# SCARIFICATION OF 3-YEAR-OLD ASPEN SUCKERS: 4- AND 6-YEAR EFFECTS ON, AND A PRELIMINARY FORECAST OF, THE INTERNAL PATHOLOGICAL QUALITY OF THE SURVIVORS

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ABSTRACT

Trembling aspen (*Populus tremuloides* Michx.) suckers that survived scarification treatment when 3 years old showed evidence of both height and diameter growth reductions, when sampled 4 and 6 years later. However, observations made 9 years after the event suggested that normal growth had resumed, and that survivors would develop to harvestable size. Wounds caused by scarification machinery were common on both stems and roots, with wounding of the parent roots apparently contributing to sucker growth inhibition. Most scarification wounds were associated with internal stain and rot. The incidence and extent of these defects in individual suckers increased progressively with the occurrence and severity of wounds. Stem rot occurred only in wounded stems and accounted for 4.1% of the volume of the 9-year-old sample, which is about 10 times the normal amount in aspen of this age class. Several hymenomycete fungi not usually found in young aspen were isolated from the defective wood associated with both stem and root scarification wounds. Many of these are known to cause serious root, butt, and stem rot in mature aspen. Hence, scarification of 3-year-old aspen carries with it the risk that the survivors will form crop trees of relatively poor quality with serious, abnormally high levels of internal stem and root rot.

RÉSUMÉ

Des drageons de peuplier faux-tremble (*Populus tremuloides* Michx.) de trois ans ont été soumis à la scarification. Lorsque, 4 et 6 ans plus tard, on a échantillonné ceux qui avaient survécu, on a constaté que leur croissance en hauteur et en diamètre avait été réduite. Toutefois, 9 ans après le traitement, il a semblé que la croissance était redevenue normale et que les survivants grossiraient assez pour être récoltables. Les scarificateurs avaient causé des blessures à la fois aux tiges et aux racines, et il semble que les blessures des racines mères avaient contribué à réduire la croissance des drageons. Dans la plupart des cas, des taches internes et de la pourriture étaient apparues, et leur fréquence ainsi que leur ampleur chez les drageons individuels augmentaient progressivement avec le nombre et la gravité des blessures. Seules les tiges blessées ont été sujettes à la pourriture qui a affecté 4.1% du volume des arbres de 9 ans échantillonnés, soit 10 fois plus qu'il est normal chez les peupliers de cette catégorie d'âge. Chez les arbres malades dont la tige et les racines étaient blessées suite à la scarification, on a isolé plusieurs hyménomycétales qu'on ne trouve pas d'ordinaire chez les jeunes peupliers. On sait qu'un grand nombre de ces champignons sont cause d'une grave pourriture des racines, de la patte et de la tige chez l'arbre à maturité. Si on scarifie des peupliers de 3 ans, il y a donc danger que, lors de la récolte, les survivants soient de piètre qualité et que la pourriture de la tige et des racines soit grave et anormalement élevée.

## ACKNOWLEDGMENTS

The author gratefully acknowledges the cooperation of Mr. N.F. Lyon, Mr. J.A. Kemperman, and Mr. D.H. Weingartner of the Northern Forest Research Unit, Ontario Ministry of Natural Resources, Thunder Bay, Ontario in carrying out this study. He also wishes to thank Mr. W.A. Ingram and Mr. B.E. Smith for describing the sampled suckers and isolating microorganisms therefrom, and Mr. W.E. Britnell for identifying those microorganisms. The assistance of personnel of American Can of Canada Limited, on whose timber limits the work was carried out and who fed and housed the field crews, is also very much appreciated.

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# INTRODUCTION

In northern Ontario, cutovers supporting prolific regeneration of trembling aspen (*Populus tremuloides* Michx.) are frequently scarified and subsequently planted with conifers. The aspen is mostly of sucker origin from the root systems of harvested trees, and the treatment usually takes place when they are from 1 to 4 years old. Finned barrels and spiked anchor chains are generally used. The objectives are to reduce the amount of brush and slash, to hasten its deterioration, to expose mineral soil, and to kill or retard the growth of the aspen. The ultimate goal is to improve growth conditions for the establishment and development of the planted conifers.

Some suckers may be killed by the scarification equipment, but most survive after being pushed over or suffering stem wounds. This is particularly true in sucker stands scarified when older than one year. Hence, the aspen becomes an integral part of the next crop, either by itself or mixed with the introduced conifers, in spite of the scarification treatment.

The importance of aspen as a commercial tree species in northern Ontario appears to be increasing. Therefore, it is necessary to understand what effects, if any, scarification has on the surviving aspen suckers. Stem wounds have been associated with the initiation and development of internal decay in many tree species. Since some of the surviving suckers will one day be crop trees, scarification has been increasingly regarded as a possible threat to the quality of those trees.

It should be pointed out that scarification of established aspen sucker stands, carried out to control or kill the aspen and thereby benefit planted conifers, is considered quite different from scarification carried out with the aim of promoting aspen sucker development. The latter is usually carried out shortly after harvesting, either before or soon after sucker formation (Weingartner 1980). A similar study is currently under way on stands treated for this purpose, and will be the subject of another report.

In 1976 the Northern Forest Research Unit (NFRU) of the Ontario Ministry of Natural Resources (OMNR) initiated a study to assess the present and potential impact of scarification carried out 4 years earlier in a 3-year-old aspen sucker stand. Suckers were examined in late August of 1976 and 1978. The Great Lakes Forest Research Centre (GLFRC) of the Canadian Forestry Service cooperated in this study by describing and measuring both wounds and internal defects of the stems and root systems of the sampled suckers, by isolating and identifying microorganisms associated with these defects, and by calculating sucker stem volumes. This is a long-term study, with the third sampling scheduled for 1982. Results obtained from data collected in 1976 and

1978 by GLFRC are considered to be of sufficient interest and importance to warrant reporting at this time.

## MATERIALS AND METHODS

This study was located in the Terrace Bay District on the American Can of Canada Limited timber limits, approximately 70 km southeast of Longlac and 25 km north of Manitouwadge, Ontario. The study area is near the boundary between Ontario Site Regions 3E and 3W, and the soil is a deep lacustrine silt.

In the spring of 1970 a 110-year-old mixedwood stand on the area was clearcut. Aspen sucker regeneration occurred during the 1970 growing season. In September, 1972 the cutover was scarified with cement-filled flange barrels (340 kg/barrel) and spiked anchor chains pulled by a wheeled skidder. There was no residual stand cover. White spruce was planted in 1973.

In 1976, three 50 m x 50 m study blocks were established in the scarified cutover. Each block was divided into 25 cells, each 10 m x 10 m. Four cells in each block were randomly selected for sampling. The five most dominant aspen stems (potential crop trees) within each selected cell were chosen for sampling, for a total of 60 stems. In 1978, four cells were again randomly selected for sampling within each block, and the sampling method in each cell was repeated.

The desirability of sampling comparable, unscarified aspen suckers to serve as a control is obvious. Although parts of the cutover were missed by the scarification skidder, no missed area of sufficient size for the establishment of a 50 m x 50 m experimental block could be found. It was decided, instead, to set up a "control" block in an unscarified cutover 3 km distant that supported aspen sucker regeneration the same age and approximately the same density as that on the scarified cutover. Unfortunately, there was a site difference in that the unscarified area was on a relatively shallow till, with a scattered residual white birch (*Betula papyrifera* Marsh.) overstory. In 1976, 20 dominant suckers in four cells of this "control" block were sampled, according to the same method of selection as was described for the scarified blocks. Thus, in 1976 a total of 80 suckers were sampled, including 60 from the scarified cutover and 20 from the unscarified cutover.

At the time of the second sampling in 1978, it was decided to use as control trees 10 suckers in the scarified stand that were in a small pocket obviously missed by the scarification equipment. Thus, in 1978 a total of 70 suckers were sampled, including 60 in the scarified blocks and 10 in the same stand that had escaped scarification.

The suckers selected for sampling were excavated by severing the lateral roots with a sharp shovel between 25 and 30 cm from the base of the stem. They were transported in this condition to the field laboratory, where the total height was measured. All stem wounds were measured and recorded for height above ground, length, and maximum width between callus growth. Each stem was then cut at ground level and at 15 cm intervals up to a height of 120 cm, and at 30 cm intervals thereafter to within 80 cm of the top. At each cut, the diameter outside and inside bark was measured and recorded on logarithmic tree measurement forms, as were the diameters of any decays or stains present. Cut pieces were further dissected to determine the extent of defects that appeared at one end only. A planimeter was used on the tree measurement sheets to determine sucker outside-bark and inside-bark volumes, as well as the volumes of any stain and decay in each stem. Each decay and stain was described, and attempts were made to isolate microorganisms inhabiting and perhaps causing these defects by means of standard cultural procedures and 2% malt agar test-tube slants.

The root systems were brushed clean of soil and debris, the parent roots of each sucker were identified when possible, and all roots were cut approximately 25 cm from their points of origin. The diameters of the roots at these cuts were recorded except for roots free of stain or decay that were smaller than 10 mm in diameter; these were merely tallied as small roots. The extent of stain or decay on the cut surfaces was recorded, as were the type and location of externally visible wounds and the presence of internal defect at cuts made adjacent to the root collar. In this report the term *root collar* refers to the belowground portion of the stem, in which individual roots are externally indistinguishable. The root collars were cut longitudinally to expose stains and decays which were described and measured. Attempts were made to isolate microorganisms from all stains and decays encountered in the roots and root collars, by aseptically placing small bits of these tissues in test tubes containing 2% malt agar.

## STEM GROWTH

The inside-bark diameter 30 cm above the ground line at the end of the 1972, 1974, and 1976 growing seasons was measured for each of the aspen suckers sampled late in August, 1976. The average diameters of the 60 scarified suckers at these three periods, as well as those of the 20 suckers sampled in the unscarified stand, are shown in Figure 1. Since the suckers began growing in 1970 and were scarified at the end of the 1972 growing season, for the scarified suckers the three slopes in Figure 1 represent the average diameter growth rates during the 3 years prior to scarification, for the 2 years following scarification, and during the third and fourth years following scarification. At the end of the 1972 growing season, just prior to the scarification treatment, the average diameters of the suckers sampled in both scarified and unscarified stands were virtually identical. At the end of the 1974 growing season the average diameter of the suckers sampled in the unscarified stand indicates that these trees in 1973 and 1974 maintained the same average diameter growth rate as they had from 1970 to 1972. On the other hand, the scarified suckers had a reduced average diameter growth rate during the 2 years following scarification. Figure 1 shows that in 1975 and 1976 the diameter growth rate in the scarified suckers had almost resumed the "normal" rate exhibited from 1970 to 1972 prior to scarification. The diameter growth rate of the suckers sampled in the unscarified plot was virtually unchanged from 1970 through 1976. When sampled late in the 1976 growing season, the average inside-bark stem diameter 30 cm above the ground line was 2.72 cm for the scarified suckers in comparison with 3.18 cm for the unscarified suckers (Fig. 1).

The average heights and diameters of unscarified and of scarified aspen suckers sampled at 4 years and 6 years following scarification are compared in Table 1. These data indicate that the scarified suckers were significantly smaller than unscarified suckers, even when the scarified sucker stems bore no visible scarification wounds.

Table 1. Comparative size of dominant unscarified aspen stems, and scarified wound-free and wounded stems. Stand scarified when suckers were 3 years old.

| Avg age of suckers | Stand, or portion of stand | Visible stem scarification wounds | No. of suckers | Avg ht (m) | Avg DBH (cm) | Avg stem vol, inside bark ($dm^3$)[b] |
|---|---|---|---|---|---|---|
| 7 | unscarified[a] | N.A. | 20 | 4.0 | 2.9 | 1.71 |
| 7 | scarified | absent | 9 | 3.0 | 2.2 | 0.87* |
| 7 | scarified | present | 51 | 3.1 | 2.1 | 0.95** |
| 9 | unscarified | N.A. | 10 | 4.6 | 4.2 | 3.10 |
| 9 | scarified | absent | 19 | 3.7 | 2.8 | 1.30** |
| 9 | scarified | present | 41 | 3.6 | 2.7 | 1.27** |

[a]These 20 suckers were sampled in an unscarified stand roughly 2 km from the scarified stand used in this study. Both stands originated from 1970 spring harvesting operations.

[b]Differences between scarified and unscarified sucker volumes are significant at the p = 0.05 level (*), and p = 0.01 level (**), respectively (t test).
Differences between scarified wound-free and scarified wounded sucker volumes are not significant (t test).

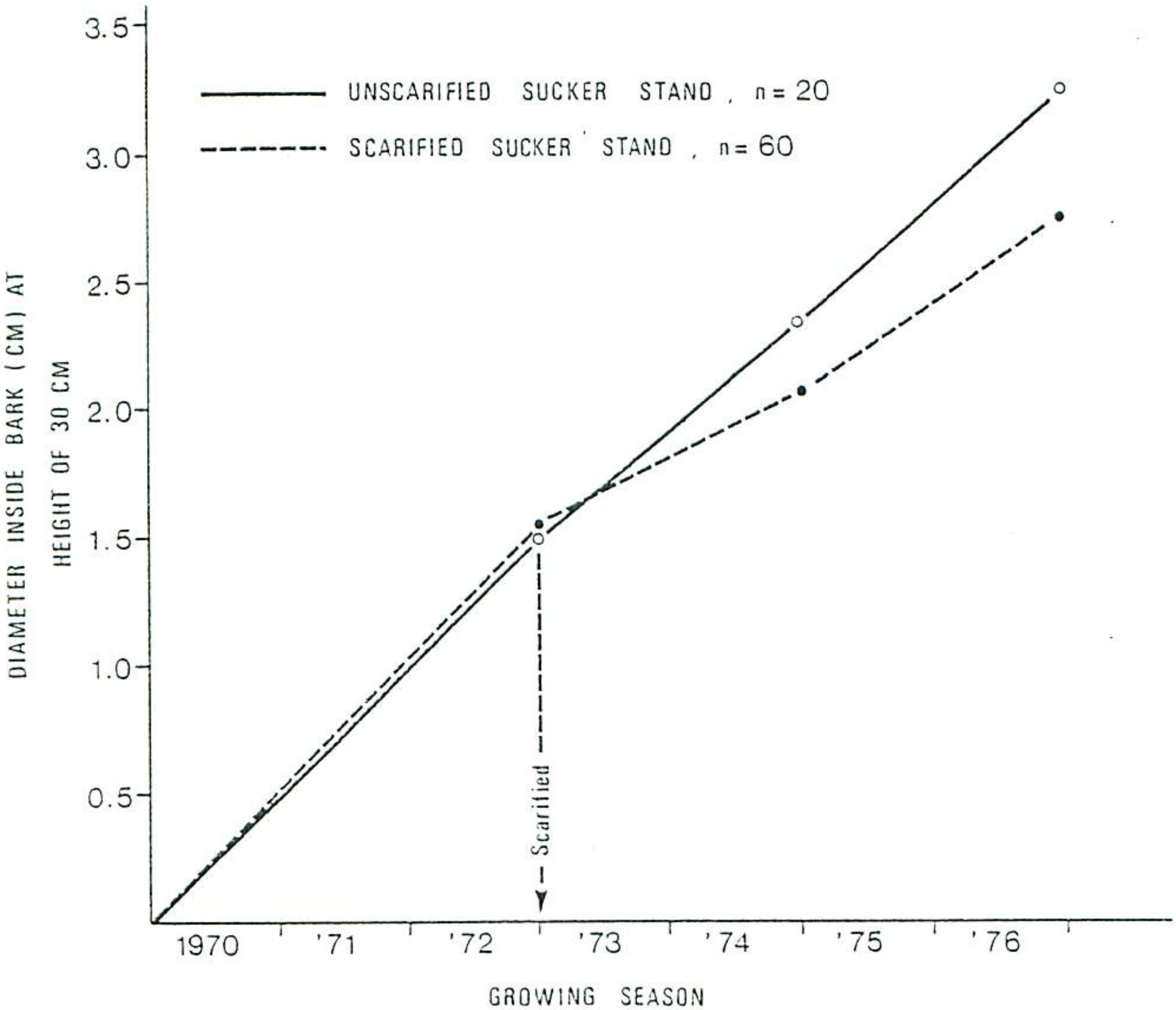



Figure 1. Effect of 1972 fall scarification on the diameter growth of surviving dominant and codominant aspen suckers by late summer 1976. Both sucker stands originated from aspen clear-cut harvesting carried out in the spring of 1970.

## STEM APPEARANCE AND QUALITY

*External*

In the region of northern Ontario studied, numerous observations suggest that codominant aspen sucker stems in most 3-year-old stands of cutover origin usually average approximately 2 m in height, with scattered dominant stems somewhat higher. In 1976, 4 years following scarification, the high density of the stand studied (7700 aspen stems per hectare) suggested that a very small proportion of trees had been killed by the treatment. Stems that are run over by the machinery may be severely bent as a result, but their resilience enables them to overcome this disturbance rapidly. Some branches and leaders may be broken off, but signs of such damage were rare 4 years later. The major forms of lasting stem damage to surviving aspen are wounds resulting from scrapes and pressure on the stem by scarification machinery, both of which either remove the bark and possibly the outer xylem, or leave the bark intact and kill the cambium and adjacent phloem (Fig. 2). By 1978, 6 years after scarification, evidence of such wounding could be seen on approximately 75% of the sucker stems in areas that had been scarified. Many of the wounds had by then callused over, but one or more wounds that were still open could be found on roughly half of the stems (Fig. 2).

*Internal*

When the occurrence of stain and decay in the stem wood of aspen suckers that had survived scarification was studied, it became evident that much of the stain and decay was associated with scarification wounds (Fig. 3), and that the extent of these defects was closely related to the severity of the wounds. Consequently, as a means of relating internal stem quality to external stem appearance, stems sampled both in 1976 and in 1978 were classified as having a) no visible scarification wounds, b) all wounds healed over, or c) one or more open wounds. The latter group was further subdivided into two groups, narrow-open and widest-open, based on the maximum width of the wounds.

The percentages of stem wood volume classified as stain (discolored, firm wood), incipient rot (slightly softened wood), and advanced rot for these four categories of suckers that survived scarification treatment are presented in Tables 2 and 3 for the 1976 and 1978 samples. These tables also include "control" suckers not subjected to scarification. The same data are shown graphically in Figures 4 and 5, in which the control suckers are combined with scarified suckers that had no visible stem scarification wounds.


Figure 2. Stem scarification wounds on surviving aspen, 6 years later. a) Moderate wound on aspen; nearby spruce was planted following scarification. b) Severe open wound.

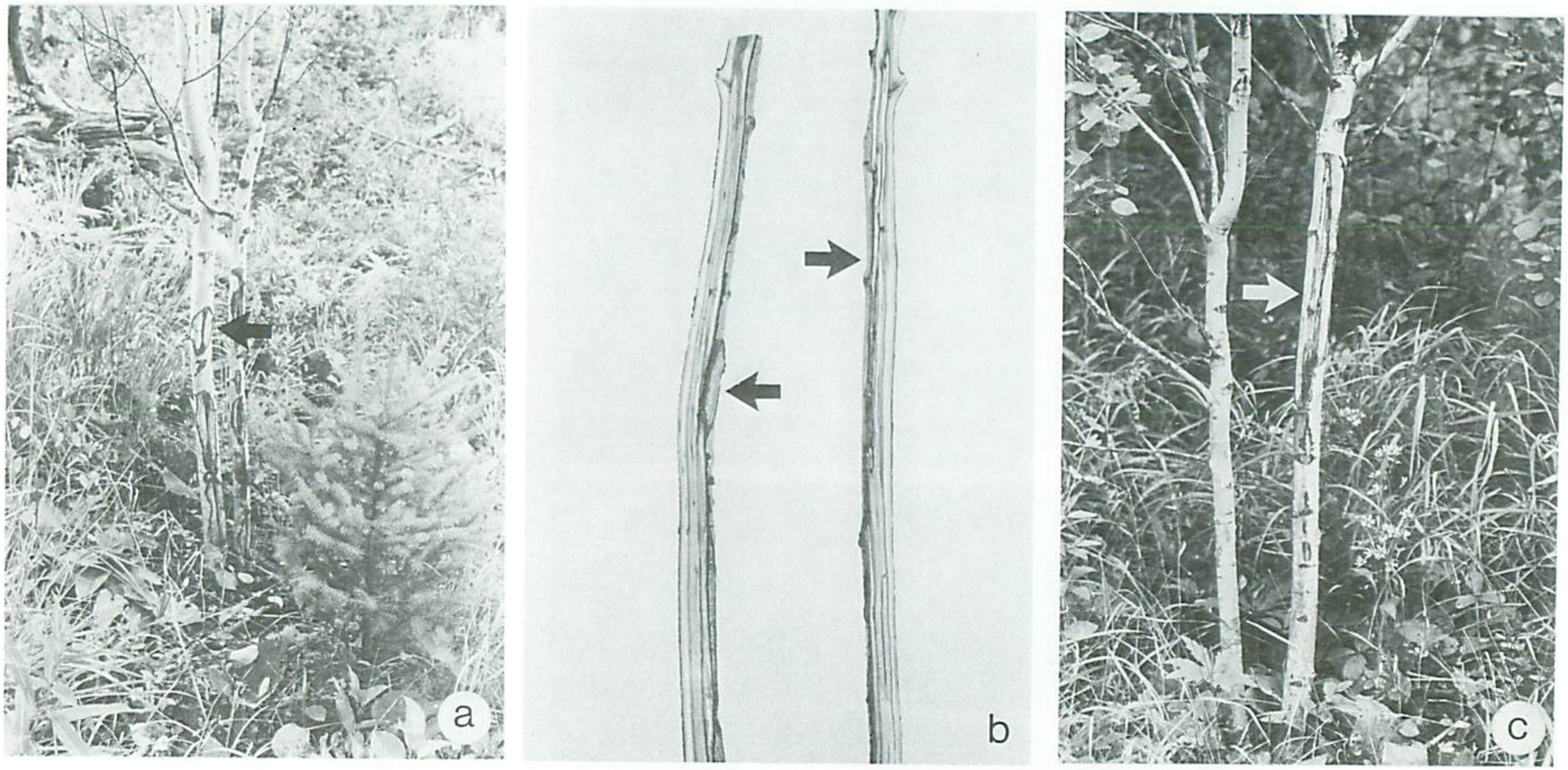



Figure 3. Rot and stain in stems of scarified suckers. a) and c) Stem wounds on surviving aspen suckers photographed in 1978, 6 years following scarification. b) Internal appearance of stems arrowed in a) and c), showing rot and stain associated with the scarification wounds.

Tables 2 and 3 and Figures 4 and 5 show clearly that the 7- and 9-year-old suckers, sampled 4 and 6 years after scarification, respectively, were progressively more defective with increasing severity of stem scarification wounds. In both years, wounded sucker stems were more defective, at a highly significant level, than unwounded stems (Tables 2 and 3). The unscarified control suckers had appreciably less defect, on a volume percentage basis, than the least defective category of scarified suckers, those showing no visible stem wounds (Tables 2 and 3). All categories of scarified suckers had slightly lower percentages of defective stem wood in 1978 than in 1976; however, the occurrence of advanced rot was approximately 60% greater in the 9-year-old suckers than in the 7-year-old suckers.

Some stained wood was found in the stems of all 150 aspen suckers sampled in this study. When only the scarified suckers were considered, incipient or advanced rot was found in 56.7% of the 1976 sampled stems whereas 2 years later this had increased to 70%. Advanced rot was present in 46.7% of all scarified sucker stems. However, advanced rot was almost always found in the stems of the widest-open wound category, in 13 of 15 such stems sampled in 1976 (86.7%) and in all of the 13 stems so classified in 1978. Tables 2 and 3 show that significantly more advanced rot occurred in stems with open wounds than in stems with callused-over wounds.

## ROOT APPEARANCE AND QUALITY

The root systems of the 7- and 9-year-old aspen suckers had the same general structure as those described in an earlier report dealing with aspen suckers that survived herbicide spray treatment (Basham 1982). Again, the distal root was always larger than the proximal parent root. An average of two new roots with diameters of 10 mm or more, and five new roots with diameters less than 10 mm at cuts made approximately 25 cm from their points of origin, were associated with each aspen sucker, in addition to the two parent roots.

### *Root-boring Insects*

As in the case of the herbicide spray study, large tunnels, 8 to 10 mm in diameter, were frequently found in the root systems of the aspen suckers examined in this study (Table 4). These were caused by larvae of the ghost moth *Sthenopis quadriguttatus* Grote (Fig. 6), which, when full grown, are about 7.5 cm long and 8 mm in diameter. They were found most commonly in the distal parent root, probably because this was usually the largest diameter root in individual suckers. Tunnels were sometimes found in the root collar, the below-ground portion of the stem to which parent and new roots were attached. Table 4 shows that the

Table 2. The occurrence of stain and rot in the stems of 60 dominant 7-year-old aspen suckers in a stand 4 years after scarification, and in 20 dominant suckers of the same age in a nearby unscarified stand.

| Stand | Stem scarification wounds | Condition of wounds | No. of suckers | Avg sucker vol, inside bark ($dm^3$) | % of inside-bark stem volume | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Stain | Incipient rot | Advanced rot[a] | Total defect[b] |
| Unscarified | absent | N.A. | 20 | 1.71 | 6.4 | trace | - | 6.4 |
| Scarified | absent | N.A. | 9 | 0.87 | 17.2 | trace | - | 17.2 |
| Scarified | present | callused over | 22 | 0.87 | 23.7 | 0.9 | trace | 24.6 |
| Scarified | present | open, $< 0.75$ cm | 14 | 1.04 | 22.6 | 7.3 | 0.6 | 30.5 |
| Scarified | present | open, $\geqslant 0.75$ cm | 15 | 0.99 | 26.5 | 4.8 | 2.6 | 33.9 |

[a]Differences between scarified suckers with callused-over wounds and scarified suckers with open wounds are significant at the $p = 0.001$ level (t test).

[b]Differences between unscarified suckers and scarified *wound-free* suckers are significant at the $p = 0.05$ level. Differences between unscarified plus scarified *wound-free* suckers and scarified *wounded* suckers are significant at the $p = 0.0001$ level (t test).

Table 3. The occurrence of stain and rot in the stems of 70 dominant 9-year-old aspen suckers in a stand 6 years after stand scarification, including 10 suckers in a patch bypassed by the scarification machinery.

| Portion of stand | Stem scarification wounds | Condition of wounds | No. of suckers | Avg sucker vol, inside bark ($dm^3$) | % of inside-bark stem volume | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Stain | Incipient rot | Advanced rot[a] | Total defect[b] |
| Unscarified | absent | N.A. | 10 | 3.10 | 10.2 | trace | – | 10.2 |
| Scarified | absent | N.A. | 19 | 1.30 | 14.0 | trace | – | 14.0 |
| Scarified | present | callused over | 16 | 1.33 | 17.9 | 0.4 | trace | 18.3 |
| Scarified | present | open, $< 0.25$ cm | 12 | 1.38 | 19.9 | 1.4 | 1.0 | 22.3 |
| Scarified | present | open, $\geq 0.25$ cm | 13 | 1.10 | 27.1 | 2.2 | 4.1 | 33.4 |

[a]Differences between scarified suckers with callused-over wounds and scarified suckers with open wounds are significant at the $p = 0.01$ level (t test).

[b]Differences between unscarified suckers and scarified *wound-free* suckers are not significant. However, differences between unscarified plus scarified *wound-free* suckers and scarified *wounded* suckers are significant at the $p = 0.0001$ level (t test).

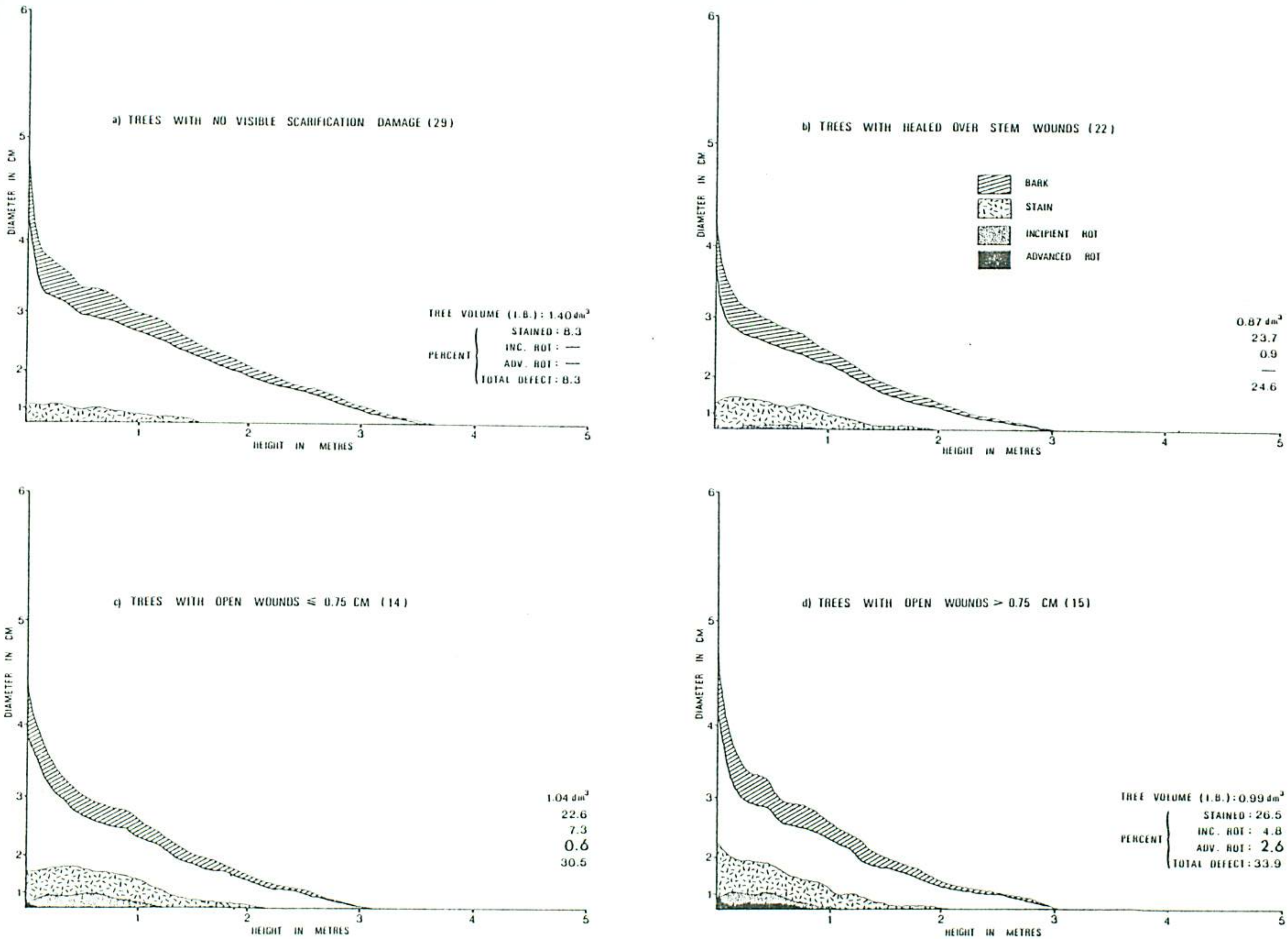



Figure 4. Tree, stain and rot volumes in surviving 7-year-old aspen, 4 years after scarification. Graph a includes 20 control trees.

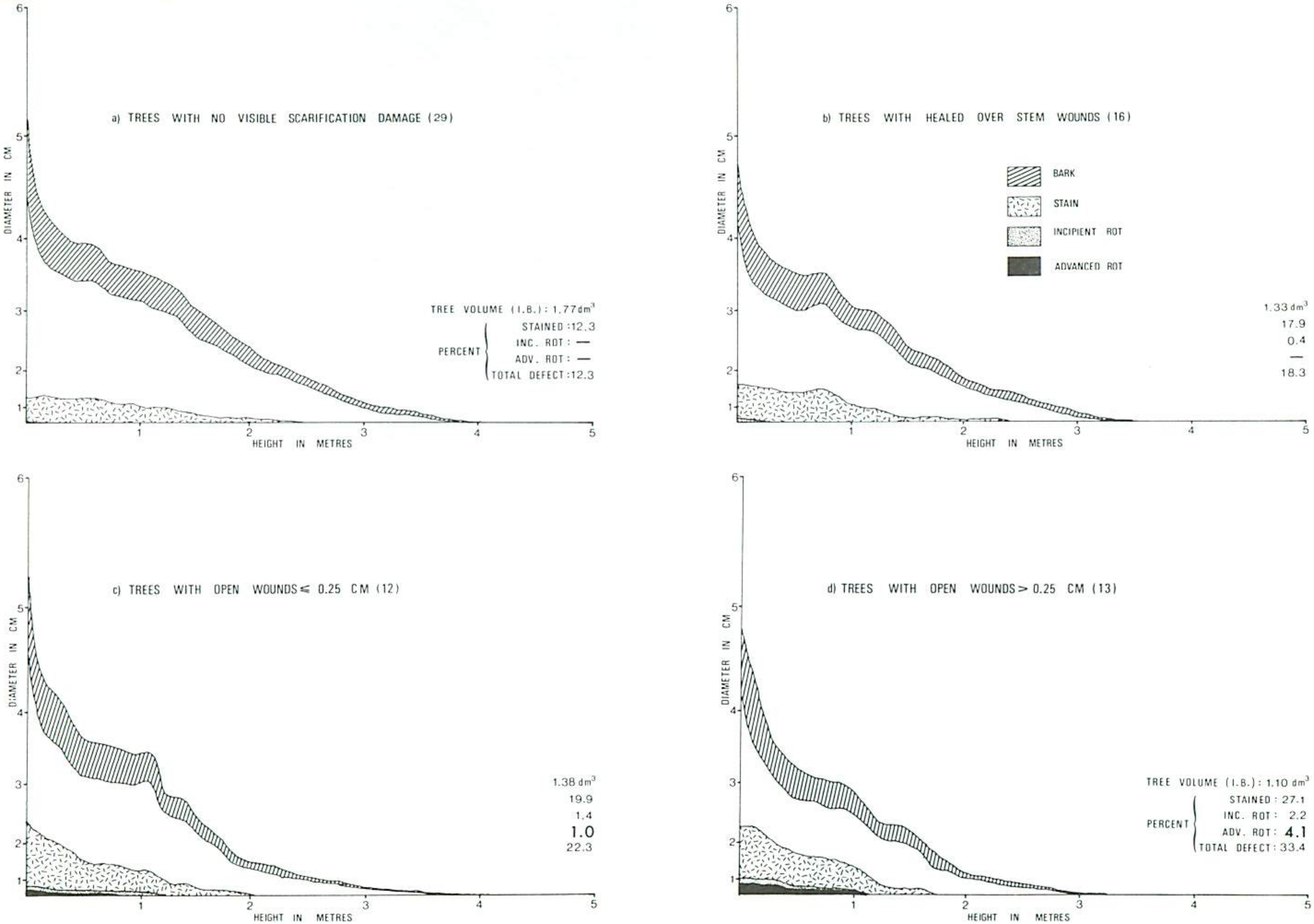
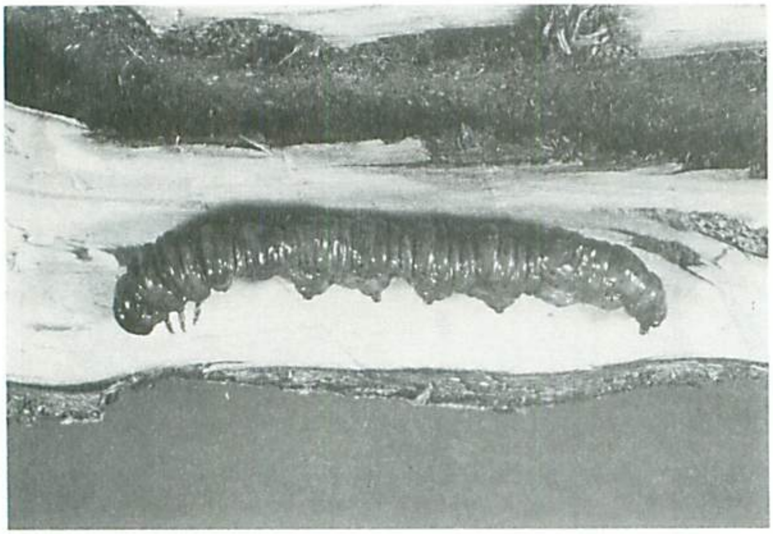
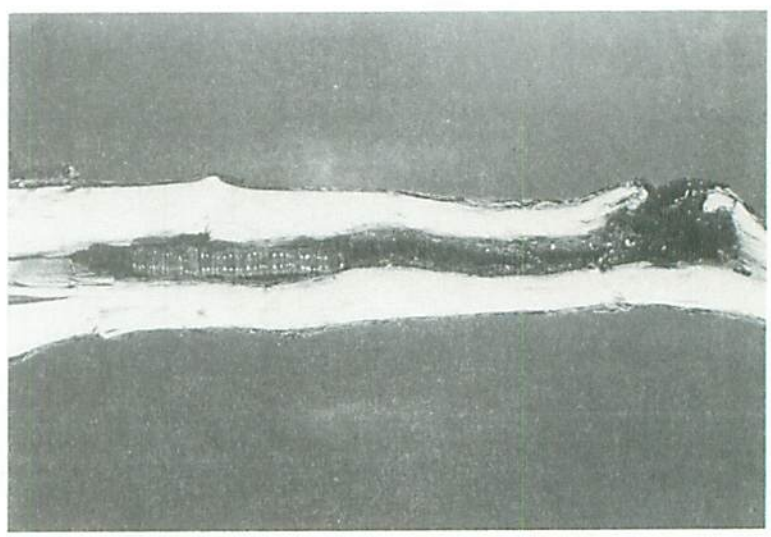



Figure 5. Tree, stain and rot volumes in surviving 9-year-old aspen, 6 years after scarification. Graph a includes 10 control trees.



Larva removed from aspen root. Photograph life-size



Larva and resulting tunnel in parent root of a dominant aspen that survived scarification. Ventilation hole is at right.
Photograph 1/2 life-size.

Figure 6. Root borer of aspen, *Sthenopis quadriguttatus*.

Table 4. The occurrence of *Sthenopis* larval tunnels in the root systems of scarified and unscarified dominant aspen suckers.

| | | | | Number of suckers with larval tunnels | | | |
|---|---|---|---|---|---|---|---|
| | | | | In parent roots | | | |
| Suckers subjected to scarification | Block no. | Year sampled | No. of suckers | Distal (large) root | Proximal (small) root | In root collar tissue | In entire root system |
| Yes | 2 | 1976 | 20 | 10 | 2 | 2 | 13 |
| " | 3 | " | 20 | 4 | 6 | 3 | 8 |
| " | 4 | " | 20 | 6 | 3 | 4 | 9 |
| Yes | 2 | 1978 | 20 | 3 | 4 | 2 | 9 |
| " | 3 | " | 20 | 5 | 3 | 1 | 7 |
| " | 4 | " | 20 | 6 | 1 | 1 | 10 |
| Yes | All | Totals: | 120 | 34 | 19 | 13 | 56 |
| " | " | Percent: | (100.0) | (28.3) | (15.8) | (10.8) | (46.7) |
| No | 1[a] | 1976 | 20 | 3 | 2 | 1 | 6 |
| " | _[b] | 1978 | 10 | 1 | 2 | 1 | 5 |
| No | All | Totals: | 30 | 4 | 4 | 2 | 11 |
| " | " | Percent: | (100.0) | (13.3) | (13.3) | (6.7) | (36.7) |

[a]Block located in a nearby unscarified sucker stand the same age as the scarified stand.

[b]In 1978, 10 suckers in the scarified stand in a patch bypassed by the scarification machinery were sampled.

root systems of 46.7% of the 120 scarified suckers had been tunnelled at the time of sampling, in comparison with 36.7% of the 30 unscarified suckers.

*Decay and Stain*

Only 2.5% of the root collar regions examined in scarified suckers, and 10% of those examined in unscarified suckers, were completely free of defect (stain or decay) (Table 5). Most of this defect could be traced to two sources, dead "companion" stems or scarification wounds at or near the collar. Although other wound types or points of entry were present, much of the remaining defect was associated with the parent roots where they formed part of the root collar. Defects extending down from the stem were rare. Of the sampled scarified suckers, 71.7% had externally visible possible sources of defect on or near the root collars, and decay was present in collar tissue of 63.3% of them. The unscarified suckers had 63.3% with visible defect sources, almost all dead "companion" stems, and 50% of these root collars had some decay.

Table 5 shows that the roots of scarified suckers were also more defective than roots of unscarified suckers. Externally visible possible sources of defect, mostly wounds, were present on 32.7% of the roots of scarified suckers, and 42.9% of those roots were defective. Unscarified suckers had fewer (26.0%) of their roots with visible defect sources, and only 32.8% of those roots were defective. Scarification wounds were the most frequently observed source of defect in the roots of scarified suckers (Fig. 7), followed by stone abrasions and *Sthenopis* ventilation holes. Stone abrasions were the most common entry points for defect in the roots of unscarified suckers; they are caused by wind repeatedly causing a root surface area to rub against a stone.

Parent roots were considerably more defective than new roots (Table 5). Whereas 66.5% of the parent roots of scarified suckers and 55.1% of the parent roots of unscarified suckers were defective, for new roots these percentages dropped to 20.6 and 14.1, respectively. Table 5 also shows that for all of the sampled suckers, defect was three to four times more common in the parent roots than in the new roots. Furthermore, the relatively large distal parent root was somewhat more likely to be defective than the smaller proximal root.

Table 5. The occurrence of defect (stain and decay) in the root systems of scarified and unscarified dominant aspen suckers.

| | | | Number of aspen sucker roots | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Parent roots | | | | | | | |
| | | | Distal (large) | | Proximal (small) | | New roots[a] | | All roots | |
| Suckers subjected to scarification | Block no., no. of suckers | Defect present in root collars | Total no. | No. defective | Total no. | No. defective | Total no. | No. defective | Total no. | No. defective |
| Yes, 1976 sampling | 2, 20 | 19 | 20 | 17 | 19[b] | 12 | 23 | 7 | 62 | 36 |
| | 3, 20 | 20 | 20 | 14 | 20 | 17 | 37 | 6 | 77 | 37 |
| | 4, 20 | 20 | 20 | 9 | 20 | 6 | 37 | 8 | 77 | 23 |
| Yes, 1978 sampling | 2, 20 | 20 | 20 | 13 | 20 | 13 | 40 | 11 | 80 | 37 |
| | 3, 20 | 19 | 20 | 16 | 20 | 14 | 62 | 8 | 102 | 38 |
| | 4, 20 | 19 | 20 | 14 | 20 | 14 | 54 | 12 | 94 | 40 |
| Yes | All,120 | 117 | 120 | 83 | 119 | 76 | 253 | 52 | 492 | 211 |
| | Percent: (100.0) | (97.5) | | (69.2) | | (63.9) | | (20.6) | | (42.9) |
| No, 1976 | 1, 20 | 20 | 20 | 10 | 20 | 10 | 56 | 7 | 96 | 27 |
| No, 1978 | -, 10 | 7 | 10 | 7 | 10 | 6 | 15 | 3 | 35 | 16 |
| No | All, 30 | 27 | 30 | 17 | 30 | 16 | 71 | 10 | 131 | 43 |
| | Percent: (100.0) | (90.0) | | (56.7) | | (53.3) | | (14.1) | | (32.8) |

[a]Includes only roots 10 mm or more in diameter, 20 cm from the root collar.
[b]In one sucker the proximal parent root could not be identified with certainty.

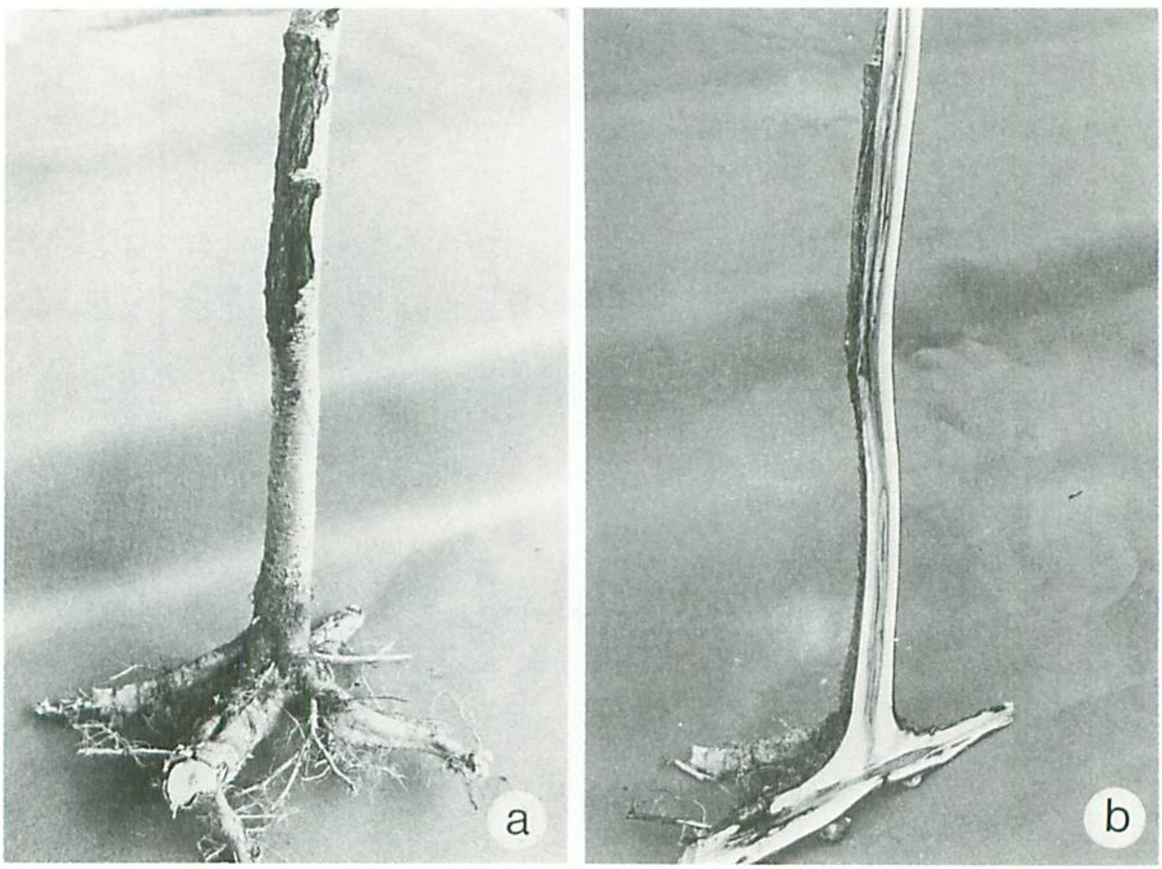



Figure 7. Severely wounded 12-year-old codominant aspen sucker photographed in 1981, 9 years following scarification. a) Stem and root wounds caused by scarification machinery. b) Cross section, showing stem rot from which *Peniophora cinerea* was isolated, and root rot from which *Armillaria mellea* was isolated.

## MICROORGANISMS ASSOCIATED WITH INTERNAL DEFECTS

### *Stems*

Table 6 shows the identity and frequency of occurrence of microorganisms isolated from defective stem wood in the 120 scarified and 30 unscarified aspen suckers examined during the 1976 and 1978 growing seasons. The percentage of isolation attempts that yielded no microorganisms, suggesting that the stem tissue was sterile, was 72.4 in the unscarified suckers in comparison with only 34.3 in the scarified stems.

Bacteria accounted for 9.4% of the isolation attempts from unscarified suckers, and were isolated far more frequently than any other single microorganism. Only two hymenomycetes were isolated from the unscarified sucker stems, *Peniophora polygonia* (Pers. ex. Fr.) Bourd. & Galz. (1.4%) and *Armillaria mellea* (Vahl ex Fr.) Kummer (0.4%).

The stems of scarified suckers yielded 10 hymenomycetes, including the two isolated from unscarified stems. Hymenomycetes accounted for 13.7% of all isolations from scarified stems, and one of them, *Polyporus zonatus* Fr., was second only to bacteria in frequency of isolation (Table 6). Unidentified fungi and miscellaneous identified fungi, i.e., fungi that occurred very infrequently, were much more common in scarified than in unscarified stems.

### *Roots*

The occurrence of microorganisms in defective wood in the roots and root collars of all 150 aspen suckers sampled in this study is presented in Table 7. By far the most common fungus was the ascomycete *Phialophora alba* van Beyma, which was also the fungus most frequently isolated from defective wood associated with root scarification wounds. *Armillaria mellea* was isolated about half as frequently as *P. alba*. It, also, was often associated with scarification wounds (Fig. 7), as well as with stone abrasions and dead roots. The only other commonly occurring microorganism, *Verticillium* sp., was the fungus most frequently isolated from defective root wood associated with *Sthenopis* borer activity.

The last column in Table 7 shows the percentage of all isolations of each organism that were obtained from root systems of the scarified suckers. Since 120 of the 150 sampled suckers, or 80%, were scarified, bacteria, with exactly 80% of isolations from scarified suckers, obviously occurred with equal frequency in scarified and unscarified suckers. Organisms that were isolated more frequently per scarified than per unscarified sucker had percentages in column 7 higher than 80. This was the case for *P. alba* (94.2%) and *A. mellea* (91.5%), the two most common fungi in the root systems of all 150 suckers. It

Table 6. The occurrence of microorganisms in defective stem wood of scarified and unscarified 7- and 9-year-old aspen suckers.

| Microorganisms or sterile | Percentage of isolation attempts | | | | | |
|---|---|---|---|---|---|---|
| | Unscarified suckers | | | Scarified suckers | | |
| | 1976[a] | 1978[b] | Both years | 1976[c] | 1978[d] | Both years |
| Sterile, no growth | 77.6 | 51.7 | 72.4 | 36.8 | 29.2 | 34.3 |
| Bacteria | 5.3 | 25.9 | 9.4 | 4.0 | 19.0 | 8.9 |
| *Polyporus zonatus* | | | | 5.5 | 7.5 | 6.2 |
| *Cytospora* sp. | 0.9 | | 0.7 | 6.4 | 2.7 | 5.2 |
| *Phialophora alba* | | 3.4 | 0.7 | 3.3 | 2.3 | 2.9 |
| *Peniophora polygonia* | | 6.9 | 1.4 | 2.9 | 2.1 | 2.6 |
| Yeasts | 2.2 | 3.4 | 2.4 | 3.2 | 1.7 | 2.2 |
| *Coryne sarcoides* | 2.6 | | 2.1 | 1.1 | 2.9 | 2.6 |
| *Collybia velutipes* | | | | 0.5 | 1.9 | 1.0 |
| *Gloeocystidiellum karstenii* | | | | 1.3 | | 0.9 |
| *Peniophora cinerea* | | | | 1.1 | | 0.8 |
| *Corticium laeve* | | | | 0.9 | | 0.6 |
| *Phlebia strigoso-zonata* | | | | 0.3 | 0.8 | 0.5 |
| *Trechispora brinkmanni* | | | | 0.7 | | 0.5 |
| *Radulum casearium* | | | | 0.5 | | 0.3 |
| *Armillaria mellea* | 0.4 | | 0.4 | 0.3 | 0.4 | 0.3 |
| Miscellaneous fungi | | | | 3.2 | 4.2 | 3.6 |
| Unidentified fungi | 11.0 | 8.6 | 10.5 | 28.3 | 24.6 | 27.1 |

[a]228 isolation attempts were made, from 20 stems.
[b]58 isolation attempts were made, from 10 stems.
[c]981 isolation attempts were made, from 60 stems.
[d]480 isolation attempts were made, from 60 stems.

Table 7. The occurrence of microorganisms, and their association with probable points of entry, in defective wood of root systems of scarified and unscarified suckers.

| Microorganisms or sterile | Scarification wounds (91) | Stone abrasions (68) | *Sthenopis* ventilation holes (67), or tunnels | Dead "companion" sucker stems | Entirely or partially dead roots (25) | Dead root branchlets (24) | Bark seams of unknown origin (23) | Wounds of uncertain origin (12) | No obvious, visible point of entry | Total occurrences in all 150 sampled suckers | Total occurrences in the 120 *scarified* suckers | Percentage of total occurrences in the 120 (80%) suckers that were scarified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Phialophora alba* | 37 | 15 | 16 | 20 | 8 | 5 | 3 | 1 | 15 | 120 | 113 | 94.2 |
| *Armillaria mellea* | 25 | 17 | 1 | | 7 | 1 | | | 8 | 59 | 48 | 91.5 |
| *Verticillium* sp. | 8 | 5 | 19 | 1 | 2 | 2 | 1 | 2 | 3 | 43 | 36 | 74.4 |
| *Trichoderma viride* | 3 | 2 | 2 | | | | 4 | 1 | 1 | 13 | 9 | 69.2 |
| *Polyporus zonatus* | 3 | 1 | 1 | 3 | 2 | | | | 3 | 12 | 12 | 100.0 |
| *Ascocoryne* sp. | 3 | 1 | | 5 | 1 | | 1 | | | 11 | 9 | 81.8 |
| *Pachybasium hamatum* | 1 | 3 | 1 | 1 | | 2 | | | 3 | 11 | 8 | 72.7 |
| *Coprinus micaceus* | 3 | 3 | 1 | | | 1 | | | | 8 | 8 | 100.0 |
| *Collybia velutipes* | 3 | 2 | | 1 | | | | | 1 | 7 | 7 | 100.0 |
| Miscellaneous fungi | 2 | 1 | 3 | 4 | | 4 | 1 | | | 15 | 13 | 86.7 |
| Unidentified fungi | 17 | 15 | 42 | 12 | 1 | 10 | 10 | 4 | 23 | 134 | 104 | 77.6 |
| Actinomycetes | 1 | | | 1 | | | 1 | | 1 | 4 | 4 | 100.0 |
| Bacteria | 9 | 3 | 24 | 10 | | 4 | 5 | 1 | 34 | 90 | 72 | 80.0 |
| Sterile, no growth | | 2 | | 1 | | | | 1 | 12 | 16 | 12 | 75.0 |

[a] Isolation attempts were not made from wood adjacent to all probable entry points, e.g., dead missing roots, or those with no associated defective wood.

should be noted that isolations of three hymenomycetes, *Polyporus zonatus*, *Coprinus micaceus* (Bull. ex Fr.) Fr., and *Collybia velutipes* (Curt. ex Fr.) Kummer, were obtained only from the root systems of scarified suckers.

## DISCUSSION AND CONCLUSIONS

The first obvious, visible effect of scarifying 3-year-old aspen suckers, when the suckers were inspected 4 to 6 years later, was a marked reduction in growth rate. Four years after scarification, scarified suckers averaged 75% of both the height and diameter of 7-year-old unscarified suckers; when 9 years old, the scarified suckers averaged 80% of the height but only 65% of the diameter of the unscarified trees (Table 1). This table also shows that differences in average stem volumes between scarified and unscarified suckers are highly significant. These results are not surprising, when we consider the damage the scarification machinery inflicts on stems of the young suckers, including broken tops, flattening, scraping and gouging. Furthermore, 3-year-old aspen suckers are almost completely dependent upon residual root systems of the previous stand for growth, and are highly dependent on them for water and nutrient absorption (Zahner and DeByle 1965). The high incidence of wounds, caused by scarification machinery, on the parent roots observed on the aspen sampled in this study, including suckers with no apparent stem wounds, is suspected of having a detrimental effect on sucker growth. This is borne out by the fact that scarified suckers with no visible evidence of stem wounds had growth reductions of approximately the same magnitude as those of the suckers that bore evidence of severe stem wounding, and were significantly smaller than unscarified suckers of the same age (Table 1).

Recent studies on young aspen suckers in northern Ontario have revealed that stained (discolored) wood develops in almost all stems at a very early age (Smith 1973, Kemperman *et al.* 1976, Basham 1982). These stains appear as zones, usually limited in extent, associated with dead branches, and as columns extending down from tops killed by numerous agents, including shoot blight (*Venturia macularis* [Fr.] Mull. & Arx), frost damage, and insects. Unscarified suckers sampled in 1976 had an average of 6.4% of stem volume stained. Scarified wound-free suckers had 17.2% of their stem volume stained, a difference that was probably significant (Table 2). However, in 1978 the difference in average percentage of stem volume stained, 10.2% in unscarified and 14.0% in scarified wound-free suckers, was not significant (Table 3). It should be remembered that in 1976 the unscarified suckers were in a stand 3 km away, and the pronounced difference in stem stain occurrence might have been related to site or other stand factors. The absence of a significant difference in 1978, when all suckers were sampled from the same stand, suggests that whereas scarification may have reduced sucker growth rate by root wounding, stems that suffered virtually no wounding showed little if any increase in the occurrence of stain. It is evident from Tables 2 and 3 that significantly more stain occurred in sucker stems that were badly wounded by the scarification machinery.

Each of the three categories of stem-wounded, scarified suckers had slightly lower percentages of defective stem wood in 1978 than in 1976, as did the unwounded scarified trees (Tables 2 and 3). This very likely reflects the increase in the average sucker growth rate in that 2-year period (Fig. 3), which enabled the suckers to grow somewhat faster than the rate of spread of defective wood in the same period.

Some idea of the stem damage inflicted on the 3-year-old suckers in 1972 by the scarification operation could be gained by visual inspection of the survivors in 1981, when over two-thirds of the now 12-year-old trees had pronounced wound scars between ground level and 2 m. The critical effect of these scarification stem wounds on internal stem quality is apparent in both the 1976 and 1978 samples, where differences in percentage of stem volume occupied by stain or rot between unwounded and wounded suckers of the same age were very highly significant, at the $p = 0.0001$ level. In both samples, the occurrence of internal stem defect increased progressively with increasing wound-severity classification (Tables 2 and 3). On the basis of the percentage of stem volume affected, suckers in the widest-open wound category had the highest incidence of defect, approximately twice as much as scarified suckers with no visible stem wounds, and three to five times as much defect as unscarified suckers.

Advanced, soft stem rot was found only in suckers that bore evidence of scarification wound on their stems. Incipient rot was present in a few unscarified or unwounded scarified sucker stems, but only in trace amounts. In the narrow-open wound category, advanced rot accounted for 0.6 and 1.0% of the stem volume in 1976 and 1978, respectively. In the widest-open wound category, these percentages were 2.6 and 4.1, respectively. In other studies of the quality of unscarified, and generally undisturbed, aspen suckers of this age class, advanced rot accounted for less than 0.5% of the stem volume (Basham and Navratil 1975, Kemperman *et al.* 1976, Basham 1982). Advanced rot zones occurred in stem wood adjacent to scarification wounds, except for occasional trace amounts associated with dead branch stubs or killed leaders. Clearly, scarification wounds inflicted on 3-year-old aspen suckers are responsible for the occurrence of abnormally high levels of stem rot in surviving trees 4 to 6 years later.

Root systems of young aspen suckers established on cutovers are generally far more defective than the stems (Basham and Navratil 1975, Basham 1982). This appears to be due in large part to the clonal growth habit of aspen and the high proportion of the suckers' root systems accounted for by the old parent roots which are frequently defective. Parent root defect, in turn, can extend into sucker root collar tissue and into new roots. The parent roots are sometimes invaded by *Sthenopis quadriguttatus* larvae, which occasionally extend into the root collars, leaving relatively large hollow tunnels surrounded by stained wood. Hence, it is not surprising that the root systems of the 30 sampled unscarified suckers, particularly the parent roots and root collars, were quite defective (Table 5).

Root systems of the sampled scarified suckers were somewhat more defective than those of the unscarified suckers (Tables 4 and 5). As in the case of herbicide spray-damaged suckers (Basham 1982), the higher incidence of *Sthenopis* activity in the scarified sucker root systems than in the controls is of insufficient statistical significance for us to conclude that scarification renders aspen suckers more susceptible to root borer invasion. The higher incidence of stain and rot in the root systems of the scarified suckers can be attributed to root and root collar wounds caused by the scarification operation. Such wounds, detected in 24% of the parent roots and 20% of the root collars, have little effect on root system defectiveness if they occur in roots or collar tissue that already were quite defective prior to scarification. However, in roughly half of the cases, scarification wounds occurred where there appeared to have been very little or no previous defect. The majority of these wounds resulted in extensive defect, usually including considerable advanced rot.

Of the three fungi most frequently isolated from the root systems of scarified trees, only one, the hymenomycete *Armillaria mellea*, is considered a potential threat to the quality of these trees as they mature to crop size. The others, *Phialophora alba* and *Verticillium* sp., are ascomycetes frequently associated with stained aspen wood, probably as secondary colonizers. However, *A. mellea* causes butt and root rot in mature aspen in Ontario. Recent studies on young aspen suckers and trees have revealed that it is by far the most common cause of rot in the root systems (Basham and Navratil 1975, Basham 1982, Basham unpublished data). *A. mellea* can invade root wounds (Shigo and Tippett 1981), and it was frequently isolated from rot adjacent to scarification wounds in this study (Fig. 7); this appears to account for its more frequent occurrence in scarified than in unscarified suckers. Three other hymenomycetes that cause rot problems in mature aspen were isolated from sucker root systems in this study. They occurred only in the scarified suckers, frequently from scarification wound regions. Two of them, *Coprinus micaceus* and *Collybia velutipes*, cause serious butt and root rot problems, and the third, *Polyporus zonatus*, is associated with stem rot. All three occur in mature aspen. Of these three fungi only one, *C. micaceus*, has previously been isolated from aspen sucker root systems, and then only very infrequently (Basham 1982). Hence, it would appear that scarifying young aspen suckers can greatly increase the risk that their root systems will be invaded by harmful, rot-causing hymenomycetes which could be a serious problem when they reach crop tree size.

Hymenomycete fungi that are known to cause serious rot problems in mature aspen were also found in the stems of suckers sampled in this study. Isolations of the following nine such hymenomycetes were limited to the stems of the scarified suckers: *Radulum casearium* (Morg.) Lloyd, second only to *Fomes igniarius* (L. ex Fr.) Kickx as the cause of stem decay in living mature aspen in Ontario (Basham and Morawski 1964), *C. velutipes*, *Peniophora cinerea* (Pers.) Cke., *Corticium laeve* Pers. ex Fr., *Polyporus zonatus*, *Gloeocystidiellum karstenii* (Bourd. & Galz.) Donk, *Phlebia strigoso-zonata* (Schw.) Lloyd, and *Trechispora brinkmanni* (Bres.) Rogers & Jacks. One other, *Armillaria mellea*, was isolated from the stems of both scarified and unscarified suckers. *Peniophora polygonia* was the only other hymenomycete isolated from sucker stems in this study, but unlike the 10 listed above, it is not associated with advanced rot in mature aspen, only with stain or occasionally incipient rot. The occurrence of these 10 hymenomycetes with rot-causing capabilities in 7- to 9-year-old aspen sucker stems that survived scarification, their occurrence in tissue adjacent to scarification wounds, and the failure to isolate most of them from unscarified aspen sucker stems in this and in other studies, constitute an obvious warning that serious, abnormally high levels of stem rot are possible in crop-size aspen that survive early scarification treatment.

In summary, most 3-year-old aspen appear capable of surviving scarification operations, although height and diameter growth rates are temporarily affected for 2 years at least. Observations 9 years following scarification suggest that most survivors had resumed good growth rates, and their dominance over the spruce planted subsequent to scarification suggests that the aspen will form an integral part of the next crop, either by themselves or mixed with the planted spruce. Evidence of light to severe wounding caused by the scarification machinery to the root systems and stems of the survivors was still present 9 years later. Rot in young, undisturbed aspen sucker stems as a rule is infrequent and present only in trace amounts; however, extensive zones of rot were frequently associated with scarification wounds, particularly those that were the most severe. The extent of stem rot and stain in surviving aspen suckers was closely related to the horizontal distance between calluses (width) of stem scarification wounds. Root scarification wounds also increased the amount of rot and stain present in the wood of the root systems of scarified suckers. Several hymenomycetes that are known to cause butt rot or stem rot problems in mature aspen were isolated from scarified suckers, usually from rot pockets adjacent to scarification wounds. The majority of these hymenomycetes are not normally isolated from 7- to 9-year-old aspen suckers, which was the age class sampled in this study. Clearly, scarifying 3-year-old aspen suckers introduces a very real risk that the survivors will form crop trees of well below average quality because of extensive butt and stem rot.

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