THE RELEASE OF WHITE SPRUCE FROM TREMBLING ASPEN OVERSTOREYS

A REVIEW OF AVAILABLE INFORMATION AND SILVICULTURAL GUIDELINES

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by

H.J. Johnson

Johnson Forestry Services

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1.0 ABSTRACT

A comprehensive review of available information on the release of white spruce from trembling aspen overstoreys and shrub competition was conducted by Johnson Forestry Services as part of the Canada-Manitoba Forest Renewal Agreement. Over 200 publications on related subjects were reviewed and many aspects of releasing white spruce were examined including ecological, biological and growth relationships. On the basis of the review preliminary guidelines for silvicultural release treatments were developed.

The review strengthened the opinion that release treatments are a viable silvicultural option but that there are also economic and social factors to consider. Present information suggests that at least a thirty-five percent increase in net merchantable white spruce volume may be expected from treatment. Ongoing silvicultural research by the Canadian Forestry Service in Manitoba and Saskatchewan should provide a more precise evaluation of volume increment due to release treatments, during the current fiscal year.

The adoption of a comprehensive forest management plan by Manitoba (Manitoba Forest Management Plan, 1981-2000) and the reinforcement of goals to preserve, protect and strengthen the forest industry coincided with the Forest Sector Strategy for Canada (1981) which has similar federal goals. Subsequently, a Canada-Manitoba Forest Renewal Agreement was signed for a five-year period commencing in 1984 on the basis that a stronger forest industry in Manitoba would contribute to the economic development of both Manitoba and Canada. It was agreed to implement four major cost-shared programs i.e. Forest Renewal; Intensive Forest Management; Applied Research, Technology transfer and Opportunity Development; and Public Information, Education and Administration.

The present study was conducted as part of the Intensive Forest Management Program and funded on a 50:50 cost-shared basis by the Canadian and Manitoba governments. Preliminary research results and available information had suggested a good growth response following release of white spruce from competing vegetation. It was considered that a comprehensive review of information and the development of silvicultural guidelines for releasing white spruce from aspen overstoreys and shrubs would aid in formulating forest management strategies to increase wood production in Manitoba over the short term and assist in priorizing longer term silvicultural programs.

The objective of this study was to review available information and prepare silvicultural guidelines for releasing white spruce from trembling aspen and shrubs in mixedwood stands in Manitoba based on ecological factors, biological relationships, and growth responses. In addition, the impact of treatment, in terms of potential increases in wood production, on the Duck Mountain Forest Management Unit (FMU 13) was to be estimated.

The mixedwood stands addressed in this study are those spruce-aspen stands growing on fresh to moist, loam and clay loam, till sites found in the B18a Mixedwood Section of Manitoba.

Scenarios for which silvicultural guidelines were required are as follows.

1. Natural spruce-aspen stands where the crowns and leaders of the white spruce are detrimentally affected ("whipped") by the lower branches of the overtopping aspen. Differences in height between the tops of the spruce and the lower branches of the aspen averages 10 feet (3m.)

2. Natural pure stands of aspen underplanted with spruce or spruce plantings and seedings in cutovers with residual aspen overstoreys, where the difference in species heights range upward of 20 feet (6m.).

3. Recently regenerated cutovers where planted and/or seeded spruce and competing aspen suckers and underbrush are approximately the same height (+ 6 feet (2 m.)).

Within stand scenario 1 above, the following twelve specific subscenarios based on white spruce understorey age and various stocking levels were addressed.

Age of spruce understorey

	0-10	10-30	30-50	50-70
No. Trees per Acre	500	250	200	175
	1000	500	400	350
	2000	1000	800	700

4.0 ECOLOGICAL AND BIOLOGICAL CONSIDERATIONS IN THE DEVELOPMENT OF SILVICULTURAL PRESCRIPTIONS

4.1 Mixedwood ecology and sites

The Mixedwood Section (B18a) of the Boreal Forest (Rowe 1972) is approximately triangular in shape extending from southwestern Manitoba to northeastern British Columbia. It is a large and important forest area north of the aspen oak and aspen parklands and is bounded in the north by the coniferous forests of the Precambrian Shield. The largest single cover type in the Section, areally, is trembling aspen. As the name of the section implies the characteristic forest association is a mixture of trembling aspen, balsam poplar, white spruce and balsam fir. Black spruce and tamarack occupy the wet depressions and muskegs. Jack pine occupies sandy ridges and the drier till soils, often in admixture with black spruce. There is also a minor occurence of white elm, green ash, Manitoba maple and burr oak in the southeast part of the Section in Manitoba.

The Mixedwood Section of Manitoba includes the Porcupine, Duck and Riding Mountains and exists as an outlier in the Spruce Woods. The most important commercial mixedwood stands available for forest management are in the Duck and Porcupine Mountains. These hills include the Cretaceous escarpment and are characterized by morainic deposits on the uplands and glacio-lacustrine deposits on the lowlands (Rowe 1972). The escarpment has been deeply incised by fast-flowing streams (Bailey 1968). Most of the mixedwood stands concerned with in this report exist on the rolling plateaux of the uplands.

Characteristically soils belong to the grey-wooded group and are calcareous in nature. Soils vary from sandy loams to clays and are stone-free to very stony (Rowe 1955).

The climate of the mixedwood Section is continental and somewhat dry (Jarvis, Steneker, Waldron and Lees 1966). Temperatures are wide spread with average winter temperatures at or below 0 degrees F. and average summer temperatures about 60 degrees F. Average annual precipitation is about 17 to 20 inches and summer moisture deficiency is characteristic. The frost-free period is about 100 days in the Manitoba segment of the Mixedwood Section.

White spruce and trembling aspen are the principal tree species. They usually grow in association, hence the name "mixedwood". Fire has played a leading role in the ecology of the Mixedwood Section; large and intense fires occuring regularly in the past. Logging of white spruce has been conducted since the turn of the century on a commercial scale. At present most of the accessible old stands of white spruce/aspen have been logged for spruce. In the past, stands have yielded 10,000 to 25,000 board feet of spruce per acre (Rowe 1955). The cubic foot equivalent of approximately 1000 to 2500 per acre does not seem that impressive but early lumber operations utilized only large trees, usually over 12 inches at d.b.h. Therefore, it is difficult to compare past merchantable yields with current yield tables based on different utilization standards.

Rowe (1955) stated that a natural successional sequence is represented by the three commonly defined forest cover types: the hardwood (coniferous component less than 25 percent); the mixedwood (coniferous component 25 to 75 percent); and the softwood (coniferous component more than 75 percent). Pure aspen stands which establish after fires are invaded by spruce if a nearby seed source exists and eventually become mixedwood and ultimately softwood. As is often the case, spruce dribble in over a long period when seed source is limited. Often succession is protracted until these few invaders are old enough to produce seed. Therefore, a wide variety of successional stages are present in the mixedwood forest and the silviculturist must understand the dynamics of this forest and be selective in planning silvicultural programs. As an example, Kagis (1952) estimated that about 35 percent of the spruce volume in mixedwood stands in Saskatchewan had been lost due to lack of stand treatment.

Kabzems, Kosowan and Harris (1976) developed an ecological site classification for the Mixedwood Section in Saskatchewan. This classification describes in detail various ecosystems in the Mixedwood Section and provides rotation ages, mean annual increments and yields at rotation and maturity for each. The classification, based on several hundred permanent growth and yield plots, is a valuable guide to ecosystem productivity. Twenty-three ecosystems are described. Eight of these have a spruce content ranging from pure to scattered spruce in aspen stands. Three of these are typical of the Mixedwood cover types under consideration and are listed below.

Ecosystem	Drainage	Soil Texture	Rot. Age	Yields ($ft+^3/a$)
Picea g./ Populus- Cornus/ Mitella	Moderate-well	fine	65	4070 (285 M_3)
Picea g./ Populas- Cornus	well	moderately fine	75	3000 (210 M_3)
Picea g./ Populas- -Cornus/ Rubus	imperfect	fine	75	2785 (195 M_3)

There may be some slight differences in site productivity between mixedwood sites in Manitoba and Saskatchewan (stand and stock tables for the Duck Mountain Forest Management Unit in Manitoba indicate a total of 3300 cu. ft. per acre for mature mixedwood stands on the best sites) but it is believed that these ecosystems occur in Manitoba and undoubtedly productivity is relative if not absolute. This provides a fairly simple site framework which is of assistance in determining priorities for silvicultural operations with respect to releasing white spruce from trembling aspen.

A site classification for the Mixedwood Section of Manitoba and Saskatchewan was developed by the Canadian Forestry Service and is outlined by Jarvis et al (1966). This site classification (Rowe 1957) is a detailed description of forest sites in Manitoba and Saskatchewan based on soil moisture regimes and pore patterns and lists typical vegetation. Some growth information is also provided.

Duffy (1965) prepared a comprehensive land classification for the Mixedwood Section of Alberta which provides estimates of total volume, merchantable volume and site index based on 68, one-fifth acre growth and yield plots. This classification stresses soils, although there is a listing of vegetation. Jarvis et al (1966) indicated that yields shown are somewhat higher than for Manitoba.

Forest inventories in the Mixedwood Section of the prairie provinces rarely define stocking levels of understorey spruce in young aspen stands. Patchy stocking has been noted and no doubt is a function of available spruce seed and suitable seed beds following fires. If large-scale release operations are to be considered, supplementary inventory information is required to adequately express the magnitude and nature of this important forest type.

4.2 Competing vegetation and control

Severe competition to spruce from overstorey hardwoods and minor vegetation, particularly shrubs, has been the subject of much research in various parts of North America. There can be no denying that tree and shrub competition results in slow growth and mortality of understorey spruce. Vegetative competition is regarded as a universal problem in reforestation programs and several methods have been recommended for control. An exhaustive review of the literature on competing vegetation was not attempted. Rather, attention was focused on information which may be of use regarding the release of white spruce from aspen overstoreys in the Mixedwood Section of Manitoba.

Shrub competition is considered one of the main factors affecting the survival and growth of white spruce seedlings (Rowe 1955, Shirley 1941). Waldron (1959) by inference indicated the low intensity of light below a dense hazel cover. On a one-acre plot on the Riding Mountain he measured the leaf surface area of the hazel which totalled approximately seven acres. Rowe (1955) discussed minor vegetation on several sites of the Mixedwood Section and considered that on the better sites, which are normally moist, the chief competitors to white spruce seedlings were dense broadleaved herbs. This would certainly apply to small natural seedlings but probably not to healthy transplants used on a reforestation project, particularly if some initial site preparation were undertaken. Stiell (1976), in his comprehensive review of artificial regeneration of white spruce in Canada, maintained that while shrubs hindered planting and restricted early growth, hardwood sprouts and unwanted residual conifers which can form a high closed canopy, provided the most serious long-term competition to spruce.

In the context of the present review the main point to be made is that both overstorey aspen and shrubs and in some cases herbs can provide serious competition to white spruce. Reforestation programs in the Mixedwood Section obviously require careful attention to this competition and in all likelihood will need more than an initial brush control treatment to achieve maximum performance. The release of well established white spruce plantations or natural regeneration obtained from seed-bed treatment, is necessary maintenance to protect the initial reforestation investment. Sutton (1965) demonstrated that the spot application of Dybar (pelleted fenuron) within up to one foot of planted white spruce seedlings killed competing vegetation but resulted in no significant damage to the seedlings. He recommended Dybar application at the time of planting and cautioned against using it one year after due to the development of spruce runner roots close to the soil surface. Spot application of herbicides at the time of planting would result in decreased costs by eliminating the need to cover the same ground twice.

Control of competing vegetation whether for planted or seeded white spruce under an aspen overstorey or for natural young or intermediate aged white spruce understoreys offers several options. There is a large body of literature on site preparation for planting or seeding white spruce to reduce vegetative competition. However, the present review addresses the question of releasing naturally or artifically established white spruce from brush and aspen overstoreys. Therefore, remarks are restricted to this aspect of vegetative control. Obviously, brush control efforts at the outset of a reforestation program will reduce efforts required later.

An example of the devastating effect of dense aspen overstoreys to plantations was reported by Haig (1959) who remeasured several white spruce plantations established in the Riding and Duck Mountains between 1918 and 1930. With the exception of one plantation, where all aspen was removed 20 years after establishment, all plantations established under aspen stands were failures. Many other examples of plantation failure, primarily due to aspen and "weed" competition in the Mixedwood Section of Manitoba, Saskatchewan and Alberta were discussed by Froning (1972) who conducted a detailed forest plantation survey in the prairie provinces. An evaluation of scarification and seeding projects (Johnson 1973) in Alberta cited competition from aspen suckers and shrubs as a major failure factor in the Mixedwood Section.

After seedlings reach a height of about 3 meters there is less concern about brush control although undoubtedly there may be competition for moisture and nutrients. At this stage the main concern is the aspen overstorey, which can reduce spruce growth substantially by "whipping" leaders and reducing light requirements. However, dense brush offers ideal habitat for snowshoe hares and browsing animals which may have a serious effect on growth and survival of trees up to sapling size. This will be discussed in a later section of the report.

Shrub and overstorey aspen control which would apply to a new reforestation project does not necessarily apply to a release project. In the former heavy machinery (Waldron 1961) or prescribing burning (Tucker and Jarvis 1967) may be used. The options are somewhat more restricted for release programs. The established seedlings must be protected. Care is usually required to minimize damage to conifers which may represent just adequate stocking. Reducing the stocking of white spruce may be an objective at high density levels.

The options for releasing white spruce are aerial spraying of herbicides, ground spraying of herbicides, poisoning or basal spraying herbicides on individual trees, hand girdling using axes or specialized tools, machine girdling, felling by powersaws or axes, or combinations such as axe frilling and poisoning. Undoubtedly there is a place for most of these techniques depending on circumstances.

Labour intensive methods of brush and aspen control have been used on several large-scale trials on the Riding Mountain Forest Research Area. These silvicultural operations between 1961 and 1969 (Pratt 1978) are examples of operational scale trials in the Mixedwood Section of Manitoba. Haig (1964) reported productivity for individually releasing and thinning a young (50 years) mixedwood stand to favour white spruce crop trees, at 1.5 to 4 man days per acre. For girdling mature hardwoods with a "Little Beaver" girdler the productivity was about 0.5 man days per acre. Peters (1984) discussed an operational release project in the Interlake Region of Manitoba. Approximately 230 acres of white spruce in a large plantation were released from aspen and the spruce correctively pruned at a cost of $172.00 per acre. Productivity was about 1.7 man days per acre. These operational trials on the Riding Mountain and the Interlake Region illustrate the range in costs which may be expected depending on the conditions of the stand when deploying hand labour.

Obviously, less costly release may be achieved on large projects by reducing the labour input. Aerial spraying of herbicides is undoubtedly less expensive than labour intensive programs. It may also be more effective than mechanical brush clearing which promotes suckering. This was the case in an experiment conducted in Newfoundland to release balsam fir and white spruce from hardwoods (Richardson 1980). However, there are some trade-offs to consider. In the writer's opinion there is a place for labour intensive programs. The development of skilled silvicultural crews in each forest district would do much to foster a forestry ethic.

Large-scale spraying programs, while undeniably more cost-effective on large projects, are often perceived by the public as environmentally unsound and yet another example of forest "mismanagement". While the great debate rages on it would be well advised to have several alternatives available in order to sustain or increase allowable cuts. It is not within the terms of reference of this review to delve into the do's and don'ts of aerial spraying. The writer merely suggests that all options be considered. There are situations where large-scale spraying of herbicides is necessary; particularly large treatment areas where access is limited. Conversely, for smaller projects, where access is good, labour-intensive programs may be a sound approach, particularly in a depressed economy. It bears repeating that skilled silvicultural crews also pay off from a public relations point of view.

Vanden Born and Malik (1984) in their review of herbicide use for forest management in North America have made several recommendations concerning the prairie provinces. Among these are greater co-ordination of federal agencies involved in the registration process and thus acceleration of registration; emphasis on public education and inclusion of vegetation management courses in forestry undergraduate programs; establishment of public forums; and increased research. Recently, joint federal-provincial research programs in herbicide use have been initiated with each of the three prairie provinces.

The need for herbicide use in the prairie provinces is critical to desperate (Drouin in Vanden Born and Malik 1984). The operational and experimental use of even the traditional herbicides (2, 4-D and 2,4,5-T) has been minimal in the prairie provinces. Additional herbicides with potential for forest management are Glyphosate (Roundup), Hexazinone (Velpar), Triclopyr (Garlon) and Fosamin ammonium (Krenite). (Vanden Born and Malik 1984).

In Manitoba, the most recent experience in the use of herbicides for forest management is a program by Abitibi-Price Ltd. of Pine Falls. Earlier trials conducted by the Canadian Forestry Service, and mentioned in the Appendix of this report provide valuable long-term information and might be considered by that agency for further analysis.

4.3 Light requirements for white spruce growth

"Since the amount of light reaching seedlings is more readily controlled than many of the other factors of the environment, it is of some practical significance to know the light requirements of the various tree species" (Logan 1969). This statement is particularly appropriate with regard to the present review. Basic research on the growth of various species of tree seedlings, under different light intensities, was conducted by Logan over a nine year period. His results for white spruce are of particular interest and are similar to a classic study conducted by Shirley (1941). These studies confirm the light requirements for white spruce in a convincing and conclusive manner.

The studies by Logan and Shirley and applied research conducted by Lees (1967), Cayford (1957) and Steneker (1963, 1967, 1974), referred to earlier, confirm the necessity of removing the aspen overstorey from white spruce at an early age in order to achieve maximum growth of the white spruce. Shirley (1941) stated, "The concept that aspen, although of little value for anything else, forms an excellent nurse crop to shelter seedling conifers during their early life has become part of the forestry dogma." Shirley continued by stating, "The material already presented affords convincing proof that dense large-sized aspen does not form a nurse crop for planted conifers in the Lake States but has a deleterious influence on them".

Brix (1972) studied the growth response of white spruce seedlings to temperature and light intensity and his findings agreed essentially with those of other researchers (Logan 1969, Shirley 1941). Regarding the question of the beneficial effects of shade to young white spruce seedlings he attributed this not to light per se but to reduced evapo-transpiration and the avoidance of lethal soil surface temperatures. For example, Waldron (1966) found a direct relationship between number of white spruce germinants and increased crown cover on treated seedbeds on the Riding Mountain. The United States Department of Agriculture (1957) reported shade being beneficial to young Engleman spruce seedlings, in that open-grown seedlings suffered high mortality due to heat girdling as a result of high soil surface temperatures. Another U.S.D.A. study (1969) noted solarization as the primary cause of mortality, but this was at higher elevations. Apparently very young seedlings can benefit from shading but within a few years of establishment are detrimentally affected if light intensity is lower than about 50 percent.

Results of Logan's study (1969) are presented in Table 1 in capsule form to illustrate the practical significance of the study and its relevance to the present review.

The results of studies by Shirley (1941) and Logan (1969) confirm that white spruce requires a minimum of approximately 45 percent light to maintain maximum height growth. However, an examination of Table 1 shows that total dry weight of shoots is 50 percent greater for white spruce seedlings grown under 100 percent light than under 45 percent light. Also, the root collar diameter of seedlings under 100 percent light is considerably larger than those grown under 45 percent light.

Interestingly, results of Logan's studies show that the amount of dry matter (shoots) produced per gram of foliage was virtually the same for seedlings grown in 13 percent light and full light, suggesting that shade foliage is more efficient than sun foliage. However, despite this fact, seedlings grown in full light produced more total dry matter because they had three times the number of needles (Table 1). Therefore, Logan concluded that the better growth found under higher light intensities was not as a result of "higher light per se" but the increased foliage production that accompanied increases in light.

Sutton (1968) recognized that excessive shading is a constraint to the growth of white spruce but stressed that the growth effect of a given level of radiation depended to some extent on the nutrient status of the plant and substrate. He also warned that increase in growth with increasing light only applied where soil moisture is not limiting.

This review relates to fresh to moist sites on loams and clay loams found in the Mixedwood Section. Prolonged, severe drought conditions would not occur often on these sites so the foregoing caveats discussed by Sutton would probably not apply. The main concern would relate to young natural or reforested seedlings and it is highly unlikely that full sunlight would result from release treatments. As an example, a study conducted by Day (1964) on logged over spruce stands in southern Alberta indicated that less than 5 percent of established seedlings were growing entirely in the open. Residual trees, herbs, shrubs, grass and slash provided shade.

Table 1 Growth of white spruce seedlings in four light intensities after nine years (Logan 1969).

Growth Parameter	Light Intensity 13%	25%	45%	100%
Av. height ins.	30	31	59	63
Av. root collar diam. (mm)	21	21	36	47
Av. no. needles (thousands)	110	113	257	340
Dry weight tot. shoot (ounces)	7.2	7.7	29.2	48.1

Note: Lines connect treatments showing no significant difference.

4.4 Rodent and ungulate problems

By far the most damaging animal to white spruce reproduction is the snowshoe hare (Lepus americanus). Seedlings immediately adjacent to or underplanted in aspen stands are most vulnerable. As the hare cycle is roughly 10 years, young white spruce seedlings can be attacked at least twice before they are tall enough to escape. Keith (1972) who has conducted intensive snowshoe hare studies in the Mixedwood Section of Alberta, estimated that seedlings have to be 6 feet tall to escape critical hare damage. Peak populations of hares may be as high as 5 per acre or 3200 per square mile (Keith 1972). Aldous and Aldous (1944) noted similar high population figures for the Lake States.

Brace and Ball (1982) presented an overview of the impact of the snowshoe hare on commercial forests of the prairie provinces. They noted that forest harvesting between 1975 and 1980 increased from 50,000 to 70,000 ha per year and since much of this was clearcutting, early successional stands were often created which are ideal hare habitat.

In an examination of reforestation projects in several Forest Districts of the Mixedwood Section of Alberta, Keith (1972) questioned the practice of attempting to convert aspen stands, so overwhelming is the snowshoe hare problem. The Manitoba and Saskatchewan scene is no different and the writer can recall vividly four cycles where plantations and natural regeneration after seed-bed preparation had been devastated. C.B. Gill (In Haig 1959) stated that hare populations reached cyclic peaks in Manitoba in 1924, 1933 and 1943 and were responsible for the failure of many early plantations. While the snowshoe hare has a preference for pine, white spruce may be severely damaged or killed during peak population periods; particularly if there is aspen cover in the younger age-classes. The writer examined severe damage and mortality north of Prince Albert, Saskatchewan about 1982, where mixed stands of spruce and pine with some aspen were logged and scarified. The aspen suckered profusely but there was also good reproduction of spruce and pine as an understorey. Both the pine and spruce were attacked and although many stems of spruce were still alive they had been pruned both terminally and laterally. Whether these seedlings would survive and grow into merchantable trees is questionable. Aldous and Aldous (1944) commented on a survival rate of 60 percent for white spruce planted in 1928 and examined in 1932 after severe rabbit damage the preceding spring. In their opinion this figure "did not tell the whole story, as many of the trees were so badly nipped there was little chance of recovery". Cook and Robeson (1945) described snowshoe hare damage in New York State during the winter of 1942-43. White spruce was heavily damaged, "many small trees being reduced to mere stubs".

Severe hare damage to white spruce plantations established in Saskatchewan between 1916 and 1946 was noted by Johnson (1953). Plantations underplanted or adjacent to aspen stands suffered repeated attacks. Froning (1972) reported substantial hare damage to plantations in Manitoba, particularly in the Western and Eastern Regions.

Moose, white-tailed deer and elk browse in hardwood stands and generally are not attracted to white spruce although they will browse pine (Rowe 1956). Trampling of two to three year-old white spruce seedlings by elk on site-prepared corridors in the Riding Mountain was very servious, amounting to 31 percent of the mortality (Waldron 1966). In this case the elk used the site prepared strips as trails. Moose and deer favour early successional stages such as young aspen and mixedwood stands (Telfer 1972), but they require dense stands of conifers as part of their winter habitat.

Squirrels generally feed on coniferous seed, berries, insects and fruiting bodies of fungi but when preferred food is scarce the red squirrel will feed on bark and buds of conifers (Wagg 1964). At times this feeding can cause damage to leaders and new lateral growth of white spruce. Also squirrels commonly cut branches in order to obtain clusters of cones. Squirrel damage most commonly occurs in the winter and early spring and is not considered serious to the tree but could cause light cone crops (Balch 1942, Rowe 1952).

Cayford and Haig (1961) reported severe mouse damage to a Scots pine plantation in the Sandilands Forest Reserve, Manitoba. Some of the trees were completely girdled. Nearby white spruce plantations were not affected. However, Wagg (1963) reported that meadow voles in captivity readily ate white spruce seedlings following germination.

Obviously the snowshoe hare is the main problem animal in aspen stands being converted to spruce or in young mixedwood stands. Damage and mortality to white spruce from this source must be considered in the planning of silvicultural operations in the Mixedwood Section of Manitoba. Brace and Ball (1982) stated that silvicultural expenditures in the prairie provinces increased from $1.2 million in 1971 to $14.1 million in 1981. They recommended development of an ecosystem hare risk rating so that expenditures could be directed to low to moderate risk areas and high risk ecosystems avoided. A habitat providing dense vegetative cover one to two meters above ground level is preferred by the hare (Radvanyi 1985).

Reducing cover by release cuttings, especially low release, was recommended by Aldous and Aldous (1944) as a remedial measure. Radvanyi (1985) recommended prescribed burning or scarification prior to a planting program, followed in subsequent years by herbicide applications. Radvanyi (1985) listed several control methods in his problem analysis of the snowsoe hare and reforestation, which are certainly applicable to reforestation programs but in most cases would not apply to release operations. A rabbit repellent, tetramethyl thiuram disulphide (TMTD) is effective but only for one year. Other methods of control such as shooting and snaring, erecting fences, use of chemosterilants and biological control are interesting but probably not too practical. Obviously, habitat manipulation offers the most promising solution for release programs.

Although the snowshoe hare is widely maligned an interesting beneficial aspect of hare depredation was first reported by Cox (1938). The hare was proven to be an excellent thinning agent in over-dense coniferous stands resulting from wild fires. Similar beneficial effects have been noted by foresters in the Mixedwood Section of the prairie provinces.

4.5 Insect problems

The annual reports of the Forest Insect and Disease Survey, Canadian Forestry Service, for the period 1950-1981, were examined for prevalent insect problems affecting white spruce in Manitoba. Spruce budworm (<u>Choristoneura fumiferana</u> (Clemens)), white pine weevil (<u>Pissodes strobi</u> (Peck.)), yellow-headed spruce sawfly (<u>Pikonema alaskensis</u> (Rokwer)), balsam fir sawfly (<u>Neodiprion abietus</u> (Harris complex)), and root weevils (<u>Hylobius</u> and <u>Hypomolyx</u> sp.) were the most common recurring insects but seldom were infestations reported high in the Duck and Porcupine Mountains where the main mixedwood forests occur in Manitoba. Forest tent caterpillar (<u>Malacasoma disstria</u> Hubner) is of interest because defoliation of overstorey aspen has a beneficial effect on understorey white spruce.

The devastating effects of spruce budworm, particularly in eastern North America, are well known and no attempt was made to review the voluminous literature on this subject. According to Dr. H. Cerezke, a senior forest entomologist at the Northern Forestry Centre, spruce budworm may be attracted to released white spruce if an infestation of the insect is in the vicinity. Schmitt et al (1984) in a comprehensive handbook entitled "Managing the spruce budworm in eastern North America" stated "spruce budworm outbreaks are less likely to occur in stands with a mixture of spruce-fir and non-host species". This supports Dr. Cerezke's view that there are inherent risks in treating areas in the vicinity of potential spruce budworm outbreaks. The handbook provides vulnerability ratings of spruce as determined by various studies. These are paraphrased below.

1. Vulnerability of spruce tends to decrease as the proportion of non-host species in the stand increases. The trend is apparently amplified if spruce is in a subordinate crown position relative to non-host trees.
2. Vulnerability decreases with increasing tree and stand vigor, as demonstrated by growth rate and crown development, which, of course, is related to site quality and growing conditions.
3. Vulnerability tends to increase as stand density increases.
4. Vulnerability of individual spruce trees increases when they are in a subordinate crown position relative to other spruce.

The spruce budworm problem has not been nearly as severe in western Canada as it has been in the east (Cerezke 1978). The reasons for this according to Cerezke are as follows:

1. Many previous outbreaks in the west occurred in northern areas, isolated from timber markets.
2. Even during outbreaks in western Canada populations have fluctuated from year to year probably as a result of weather.

3. Outbreaks in the prairie provinces have occurred in forests with a very low content of balsam fir which is the preferred host.

One factor not listed above, but mentioned in the same report, is the extensive nature of mixedwood forests which do not have the same vulnerability as pure stands of the host species. Large-scale operations to remove the aspen from mixedwood stands should be viewed at least with some trepidation. Obviously it would not be prudent to treat stands in an area where the spruce budworm is expanding.

The white pine weevil was active throughout the prairie provinces in 1984 (Moody and Cerezke 1985). Infested dead tops were common on young spruce throughout the region and apparently top-killing occurred on spruce in several nurseries and plantations. This insect is mentioned in Forest Insect and Disease survey reports for the past 30 years and can be regarded as a perennial problem.

The white pine weevil closely resembles the lodgepole terminal weevil (Pissodes terminalis) and has a similar life history, however, their feeding characteristics are different (pers. comm. Dr. H. Cerezke 1985). The white pine weevil, as the name implies, is a serious predator of white pine in eastern Canada. However, in the prairie provinces spruces are its main host (Drouin 1984). The lodgepole terminal weevil which is generally less common attacks only lodgepole pine and jack pine.

According to Dr. Cerezke the weevil attacks young trees up to sapling size. Open-grown trees in nurseries and plantations are highly vulnerable. Undoubtedly young released spruce in mixedwood stands would be attractive. However, trees seldom die as a result but damage and loss of growth occurs. Interestingly, a recommended silvicultural control by Dr. Cerezke is to plant the susceptible host under aspen or in mixture with other non-host conifers.

The yellow-headed sawfly is referred to annually in Forest Insect and Disease reports of the Canadian Forestry Service. Although it will attack forested areas it is more prevalent in shelterbelts and urban plantings (Kusch 1978). This insect will attack virtually all species of spruce both native and exotic (pers. comm. Dr. H. Cerezke 1985). Open-grown stands are preferred; closed stands are rarely attacked. Mortality of young spruce occurs after three to four consecutive years of moderate to severe defoliation. A study of the effect of white spruce release on defoliation by the yellowheaded spruce sawfly in the Lake States was conducted by Morse and Kulman (1984). The study took place in 5-year-old white spruce plant- ations in the Chippewa National Forest, Minnesota. The plantations were overtopped by aspen at a density of 3000 to 5000 stems/ha. Treatment consisted of cutting all aspen within 1.5 meters of the spruce. One year later, defoliation was six times greater on the treated plots than the controls. The authors stated that the yellowheaded spruce sawfly is a sun-loving insect and that south facing slopes are a high risk. They recommend that in such locations a light overstorey of aspen should be left.

"The balsam fir sawfly is second in importance to the yellow-headed spruce sawfly as a pest on shelterbelts and ornamental plantings" (pers. comm. Dr. H. Cerezke 1985) (Hildahl and Peterson 1970). Apparently the parkland and prairie areas of Manitoba can be heavily infested but usually only light infestations occur within the forested zone. The exception to the rule was during 1960-65 when a huge area (3600 sq. mi.) was infested in the Interlake region and heavy mortality of balsam fir and spruce occurred. Although named the "balsam fir sawfly" this insect will attack all Picea species.

Root weevils (Hylobius sp. and Hypomolyx sp.) were studied by Warren (1956a, 1956b) and Warren and Whitney (1951) in Manitoba and Saskatchewan. While these insects can cause serious damage and mortality to young plant- ations damage to larger trees is insidious in that root diseases may enter wounds caused by the insect. High populations occur on the wetter sites with a deep duff layer (Warren 1956a).

Forest tent caterpillar (Malacosoma disstria Hbn.) outbreaks are common in the Mixedwood Section of the prairie provinces. Although this insect does not feed on white spruce it is of interest in the context of this review because severe defoliations of overstorey aspen benefit the understorey spruce. It has been estimated that heavy defoliation of overtopping aspen can result in a twenty percent increase in the radial growth of understorey conifers (Froelich et al, 1955).

Although infrequently mentioned in Forest Insect and Disease Survey reports for the prairie provinces the spruce bud midge (Rhabdophoga swainei Felt) is considered of some importance because the insect attacks young spruce commonly in the 6 to 12 foot range (Cerezke 1972). The insect is distributed throughout the Boreal Forest of Canada and was first detected in large numbers in Alberta in 1967.

A field examination of research release plots in Saskatchewan during the fall of 1985 by the writer substantiated reports of carpenter ant activity by field crews engaged in remeasurement of the plots a few weeks earlier. Camponatus sp. do not eat the wood per se but their galleries in living and dying wood can cause significant damage (Sanders 1970). The trees examined in Saskatchewan were also probably weakened by root rots. Subsequent windthrow seems to have resulted in a high carpenter ant invasion. Perhaps in some instances the carpenter ants were responsible for blowdown.

Prior to embarking on large scale release of white spruce from aspen programs silviculturists should consult with the Forest Protection Division of the Manitoba Dept. of Natural Resources to ensure that planned programs are not located in high hazard areas with respect to insect problems. It would appear that release treatments may create conditions attractive to some insects. The Forest Insect and Disease Survey of the Canadian Forestry Service is also knowledgeable regarding insect infestations and problems.

Prior to writing this section of the report some time was spent in discussion with Dr. Y. Hiratsuka, senior forest pathologist, at the Northern Forestry Centre, Edmonton. Dr. Hiratsuka pointed out that in general white spruce is quite resistant to decay and unless trees are predisposed to disease by some damaging agent (insects, frost, mechanical damage by logging, etc.) there are no primary, progressively killing diseases which affect white spruce. Baranyay, Bourchier and Thomas (1968) in their "Supplement to Lectures on Forest Pathology to the Alberta Forest Training School" stated "tree diseases only occasionally result from a single cause. Most of them are the result of a series of damaging disturbances, each having its separate cause. These are termed either casual agents or disease agents, of which there are many examples in nature". Damage to trees may be caused by frost, heat, fire, hail, snow, ice, lightening, air pollution, nutrient imbalance, water deficiency, water excess, wind and animals (including insects). To this list mechanical damage resulting from man's activities may be added.

In general, major tree diseases to spruce may be categorized as foliage diseases, diseases affecting fruit (cones), diseases affecting bark, and diseases affecting wood (decay and stain). Baranyay, Bourchier and Thomas (1968) provided the following list of diseases in each of the above categories as being of some importance insofar as white spruce is concerned.

1. Diseases affecting foliage

(i) Spruce needle rust <u>Chrysomyxa ledicola</u> (Pech.) Logerb., and <u>Chrysomyxa</u> <u>Emptri</u> (Pers.) Schroet.

Importance - Infected needles are generally shed late in their first season but defoliation is not usually serious enough to kill trees.

2. Diseases affecting fruit

(i) Spruce cone rust _Chrysomyxa_ _pirolta_ Wint.

Importance - Severe infections markedly decrease seed production and may be an important factor in spruce regeneration.

3. Diseases affecting bark

(i) nil

4. Diseases affecting wood

Root and butt decays

(i) Shoestring root rot _Armillaria_ _mellea_ (Vahl ex Fr.) Quel.

Importance - Sometimes causes extensive damage in reproduction otherwise moderate losses through decay.

(ii) Brown cubical butt rot - _Coniophoria puteana_ (Schum. ex Fr.) Karst.

Importance - Causes significant loss in wood volume through decay in mature and over-mature stands.

(iii) Red root and butt rot of conifers - _Polyporus_ _tomentosus_ Fr.

Importance - losses highly variable between stands.

(iv) Yellow stringy butt rot of conifers _Flammula_ _alnicol_ (Fr.) Kummer

Importance - causes occasional high losses

Stem decays

(i) Red ring rot - Fomes pini (Thor) ex Pers.) Lloyd

Importance - loss in wood volume through decay stains.

(ii) Blue stain -_Leptographium_ _sp._
Ceratocystis sp.

Importance - causes degrade.

5. Diseases affecting more than one tissue

(i) Yellow Witch's broom Melampsorella caryophyllacearum Schroet.

Importance - not important.

There are more diseases of minor importance to white spruce but the preceding list is considered representative of the main diseases which may be of some interest relative to this review. There are also numerous aspen diseases which are of interest insofar as the release of white spruce from aspen overstoreys is concerned. The reader is referred to "Decay of aspen and balsam poplar in Alberta" (Hiratsuka and Loman (1984)). This publication was prepared for the Alberta Poplar Research Committee and is a practical report written for resource managers which includes several references to aspen decay in Manitoba.

Whitney and Denyer (1968) studied decay rates caused by two important root rotting fungi (Coniophora puteana (Schum. ex. Fr.) Karst and Polyporus tomentosus Fr.) near Candle Lake, Saskatchewan. C. Puteana was the main butt decay in dead trees while P. tomentosus caused white pocket root and butt rot in living spruce trees. Denyer and Riley (in VanGroenwoud and Witney (1969)) conducted a disease survey of white spruce stands in Manitoba and Saskatchewan and found that of 797 trees examined, 364 had fungal infections of which 19 percent were by the disease (P. tomentosus). Most of the damage caused was by subsequent windthrow. VanGrooenwoud and Whitney (1969) found most root rot and resulting windthrow in shallow wet soils and very dry soils. The former soils are characterized by a complete absence of minor vegetation other than feather mosses. Similarly, ground cover on the dry soils was limited to sporadic mosses and herbaceous plants and the forest floor was carpeted with needles.

As the present review is concerned with spruce-aspen stands growing on fresh to moist till sites the "stand opening disease complex" discussed by Whitney and VanGroenwoud (1964) and Whitney (1962) is probably not too important. The disease is a combination of adverse soil conditions and Polyporus tomentosus. Apparently the disease complex was not found on alkaline soils.

Root wounding and associated root rot was studied in three locations in Manitoba and Saskatchewan (Whitney 1961). Twenty-seven percent of diseased roots from 656 white spruce between 7 and 180 years old bore wounds from Hylobius spp. larvae. Fungi entered through insect-girdled roots. Other wounds associated with decay were far less prevalent and included root compression, excessive moisture, and animal trampling. In all, root rot or stain was found on 82.7 percent of the trees. Infection traced to wounds was 53.5 percent. Hylobius wounding was most severe on sites with moist deep duff.

In general, stem decays are not a serious factor in white spruce until the trees are over 100 years of age (Nordin 1956). Provided reasonable rotation ages are maintained, stem decays are not considered to be a threat unless logging damage is incurred while partial cutting. Release of spruce from aspen could result in stem injuries and increased stem rot necessitating considerable care in logging.

4.7 Climatic factors

Climatic damage to residual spruce after removing aspen overstoreys is most often wind damage, hail damage, snow breakage, or icing and glazing damage. While all of these factors have the potential to cause severe damage in isolated instances, the most common results from wind. A more subtle type of climatic damage is caused by winter temperature fluctuations and is known as "winter browning". Frost damage to new shoots is also very common particularly on seedlings but can also occur on mature trees. Occasionally drought will result in foliage mortality on larger trees. Denyer and Riley (1964) reported one such occurrence near Big River, Saskatchewan in May, 1963. Young white spruce up to 10 feet in height without an overstorey and to a lesser extent trees up to 20 feet with an aspen overstorey were affected.

Sutton (1968) stated "white spruce is not duly susceptible to windthrow. On the contrary, it is very wind firm except when root-rotted or where rooting is grossly restricted by edaphic conditions". The last segment of this quote is most important in relation to the present review. Dense, intermediate-aged or mature mixedwood stands from which the aspen has been removed undoubtedly leave the residual spruce susceptible to wind damage. Rowe (1964) conducted a study of white spruce rooting at the Petawawa Forest Experiment Station. He concluded that large sinker roots are rarely if at all encountered under the spruce bole. He also noted that lateral roots are enhanced on the side of the tree having the heaviest crown. Jeffrey (1959) reviewed the literature on white spruce rooting and noted that the normal root system is one of very strongly developed lateral roots from which secondary roots descend to variable depths.

The writer has seen examples of wind-damaged understorey spruce in a mixed pine-spruce stand in Alberta where the pine was logged due to an infestation of mountain pine beetle. The spruce was intermediate-aged and in some very exposed areas suffered 100 percent blowdown. Of more direct relevance to this review the writer examined research plots of a release study (MS-153) by the Canadian Forestry Service in October of 1985. Although excellent results were reported after the last remeasurement (Steneker 1967) there was some recent blowdown of the residual near mature spruce which is rather alarming. The windthrown spruce exhibited a relatively shallow root system and evidence of root rot and associated carpenter ant activity. A forthcoming report by Dr.Richard Yang of Northern Forestry centre will elaborate on this damage.

Alexander (1974) discussed windfirmness of sub-alpine spruce and stated that although the tendancy for spruce to windthrow is attributed to a shallow root system; the development of the root systems varies with soil and stand conditions. Root systems in deep, well-drained soils are better developed than in shallow, poorly drained soils. However, trees in dense stands offer mutual protection and do not have the roots, boles or crowns to withstand sudden exposure to wind by partial cutting. If understorey white spruce are released at an early age, in all probability root development will accelerate and improved windfirmness should result.

A wind risk rating system was developed by Alexander (1974) which could be used for the Duck and Porcupine Mountains, where prevailing winds in the summer are westerly and southerly and in the winter northerly. Although the rating was developed for subalpine topography, where relief is greater than in the Duck and Porcupine Mountains, it is believed that gentler relief would have the same relative risks insofar as wind is concerned. Turbulence, however, may be quite a different matter. Alexander's wind rating is shown below. It may require some modification to suit local conditions.

BELOW AVERAGE

1. Valley bottoms, except where parallel to the direction of prevailing winds and flat areas.
2. All lower, gentle middle north and east facing slopes.
3. All lower,and gentle middle south and west facing slopes that are protected from the wind by considerably higher ground not far to windward.

ABOVE AVERAGE

1. Valley bottoms parallel to the direction of prevailing winds.
2. Gentle middle south and west slopes not protected to the windward.
3. Moderate to steep middle, and all upper north and east facing slopes.
4. Moderate to steep middle south and west facing slopes protected by considerably higher ground to windward.

VERY HIGH

1. Ridgetops.
2. Saddles in ridges.
3. Moderate to steep middle south and west facing slopes not protected to the windward.
4. All upper south and west facing slopes.

Hail damage to forest stands in Manitoba and Saskatchewan has been reported by Riley (1953) and Laut and Elliot (1966). Although hail damage to trees is common, rarely does it occur on an extensive scale. Laut and Elliot reported such an occurrence in northern Manitoba where hail-damaged areas ranging from 10 to 40 square miles were observed and one huge area of 600 square miles was aerially mapped. Damage consisted of dead twigs and branches and some dead tops. A few dead trees were noted. While hail damage could result in some growth loss to residual spruce released from overstorey aspen, it is not considered a major threat.

Glaze damage occurs occasionally in Manitoba but is not as common as on the east coast of North America. A severe ice storm occurred in the Sandilands Forest Reserve on November 17, 1958 (Cayford and Haig 1961). The authors also reported a serious ice storm which occurred in 1930 (C.B. Gill in Cayford and Haig 1961). The 1958 storm encompassed an area over 200 square miles. Young stands of dense jack pine sustained the greatest damage and it was recommended that thinnings would reduce the risk of yield loss from glaze damage. Undoubtedly the same rationale would apply to dense young spruce stands released from trembling aspen.

These few documented cases of wind, hail and ice damage to forest stands in Manitoba and Saskatchewan illustrate that losses from these factors is not insignificant especially when one considers the lengthy crop rotations involved. In fact, many occurrences of this type are not documented and losses are probably greater than generally believed. Although documented cases of snow damage were not obtained for the Mixedwood Section this is another factor to consider.

Newly flushed shoots of white spruce are particularly sensitive to spring frosts (Sutton 1968) and all foresters have noted this type of damage. Release treatments may affect this ocurrence in young stands. An interesting example was reported to the writer by the Saskatchewan Forestry Branch. Apparently areas reforested after logging were heavily invaded with aspen suckers. On one area the suckers were removed; on an adjacent area suckers were left. Heavy frost damage ocurred to released white spruce seedlings on the former while damage was negligible on the latter. In Manitoba spring-frosted white spruce seldom flush again during the year of damage (Rowe 1955). Apparently "re-flushing" is more common in eastern Canada and is thought to be due to higher soils moisture levels (Sutton 1968). Rowe (1955) stated that frost damage to white spruce seedlings in successive springs would probably be lethal.

Extensive winter drying and frost damage to forests of Manitoba and Saskatchewan in 1958 was reported by Cayford et al (1959). Unseasonably warm temperatures and strong winds during the winter months caused drying of conifers. High temperatures in April followed by frosts in April, May and June caused severe damage.

By stand manipulation it is possible to reduce some of the climatic damage discussed. For example, extreme opening of dense intermediate aged to mature mixedwood stands in a high wind risk area is asking for trouble. Similarly, dense young stands of understorey spruce released from aspen overstoreys could be thinned not only to increase growth but to reduce risk of damage from glaze and snow. Obviously, silvicultural treatments in frost pockets do not make much sense. In summary, while it is impossible to eliminate risk of damage from climatic factors there are some obvious preventative measures which can be taken.

4.8 Aesthetics

The visual impact of forestry operations, both commercial and silvicultural, is a difficult, nebulous and until fairly recently, an ignored problem. There is little literature on the subject and usually no more than a passing reference is made in management plans. A taskforce appraisal of management practices on the Bitterroot National Forest in Montana (U.S.D.A. 1970) expressed considerable concern over the aesthetic impact of past forest management and road construction practices on the National Forest and recognized the need for input by landscape architects in developing future forest management plans.

A few years ago it was possible to ignore the visual impact of forestry operations as most were beyond the travel routes of the general public. However, with improved access and the use of all-terrain vehicles by a large segment of the public, untidy forestry operations are subject to a great deal of criticism. Some people consider any form of timber utilization as a desecration of the wilderness. Fortunately, these are few in number; albeit a very vocal minority. At the other end of the scale are individuals with some forest management expertise who regard the fresh scars of woods operations as temporary with relatively short recovery rates.

It is possible to conduct logging operations in a visually acceptable manner without too much debris and this is particularly true of silvicultural operations to release white spruce from aspen. Where aspen can be utilized and there is adequate stocking of well-established understorey spruce, say over ten feet in height, the visual impact will be negligible; particularly if reasonable slash disposal measures are practiced. This would apply to all mixedwood stands with the possible exception of areas recently reforested with white spruce under a mature aspen cover. Here potential damage to the newly planted stock would invalidate logging operations for some time.

If aspen cannot be utilized commercially and are felled to release a white spruce understorey, planned logging and skidding accompanied by lopping and scattering of the slash will reduce the negative visual impact and shorten the recovery period. Of course, removing the aspen will influence the pattern of wildlife use of the area for many years. However, visually the release operation will not be offensive.

Releasing white spruce by killing large aspen with herbicides or girdling will leave standing dead trees for several years. These trees will provide wind protection to the residual spruce but undoubtedly will result in some criticism for a number of years. Although this is a perfectly valid silvicultural practice it may be considered by some politic to restrict this type of operation to the backcountry; particularly if large scale operations are planned. This is a policy decision which is considered a deception by some (Twiss 1969). In the writer's opinion, primary and secondary access routes should be screened from large-scale operations by a natural buffer strip along the right-of-way. This should not be considered a deceptive tactic but rather the ensurance of a pleasing visual experience for the traveller. "Show and tell" turn-outs along the right-of-way, to reveal and explain the operations by appropriate signage, would do much to reduce public apprehension and criticism, as well as perform an educational function. Ultimately the educational process will foster a forestry ethic and a better appreciation of forest management by the public.

5.0 GROWTH AND YIELD CONSIDERATIONS IN THE DEVELOPMENT OF SILVICULTURAL PRESCRIPTIONS

5.1 Aspen suckering

5.11 Density

The growth aspects of aspen suckering after logging were studied by Bella and DeFranceschi (1972). This work centred in the Hudson Bay area of Saskatchewan where commercial logging of aspen is conducted by MacMillan-Bloedel (Saskatchewan) Ltd. Summer and winter logging were conducted and the following four conditions created.

1. Normal logging practice-tops left, non-commercial trees left standing.

2. As 1, except trees skidded with tops attached.

3. As 1, except non-commercial trees felled.

4. A combination of 2 and 3 i.e non-commercial trees felled and all trees skidded with tops.

Winter logging was done in March, 1966 and summer logging in mid-July and August 1967. Several hundred sample quadrats were examined in the late summers of 1967, 1968, 1969, and 1970.

Initial sucker density was about twice as high after summer cutting than winter cutting. A very interesting finding of this study was that after 6 years, density differences due to season of cutting and logging treatment had all but disappeared. One year after treatment the sucker densities ranged from approximately 22,000 to 58,000 stems per acre. After 6 years sucker density was between 9,500 and 10,700 stems per acre on all treatments.

A study by Bella (1975) to determine the effects of dense stocking on diameter increment revealed tree densities of approximately 13,000 to 64,000 stems per acre on control plots on which trees were from 5 to 8 years old at the time of the remeasurement.

5.11 Density - cont'd.

Studies in southeastern Manitoba (Bella and Jarvis 1967) indicated numbers of stems between 3,900 and 10,000 in a 13-year-old aspen stand. Obviously stocking can vary considerably but even the minimum numbers per acre indicated by the above studies offer formidable competition to white spruce planted or seeded after logging aspen stands or young white spruce released from aspen by logging.

Figure 1 shows the trend of number of trees per acre by age for Site Index 50 (dominant trees 50 ft. tall at 50 years) from aspen yield tables prepared for the Duck, Porcupine and Riding Mountains of Manitoba (Johnson 1957). Also shown is the same relationship from Saskatchewan aspen yield tables for Site Index 53 (Kirby et al 1957). Figure 2 shows average stand d.b.h. by age for aspen in Manitoba and Saskatchewan from the same yield tables.

5.12 Height growth

According to Jarvis (1967 in C.I.F. Meeting, Manitoba Section) suckers will grow 3 to 5 feet the first year and some may even reach heights of 8 feet. He also stated that in the second and subsequent years leader growth averages approximately 2 feet. Maini and Horton (1966) found height growth after one year on small treated plots in Ontario to be a miximum of 16 inches. However, these small treatment plots probably did not open the crown cover sufficiently to provide maximum heat and light for suckers. Steneker (1966) examined sucker growth in south-eastern Manitoba on logged areas. Average height varied between 2.6 and 4.4 feet after two years in stands with a residual canopy. Where the canopy was absent, heights were between 3.1 and 5.5 feet. The range in height was associated with slash and ground vegetation on the area.

Bella and DeFranceschi (1972) and Bella (1986) provided curves for the tallest aspen per quadrat for their study of suckering in the Hudson Bay Region of Saskatchewan. These curves are differentiated on the basis of season of cut (winter or summer) and slash conditions after logging.

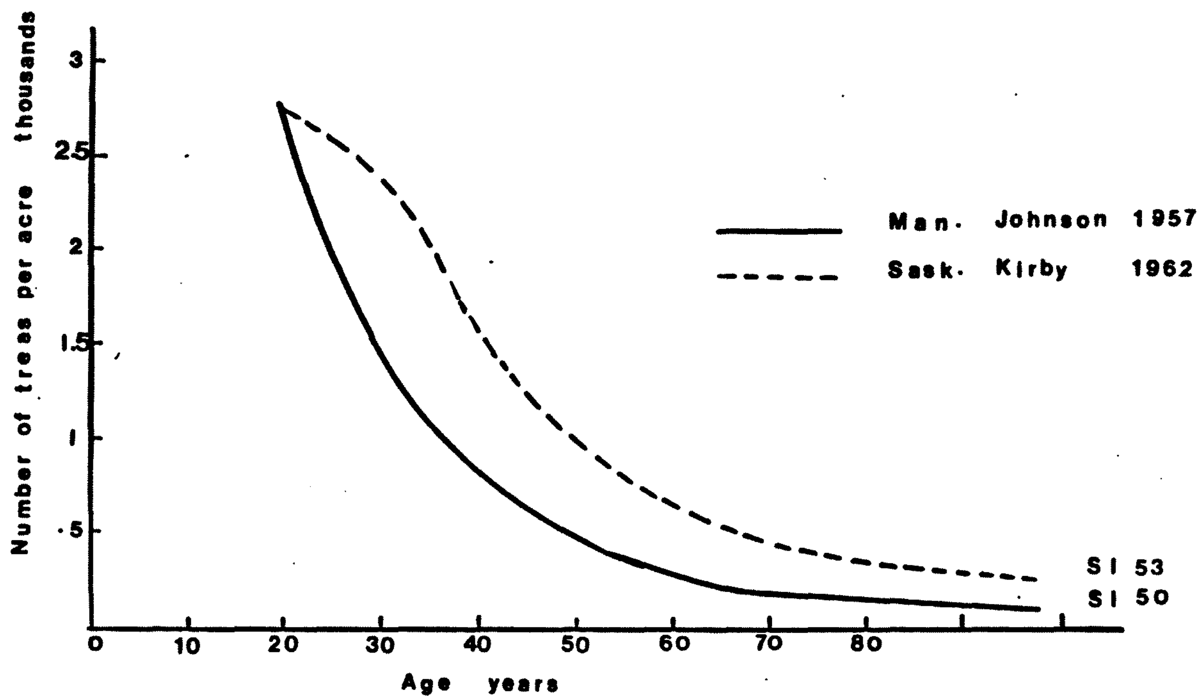

Fig. I Trend of number of trees per acre by age for aspen stands in Manitoba and Saskatchewan

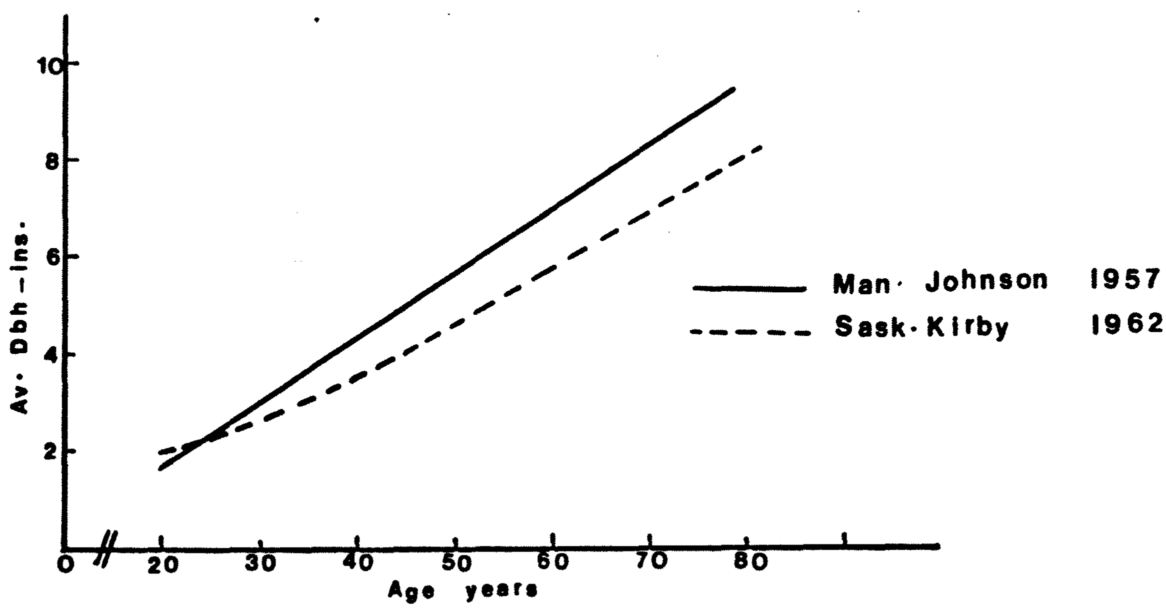

Fig. 2 Trend of average Dbh by age for aspen stands in Manitoba and Saskatchewan

5.12 Height growth - cont'd.

There is considerable difference between height growth on the winter and summer cuts; the former being greater. However, this difference diminished after six years. The difference in heights as a result of slash conditions, within a cutting season, were minor and height growth was not considered to have been affected by slash conditions. Height-age curves prepared by Bella and DeFranceschi are shown in Figure 3.

The average height of dominant aspen by age is shown for Manitoba (Johnson 1957) and Saskatchewan (Kirby et al 1957) in Figure 4. The Manitoba relationship is for Site Index 50 and the Saskatchewan relationship is for Site Index 53.

5.2 Shrubs

5.21 General

Shrubs in some mixedwood stands of the Mixedwood Forest in Manitoba are a major problem with regard to the establishment of white spruce. This is particularly true where areas have been selectively cut for large spruce and the overstorey is now scattered spruce and poplar. Bailey (1968) found this condition to be common on the Riding Mountain where he noted that the shrub cover is dominated by hazel (Corylus cornuta Marsh) on fresh to moist sites. Rowe (1955) regarded shrubs as one of the main factors affecting the survival and growth of white spruce. In fact, he stated that severe competition prevents establishment on the better growing sites, particularly cut-over areas where a luxuriant growth of hazel, raspberry (Rubus idaeus) and grass (Calamagrostis (Canadensis) usually occurs.

Kabzems et al (1976), in their ecological claassification of the Mixedwood Section in Saskatchewan, recognized four mixedwood ecosystems. Three of these are considered to have low herbs as the dominant understorey vegetation and one tall shrubs. The latter is primarily hazel. In their classification the tall shrub ecosystem is of lower productivity

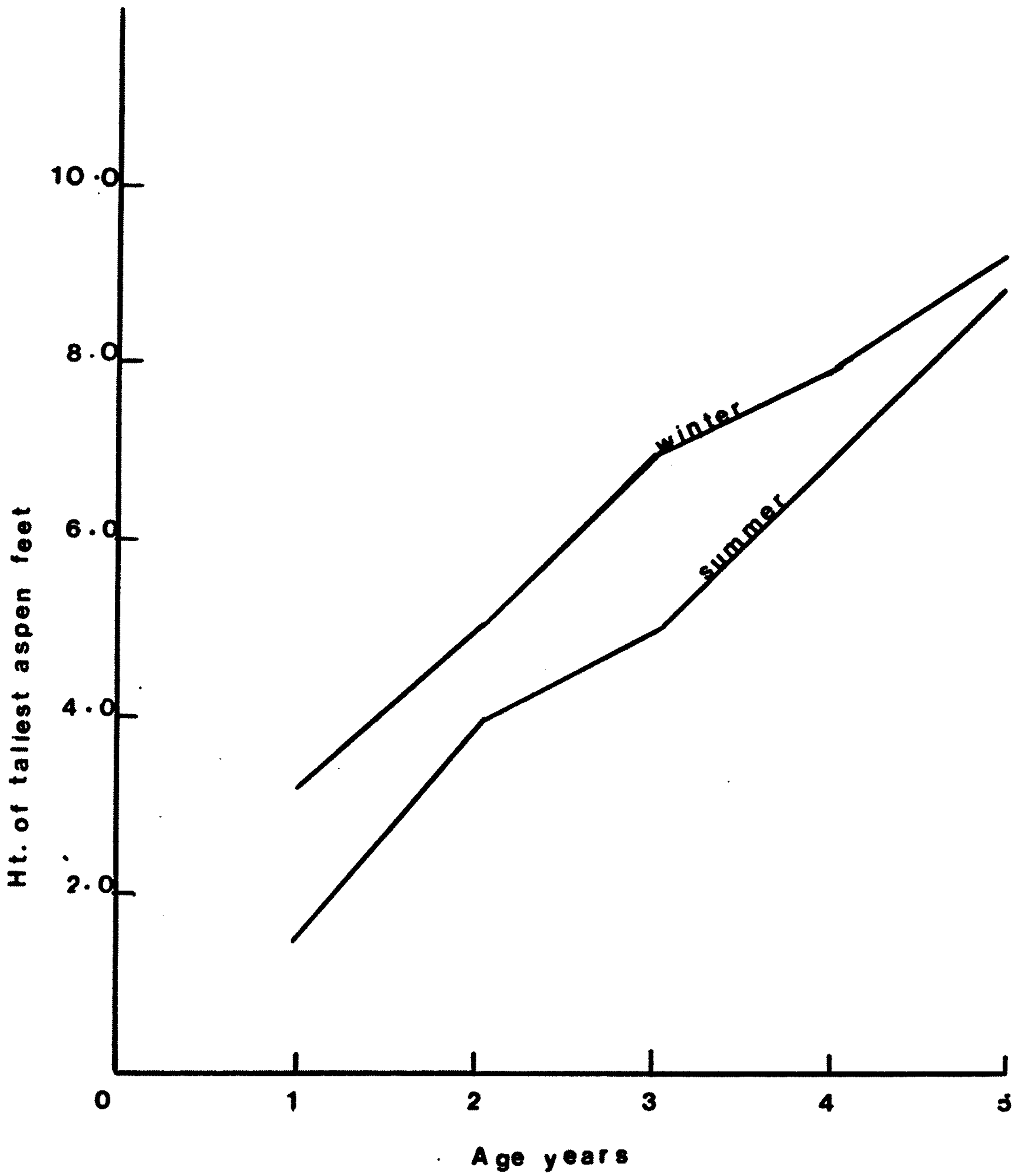

Figure 3. Approx. ht. of the tallest aspen per quadrat for summer and winter cuts (after Bella and DeFranceschi 1972)

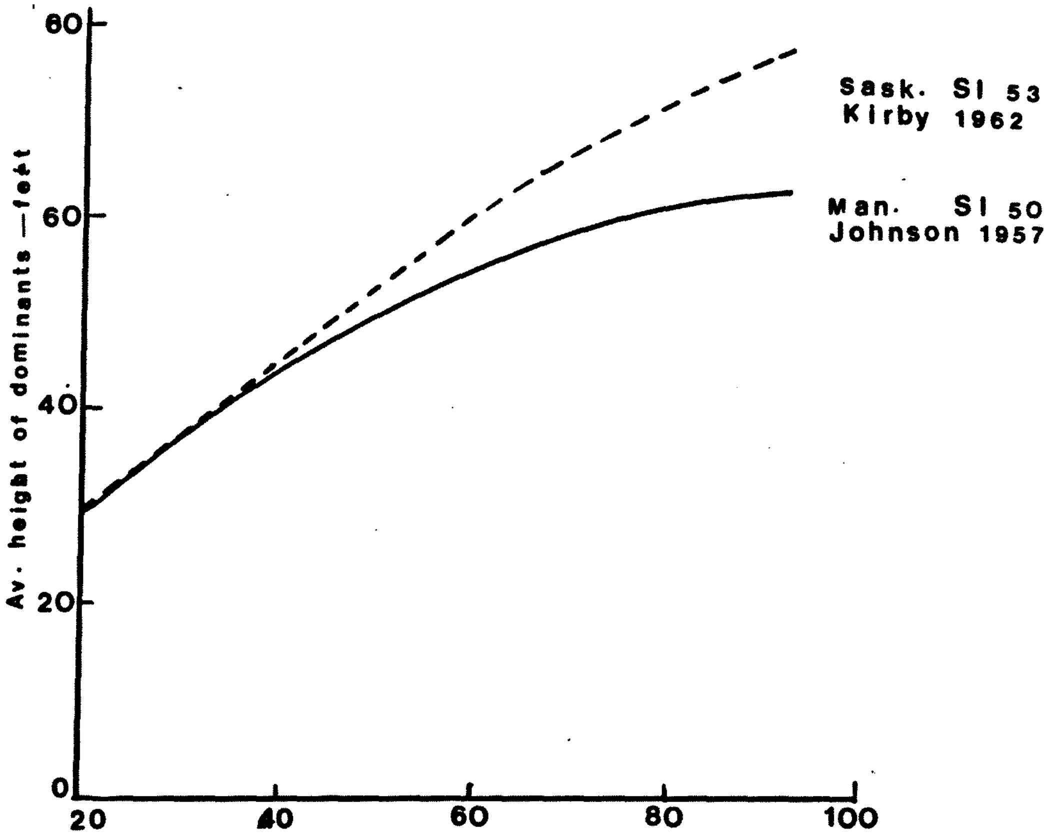

Fig.4 Height of aspen by age —Manitoba and Saskatchewan

than the others. The publication does not provide the aereal extent of each of these ecosystems, although this information may be available from current forest inventories which the writer understands include the ecological classification of forest types. The extent of dense shrub types in mixedwood stands of Manitoba is not known but is believed to be substantial. As mentioned earlier, Bailey (1968) found this condition to be common on the Riding Mountain. Undoubtedly mixedwood stands in the Duck and Porcupine Mountains would have a similar percentage of tall shrub sites.

Open mixedwood stands with tall shrubs present difficult problems in the establishment of a spruce content; naturally or artificially. Natural regeneration will probably occur only on rotten wood in such situations, given that a seed source is nearby. Artificial regeneration requires use of heavy machinery to bulldoze corridors and the use of herbicides to prevent re-invasion of the shrubs. In these cases large transplant stock would be necessary for reforestation. Prescribed burning was tried on the Riding Mountain (Jarvis and Tucker 1968) after logging but suitable habitats for conifer reproduction were few after burning.

Denser, mixedwood stands which are logged followed by immediate reforestation with good transplant stock, is a much easier proposition than the rehabilitation of shrub covered areas mentioned above. Mechanical site preparation is essential and it will probably be necessary to treat with herbicides at a later date due to the profuse aspen suckering which will undoubtedly occur.

5.22 Abundance and growth

In a study to reduce suppression of white spruce reproduction by foliage spraying of hazel with herbicides Waldron (1959) tallied shrub stems on research plots. The numbers of stems per acre on the plots prior to treatment varied between 29,000 and 41,000. According to Bailey (1968) aspen/white spruce communities on fresh to moist sites on the Riding Mountain are dominated by hazel; the relative frequency of this species being 76-100 percent. Prunus virginiana and Rosa acicularis followed with a relative frequency of 51-75 percent. A relative frequency of 26 to 50

5.22 Abundance and growth - cont'd.

percent was recorded for Amelanchier alnifolia Nutt., Rubus ideaus L. var Strigosis (Michx.) Maxim., Viburnum edule (Michx) Raf., Lonicera dioica L. var glaucescens (Rydb.) Butters, and Ribes hirtellum Michx. Relative frequencies of 1 to 25 percent were recorded for Cornus stolonifera Michx., Diervilla lonicera Mill., Ribes hudsonianum Richards and Ribes triste Pall. Waldron (1959) also mentioned Acer spicatum Lam. and Symphoricarpos albus (L.) Blake which are not mentioned in Bailey's "Notes on the vegetation in the Riding Mountain National Park". However, Waldron noted that these species accounted for a very low percentage of the total.

The shrubs mentioned are considered to represent the main species present in the mixedwood stands under consideration. Frequency and abundance may vary between the Duck and Porcupine Mountains and the Riding Mountain.

Corylus cornuta Marsh. averaged about 4 feet in height on the Riding Mountain and the other species varied between 3 and 5 feet (Waldron 1959). Acer spicatum Lam. is known to greatly exceed these heights as are other species. Obviously shrubs over 4 feet offer severe competition to coniferous reproduction and if release or planting is done where shrub abundance is great, overtopping will seriously retard the growth of seedlings.

5.3 White spruce regeneration under aspen

5.31 Stocking

5.311 Natural

Most mixedwood stands have resulted from fires and white spruce seeding has occured at the same time or after invasion of trembling aspen suckers. The stocking and density of the white spruce understorey is a direct reflection of suitability of seedbeds for germination and availability and quantity of seed. The spruce invasion can be very protracted with a few spruce becoming established and further invasion curtailed until these trees become of seed-bearing size. However, spruce under-

5.311 Natural - cont'd.

storeys of interest in this review would have become stocked rather heavily at the same time as the aspen or shortly after (10 to 30 years). Kabzems et al (1976) stated that, assuming white spruce seed is available, a hot fire will promote seeding of white spruce and suckering of aspen at the same time while a light surface fire, which does not burn the duff layer, will stimulate aspen sprouting and the regeneration of white spruce will be delayed 10 or 15 years.

As understorey white spruce stocking is dependent on seed availability and quantity and the receptivity of seedbeds, there is a considerable range of stocking densities and patchiness may be characteristic. Release treatments would only be viable where understorey spruce meets minimum stocking standards. While the Mixedwood Section has a large content of stands meeting this criterion the extent is not known in absolute terms. Special surveys, supplementing recent forest inventories, would be required to provide this information.

5.312 Artificial

There is a dearth of information on the performance of plantations under aspen stands in the Prairie Provinces but early plantations under aspen in Manitoba were failures (Haig 1959). Johnson (1953) found the same to be true of plantations established before the forties in Saskatchewan.

Walker (1984) examined white spruce plantations estabilished under 45 to 85 year-old aspen stands in the Athabasca Forest District of Alberta in 1962. Plantations near Fawcett Lake were complete failures in 1984; hare browsing occured during 1979-81 and probably occurred during 1969-71. Plantations near Lawrence Lake showed good survival. Success here was attributed to planting on prepared sites which controlled shrub competition and likely hare cover. Similar plantations established under aspen in the Foothills Section of Alberta were much more successful than those established in the Mixedwood section.

5.312 Artificial - cont'd.

In the early sixties large-scale conversion of trembling aspen stands to white spruce was attempted in Alberta. In 1972 the Canadian Forestry Service in cooperation with the then Alberta Department of Lands and Forests conducted an assessment of this program (Johnson 1973). Approximately 100,000 acres of scarification and spot seeding were examined. This represented about one-half the total area treated. In most cases bulldozed corridors were run through young aspen stands to prepare seedbeds and reduce competition. The results of these treatments were very poor and scarification and direct seeding was in disrepute for some time. Several factors accounted for the failure; insufficient exposure of mineral soil, insufficient white spruce seed, snowshoe hare depredations, drought, etc. all contributed to the 80 percent failure rate of this program. It is understood that recent success is much higher with the modification of the technique and use of more seed. Recent scarification and seeding trials on cutovers in the Western Region of Manitoba show successful first year results (Segaran, McColm, Ardron and Bell 1984). However, as the authors indicate, it will be several years before success can be determined.

Four plantations of white spruce in the Western District of Manitoba were examined by Froning (1972). These plantations were largely aimed at stand conversion and three of the four had survivals over 65 percent in 1972. Plantation ages were 3 to 5 years at the time of the examination. The technique of bulldozing strips appears to have been successful in eliminating heavy competition but rabbit damage was general and ranged from light to severe.

Soos (1967) reported high first-year mortality (43 percent) when seedlings in plastic containers were underplanted in 80-year old aspen in Alberta; whereas survival was excellent when underplanting was done in young aspen stands. He attributed the high mortality of the former planting to leaf smothering.

A study conducted near Sault Ste. Marie, Ontario, on the effects of underplanting aspen with white spruce concluded that survival and height

5.312 Artificial - cont'd.

growth was highest with 2-2 transplant stock as opposed to 2-0 and 3-0 stock (Wang and Horton 1968). Canopy density at the time of planting was 34 percent; therefore shade intensity was relatively low. However, the authors warned that the planting stock would probably face the greatest competition from aspen suckers which were growing rapidly.

To date there has not been a high level of success in converting aspen stands to white spruce in the Prairie Provinces; immediately after clearcutting, under old aspen stands, or in young aspen stands. Where survival success has been achieved there is certainly ample evidence that overstorey aspen will impede growth of white spruce and some type of release program will be required ultimately if growth potential is to be reached.

5.32 Height growth

In obtaining information on height growth of natural white spruce growing in association with aspen an attempt was made to obtain data for "free-growing" and "suppressed" white spruce in mixedwood stands which represent Manitoba site conditions. Fortunately, Cayford (1957) conducted a study in Saskatchewan which comes very close to fulfilling these criteria. Height and age data were collected by stem analysis on individual spruce trees which were designated as either free-growing or suppressed. The information was obtained in mixedwood stands near Big River and Candle Lake which are considered to be similar to many spruce/aspen stands in the Mixedwood Section of Manitoba. In order to check spruce growth in the two provinces, Cayford's information was plotted with curves prepared by Jameson (1963) for two sites on the Riding Mountain, Manitoba (fresh Waiteville and moist Granville soil series). It will be noted in Figure 5 that Cayford's height-age curve for dominant trees falls between Jameson's two curves of dominants for the Riding Mountain. White spruce plantations in the Turtle Mountain, Manitoba, also serve as a check point (Bella 1968). This reference point falls on Jameson's moist Granville site. As an additional check a height/age curve of dominants in untreated plantations representing mid sites (SI 70) in the Petawawa area of Ontario is shown (Stiell and Berry 1973). This curve is very slightly above Jameson's fresh Waiteville site for the Riding Mountain.

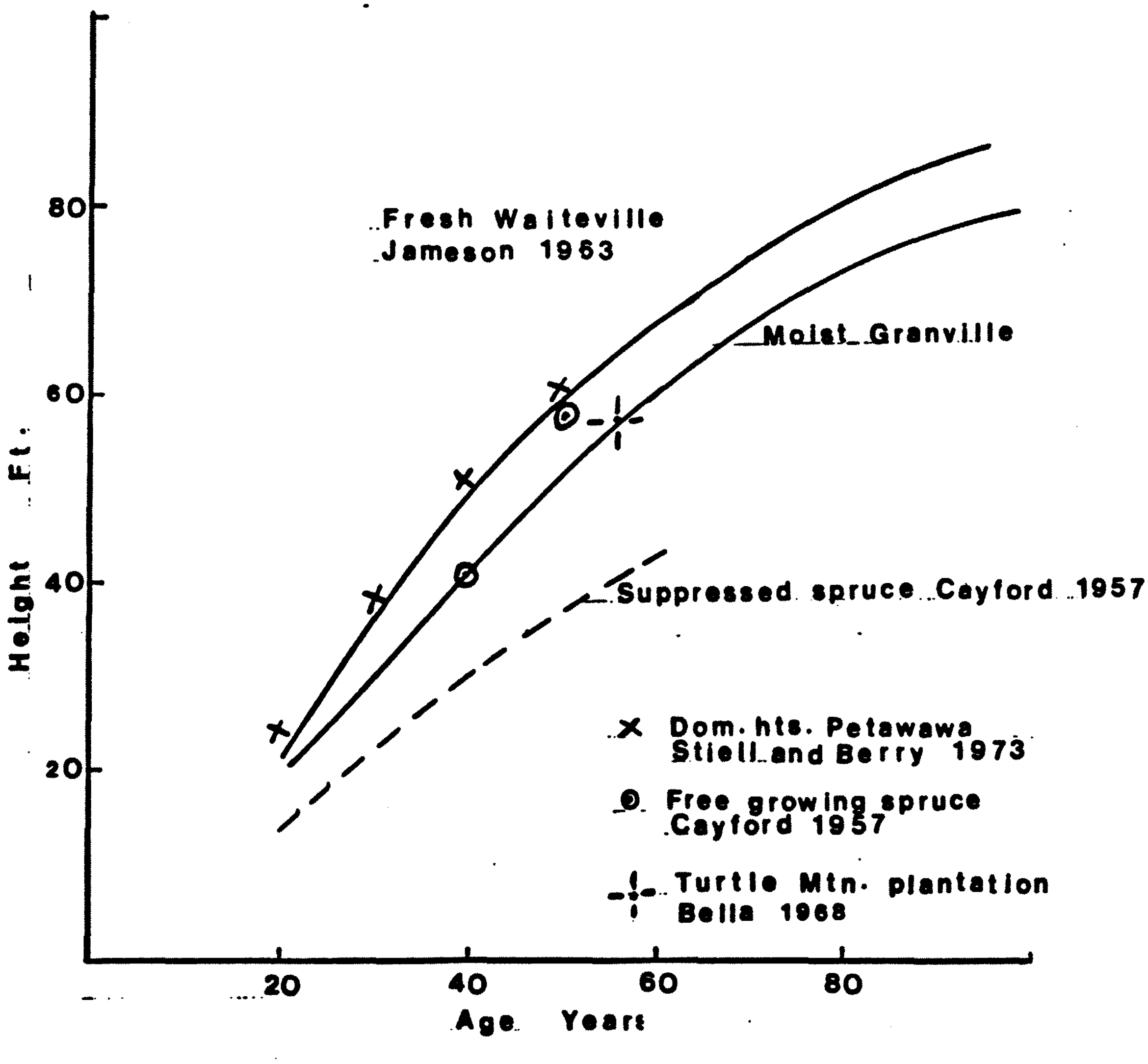

Fig.5 Height—Age curves for white spruce

5.32 Height growth - cont'd.

A height-age curve for suppressed white spruce in mixedwood stands was derived from information provided in Cayford's publication (1957) on "The Influence of the Aspen Overstory on White Spruce Growth in Saskatchewan". Cayford defined suppressed spruce as those "growing near groups of larger aspen, and consequently their growth may have been retarded by shade and root competition. Many of the suppressed trees had been damaged by mechanical action of the aspen". The height-age curve for suppressed white spruce is also shown in Figure 5. Unfortunately no other references were located dealing with the growth of suppressed spruce, however, it is believed that this curve would be appropriate for suppressed trees in many Manitoba mixedwood stands.

Cayford's (1957) study of the influence of aspen on the growth of white spruce in Saskatchewan revealed that free-growing white spruce required 7.1 years to reach breast height (4.5 ft.). Suppressed spruce required 8.7 years. It is probable that these growth rates would be lower if shrub competition such as hazel were present in abundance. Waldron (1986 pers. comm.) suggested that it would take 15 years for white spruce to reach breast height under these circumstances.

5.4 White spruce/aspen growth relationships

5.41 Competition indices

"An insight into the interrelationship between individual trees in a stand is fundamental to an understanding of the effect of various types of thinning and release cuttings on the performance of individual residuals and the stand as a whole" (Steneker 1965). This statement neatly sums up the need for an expression of the competition in a stand. A study by Steneker and Jarvis (1963) attempted to do this in a mixed stand of white spruce and trembling aspen. This study targeted individual white spruce within the stand which varied from 40 to 70 years of age. Ten-year diameter increments of thirty-eight white spruce were determined. Competition indices were derived from four formulae, which basically considered distance to competing tree (D), breast height diameter (d) of a surrounding tree, and number (n) of surrounding trees within specific radii of the sample tree. Formulae using D and d were variations of these functions either squared or simple. Another formula was used based on basal area. It was concluded that the latter formula

Competition Index = 1-n x Sum BA

gave the best correlation. For 4 to 6 inch trees, 56 percent of the variation in diameter increment was accounted for when considering trees within a 25 foot radius of the sample tree. For the 7 to 10 inch trees, 76 percent of the variation was accounted for by considering the basal area of surrounding trees within 15 feet.

Bella (1971) developed a competition model which considered individual trees and not stand variables such as basal area. He pointed out the problems associated with the use of stand variables i.e. "...... it is difficult to define the radius within which competitors should be measured and to decide whether crown class of the subject tree should be included along with a description of the spatial distribution of the competitors". Bella (1969), in his paper on "zone influence" or crown overlap and the development of a competition model for individual trees, stated that models assuming a linear additive type of competition effect by using basal area, in effect would only be viable if the subject trees and competitors were of equal size.

Bella's model (1971) was tested on five species and was found satisfactory for describing competition. All growth competition regressions were highly significant and growth rate declined with increase in competition within the range examined. He recommended that future analyses consider more complex growth-competition regression models. While Bella's model is effective in pure, even-aged stands he does suggest that large trees"... receive competition only from immediate neighbours, whereas a small subject tree may be affected by bigger competitors from a considerable distance. Competition in the latter instance, therefore, seem to be determined largely by variables like stand density, or crowding of the competitors, which are fairly well described by basal area".

Pending further modelling work, and recognizing weaknesses referred to by Bella, it is suggested that the model developed by Steneker and Jarvis (1963), based on basal area, be used as a simple method of describing stand competition in mixedwood stands.

5.42 Optimum spacing of white spruce understorey after release.

One of the requirements of this review is to estimate the number of trees per unit area, by age, which would represent optimum stocking, assuming a reasonable distribution of stems. The Manitoba government has requested the examination of twelve theoretical stocking levels in this regard as follows:

	Age of the white spruce understorey			
	0-10	10-30	30-50	50-70
No. White Spruce	500	250	200	175
per acre	1000	500	400	350
	2000	1000	800	700

Presumably a major factor in priorizing release treatments will be the number of understorey residuals. It may be necessary to reduce understorey spacing by thinning in addition to removing overstorey aspen. The task of defining optimum spacing is very difficult as there are few plantations or thinning experiments in Manitoba which have been documented through to rotation age. Fortunately there are two white spruce plantations in Manitoba which have been well documented to 1984 (Bella 1968, 1985). There is also one old thinning experiment on the Riding Mountain which was documented from treatment at age 60 to a final remeasurement in 1952 (Haig 1955). These two research studies provide bench marks which can be compared to yield tables for mixedwood and white spruce stands prepared for Saskatchewan and Alberta. The yield tables represent what was considered to be "well-stocked" stands. Two are for mixedwood stands in Alberta (Johnstone 1977) and (McLeod and Blyth 1955) and the others are for pure white spruce stands in Saskatchewan (Kabzems 1971) and mixedwood stands in Saskatchewan (Kirby 1962). The problem with these tables is that they are for natural stands and as such present lower yields than would be expected from plantations where stem distribution is ideal. Bella (1968) stated that the two white spruce plantations on the Turtle Mountain, at age 58, produced twice the yield of natural stands in Saskatchewan as indicated in yield tables for excellent sites prepared by Kirby (Kirby 1962). This was explained as a function of the greater number of trees per unit area and the regular stem distribution in the plantations.

5.42 - cont'd.

Yield table data for number of trees as related to age is shown in Figure 6. Numbers of trees per acre are shown for approximately site index 50 (dominants 50 feet tall at 50 years) and represents average to good sites for white spruce. Bella and DeFranceshi's (1978) minimum stocking standard for white spruce at one-half rotation (50 years) is also shown. It will be noted that Johnstone's (1977) curve for Alberta falls between the plantation data for the Turtle Mountain (Bella 1968, 1984) and data from the Riding Mountain (Haig 1955). The curve from the yield tables prepared by McLeod and Blyth (1955) seems high, while the curve for Saskatchewan (Kabzems 1971) is rather flat (due to the fact that data for trees smaller than 3.6 inches d.b.h. were not recorded). The data available for numbers of trees per acre is restricted for Kirby's tables (1962). Since Johnstone's curve at age 90 is very close to the data from the Riding Mountain, and has a similar slope to the data from the Turtle Mountain plantations, perhaps it can be used as a guide to optimum stocking, at least for stands over 50 years of age. Johnstone's tables indicate a very high number of stems per acre at the younger age classes but if distribution of stems is good this is not a problem. Stiell (1976) shows number of trees per acre for site index 50, at 4 foot spacing, to be 1680 in 50 year-old plantations at Petawawa, Ontario. At the time of planting there were over 2,700 trees per acre. At age 50 total and merchantable volumes still exceeded plantations planted at wider spacings. However, mean diameters are lower than for wider spaced plantations which would affect the rotation age, particularly for sawlogs. If sawlogs are desired, considering present conversion technology, numbers of well-distributed trees per unit area in the lower age classes should be reduced.

Residual stands over 1000 trees per acre at age 0-10 require thinning in addition to a release treatment. In the 10-30 age class, 250 trees per acre is below Bella's (1978) minimum standard for stocking of average sites in Alberta and stands with such limited understorey spruce should not be treated. In the 30-50 year age class 400 and 800 stems per acre are worth releasing and require no further treatment. Stands below the 400 trees per acre level do not justify overstorey release. In the 50 to 70 year age class stands from 350 to 700 stems per acre would not require additional thinning after release from aspen. Stands in the 175 trees per acre category are well below data shown for stands in this age class and do not justify treatment.

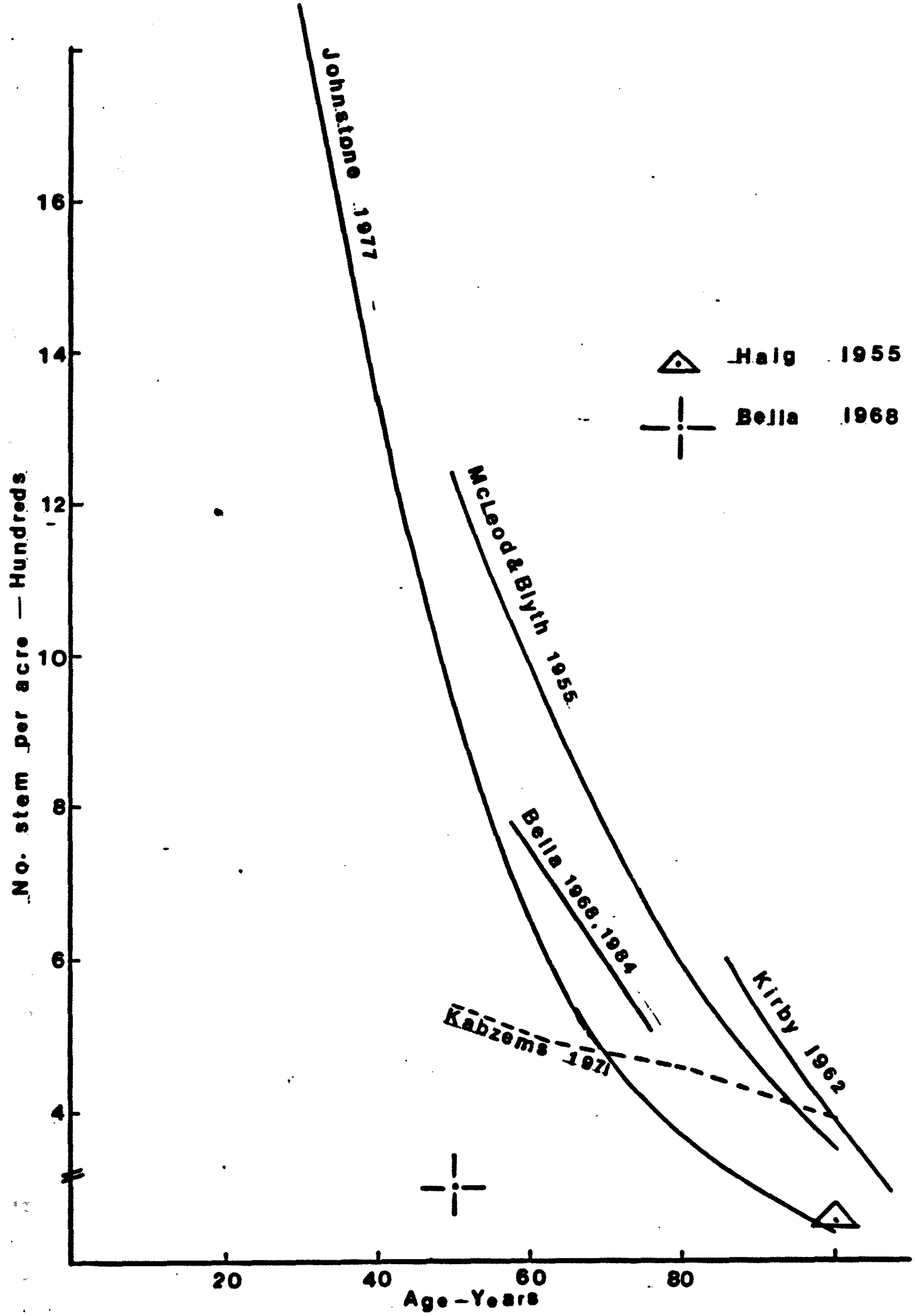

Fig. 6 No. spruce stems per acre — various sources

5.42 cont'd.

To summarize, the following recommendations are made regarding numbers of trees per unit area and proposed treatment.

Table 2. Treatment recommendations by stocking and age.

	Age of white spruce understorey			
	0-10	10-30	30-50	50-70
No. of white spruce	500_2	250_1	200_1	175_1
per acre	1000_2	500_2	400_2	350_2
	2000_3	1000_2	800_2	700_2

1. Treatment not justified, stocking too low.
2. Release warranted.
3. Release treatment warranted, thinning of residuals beneficial.

Number of trees per unit area above a critical level (sufficient to fully utilize the site) does not affect total volume. A lower number means the concentration of growth on fewer stems. However, rotations can be shortened depending on the anticipated utilization. At present it is generally assumed that white spruce will be utilized for sawlogs and dense stands will require a longer rotation age to produce material large enough to harvest.

It would be useful to know the number and average d.b.h. of aspen at various age-classes in mixedwood stands in order to estimate costs of white spruce release, particularly manual release. Unfortunately, the mixedwood yield tables available do not provide this data. These stand parameters are available for pure aspen stands (Section 5.11) and it is believed that they would apply to mixedwood stands at least to approximately age 40. Total cubic foot volumes of aspen are available for two of the mixedwood tables. These are shown for the best sites in Table 3.

5.42 - cont'd.

Table 3. Volumes of spruce and aspen in mixedwood stands at various ages.

	Johnstone (1977) Tot. cu. ft./acre		McLeod and Blyth (1955) Tot. cu. ft./acre	
Age	white spruce	aspen	white spruce	aspen
20	155	1880	-	-
30	740	2210	255	1755
40	1335	2415	880	2745
50	1900	2525	1710	3750
60	2435	2570	2570	4600
70	2930	2580	3445	5285

Aspen volumes for the two yield tables shown in Table 3 are quite similar to age 40. Beyond that age the McLeod and Blyth table shows much higher aspen volumes. If manual release programs are contemplated there is a high volume of aspen to deal with; from approximately 20 cunits at age 30 to 50 or more cunits at age 70, on the best mixedwood sites.

5.43 Age at which white spruce overtops aspen in mixedwood stands.

Cayford (1957) studied three age groups (55-60, 70-75, and 95-100) of mixedwood stands in Saskatchewan and found that free-growing white spruce overtopped aspen in the stand when between 40 and 65 years of age. At ages above 50 or 60 years, height growth of suppressed spruce approached that of aspen. At this stage severe whipping occurred. Lees (1967) indicated that between age 55-75 the spruce pushes through the overstorey as the aspen becomes decadent. Kagis (1952) in his discussion of problems of mixedwood stands in Saskatchewan, suggested that at an age of 50-60 years some spruce succeed in struggling through the overstorey aspen and start to grown under better conditions.

Generally there is concurrence that between the ages of 50 and 75 years, white spruce would commence to penetrate overstorey aspen. However, because of years of whipping they may not respond significantly to release. Free-growing white spruce will overtop aspen between ages 40 and 65.

5.43 - cont'd.

An important growth relationship to know is the height at which free-growing white spruce will continue to exceed the new aspen sucker height after a release treatment. This was estimated by using the white spruce height-age curve for Waiteville soils on the Riding Mountain prepared by Jameson (1963) and comparing it with the site index 50 height-age curve prepared for aspen on the Duck, Porcupine and Riding Mountains (Johnson 1957). These relationships are shown in Figure 7. The x-axis was shifted 5 and 10 years to show the relationship of new aspen sucker growth to 5 and 10 year-old spruce. It will be noted that the spruce must be approximately 10 years old or 8-10 feet in height to escape being overtopped by future aspen suckers after a single release treatment. If the spruce is shorter it will require subsequent release treatments.

5.44 Diameter-crown width relationships

Figure 8 shows crown width-d.b.h. relationships for white spruce and trembling aspen. The relationship for aspen was prepared by Bella (1970) using data from Manitoba, Saskatchewan, Alberta and interior British Columbia. According to Bella there was remarkable uniformity of data across western Canada.

The relationship prepared for white spruce from Alberta data presented by Ontkean and Smithers (1959) is almost identical to the relationship prepared by Bella and DeFranceschi (1978) for white spruce in Alberta. Also shown in Figure 8 is the relationship prepared from data presented by Stiell (1969) for young white spruce plantations (13-41 years) with spacings ranging from 3' by 3' to 7' by 7'. Crown closure had occurred on many of these plantations.

In an individual tree release experiment in Alberta, Ontkean and Smithers (1959) removed all aspen competition within twice the crown width of spruce trees being treated. Individual spruce trees aged 10 to 70 were released. In the older age classes, removing competition within twice the crown width of open-grown spruce (Figure 8) would result in a large reduction of the aspen component. For example open grown white spruce 10

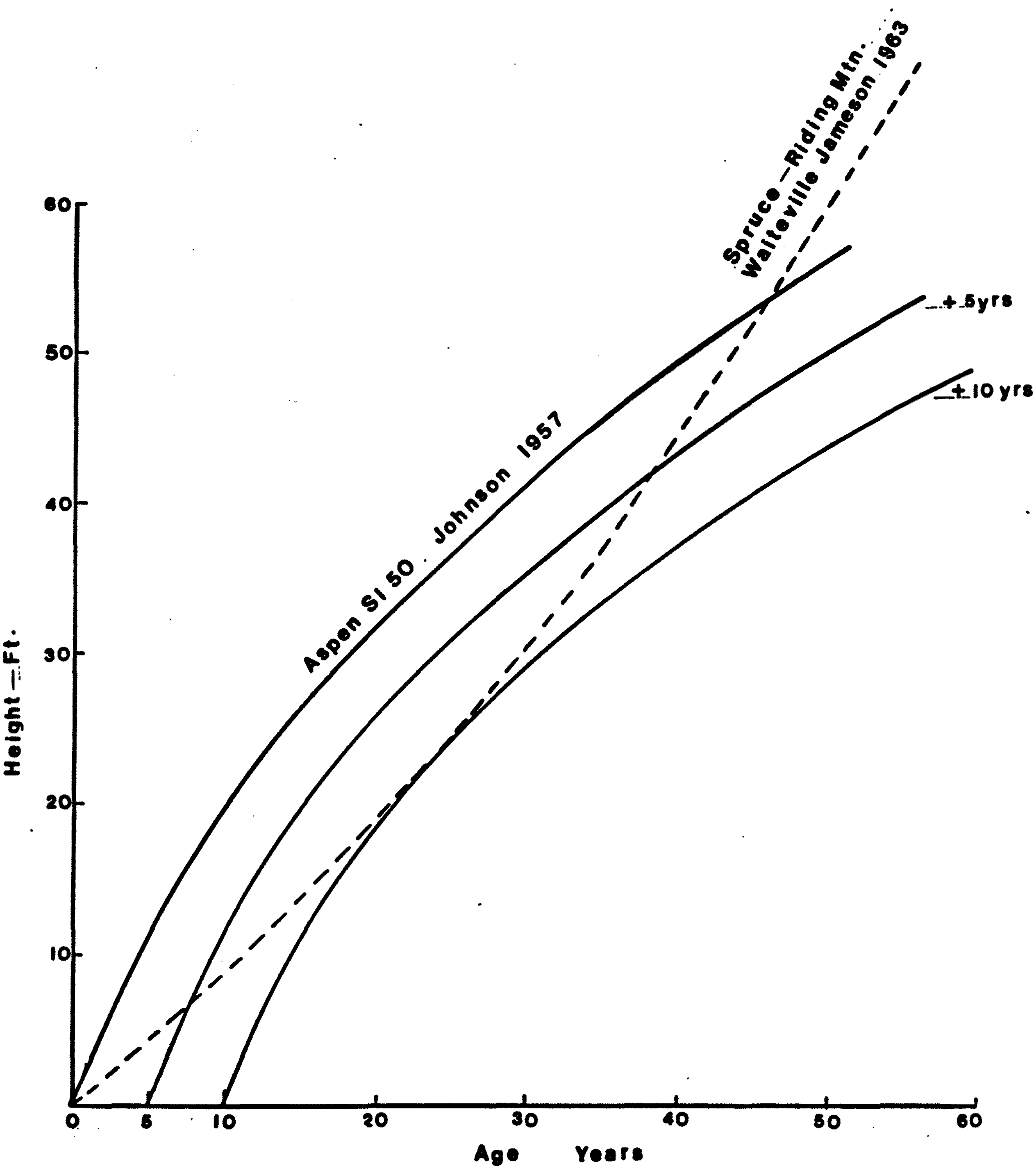

Fig. 7 Growth of white spruce and aspen in Manitoba showing new aspen growth 5 & 10 years after spruce initiation

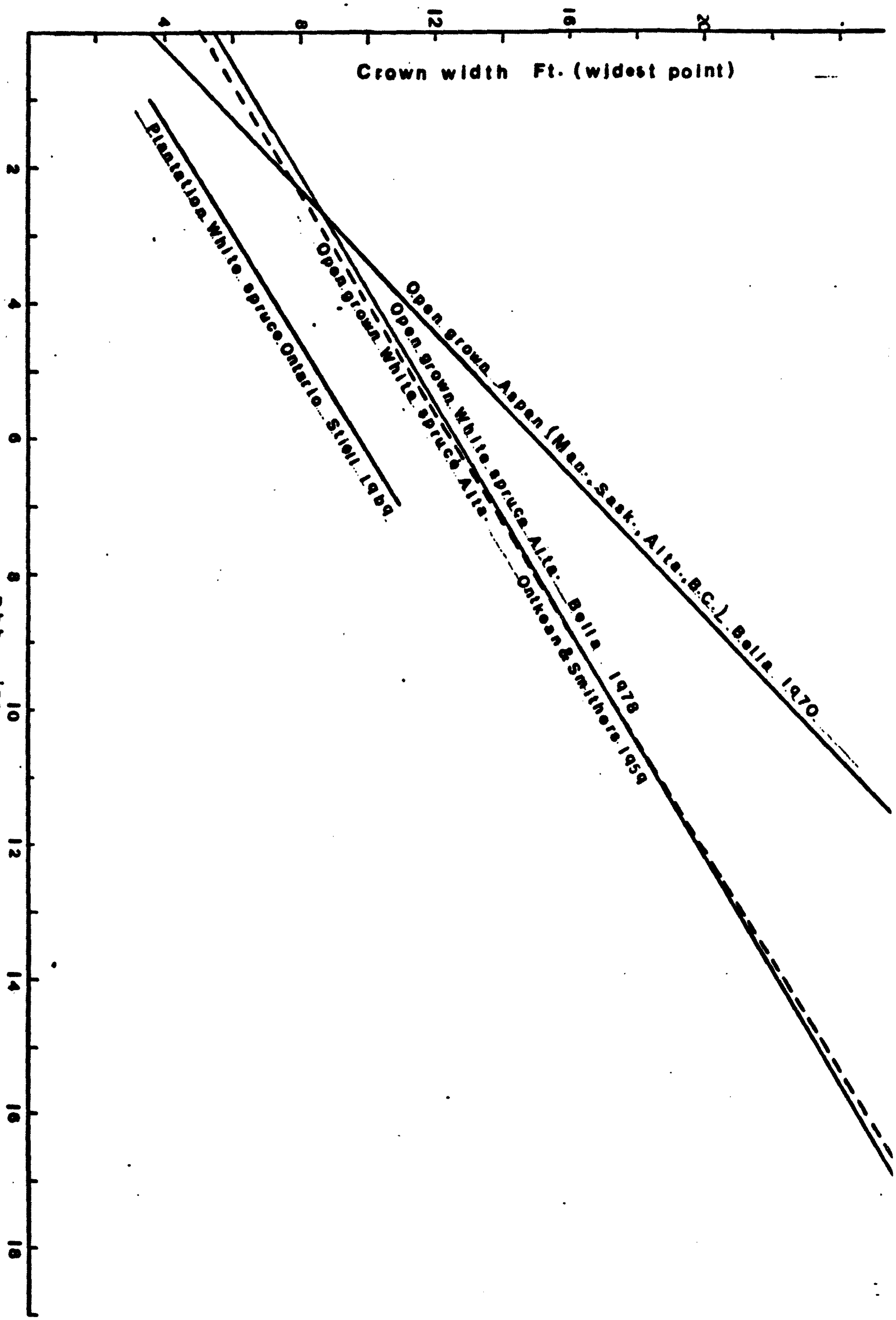

Fig. 8 Crown width–Dbh relationships – White spruce and Aspen

5.44 - cont'd.

inches at d.b.h. have an average crown width of approximately 17 feet (Figure 8). Trees of similar d.b.h. in stands with some competition, would have much smaller crown diameters and probably would not require competition removal to this degree. Perhaps removal from one crown width would suffice.

In young stands, removing competition from twice the crown width of released trees would be effective for a relatively short time before further release treatments would be required.

Obviously releasing crop white spruce depends to a large extent on the nature of the overstorey canopy. For young spruce, removal of the overhead canopy to allow at least 50 percent light is a requirement to ensure adequate growth (Logan 1969). For older crop trees, sufficient release to stop whipping is essential if the release treatment is to ensure accelerated growth and lowering of the rotation age.

A stand of free-growing spruce would be less than ideal for lumber utilization due to heavy branching. Allowing trees to develop without competition would result in 12 inch trees having a crown width of approximately 19 feet which really means 19' by 19' spacing or 120 trees per acre. This is considerably lower than the standard set for white spruce stocking in Alberta by Bella and DeFranceschi (1978) at one-half rotation age (50 years).

As the maximum crown width of a spruce tree tends to be at mid height or lower, it is not necessary or desirable to keep spruce crowns from overlapping in order to have a fully released top. On the other hand, crowns of aspen are rounder in shape and usually form an overstorey thus presenting a greater competition problem to spruce than neighboring spruce.

From approximately 2 inches at d.b.h. the crown widths of free-growing aspen exceed the crown widths of free-growing spruce substantially (Figure 8). The difference in crown width increases with increases in diameter. Therefore, younger stands require a drastic release if further release treatments are not part of the management strategy. Older stands, which are treated to obtain a short-term growth benefit before harvest, would require removal of fewer, but of course, much larger trees. Simply girdling and leaving larger trees would not totally solve whipping problems as the dead standing trees would be an impediment to the white spruce for several years.

Since mixedwood stands do not grow regularly spaced, it is difficult to recommend a precise spacing between spruce and aspen for each age-class. In the older age-classes, aspen which are obviously competing, should be removed, assuming that the released spruce are to be harvested within a relatively short period, say 10 to 15 years. In the younger age-classes spacing is more-or-less dependent on the frequency of release treatments. If only one treatment is proposed at an early age, most if not all of the aspen competition should be removed and this can probably best be accomplished with herbicides.

In summary, if young spruce understoreys (1 to 30 years) are to be released from mature aspen overstoreys in a one stage operation, all aspen should be removed, preferably with herbicides, as cutting the older aspen will destroy much of the young understorey. Young spruce understoreys (1 to 10 years) growing in similar aged aspen overstoreys may be treated with herbicides or the aspen can be removed with hand tools. If only one release operation is planned, aspen reduction will have to be quite drastic and chemical treatment will be necessary to inhibit suckering. In intermediate aged understoreys (30 to 50 years) removal of competition from a distance of one average white spruce crown width for the d.b.h. under consideration, is probably satisfactory and using the relationship for "free-growing" white spruce in Figure 8 will provide a guide as to the distance that competing aspen should be removed from individually released white spruce. In stands older than 50 years, release should be done by eye, ensuring that the tops of released trees are free from aspen whipping and that the crown of the released spruce has room for development. However, removal of competition within at lease one actual crown width of the tree to be released would be advisable.

5.5 Effects of releasing white spruce - General

Most of the research concerning the release of white spruce from aspen overstoreys is described in five Canadian Forestry Service publications (Cayford 1957, Steneker 1963, Lees 1967, Steneker 1967, Steneker 1974). All of these studies were conducted in the Mixedwood (B18a) Section of the Boreal Forest (Rowe 1972) and are summarized in a review of silvicultural research in the Mixedwood Section (Jarvis, Steneker, Waldron and Lees 1966).

An overview of the key studies in the prairie provinces, and related studies in North America, is presented in the Appendix. Results from the studies in the prairie provinces show conclusively that all ages of spruce to approximately age 75 respond to release treatments positively, with 30 to 40-year-old trees showing the greatest response. Increases in diameter growth to 80 percent and height growth over 50 percent after ten years, resulted from releasing young to intermediate aged spruce in eastern Saskatchewan. A 50-year old stand in the Duck Mountain of Manitoba had 200 percent more total cubic foot volume than a control stand after twenty years. The board foot volume of the treated stand was 300 percent more than that of the control (Steneker 1963).

Research release plots in eastern Saskatchewan were remeasured in September, 1985. The results have not been analyzed but a report will be prepared by Dr. Richard Yang of Northern Forestry Centre in 1986.

5.51 Rotation age

Rotation age is usually considered to be the age at which mean annual volume increment culminates. That is, the age at which the stand will yield the maximum volume per unit area per year. Utilization is also a large factor in determining rotation age; the more complete the utilization, the lower the rotation age. Rotation age is also affected by site. Rotation ages provided in this section are for the white spruce only.

5.51 - cont'd.

Johnstone's (1977) . yield tables for fully-stocked spruce-poplar stands in Alberta provide rotation ages for natural stands that are differentiated by site index and utilization. For an average site (Site Index 20 or 20 m dominant heights at 70 years) the rotation age for all softwood stems over 4.6 ins. (approx. 11.7 cm) is 135 years. Rotation ages for lumber products over 8.6 ins. (21.8 cm) is calculated at 165 years. For the best site, rotation age for lumber products is estimated at 146 years.

Yield tables for even-aged fully stocked stands of spruce-poplar in Saskatchewan (Kirby 1962) provide rotation ages for white spruce which are very similar to those calculated by Johnstone (1977). Yield tables prepared by McLeod and Blyth (1955) indicate somewhat lower rotation ages for white spruce.

The yield tables for normal mixedwood stands examined indicate a rotation age for the spruce component of between 95 and 135 years. For lumber utilization (over 7 or 8 inches d.b.h.) this increases to 125 to 165 years on average sites.

Kabzems et al (1976) indicate rotation ages of between 65 and 75 for three mixedwood sites in Saskatchewan. However, these ages include the aspen component of the stands.

Kabzems (1971) prepared yield tables for well-stocked white spruce stands in the Mixedwood Section of Saskatchewan. Essentially these were pure spruce stands. A rotation age of 75 years was calculated for trees over 3.6 inches at d.b.h. (9.0 cm) on average sites (Site Index 52). For trees over 7.6 ins. (19.0 cm) the rotation age is 110 for average sites. On the best sites the rotations are 70 and 85, respectively.

Table 4 presents approximate rotation ages for average and best sites for the four yield tables examined. An examination of the data shows that the rotation age for best sites averages about 110 years for the spruce component of mixedwood stands. If lumber utilization is

5.51 Rotation age - cont'd.

planned the rotation age would increase to at least 125 years on the best sites and up to 165 years on average sites. Pure stands of well-stocked white spruce would have much shorter lumber rotation ages; in the order of 85 for the best sites and 110 years for average sites.

Admittedly rotation ages provided in Table 4 are not exactly on the same base (e.g. site classifications differ somewhat). However, they are considered to be in the "ball park" and would probably apply to natural, well-stocked stands in the Mixedwood Section of Manitoba. This comparison of natural pure white spruce stands and mixed white spruce and trembling aspen stands provides an estimate of spruce rotations for the two stand types. On the average, white spruce in pure stands reach rotation 40 years (110 - 70) before white spruce growing in mixedwood stands, on the best sites. Undoubtedly the rotation age could be further reduced by subsidiary silvicultural treatments to improve the spacing of residual spruce after aspen competition has been removed.

Table 4. Approximate rotation ages of white spruce by site and stand type.

Yield table	Stand Type	Rotation age (years) Pulpwood		Rotation age (years) Lumber[1]	
		Av. Site	Best Site	Av. Site	Best Site
Kirby (1962)	Mixedwood	125[2]	116[2]		
McLeod, Blyth (1955)	"	115[2]	95[2]	140	125
Johnstone (1977)	"	135[2]	119[2]	165	146
Kabzems (1971)	Pure white spruce	75[2]	70[2]	110	85

1. 7-8 ins. + d.b.h.

2. Stems over 3.6 ins. d.b.h.

5.52 Volumes at rotation

Table 5 summarizes all source information as to volumes and rotation ages for white spruce. Cubic foot volumes were selected rather than metric volumes as most of the yield tables were developed using Imperial measurements. Where necessary, metric measurements were converted. Also in one case board foot volumes were converted to cubic foot volumes. These kinds of conversions are not ideal and it is stressed that the data are approximate. However, for purposes of estimating volumes at rotation age for mixedwood stands, pure stands, plantation stands and released stands there was no other alternative approach.

A comparison of the three yield tables for mixedwood stands (Johnstone 1977, Kirby 1962, McLeod and Blyth 1955) indicates average spruce pulpwood volumes of approximately 3850 cubic feet at an approximate rotation of 125 years for stands on average sites. Pulpwood volumes on the best sites average about 4800 cubic feet at 110 years. It is difficult to generalize for the lumber volumes which are twice as high for the Johnstone (1977) yield tables due to the longer rotation ages.

Pulpwood volumes for pure spruce stands in Saskatchewan (Kabzems 1971) compare favorably with yields from mixed stands but the rotation age is much shorter. This is considered to be a reflection of better growing conditions for the spruce in pure rather than mixed stands. Lumber volumes are in the same range as the McLeod and Blyth (1955) yield tables but considerably less than Johnstone's (1977). Here again the rotation ages are substantially lower for the former.

Plantation yields from the Turtle Mountains are much superior to yield table yields at age 76 for both pulpwood and lumber. This is as a result of the better spacing of trees. Certainly the yield potential of intensively managed plantation forests is indicated by these results.

An old thinning experiment in a pure white spruce stand on the Riding Mountain Forest Experimental Area is included in Table 5 to show the yield of the 92 year old control plot which incidentally was superior to the stands thinned from below and above at age 60 (Haig 1955). It is indicative of the yields which may be expected from well-stocked, unmanaged, pure spruce stands at age 90+.

5.52 Volumes at rotation - cont'd.

The results of a release experiment conducted in a 50-year old white spruce/aspen stand in the Duck Mountain in 1920, is also illustrated. Note that the white spruce are at approximately rotation age. Unfortunately these stands at the time of release contained only 260-375 white spruce stems per acre at age 50, which is somewhat lower than optimum for treatment. The heavy release plot contained more than three times the volume of lumber and pulpwood calculated for the control at age 71. The light release had about twice the lumber volume and approximately three times the pulpwood volume of the control. These percentages are very impressive but the actual volumes are lower than would be expected if initial white spruce stocking had been higher.

It is difficult to predict volume of released stands on the basis of available data. However, there seems little doubt that rotation age can be reduced by as much as 40 to 50 years on average and best sites. Due to the long rotations indicated for poor sites, release treatments on these sites should have low priority.

As mentioned earlier in this report, analysis of research release plots by Dr. Richard Yang of Northern Forestry Centre, Edmonton, will provide accurate information for predicting yields of released white spruce. His report is expected in 1986.

Considering the best sites, which should be the highest priority for release treatment, the following rough approximations are presented which will indicate the value of release treatments.

1. White spruce volumes of well-stocked, natural, untreated spruce/aspen stands are between 4000 and 5000 cu. ft. (4 ins. d.b.h. and over) at about 110 years.

2. Volumes of pure, well-stocked, natural white spruce stands are approximately the same or a little lower at about 70 years.

5.52 Volumes at rotation - cont'd.

3. Average volume of released white spruce stands should be at least equal to or greater than untreated pure stands at about the same rotation age, depending on the age when release occurred and stocking and spacing of the residual spruce trees.

A rough estimate of spruce volume loss in unmanaged mixedwood stands is obtained by examining the four yield tables compared in this review. If one assumes that stands on average sites are to harvested at age 90, the yield tables present the following volumes of trees 3.6 ins. + at d.b.h.

Kabzems (1962) Pure Spruce	3800 cu. ft. at age 90
McLeod and Blyth (1955) Spruce/aspen	2530 cu. ft. at age 90
Johnstone (1977) Spruce/aspen	2600 cu. ft. at age 90
Kirby (1962) Spruce/aspen	2200 cu. ft. at age 90

White spruce volume at age 90 averages 2450 cu. ft. for the mixedwood yield tables. The pure spruce table indicates a volume of 3800 cu. ft. at age 90. This represents a theoretical volume loss of white spruce in mixedwood stands of approximately 1350 cu. ft. or 35 percent during the 90 year rotation.

Estimates of volume loss in mixed stands versus pure stands, using yield tables and bench mark plots, are necessarily crude because of differences in stocking and minor site variations. However, they do indicate a substantial loss in spruce volume by lack of stand treatment. Amazingly, the estimate of 35 percent volume loss discussed above coincides with Kagis' (1952) estimate of spruce volume loss in mixedwood stands of Saskatchewan without stand treatment.

The normal yield tables discussed indicate average volumes represented by many stands and are therefore lower than might be found in some individual stands. For example, at age 92 a control plot on the Riding Mountain contained 5946 cu. ft.; substantially more than indicated in Kabzem's yield table for pure white spruce. Undoubtedly this plot was well stocked and the spacing was close to ideal.

Obviously if the stocking of residual white spruce after treatment is optimum, and spacing has been improved by thinning at an early age, volumes would be higher than for natural, pure stands and would probably approach that of plantations such as the one shown for the Turtle Mountain in Table 6. This plantation had a volume of 5300 cubic feet and a very high volume of sawlog-sized trees (4500 cu. ft.) at 76 years, which is probably past the rotation age for this stand.

In effect, the best payoff in increased merchantable volumes and shortened rotations is to release adequately stocked spruce understoreys on the best sites and in conjunction with the release treatment improve the spacing of the residuals if required.

Table 5. Approximate volumes of white spruce per acre at pulpwood and lumber rotations by stand type and site.

Source	Stand type	Site	Pulpwood Vol.cu.ft.4"+ (Rotation) Age	Lumber Vol.cu.ft.8"+ (Rotation) Age
Kirby	Mixedwood	Poor	3050 (130)	-
(1962)		Average	3600 (125)	-
		Best	4500 (116)	-
Johnstone	Mixedwood	Poor	- (192)	- (208)
(1977)		Average	4155 (135)	- (165)
		Best	4540 (119)	4600 (140)
McLeod &	Mixedwood	Poor	2890 (145)	- (170)
Blyth		Average	3800 (115)	1600 (140)
(1955)		Best	5200 (95)	2240 (125)
Kabzems	Pure Spruce	Poor	2220 (80)	1180[6] (130)
(1971)		Average	3350 (75)	1640[6] (110)
		Best	4350 (70)	1830[6] (85)
Plantation 5 WS Turtle Mtn. Man.	Pure Spruce	Average	5290 (76)[1]	4500 (76)[1]
Thinning Riding Mtn. Haig (1955)	Pure Spruce	Average	5946 (92)[1]	2456 (92)[1]
Release 4	Mixedwood	-	1423 LR[2] (71)[1]	668 LR[2] (71)[1]
Duck Mtn.			1498 HR[3] (71)[1]	1074 HR[3] (71)[1]
Steneker			450 C[4] (71)[1]	368 C[4] (71)[1]
(1963)				

1. Age of stand
2. Light release
3. Heavy release
4. Control
5. Data from Dr. I.E. Bella, Northern Forestry Centre.
6. Conversion: 10 board ft. = 1 cu. ft.

5.53 Branch development

"The spruces have long straight trunks with scaly bark, and dense narrow crowns of many pliable branches that often extend to the ground-particularly on open-grown trees" (Hosie 1969). The above quote from "Native Trees of Canada" aptly describes the branching habit of white spruce. Since the species is shade tolerant, it retains branches for many years and in an open growing situation large branches will develop.

Haig (1959) examined 25 to 39 year-old plantations on the Riding and Duck Mountains and noted that, "even where stocking was high, trees showed little evidence of natural pruning". A similar statement was made by Bella (1968) after remeasuring white spruce plantations over 50 years old on the Turtle Mountain. He noted that the trees had good form but dead branches persisted almost to the ground. Stiell (1955) reported on the Petawawa spruce plantations and stated that no self-pruning had occurred on plantations ranging in age from 16 to 34 years even at the tightest spacing which was 4' by 4'.

Berry (1964) conducted a time study on pruning plantation white spruce. The justification for pruning was that although white spruce is one of the most important lumber species in eastern Canada, lumber grades are normally low since clear grades are seldom available. This is due to the fact that the species fails to prune itself naturally.

Berry (1968) reported epicormic branching following thinning and pruning of plantation spruce at Petawawa Forest Experiment Station. Initially this was thought to be a problem. The original epicormic branches were removed and five years later no further branching had occurred (Berry 1974).

It is apparent that branchiness is a problem with white spruce and only low grade lumber may be expected from poorly stocked stands. Branch retention is very persistent with sound branches noted on plantation trees at Petawawa for a period of 26 years (Stiell 1976). Pruning of the lower bole will result in a higher recovery value and is recommended in conjunction with thinning programs (Berry 1964). A time study of pruning plantation white spruce to a height of 17 feet by sectional curve-bladed pole saw was conducted by Berry (1964) at Petawawa. The average time required to prune a spruce tree to this height was 9.9 minutes. Pruning was also conducted on red pine and the average time per tree was 4.2 minutes, less than half the time required for white spruce. Although pruning of white spruce was recommended there was some doubt as to the economic advantage due to grading practices in eastern Canada at that time. This is an area that requires some economic analysis before large pruning programs are conducted in white spruce residuals after release from aspen.

6.0 SILVICULTURAL GUIDELINES FOR THE RELEASE OF WHITE SPRUCE FROM TREMBLING ASPEN IN THE MIXEDWOOD SECTION OF MANITOBA

6.1 The decision to treat

The decision to release white spruce from trembling aspen on an operational basis must be made with some knowledge of market forecasts and other economic indicators. It would be very easy to justify operational release programs on a purely silvicultural basis but when aspen is destroyed to release spruce the assumption is made that it is an inferior species with no future market value. Certainly this has been the thinking for many years but when one looks at the industry in the Lake States, where aspen was considered a weed in the early forties and is now the backbone of the forest industry, a certain amount of caution is warranted. Aspen utilization is expanding in the prairie provinces. Lately, two oriented strand board plants, utilizing poplar exclusively, have been constructed in Alberta. Also, Prince Albert Pulp and Paper company is presently utilizing more aspen than softwoods. The writer recalls attending a Canadian Institute of Forestry Section meeting in Prince Albert about ten years ago. The mill manager presented a talk on pulp processing and was emphatic that there was no market for hardwood pulp from Saskatchewan and he couldn't visualize the acceptance of anything but high grade softwood pulp in the foreseeable future. Certainly no attempt is being made here to belittle the mill manager as most of the foresters, at the meeting, held a similar view. Marketing opportunities do change and sometimes with dramatic swiftness.

Obviously aspen conversion plants can only be established where there is a good supply of the species on the appropriate sites; enough to sustain an economic production facility. Therefore, there are undoubtedly several areas where releasing white spruce from aspen will be a viable option for many years. Certainly in areas where large spruce sawmills presently exist there is a real opportunity to increase merchantable spruce volumes at a reasonable cost; particularly if there is a relatively short pay-off period.

Since utilization may change considerably in the next ten or twenty years it may be prudent to accent release treatment of older understorey stands (40-70 years) in order to get a relatively quick return. The conversion of good site aspen may be expensive and imprudent; either by reforestation or releasing young established spruce. The ideal situation would be to commercially utilize the aspen while performing a release function to the understorey spruce.

Prior to planning release programs a good inventory of understorey stands is required along with current aspen inventories. The latter is available in Manitoba but special surveys may be required to obtain the former. When this information is available and is coupled with a marketing analysis, sound silvicultural planning can be done concerning operational release programs.

6.11 A look at total yields of natural, unmanaged, mixedwood stands versus anticipated yields from treated stands.

Mixedwood stands on good sites produce high total wood fibre yields during relatively short rotations. The problem until fairly recently has been that the hardwood content of this fibre yield has not been marketable. Kabzems et al (1976) estimated yields of 2860 cu.ft. to 4075 cu.ft. (200 M_3 to 285 M_3) of white spruce and aspen at rotations of 65 to 75 years. Johnstone (1977) indicated total yields for spruce and aspen in mixedwood stands on the best sites in Alberta to be approximately 5500 cubic feet at age 70 and the McLeod and Blyth (1955) yield tables show yields for both species of over 8500 cubic feet.

Bella (1970) has shown yields of aspen to be higher in Alberta than Manitoba and Saskatchewan and this may account for the higher total mixedwood yields for Alberta. Nevertheless, total yield of mixedwood stands on the best sites in Saskatchewan is approximately 4,000 cu.ft. per acre at age 70 (Kabzems et al (1976). As indicated in Section 5.52 (Volumes at rotation) the yield for pure unmanaged spruce stands, at age

70, on the best sites in Saskatchewan, is 4350 cu.ft. Therefore, on the best sites in Saskatchewan, the mixedwood stands produce about the same total yield of fibre as the unmanaged, pure white spruce stands (where rot or stain is a major utilization problem with regard to the aspen component, this statement may be questionable). It is believed that yields would be similar in Manitoba. Yields of managed stands (plantations) are over 5000 cu.ft. at about age 75 and it is assumed that this is about the highest average production possible at this age on most sites.

Since total yields appear to be about the same for pure spruce or mixedwood stands, in unmanaged stands at rotations of about 70, it becomes a question of product values. Presently white spruce is a higher value product but will this be the case 20 or 30 years hence? This question must be considered before a large investment is made to release white spruce from aspen.

6.12 Product values

The writer has no current information on product values and in any case an analysis of this kind is best left to specialists. Since aspen is being utilized to a greater extent in the prairie provinces, it would seem likely that product values could be determined and a study initiated on a particular forest management unit such as the Duck Mountain. A market analysis to determine supply and demand in North America and other regions of the world would provide some indication of the acceptance of hardwood pulp and other products.

It would seem a safe bet that there will continue to be a demand for conventional spruce lumber for many years but the main problem will be the commitment of lands for this purpose. The release treatment of large areas would be a definite commitment to this type of product management and it may be difficult at some time in the future to overlay another type of product management on the same lands. It is understood that some problems have developed in this regard in the Hudson Bay area of Saskatchewan, where two companies (one producing aspen flake board and the other spruce lumber) with different forest management objectives are experiencing some conflicts. A study of this situation would be worthwhile to better understand the problems and to benefit from resolutions achieved by the companies and the Saskatchewan government.

6.2 Impact of treatment-benefits and risks

There are several anticipated benefits and risks or problems associated with large-scale programs to release white spruce from aspen overstoreys.

A list of anticipated benefits follows:

Silvicultural

1. Increased growth of white spruce
2. Higher volumes of spruce at rotation
3. Shorter rotation

Economic

1. Increased allowable annual cut of white spruce
2. Increased regional employment
3. Economic multiplier effect

Social

1. Increased employment opportunities
2. Increased regional affluence
3. Development of a forestry ethic
4. Increased forestry educational and public relations opportunities.

Anticipated risks or problems associated with the implementation of large-scale release programs include the following:

Silvicultural

1. Mortality of residual white spruce by natural causes which may negate treatment benefits
2. Renewed competition from aspen suckers and shrubs
3. Reduced growth of residuals due to climate, mammals, insects and disease
4. Water table rise on moister sites resulting in slower growth

Economic

1. Change in product values between treatment and rotation
2. Subsidization of logging overstorey
3. Increased access costs
4. Increased fire protection costs
5. Acquisition of funds for treatment program

Social

1. Visual (aesthetics)
2. Perceived environmental damage
3. Actual environmental damage
4. Change in wildlife patterns due to treatment
5. Change in vegetational patterns after treatment

6.3 Rationale for guideline preparation

There are several factors to consider in the preparation of silvicultural prescriptions or guidelines for the release of white spruce from trembling aspen overstoreys. Most of these are silvicultural but there are also some eocnomic and social factors which should be examined.

Silvicultural

Stand age structure must be known to determine the type and frequency of treatments required. If the spruce understorey is intermediate-aged or older only one treatment will likely be necessary but there are some special considerations in order to protect the understorey from severe windthrow or in some cases logging damage. Similarly if the understorey is young some special precautions are necessary in order to avoid damage and mortality to residuals.

In addition to height of the spruce understorey, it is important to examine the stocking and distribution. These stand qualities must be known in order to decide whether release treatments are worthwhile and if so whether or not the residual spruce requires thinning.

The maturity, density and quality of the aspen overstorey are important considerations in the development of silvicultural guidelines. Density will probably determine the release method used and size and quality will have a bearing on the commercial utilization. If there is no market for the aspen, the size of the trees which must be removed or killed is an important factor.

Site, exposure and aspect are essential in order to evaluate wind risk to residual spruce, particularly intermediate-aged stands. Normally wind risk is higher on very moist or dry sites.

Other silvicultural considerations would be the recognition of problems associated with the maintenance of a monoculture. Releasing large areas of spruce may result in insect problems and a higher fire risk.

Economic

There are some economic factors to consider in the development of prescriptions or guidelines. These are:

1. Size of treatment area.
2. Access.
3. Availability of a workforce.
4. Proximity to conversion plants.
5. Overstorey logging opportunities.
6. Economic advantage of herbicide use over manual release.
7. State of the local economy.

Social

The main social considerations are:

1. Aesthetics
2. Employment opportunities.
3. Environmental damage - damage to streams and lakes, erosion, etc.
4. Altered habitat for birds, animals and minor vegetation.

6.31 Silvicultural axioms

A detailed review of this nature uncovers many pieces of information, both quantitative and qualitative. As an aid to developing silvicultural guidelines the major facts and findings are listed below.

1. White spruce has to be at least 6 feet tall to avoid serious snowshoe hare damage (Keith 1972).
2. White spruce must be at least 8 feet tall to stay ahead of new aspen sucker and shrub competition subsequent to a single manual release treatment. (Jameson 1963, Johnson 1957).

3. Aspen sprouts average 9 feet tall in 5 years. (Bella and DeFranceschi 1972).
4. Aspen sucker densities are between 9500 and 10,700 stems per acre after 6 years. (Bella and DeFranceschi 1972)
5. Free-growing white spruce require 40 to 65 years to over-take free-growing aspen on the same site. (Cayford 1957).
6. Free-growing white spruce requires 7.1 years to reach breast height in eastern Saskatchewan. Suppressed white spruce requires 8.7 years. (Cayford 1957).
7. Greatest growth response from release occurs in white spruce 20-40 years-old (Lees 1967, Cayford 1957).
8. Between ages 50 and 75 "suppressed" spruce pushes through the aspen canopy but may be in poor condition due to whipping. (Lees 1967, Cayford 1957, Kagis 1952).
9. White spruce over 75 years of age did not respond to release cuttings in Saskatchewan. (Steneker 1974)
10. Volumes of suppressed spruce were one-half those of free-growing spruce in all age classes sampled in eastern Saskatchewan (Cayford 1957).
11. Mixedwood total yield is approximately the same as pure white spruce yield in Saskatchewan (Kabzems et al 1976, Kabzems 1972).
12. Total spruce yield is about 35 percent lower in mixedwood stands than in pure spruce stands over a 90 year rotation, in Saskatchewan.
13. Rotation age is about 30-40 years shorter for spruce in pure stands than in mixed stands.
14. White spruce seedlings require at least 45 percent light but larger seedlings are produced with 100 percent light (Logan 1969, Shirley 1941).
15. Sunlight needles produce a much bigger plant than shade needles (Logan 1969).

16. Intermediate and mature white spruce in dense mixedwood stands may not be windfirm when released (Alexander 1974, Froning 1980).

17. Carefully planned logging of aspen is required on commercial operations - logging and skidding must be done to minimize damage and mortality to understorey white spruce (Froning 1980).

18. Aspen should not be felled in extremely cold weather in order to minimize damage and mortality to the white spruce understorey (Froning 1980).

19. Approximately 25 percent aspen overstorey should be left in some instances to provide wind protection to residual spruce. (Froning 1980).

20. Aspen girdled or sprayed and left standing should provide some wind protection. However, those which will impede spruce growth due to whipping should be felled.

21. Release treatments (felling, girdling, spraying with herbicides) may create adverse visual impact for a considerable period of time.

22. Open-grown white spruce provides favorable conditions for some insects. (Morse and Kulman 1984, Cerezke 1985, pers. comm.)

23. The conversion of mixed stands to pure stands could result in some insect related problems. (Cerezke 1985, pers. comm.)

24. Manual release productivity varies between 1.5 and 4.0 man-days per acre. (Haig 1964, Peters 1984)

25. Costs (1960) "handi-girdling" \$.05 per tree.
    2, 4, 5-T in frills .07 per tree.
    axe girding .08 per tree.
    basal spraying .13 per tree.
    (Waldron 1961)

26. Aerial spraying cost (280 acres in 1964)-\$6.22 per acre. (Pratt 1966)

Guidelines have been prepared for three scenarios.

1. Natural spruce/aspen stands where the crowns and leaders may be detrimentally affected by the lower branches of the overtopping aspen (whipping). The difference in height between the tops of the spruce and the lower branches of the aspen averages 10 feet in intermediate-aged and older stands.

2. Stands of aspen underplanted with spruce (stand conversion) or spruce plantings and seedings in cutovers with residual aspen overstoreys. The difference in species height may be over 20 feet.

3. Recently regenerated cutovers where planted or seeded spruce and aspen suckers as well as competing shrubs are approximately the same height.

Guidelines for the release of white spruce from aspen overstoreys are presented with the following provisions:

1. It is assumed that only average to good sites warrant release treatment.

2. It is presumed that the highest priority for treatment will be stands closest to conversion centres.

3. In most cases aerial application of herbicides will prove to be the most economical treatment option, both from the standpoint of immediate release and the need for subsequent treatment. As an example Vanden Born and Malik (1984) reported that red pine/black spruce plantations required 5 hand cuttings to obtain the level of conifer release produced by one chemical treatment. Manual release will promote vigorous suckering of aspen and if spruce are less than 8 or 10 feet in height subsequent treatments will be required.

4. It is assumed that treatment areas smaller than 100 acres would not be viable insofar as conventional aerial applications of herbicides is concerned (helicopter applications may be viable on smaller areas). A treatment area may be composed of more than one stand provided they are in close proximity.

5. Manual release treatments, where felling of large trees is concerned, are to be carefully executed in order to minimize damage to residual spruce.

6. Where spruce in the 1-30 year age-class constitutes the understorey in natural stands, the aspen overstorey, in most cases, will not be merchantable.

7. As the treatment option is a management decision based on silvicultural efficacy and economic and political considerations, these guidelines will not prescribe one definite treatment but the most feasible options will be listed with what is considered to be the most economic method shown first.

8. <u>Treatment options</u>

   1. Aerial spraying with herbicides
   2. Ground foliage spraying
      a. Tractor or truck mounted
      b. Back pack
   3. Basal spraying
   4. Use of specialized herbicide applicators
      a. Tree injection
      b. Cyclone seeders (granular)
   5. Hand application of herbicide crystals
      a. In axe frills
      b. At the base of trees
   6. Girdling
      a. Machine
      b. Axe or specialized hand tool
   7. Felling
      a. Chain saws
      b. Circular brush saws
      c. Hand saws
      d. Axes
      e. Machetes

Silvicultural guidelines for each age-class and stocking level are presented on the basis of key stand qualities and silvicultural factors. Combinations of these variables represent the prescription guideline unit. Risks, problems and treatment options are indicated for each unit. A treatment priority rating is also provided for each unit.

6.411 Spruce understorey 0-10 years
Stocking levels 500, 1000 and 2000 stems per acre.

A. Spruce understorey 500 and 1000 stems per acre
B. Spruce understorey 2000 stems per acre
C. Spruce understorey averages less than 8' tall
D. Spruce understorey averages more than 8' tall

Note 1. Treatment areas less than 100 acres not suitable for aerial application of herbicides.
2. Poor acess will limit ground release treatments.
3. Dense, patchy stocking may require spot thinning.

1. (AC)
Risks and problems - 1. Residual spruce vulnerable to snowshoe hare problems. 2. Will require more than one release treatment.
Treatment priority - Low
Treatment options - 1;2;4b;7b,d,e (subject to Notes 1,2 and 3)

2. (AD)
Risks and problems - Minimal
Treatment priority - High
Treatment options - 1;2;4b;7b,d,e (subject to Notes 1, 2 & 3)

3. (BC)
Risks and problems - 1. Residual spruce vulnerable to snowshoe hare problems. 2. Will require more than one release treatment. 3. Residual spruce requires thinning.
Treatment priority - Low
Treatment options - 1;2;4b;7b,d,e (subject to Notes 1,2).

4. (BD)

Risks and problems - Residual spruce requires thinning.

Treatment priority - Medium to High

Treatment options - 1;2;4b;7b,d,e (subject to Notes 1,2)

6.412 Spruce understorey 10-30 years
Stocking 250, 500 and 1000 stems per acre.

A. Spruce understorey 250 stems per acre - Treatment not recommended
B. Spruce understorey 500 and 1000 stems per acre
C. Windfall risk High
D. Windfall risk Low
E. Spruce understorey averages Less than 8' tall
F. Spruce understorey averages More than 8" tall

Note 1. Treatment areas less than 100 acres not suitable for aerial application of herbicides.
2. Poor access will limit ground release treatments.
3. Dense, patchy stocking may require spot thinning.

1. (BCE)

Risks and problems - 1. Future windfall risk may be high. 2. Residual spruce subject to snowshoe hare problems. 3. Will require more than one treatment.

Treatment priority - Low

Treatment options - 1;2;4b;5b;7a,b,c,d (subject to Notes 1,2 and 3).

2. (BCF)

Risks and problems - Future windfall risk may be high

Treatment priority - Low

Treatment options - 1;2;4b;5b;7a,b,c,d (subject to Notes 1,2)

3. (BDE)

Risks and problems - 1. Residual spruce will require more than one release treatment. 2. Residual spruce subject to snowshoe hare problems.

Treatment priority - Medium

Treatment options - 1;2;4b;5b;7 (subject to Notes 1,2 and 3).

4. (BDF)

Risks and problems - Minimal

Treatment priority - High

Treatment options - 1;2;4b;5b;7a,b,c,d (subject to Notes 1,2 and 3).

6.413 Spruce understorey 30-50 years
Stocking levels 200,400 and 800 stems per acre

A. Spruce understorey 200 stems per acre - Treatment not recommended.
B. Spruce understorey 400 and 800 stems per acre
C. Windfall risk High
D. Windfall risk Low
E. Commercial logging of aspen will occur
F. Commercial logging of aspen will not occur

Note. 1. Treatment areas less than 100 acres not suitable for aerial application of herbicides.
2. Poor access will limit ground release treatments.
3. Dense, patchy stocking may require spot thinning.

1. (BCE)

Risks and problems - 1. Windfall risk high. 2. Special logging precautions required.

Treatment priority - Low to Medium

Treatment options - Special logging precautions required.

Must leave 25% aspen to provide wind protection. Must not log in severely cold weather.

2. (BCF)

Risks and problems - Windfall risk high. Should leave 25% live aspen to provide wind protection.

Treatment priority - Low

Treatment options - 1;3;4;5;6;7a,c,d (subject to Notes 1,2 and 3)

3. (BDE)

Risks and problems - Special precautions required in logging aspen to preserve spruce understorey.

Treatment priority - Medium to High

Treatment options - No treatment required other than special precautions in logging to preserve spruce understorey.

4. (BDF)

Risks and problems - Minimal

Treatment priority - High

Treatment options - 1;3;4;5;6;7a,c,d (subject to Notes 1,2 and 3)

6.414 Spruce understorey 50-70 years
Stocking levels 175, 350 and 700 stems per acre

A. Spruce understorey 175 stems per acre - Treatment not recommended
B. Spruce understorey 350 and 700 stems per acre
C. Windfall risk High
D. Windfall risk Low
E. Commercial logging of aspen will occur
F. Commercial logging of aspen will not occur

Note. 1. Treatment areas less than 100 acres not suitable for aerial application of herbicides.
2. Poor access will limit ground release treatments.

1. (BCE)

Risks and problems - Windfall risk high.

Treatment priority - Low to Medium

Treatment options - Special logging precautions required to protect spruce understorey. Must leave 25% aspen to provide wind protection. Must not log in severely cold weather.

2. (BCF)

Risks and problems - 1. Windfall risk high. 2. Must leave 25% live aspen for wind protection.

Treatment priority - Low to Medium

Treatment options - 1;3;4;5;6;7a,c,d (Subject to Notes 1 and 2)

3. (BDE)

Risks and problems - Special logging precautions required to preserve spruce understorey.

Treatment priority - High

Treatment options - No treatment required other than special precautions in logging to protect spruce understorey. Do not log in severely cold weather.

4. (BDF)

Risks and problems - Minimal

Treatment priority - High

Treatment options - 1;3;4;5;6;7a,c,d (Subject to notes 1 and 2)

6.42 White Spruce underplanted in pure aspen stands

Stand conversion of pure aspen stands to white spruce by planting is a difficult and expensive silvicultural undertaking. Conversion of young aspen stands results in competition from sucker growth as a result of initial attempts to reduce competition adjacent to spruce seedlings. Also young aspen stands offer ideal habitat for the snowshoe hare. Conversion of older aspen stands may result in less than optimum light conditions for the young spruce. In addition it is difficult to remove the aspen overstorey without destroying the planted spruce.

Attempts to convert aspen stands by reforestation should be done only on the best spruce sites and in areas where spruce management is a long-term economic reality.

Guidelines for releasing white spruce underplanted in pure aspen stands.

1. Young aspen stands

   a. Stand conversions will usually require several treatments, preferably by aerial application of herbicides, but manual release may be done if warranted using methods 2; 4a; 7b, d, e.

b. Several plantation inspections will be required in order to recommend release treatments which will result in optimum spruce growth.
c. Aspen overstorey must allow at lease 50 percent light in order to maintain adequate spruce growth.

2. Older aspen stands
   a. The aspen overstorey must allow 50 percent light in order to maintain adequate spruce growth.
   b. Subsequent release will have to be done by aerial application of herbicides or methods 2; 3; 4; 5; 6.
   c. Several project inspections will be required in order to recommend plantation maintenance which will result in optimum spruce growth.

6.43 White spruce plantings or seedings in cut-overs with residual aspen

Residual aspen stands which are fairly dense do not sucker profusely so competition from this source may not be serious. On the other hand, there could be dense underbrush such as hazel which would offer severe competition to planted or seeded stock. However, control may be less expensive than for aspen suckers as the period of intense competition would be shorter due to the lower maximum height of shrubs.

Light residual stands of aspen may sucker profusely and conversion may really be analagous to conversion of young aspen stands. Guidelines relate to residual stands of aspen where suckering occurs but is not profuse.

Guidelines

a. Spruce seedlings require at lease 50 percent light, therefore, a schedule of release treatments will be required to maintain optimum growth and also reduce snowshoe hare cover.

b. Release treatments must exclude felling or commercial utilization of the aspen overstorey which could result in severe damage to seedlings. Methods 1, 2, 5 and 6 are recommended.

c. Monitoring and expensive maintenance will be required to ensure optimum growth and survival of the spruce.

6.44 Recently regenerated cutovers with aspen suckers and competing shrubs.

This scenario assumes that the competing aspen suckers and shrubs are approximately the same height (± 6') as the spruce. Therefore, the spruce is well established but is suffering competition. If this suppression can be alleviated for a short period the spruce will reach a height (8' +) where it will stay ahead of new aspen suckers or shrubs. Normally 6 foot spruce would require a minimum of 2 years in order to be free of overhead competition. The following guidelines are offered.

Guidelines

a. Aerial spraying of herbicides would undoubtedly be the most economical release method if the project is of sufficient size. Ground spraying could also be done if access is good.

b. Manual release around each seedling with axes, machetes, or possibly circular brush saws is feasible if labour-intensive programs are warranted. All competing vegetation within a minimum of three feet from the base of spruce should be removed.

c. Depending on the growth rate of the spruce a subsequent release treatment may be required.

7.0 IMPLICATIONS OF RELEASE PROGRAMS IN THE DUCK MOUNTAIN FOREST MANAGEMENT UNIT (FMU 13)

The contractor was requested to determine the impact of treating all mixedwood stands in the Duck Mountain Forest Management Unit (FMU 13). The volume increase obtained by releasing all spruce in mixedwood stands is, of course, a hypothetical value as many factors will determine the scope of silvicultural release programs and certainly not all mixedwood stands would be candidates for treatment. However, the theoretical treatment impact on total spruce volume represents the potential for the unit and emphasizes the value of silvicultural release programs.

The Forest Inventory Division of the Manitoba Department of Natural Resources provided all summaries and maps for FMU 13. The inventory of this unit was completed recently and is fully computerized which allows for accurate summaries based on a large number of variables including cover type, subtype, cutting class, crown closure, and site as well as land status, ownership and productivity. Although age-class is not designated it is indicated in the cutting class description. The reader is referred to the "Guide For Use Of Forest Inventory Maps" prepared by the Forest Inventory Division of the Department of Natural Resources.

The availability of an excellent inventory made it possible to examine various cover-types with relative ease. In addition to area and volume summaries for the sub-types of interest in this study, it is possible to obtain information on the size of any subtype within a Township (the inventory mapping unit) or the average size of a particular sub-type within the Forest Management Unit. Also it is possible to compile area and volume summaries on the basis of cutting class and site. This flexibility demonstrates the usefulness of the inventory for planning silvicultural programs and designating priorities.

Unfortunately definitive spruce release results for each age-class of mixedwood stands are not available. Hopefully after an analysis of the work being conducted by Dr. Yang of Northern Forestry Centre, foresters will be in a better position to re-evaluate the impact of release programs for a particular forest management unit based on area and age-class inventory information. For the present, a percentage increase based on the yield table analysis of this study and the work of others indicates an average of 35 percent volume increase. Kagis (1952) implied an average increase in spruce volumes of 35 percent by release treatments and Dempster (1981) estimated 30 percent for mixedwood stands in Alberta. The estimate of 35 percent volume increase is considered to be conservative and for the purpose of determining potential impact of release treatments in the Duck Mountain is applied to the volume summaries provided by the Inventory Division. Admittedly this is a rough approximation but may be refined when data from research studies conducted by Dr. Yang are available.

In summarizing mixedwood stands, cover types "M" (softwood-hardwood: 51-75% spruce); "N" (hardwood - softwood: 26-50% spruce); and "H" (hardwood less than 25% spruce) were examined. The "H" covertype was examined because there is a number of these stands which contain an understorey of white spruce with low basal areas and therefore are regarded as hardwood stands. In designating covertypes the basal area of component species is considered, therefore, older stands with a young understorey may not reflect the understorey component unless identified on aerial photographs.

Sub-type codes, based on basal area of component species, considered in this analysis are 50 (white spruce 51%+); 51 (white spruce 50% or less-balsam fir, jack pine, black spruce); 53 (black spruce 51%+); 54 (black spruce 50% or less-jack pine); 55 (black spruce 50% or less-balsam fir); 81 (trembling aspen-jack pine): 82 (trembling aspen-spruce, balsam fir larch); 90 (trembling aspen); 91 (trembling aspen, less than 50%, white birch 20%+). It will be noted that in covertypes N and M there are some coniferous species other than white spruce e.g. jack pine, balsam fir, black spruce etc. All of these would benefit from release treatments but it could be argued that these should be deleted from the present analysis. Although these subtypes are relatively few in number they could be deleted easily if warranted.

As indicated earlier, a simplistic approach to determining the impact of release treatments on total white spruce volume for FMU 13 is

7.0 - cont'd.

used whereby a direct percentage increase of 35 percent of the net merchantable spruce volumes for the foregoing sub-types is used. Also in the area analysis these same sub-types are used to provide estimates of the mixedwood and hardwood sub-types in the unit.

Table 6 provides estimates of total area of FMU 13, total area of mixedwood and aspen subtypes, and the total area of mixedwood subtypes and aspen subtypes identified as having spruce understoreys.

Table 6. Area summaries for FMU 13.

Forest type	Area
Total area FMU 13	376,781 ha (931,045 acres)
Total area mixedwood and aspen subtypes (50, 51, 53, 54, 55, 81, 82, 90, 91)	216,324 ha (534,547 acres)
Total area mixedwood and aspen stands identified with spruce understoreys	149,324 ha (368,987 acres)

Table 7 provides volume summaries for white spruce and aspen in mixedwood and hardwood stands.

Table 7. Volume summaries for FMU 13.

Forest types	Net merchantable volume
White spruce in mixedwood and hardwood stands	5,525,560 M_3 (1,951,335 cunits)
Trembling aspen in mixedwood and hardwood stands	11,160,690 M_3 (3,941,364 cunits)

7.0 - cont'd.

The theoretical additional spruce volume of all mixedwood and hardwood stands having been treated would be .35 times 5,525,560 = 1,933,946 M3 (682,967 cunits). As cautioned earlier this is merely a hypothetical estimate which is used for emphasis but it does indicate the substantial benefits that may be derived from intensive silvicultural programs.

This analysis also indicates an area of 149,324 ha (368,987 a) or approximately one-third of the Duck Mountain (FMU 13) which could be considered for silvicultural release treatments. Much of this could be ruled out for various reasons discussed in this report, but obviously there is a very large area which could benefit from treatment. A more detailed analysis of the inventory data by cutting class, site, access, etc. would be required before large-scale release programs are considered. However, the excellent quality of the Manitoba forest inventory provides the opportunity to identify stands which will respond positively to treatment. Supplementary large-scale aerial photography may be necessary to identify understorey white spruce.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions reached following a review of available literature and other information are as follows. These are not in any particular order of importance.

1. Present information suggests at least a thirty five percent increase in merchantable white spruce volume following appropriate release treatments.

2. On a purely silvicultural basis, release of white spruce from trembling aspen and shrubs is a viable forest management option.

3. The greatest growth response from releasing white spruce appears to be in the 20-40 year-old age-class.

4. White spruce over 75 years of age does not respond well to release treatments.

5. Gross total yields of well-stocked mixedwood stands are not changed significantly by treatment. However, growth is concentrated on the preferred species.

6. White spruce volumes in natural, well-stocked mixedwood stands average approximately 2500 cubic feet at age 90.

7. White spruce volumes in natural, well-stocked, pure stands average approximately 4000 cubic feet at age 90.

8. White spruce volumes in managed stands (plantations) average over 5000 cubic feet at age 75.

9. Rotation age of spruce in pure stands is 30-40 years less than in mixed stands, due to the aspen competition in the latter.

10. White spruce seedlings require at least 45 percent light, but larger seedlings are produced with 100 percent light.

8.0 - cont'd.

11. White spruce understoreys must be at least 8 feet tall to stay ahead of new aspen sucker growth and shrub competition subsequent to a single manual release treatment.

12. If white spruce seedlings are less than 8 feet tall at the time of release they will likely require additional release treatment(s).

13. White spruce seedlings must be at least 6 feet tall to avoid devastating snowshoe hare damage during peak hare populations.

14. In general, above a minimum treatment area size, aerial application of herbicides is the least expensive release method but there are some social and environmental problems.

15. Some release treatments may have an adverse aesthetic effect for several years.

16. There are several biological, climatic and edaphic considerations in planning release treatments. e.g. wind, dry soils, rodents, insects and disease. Some treatments may exacerbate these problems.

17. Manual release programs may be viable options in troubled economic times, where herbicide use has not gained acceptance, or on small areas with good access.

The following recommendations are made regarding the initiation of large-scale release programs in Manitoba.

1. Careful consideration should be given to all economic and social factors when deciding the type of release programs or if indeed release programs should be conducted.

2. Market analyses and forecasts are very important when considering long-term silvicultural benefits of a treatment.

8.0 - cont'd.

3. All projects should be carefully documented and budgets made available to monitor, remeasure and if necessary conduct additional treatments.

4. Full use should be made of Manitoba's excellent forest inventories in order to make valid decisions concerning candidate treatment areas.

5. Treatment areas should be priorized according to site, distance from conversion centres, access and viability of white spruce lumber production in the long term.

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10.1 Overview of studies and trials related to the release of white spruce from trembling aspen.

10.11 Mixedwood section of the prairie provinces

10.111 Release studies

10.1111 Study 1

The earliest release study was conducted in the Duck Mountains of Manitoba in 1936 (Steneker 1963) and is testimony to the early recognition of the problem of suppressed white spruce in mixedwood stands. This study was done in a 50-year old trembling aspen/white spruce stand. Two, one-quarter acre plots were treated by removing 44 and 66 percent of the basal area of competing trees (mostly aspen) and a third untreated plot was retained as a control.

The release cuttings resulted in spruce total cubic foot volumes almost double that of the control after 20 years. The heavy release resulted in almost triple the merchantable volume and the light release almost double that of the control. These results are very impressive and are considered a bench-mark in the development of a rationale for release prescriptions.

The spruce content of the treated plots in 1957 varied between 265 and 375 trees per acre which is considered marginally stocked (Bella and DeFranceschi 1978). Table 8 shows total volume and merchantable volume of the plots at treatment and in 1957.

Table 8. Volumes after release (1936) and in 1957 (20-year period).

Total Volume - cubic feet

Control				Light Release				Heavy Release			
WHITE SPRUCE		OTHER SOFTWOODS		WHITE SPRUCE		OTHER SOFTWOODS		WHITE SPRUCE		OTHER SOFTWOODS	
(1936)	(1957)	(1936)	(1957)	(1936)	(1957)	(1936)	(1957)	(1936)	(1957)	(1936)	(1957)
398	844	643	909	480	1440	325	545	355	1502	193	550
Merchantable volume - Bd. ft. Trees 8" + d.b.h.											
212	1510	844	2438	-	2600	312	1665	-	4230	822	2831

10.1112 Study 2

This study (Steneker 1967) is considerably larger in scope than the first and included study areas established between 1951 and 1954 in the Riding Mountain of Manitoba and several locations in the Mixedwood Forest Section of Saskatchewan, namely in the vicinities of Bertwell, Big River, Montreal Lake, Candle Lake and Reserve.

Growth data were obtained from one-tenth acre plots. Two plots were established at each location as controls and two for release from which all aspen were removed. Two additional plots were chosen at Bertwell and Reserve for partial release. On these plots 50 percent of the aspen was removed by cutting every other stem.

The ages of the mixedwood stands varied from aspen 25-30 years old with a 10-25 year-old understorey of white spruce to aspen 50-60 years old with a 25-60 year-old understorey of white spruce. The age of the spruce understorey varied considerably in stands with an age spread of 10 to 35 years indicating a rather long period of ingress and undoubtedly some mortality. In fact this was particularly evident in the Bertwell plots. As these mixedwoods stands were relatively young (10-30) it can be assumed that a good seed source must have been in the close vicinity. Most plots did increase modestly in number of white spruce per acre after treatment due to ingress.

Due to the large variation in the age of spruce within individual stands, the response in diameter increment due to age was not determined. Steneker (1967) assumed that age, within the range examined, had little or no effect on the subsequent diameter increment of released spruce. Increase in height due to release was inconsistent and was attributed to the spatial distribution of the spruce e.g. spruce versus spruce competition. Merchantable volume (cords) ten years after release was about 60 percent greater on the release plots than on the control.

This project was remeasured during September 1985 and the results will strengthen information on growth for a much longer period and will provide more definitive results which must be considered in the development of release prescriptions.

10.1113 Study 3

This study Lees (1967), which was established in 1951, consisted of 333 white spruce trees which were individually released from trembling aspen competition. The treated trees are in 25 trembling aspen-white spruce stands within a 30-mile radius of Smith, Alberta, in the Mixedwood Section. A similar number of untreated white spruce were selected as controls. Stands in which sampling occurred were composed of aspen with a spruce understorey generally 10-20 years younger than the aspen. Individual white spruce having only aspen competition were selected subjectively. Competing aspen within twice the crown width (widest point) of treated spruce were cut. To prevent suckering and root competition all aspen stumps were treated with ammate (ammonium sulphamate).

Spruce release was greatest in the 20-40 age class and in the 2.6 to 5.5 inch diameter class.

Table 9 shows mean annual diameter and height increment for treated and control stems by diameter class for the ten year period 1951 to 1961.

Table 9 Mean annual diameter and height increments for treated and control stands by diameter class (Lees 1967).

	Diam. Increment ins.		Height increment ft.	
Diam. ins.	Treated	Control	Treated	Control
1	0.23*	0.14	1.27*	0.87
2	0.27*	0.14	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	1.71NS	1.08
7	0.44*	0.26	1.56NS	1.20
8	0.44*	0.32	1.38NS	0.85
9	0.40*	0.24	1.21NS	0.99
10	0.39NS	0.26	1.38*	0.80

* Significant difference

NS Non significant difference

10.1114 Study 4

This study (Cayford 1957) was initiated in 1953 and consisted of a single examination of free-growing white spruce and suppressed white spruce growing in typical Mixedwood stands in the vicinity of Candle Lake and Big River, Saskatchewan. Aspen ranged in age from 70-105 years and the spruce understoreys between 55 and 100 years. It is noted that at the time of establishment the aspen was decadent in many of the stands. There was also a wide variation in the diameters and heights of spruce growing in the same stand.

Study areas were chosen where the white spruce had penetrated the aspen canopy. Ten groups of trees were selected in each stand; one free-growing spruce and one suppressed spruce and its main competing aspen. Stem analysis was done on each sample tree.

Free spruce overtopped aspen when between 40 and 65 years of age. An analysis of the data indicated volumes of suppressed trees were approximately one-half the volume of free-growing spruce in the three age groups sampled (55-60, 70-75, 95-100). Up to 100 years of age, suppressed white spruce were affected by an aspen overstorey.

Table 10 shows total cubic foot volume of free and suppresssed trees by age groups.

Table 10. Total volume (cubic feet) free and suppressed white spruce (Cayford 1957)

Age Group	Free	Suppressed	Percent Difference
55-60	11.1	6.0	54
70-75	17.7	9.0	51
95-100	19.8	10.8	54

10.115 Study 5

This project (Steneker 1974) commenced in 1961 and the objective was to study the effect of commercial release cutting in 75-100 year old mixed wood stands upon the volume production of residual white spruce. The two areas selected for release cutting were in the Sled Lake area (120 miles northwest of Prince Albert, Saskatchewan) and the Divide Forest Reserve (10 miles south of Meadow Lake, Saskatchewan). In order to study the diameter growth of individual spruce trees in relation to competitors, a third stand was selected two miles from the Divide stand.

White spruce in the 10 to 14 inch d.b.h. class were removed along with some high quality aspen. After the commercial cut, remaining aspen stands competing with residual spruce were either cut and left or girdled. Portions of each treated stand were left uncut to serve as controls. Reduction in spruce basal area due to the commercial logging varied between 25 and 50 percent. Four, one-fifth acre plots were established in the released and unreleased portion of each stand and d.b.h. tallies and height measurements made. In addition increment cores were collected from a number of trees.

In 1971 all plots were remeasured. Results of the release cuttings were negative insofar as volume production was concerned. Furthermore, increment response for individual white spruce trees was slight. This is in sharp contrast to younger stands in other studies. Steneker (1974) concludes that white spruce in the 70-100 year range is too old to respond significantly to release. This supports Lees' (1967) statement that release cuttings should not be conducted in spruce stands over 70 years of age.

10.1116 Summary

Table 11. Summary of results studies 1-5

Study	Age wS	Age tA	Release effect
1	50	50	Released wS tot. cu. ft. vol.= 2.0 times that of suppressed wS after 20 years.
2	10-60	20-60	Released wS vol. increase = 1.5 times that of suppressed wS after 10 years.
3	55-60	same	Released wS tot. cu. ft. vol. = 1.5 times that of suppressed wS after 10 years.
4	15-75	85-100	Released wS tot. cu. ft. vol. = 1.2 - 1.4 times that of suppressed wS
5	75-85	85-100	No significant release effect after 10 years.

All studies with the exception of study 5 indicated excellent results (Table 11). The white spruce in this study were for the most part older than those in others and it is evident that there is no gain to be realized, in most cases, from treatment of mixedwood stands where the major portion of the white spruce component is over 75 years of age (Lees 1967, Steneker 1974). In general competing aspen is 10-20 years older than the spruce understorey, although there may be quite an age range for spruce if there is significant ingress.

Lees (1967) stated that the greatest white spruce release occured in the 20-40 year age class. Cayford (1957) stated that the maximum diameter growth occurs between 10 and 30 years for both free-growing and suppressed white spruce. He also suggested that release of the spruce as soon as it is well established would produce the maximum silvicultural benefit. However, he warned that losses may occur due to changed environment and competition from aspen sprouts and underbrush.

Steneker (1967) suggested that aspen in mixedwood stands be clearcut at age 60 providing 40-60 cords per acre. Thinning of an overdense understorey may be necessary to obtain maximum release benefits. Cayford (1957) also recommended aspen removal at 40-50 years when a good return can be expected and the aspen should be relatively free of defect. Of course this depends on the market for aspen products at the time of treatment.

Cayford (1957) presented data on the time required for free-growing and suppressed white spruce to reach breast height. For the latter 8.7 years was required; the former required 7.1 years. This difference is statistically significant and indicates that suppression effect occurs when the spruce is very young and continues through to rotation in natural mixedwood stands.

10.112 Related studies

10.1121 Aspen and brush control studies

10.11211 Study 6

The earliest aspen control study in the Mixedwood Section of the Prairie Provinces was conducted by Quaite (1955). Ammate (ammonium sulphamate) crystals were used to "poison" stumps of aspen removed in a white spruce release study in Alberta (Lees 1967). Quaite found that poisoning of stumps not only reduced suckering but killed several standing live aspen which had not been removed in the release treatment. This he attributed to root grafting. In a parallel investigation ammate was applied to frills above the root collars of standing live aspen. Results with both the application to stumps and live trees were good and the ammate was effective in killing trees and preventing root suckering in all but very young stands. Apparently the younger trees were more resistant to the herbicide.

10.11212 Study 7

Hazel, Corylus cornuta (Marsh), constitutes one of the most serious shrub problems in the Mixedwood forests of Manitoba and Saskatchewan. This species is considered one of the main factors affecting white spruce reproduction (Rowe 1955).

In 1950 an experiment was conducted on the Riding Mountain Forest Experimental area in Manitoba to study the use of herbicides as a means of reducing shrub competition to natural white spruce reproduction (Waldron 1959).

One-tenth acre plots were established in dense hazel under a light stand of white spruce and aspen. Each plot was sprayed during August with an aqueous solution of the following chemicals at different dosages and concentrations: 2,4-D; 2,4,5-T; or a 50-50 mixture of 2,4-D and 2,4,5-T. All chemicals produced a fairly complete kill. Subsequent sprouting was high but less after 2,4-D treatments than others.

Treatment resulted in an increased growth rate of natural white spruce reproduction. It was believed that a high proportion of the released spruce would not again be overtopped by the hazel. Although spruce had a higher growth and survival rate on treated plots there was some damage to terminal shoots. This was also mentioned by Gardner in Vanden Born and Malik (1984).

Transplanted white spruce on treated plots had an average cumulative height growth of approximately 10 inches from 1954 to 1957. Transplants on untreated plots had just over 5 inches of height growth during the same period.

10.11213 Study 8

An experiment to kill mature aspen on the Riding Mountain Forest Experimental Area was conducted in 1955 (Waldron 1961). The rationale for removing the mature aspen was to reduce leaf smothering to natural reproduction on site prepared areas.

Four treatments were applied:

Axe girdling at breast height
Basal spraying with 2,4,5-T
Applications of 2,4,5-T in basal frills
Girdling with a "handi-girdler" (a specialized hand tool)

All treatments resulted in complete mortality of the treated trees. The 1960 costs for treatments were calculated at $.05 per tree for the "handi-girdler"; $.07 per tree for the 2,4,5-T in frills; $.08 per tree for the axe girdling; and $.13 per tree for the basal spraying.

Aspen suckers were not prevalent after treatment but dense hazel underbrush existed which may have been the reason for the lack of suckers. It was noted that in small openings in the hazel underbrush, suckers appeared to be more numerous.

10.11214 Study 9

In 1964, 280 acres of the Riding Mountain Forest Experimental Area were treated with an aerial application of 2,4-D to erradicate the trembling aspen (Pratt 1966). The overmature aspen on the area was non-commercial and was impeding natural spruce reproduction by heavy leaf fall. Five gallons of aqueous solution containing 48 ounces, acid equivalent, of 2,4-D was applied per acre with a Piper Cub having a spray-carrying capacity of 80 gallons.

One year after treatment, 75 percent of the hardwoods were severely top-killed but the herbicide had little effect on many of the shrubs. White spruce reproduction was not affected. Results demonstrate that 2,4-D can be used successfully to kill unwanted, over-mature, trembling aspen and some shrub species.

Cost of the treatment in 1964 was $6.22 per acre. It was believed that this cost could be reduced substantially on larger areas. This study infers that on areas where aspen cannot be harvested economically, spraying 2,4-D is an alternative for silvicultural use.

10.11215 Study 10

In 1984 an exhaustive literature survey of herbicide use in North American forestry was conducted under contract for the Canadian Forestry Service in Edmonton (Vanden Born and Malik 1984). This survey also provides an assessment of environmental impact and future potential for forest management in the Prairie Provinces. Reading of this review is a must for forest managers embarking on herbicide trials or operations.

The authors of the review state seven factors limiting herbicide use in forestry; these are worth repeating here.

1. Lack of registered herbicides. The Canadian forester needs a large number of versatile yet environmentally safe herbicides for various silvicultural purposes.
2. Reluctance of agricultural chemical companies to invest in research and development of herbicides for forestry use.

3. The foresters are hesitant to promote herbicide uses because of fear of unfavorable publicity.
4. Lack of trained foresters in herbicide use.
5. Lack of undergraduate teaching on chemical methods of vegetative management.
6. Inadequate research on the use of herbicides by universities and provincial agencies for their local needs.
7. Negative impact of the media.

A number of interesting statements and statistics are provided in the review:

- 2,4-D is still the number one herbicide used in North America. All uses of 2,4,5-T and Silvex have been banned in the United States. This chemical is also becoming increasingly restricted and unavailable in Canada.
- in addition to 2,4-D and 2,4,5-T (banned in several provinces), glyphosate and hexazinone have recently been registered in Canada for ground application. (glysophate has recently received full registration (pers. comm. L. Yarn 1986).
- 59.3 percent of the use of herbicides by the U.S. Forest Service is for conifer release.
- the total amount of herbicide used in Canadian forestry is about 0.5 percent of the total amount used in agriculture.
- herbicide use in forestry, although still very limited in Canada, is more common in British Columbia and the eastern provinces than in the prairie provinces. In 1980-81 Manitoba used 2,4-D on 1000 hectares. Saskatchewan and Alberta totals for the same year were 120 hectares each.

Although VandenBorn and Malik (1984) mention alternative methods of vegetative management e.g. manual and machine use, they do not believe these methods are feasible in densely vegetated areas. They cite Green (1982) who provides an example of the cost of 1981-82 chemical release project in Ontario at $900,000.00. Had the operations been done manually, it would have required 1300 persons at a total cost of 15 million dollars. He concluded that manual vegetative control is not an economically sound proposition. This may be true but the implications of hiring 1300 men are certainly worthy of consideration in troubled economic times and indeed there may be a payoff by conducting a certain percentage of manual projects; particularly with respect to the release of natural white spruce from trembling aspen. Often the stands tend to be limited in size and may not be suitable for aerial application of herbicides.

10.1122 Releasing white spruce by the commercial logging of aspen.

In some areas of the Mixedwood forest, aspen is being logged commercially. In these stands there has been little attempt made to reduce mortality and damage to understorey white spruce. In 1974 an excellent trial was conducted near Hudson Bay, Saskatchewan to reduce damage to white spruce understoreys by planned logging of the aspen overstorey (Froning 1980).

Two areas of about 60 hectares were establishd where no particular guidance was provided to reduce damage to the spruce. Damage to the spruce was 56 percent on these areas. A trial of 16 hectares, in a nearby area, was conducted where logging was planned and skidder operator supervision provided. Surveys were conducted prior to logging to map the spruce understorey. Major skid trails were flagged, based on the stocking of white spruce, with sufficient flexibility to take advantage of holes in the understorey. Bunching of the logs was done in the direction of skidding. Careful and judicious planning resulted in only 12 percent damage and 7 percent destruction of the white spruce understorey after skidding. Over 75 percent of the hardwoods were logged. Those remaining were often in dense clumps of spruce which would not have been removed under normal conditions.

Froning (1980) made the point that vulnerability to windthrow is high when dense mixed stands are opened. Leaving some hardwoods will likely reduce wind damage to critically exposed spruce trees. This is a most important point for consideration in the development of silvicultural guidelines for spruce release from trembling aspen. Froning also warned against logging when temperatures are very low as this increases mortality and damage to spruce understorey trees.

This trial has shown that careful logging can preserve a high percentage of the spruce understorey. Some subsidization is necessary but is undoubtedly warranted if a well-stocked white spruce stand remains after logging the aspen. Dense clumps of spruce would require thinning to benefit substantially from the release felling.

10.12 North America

10.121 Release studies

10.1211 General

Twelve studies concerning the release of white spruce were reviewed. All of these were in eastern Canada and the northeastern United States.

An early publication by H.L. Shirley (1941) is a general treatise of the problems of restoring conifers to lands occupied by aspen in the Lake States and provides some excellent background information, much of which is applicable to Manitoba.

Shirley (1941) discussed the economic importance of restoring conifers to the vast area of aspen which he described as a financial drain to the region because it had to be supplied with roads and services but at that time yielded only a negligible revenue. These statements would be difficult to defend today when one considers the present high degree of aspen utilization in that region. This illustrates the difficulty of forecasting utilization for a lengthy period. Nevertheless, his knowledge of the ecology of the Mixedwood Forest is impressive and many of the conclusions in the publication are useful in the development of guidelines to release white spruce from aspen overstoreys. Although the publication is almost forty-five years old it is recommended reading for anyone managing mixedwood stands. Many of Shirley's observations are quoted in earlier sections of this report.

10.1212 Release from hardwoods

Several studies related to the release of white and red spruce from hardwood overstoreys were conducted in the period 1905 to 1930 (Robertson 1930; Plice and Heddon 1931; Westveld 1937; Clarke 1940; Thomson 1949; Daley 1950; Armstrong 1963; Hatcher 1967; Berry 1982).

Climatic, edaphic and vegetational differences between eastern North America and Manitoba are manifest. However, it was considered useful to examine the results of these studies, in relation to white spruce release, because results generally corroborate those found in similar studies conducted in the Mixedwood Section of the prairie provinces.

It is difficult to compare the various studies conducted in the east. Stand conditions and age-classes varied considerably and often detailed descriptions were not provided. Grouping on the basis of the age of the spruce understorey is perhaps the most useful means of discussion. With respect to natural reproduction and reforested areas in the seedling stage released from hardwood overstoreys, three studies were reviewed after a literature search. Plice and Heddon(1931) discussed the results of releasing young spruce five years after the hardwoods were girdled. Released trees had about twice the height growth of suppressed trees. Westveld (1937) presented 30-year results of releasing well-stocked red spruce from hardwoods by girdling. These results were very impressive with the heavily girdled treatment plot having over 1600 cubic feet of spruce and the control 170 cubic feet. This is almost a ten-fold increase in volume over the 30-year period. Berry (1982) discussed the results of releasing white spruce seedlings from a seeding project under hardwoods 27 years after seeding. In the ten-year period after release (1970-1980) height growth of spruce on treated plots accelerated to ten times that of trees on the control demonstrating that release can be beneficial even after 27 years of stagnation.

Young to intermediate aged spruce release studies were fairly commonly established in the twenties and thirties. These have provided some long-term information which further substantiates the benefits of releasing spruce from hardwood overstoreys. Robertson (1930) and Best (1932) reported on the results of girdling hardwoods to release juvenile spruce in Quebec. Over a five-year period, increase in diameter growth of released spruce was 50-300 percent greater than for the suppressed spruce. Seven years after treatment periodic average annual growth percent was 6.6 for the control and 9.6 for the treated spruce. The increase of 3 percent was considered due to the girdling treatment. Clarke (1940) reported a net profit of 9 percent compound interest on the initial cost of girdling hardwoods to release young spruce in New Brunswick. Similarly for New Brunswick, Thomson (1949) discussed a release of juvenile white spruce by cutting overstorey hardwoods. He indicated that in the one to four inch diameter classes the total volume of the conifers trebled on the control area and quadrupled on the treated area during a ten-year priod. Hatcher (1967) stated that after twenty years intermediate-aged red spruce, which was released from a hardwood overstorey by cutting and girdling, produced an average of 2.5 cords per acre and as high as 6 cords per acre more than untreated stands.

Armstrong (1963) at a Canadian Pulp and Paper Association meeting described applied research done by Spruce Falls Power and Paper Co. Ltd. in Ontario. Girdling experiments were conducted in 1951. The stand was 55-year old mixedwood containing a white spruce and black spruce understorey and an aspen, white birch, balsam poplar overstorey. All overstorey trees were girdled. In 1962 merchantable volume was 12.2 cords on the girdled plots and 6.5 on the controls. In order to release plantations the company has conducted large-scale herbicide programs and claim yields of 22 cords per acre will be achieved on a 60-year rotation. The average yield in 1963 was 15 cords at a 100-year rotation.

10.1213 Release from Shrubs

Shrub competition alone can be serious insofar as white spruce natural reproduction or planted seedlings are concerned. Vincent (1954) and Baskerville (1961) described a situation in New Brunswick where well-stocked fir and spruce reproduction was overtopped by mountain maple (Acer spicatum Lam.) which formed a closed canopy and consisted of 6000-7500 stems per acre.

The conifers were treated by cutting out the shrubs in a 3-foot radius around each tree. An untreated plot was established nearby. After four years, conifer height growth doubled as a result of release. Nine years after release height growth of treated trees increased up to six times that of control trees. Although shrubs re-invaded the openings created, the conifers continued to grow at increased rates throughout the study period.