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by

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The extent of variation in average tree growth and stem defect (stain, incipient rot, and advanced rot) was assessed for 12 trees in each of five trembling aspen clones (Populus tremuloides Michaux) *in a 65-year-old stand and 15 clones in a 115-year-old stand in northern Ontario. Significant differences were found among clones in the selected characteristics, except for advanced rot in the stand with five sampled clones. The broad-sense heritability values and general lack of correlation between tree growth and defect and the site conditions (soil texture and moisture regime) indicate that genetic differences contributed significantly to the observed phenotypic differences (mainly tree growth rate and extent of defect) among clones. The clones also differed in the decay-causing fungi associated with defect; in some clones nearly all rot was caused by* Fomes igniarius *(L. ex Fr.) Kickx, while in other clones rot was caused primarily by* Radulum casearium *(Morg.) Lloyd or various butt-rot fungi. The degree of variation found among these clones may be sufficient to justify the development of a clonal management system to genetically improve natural aspen stands in northern Ontario.*

INTRODUCTION

Both trembling aspen *(Populus tremuloides* Michaux*)* and largetooth aspen *(P. grandidentata* Michaux*)* typically regenerate vegetatively by root suckers. This results in the formation of naturally occurring clones (Barnes 1966) which can vary in size from one tree to several thousand trees spreading over many hectares (Kemperman and Barnes 1976). Genetic diversity among clones has been documented for many characteristics. Because of this diversity, Wall (1971), Steneker (1973), and Heeney et al. (1975) have suggested that it may be possible to improve aspen stands by manipulating the clonal composition to promote superior clones.

The potential gain from altering the clonal composition of natural stands will depend largely on the extent of clonal variability of desired characteristics. In Ontario, one of the most important characteristics that should be considered in any aspen stand improvement program is that of disease resistance. Traditionally low utilization levels of aspen in Ontario have been due in part to high total defect (stem rot, and stain) volumes. Basham and Morawski (1964) in their studies showed defect volume to vary from 8% to 37% in relation to gross merchantable volume.

Apparent differences in disease susceptibility among aspen clones have been reported. French and Manion (1975) found that trembling aspen clones inoculated with *Hypoxylon mammatum* (Wall) Miller varied in susceptibility to Hypoxylon canker enlargement. In another study of Hypoxylon canker in 80 clones, the incidence of trees with cankers ranged from 9% to 90% (Copony and Barnes 1974). Wall (1969) reported that the incidence of *Fomes igniarius* var. *populinus* (Newman) Campbell conks on trees of three intermingled clones was 92%, 48%, and 21% while in another set of three clones, the incidence was 64%, 47%, and 21%. Wall (1971) also reported that adjacent or intermingled clones on apparently the same site differed significantly in the percent of decayed wood and that clones tended to have distinct patterns with respect to position and size of rot columns within the stems. Further, the major types of rot encountered varied between clones.

The extent of variability in disease resistance among aspen clones in Ontario is unknown. The objective of this study was to provide a preliminary assessment of defect variation among clones in northern Ontario.

STUDY AREA AND METHODS

The study was located in the Terrace Bay District on the American Can of Canada Limited timber limits approximately 50 km southeast of Longlac, Ontario. This area is on the boundary between Site Regions 3E (Lake Abitibi) and 3W (Lake Nipigon) (Hills 1961). The location was chosen because the forest conditions were considered reasonably representative of aspen stands in northern Ontario.

Two stands were studied; one near Kagiano Lake and the other near Stevens, a former industrial town site. The approximate age of the Kagiano Lake and Stevens stands were 65 and 115 years respectively. Both stands are located on relatively deep to shallow calcareous till deposits. Stand composition was primarily trembling aspen with a minor component of balsam poplar *(P. balsamifera* L.*)*, white birch *(Betula papyrifera* Marsh.*)*, white spruce *(Picea glauca* (Moench) Voss*)*, and black spruce *(Picea mariana* (Mill) B.S.P.*)*.

Five clones were sampled in the Kagiano Lake stand and 15 clones in the Stevens stand. The clones were initially delineated on infrared aerial photographs taken in September 1971 and May 1972. The clones were differentiated based on leaf coloration and leaf fall in the September photographs and confirmed by the stage of leaf flush in the May photographs. In July 1972 the clones, as differentiated on the photographs, were located in the field and sampled.

Twelve aspen (suppressed trees excluded) along a line passing through the centre of each clone were felled and cut at the 0 m, 1.4 m, 2.4 m, and each subsequent 2.4 m level to a top diameter of approximately 10 cm. At each cut, discs, 7 cm thick, were obtained and placed as soon as possible in cold storage at the Northern Forest Research Unit in Thunder Bay. During the winter of 1972-73, the discs were removed from storage, split in half, and examined. The cut surfaces of each disc were sketched showing the location and color of each stain and rot. The presence of fungus conks and branch stubs at these points were recorded, and any other unusual features were described. From all major rots encountered, and occasional stains, attempts were made to isolate the causal or associated microorganisms using 2% malt agar as a growth medium. Wood defect was classified as advanced rot, incipient rot, and stain. Advanced rot was wood decomposed to the point where it was noticeably soft; stain was discolored wood that was at least as hard as sound, clear wood; and incipient rot was discolored wood that was "slightly softer" than sound, clear wood when tested with the point of a sharp knife. All of the isolated organisms were forwarded to the Great Lakes Forest Research Centre in Sault Ste. Marie for identification.

Disc and defect diameters were plotted on logarithmic tree measurement graphs from which the actual stem volumes (inside bark) from stump height to a top diameter of approximately 10 cm and the volumes of the various defects were determined using a planimeter. From the planimetered volumes, the percent total defect, stain, incipient rot and advanced rot were calculated. These percentages were transformed to arc-sine percentages and the clonal

means of these and other tree measurements were compared by Duncan's new multiple-range test (Duncan 1955). Broad sense heritability (Wright 1962) estimates were calculated for tree volumes and the percent defect values.

For each clone in the Stevens stand soil samples were collected from the B_2 horizon and the texture was subsequently determined by the hydrometer method. The soil moisture regime was estimated at each soil pit based on criteria described by Hills (1952). The correlation coefficients were calculated to determine if relationships existed between both soil texture (percent silt plus clay in the B_2 horizon) and soil moisture regime and the clone means for tree size and defect volumes (significance level, P=0.05). No site information was taken for the five Kagiano Lake clones.

RESULTS

Kagiano Lake Clones

In the Kagiano Lake stand the difference in average tree volume was statistically significant among several clones with a 2.6 fold difference between clones A and F (Table 1). Over the five clones the percent of stem volume affected by defect ranged from 4.2% to 10.3%. The breakdown of defect into stain, incipient rot, and advanced rot which is an important consideration in the manufacturing process since stain and incipient rot can be used in some pulping processes whereas advanced rot can not, showed that significant clonal differences occurred in percent stain (range 1.2% to 4.9%) and also in percent incipient rot (range 1.4% to 6.8%). The percent advanced rot was small and did not vary significantly over the 5 clones (range 0% to 0.3%).

In general, no relationship between growth rate and percent defect was apparent among the five Kagiano Lake clones. However, in each of the two fastest growing clones, E and F, the four trees with the slowest growth rates were the four most defective trees sampled within these clones. There was no apparent relationship, however, between tree growth rate and defectiveness within the other three clones. Overall, clone F was clearly the superior clone of the five sampled having fastest growth rate, an intermediate amount of stain, little incipient rot, and no advanced rot.

Only three of the 60 aspen trees examined at Kagiano Lake had advanced butt rots, and these were limited in extent. Very few trees had incipient butt rot, although extensive butt stain was occasionally encountered. This is reflected in the low occurrence of butt rot fungi; only one isolation each of *Pholiota spectabilis* (Fr.) Kummer and *Coprinus micaceus* (Bull. ex Fr.) Fr. were obtained. The most frequently isolated Basidiomycete fungi were *Peniophora polygonia* (Pers. ex Fr.) Bourd. & Galz. (15 times), *Trechispora brinkmanni* (Bres.) Rogers & Jacks (7 times), and *Stereum purpureum* (Pers. ex Fr.) Fr. (6 times); all of these were associated with the incipient rot or stain. These fungi are seldom, if ever, associated with advanced rot in aspen. The two major causes of advanced trunk rot in aspen, *Radulum casearium* (Morg.) Lloyd and *Fomes igniarius* (L. ex Fr.) Kickx, were isolated only three times and twice, respectively. The most frequently isolated non-Basidiomycetes were bacteria (48 times), *Trichoderma sporulosum* (Link) Hughes (25 times), *Verticillium* sp. (21 times), *Rhinocladiella* sp.

TABLE 1 Average clonal stem height, diameter, volumes and percent of stain, incipient rot, and advanced rot in the Kagiano Lake and Stevens aspen stands

Clone	Total height (m)	DBH outside bark (cm)	Total vol/tree (dm^3)	Defect vol/tree (dm^3)	Percentage[1] of merchantable volume per tree			
					Defect	Stain	Incip. rot	Adv. rot
Kagiano Lake								
A	--[2]	16.26 a..[3]	191.4 a.	12.5 a.	6.5 ab	1.2 a..	5.0 ab	0.3 a
C	--	18.80 a..	199.1 a.	20.4 ab	10.3 ab	3.4 abc	6.8 .b	0.1 a
D	--	20.07 ab.	278.6 ab	11.9 a.	4.2 a.	1.5 ab.	2.5 a.	0.1 a
E	--	21.34 .bc	333.3 .b	31.1 .b	9.3 .b	4.9 ..c	4.3 ab	0.1 a
F	--	24.89 ..c	507.4 ..	31.4 .b	5.1 ab	3.7 .bc	1.4 a.	0 a
Stevens								
A	22.8 .b.....	20.8 a.....	290.0 a.....	41.1 abcd..	14.1 ....ef	2.5 abc.	9.2 ...de	2.4 .b
N	21.6 a.....	22.1 ab.....	335.0 ab.....	67.4 ..cdef	20.2 .....f	4.0 abc.	16.6	0.1 ab
L	21.7 a.....	23.1 abc....	352.8 abc.....	28.9 ab....	8.2 abcde.	1.0 a...	5.5 .bcd.	1.6 ab
E	22.9 .b.....	26.7 ...def.	426.2 abcd....	15.0 a.....	3.5 ab....	1.7 abc.	1.7 a....	0.1 ab
B	24.9 ...d...	24.9 .bcd...	438.3 abcd....	16.1 a.....	3.7 ab....	0.9 a...	1.7 ab...	1.1 ab
I	24.0 ..c....	25.6 ..cde..	475.2 .bcde...	89.5 .....f	18.8 .....f	7.9 ...d	9.7 ....e	1.2 ab
O	24.6 ..cd...	25.6 ..cde..	498.4 ..cdef..	32.0 abc...	6.4 abcd..	1.4 abc.	4.5 .bcd.	0.5 ab
G	24.9 ...d...	27.7 ...def.	551.6 ...def..	36.0 abcd..	6.6 abcd..	1.3 ab..	2.7 abc..	2.8 .b
D	27.3 ......g	26.7 ...def.	557.3 ...defg.	56.4 .bcdef	10.1 ..cde.	2.6 abc.	5.3 .bcd.	2.2 ab
F	25.1 ...de..	27.9 ...def.	587.3 ...defg.	85.2 .....f	14.5 ....ef	6.5 ..cd	6.5 ..cde	1.5 ab
M	26.5 ....fg	29.7 .....fg	622.7 ....efg.	31.4 abc...	5.0 abc...	1.9 abc.	2.8 abc..	0.3 ab
R	27.3 ......g	27.4 ...def.	627.2 ....efg.	45.0 abcde.	7.2 abcd..	5.2 ..cd	2.0 ab...	0.1 a.
C	27.4 ......g	29.0 ....efg	652.4 ....efg.	20.6 abc...	4.7 a.....	2.1 abc.	0.7 a....	1.8 ab
K	25.9 ....ef.	30.0 .....fg	719.8 ......gh	77.9 ....ef	10.8 ...de.	3.8 .bcd	4.8 .bcd.	2.2 ab
P	27.4 ......g	32.0 ......g	823.5 ....h	71.9 ...def	8.7 .bcde.	2.0 abc.	4.8 .bcd.	2.1 .b

NOTE: Means followed by a letter in common are not significantly different (Duncan's new multiple range test: P=0.05)

[1] Percent values are not transformed

[2] Total heights of Kagiano Lake trees were not measured

[3] Only inside bark diameters were available for Kagiano Lake Clone A

(15 times), and *Cephalosporium* sp. (10 times). None of these organisms causes rot, and although some may result in stain it is believed that most of them occur as secondary inhabitants of defective aspen wood.

The two advanced trunk rot fungi, *R. casearium* and *F. igniarius*, were isolated only from the two slowest growing clones, A and C. *Radulum casearium* was isolated from two trees in clone C, from advanced rot in one and incipient rot in the other. It was also isolated once from incipient trunk rot in clone A. *Fomes igniarius* was isolated from the two trees with advanced trunk rot in this clone, and the appearance of much of a widespread incipient rot in clone A suggests that it, too, was largely caused by *F. igniarius*.

Stevens Clones

Average tree height of the clones in the Stevens area ranged from 21.6 m to 27.4 m. The maximum difference among clones in average tree volume was 2.8 fold (range 0.29 m^3 to 0.81 m^3). The interclonal range in the percent total defect, stain, and incipient rot was from 3.5% to 20.2%, 0.9% to 7.9%, and 0.7% to 16.6% respectively. The differences in the percent advanced rot, while significant between some clones, were relatively small (range 0.01% to 2.8%).

As with the Kagiano Lake clones, no relationship was apparent between the clonal growth rate and percent defect at the Stevens location. No one clone stood out as the obviously superior clone as did clone F in the Kagiano Lake stand. The three fastest growing clones (P,K and C) contained appreciable stem defect particularly in terms of advanced rot, and the three smallest clones (A, N and L) also were relatively defective. From Table 1, at first glance clone C appears the most outstanding, with the third fastest growth rate (total volume) and an overall defectiveness of just 4.7%, however, over one-third of this defect is in the form of non-utilizable advanced rot. In terms of overall minimal defectiveness and considering the proportions of advanced rot, incipient rot, and stain, three clones E, M and R, are clearly superior to the rest. Of these, clone E has a relatively slow growth rate and while both clone M and clone R had similar fast growth rates, clone M had the least overall defectiveness of the two but clone R was the only one with practically no advanced rot. It is difficult therefore to designate a single "best" clone.

In all but three of the 15 Stevens clones, the slowest growing trees tended to be the most defective trees, although one or more individual trees were encountered within each of these clones that proved to be exceptions to this rule. The same pattern was found in two of the five Kagiano clones. Similar results were reported by Kemperman et al. (1976) in second growth aspen stands in northern Ontario. They found that the slower growing trees (intermediate crown class) had relatively more defect than faster growing trees (codominant and dominant crown classes).

Approximately 70% of the advanced rot in the Stevens clones was trunk rot, the remainder was butt rot (rot originating below or near ground level) plus any trunk rot within 1.5 m of ground level. In nine clones butt rot was classified as heavy, averaging between 6 and 8 cm diameter at stump height.

All of these clones had at least two sample trees with no advanced butt rot and had an average of four trees with butt rot diameters between 8 and 23 cm at stump height. Two of these "heavy butt rot" clones had virtually no trunk rot (0 and L); in the remainder butt rot constituted between 25% and 50% of the total advanced rot volume. The other six clones classified as "light butt rot" had between one and seven trees with some advanced butt rot, but in almost all cases the rot diameter was 2.5 cm or less at stump height. These six "light butt rot" clones included four of the five fastest growing clones.

Two earlier studies of stem rot and causal fungi in mature aspen have been carried out in Ontario, one in the same region as the present study (Basham 1958), and the other throughout the forested region of the province (Basham and Morawski 1964). These studies have indicated that trunk rot is more extensive than butt rot, and that *F. igniarius* and *R. casearium* cause most of the advanced trunk rot with both these fungi plus *P. polygonia* being frequently isolated from incipient trunk rot. The chief causes of advanced butt rot appear to be *P. spectabilis*, *Armillaria mellea* (Vahl ex Fr.) Kummer, and *Pholiota adiposa* (Fr.) Kummer. Furthermore, extension down to ground level of defects associated with the three trunk fungi is not uncommon.

The only butt rot fungus isolated from the Stevens clones was *P. spectabilis*; it was isolated from a total of five trees in four clones. Butt rot was encountered in over 80 trees; clearly many of these were caused by *A. mellea* and *P. adiposa*, and probably more by *P. spectabilis* than the five from which it was isolated. Because the rots caused by these three fungi are similar in appearance, no attempt was made to assign a causal fungus to the numerous unidentified butt rots.

Radulum casearium was the Basidiomycete fungus most frequently isolated from the Stevens aspen (50 times), followed by *P. polygonia* (32 times), *F. igniarius* (9 times), *P. spectabilis* (8 times), *T. brinkmanni* (8 times), *S. purpureum* (7 times), *Polyporus adustus* Willd. ex Fr. (5 times), and several others isolated only once. The most frequently isolated non-Basidiomycetes in the Stevens clones were bacteria (129 times), *Verticillium* sp. (119 times), *Rhinocladiella* sp. (55 times), *Cephalosporium* sp. (53 times), and *Trichoderma sporulosum* (49 times).

From the earlier studies on aspen decay in Ontario it seems likely that *F. igniarius* was far more common in the sampled aspen than the low number (9 times) of isolations would suggest. Fortunately *F. igniarius* causes a very distinctive spongy, soft rot interlaced with black zone lines, frequently accompanied by large, characteristic conks at adjacent branch stubs. Thus from the field data, photographs, and rot descriptions it was possible to attribute many additional rots to this fungus with reasonable certainty.

Unlike butt rot, there was a tendency for the faster growing clones to have a greater proportion of the stem volume affected by trunk rot than the slower growing clones. Advanced trunk rot was generally most extensive between 2.5 m and 7.5 m, although in two clones it occurred only between 6.0 and 14.0 m. *Fomes igniarius* was the fungus responsible for the greatest volume of rot in the Stevens clones, mainly because of its ability to spread

extensively in the stem once established, resulting in a large volume of advanced trunk rot. Thus two otherwise relatively sound clones with good growth, P and C, were classified as moderately defective clones because one sample tree in each contained massive *F. igniarius* rot columns. *Radulum casearium* was present in just as many or perhaps more of the sampled trees, but was almost always associated with limited advanced rot or incipient trunk rot. *Peniophora polygonia* was isolated from several incipient rots, seldom from advanced rot. The fungi responsible for butt rots were less important than the trunk rot fungi on the basis of volume of merchantable stem affected, although in some clones they accounted for an average of 4 dm^3 of advanced rot per tree (average total volume of advanced rot per tree in all clones was 8 dm^3).

Two clones, R and E, were assessed as having no major defect problems. Of the remaining 13, *F. igniarius* trunk rot was the main cause of serious defect in nine clones, *R. casearium* trunk rot in two (I and N, the two clones with by far the highest percentages of total stem volume defective), and in the remaining two (O and L) butt rot was the principal source of serious defect. The most striking evidence of interclonal variation in stem rot susceptibility was the almost complete absence of any detectable *F. igniarius* rot in six aspen clones, compared with the high incidence of this type of defect in the nine other Stevens clones.

DISCUSSION AND CONCLUSIONS

Within both the Kagiano Lake and Stevens stands the significant differences among clones in tree size and all classes of defect, except advanced rot at Kagiano Lake, suggest that a degree of genetic control exists over tree growth and disease susceptibility. An accurate assessment of the extent of genetic variation would require a clone transplanting experiment to determine the amount of phenotypic variation that is related to site differences. The broad-sense heritability estimates (Table 2), however, do indicate that approximately 38% of variation in average tree volume and 24% of variation in average defect volume in these stands may be explained by genetic differences among clones. The genetic control of the percent incipient rot was considerably stronger than for advanced rot. As advanced rot increases with age (Basham 1958), clonal differences may become more evident.

No significant correlations were found in the Stevens stand between site as indicated by soil moisture regime and the percent fines (silt plus clay) in the B_2 horizon and the average clonal tree volume or defect. This further suggests that genetic differences contributed significantly to the observed phenotypic differences among clones. Because of the lack of site information, no similar assessment was made of the Kagiano Lake stands. Previous studies in northern Ontario, while not considering the clonal composition of aspen stands, similarly reported that soil moisture regime did not have an important influence on defect in aspen (Morawski et al. 1958, Basham 1960, Kemperman et al. 1976).

TABLE 2 Broad-sense heritability values[a] for selected growth and defect characteristics of clones in two northern Ontario aspen stands

Stand	Total height	DBH (inside bark)	Total volume	Defect volume	% vol. stain	% vol. incip. rot	% vol. adv. rot
Kagiano Lake (5 clones)	--[b]	28%	38%	24%	15%	11%	2%
Stevens (15 clones)	78%	37%	38%	23%	16%	41%	4%

[a]That portion of variance due to all genetic factors (Wright 1962)

[b]Total tree height not measured for Kagiano Lake clones

The results of this preliminary study suggest that the degree of variation among clones in northern Ontario may be sufficient to justify the development of a clonal management system for natural aspen stands in northern Ontario. Additional aspen stands are being more intensively studied to obtain a better understanding of clonal variation.

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