DECAY OF ASPEN AND BALSAM POPLAR IN ALBERTA

Y. Hiratsuka and A.A.Loman[1]

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ABSTRACT

Aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera* L.) represent about 40% of Alberta's forest resources, but utilization is only 1% of the total available. Decay and stain are two major factors limiting utilization of these species. Major decay-causing agents and types of decay of aspen and balsam poplar are reviewed, and the implications for management and utilization are discussed.

RESUME

Le peuplier faux-tremble (*Populus tremuloides* Michx.) et le peuplier baumier (*P. balsamifera* L.) constituent environ 40% des ressources forestières de l'Alberta, mais leur utilisation ne s'élève qu'à 1% du total disponible. Les deux principaux facteurs limitant leur utilisation sont la carie et les taches colorées. Les principaux agents et les types de caries observés chez ces deux essences sont discutés, de même que leurs répercussions sur l'aménagement et l'utilisation de ces essences.

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INTRODUCTION

Hardwoods, mostly aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera* L.), represent about 40% of Alberta's forest resources. Current utilization amounts to only about 1% of the total, but the time is fast approaching when the softwood resources will be harvested to their limits of annual allowable cut. The aspen-balsam poplar resource will then be expected to play a much more significant role in meeting the demand for forest products in the future. The relative amounts of hardwood (mostly poplar) volume across Canada and potential annual allowable cut in Alberta are shown in Figures 1 and 2. Typical aspen forests in Alberta are illustrated in Figures 3 and 4. Three other poplar species (black cottonwood, *P. trichocarpa* Torr. & Gray; eastern cottonwood, *P. deltoides* Bartr.; and narrowleaf cottonwood, *P. angustifolia* James) also occur in Alberta, but they are economically insignificant.

Decay and stain have been identified as two of the most important factors limiting the utilization of aspen and balsam poplar. Several terms used in this report are defined as follows: Incipient decay indicates an early stage of decay in which the wood is hard and firm but may show discoloration or dark lines. Advanced decay refers to an advanced stage of decay of wood that is softened and has lost structural strength. Stain is a discoloration of wood by microoganisms or other physiological causes and may or may not be the early stage of incipient decay.

Many reports containing information on decay of aspen and balsam poplar have been published in various parts of North America, including Alberta. The most significant and relevant contributions are the following: Alberta (Bailey and Dobie 1977; Paul and Etheridge 1958; Thomas et al. 1960), Manitoba and Saskatchewan (Wall 1971; Black and Kristapovich 1954), Ontario (Basham 1958, 1979; Riley 1952), Colorado (Davidson et al. 1959; Hinds and Wengert 1977), and Minnesota (Meinecke 1929). Unfortunately, the abovementioned reports and many others written on the subject are not easily accessible because they have been reported mostly in specialized scientific journals or unpublished government reports.

The purpose of this report is to compile and review available information on decay of aspen and balsam poplar and to attempt to interpret it in relation to aspen-poplar management and utilization in Alberta.

This report was prepared originally for the Alberta Poplar Research Committee, composed jointly of personnel from the Alberta Forest Service (J. Soos, B. Karaim, and E. Gillespie) and Blue Ridge Lumber (1981) Ltd. (M. Summers, P. Caldwell, and R. Kerr) and chaired by A.D. Kiil of the Canadian Forestry Service.

MAJOR DECAY-CAUSING AGENTS AND TYPES OF DECAY

Many fungi have been isolated and identified from decay and stain of aspen and balsam poplar (Basham 1958; Gilbertson 1981; Hinds and Wengert 1977; Lindsey and Gilbertson 1978; Thomas et al. 1960; Wall 1971). Fourteen major decay fungi have been isolated and identified from incipient and advanced decay in aspen and balsam poplar in the Slave Lake area of Alberta by Thomas et al. (1960) (Table 1). According to Thomas et al., *Phellinus tremulae* (=*Fomes igniarius*) is the most common and important decay-causing organism in both aspen and balsam poplar. This species has also been identified as the main decay organism of aspen in other parts of North America (Basham 1958; Black and Kristapovich 1954; Hinds and Wengert 1977; Meinecke 1929; Wall 1971). This fungus is commonly called the false tinder fungus and causes soft yellowish and characteristic brown to blackish brown lines surrounding each decay column (Figs. 5-7). Hoof-shaped sporophores (conks) of *P. tremulae* are about 10 cm in width (Fig. 8). The upper side of the sporophore is greyish black at first and later becomes cracked and appears cinder-like. The undersurface is covered with brown to whitish-brown spore-producing tubes. The interior of a conk is dark brown (Fig. 5).

On aspen, *Radulum casearium* and *Peniophora polygonia* (=*Corticium polygonium*) have been commonly and constantly isolated from yellowish or reddish stringy rot and from variously colored (brown, yellow, red) incipient decays. They are considered to be the next most important aspen decay after *P. tremulae* (Basham 1958; Black and Kristapovitch 1954; Laflamme and Lortie 1973; Thomas et al. 1960; Wall 1971).

Characteristically, *P. polygonia* has been isolated from younger aspen trees, and most isolations were from incipient decay (Basham 1958). Sporophores of *P. polygonia* are often observed on branch stubs of trees

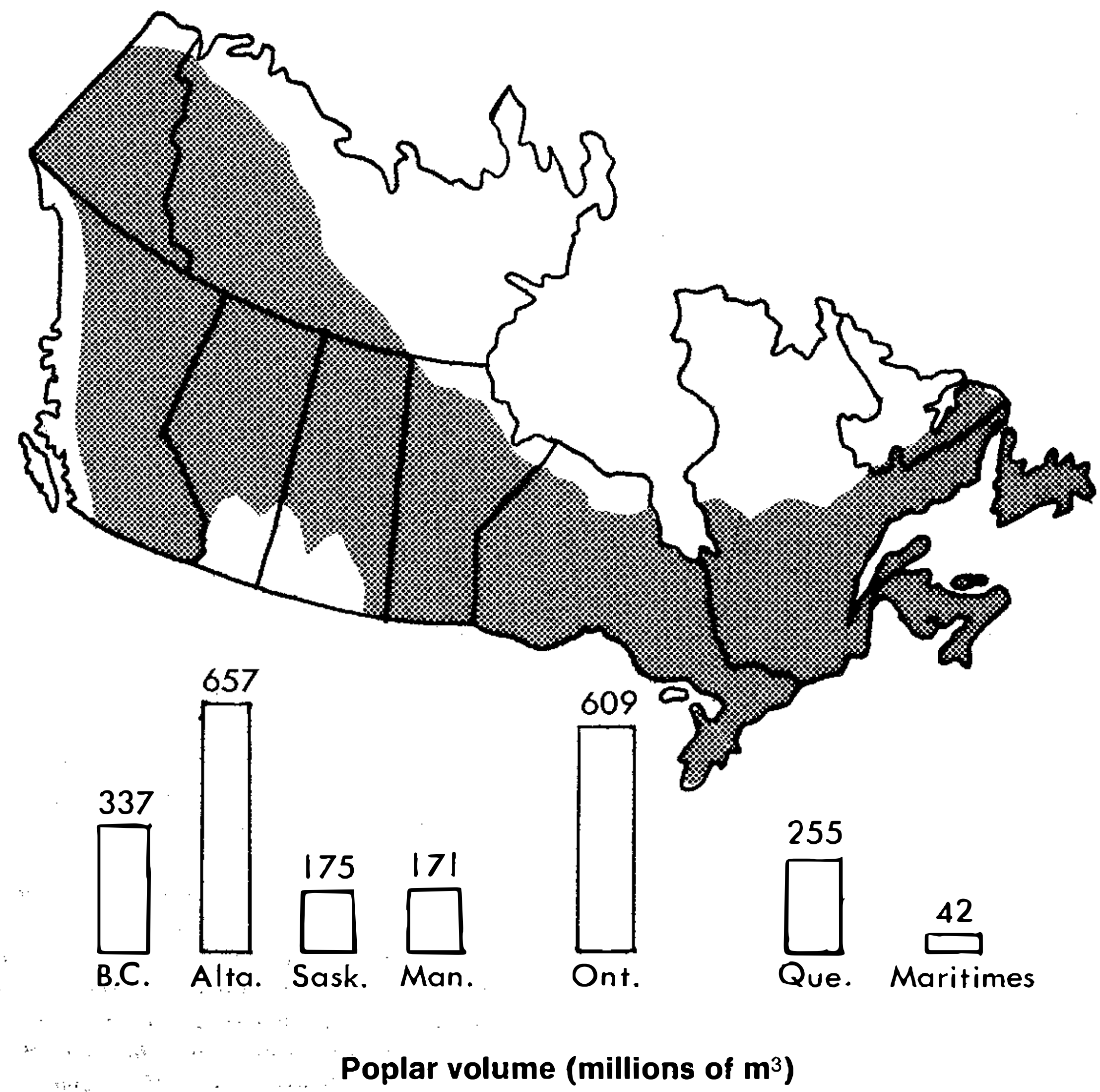

Figure 1. Poplar distribution across Canada (shaded area) and estimated gross merchantable volume for each province or region (based on Bonnor 1982).

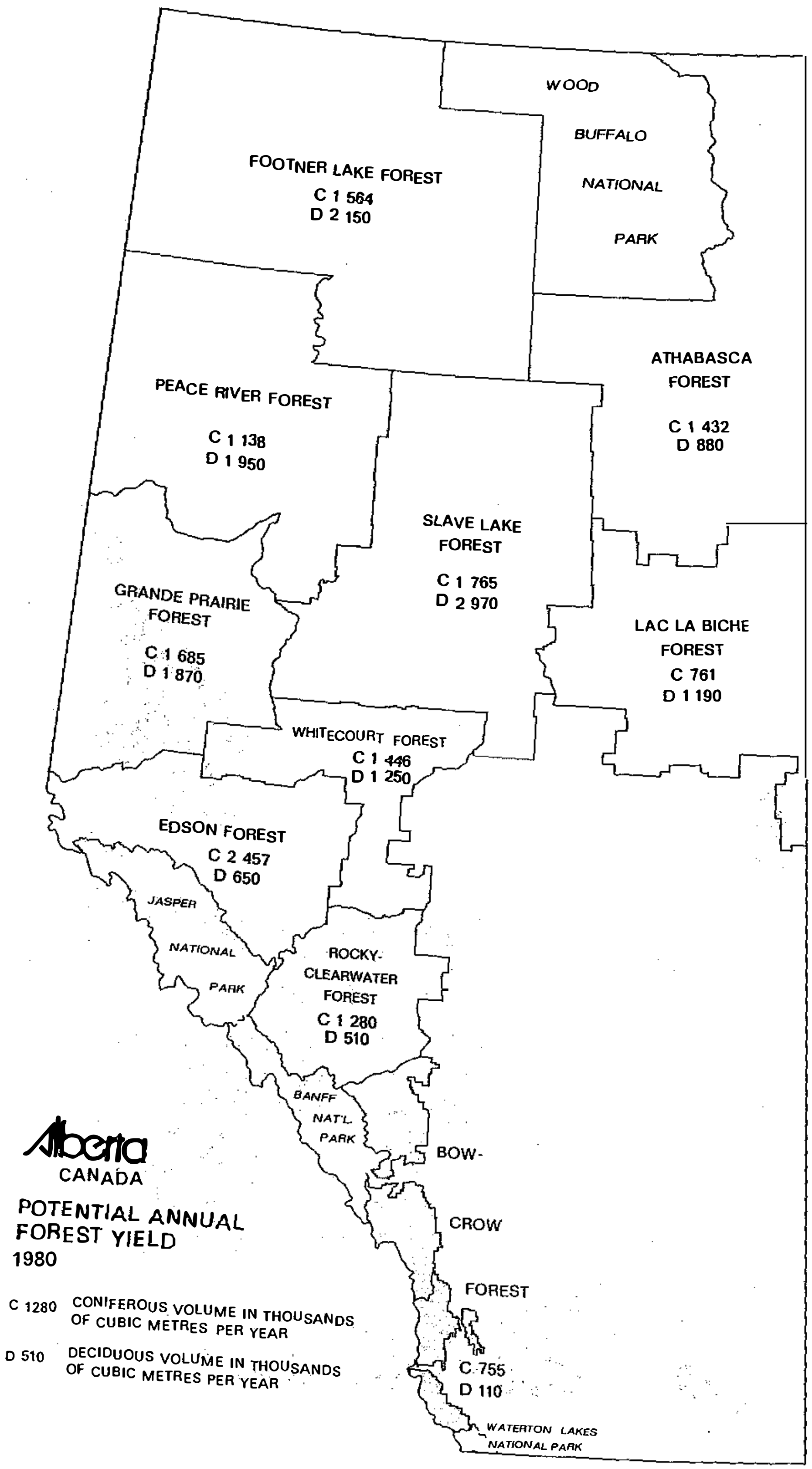

Figure 2. Potential annual forest yield of coniferous and deciduous (mostly poplar) species in Alberta. (Alberta Forest Service map.)

Figure 3. Pure aspen stand along a logging road near Blue Ridge, Alberta. Figure 4. A stand of mature aspen near Blue Ridge, Alberta, after softwood harvest.

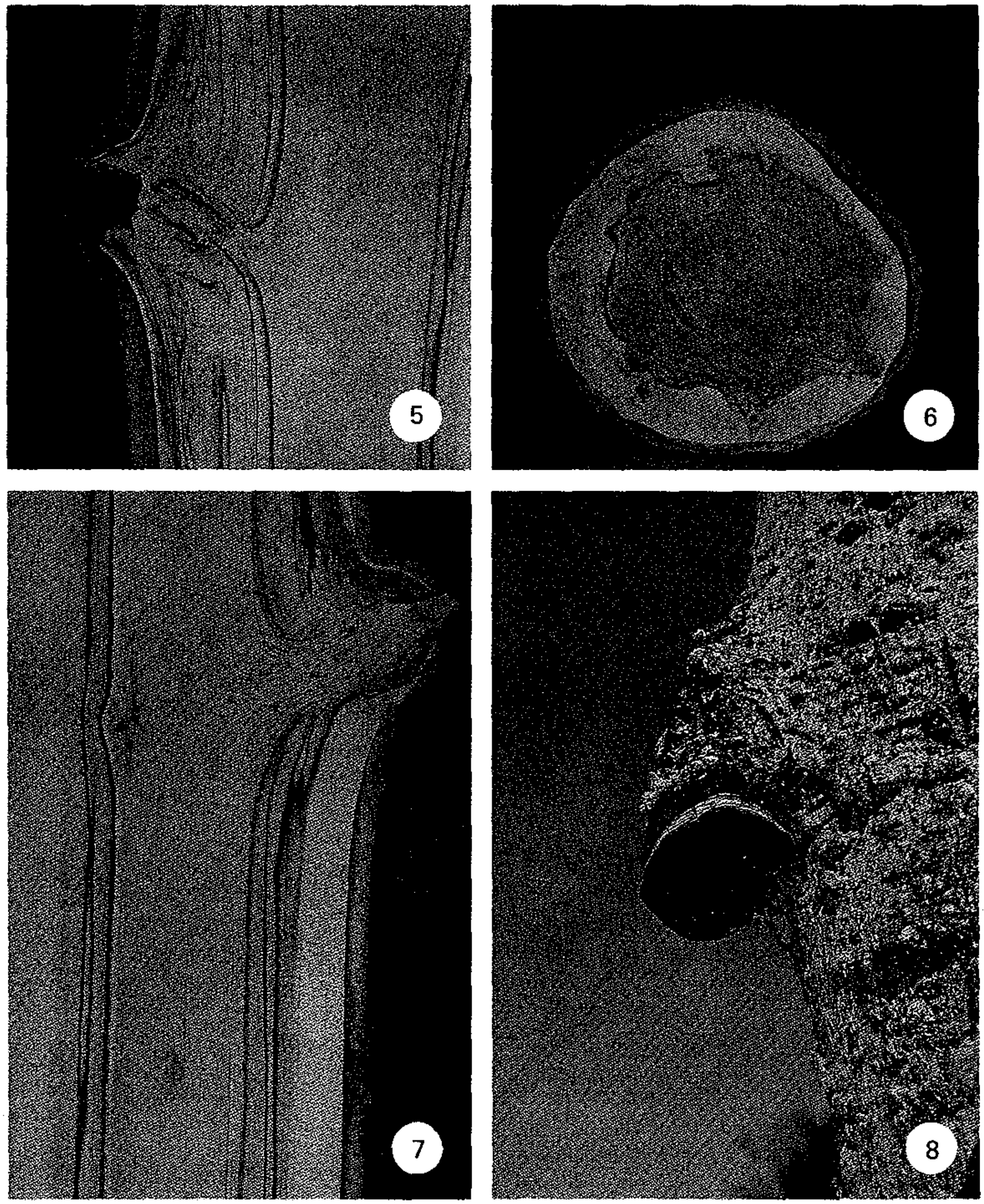

Figure 5. Vertical section of an aspen stem with a fruiting body of *Phellinus tremulae* and a column of advanced decay bordered by characteristic black lines. Figure 6. Cross section of an aspen stem with advanced decay caused by *Phellinus tremulae*. Figure 7. Relation of rotten knot and decay column of *Phellinus tremulae* in aspen. Figure 8. A fruiting body (conk) of *Phellinus tremulae* on aspen.

Table 1. Percentage infections by major decay-causing fungi on aspen and balsam poplar in the Slave Lake area of Alberta. Based on Thomas et al. (1960).

	Aspen		Balsam poplar	
	Trunk	Butt	Trunk	Butt
Phellinus tremulae (*=Fomes igniarius*)	13.4	0.2	26.8	—
Radulum casearium	14.2	1.2	—	—
Peniophora polygonia (*=Corticium polygonium*)	12.8	1.5	—	—
Coriolus zonatus (*=Polyporus zonatus*)	2.1	trace	—	—
Bjerkandra adusta (*=Polyporus adustus*)	1.5	0.7	2.5	0.1
Pholiota adiposa	0.5	0.2	—	—
Phlebia strigosa-zonata	—	2.2	—	—
Armillaria mellea (*=Armillariella mellea*)	—	0.9	trace	1.6
Gymnopilus spectabilis (*=Pholiota spectabilis*)	0.1	1.2	1.3	4.2
Pholiota destruens	—	—	17.7	0.4
Corticium expallens	—	—	5.2	0.4
Trechispora raduloides	0.5	trace	0.8	0.1
Corticium vellerum	—	—	0.3	0.1
Pholiota subsquarrosa	—	0.4	—	—
Mixed	12.4	0.7	—	—
Unknown	10.7	1.4	34.7	3.5
Total	89.2	10.8	89.5	10.5

of small dimensions (Fig. 9) or on old stem scars (Fig. 10). The wood supporting sporophore-bearing branch stubs or stem scars is characteristically in a state of yellowish and pinkish incipient decay (Fig. 11). *Peniophora polygonia* is seldom associated with advanced decay.

Although *R. casearium* is commonly isolated from living trees, sporophores are usually found only on dead trees. They are resupinate, yellow-brown, and have coarse teeth. Basham (1958) suggested that *R. casearium* maybe the cause of most of the characteristic advanced stringy trunk rot of aspen.

Of the three most dominant decay fungi on living trees mentioned above, only *R. casearium* is commonly isolated from stored log piles, indicating that the vitality of the other two species decreases in storage (Fritz 1954).

On balsam poplar, *P. tremulae* is again recognized as the most common and dominant decay-causing species, followed by *Pholiota destruens* (Fig. 12), *Corticium expallens*, and *Bjerkandra adusta* (*=Polyporus adustus*) from trunk rot and *Gymnopilus spectabilis* (*=Pholiota spectabilis*) and *Armillaria mellea* from butt infections (Figs. 13, 14) (Thomas et

Figure 9. Fruiting structure of *Peniophora polygonia* on aspen. Figure 10. Large scars (cracks) on mature balsam poplar. Figure 11. Dead branch and column of discolored incipient decay of aspen caused by *Peniophora polygonia*. Inside of Figure 9. Figure 12. Fruiting bodies (mushrooms) of *Pholiota destruens* on balsam poplar.

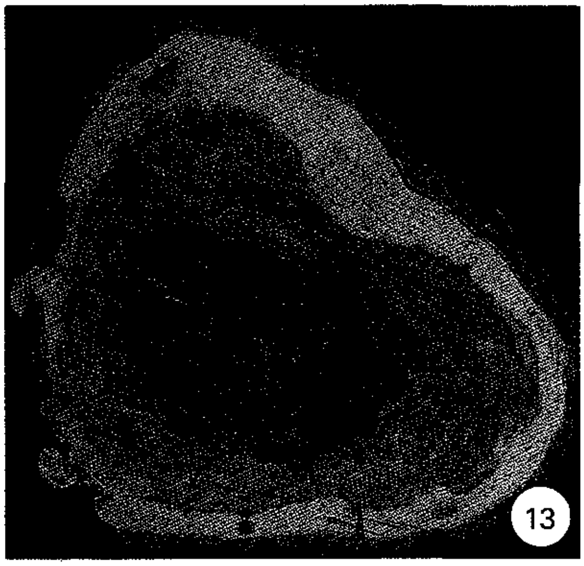

Figure 13. Brown butt rot of balsam poplar, probably caused by *Armillaria mellea*. Figure 14. Butt rot (brown rot) of aspen caused by *Armillaria mellea*. Figure 15. Black gall on aspen.

al. 1960). Decay caused by unknown organisms accounted for 38.2% (34.7% of trunk infections and 3.5% of butt infections), which is greater than decay volume due to *P. tremulae* (26.8%) (Thomas et al. 1960). More investigations are needed to determine the unknown organisms causing the decay in this species and the relative importance of decay fungi.

Many bacteria and other fungi are constantly isolated from decayed and stained tissues (Etheridge 1961; Good and Nelson 1962; Laflamme and Lortie 1973; Shigo 1967; Thomas et al. 1960). These are not considered decay-causing organisms, but they are believed to play an important role in microbial succession leading to incipient decay in aspen and poplar.

On trembling aspen, blackish galls with a rough surface are often found (Fig. 15), but the interior of the galls is sound and not associated with decay. Except for one tree with large scars and conks, about 20 trees with black galls did not have conks and did not have advanced decay[1].

AGE-DECAY RELATIONSHIPS

Aspen and balsam poplar are shade-intolerant species, hence they tend to grow in even-aged stands. These stands originate primarily by means of suckering after forest fires or logging. Regeneration of shade-intolerant aspen and balsam poplar ceases when the forest canopy is closed.

Age-decay relationships are usually tabulated in 10-20 year classes; therefore, all published age-decay relationships show decay percentages of aspen and balsam poplar that are ranked by the ages of unrelated, noncomparable aspen and balsam poplar stands. Because each stand is unique with respect to fire history, genetic origin, site quality, and species composition, there is a great variability in the data published by different researchers. Tables 2 and 3 demonstrate how aspen decay and balsam poplar decay percentages vary across Canada and the United States. A second major cause of the high variability of data published on age-decay relationships in aspen and balsam poplar relates to the lack of clear distinction between incipient and advanced decay and between stain and incipient decay. A third cause of variability is the selection of different assessment standards in the various decay and cull surveys.

Pedology Consultants (1982) analyzed 1015 trees in the O'Chiese Block of the Rocky-Clearwater Forest. Fire history in this forest district has restricted the growth of aspen and balsam poplar stands to single age classes. Eighty-five percent of their 1015 sample trees were over 45 years old, and the average age was 70 years. Their estimated decay percentage was 8.7% for aspen and 7.4% for balsam poplar and did not include unmerchantable stems. Only merchantable sawlogs with less than 50% decay and having more than 9.0 cm top diameter were analyzed. Bailey and Dobie (1977) employed similar standards of utilization, and obtained comparable results (Tables 1 and 2). Paul and Etheridge (1958) analyzed decay and cull relationships at the logging site. For aspen they show nearly five times more decay (30%) in the 51-60 year age class than Bailey and Dobie (6.2%), five times more decay in the 71-80 years age class, and three times more decay in the 91-100 years age class. For balsam poplar, Bailey and Dobie show nearly equal decay percentages throughout 140 years of age (range 0.7%), while Paul and Etheridge show a range of 21.6% through 170 years of age.

In general, decay percentages of gross volume increase with age; however, comparisons between published results obtained by different researchers across Canada and the United States are difficult. Although preselection and rejection of unmerchantable logs at the logging site give low decay incidence figures in some surveys (Bailey and Dobie 1977; Pedology Consultants 1982), the high labor costs of felling, cutting, and selecting may make the operation uneconomical.

SITE-DECAY RELATIONSHIPS

Frequently, a wide range of diameters exists in even-aged aspen stands because of variations in site quality and competition by surrounding trees. This makes it difficult to obtain correlations between tree age and diameter. When diameter limit cuts provided the stems for decay and volume analyses (Bailey and Dobie 1977; Pedology Consultants 1982), poor correlations were found between age and decay (Tables 2 and 3).

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[1] Field observations at Blue Ridge, Alberta, in 1982 by Y. Hiratsuka and A.A. Loman.

Table 2. Age-decay relationships in aspen stands in Canada and the United States

Age class (years)	Percentage decay							
	Minnesota[a]	Manitoba-E. Sask.[b]	Petawawa, Ontario[c]	Upper Pic, Ontario[d]	Lesser Slave Lake, Alta.[e]	Lesser Slave Lake, Alta.[f]	Colorado[g]	Rocky-Clear-water, Alta.[h]
31-40	1.4	—	2.9	—	12.0	—	—	—
41-50	—	1.8	4.4	—	14.0	—	—	—
51-60	4.7	3.2	5.9	1.0	30.0	6.2	6.5	—
61-70	5.9	7.1	7.4	—	40.0	—	—	—
71-80	5.6	14.4	8.9	3.0	42.0	8.4	14.5	8.7
81-90	3.0	21.3	—	—	40.0	—	—	—
91-100	11.5	25.2	—	5.0	36.0	12.2	23.0	—
101-110	18.1	31.1	—	—	33.0	—	—	—
111-120	26.5	36.9	—	8.0	30.0	—	31.0	—
121-130	41.5	41.9	—	—	—	—	—	—
131-140	10.3	—	—	8.0	—	—	45.0	—
141-150	22.5	—	—	—	—	—	—	—
151-160	—	—	—	15.0	—	—	48.5	—
161-170	—	—	—	—	—	—	—	—
171-180	—	—	—	17.0	—	—	—	—

[a] Meinecke (1929).
[b] Black and Kristapovich (1954).
[c] Riley (1952).
[d] Basham (1958).
[e] Paul and Etheridge (1958).
[f] Bailey and Dobie (1977).
[g] Hinds and Wengert (1977).
[h] Pedology Consultants (1982).

Better correlations between site and decay were obtained when the factors of site quality and competition were considered. Paul and Etheridge (1958) divided the sample trees into fast- and slow-growing classes. Slow-growing aspen and poplar occur as a rule on the poor sites and very rarely make up the understory trees on the better sites. The fast-growing trees usually occur on good sites but may occasionally include some dominants from the poorer sites. The diameter classes yielding the maximum net increments in fast- and slow-growing aspen were 35 cm and 30 cm, respectively. In fast- and slow-growing balsam poplar, the diameter classes yielding the maximum net increment were 58 cm and 56 cm, respectively. It appears, however, that genetic factors significantly affect site-decay relationships in aspen.

CLONE-DECAY RELATIONSHIPS

In aspen, highly significant differences have been found between clones in percentage decay, volume of decay, gross volume, and net volume (Kemperman et al. 1978; Wall 1969, 1971). Wall (1971) reported that each clone had a unique pattern with respect to position of rot columns within the stem (Fig. 16) and the major types of rot present. Adjacent or intermingled clones apparently on the same site differed significantly

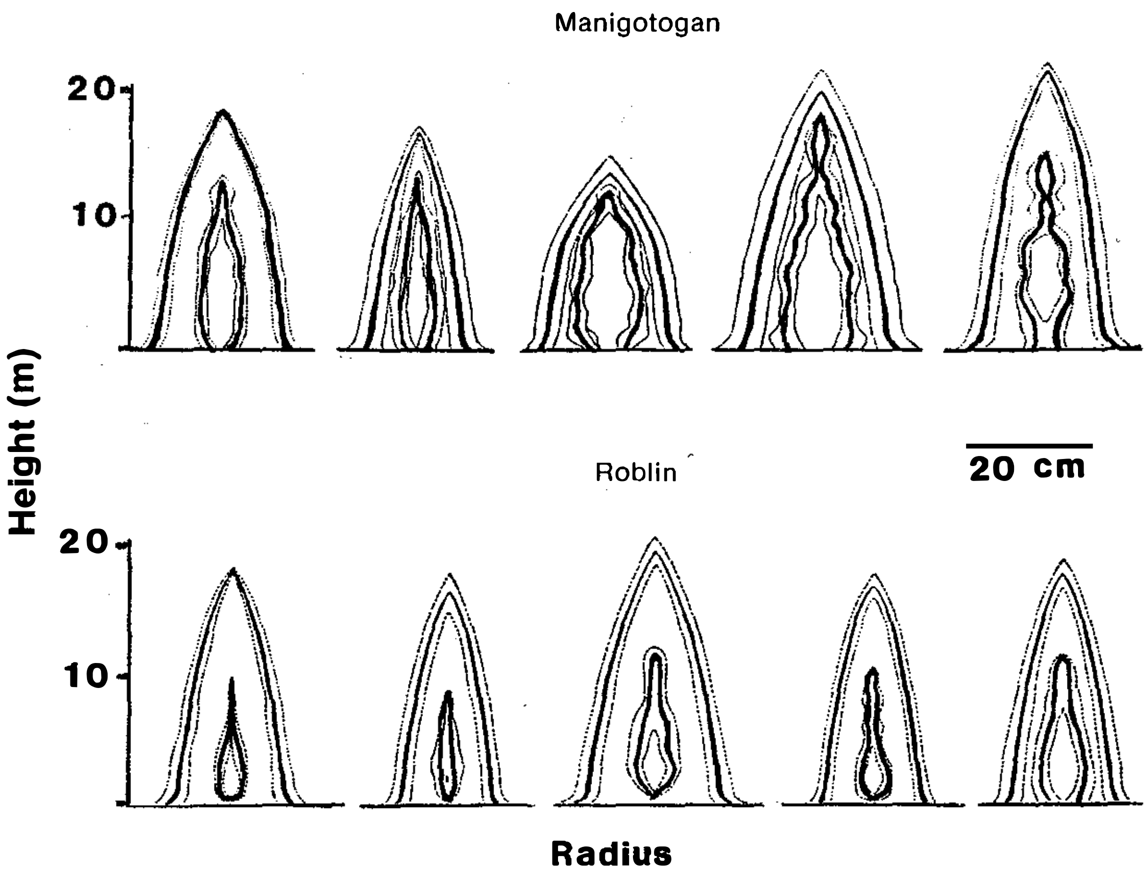


Figure 16. Representation of average tree dimensions and size, position, and shape of decay columns in some aspen clones in two Manitoba locations (Manigotogan and Roblin). Solid outer lines represent bark layer. Inner solid lines indicate decay columns (from Wall 1971).

Table 3. Age-decay relationships in balsam poplar stands in Alberta

Age class (years)	Percentage decay: Lesser Slave Lake 1958[a]	Lesser Slave Lake 1977[b,c]	Rocky-Clearwater forests[d]
31-40	2.9	—	—
41-50	8.7	6.2	—
51-60	8.2	—	—
61-70	7.4	—	—
71-80	8.4	5.0	7.4
81-90	10.1	—	—
91-100	11.4	5.5	—
101-110	13.3	—	—
111-120	15.2	—	—
121-130	17.3	—	—
131-140	19.4	—	—
141-150	21.3	—	—
151-160	22.9	—	—
161-170	24.5	—	—
171-180	—	—	—

[a] Paul and Etheridge (1958).
[b] Bailey and Dobie (1977).
[c] Preselected logs.
[d] Pedology Consultants (1982).

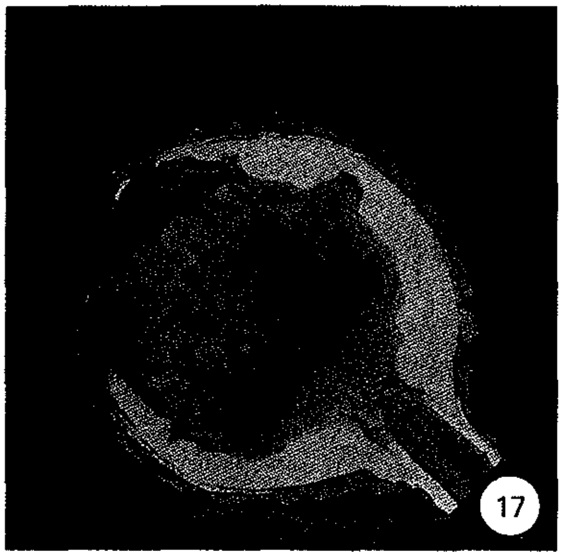
in percentage decay in several instances. Components of the same clone occupying two distinguishable sites did not differ significantly in percent decay in any of the clones harvested, but considerable differences in gross volumes and decay volumes were observed between clones. In one study (Wall 1969), the incidence of *P. tremulae* among intermingled clones on the same site varied from 12% to 64%; on another site the variation ranged from 21% to 92%.

The above observations indicate that the genetic origin of aspen is more important than site quality. When aspen and poplar utilization become economically attractive, the identification of genetically healthy aspen clones will be important in regeneration programs (Steneker 1976; Steneker and Wall 1970).

No published work is available on clones of balsam poplar.

CULL ESTIMATION WITH EXTERNAL INDICATORS

Attempts have been made to find a method to predict relative incidence and extent of decay before harvesting is planned. Most of the published work uses external indicators such as sporophores (mainly conks of *P. tremulae*, Fig. 8), rotten knots, and main stem scars (Figs. 10, 17-20) (Bailey 1974; Bailey and Dobie 1977; Basham 1958; Riley and Biers 1936) to predict decay in the tree stems. Balsam poplar does not produce fruiting bodies of *P. tremulae* easily, and external indicators of decay are mainly rotten knots and large scars (Fig. 10).



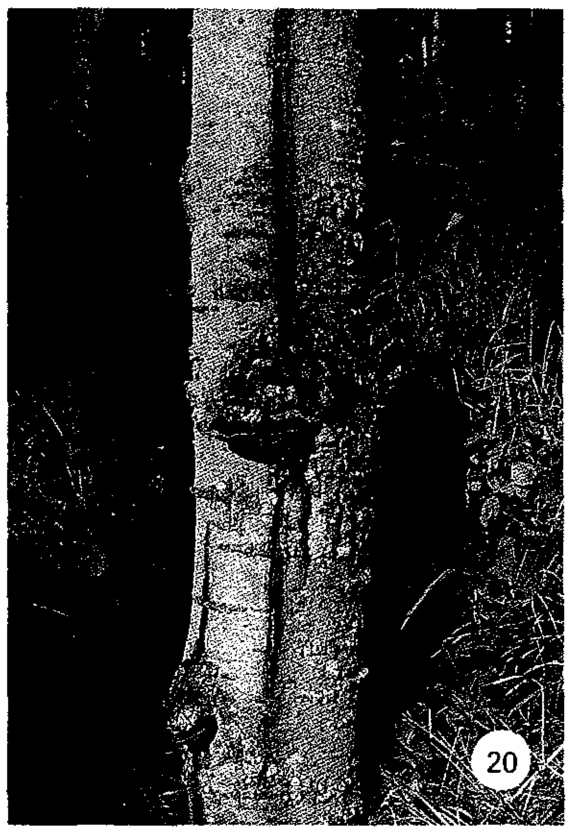


Figure 17. Decay of balsam poplar showing a scar and a branch knot as the entry points for an unknown decay organism. Figure 18. Extensive stem damage at the bottom of a mature balsam poplar. Figure 19. An old healed wound on a small diameter aspen with fruiting bodies of *Peniophora polygonia*. Figure 20. A long scar on a mature aspen with conks of *Phellinus tremulae*.

Among the indicators mentioned above, the presence of conks of *P. tremulae* was found to indicate a significant amount of advanced decay. Basham (1958) found that between 61.1% and 97.6% (average 86.2%) of trees with one or more *P. tremulae* conks had advanced decay (Table 4). At Blue Ridge, Alberta, 17 out of 18 sampled trees (94.5%) with conks and/or large scars had a significant amount of advanced decay, but only 1 of 6 trees (16.7%) without external indicators had advanced decay (Table 5). Although the number and distribution patterns of conks and other external indicators may indicate the shape and extent of decay columns, no quantitative prediction of relative amount of advanced decay can be made from examining external indicators.

Considering the strong clonal uniformity of decay patterns discussed previously, a meaningful decay prediction scheme may be established by checking several selected trees for major clones in the area concerned.

Anderson and Schipper (1978) proposed a system for predicting the amount of *P. tremulae* rot in aspen by applying a constant (1.9) to the stand basal area with *P. tremulae* conks in Minnesota.

ASPEN AND BALSAM POPLAR DECAY MANAGEMENT

Aspen and balsam poplar decay management, sound silviculture practice (Steneker 1976), utilization, and marketing are interdependent in a free market economy and cannot be discussed separately in a meaningful way. Ultimately, the aspen and balsam poplar decay management in Alberta is dependent on matching the biological characteristics of these species with 1) available utilization technology, 2) the demand for specific products on a long-term basis, and 3) the distance to markets. As long as any one of these three factors is unfavorable, aspen and poplar decay management will continue to be irrelevant in Alberta.

Several biological characteristics of aspen and balsam poplar regenerate almost exclusively from root suckers, which share a vast network of roots. Early growth after forest fires or clear-cutting is extremely rapid, giving aspen and balsam poplar (but also alder and willow species) an advantage over trees that regenerate from seeds and over competing grasses, shrubs, and herbs.

The most healthy and vigorous root suckers grow after *all* mature aspen and balsam poplar have been removed (Walters et al. 1982). Even a few residual mature trees left standing after harvesting will be dominant competitors of root suckers for available nutrients through their common root system. Walters et al. also found that partial cutting of 60-80% of basal area may maintain an aspen cover type, but remaining large trees degenerate rapidly with decay and other pathological conditions (Walters et al. 1982).

All species that regenerate vegetatively grow rapidly, but they also have very short pathological rotation ages. Harvesting at pathological rotation age means harvesting when decay rates begin to exceed growth rates, which is estimated as 40-50 years for aspen and 70-80 years for balsam poplar by Paul and Etheridge (1958), although most other decay studies indicate a higher pathological rotation age. In Alberta, harvesting at low pathological rotation age means harvesting aspen and balsam poplar of small diameters unless thinning programs are adopted (Steneker and Jarvis 1966).

Economics dictate a minimum return per hectare in terms of merchantable fiber volume. Biological constraints and the demand for forest products derived from small diameter trees determine whether the costs involved in decay management and aspen-poplar silviculture are justified. To date this has not been the case in Alberta.

If the successes from ongoing research in cellulose and hemicellulose recovery (Boone and Cyr 1981; Cyr and Schultz 1982) from stained and decayed aspen and balsam poplar can be synchronized with a demand for cellulose and hemicellulose and their derivatives, the decay management of Alberta's aspen and poplar forests will also change. For example, if up to 70% of the decayed wood contains extractable, utilizable cellulose and hemicellulose, the pathological rotation age for aspen at 40-50 years becomes irrelevant, and a different economic rotation age would be selected. If the presence of advanced decay is not the limiting factor for utilization, the continued increase in volume per unit area would be achieved at up to 100-110 years for aspen and 140-150 years for balsam poplar (Paul and Etheridge 1958).

Table 4. Relationship between visible *Phellinus tremulae* fruiting bodies and the occurrence of decay in aspen (Basham 1958)

Age class (years)	No. trees sampled	No. trees with decay	No. trees with one or more visible fruiting bodies	% of trees with fruiting bodies
41-60	131	18	11	61.1
61-80	271	52	41	78.8
81-100	553	183	150	82.0
101-120	357	179	151	84.4
121-140	165	100	86	86.0
141-160	238	170	166	97.6
161-180	39	29	25	86.2

Table 5. Relationship between decay and stain occurrence and external indicators in aspen[a] sampled at Blue Ridge, Alberta, in 1982

External indicators	No. trees	Stain and advanced decay	Stain	No decay
Conks	4	4	—	—
Conks and scars	1	1	—	—
Scars	11	10	1	—
Rotten knots	2	2	—	—
No external indicators	6	1	4	1
Total	24	18	5	1
Percentage	—	75	21	4

[a] Age range 75-80 years.

SIGNIFICANCE OF DECAY AND DISCOLORATION TO ASPEN AND BALSAM POPLAR UTILIZATION

Plywood

Plywood production demands decay-free, high-quality logs for veneer. Discoloration also downgrades the products. Besides discoloration and decay, the following problems contributed to the failure of the poplar plywood industry in Alberta (Rytz 1980a; Wells 1980).

a) The high incidence of decay resulted in enormous amounts of waste at the logging and mill sites.
b) Decay-free trees of peeler quality were scattered over vast areas in the forest, making harvesting costly.
c) Not all decay was detected in the forest, hence at the mill site the volume of waste material due to decay was enormous.
d) Poplar is difficult to peel because of ring shake, rot pockets, and tension wood.
e) Defects in veneer result in a sheet ratio that is generally below 50%. Defects are oversized knots, splits, feathered grain, and ring shake.
f) The high moisture content in poplar increases the shipping costs.
g) Higher moisture content in poplar veneer requires 15% more drying time than spruce to reduce the moisture content to 5%.
h) Dryer loss is substantial because of cracks and splits that open up in the drying process.
i) Poplar veneer requires 8-10% more glue than is required for spruce.

Dimension lumber, boards, and timbers

With respect to a previous sawmill operation in the Slave Lake area, lumber recovery from logs to merchantable material was only 15% of the total volume handled because of the presence of advanced and incipient decay. Enormous waste burners, more than double the capacity required for softwoods, were needed. Also, compared with softwoods, hardwood lumber requires 2.5 to 4.0 times as long to kiln dry (Rytz 1980a). As a result, there are the additional capital and carrying costs for extra kiln capacity. Twenty percent of poplar studs from Alberta were classified as economy grade, the lowest of four grades. This was a much greater percentage than that for softwoods.

Wafer board, flakeboard, chipboard, and oriented strand board

Clear decay-free logs are not as essential for the production of wafer board, flakeboard, and oriented strand board as they are for plywood. Decayed wood definitely affects these products, however, and could be a critical factor in the success of a mill producing them.

Pulp and paper

Excessive amounts of decayed wood processed by a pulp mill are known to affect the yield and quality of pulp and the quality of paper products (Fritz 1954; Hatton 1974; Hunt et al. 1978) MacLeod et al. (1982) reported success in designing a chip improvement process (Paprifer Chip Improvement Process) that eliminates most of the decayed wood and produces chips of the same quality as chips from sound healthy wood. If this type of process is incorporated into a pulping operation, the incidence and amount of decay would have no influence on utilization as long as sufficient sound wood was available.

Integrated wood products complex

The best way to utilize the poplar resource appears to be through the development of an integrated complex to minimize waste caused by decay, poor quality logs, and rejected finished products. The objective would be to develop as many high-value-added products as possible to offset the high logging and manufacturing costs. In the process of obtaining sound wood in the logging as well as the milling phase there is much waste, and other users must be found for the residual fiber that is generated. Such a complex could consist of a plywood plant, a wafer board mill, a sawmill, and a mill using waste (i.e., particleboard mill, chemical conversion plant). The waste can be used as an energy source for the mill. For this type of complex, the wood would be allocated as follows:

a) The highest-quality logs would be sent to the plywood mill for veneer.
b) Thirty to fifty percent of the better-quality wood would be sent to the sawmill.
c) All rejected wood from the first two processes would then be sent to reconstituted board production, supplemented by roundwood as required.
d) These three processes would generate by-products such as shavings, chips, rejects, low-quality roundwood, bark, sawdust, fines, and oversized pieces, all of which could be processed by a plant using all fibers regardless of quality.

Conversion of biomass into energy and chemicals

The advantage of considering Alberta's aspen-balsam poplar inventory as a source of biomass is that all available wood biomass would be utilized regardless of the presence and extent of decay in the wood. All cellulose materials—bole, bark, branches and twigs, foliage, and roots—can be converted to energy (Silversides 1980). Biomass harvesting for energy means being able to low-grade the forest, leaving the best trees for conventional forest products. The best harvesting system is complete clear-cutting to improve stocking, rapid growth, and natural thinning. Arguments against use of biomass for energy purposes were outlined by Kennedy (1980), who claimed that land assembly, soil depletion through short rotations, and common-sense economics make hardwood energy planning unattractive.

With the abundance of natural gas, oil, and especially coal in Alberta and British Columbia, ethanol can be manufactured more efficiently and cheaply from natural gas than from wood. It is therefore uneconomical to make wood sugar from hardwoods and then ferment it to ethanol.

Cattle feed

Steamed poplar chips have good digestibility and provide an energy component to cattle feed. The aspen-poplar inventory is a potential emergency silo for Alberta cattle (Kennedy 1980). There appears to be some problem with mycotoxins, however, which requires further study.

For this use, decay should not have much consequence, although no report has been found that discusses the food value of the decayed part of the wood.

Cultivation of edible mushrooms

Biomass of aspen and balsam poplar can be utilized to cultivate edible mushrooms such as oyster mushroom (*Pleurotus ostreatus*), the commonly cultivated mushroom (*Agaricus bisporus*), and Nameko (*Pholiota nameko*).

The presence of advanced and incipient decay should not significantly affect mushroom production if sterilized sawdust or wood chips are used. If unsterilized logs are used to cultivate mushrooms, the presence of other microorganisms in the wood, including decay fungi, will affect the growth and yield of the mushrooms.

CONCLUSIONS

1. A significant amount of early advanced decay is inherent in aspen and balsam poplar in Alberta and is caused mainly by *Phellinus tremulae*.
2. Very little information is available on decay of balsam poplar compared to that of aspen.
3. Various decay loss studies indicate that the amount of decay increases with age, although reported figures are varied.
4. Each clone seems to have its own decay pattern, which is less influenced by site or age.
5. External indicators such as conks, large stem scars, and rotten knots can be used to predict the presence of advanced decay but cannot be used to estimate the extent of decay.
6. Clone by clone predictions can be made by felling and examining several trees for the presence and amount of decay.
7. Decay appears to be less of a limiting factor when considering utilization of poplar as biomass for energy conversion and cattle feed. Intensive research and development efforts are needed to make these options viable in Alberta.

RECOMMENDATIONS

1. The identification and mapping of decay-free clones in accessible aspen and balsam poplar stands in Alberta are important and should have high priority.
2. Any aspen or balsam poplar improvement program should include the degree of clonal decay resistance as an important selection criterion.
3. Research involving the utilization of various components from trees with a significant amount of advanced decay should be encouraged. For example, research involving extractable cellulose

and hemicellulose from aspen and balsam poplar with advanced decay would be useful.

4. Since decay is only one of a multitude of factors determining the marketability of a specific product, it is recommended that decay research be integrated into studies of all other factors that contribute to the marketability of a specific product.

5. When more intensive management of aspen and balsam poplar is considered in Alberta, important biological aspects such as microbial succession leading to advanced decay, the modes and sites of decay organism infection, and the nature and heritability of clonal decay resistance should be investigated.

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