intact.

NATURAL REGENERATION OF WHITE SPRUCE UNDER SPRUCE-ASPEN SHELTERWOOD, B-18a FOREST SECTION, ALBERTA

by

J.C. Lees[1]

INTRODUCTION

Management of spruce-aspen stands in the Slave Lake (Alberta) Forest by partial cutting with individual tree-marking began in 1951. Research into the selection of the most suitable harvest-cutting methods and testing of mineral soil seedbeds for white spruce regeneration were initiated in that year. Scarification consisted in exposing mineral soil by removing the surface organic-soil horizons with hand-tools on small 5-foot-square patches. White spruce[2] (*Picea glauca* (Moench) Voss) germination and survival were compared on exposed and undisturbed seedbeds. Mineral-soil seedbeds gave the best regeneration results (Quaite, 1956; Lees, 1963). In 1952, studies of mechanical seedbed scarification under a range of residual stand densities were initiated. Here scarified strips were bulldozed to expose patches of mineral soil on 40 half-acre plots. Regeneration was successful on scarified patches but failed on the undisturbed and mounded spoil seedbeds (Lees, 1963). Removal of up to 65% of white spruce basal area in the mature mixed spruce-aspen stands resulted in increased growth of residual spruce, with no loss of wind-firmness (Smithers, 1959; Lees, 1963). As few as six parent spruce per acre constitute an adequate seed source (Quaite, 1956). Similar results have been obtained in regeneration and growth studies carried out in the Mixedwood forest section in Manitoba and Saskatchewan. Regeneration trials and a review of machine application in scarification are presented by Jarvis *et al.* (1966). Survival and growth of seedlings is affected by surface drying of the seedbed while the germinant roots are superficial (Eis, 1965), and subsequently by competition from ground vegetation, especially grasses (Waldron, 1966). Seedlings on cultivated seedbeds are better able to withstand limiting conditions of moisture and light (Sutton; 1968).

The study now being reported began in 1959, when more extensive machine scarification was carried out in stands that had been cut over for

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[2]Botanical nomenclature follows Moss (1959).

spruce sawtimber on an individual tree-marking basis in 1953 and 1954. Regeneration after cutting was inadequate. The object of the treatment was to raise white spruce regeneration stocking to acceptable levels and to test mechanical seedbed scarification over a wide range of soil-moisture conditions. The existing uniform shelterwood cutting in the Slave Lake Forest was used and was followed by mechanical scarification to create receptive mineral-soil seedbeds. The investigation then undertaken involved scarification on a range of sites, and support studies of subsequent white spruce seedling survival and growth. Scarification with a toothed bulldozer blade was completed in the summer months of 1959 in co-operation with the Alberta Forest Service. It is proposed to remove the remaining spruce overstory after seedlings are well established on the scarified ground. Unmerchantable trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.) stems remain as a deteriorating nurse stand. This report covers observations made during the early regeneration period 1959-64.

SITE DESCRIPTION

To investigate site-range application of the treatments, three major site groups[3] were sampled: dry upland, moist transition, and wet bottomland. Three homogeneous 10-acre plots were established on each site group. Descriptions of the sites follow:

Dry Upland

These are well-drained[4] sites occurring along ridges and on upper slopes. Stony, sandy loams and clay loams are predominant. Parent material is calcareous. The litter and humus layer (L-H) is shallow, 1 to 4 inches in depth. In a total moisture-regime range[5] from 0 (very dry - sandy aeolian knolls) to 9 (wet - deep bog), these sites lie in the 2 to 3 moisture-regime range. The vegetation is a dry grass-low shrub-herb type. The mean residual stand amounted to 134 square feet of basal area per acre with 31% spruce and 69% hardwoods. Stand age was around 100 years for all species. In 1959, pretreatment milliacre stocking to white spruce was 10%.

Moist Transition

This site group has a moisture-regime range of 4 to 6 occurring on middle slopes and flats and is moderately well drained, often associated with lateral water movement. These deep, well-developed, Grey Wooded soils

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[3]Information for physiographic sites follows Duffy (1965).

[4]Horizon nomenclature and soil-moisture status follow usage in Classification of Canadian Soils (National Soil Survey Committee of Canada, 1963).

[5]Moisture regimes after Horton and Lees (1961).

are fine-textured, mainly clay loams and clays. Litter and humus layers (L-H) range from 4 to 12 inches in depth. Ground vegetation is heavy, with abundant shrubs and grasses. Deep moss cover is common under groups of pure spruce. Dense tall grasses, especially *Calamagrostis canadensis* and *Elymus innovatus*, typify these sites.

Mean residual stands on the sample areas comprised 123 square feet of basal area per acre, with 55% spruce and 45% hardwoods. Before treatment, milliacre stocking to white spruce regeneration was 14%.

Wet Bottomland

This group has a moisture-regime range of 6 to 7 on lower slopes and wet depressions, with an extreme of moisture regime 8 where bordering deep bogs. These sites are common in the gently rolling terrain and support vigorous white spruce stands. Soil profiles show very deep litter and humus development (L-H), with layers from 12 to 36 inches in depth overlying a shallow but sharply defined Ae horizon. Below this are gleyed massive clays. The site is poorly drained. Ground vegetation includes abundant grasses, sedges, and horsetails. Residual-stand mean basal area per acre was 124 square feet with 38% spruce and 62% hardwoods. Pretreatment milliacre stocking to white spruce regeneration was 11%.

MAIN TREATMENT

Methods

Scarification

The TD-9 tractor was equipped with a 10-foot scarification blade fitted with six 12-inch teeth of 3/4-inch steel. These teeth were welded below the blade bit against the reinforcing webbing (Figures 1 and 2). Fourteen acres per 8-hour day were scarified. Alternate lowering and raising of the blade created scarified spots of approximately 11 x 15 feet (Figure 3). The blade bit scalped off all surface organic matter and most of the shallow Ae horizon. The teeth penetrated to the Bt horizon, bringing some of the finer-textured soil to the surface. This, it was hoped, would provide a receptive moisture-conserving seedbed having a variety of micro-seedbed types and relative freedom from drainage problems. The cost of the scarification was $10 per acre, which was paid by the Alberta Forest Service.

Site differences had a marked effect upon the ease of tractor operation. The frequency of mineral-soil exposure on milliacre quadrats in 1963 was 29% exposure on dry sites, 24% on moist sites, and 22% on wet sites. Scarification of dry sites proceeded most rapidly, although large boulders occasionally broke teeth from the bulldozer blade. The operation was most costly and least efficient on wet sites, where traction is poor. To reach mineral soil a deep gouge is created, which often fills with water. Characteristically uneven distribution of suitable seedbeds created on these

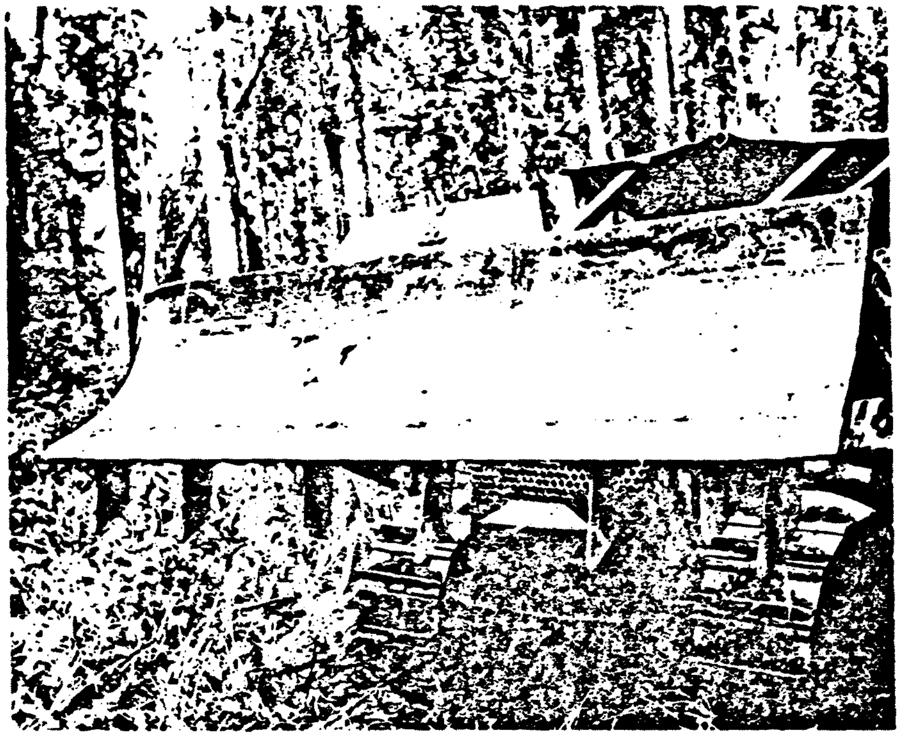

Figure 1 (above). View of tractor and six-toothed blade.

Figure 2 (left). Detail of scarification teeth.

Figure 3. Scarified seedbed - moist site.

wet sites is thus related to the depth of the organic horizons and the difficulties of machine operation. Similarly, damage to residual stems varied with machine maneuverability. Wherever necessary, hardwoods rather than spruce were pushed down. A survey of damage revealed fewer than 10 butt-scarred spruce stems per acre.

Regeneration Assessment

Stocking to white spruce regeneration was assessed in 1963 on 100 milliacre quadrats laid out systematically in two strips across the scarification pattern on each 10-acre plot. Within each strip were units of 10 contiguous quadrats 1 chain apart. On a total of 900 quadrats, data were collected in accordance with the following:

1. Scarification (any quadrat was classed as scarified provided it contained at least one square-foot patch of exposed mineral soil)
2. Stocking to white spruce seedlings
3. Height of the tallest white spruce seedling
4. Leader length of the tallest white spruce seedling
5. Rooting medium of the tallest spruce seedling - five classes
   a) mineral soil
   b) duff
   c) rotten wood
   d) moss
   e) stump

6. Vegetative competition in relation to the tallest white spruce seedling - three classes
   a) light - side competition only
   b) moderate - side and some overtop
   c) heavy - mostly overtop competition

Results

Regeneration status, 1963, is presented in Table 1.

TABLE 1. REGENERATION RESULTS, WHITE SPRUCE STOCKING, 1963*

Site	Percentage quadrats scarified	Percentage milliacre stocking			Average height tallest wS (inches)	Average leader length (inches)
		Overall	Unscarified	Scarified		
Dry upland	29	44	28	85	2.9	1.1
Moist transition	24	47	34	94	2.8	1.0
Wet bottomland	22	38	27	75	2.3	0.8
Mean	25	43	30	85	2.7	0.97

*Based on 900 milliacre quadrats.

On all sites regeneration may now be considered satisfactory. Scarification has raised overall spruce regeneration stocking from 12% in 1959 to a mean of 43% in 1963 (Table 1). The effect of scarification treatment is significant (1% level). Mean stocking on scarified ground is 85% versus 30% on unscarified ground. The differences in stocking values due to site effects alone are not significant. The distribution of regeneration is patchy, however, on wetter sites, because of the poor distribution of scarified seedbeds and because of flooding damage.

Variation in seedling height growth by vegetative competition and site classes is shown in Table 2. The differences in mean leader lengths between competition classes are significant (5% level): light competition, 1.1 inches; moderate competition, 1.07 inches; heavy competition, 0.85 inch. On all sites light vegetation cover allows greatest mean height development. The poorest height growth has occurred on wet sites. Improved soil drainage is reflected in greater seedling growth.

Rotten wood is the most productive seedbed on the unscarified quadrats, especially in the wet areas, where it provides a raised moisture-conserving habitat (Table 3). It also supports 8 to 12% of the tallest seedlings on scarified quadrats. Disturbed duff seedbeds, otherwise very droughty, support 25% of the tallest seedlings on wet sites. Mineral soil is the most productive seedbed on scarified quadrats.

TABLE 2. VEGETATIVE COMPETITION AND HEIGHT GROWTH OF WHITE SPRUCE SEEDLINGS ON SCARIFIED QUADRATS, 1963

	Vegetative competition*	Percentage of quadrats	Average height tallest wS (inches)	Average leader length (inches)
Dry upland	Light	8	2.9	1.2
	Moderate	33	2.6	1.2
	Heavy	59	1.9	0.8
Moist transition	Light	14	3.1	1.2
	Moderate	19	2.9	1.1
	Heavy	67	2.7	1.0
Wet bottomland	Light	12	2.4	0.9
	Moderate	19	2.3	0.8
	Heavy	69	2.3	0.8

*Competition:
Light - side competition only.
Moderate - side competition with some overtop.
Heavy - mostly overtop.

TABLE 3. PERCENTAGE OCCURRENCE OF TALLEST WHITE SPRUCE SEEDLINGS ON FIVE SEEDBED TYPES

Site	Seedbed				
	Mineral soil	Duff	Rotten wood	Moss	Stump
Dry upland					
Scarified	68	66	12	4	Nil
Unscarified	24	25	39	12	Nil
Moist transition					
Scarified	71	13	8	8	Nil
Unscarified	1	32	49	18	Nil
Wet bottomland					
Scarified	55	25	10	10	Nil
Unscarified	2	9	63	25	1

SUPPORTING STUDIES

Early Survival

A subsample of nine quarter-milliacre quadrats was randomly located on each site. In 1959, 50 white spruce seeds were fall-sown on each quadrat. The original germinants were permanently marked with plastic toothpicks. Survival tallies were made in June and September of 1960, 1961, 1962, and 1963 to assess overwinter and growing-season mortality.

The results are shown for each site in Table 4. The initial germination, 1960, includes the abundant natural seedfall of 1959. The Table 4 values represent only this original seedling population. Overwinter mortality was high for all years. Most of the dead seedlings were found still standing the following spring. Snow mould (*Phacidium* spp.) may have caused this mortality. Major factors contributing to summer mortality are thought to be heat and drought. Damping-off fungi may also have contributed.

Seedbed Deterioration

Each year a further 18 quadrats were fall-sown with 50 seeds on each site group, nine of the quadrats being on the original scarified seedbeds and nine on seedbeds freshly scarified with hand-tools. Survival of germinants was tallied at the start and completion of the growing season each year, and performances on the seedbeds were compared. This control test provided an evaluation of the rate of deterioration of seedbed receptivity on the original scarified ground and a measure of the rate of vegetation encroachment.

The germination shown in Table 5 includes the natural seedfall of each year. Receptivity markedly decreased in 1962, and the very low 1963 germination on the original 1959 scarification indicates that the seedbed is no longer receptive.

Seedbed Flooding

Scarified-seedbed flooding was first observed in the spring of 1960. It was most prevalent on wet sites and of less importance on moist sites. Scarified seedbeds on wet sites, when inundated, remained flooded long enough for the flooding to kill any seedlings under water. On moist sites inundation was intermittent and ended, in all cases, in August. To assess the severity of inundation, all three moist-site plots were selected for survey of frequency and distribution of flooding. All scarified spots on moist sites were visited in 1960 and 1961 at intervals throughout the growing season, and the locations of flooded spots with standing water were mapped. These records are summarized in Table 6. The percentage of scarified spots flooded on each 10-acre plot is presented together with the frequency of inundation.

TABLE 4. SURVIVAL OF 1959 SEEDLINGS* (NINE SEEDSPOT SAMPLES PER SITE)

Site	Total germ. 1960 Num.**	1960 Sept. Num. (%)	1961 June Num. (%)	1961 Sept. Num. (%)	1962 June Num. (%)	1962 Sept. Num. (%)	1963 June Num. (%)	1963 Sept. Num. (%)
Dry upland	1,030	139(14)	110(11)	91(9)	60(6)	56(5)	56(5)	55(5)
Moist transition	2,285	1,599(70)	1,067(47)	954(42)	372(16)	354(16)	243(11)	235(10)
Wet bottomland	1,270	785(62)	488(38)	402(32)	251(20)	222(17)	159(13)	154(12)
Mean	1,528	841(49)	555(37)	482(28)	228(14)	211(13)	153(10)	148(9)

*Permanently marked.

**These figures include natural seedfall, 1959.

TABLE 5. YEARLY SURVIVAL FIGURES FOR WHITE SPRUCE ON ORIGINAL (1959) AND FRESH SCARIFICATION: NUMBERS GERMINATING DURING SEASON, AND SURVIVAL

Site	1961				1962				1963			
	Original seedbed		Fresh seedbed		Original seedbed		Fresh seedbed		Original seedbed		Fresh seedbed	
	Number		Number		Number		Number		Number		Number	
	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.
Dry upland	21	9	14	1	9	4	127	76	Nil	Nil	48	31
Moist transition	57	40	45	29	50	40	281	188	11	9	24	21
Wet bottomland	42	16	64	17	23	15	91	39	6	5	42	25
Mean	40	22	41	16	27	20	166	101	6	5	38	26

TABLE 6. FLOODING FREQUENCY FOR SCARIFIED SPOTS ON MOIST SITES, 1960 AND 1961

	Number and percentage* of scarified spots flooded							Frequency of flooding percentage* of scarified spots			
1960	May 30 Num.(%)	June 13 Num.(%)	June 23 Num.(%)	June 29 Num.(%)	July 6 Num.(%)	Aug. 3 Num.(%)		Not flooded	Less than three times	Three times	Four times or more
Mean	59(13)	19(4)	58(12)	9(2)	14(3)	0(0)		87	8	3	2
1961	June 19 Num.(%)	July 6 Num.(%)	July 10 Num.(%)	July 19 Num.(%)	July 29 Num.(%)	Aug. 3 Num.(%)	Aug. 7 Num.(%)				
Mean	1(0.2)	21(4)	66(14)	12(3)	66(14)	4(1)	1(0.2)	86	9	3	2

*Percentages based on mean density of 465 scarified spots per 10-acre plot.

Seedling survival was examined on a small subjective sample of flooded and control scarified spots. Flooding reduced the mean numbers of seedlings on 20 quarter-milliacre quadrats in 1960 from 62 to 19. Seedlings germinating on the margins of flooded seedbeds survived and grew vigorously. An example of seedbed flooding is shown in Figure 4.

In a subsequent laboratory test, total immersion of white spruce seedlings for 14 days resulted in 100% mortality of 1- and 2-year-old seedlings. A small percentage survived immersion for shorter periods (Lees, 1964b). Since the duration of inundation is most important, areas of deep humus accumulation on wet sites should be avoided in tractor scarification to prevent formation of flooded 'basins.' Flooding, however, is not such a serious threat to seedling survival on other than the wetter areas.

Figure 4. Flooded seedbed.

Seed Supply

An annual estimate of seed supply was obtained ocularly on a half-chain sample strip across each 10-acre plot. The percentage of cone-bearing live crowns was recorded for each spruce stem on these strips. Good seed years occurred in 1959 and 1961. Only a few trees carried cones in 1960, 1962, and 1963. In the years following good cone crops, infestations of cone worm (*Dioryctria abietivorella* Crt.), seed moth (*Laspeyresia youngana* Kearf.), and cone rust (*Chrysomyxa pirolata* Wint.) increased. Larvae affected 30% of the cones sampled in 1962. Estimates of seed supply are presented in Table 7. Regeneration assessed in 1963, therefore, originated mainly in 1959 with some seeding-in in 1961.

TABLE 7. WHITE SPRUCE SEED SURVEY

Site	Mean percentage of live crown with cones				
	1959	1960	1961	1962	1963
Dry upland	16	5 approx	22	Less than 5	Nil
Moist transition	17	"	25	"	Nil
Wet bottomland	18	"	31	"	Nil

DISCUSSION AND CONCLUSIONS

The 1963 regeneration assessment shows that major requirements for successful natural regeneration of white spruce have been satisfied largely by shelterwood cutting and scarification. The overhead residual stand provided adequate seed and a sheltered environment for germination and early survival of spruce seedlings. Scarification provided a satisfactory seedbed, which diminished in receptivity over four growing seasons. In summary:

1. Regeneration stocking in 1963 was satisfactory and amounted to 43% on a milliacre-quadrat basis. Stocking to spruce on scarified seedbeds was 85% and on unscarified seedbeds 30%.
2. The poorest height growth occurred on wet sites.
3. Vegetative competition was heaviest on wet sites where grasses were the most serious competitors.
4. The height growth of seedlings was significantly affected by vegetative competition.
5. Mineral-soil seedbeds supported the greatest proportion of tallest seedlings on scarified quadrats. Rotten wood supported the greatest proportion on unscarified quadrats.
6. Heavy mortality of white spruce seedlings occurred in the first two years after scarification. Survival rates subsequently improved.
7. Overwinter mortality was greater than growing season mortality.
8. The receptivity of scarified seedbeds ceased after four growing seasons.
9. Flooding of scarified seedbeds was most frequent on wet sites and is a serious threat there to regeneration establishment.

The spruce overstory was removed on two of the three plots on each site during the 1966-67 winter logging season. Adequate snow cover protected regeneration against logging operations, and the use of existing (1953) skid trails, haul roads, and millsites minimized damage. The success of this early stage in natural regeneration under shelterwood is supported by the studies of Waldron (1966) in Manitoba. Removal of the residual stand, he recommends, should be carried out at the 2- to 3-year-old-seedling stage and over snow. Release of seedlings from vegetation competition, particularly on moist sites, will be necessary. Further research is needed into the interaction of vegetative competition and site and its effect on regeneration development.

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SITE FACTORS CONTRIBUTING TO THE SPRUCE REGENERATION PROBLEM IN ALBERTA'S MIXEDWOOD

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ABSTRACT: Soils in the Mixedwood Section are clayey and wet. White spruce regenerated under natural conditions when two major limiting conditions were met: a receptive seedbed of rotten wood or mineral soil from wind-thrown stumps, and freedom from severe competition from ground vegetation. Wildfire, hot enough to burn off organic surface horizons, was an important factor under natural conditions. In recent years, fire has been effectively controlled and the forest manager is unwilling to wait for gradual seeding-in on preferred seedbeds. Silvicultural treatments and results of experimental studies are reviewed and the course of future investigations if indicated.

INTRODUCTION

The spruce-aspen Mixedwood Section (B18a) of the Boreal Forest (Rowe 1959) extends from northeastern British Columbia in a decreasing strip to the southeast corner of Manitoba. It reaches its optimum development in the Province of Alberta, extending from south of Lesser Slave Lake, close to the geographical centre of the Province, to the North West Territories around Wood Buffalo Park. The spruce-aspen Mixedwood is typified by gently rolling topography, with abundant lakes joined by short, well-filled river channels. Typical of these are Lesser Slave Lake, the largest in Alberta; the Wabasca Lakes; Fawcett Lake; Calling Lake; Lac la Biche and Cold Lake in Alberta, and Meadow Lake in Saskatchewan; and the interlocking system of river channels which take these waters on to the Great Lakes, and via Lake Athabaska to the Arctic Ocean. Since the town of Slave Lake, for example, is roughly 1800 feet above sea level and the Arctic Circle is about 1800 miles away as the rivers flow, the drop-off is only about one foot per mile.

Climate in the region is typified by long, severe winters and short, hot summers with total annual precipitation around 18 to 20 inches, of which 15 inches falls as rain in the summertime. There are approximately 3-4 feet of winter snowfall.

Soils in the area are derived from tills dumped by two great ice sheets: the Cordilleran ice sheet moving from the Rocky Mountains southeastward, and the Keewatin ice sheet moving southwestward from the Arctic regions and joining in a tension zone around Barrhead, Obed and Edson, and are mainly fine textured silts and clays. They are generally poorly structured and have impeded vertical water drainage. Horizontal water movement within the profile is common at the interface of the various soil horizons, particularly at the interface of the organic and mineral soil horizons. Organic matter accumulates on the surface of heavy textured soils to a depth of 3 to 36 inches in the forested areas. Soils are typified by the Grey Wooded group, which occurs on more than 50 million acres in Alberta and is associated with approximately 40 million acres of organic soils (peat more than 12 inches deep). Series names assigned to the type are usually local names, and it is the Braeburn Orthic Grey Wooded soil (Odynsky, Wynnyk, and Newton: 1952) from which the moisture regime variations to be discussed are derived. Although these soils are often very moist to wet during the growing season, they support productive stands of white spruce (*Picea glauca* (Moench) Voss). Windblow is a hazard to the shallow rooted spruce trees characteristic of the Mixedwood.

Productive logging is not a problem since operations take place over frozen ground in wintertime. Logging, however, removes a very useful water pump, loss of which is manifest by an abrupt rise in the water table and a proliferation of vegetation, particularly grasses. Timber operations in the area are currently managed under a "Quota" system whereby established operators are entitled to a continuous supply equal to their best productivity over the previous six years, provided they assume responsibility for regeneration. However, they have the option of regenerating the cutover areas or paying a levy of $2.00 per thousand board feet logged to the Provincial Government. The Alberta Forest Service then assumes responsibility for regeneration.

CONDITIONS FOR REGENERATION

The distribution of white spruce as a component of the spruce-aspen Mixedwood complex is dependent on several major constraints: (1) an adequate seed supply, (2) a receptive seedbed, (3) a favourable microclimate, and (4) freedom from severe ground vegetation competition. In natural successional stages, the requirements for spruce regeneration are met largely on two distinct seedbed types: exposed mineral soil, and rotten wood - mineral soil from the upturned root plates of windblown stems and rotten wood from the shorter-lived hardwoods of the species mix. Mineral soil seedbeds occur only sporadically but, with the intimate mixture of spruce and aspen (*Populus tremuloides* Michx.), rotten hardwood seedbeds are fairly evenly distributed. A rotten wood seedbed is usually moisture-conserving on drier sites. On wet sites, the old logform is raised above the surrounding surface water, yet remains in good contact with it during short summer droughty periods. For several growing seasons a fallen log or broken stump resists colonization by lesser vegetation since such microsites are colonized by seedlings rather than perennating root-stocks that can quickly invade freshly exposed patches of mineral soil. The rotten log, receptive to conifer seed, moist, and resisting vegetation colonization, is the preferred spruce seedbed. When forests are undisturbed, the regeneration period is essentially continuous. Seedlings slowly filter in as gaps develop in the overwood and as receptive seedbeds are created.

Fire interrupts the progression to this climax state. In the past, wildfire was often hot enough to burn off the organic soil horizon, which otherwise effectively sealed off the site for spruce regeneration. Wildfires exposed mineral soil and promoted aspen suckering since the increased insolation raised soil surface temperatures and created the necessary environment to induce aspen roots to sprout. Spruce then seeded in from the unburned stand margin, although rotten wood remained the preferred seedbed. The aspen shelterwood was a favourable environment for survival and growth of spruce seedlings.

SILVICULTURAL PRACTICES TO PROMOTE REGENERATION

Wildfire is now intolerable in the Mixedwood and the forest manager is unwilling to wait 30 years or more to see productive spruce forests reestablished. Silvicultural treatments, if carefully applied, may restock cutover and burned over areas. A two-cut uniform shelterwood system with seedbed scarification after the first cut, has produced satisfactory stocking of natural seedlings and vigorous growth of planted stock (Lees 1970). Time of overstory removal must be adjusted to seedling development, especially height growth. Seedbed scarification with planting under immature aspen successfully utilizes the shelterwood concept.

Problems remain on wet sites on the poorly drained fine-textured soils. Machine scarification techniques are unsuccessful, and mineral soil seedbeds exposed with a bulldozer blade are subject to severe flooding at snow-melt and after heavy growing-season rains. Seedbed flooding can occur several times each growing season. Laboratory and controlled field testing, using trays of healthy seedlings, showed that 14 days' immersion are lethal for 2-year-old spruce seedlings (Table 1). Repeated shorter periods are also lethal. Analysis of individual tray data confirmed the significance of date of immersion during the growing season (Lees 1964, 1971).

TABLE 1. White spruce seedling survival by date and duration of immersion under field and laboratory conditions.

	Field test				Laboratory test
	Date of immersion				
Duration of immersion	June 30	July 30	August 13	Mean	
3½ days	84	92	96	90.7	64
7 days	74	88	90	84.0	34
10½ days	60	72	64	65.3	18
14 days	54	70	52	58.7	0
Mean	68	80	76		

Wetter areas have the most severe vegetation competition. Any treatment that improves these sites for spruce regeneration will also improve them for grasses, sedges, herbs and shrubs. Results from shelterwood study blocks have shown that spruce overstory removal (the second cut), which allowed more light to reach the seedbed and raise soil temperatures, resulted in severe vegetation competition. On cut blocks, stocking to spruce seedlings fell from 40 to 16 percent 10 years after cutting. Competition was most severe on the wetter areas. On uncut blocks, stocking remained at 33 percent but the shading and low temperatures, which controlled ground vegetation growth also held back height growth of spruce seedlings. Seedlings tallied 10 years earlier were still present, but their height growth was unsatisfactory and their vigor was poor. Ground vegetation cover, estimated by sighting on a checkerboard of 100 squares from a distance of 33 ft (Fig. 1) averages 74 per cent for cut blocks

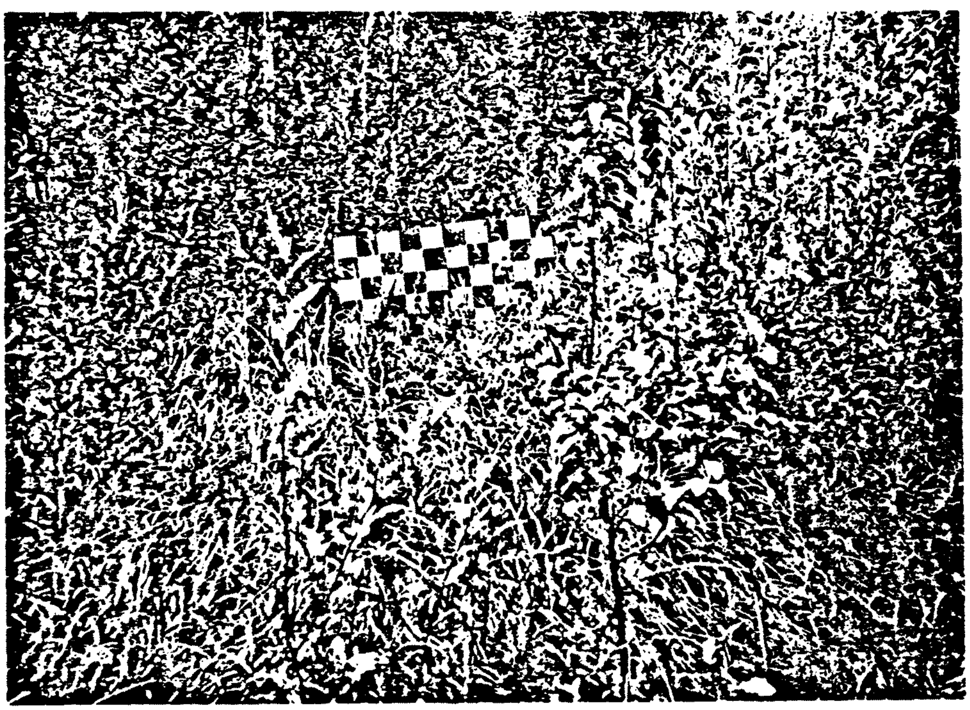

FIG. 1. Vegetation competition in cut-over Mixedwood stand, showing checkerboard used to estimate cover, in this case rated as 95 percent.

10 years after cutting and 48 per cent for uncut blocks (Table 2). Seedling height growth was reduced from 2 inches per year to only 1 inch per year.

TABLE 2. Vegetation competition, regeneration stocking and height growth of spruce seedlings in uncut and cut blocks after 10 years.

Parameter assessed	Site	Cut	Uncut
Vegetation Competition (percent cover)	Dry	70	51
	Moist	77	51
	Wet	76	44
	Mean	74	48
Regeneration Stocking (percent milliacre)	Dry	17	32
	Moist	17	43
	Wet	15	25
	Mean	16	33
Mean height of tallest seedling each quadrat (in)	Dry	15.5	9.4
	Moist	14.4	10.5
	Wet	14.2	7.4
	Mean	14.7	9.4
Mean leader length of tallest seedling each quadrat (in)	Dry	1.9	1.0
	Moist	2.2	1.4
	Wet	2.6	1.0
	Mean	2.2	1.2

FUTURE DEVELOPMENT

Before the forest manager invests in regeneration of the cutover areas, he must know how to assess the site for regeneration and potential productivity. To make this decision, he should be provided, by the ecologist with tools for a "regeneration chance" assessment, including a forest cover-type classification, a physiographic site assessment, a soil-series identification kit, a soil-moisture status measure, a vegatation-competition hazard rating, and a probing of depth to mineral soil. The combination of these assessments in many areas of the Mixedwood will result in "little chance" or "too expensive" rating.

The Stand Establishment Group at the Northern Forest Research Centre plans to investigate two main problems in the Mixedwood:

1. Regeneration of spruce on potentially productive forested wetlands.
2. Vegetation competition for spruce seedling and transplant growth.

The first study will establish the characteristics of preferred microsites for spruce on wetlands. A range of promising site preparation techniques designed to create a uniform distribution of 'safe' sites will be tested. Seedling responses to site improvement treatments will be measured, together with changes in soil physical characteristics, including soil moisture content, available pore space, aeration and water levels.

The second study will examine the interaction of severity of vegetation competition and seedling growth over a soil-moisture regime range, and will isolate some key competition components above and below ground surface level. In the greenhouse, competing species will be raised from seed collected in the field. Once competition treatments are established, conifer seedlings at different stages of development will be introduced.

A major objective is to develop a hazard rating for the forest manager to use in the assessment of regeneration chance. The site factors that will have the greatest influence on the forest manager's decision to regenerate white spruce in Alberta's Mixedwood are: landform; physiographic site; forest cover type and regeneration status; soil series; depth to mineral soil; moisture regime in the rooting zone, and vegetation competition. From a consideration of these, silvicultural prescriptions for regeneration may be written.

Further ecological research is required into the potential of spruce advance growth, the usefulness of existing balsam fir regeneration and the environment under immature aspen stands where white spruce grows satisfactorily.

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Aspen: Ecology and Management in the Western United States

Norbert V. DeByle and Robert P. Winokur, editors

Abstract

Information about the biology, ecology, and management of quaking aspen on the mountains and plateaus of the interior western United States, and to a lesser extent, Canada, is summarized and discussed. The biology of aspen as a tree species, community relationships in the aspen ecosystem, environments, and factors affecting aspen forests are reviewed. The resources available within and from the aspen forest type, and their past and potential uses are examined. Silvicultural methods and other approaches to managing aspen for various resources and uses are presented.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

FOREWORD

This book reviews the body of knowledge applicable to ecology and management of aspen on the mountains and plateaus of the interior western United States and, to a lesser extent, Canada. Alaska and Canada farther north and east are only incidentally considered. Much of the information on aspen is from other parts of North America. If something was pertinent to aspen in the West, it was included. The large volume of knowledge about aspen in the Lake States and eastern Canada is included only when it applies to the West.

This book is organized in four parts: PART I. THE TREE, reviews the biology of aspen as a species. PART II. ECOLOGY, reviews environments and community relationships. PART III. RESOURCES AND USES, considers the resources available in and from the aspen forest type. All of these provide the background for PART IV. MANAGEMENT, which discusses silvicultural methods and management approaches.

This is a reference and source book—a structured compilation and review of information. The authors have attempted to resolve contradictions in the literature, and have summarized each subject area to the best of their understanding. Gaps in knowledge are apparent as voids in this compilation; pure speculation is avoided. Because this publication will be used as a reference, each chapter is fairly self-contained. As a result, there is some repetition among chapters, with a different content and focus in each.

The latest available information has been included wherever feasible. However, as aspen research continues, new findings may differ from those presented here. Nevertheless, this book should provide a foundation upon which new research can build.

A compilation of this nature and size would not be possible without the able assistance of many people. Each of the authors deserves a special thanks for searching the literature, interpreting and summarizing it, and then writing chapter(s) that fit the style and objectives of this volume.

John R. Jones began this work several years ago, and developed the basic organization of this publication. He amassed a wealth of aspen literature and wrote the first drafts of all chapters that bear his name as an author. Later revisions, updates, and sometimes extensive rewriting of these chapters by others, as well as preparation of new chapters resulted in additional authorship credit. Thanks John, for getting us started on this needed publication!

More than 40 people technically reviewed chapters of this volume. George Schier of the Intermountain Forest and Range Experiment Station, and Burton Barnes of the University of Michigan, provided especially detailed and useful critiques of several chapters. Wayne Shepperd of the Rocky Mountain Forest and Range Experiment Station provided valuable review and revision of most of the chapters in PART IV. MANAGEMENT, consistent with the latest available information. Dean Einspahr at the Institute of Paper Chemistry also was very helpful. Revision of each chapter after high-quality technical review markedly improved this work. We greatly appreciate the contribution of all reviewers, whether or not their names are mentioned.

Special thanks go to Delloris M. Cade, Editorial Assistant at the Rocky Mountain Forest and Range Experiment Station, who spent countless hours reviewing and researching the hundreds of literature citations, and cross-checking them with each chapter, and copy editing and proofreading the typeset galley proofs. Her diligent efforts greatly improved the quality of this book, and speeded its publication.

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Aspen: Ecology and Management in the Western United States

Norbert V. DeByle and Robert P. Winokur, editors[1]

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Aspen: Ecology and Management in the Western United States

Norbert V. DeByle and Robert P. Winokur, editors

INTRODUCTION

Norbert V. DeByle and Robert P. Winokur

Quaking or trembling aspen (*Populus tremuloides* Michx.) is the only aspen in western North America. Therefore, in this part of the continent, it is commonly and correctly referred to simply as "aspen". Throughout much of the interior West, it is the only upland hardwood. Aspen occupies millions of acres, and, in some states, it is the most widespread forest type.

This review begins with the description by Charles Sprague Sargent (1890):

> "In the West and Southwest, Aspen grows on the high slopes of mountains and along the banks of streams, and is usually not large, although individuals a hundred feet tall sometimes occur.... A graceful tree with its slender pendulous branches, shimmering leaves, and pale bark, the aspen enlivens the spruce forests of the north, and marks steep mountain slopes with broad bands of color, light green during the summer and in autumn glowing like gold against backgrounds of dark cliffs and stunted pines."

Several major publications about aspen ecology and management predate this one. Most notable are: "Aspens: Phoenix Trees of the Great Lakes Region" by Graham et al. (1963), "Aspen: Symposium Proceedings" published by the USDA Forest Service (1972), and "Quaking Aspen: Silvics and Management in the Lake States" by Brinkman and Roe (1975). All deal specifically with the aspen east of the Great Plains. Aspen was also given major consideration in "Growth and Utilization of Poplars in Canada" by Maini and Cayford (1968). For the western United States, Frederick Baker's (1925), "Aspen in the Central Rocky Mountain Region," remains a rich source of information, although it is clearly outdated in several respects.

The aspen-dominated forest has multiple values. It is truly a multiple-use type. In the West, it is a producer of forage for domestic livestock as well as food and cover for many wildlife species. It produces wood fiber in abundance, but has been grossly underutilized in this respect. Yields of high-quality water are greater from aspen forests than from some other forest types on similar sites in the western mountains. Esthetically, aspen is very appealing, especially when juxtaposed as groves within a mosaic of other vegetation types on the landscape. It attracts recreationists. Aspen forests also provide fire protection by acting as living firebreaks for the more flammable coniferous types.

Perhaps because aspen has not been economically appealing to wood-using industries in the West, there has been little urgency to learn the details of aspen ecology and to design effective management methods. Aspen research in the West has been somewhat piecemeal, with emphasis on specific attributes, such as forage production or water yield. However, both the utilization and research situations are changing. The sheer amount of aspen, its rapid regeneration by root sprouts after fire or logging, its rapid growth, and other characteristics that make the species distinctive are stimulating greater interest. Increasing demands are being made for the goods and services the aspen type can provide. These demands have caused forest managers and researchers, particularly in Colorado, Utah, Arizona, and New Mexico, to express a need for a synthesis of the available ecological and management information applicable to the western aspen type. This publication has been prepared in response to that increasing need.

PART I. THE TREE

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Page

PART II. ECOLOGY

PART IV. MANAGEMENT

Page

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COJFRC Symposium
Proceedings O-P-9

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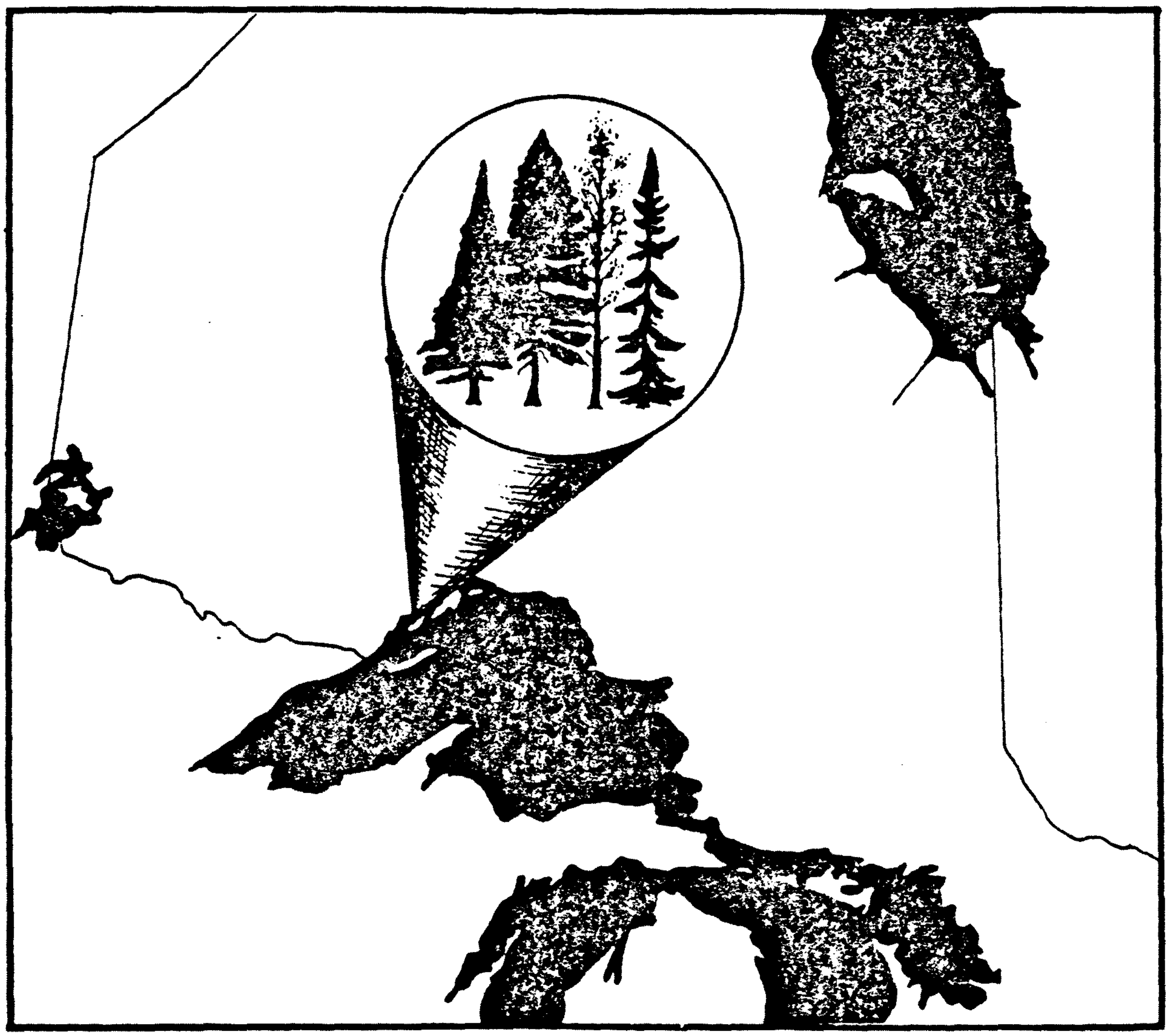
Boreal Mixedwood Symposium



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BOREAL MIXEDWOOD SYMPOSIUM

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CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

APRIL 1981

FOREWORD

The Boreal Mixedwood Symposium, cosponsored by the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre (Canadian Forestry Service), was held from 16 to 18 September, 1980 in Thunder Bay, Ontario. The symposium was the ninth in a continuing series of symposia initiated in 1972 by the Canada-Ontario Joint Forestry Research Committee (COJFRC). The main purpose of the series is to provide a forum for discussion for researchers, provincial and industrial forest managers, and educators in the field of forestry in Ontario. Forestry officials from outside the province are invited as well.

The purpose of the Boreal Mixedwood Symposium was twofold: to review current management procedures and problems in Ontario's boreal mixedwood forests[1], and to stimulate interest in, and improvement of, the management of this difficult and complex forest type.

About 160 delegates were welcomed by Mr. J.H. Cayford, Acting Director General, Research and Technical Services, Canadian Forestry Service and current Chairman of COJFRC, and by Mr. G.A. McCormack, Assistant Deputy Minister for Northern Ontario, Ministry of Natural Resources. The formal program was chaired by Mr. W.K. Fullerton, Director, Forest Resources Branch, Ministry of Natural Resources.

Boreal mixedwood management deals with five major Ontario species and covers a broad range of subject areas; hence, it was obvious that not all facets of the topic could be covered in a three-day symposium. Six general areas that had not been discussed in depth in previous symposia of this series were therefore selected for broad coverage. Twenty-four papers were presented and a conscious attempt was made to introduce the ecosystem concept and to include management purposes other than fibre utilization (e.g., wildlife). The discussion which followed the papers was recorded and paraphrased and is presented at the end of each section.

A digest of each paper was circulated to delegates about six weeks before the symposium and most of the 24 papers were distributed to session chairmen before the symposium. Members of the planning committee wish to thank all authors for their cooperation in meeting deadlines.

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[1] *Defined on page 1 of these proceedings.*

The field trip on 17 September to the Fort William and Shebandowan management units was intended to demonstrate principles, practices and problems described during the indoor sessions, and to show delegates examples of conditions and management options in the boreal mixedwood forest. Delegates found the walking trail a welcome change from formal meetings.

Members of the planning committee wish to express their appreciation to staff of the Shebandowan and Fort William management units, especially Ron Calvert and Karl Latt, and Terry Casella, Bob Forslund and Gerry Page, technical staff, Northern Forest Research Unit, OMNR, Thunder Bay for organizing the field trip and for operating the recording and projection equipment during the presentation of papers. Blake MacDonald and Del Parker, who conducted the field trip, and Geoffrey Pierpoint, who provided soil and site descriptions, deserve special recognition. We also acknowledge our indebtedness to Nancy Knudsen, Northern Forest Research Unit, for her help in handling correspondence and registrations.

It is to be hoped that deliberations during the symposium not only improved our understanding of this difficult to manage section of the Boreal Forest, but also enhanced the working relationships between researchers and forest managers. We have a common goal in attempting to improve our utilization of this resource for all purposes; it is only that we approach this goal from different perspectives. Let us make a sincere attempt to complement one another's efforts in order to reach our common goal.

TABLE OF CONTENTS

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TABLE OF CONTENTS (continued)

(continued)

TABLE OF CONTENTS (concluded)

Page

SESSION VI: FOREST MANAGEMENT CONCERNS:
CONTROL OF VEGETATION

267
VP-X-127

POPLAR UTILIZATION SYMPOSIUM

Environment Canada / Environnement Canada
Forestry Service / Service des Forêts

EDITED BY R.W. NEILSON
AND C.F. McBRIDE

POPLAR UTILIZATION SYMPOSIUM

PROCEEDINGS

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TABLE OF CONTENTS

FOREWORD

The 1974 Poplar Utilization Symposium was held in response to the high level of interest in poplars in western Canada. With provincial governments and industry showing increased attention to this largely untapped resource, the time was appropriate to discuss current utilization opportunities and problems related to the increased use of poplars.

Previous poplar symposia were held in Edmonton in 1966 (sponsored by the Canadian Department of Industry, Trade and Commerce) and at Harrison Hot Springs, B.C., in 1967 (sponsored by the Canadian Forestry Service) to review and discuss the status of poplars in Canada. The interest in poplars is understandable when it is realized that only the spruces, pines and true firs exceed the poplars in volume in Canada. Poplars comprise about 9 percent of the merchantable timber in Canada. In spite of this, very little poplar wood has been used in the past.

For the entrepreneur contemplating the utilization of poplar, the immediate problem is firstly to assess stand quality and then to determine the products for which poplar is best suited, what techniques are required to produce these products, and under what set of economic conditions a poplar-using enterprise is likely to be viable. The Canadian Forest Products Laboratories have undertaken to answer some of these questions and in 1970, the Western Forest Products Laboratory initiated a series of studies aimed at increasing our knowledge of poplar utilization. These took the form of sawmill-recovery, kiln-drying, pulping and wood-chip deterioration studies. The Eastern Forest Products Laboratory also began sawmill-recovery and kiln-drying studies about this time.

The 1974 symposium was planned to bring together the results of several recent laboratory studies, provincial attitudes to poplar management, wood-property data and, most importantly, the experience of some industrial poplar users and consultants. The emphasis is on utilization, realizing that in this country there exists a ready-made poplar resource, whose management can move forward only as the resource is utilized.

273

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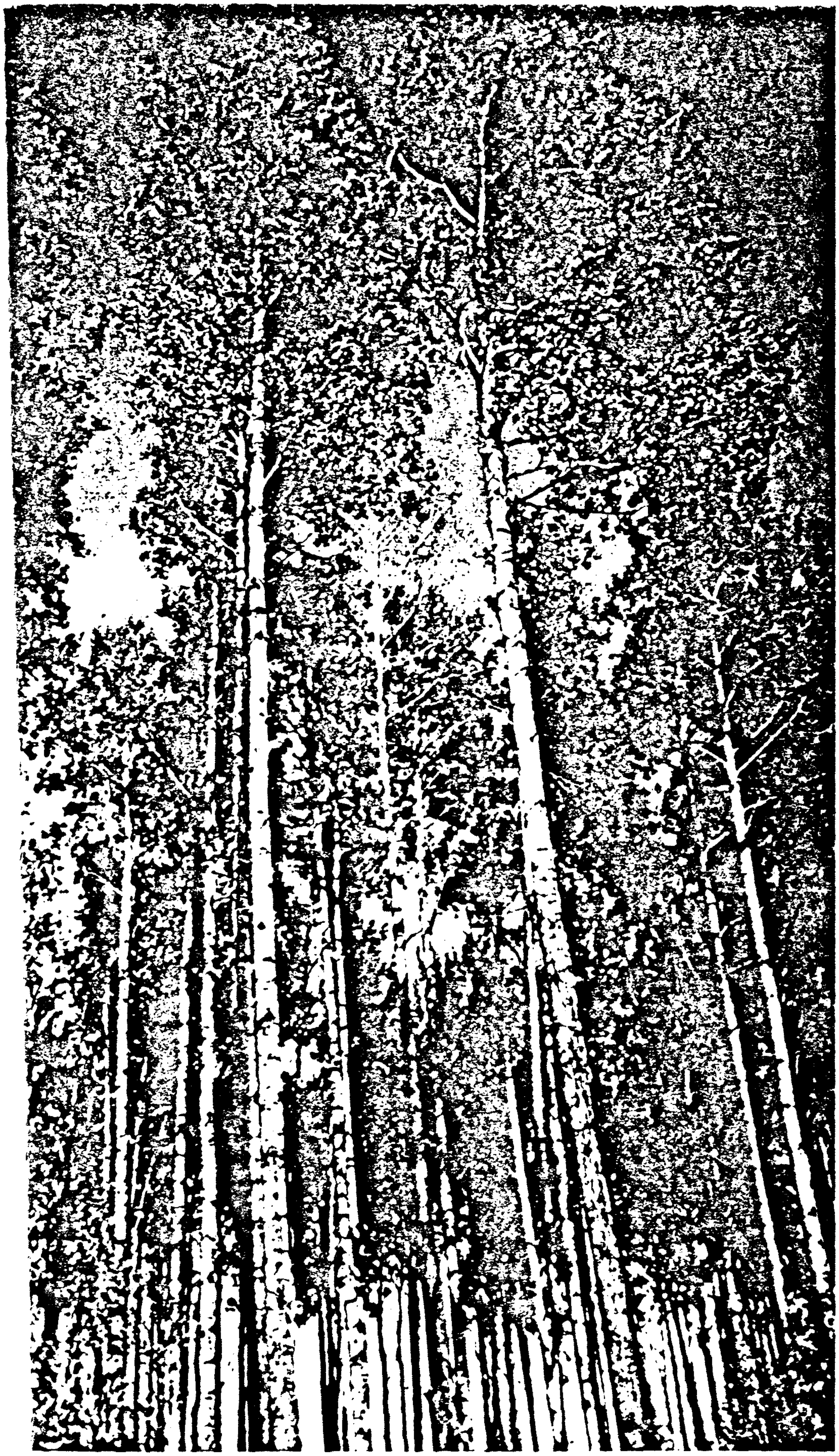

GROWTH UTILIZATION POPLARS CANADA

J. S. MAINI
J. H. CAYFORD

PARTMENT OF FORESTRY AND RURAL DEVELOPMENT

GROWTH AND UTILIZATION OF POPLARS IN CANADA

Editors: J. S. Maini
J. H. Cayford

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PREFACE

Poplars occupy a unique and anomalous position in the Canadian forest economy. They have the widest range and greatest volume of any of the hardwood genera yet only an insignificant part of the theoretical yield is harvested and utilized. Poplars grow on a wide range of site conditions: on some sites the growth is so poor that merchantable size is never attained, but on others the poplars are the fastest growing of all our native species. These and many other paradoxical characteristics make *Populus* a fascinating genus from a scientific standpoint, but an extremely frustrating one for those who wish to grow and utilize it.

In Europe and Asia the genus has received much scientific study and has been intensively cultivated in many countries over a wide range of growing conditions for many years. Although some of the best material originated in North America, until comparatively recently there has been little Canadian interest in the more effective utilization of natural stands or in the high yield potential of plantations under intensive cultivation. Now, the general trend towards a greater utilization of hardwood species, together with reduced wood supplies in areas close to mills is focusing attention on species such as poplar that have a capacity for high yields on short rotations.

In response to the rapidly developing interest in poplar, the Forestry Branch, Department of Forestry and Rural Development, organized a Poplar Symposium in February 1967 at Harrison Hot Springs in British Columbia, to review and discuss the status of poplar in Canada. This was considered to be an essential preliminary to future scientific, technical, and economic programs designed to improve the contribution of these species to the national forest economy. A complementary objective was to make generally available a comprehensive and authoritative account of the state of knowledge relating to poplars in Canada. This publication provides such an account.

All of the papers presented at the symposium by representatives of government, industry, and universities are included in this volume and cover the main aspects of poplar supply, silvical characteristics, management, manufacture, and marketing in Canada. To provide broader coverage, two additional papers (by O.A. Feihl and V. Godin, and G.P. Thomas), published prior to the symposium, are reprinted herein. In addition, an introductory paper by J.S. Maini briefly describes the physiography, climate, and vegetation of Canada to provide a broad framework within which the other papers may be oriented. Conclusions from the workshop sessions held during the three day meeting are not included since they were published in the Forestry Chronicle, June 1967.

As organizer and chairman of the symposium I wish to acknowledge both personally and on behalf of the Forestry Branch the fine cooperation and major assistance provided by the authors of these papers and their organizations, and to thank them for their participation. Special thanks are extended to Mr. G. Blom of West Tree Farms and Dr. J.H.G. Smith of the University of British Columbia for the organization and conduct of the field tours.

A. Bickerstaff,
Chairman,
Poplar Symposium, 1967,
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CONTENTS

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