REGENERATION, DEVELOPMENT AND DENSITY MANAGEMENT IN ASPEN STANDS.

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INTRODUCTION

With increased aspen utilization and new approaches to hardwood and mixedwood management, aspen silviculture is becoming complex and more challenging. To help fulfill changing management objectives we need to synthesize all relevant information, and fill knowledge gaps where necessary in the areas of aspen regeneration,density management and growth and yield.

In this paper we review regeneration silviculture and early development of aspen, and provide preliminary guidelines for density management of aspen stands. To begin, we present some principles that control initial density of aspen sucker and seed regeneration, and techniques and approaches for either enhancing or reducing aspen sucker density. This knowledge may be particularly useful when choosing among the following management scenarios, which either aim to promote or reduce aspen regeneration:

- hardwoods managed for hardwoods,
- hardwoods managed for mixedwoods,
- hardwoods managed for softwoods,
- mixedwoods managed for hardwoods
- mixedwoods managed for mixedwoods,
- mixedwoods managed for softwoods, and
- softwoods managed for softwoods

ASPEN REGENERATION

VEGETATIVE REPRODUCTION BY ROOT SUCKERING

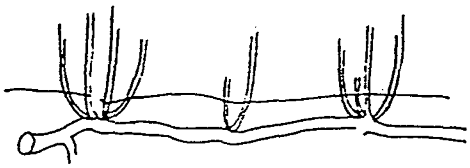
Aspen reproduction by root suckering is well-understood and the factors controlling it are in generally well-defined (Fig.1).

Sucker development on aspen roots is triggered by a disturbance of apical dominance, i.e., by changing the hormonal balance, and more specifically by changing the ratio of auxins and cytokinins in roots. This occurs when the flow of auxins into roots is interrupted or reduced by cutting or wounding stems and roots and reducing the auxins/cytokinins ratio. A high auxins/cytokinins ratio suppresses suckering, a low ratio stimulates it.

An increase in soil temperature can stimulate suckering for the same reason. High temperature increases cytokinin production by root meristematic tissues (Williams 1972 cited in Schier et al. 1985) and enhances degradation of auxins. The resulting low auxins/cytokinins ratio promotes sucker initiation.

The third factor controlling sucker density is the energy available for sucker development. Sucker development, particularly elongation and emergence above the ground depends upon carbohydrates reserves in the parent roots. Changes in carbohydrate concentrations during the growing season, or clonal variation (Schier and Johnston 1971), killing of crowns and stems of

1 YEAR AFTER HARVEST



FACTORS INFLUENCING SUCKERING:

DISTURBANCE OF APICAL DOMINANCE: $\frac{\text{AUXINS}}{\text{CYTOKININS}}$

SOIL TEMPERATURE

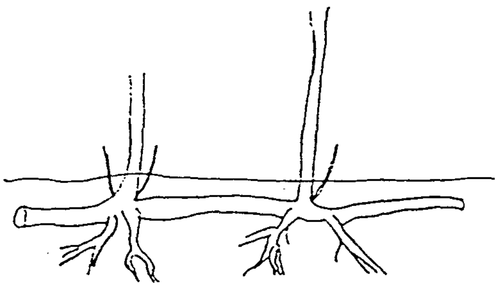
CARBOHYDRATE RESERVES IN ROOTS

PARENT ROOTS:

70% IN 0-8cm. DEPTH

90% LESS THAN 2cm. DIAMETER

5 YEARS AFTER HARVEST



LIGHT

- RESIDUAL CANOPY
- COMPETITION

FIG. 1. ILLUSTRATION OF ASPEN REPRODUCTION BY ROOT SUCKERING

parent trees by chemical or mechanical means, or repeated destruction of developing suckers can all affect the level of carbohydrate available in the roots and thus influence suckering density.

Although light is not required for sucker initiation the lack of it due to shade from competing vegetation or residual trees can slow down or halt the growth of suckers and may lead to sucker mortality.

Site, parent stand and harvesting effects on sucker regeneration density

(schematic illustration in Fig.2)

Aspen content in the parent stand is the major factor influencing aspen sucker regeneration density. Basal area as low as 2-5 m^2/ha (Perala 1972, 1977; Doucet 1988) and volume as low as 26 m^3/ha (Stoeckeler and Macon 1956) can produce adequate aspen stocking after clearcutting. Similarly, about 25-50 well-distributed trees/ha may produce over 10,000 suckers/ha. On 15-years-old pine cutovers in the Grande Prairie region of Alberta we found that a single aspen parent tree may restock a 400-500 m^2 area with suckers. Our observation compares fairly well to the above estimate of 25-50 aspen trees/ha to adequately regenerate the area. The age of parent trees does not seem to affect density of suckering at ages between 35-70 years (Graham 1963 et al. 1963). Younger trees,particularly those of expanding clones with young root systems, have a better suckering ability, whereas overmature aspen clones have poorer suckering ability.

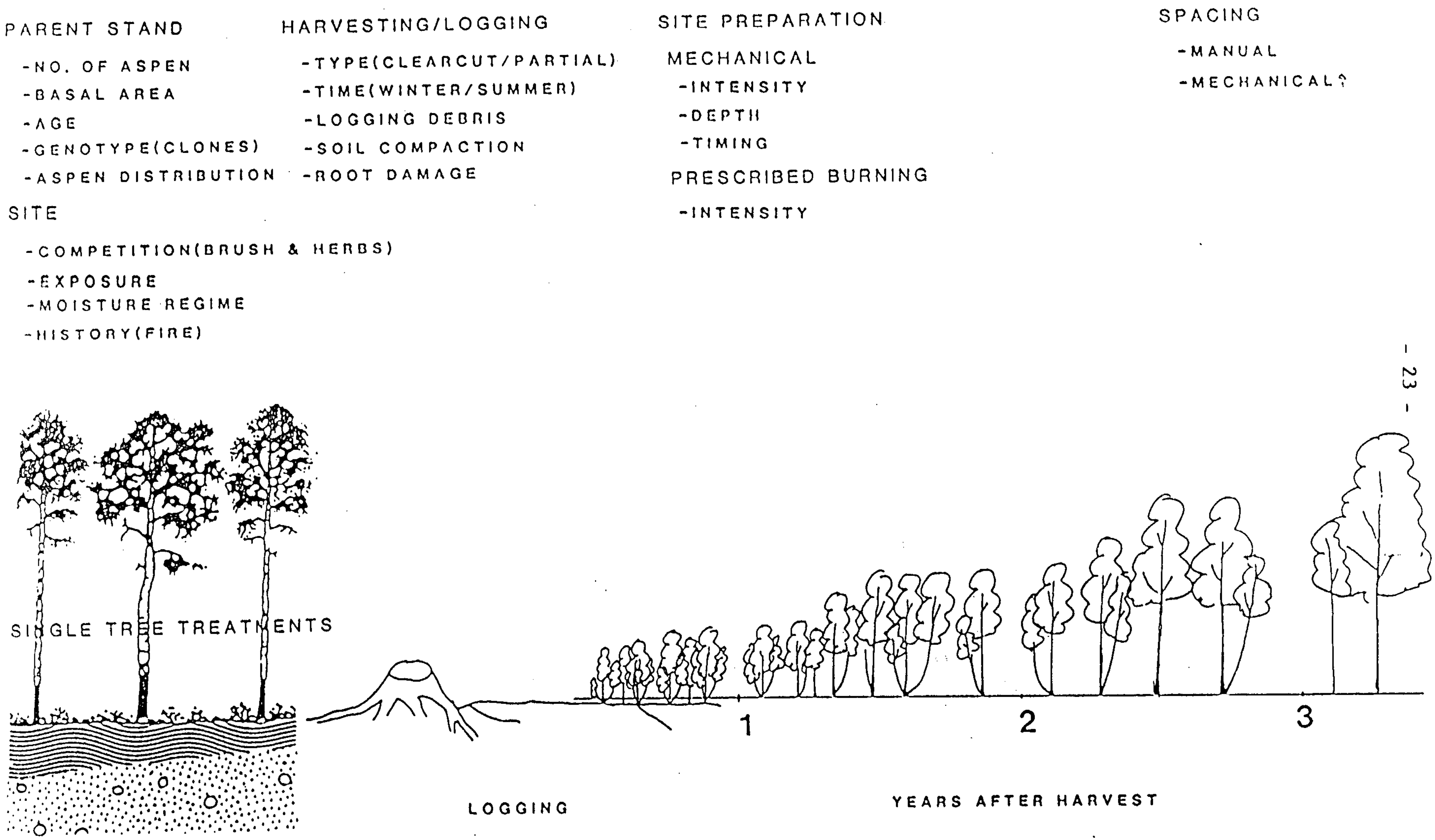


FIG. 2. FACTORS INFLUENCING INITIAL DENSITY OF ASPEN REGENERATION OF SUCKER ORIGIN

Initial sucker density can vary markedly among clones (Schier et al. 1985) and differences up to twenty-fold have been noted (Garrett and Zahner 1964). When individual clones occupy large areas, such clonal differences may confound the results of silvicultural trials.

The next most important influence on aspen sucker regeneration density is the method of harvesting: clearcutting versus partial cutting. A partial cut with residual canopy can severely reduce aspen regeneration density. The negative effects of such a canopy are threefold: a) maintenance of apical dominance, b) reduced soil temperature, and c) reduced light. A residual canopy allowing 50% sunlight has been found to reduce suckering density ten fold, from 98,000 to 7,400 stems/ha (Baker 1925). As little as 1-1.5 m^2/ha basal area of residuals may slow sucker growth by 40% (Perala 1977).

On some sites, openings created by a partial cut can be invaded by brush, like hazel, which competes with developing suckers for light. Poor or marginal aspen regeneration can result from the combined effects of residual trees, brush and slash.

Results from studies of the effects of season of logging on sucker density are not consistent. In Saskatchewan's Boreal mixedwood zone, initial sucker density after the first growing season was about twice as high after a summer cut as after a winter cut (Bella 1986). Elsewhere harvesting in the dormant season initially produced more suckers than summer cuts (Heeney et al. 1975). These conflicting results may be explained by other factors such as regional and site differences in soil temperature, types of logging and related differences in soil surface disturbance and root wounding, variable depth of aspen roots and clonal differences in energy reserves and energy requirements.

Site preparation and stand establishment techniques

Most aspen suckers originate from long, cord-like lateral roots near the soil surface which extend radially from an aspen stem. Distance may reach 15 to 30 meters from a parent aspen tree.

Up to 80% of suckers come from roots within the upper 6 cm of the surface in the Boreal mixedwood in Ontario (Kemperman 1978) and within the top 8 cm in the mountains of Utah,USA (Schier and Campbell 1978). Clonal differences and fire history may also influence depth of the roots from which sucker originate.

The consistent occurrence of sucker-producing roots in the upper soil layers is important in aspen management, in both a positive and negative sense. For example site preparation techniques can be selected to influence aspen regeneration as needed for specific management objectives by varying intensity, depth of soil penetration and timing of site treatment, subsequently influencing sucker density and the growth, development and quality of aspen regeneration.

Light scarification can increase suckering by wounding the roots and removing or distributing logging debris; whereas severe site preparation such as intensive disking may be used to reduce aspen suckering.

Currently, mechanical site preparation and release treatments causing root segmentation are being explored as a possible non-chemical means of aspen density manipulation. A cooperative study between Forestry Canada and the Alberta Forest Service is in progress with support from the Canada-Alberta Forest Resources Development Agreement. The Alberta Forest Service is currently using double-disking for aspen control in operational site preparation and reforestation.

The drawback of shallow rooting is manifested by the vulnerability of such roots to logging damage. Excessive root damage and surface soil compaction can severely reduce suckering and sucker growth. The result is reduced sucker regeneration on summer logged wet sites, skidding trails and landings. Site factors and the timing of site preparation should be carefully considered if aspen is expected to be the next crop. Delayed site preparation after sucker development can cause wounding and subsequent wood decay infection of surviving aspen trees.

ASPEN REGENERATION OF SEED ORIGIN

(schematic illustration in Fig. 3)

Aspen begins flowering by 10-20 years of age and reaches a peak in seed production at 50 years. A mature aspen tree can produce up to 1.6 million seeds per crop in 3 to 5 year cycles of light and heavy crops (McDonough 1979, Schopmeyer 1974).

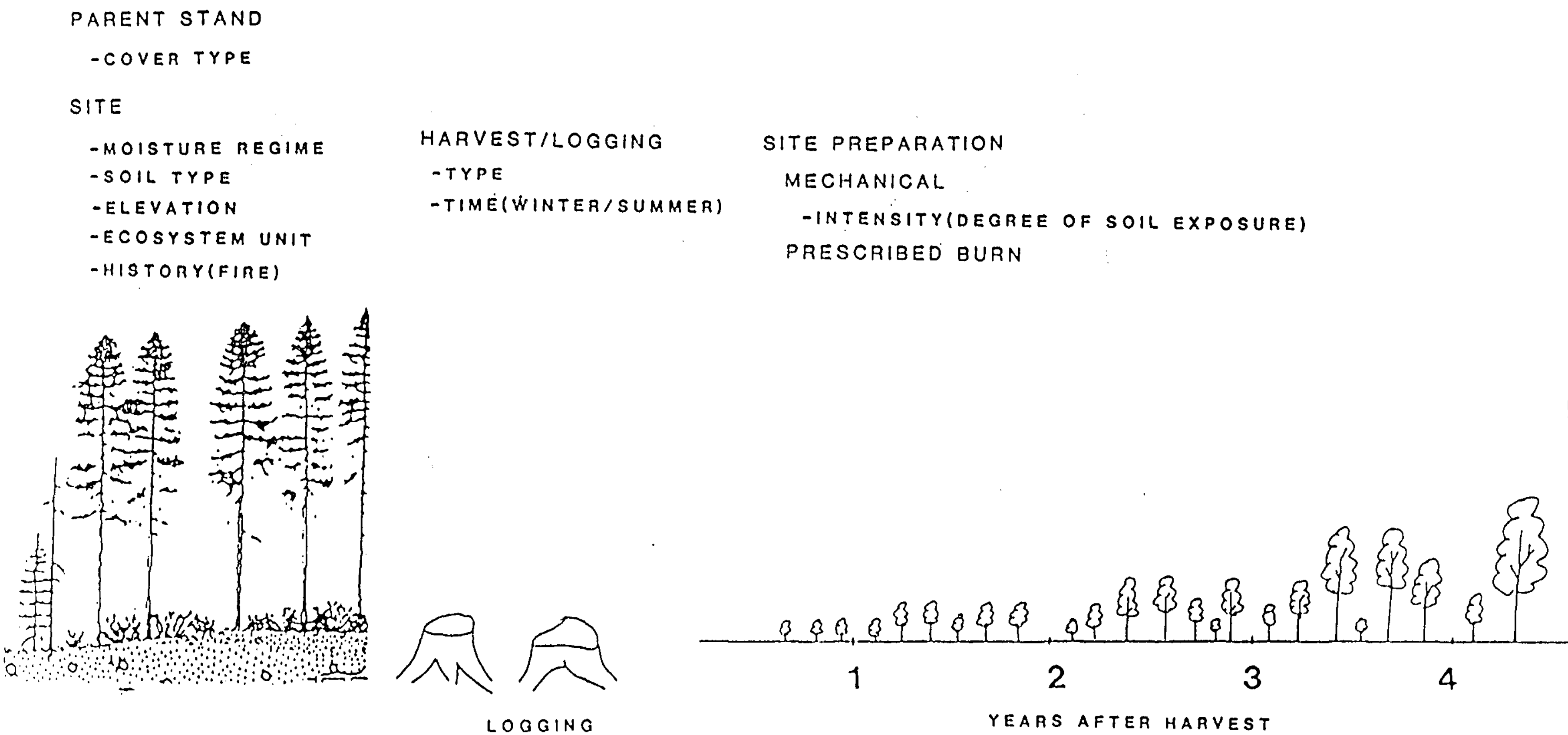


FIG. 3. FACTORS INFLUENCING INITIAL DENSITY OF ASPEN REGENERATION OF SEED ORIGIN

Seeds can germinate in a broad range of temperature, however, high temperatures inhibit germination on dark soils and burned areas. Seed germination and seedling establishment requires continuous supply of moisture and relatively cool temperatures (McDonough 1979). It is generally believed that these seedbed requirements are seldom met in nature and that seedling establishment in the field is uncommon (Maini 1968, Brinkman and Roe 1975, Doucet 1988).

Foresters in Alberta and in Northern Ontario (G.Marek, pers. comm.) have observed the changing appearance of conifer regenerated cutblocks, and gradual ingress of aspen where no aspen sucker regeneration had been noted. Concerns were raised about the competition level of ingressing aspen of seed origin, their effects upon the development and composition of juvenile stands, and a consequent gradual shift to mixedwood stands.

We have initiated a study to assess the occurrence of seed-origin aspen in lodgepole pine cutblocks in the Alberta foothills. Results obtained so far show clear evidence of aspen seeding-in, primarily on sites with mesic and subhygric moisture regimes. The incidence of aspen seedlings varies, from cutblocks with 100% of seed-origin aspen to cutblocks with various mixtures of seed- and sucker-origin aspen in cases where the original softwood stand had a sporadic occurrence of aspen trees. The density of aspen seedlings varied from 1,500 - 10,000 seedlings/ha in 7-20 years old cutblocks. Seedling establishment occurred over 1-5 years after cutting, and scarification appeared to initiate and enhance seedling establishment. Growth rates of juvenile aspen and lodgepole pine seedlings were very similar.

To sum up, we believe that we can predict reasonably well, and manipulate the initial density of aspen regeneration to some extent, to suit management objectives. A knowledge of site and stand characteristics, harvesting, and site preparation prescriptions can be used to obtain optimum stocking and to a lesser degree to control the aspen component in mixedwood and softwood cover types.

Having completed an extensive review of biological factors and management practices that affect initial density of aspen sucker stands, we are now in the process of verifying this information by local observations in Alberta.

We believe that available knowledge on aspen regeneration can be synthesized into a predictive model based on inputs of stand,site, harvesting and stand establishment information.

In prediction of aspen regeneration development, and surveys involving aspen stocking densities, a rapid decline in the number of suckers during the establishment phase must be anticipated. Initial high numbers of suckers change rapidly with time, as a clump of suckers is reduced to a single stem in about five years and natural thinning is initiated (Fig. 1 and Fig. 4). Regeneration surveys and standards, and any model of regeneration, will have to be formulated accordingly.

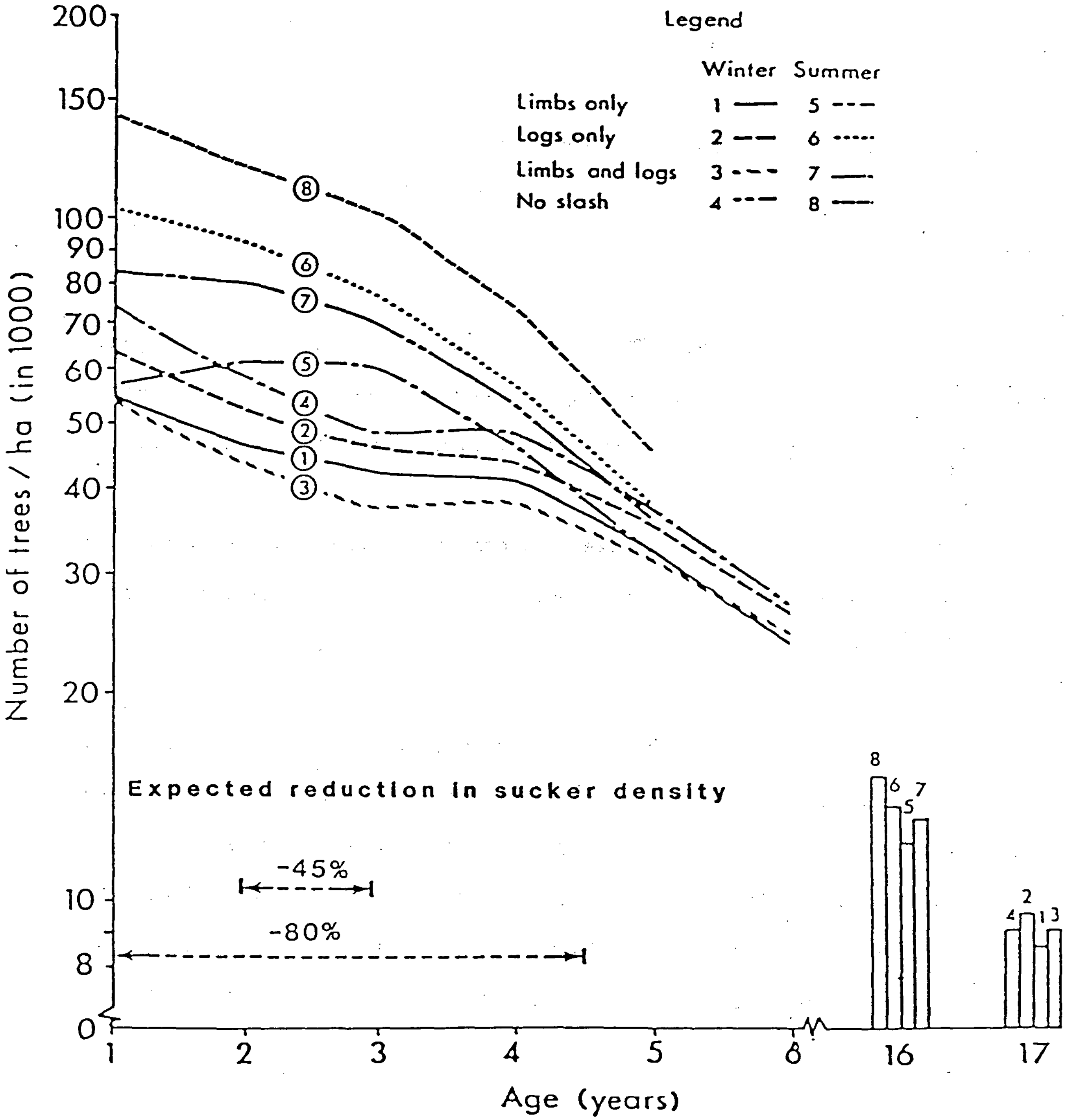


FIG. 4. SUCKER DENSITY IN RELATION TO SLASH CONDITIONS, TIME OF CUTTING AND AGE AFTER LOGGING (FROM BELLA 1986). IN THE LOWER PART OF THE GRAPH AVERAGE REDUCTION IN SUCKER DENSITY FROM YEAR 2 TO 3 AND YEAR 1 TO 5 IS SHOWN AS REPORTED IN THE LITERATURE (ADOPTED FROM WEINGARTNER 1980 AND DOUCET 1988).

JUVENILE STAND DEVELOPMENT AND DENSITY MANAGEMENT IN ASPEN STANDS

A study (Bella 1986) conducted in essentially pure aspen stands in the Boreal Mixewoods Forest Section (Rowe 1972) of east-central Saskatchewan, provided information on early stand development that may be applicable in other aspen stands in central and western Canada.

These results showed initial sucker density after the first growing season about twice as high after a summer clear cut (even exceeding 200 000 per ha.) as after a winter cut (Fig. 4). The greatest number of suckers and the highest variation in numbers occurred with no slash cover. The number of suckers generally declined as the amount of slash increased. It seems that factors which enhance soil warming — e.g., summer logging that destroys the shrubs layer; or reduction in slash cover — had the greatest influence on suckering.

The large initial difference in stand density due to season of cut and slash condition had diminished to a range of 30% or less five years after cutting (Fig. 4). Average density dropped rapidly to between 30 000 and 45 000 suckers per ha, again lower for winter than for summer logged areas. By 17 years, winter logged areas dropped below 10 000 stems/ha, and density differences due to slash virtually disappeared. After summer logging some differences remained between the two extreme slash treatment classes, while the overall density dropped to around 14 000 stems/ha by age 16. Similar rapid declines in density have been noted by several other researchers (e.g., Doucet 1988).

What does this mean to the forester managing pure aspen stands for wood fibre production ?. It means that after clear cutting there should be excellent stocking and more than adequate density of aspen sucker regeneration on fresh aspen sites with light and medium soil texture, regardless of season of logging and slash conditions. Also, young aspen stands, even at high density, will thin themselves naturally, and generally require no thinning treatment for maximum wood fibre production. Thinning may be justified if large diameter timber is the objective (such as sawlogs or veneer logs), and if reduction in the time required to grow usable (merchantable) material is desired (Bickerstaff 1946; Steneker and Jarvis 1966; Steneker 1976). If thinning is contemplated for these purposes, it should be done precommercially when the trees are large enough to show their growth potential and possibly their resistance to damaging agents ,usually when the stand is between 5 to 10 m high, and between 10 and 15 years old. At that time stump diameters are still small enough for easy cutting with thinning tools.

Thinning done close to the limits stated above (5 m and 15 years) should result in earlier crown closure after treatment, which is an advantage in preventing new suckering and shrub invasion in these stands.

Because of the clonal structure of aspen sucker stands, thinning treatment may provide an opportunity to favor desirable clones and thus improve stand quality. This "sanitary thinning" (Navratil 1987) is particularly feasible where the trees (ramets) of different clones are intermixed, rather than grouped.

Regardless of clonal structure, thinning should leave the best quality and most vigorous trees. Depending on management objective this should be between 1500 to 2500 trees/ha.

Although thinning may be desirable under some management scenarios, there are some arguments against it, such as:

- the cost of treatment;
- stem wounds and infections by various diseases (Anderson and Anderson 1968);
- increased risk of sunscald and Hypoxylon canker;
- increase in branch size, reduction in wood quality and possibly greater risk of decay through larger branch stubs;
- likelihood of aspen suckering and invasion of the stand by grasses, herbs and shrubs. This may be a serious hindrance to regenerating aspen stands after harvest.

PREDICTING FUTURE YIELD

Several systems are available now for predicting the future yield of aspen for different stand densities and productivity classes (expressed in terms of site index). STEMS (Stand and Tree Evaluation and Modelling System; Belcher et al. 1982; Miner and Walter 1984) developed by the U. S. Forest Service in Minnesota, is an individual tree, distance independent model which was calibrated recently for aspen and jack pine at the Northern Forestry Centre and provides reasonable predictions.

Also for the Lake State region, a simple variable density yield table (function) (Schlaegel 1971) that can predict future yield from stand basal area, average stand height, and average stand diameter is available for aspen. It may be used both in thinned and unthinned stands.

Mowrer (1987) used RMYLD updates (Edminster and Mowrer 1985) in the central U. S. Rocky Mountain region to estimate yield of thinned and unthinned aspen stand. He found that for longer rotations (i.e., close to 100 years) total stem volume is maximized over all sites qualities in unthinned stands, and sawlog volumes only on better sites.

CONCLUSIONS

Clear-cutting mature aspen stands generally results in excellent stocking and more than adequate density of sucker regeneration, except in areas of drastic soil disturbance and heavy shrub competition.

Significant aspen ingress both from sucker and seed origin may occur even in previous softwood stands, and may shift these cover types to mixewoods. At present, we know little about the development of such new stands, but several monitoring and research studies are in progress.

In mixewood stands, clear-cutting where the aspen component is as low as 25-50 well distributed trees/ha will result in adequate density aspen regeneration without any site treatment. Summer logging with heavy equipment in wet conditions may compact the soil, damage the roots and reduce suckering below acceptable levels in localized areas.

We know how site and stand characteristics and harvesting techniques affect aspen regeneration. This knowledge can be synthesized into predictive models of aspen regeneration.

Dense, juvenile aspen sucker stands will thin naturally and produce maximum fibre yield without treatments. A precommercial thinning may be justified if large sized timber such as veneer or sawlogs, or shorter rotation for specific log sizes, are the objectives. Such thinning may involve some risks of injuries and disease in crop trees and invasion by grass and shrubs.

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CONTENTS

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