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# Aspen Sucker Damage and Defect in Colorado Clearcut Areas

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## Management Implications

Substantial acreages of aspen in the Rocky Mountains are being regenerated by clearcutting; however, there is little information on the quality of suckers that reestablish in these areas. Whether the new stands will be more or less defective than their predecessors is unknown.

Young stands of suckers are susceptible to natural catastrophies, such as hail, snow, frost, insects, diseases, browsing, wounding, and branch breakage—all of which may contribute to decreased growth, internal defect, and mortality. Damage is common in most young sucker stands, and, except for browsing, little can be done to reduce it. Although the quality of suckers in young stands cannot be fully assessed until they mature somewhat, this study suggests they may be similar in quality to natural stands at comparable ages.

## Introduction

Aspen (*Populus tremuloides* Michx.) grows on about 25% of the commercial timberland in Colorado (Green and Van Hooser 1983). More than 2 million acres of aspen provide an esthetic resource widely used for recreation, wildlife, grazing, and wood products. Many of these benefits from aspen cannot be achieved without proper stand management and maintenance. The utilization of aspen for wood products has increased over the past 10 to 20 years, and harvesting is used as a management tool to maintain the species.

Although various methods of timber harvesting have been used, clearcutting is currently favored to regenerate new stands of aspen. Because these stands have been clearcut, they will develop under different circumstances and ecological conditions than did their parent stands. Clearcutting, like other major disturbances of the existing overstory, usually results in the production of thousands of aspen suckers per acre.

A decrease in the number of suckers over time is natural, and tree densities of 400–600 stems per acre in mature stands are expected. A brief review of the few studies on the pathological condition of young aspen suckers, which were conducted primarily in Minnesota or Ontario, Canada, is presented in the Appendix. On Stoner Mesa in southwestern Colorado, Crouch (1983) found a 23% reduction of suckers in clearcut areas after 7 years. Of the remaining 7,210 suckers per acre, 40% had basal injuries, and 57% had internal discoloration or decay; these values compare to 33% injured and 47% discolored or decayed in uncut areas. Crouch (1983) questioned if the replacement of sawlog-quality growing stock had been successful, because trampling by cattle and breakage by snow damaged most suckers.

That case raised questions as to the future quality of aspen suckers growing on recent cutover areas in Colorado. The objective of this study was to assess the quality of aspen suckers that have developed over the past 19 years in stands that have been regenerated after clearcutting of older aspen stands.

## Methods

Stands of aspen suckers regenerated after clearcut harvesting, and representing a range of physiographic and site conditions, were examined in 32 areas on 8 National Forests (NFs) in Colorado, in June and July of 1984 (fig. 1). Stands ranged from 8,000 to 10,000 feet in elevation. At each stand, a one-half-acre square block was laid out that was uniform in stocking and appeared to include only one clone of aspen. Twenty circular, milacre plots (3.75-foot radius), equally spaced on 4 transects across the block, were used to estimate stocking, density, size class distribution, and occurrence of damage and defect. Only sucker damage and defect are reported here.

The tallest sucker in each milacre plot was sampled for diseases, stem and root damage, and other defect. Stem age at ground level, total height, diameter at breast height, and crown class of this sucker were recorded. Individual plot data appear in Table A–1. Stems were dissected at 1-foot intervals to measure internal defect and its association with external damage. Major roots were examined, when possible, along a distance of one foot or more from the main stem for evidence of wounds or internal defect.

Types of damage were recorded, each of which was further coded as associated with: insects or disease, old wounds or new, open or closed wounds, light or heavy foliar damage, probable cause of broken branches and dead leaders, and forked or one-sided crown. Suckers with multiple forks, crooked, broken, or nondefinable terminal leaders were considered to be questionable crop trees because of their poor form. Heights of stem damage on the lower bole were recorded as from 0 to 1 foot, or from 1 to 6 feet. Above 6 feet, stem damage, leaf diseases, and insect infestations were recorded by location in the live crown: lower, middle, and upper.

Branches broken at the stem were classified as: cause unknown, the result of a heavy snow load, or having been stripped from the main stem by settling of the snow pack. Visible fruiting structures of fungi were used for their identification in the field, otherwise they were identified from cultures processed in the laboratory. Insect damage was recorded as wood borers or defoliators. Damage severity was rated as the portion of a stem girdled, percent of foliage damaged, number of individual damages, and the prospect of the stem not developing into a crop tree because of damage. Lengths of external and internal stem defects were measured to the nearest 1/10 foot.

Stem tissues with any stain or discoloration were classed as internal defect. Black stain, brown stain, wetwood, and decay, were checked for any association with external damage. Wetwood was considered to be any internal zone of discoloration whose perimeter was wetter than the inner sapwood (Ward and Pong 1980). Isolations were made onto 2% malt agar from discolored wood on the day collected; cultures were incubated at room temperature for later identification.

A total of 591 stems were examined, because suckers were absent on 49 of the 640 plots. Sucker age varied from 1 to 5 years old on 16 areas, from 6–10 years on 13 areas, and from 11 to 19 years on 3 areas. Distribution of suckers by age and crown classes appear in figures 2 and 3, respectively.

One-way analysis of variance (P = 0.05), raw Chi-square tests, and Cochran's test for homogeneity of variances were used to test relationships among variables. Group means were compared using Student-Newman-Keuls' procedure at P = 0.05.

## Results

Of the 591 suckers examined, 98% were either diseased, damaged, or dead (table 1). There were 1,613 coded cases in the 16 damaged categories. Many stems had multiple occurrences of more than one type of damage. Only 2% of the stems had no external damage or internal defects, 9% were questionable as crop trees, and 1% were dead. Damage occurred on 67% of the 1- to 5-year old trees, 97% of the 6- to 10-year old, and 93% of those more than 11 years old (fig. 2). Damage incidence increased as crown class improved: suppressed 72%, intermediate 78%, codominant 81%, and dominant 89% (fig. 3). Differences in damage by age and crown class were significant.

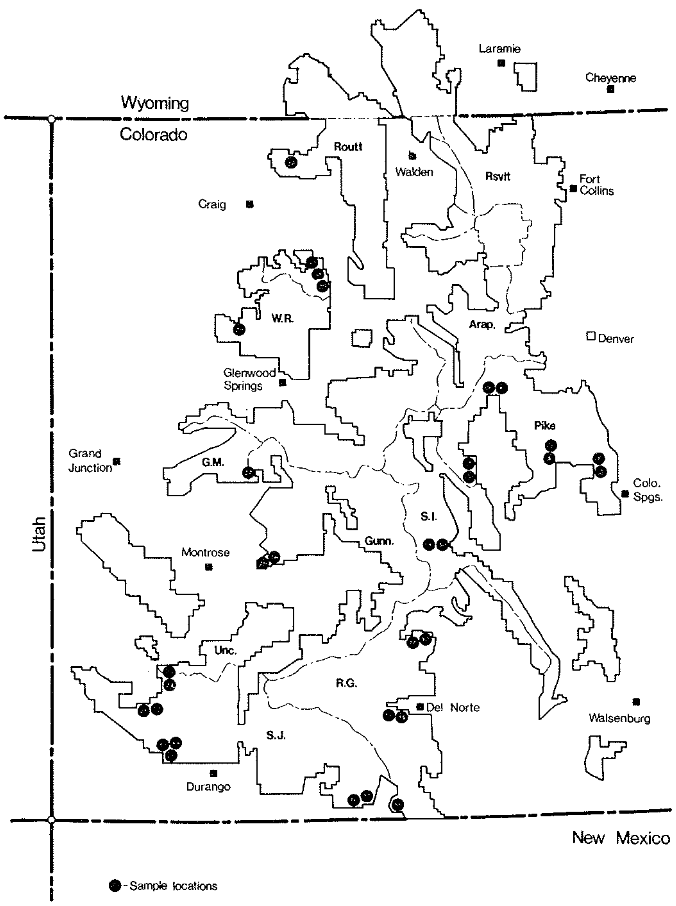


**Figure 1.—Location of aspen stands sampled for external damage and internal defect in 8 National Forests of Colorado.**

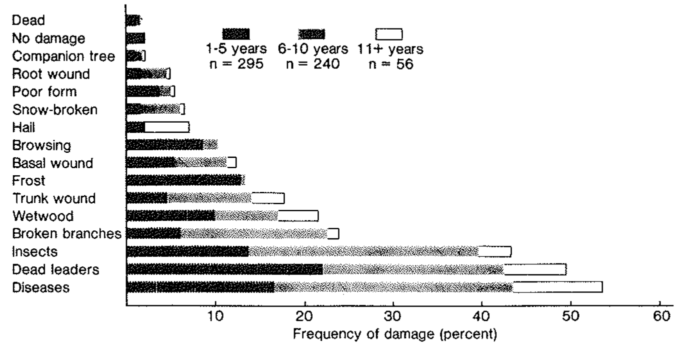


**Figure 2.—Distribution of damage to aspen suckers sampled by stem age classes (591 total suckers).**

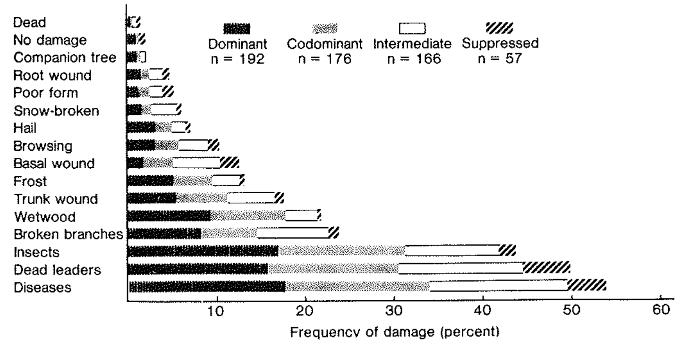


**Figure 3.—Distribution of damage to aspen suckers sampled by crown classes (591 total suckers).**

## Internal Defect

Internal defect occurred 695 times in 484 suckers (82% of those examined). Internal defect was commonly associated with external damage (fig. 4), except for browsing and frost damage to leaves. Black stain occurred in 4% of the stems, brown stain in 21%, wetwood in 62%, and decay in 6%. Associations of these internal defects with various types of damage appear in figure 5. Microorganisms isolated from internal defect appear in table A–2. Of the 476 isolations made, 176 were sterile, 51 were unidentified fungi, 90 were bacteria, and 202 were identified fungi. The association of identified microorganisms with types of damage appear in table 2, their association by stem age in table 3.

Recovery of decay fungi was low (6%), although their occurrence may be somewhat greater because isolations were not made from all discolored stem tissues. Ad-

Table 1.—Percentage of damage to aspen suckers in eight national forests in Colorado.

| | National Forests | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Pike** | **San Isabel** | **Rio Grande** | **San Juan** | **Uncompahgre** | **Gunnison** | **White River** | **Routt** | **Total** |
| | **Areas examined (no.)** | | | | | | | | |
| | **8** | **2** | **5** | **7** | **2** | **3** | **1** | **4** | **32** |
| | **Stems sampled (no.)** | | | | | | | | |
| | **144** | **34** | **96** | **126** | **39** | **59** | **18** | **75** | **591** |
| Damage type | | | | | | | | | |
| Dead | 2 | 9 | 2 | 1 | | | | | 1 |
| No damage | 6 | | 2 | 1 | | | | | 2 |
| Companion tree | 2 | 3 | 1 | 1 | 5 | 3 | 6 | | 2 |
| Root wound | 6 | | 5 | 4 | 5 | 7 | | 4 | 5 |
| Poor form | 15 | 3 | 6 | 2 | | | | | 5 |
| Snow-broken | | | 5 | 17 | | 5 | 6 | 7 | 6 |
| Hail | | | | | 74 | 19 | | 1 | 7 |
| Browsing | 25 | 27 | 7 | 6 | | | | 1 | 10 |
| Basal wound | 10 | 6 | 11 | 14 | 15 | 15 | 6 | 15 | 12 |
| Frost | 33 | 88 | | | | | | | 13 |
| Trunk wound | 17 | 9 | 10 | 14 | 46 | 22 | 28 | 15 | 17 |
| Wetwood | 6 | 29 | 31 | 11 | 61 | 32 | 11 | 27 | 21 |
| Broken branches | 14 | 9 | 10 | 51 | 8 | 25 | 11 | 31 | 24 |
| Insects | 17 | 3 | 63 | 50 | 26 | 69 | 68 | 47 | 43 |
| Dead leader | 58 | 38 | 37 | 54 | 64 | 25 | 100 | 48 | 50 |
| Diseases | 4 | 3 | 29 | 86 | 100 | 68 | 56 | 100 | 54 |

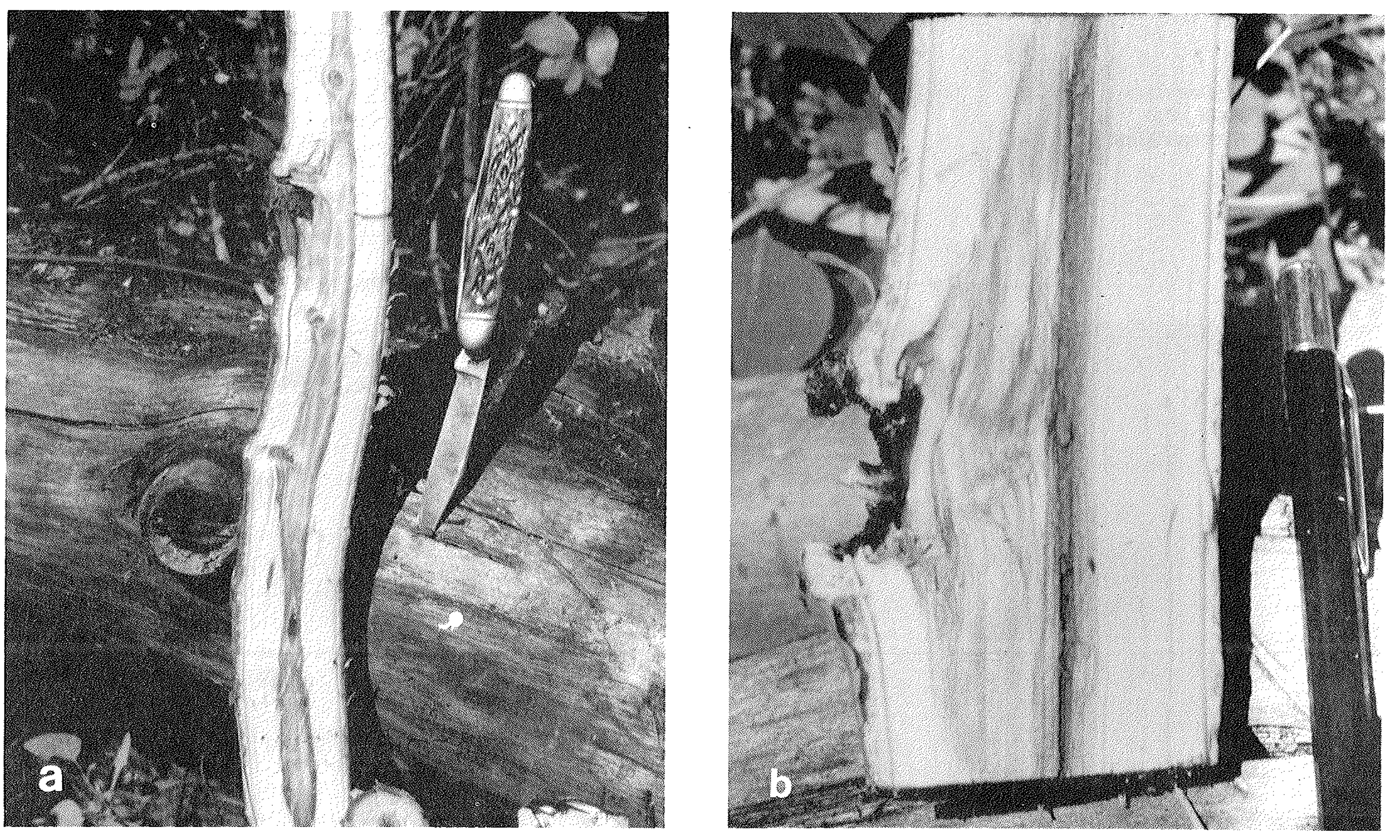


**Figure 4.—Internal defect in aspen suckers associated with (a) trunk wound, and (b) broken branch.**

Table 2.—Percentage of microorganisms associated with aspen sucker stem damage.

| Microorganism | Dead | Root wound | Snow-broken | Hail | Basal wound | Trunk wound | Wet-wood | Broken branches | Insects | Dead leader | Disease | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bacteria | | 1.1 | 0.4 | 0.4 | 4.2 | 5.5 | 3.5 | 8.4 | 0.4 | 5.9 | 1.7 | 31.5 |
| *Pleurostromella* sp. | | | 0.4 | 0.7 | 2.4 | 3.9 | 1.1 | 2.8 | 0.4 | 1.7 | 0.3 | 13.7 |
| *Dothiora polyspora* Shear & Davidson | 0.4 | | | | 0.4 | | | 0.4 | | 4.5 | 3.0 | 8.7 |
| *Cytospora chrysosperma* Pers. ex Fr. | 0.7 | | | 1.3 | 0.4 | 0.7 | | 0.4 | | 1.0 | 2.1 | 6.6 |
| *Rhinocladiella* sp. | | 0.4 | 0.7 | 0.4 | 0.7 | 1.0 | 1.0 | 1.0 | | 0.7 | | 5.9 |
| *Sirodothis populnea* (Thum.) Sutton & Funk | | | | | 0.7 | 0.7 | | 0.7 | | 1.8 | 0.7 | 4.6 |
| *Candida* sp. | | | | | | 0.7 | 1.1 | 1.4 | | 1.4 | | 4.6 |
| *Flammulina velutipes* (Curt. ex Fr.) Sing. | | 0.4 | 0.7 | | 1.4 | 1.0 | | | | | 0.7 | 4.2 |
| *Peniophora polygonia* (Pers. ex Fr.) Bourd. | | | 0.4 | 0.6 | 0.4 | 0.4 | 0.4 | | | 1.3 | | 3.5 |
| *Phoma* sp. | | | | 0.4 | 0.4 | 0.3 | | 0.3 | | 0.4 | 0.3 | 2.1 |
| *Armillaria* | 1.0 | 0.4 | | | | | | | | | 0.4 | 1.8 |
| Actinomycetes | | | | | 0.4 | 0.4 | 0.3 | | | 0.3 | | 1.4 |
| *Gonatobotryum* sp. | | | 0.4 | | | 0.3 | 0.4 | | | | | 1.1 |
| *Leptographium* sp. | | | | | | 0.4 | | | | 0.7 | | 1.1 |
| *Gliocladium* sp. | | | | | | 0.4 | | | 0.3 | 0.3 | | 1.0 |
| *Cephalosporium* sp. | | | | | 0.4 | | | | | 0.3 | | 0.7 |
| *Ceratocystis alba* DeVay, Davids., & Mullar | | | | | | 0.4 | | | | | 0.3 | 0.7 |
| *Graphium* sp. | | | | 0.4 | | | | | | | 0.3 | 0.7 |
| *Hypoxylon mammatum* (Wahl.) Miller | | | | | | 0.4 | | 0.3 | | | | 0.7 |
| *Penicillium* sp. | | 0.7 | | | | | | | | | | 0.7 |
| *Phellinus tremulae* (Bond.) Bond. et Borris | | | | 0.7 | | | | | | | | 0.7 |
| *Phialophora* sp. | | | | | 0.4 | | | 0.3 | | | | 0.7 |
| *Trechispora* sp. | | | | | | | | | | 0.4 | 0.3 | 0.7 |
| *Verticillium* sp | | | | | | | | 0.7 | | | | 0.7 |
| *Ganoderma applanatum* (Pers. ex Wallr.) Pat. | | 0.4 | | | | | | | | | | 0.4 |
| *Ceratocystis crassivaginata* Griffin | | | | | | | | | | | 0.3 | 0.3 |
| *Coniothyrium* sp. | | | | | | | 0.3 | | | | | 0.3 |
| *Libertella* sp. | | | | | 0.3 | | | | | | | 0.3 |
| *Moniliella* sp. | | | | 0.3 | | | | | | | | 0.3 |
| *Tropospora* sp. | | | | | | | | | | 0.3 | | 0.3 |
| Total | 2.1 | 3.4 | 3.0 | 5.2 | 12.6 | 16.4 | 8.1 | 16.7 | 1.1 | 21.0 | 10.4 | 100.0 |

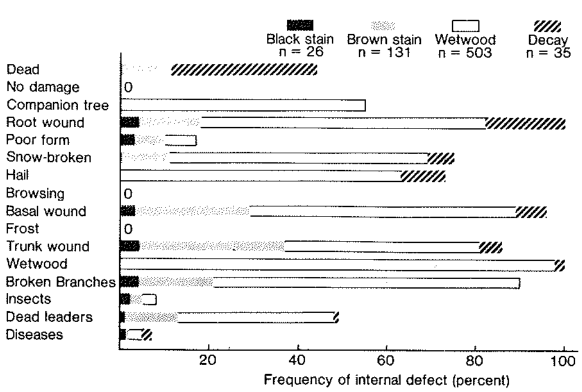


**Figure 5.—Occurrence of stain, wetwood, and decay in aspen suckers with internal damage (695 cases).**

vanced decay occurred only 12 times; however, 6 of the decay fungi common in mature aspen were isolated, mainly from stain or incipient decay associated with external damages (table 2, fig. 5). Trunk rot fungi, including *Phellinus tremulae* (Bond.) Bond. et Borris, *Peniophora polygonia* (Pers. ex Fr.) Bourd, *Flammulina velutipes* (Curt. ex Fr.) Sing., and *Libertella* sp. were isolated from 4% of the live stems. Root rot fungi were present in 2% of the stems and *Armillaria*[3], *Flammulina velutipes* and *Ganoderma applanatum* (Pers. ex Wallr.) Pat. were associated with sucker mortality and root wounds. *Armillaria* also was present on root collars and stumps of previously cut aspen (fig. 6a) in four areas with sucker mortality and sparse stocking of live suckers (fig. 6b).

*[3]Several species of Armillaria have been delineated in recent taxonomic and genetic studies of the fungus. One isolate from an aspen root in northern New Mexico was identified as A. ostoyae (Romagn.) Kerink, by D. J. Morrison of the Canadian Forest Service. However, because the taxonomic status of the group is uncertain, the generic term "Armillaria" is used here (Wargo and Shaw, 1985).*

Table 3.—Relative percentage of 286 identified stem microorganisms associated with three aspen age classes.

| Microorganism | Age class | | | Total |
|---|---|---|---|---|
| | 1-5 years | 6-10 years | 11+ years | |
| Bacteria | 7.3 | 19.2 | 5.0 | 31.5 |
| *Pleurostromella* sp. | 2.8 | 7.7 | 3.2 | 13.7 |
| *Dothiora polyspora* Shear & Davidson | 4.9 | 3.5 | 0.3 | 8.7 |
| *Cytospora chrysosperma* Pers. ex Fr. | 1.7 | 2.1 | 2.8 | 6.6 |
| *Rhinocladiella* | 1.7 | 3.5 | 0.7 | 5.9 |
| *Sirodothis populnea* (Thum.) Sutton & Funk | 1.8 | 1.7 | 1.1 | 4.6 |
| *Candida* sp. | 1.8 | 2.5 | 0.3 | 4.6 |
| *Flammulina velutipes* (Curt. ex Fr.) Sing. | 1.0 | 2.5 | 0.7 | 4.2 |
| *Peniophora polygonia* (Pers. ex. Fr.) Bourd | 0.3 | 1.4 | 1.8 | 3.5 |
| *Phoma* sp. | 0.7 | 0.7 | 0.7 | 2.1 |
| *Armillaria* | 1.4 | 0.0 | 0.4 | 1.8 |
| Actinomycetes | 0.4 | 1.0 | 0.0 | 1.4 |
| *Gonatobotryum* sp. | 0.0 | 0.4 | 0.7 | 1.1 |
| *Leptographium* sp. | 0.0 | 0.4 | 0.7 | 1.1 |
| *Gliocladium* sp. | 0.4 | 0.3 | 0.3 | 1.0 |
| *Cephalosporium* sp. | 0.7 | 0.0 | 0.0 | 0.7 |
| *Ceratocystis alba* DeVay, Davids., & Mollar | 0.4 | 0.3 | 0.0 | 0.7 |
| *Graphium* sp. | 0.0 | 0.0 | 0.7 | 0.7 |
| *Hypoxylon mammatum* (Wahl.) Miller | 0.0 | 0.7 | 0.0 | 0.7 |
| *Penicillium* sp. | 0.3 | 0.4 | 0.0 | 0.7 |
| *Phellinus tremulae* (Bond.) Bond. et Borris | 0.0 | 0.0 | 0.7 | 0.7 |
| *Phialophora* sp. | 0.0 | 0.7 | 0.0 | 0.7 |
| *Trechispora* sp. | 0.4 | 0.0 | 0.3 | 0.7 |
| *Verticillium* sp. | 0.0 | 0.7 | 0.0 | 0.7 |
| *Ganoderma applanatum* (Pers.:Wallr.) Pat. | 0.0 | 0.4 | 0.0 | 0.4 |
| *Ceratocystis crassivaginata* Griffin | 0.0 | 0.0 | 0.3 | 0.3 |
| *Coniothyrium* sp. | 0.0 | 0.3 | 0.0 | 0.3 |
| *Libertella* sp. | 0.0 | 0.0 | 0.3 | 0.3 |
| *Moniliella* sp. | 0.0 | 0.0 | 0.3 | 0.3 |
| *Tropospora* sp. | 0.0 | 0.3 | 0.0 | 0.3 |
| Total | 28.0 | 50.7 | 21.3 | 100.0 |

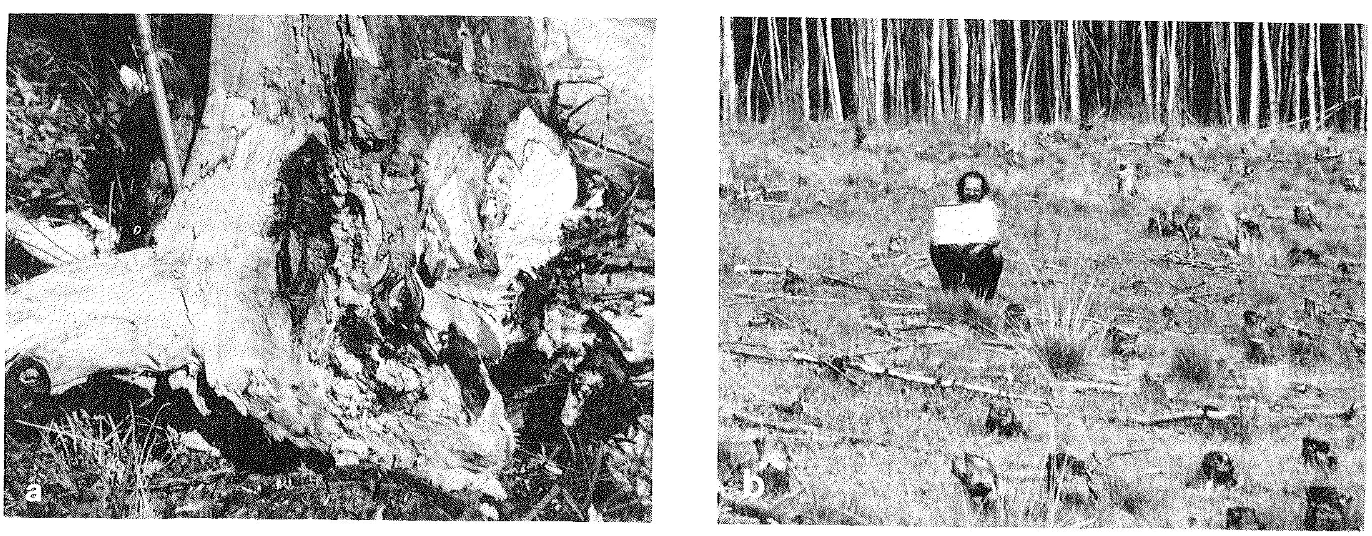


**Figure 6.—(a) *Armillaria* root rot at base of aspen stump. Black zone lines around the perimeter of decay and mycelia mats beneath dead bark typify infection. (b) Root rot center with no suckers and sucker mortality around the perimeter of infection center.**

Wetwood which could not be associated with any external damage occurred in 118 live suckers on 22 areas in all NFs. The proportion of stems affected in any area ranged from 5% to 100%. All age and crown classes were affected. Five percent of the wetwood cases occurred in roots. Numerous organisms were isolated from such wetwood, including the decay fungus *Peniophora polygonia*.

### Root Damage

Root wounds occurred in 50% of the areas examined and were consistently associated with either stain, wetwood, or decay. There were 44 cases of internal root defect, 28 of which were associated with root wounds. Open wounds were most common; but closed wounds were associated more often with stem discoloration. Internal root discoloration associated with wounds, extended into the stem in 81% of the cases, and ranged from 0.1 to 1.8 feet in height. Wound severity ranged from under 25% of the root circumference to complete girdling; however, lengths of internal defect were not significantly related to wound severity.

### Stem Damage

Only 11 of the suckers examined were considered free of external damage and internal defect. All were 2 to 4 years old. Seven of these suckers were considered to be future crop trees; the remaining 4 were suppressed and considered questionable crop trees.

Of the 640 plots sampled, 9 of the suckers examined were dead. They were predominately in the intermediate and suppressed crown classes of 2 to 6 feet in height. Mortality was attributed to snow breakage, *Armillaria*, and stem girdling by cankers.

Eleven suckers were connected at the base to another sucker. Wetwood was present in over half of these stems and associated with the other stem. Because of competition with the companion stem, three were considered non-crop trees.

One-sided, forked, or snow broken suckers occurred in 20 areas. More than 50% of these 64 stems were questionable crop trees. Stain or wetwood was associated with 17% of these poorly formed stems. Snow breakage was common in forests on the western slope, and was most common on the San Juan NF. Snow breakage usually occurred near the ground when the entire sucker was bent over by the snow, or in the lower crown when branches embedded in the snow pack were stripped from upright suckers. Internal defect was associated with 75% of the broken stems; *Flammulina velutipes* and *Peniophora polygonia* appear to be good indicators of future stem rot.

Branch and stem wounds attributed to hail (fig. 7) occurred on 41 suckers in four areas. From 60% to 89% of the stems were damaged in two, 15-year-old stands on the Uncompaghre NF. Damage was primarily in the upper crowns or throughout the crowns of dominant and codominant stems. Internal defect, primarily wetwood, was common but not extensive, (a maximum of 0.3 feet of discoloration). Cytospora cankers (*Cytospora chrysosperma* Pers. ex Fr.) were associated with hail damage in older stems, and *Dothiora polyspora* Shear & Davidson with cankers and dead terminals in young stands. Two decay fungi, *Peniophora polygonia* and *Phellinus tremulae*, were isolated from wounds on older stems.

Figure 7.—Hail damage to the main stem of an aspen sucker.

Damage attributed to animal browsing occurred on 61 suckers in 14 areas. Domestic livestock generally browse by stripping branches of their foliage, whereas branches are nipped by deer and elk. Of the browsing encountered, 26% was stripping, 64% nipping, and 10% was not distinguishable. Most browsing occurred on stems under 6 years old; no damage occurred on stems over 10 years old. Stems with damage in the upper crown or throughout the crown had a mean height of 5 feet and were significantly shorter than stems with damage in the lower crown with a mean height of 8 feet. Older, taller stems apparently grow out of reach of the animals. Except on a few dead terminals, stem defect was not associated with browsing damage.

Basal wounds, up to 1 foot on the bole, occurred on 73 suckers in 30 areas. Internal stem discoloration was associated with most of these wounds. Neither open or closed wounds, with mean internal defects of 2.2 and 1.7 feet, respectively, nor wound circumference classes, differ significantly in lengths of internal defect.

Trunk wounds occurred on 89 stems in 28 areas, 85% of which were from 1 to 6 feet up the stem. Forty-seven percent of these wounds were closed, 37% open and cause unknown, and 16% open and attributed to animals, mainly voles (*Microtus montanus* Peale). Most wounds girdled under 50% of the bole circumference and there was no significant relationship between girdling severity and lengths of internal defect ($\bar{x}$ = 2.6 feet). Stain, wetwood, decay, and cankers were associated with 86% of the trunk wounds.

Broken branches occurred on 140 suckers, in 25 areas, in all NFs. The greatest damage occurred in the 6- to 10-year age class. Branch damage appeared to be related to snow depth. Seventy-seven percent of the damage occurred in the lower crowns. This group had a mean stem height of 11 feet. Midcrown damage was found on 17% of the stems which had a mean height of 8 feet. Snow broken branches were the most common (55%). Stripped branches (21%) occurred mainly on codominant and intermediate stems where crowns would be within the snowpack. Differences between the number of branches broken and stem height were not significant.

Internal defect was associated with 90% of the broken branches. Black stain occurred in 4% of these stems, but was very localized (maximum length of 0.2 feet). Brown stain occurred in 17% of the stems and ranged up to 7.6 feet ($\bar{x}$ = 2.2 feet). Wetwood was associated with 69% of the broken branches, extending up to 11.0 feet ($\bar{x}$ = 3.1 feet). Lengths of brown stain defect did not differ significantly from either black stain or wetwood. Wetwood had significantly *longer* internal discoloration than did black stain. Although bacteria and 10 fungi were isolated from defects associated with broken branches, decay fungi were not (table 2). Three canker fungi also were associated with broken branches, as might be expected.

The importance of dead terminal leaders, which were found on 256 stems in all areas, requires emphasis because they are points of entry for stain and decay organisms. They also affect tree form, as the dead stub causes a stem crook when the next terminal begins. Some stems (8%) had multiple dead leaders indicating previous damage. Ninety percent of the dead leaders were old, causes unknown. Internal defect was associated with 49% of these dead leaders. Bacteria and numerous fungi were isolated there (table 2).

Canker fungi occurred on 8% of the stems and were associated with sucker mortality, dead terminals, and wounds. *Cytospora chrysosperma* occurred on 3% of the stems, and was isolated from stained sapwood adjacent to cankers. Although the fungus was associated with six cankers of unknown origin, five were in an area that had been heavily damaged by hail. *Dothiora polyspora*, or the *Dothichiza* perfect state, was associated with cankers or stain in 4% of the stems, including 9 cankers whose point of origin was undetermined (although most were also in an area heavily damaged by hail). Although the pathogenicity of *Dothiora polyspora* has not been proven (Shear and Davidson 1940), its occurrence on suckers has been observed in New Mexico, Utah, and Alaska (Hinds et al. 1985). Internal discoloration ranging from 0.2 to 3.8 feet was associated with these cankers. Cankers of undetermined cause occurred on 1% of the stems. Hypoxylon cankers (*Hypoxylon mammatum* [Whal.] Miller) were not found, although the fungus was isolated from stain associated with a trunk wound, and a broken branch.

Stem galls of unknown origin occurred on eight suckers in four areas. Small amounts of internal wetwood were associated with four galls.

## Insect Damage

Sucker damage by insects occurred on 226 suckers, in 28 areas, in all NFs. Galleries of wood borers, such as *Saperda calcarata* Say., *Agrillus liragus* B. and B., and *Trypodendron retusum* (Lec.) occurred in 21 stems in 13 areas. Two trees also had root insects boring in large lateral roots. Internal discoloration was associated with 71% of the borer damage, but averaged only 0.7 feet in length.

An outbreak of the western tent caterpillar, *Malacosoma californicum* (Packard), occurred during 1984 in aspen stands of southern Colorado and northern New Mexico. This caterpillar occurred on 46 live suckers in 5 of the sampled areas, including 3 on the Rio Grande NF. Dominant stems were more heavily infested (44%), codominant and intermediate about equal (26–28%). Only 2% of the suppressed stems were infested. The proportion of leaves affected varied from under 10% in one-half of the suckers, to over 50% in one-third of the suckers.

Leaf rollers, tiers, and gall formers, such as *Choristoneura conflictana* (Walker), *Sciaphila duplex* (Walsingham), and *Mordwilkoja vagabunda* (Walsh), occurred on 94 live suckers in 18 areas, and in all NFs. All age classes were infested. Dominant and codominant crown classes were more heavily attacked (73%) than suppressed suckers (6%). In any one area, infestations were either heavy or light: more than 50% of the sampled suckers affected, or less than 25%. Insect attacks were more common in the mid- and upper crowns. Although the insects were common and widespread, generally less than 10% of the live crown was affected.

Leaf miners and beetles, such as *Phyllocnists populiella* (Chambers) and *Chrysomela* spp., occurred on 84 live suckers in 13 areas, and in all NFs. In 6- to 10-year-old stands anywhere from 10% to 95% of the stems were affected, most commonly throughout the crowns of dominant or codominants. One-third of the affected stems had under 10% of their leaves damaged, and 38% had over 50% damaged.

## Foliar Damage

Dead leaves attributed to frost occurred on 78 suckers in 6 areas. Damage was most apparent in the first 2 weeks of June in areas on the eastern slope with southeast and northeast aspects. On the Pike NF, 3 of 4 areas had more than 70% of their stems affected, and two areas on the San Juan NF had over 80% affected. Stems under 6 years of age sustained the most damage. Damage occurred throughout the crown on stems with a mean height of 6 feet, whereas less damage occurred in the lower crown of taller stems. Because frost damage is usually confined to juvenile leaves, stem defect was not associated with its presence. Terminal growth often is affected; but it was too early in the growing season to assess this type of damage. Old dead terminals were common in frost-affected areas, possibly indicative of past frost damage.

Marssonina leaf blight (*Marssonina populi* [Lib.] Magn.), considered to be the most common leaf disease of aspen in the West (Mielke 1957, Harnis and Nelson 1984), occurred on 20% of the live suckers in 8 areas. Infections predominated on dominant and codominant stems in 1- to 10-years old stands. Infected suckers averaged 14.8 feet in height. Stems with more than 50% of their leaves infected were significantly shorter (12 feet) than those with less than 10% of their leaves infected (14 feet).

Ink spot (*Ciborinia whetzelii* [Seaver] Seaver) occurred on 13% of the live suckers, in 6 areas, on 3 NFs. Three areas on the San Juan NF had more than 95% of the suckers infected. However, 2 areas on other Forests had less than 8% infection. Infection occurred in all crown classes, but only on sampled stems from 1 to 10 years old. Trees with less than 10% of their leaves infected averaged 14.1 feet in height, whereas trees with more than 50% infection averaged only 7.8 feet.

Shepherd's crook, caused by *Venturia macularis* (Fr.) Mull. & Von Arx, is associated with leaf and shoot mortality. The disease was found on 8% of the live suckers, in 12 areas, on 5 NFs. Usually, less than 15% of the suckers were infected in an area, but the infection rate ranged from 35% to 85% in 3 areas on the San Juan National Forest. Suckers with more than 50% of their leaves infected were significantly shorter (6.5 feet) than either those with 20% to 50% infection (9.5 feet), or those with less than 10% infection (11.4 feet).

Because some fungal fruiting structures had not formed by June, unidentified "leaf spots" were found on 8% of the live suckers, in 7 areas, in 5 NFs. Leaf spotting generally occurred throughout the crowns, but usually affected less than 10% of the leaves.

## Discussion

Although nearly all suckers had some form of damage, the frequency of external damage to suckers, except for that caused by hail, was greatest in the younger age classes. In contrast to Kemperman et al. (1976) and Zehngraff (1946), damage and frequency of defect generally increased as the dominance class increased.

The high incidence of internal defect common to regenerated stands of aspen in Colorado was comparable to that found in other studies of internal defect in aspen suckers. Although sampling techniques differed among these studies, all indicate that internal defect develops in sucker stems at an early age, and result in a high incidence of defect by age 20 to 30. Even so, with high initial sucker densities and subsequent natural thinning, the resultant stands could be less defective at older ages. Reanalysis of data from 40- to 60-year-old trees in an earlier study of aspen decay in Colorado (Davidson et al. 1959) indicates that internal defect was present in more than 50% of the trees.

Numerous microorganisms isolated from discolored aspen wood have been reported from suckers in other stands (Basham and Navratil 1975, Kemperman et al. 1976), and are considered incapable of causing rot. *Rhinocladiella* sp. and *Phoma* sp. are, generally, the most common. *Sirodothis populnea* (Thum. Sutton & Funk) is an exception. It has previously been found on dead branches of live aspen, but not on live suckers. Its association with wounds, dead leaders, and broken branches, in all three age classes sampled raises concern as to its pathogenicity in suckers. The isolation of *Sirodothis populnea* from 13 suckers and the presence of fruiting bodies on 3 dead leaders also warrants further study of this fungus.

Although more than 30 different microorganisms were isolated from internal defects, only the decay and canker causing fungi are considered pathologically important to aspen management. *Phellinus tremulae*, the most important decay fungus in older aspen, seldom occurs in stems younger than 20 years (Basham and Navratil 1975, Gross and Basham 1981). Its apparent entrance through recent hail wounds on two, 15-year-old suckers in this study may be questionable. *Peniophora polygonia* is the most common decay in Colorado aspen (Davidson et al. 1959). It was associated with 6 types of stem damage in this study. These results confirm those of Basham and Navratil (1975) showing that the fungus can also infect young suckers.

*Flammulina velutipes* is a common butt rot of older aspen in Colorado. Davidson et al. (1959) believed it entered stems through roots. The fungus was associated with three types of stem damage, and the roots of suckers as young as 3 years old. *Libertella* sp. frequently was found as a top rot in older Colorado aspen (Davidson et al. 1959). Although its status as a decay organism was questionable at that time, its ability to cause decay, stem cankers, and tree mortality, has since been documented (Hinds 1981). *Libertella* sp. was only isolated from one stem wound on one 18-year-old sucker.

How decay in these regenerated stands will compare to that found in natural stands of comparable age is questionable. The discolored wood encountered in this study was as hard as that of healthy wood, and appeared sound. Certainly, some discolored wood is of physiological origin, rather than fungal; but some is also incipient decay that will advance as stems age. Although Davidson et al. (1959) found little decay in stands younger than 40 years, defect occurred in 52% of the 41- to 60-year-old trees. The low incidence of decay that was found in young suckers, coupled with the high incidence in 40- to 60-year-old stems, indicates that the period between ages 20 to 40 may be critical for the development of decay in these regenerated stands.

The potential for root disease centers to develop in these stands is of concern, because they could limit successful regeneration. *Armillaria* spp. colonizes roots and stumps of cut trees and can kill both small suckers and large trees. Since disease centers frequently develop after harvest operations (Wargo and Shaw, III 1985), bare areas with sucker mortality around stumps (fig. 6) should be carefully examined for signs and symptoms of *Ar-*

*millaria*. Although evidence of *Armillaria* attack was limited, its potential to damage these stands should be further investigated. The potential for root or butt damage, and windthrow of older trees (Landis and Evans 1974), to develop from infestions by *Ganoderma applanatum* should also be clarified.

## Summary

Damage was common on aspen suckers in all National Forests surveyed. Internal defect was associated with all types of damage except frost and browsing, which indicates that bark damage of any kind may lead to internal stains, wetwood, and decay. How these internal defects develop as the suckers mature will affect future stand development, even though the volume affected is low now. Some defects will be compartmentalized and spread no further, and thus be limited to heartwood stain in older trees. Decay is likely to increase with age for stem wounds; dead branch stubs, broken tops, and other injuries will be invaded by decay fungi common in older stands.

These observations agree with other studies that indicate that sucker damage and internal defect develop at an early age in aspen stands regenerated by clearcutting. Sucker mortality will occur; but this is normal in aspen, where initial stocking rates of several thousand stems per acre are reduced to a few hundred stems per acre by maturity. Natural catastrophies, such as hail, snow, and insect or disease epidemics, may make certain areas more prone to damage and subsequent defect than others. Repeated damage by a single agent, or multiple damage by several agents, also may reduce stand stocking and vigor to a point where successful regeneration is questionable.

It is too early to predict the future quality of aspen growing in the regenerated stands on the basis of their present conditions. Even though their health cannot be fully assessed until they mature, there is reason for optimism concerning most of the stands sampled in this study. The low occurrence of serious decay-causing fungi indicates that decay defect in the second growth stands probably will not exceed that encountered in natural stands of comparable age.

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## Appendix: Literature Review

This review is presented for comparison, and as an aid in our evaluation of present and future quality of stands of aspen suckers in Colorado.

In a 10-year-old stand of aspen in Minnesota, 54% of the suckers had internal defect, and 67% were defective in a 22-year-old stand (Zehngraff 1946). Even if considerable losses occur in the future, both stands would still be well-stocked at age 45 to 50. Zehngraff (1946) concluded that the study tended to disprove a common belief that a high percentage of defective and diseased stems in young aspen stands would produce mostly cull trees.

High densities of suckers are not necessary to produce adequately stocked stands in Minnesota, where stands with 10,000 stems per acre at age 1 had fewer than 2,000 stems after 15 years, about 85% mortality over the period (Sorensen 1968). At age 1, stands on good sites with from 1,000 to 10,000 suckers per acre, would have an adequate number of potential crop trees 15 years later. Thinning would not be necessary and lack thereof would not affect mean tree diameter.

In another Minnesota study, Perala (1984) reported on how endemic injuries affected young aspen suckers. Injuries, and reactions thereto, peaked at 2 to 5 years, depending on site and type of injury. Potential crop trees sustained more injuries than other trees. Of the three major types of injuries—shoot blight, galls, and lesions—only shoot blight was associated with the expression of dominance. Galls and lesions were related directly to bole area but not tree class. Shoot mortality was caused by intraspecific suppression, and did not appear to be enhanced by any injuries. The high incidence of injury from insects and diseases was considered to be normal, and fiber yield was not expected to be less than current predictions.

Because of an increased interest in poplars for wood products in Ontario, Canada, the future quality of their aspen stands has been addressed. Pollard (1971) found that annual reductions in stand density resulted from mortality of small stems; but the loss of many suppressed suckers had little effect on total stand biomass. Loss of larger individual stems, however, seriously reduced biomass and affected annual production by the 7th year of stand development. Mean annual production was strongly influenced by disease because of insufficient time for enhanced growth of survivors. Aspen production in very short rotations might be more dependent upon environmental vagaries than in conventional rotations.

Smith (1973) studied 24 stands of aspen suckers in areas cut 5 to 20 years earlier in Ontario. The original composition of the hardwood stand had no consistent effect upon the quality or growth rate of aspen suckers. In 5-year-old stems, 76% had some light- to dark-brown stain, and all stems in the 15- and 20-year-old cutovers had some stain. The percentage of sucker stems with incipient decay varied from 20% to 25%; but only 5% had advanced decay. Many trunk defects were associated with broken branches, and most butt stains apparently entered through roots. *Peniophora polygonia* was consistently isolated from all age classes; *Phellinus tremulae* (Bond.) Bond. et. Borris ( = *F. igniarius* (L.: Fr.) Kickx) was rarely isolated, and then only from 25-year-old cutovers, and *Flammulina velutipes* (Curt.: Fr.) Sing. ( = *Collybia velutipes* (Curt.: Fr.) Quel.) occurred only once in a 10-year-old stand (Basham and Navratil 1975).

While Kemperman et al. (1976) found that defect varied considerably among stands sampled 25 years after cutting in northern Ontario, the incidence of stain, rot, and combined defect was 84%, 63%, and 96%, respectively. The percent volume of wood affected however, was only 1.4%, 0.5%, and 1.9%, respectively. The percent volume affected by both stain and rot increased as the dominance classes decreased. Most forms of internal defect did not have specific indicators of decay; but relationships were found between the incidence of defect and rate of stub healing, the degree of natural pruning, and crown class. Of the 33 different organisms identified, only a few decay fungi were considered important to forest management. The incidence of these fungi was low except for *Peniophora polygonia*, which was encountered in over 40% of the stems, but only in association with stain or incipient decay.

Basham and Navratil (1975) analyzed the mycological result of Smith (1973) and Kemper et al. (1976) in detail, along with a separate investigation of root systems in 4- to 14-year-old suckers. They found that about one-half of the stems had defect at ground level, within root collars, or on one or more roots. *Armillaria mellea* (Vahl: Fr.) Kummer was isolated from rot in two root collars and one root. They concluded that the extent of defect within an individual tree increased with its age, and that microorganisms responsible for rot and stain needed avenues of entrance such as wounds, branch stubs, or dead or broken tops. They also considered that, even up to age 25, examinations are too early to accurately predict the future quality of aspen.

Gross and Basham (1981) assessed the importance of disease in aspen regeneration less than 10 years old in northern Ontario. Cytospora canker occurred in most stands, but Hypoxylon canker was rare. Neither disease was considered to be important in young sucker stands. Ink spot, a leaf disease which had earlier damaged considerable foliage in some areas, was not prevalent in 1977, and caused negligible damage. Shoot blight (*Venturia macularis* [Fr.] Mull. & Von Arx) was widespread, and was considered serious, because it kills the uppermost terminals which reduces tree height growth, distorts tree form, and provides infection courts for canker and rot-causing fungi. In their survey, 61% of the stems had internal stain, 32% had rot and stain, and 30% had root defects. Injuries or nearby dead tissue, such as insect tunnels, stone bruise, parent root wound, dead companion stem, and small dead roots, were associated with 43% of the defects. *Armillaria mellea* was isolated from 4% of the root systems and was present in 24% of the stands sampled. Many of the organisms isolated from rots and stain sites were also found by Basham and Navratil (1975). Because of the high incidence of internal defect, they also maintained that it would be difficult to assess future mortality and cull as the stands mature.

Table A-1.—Summary data for regenerated aspen stands sampled for sucker damage in 1984.

| National forest | Location no. | Sucker age Range | Sucker age Aver. | Suckers sampled[1] | Diameter Range | Diameter Aver. | Crown class-aver. ht. D | CD | I | S |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ----- yrs. ----- | | -- no. -- | ------ in. ------ | | ----------- ft. ----------- | | | |
| Pike | 1 | 5–9 | 7.8 | 20 | 0[2]–0.7 | 0.2 | 8.7 | 8.1 | 6.4 | 4.4 |
| | 2 | 4–7 | 4.4 | 20 | 0–1.1 | 0.4 | 11.1 | 8.8 | 6.9 | 3.3 |
| | 3 | 3–4 | 3.2 | 19 | 0–0.5 | 0.3 | 8.3 | 7.9 | 4.2 | 0.9 |
| | 4 | 2–5 | 3.5 | 20 | 0–0.6 | 0.2 | 8.0 | 6.0 | 5.3 | 3.7 |
| | 5 | 3–8 | 3.6 | 8 | 0–0.5 | 0.1 | 4.4 | 2.0 | 1.7 | - |
| | 6 | 2–9 | 4.4 | 17 | 0–0.4 | 0.1 | 8.8 | 4.4 | 3.6 | 1.8 |
| | 7 | 3–5 | 3.9 | 20 | 0–0.4 | 0.1 | 6.8 | 5.5 | 4.3 | - |
| | 8 | 3–8 | 4.2 | 20 | 0–1.2 | 0.4 | 11.2 | 7.5 | 4.7 | - |
| San Isabel | 9 | 2–5 | 3.3 | 15 | 0–0.2 | 0.0 | 5.2 | 3.8 | 2.9 | 2.0 |
| | 10 | 3–5 | 3.7 | 19 | 0–0.3 | 0.2 | 6.8 | 6.3 | 5.1 | 2.5 |
| Rio Grande | 11 | 3–9 | 5.9 | 20 | 0–1.7 | 0.8 | 12.3 | 8.3 | 6.2 | 2.2 |
| | 12 | 2–7 | 4.6 | 20 | 0–1.0 | 0.4 | 10.3 | 8.2 | 7.0 | 4.1 |
| | 13 | 3–5 | 4.8 | 20 | 0–1.1 | 0.8 | 13.0 | 11.1 | 9.8 | 4.8 |
| | 14 | 2–4 | 3.6 | 19 | 0–0.8 | 0.4 | 10.9 | 9.5 | 8.0 | 3.0 |
| | 15 | 4–7 | 5.5 | 17 | 0–0.7 | 0.3 | 8.9 | 7.0 | 5.3 | 2.9 |
| San Juan | 16 | 8–14 | 9.1 | 20 | 1.1–2.1 | 1.5 | 19.4 | 17.3 | 13.4 | - |
| | 17 | 6–10 | 7.5 | 17 | 0.5–1.8 | 1.0 | 15.9 | 12.8 | 9.5 | 5.3 |
| | 18 | 2–7 | 5.0 | 18 | 0–1.2 | 0.5 | 11.7 | 11.3 | 8.0 | 4.6 |
| | 19 | 5–8 | 7.1 | 13 | 0–1.2 | 0.4 | 12.8 | 8.1 | 5.0 | - |
| | 20 | 6–10 | 7.5 | 20 | 0–1.7 | 0.6 | 9.1 | 6.4 | 5.1 | 2.8 |
| | 21 | 4–10 | 6.1 | 20 | 0–1.5 | 0.6 | 13.3 | 9.9 | 7.7 | 3.9 |
| | 22 | 5–15 | 7.0 | 18 | 0–1.7 | 1.0 | 16.4 | 12.4 | 9.5 | 6.6 |
| Uncompahgre | 23 | 13–16 | 14.8 | 19 | 1.2–3.0 | 2.1 | 22.8 | 21.8 | 17.9 | 16.0 |
| | 24 | 10–16 | 15.2 | 20 | 1.9–3.1 | 2.6 | 32.9 | 31.0 | 27.7 | 13.8 |
| Gunnison | 25 | 6–7 | 7.0 | 20 | 1.0–2.2 | 1.5 | 20.9 | 17.9 | 15.0 | - |
| | 26 | 6–10 | 6.7 | 20 | 1.0–3.3 | 1.5 | 17.3 | 15.2 | 14.7 | - |
| | 27 | 3–4 | 3.8 | 19 | 0–0.6 | 0.3 | 9.1 | 7.4 | 6.7 | 3.1 |
| White River | 28 | 9–19 | 15.4 | 18 | 0–2.8 | 1.9 | 24.4 | 21.3 | 15.8 | 6.1 |
| Routt | 29 | 3–5 | 4.4 | 20 | 0–1.2 | 0.7 | 11.8 | 10.0 | 8.8 | 5.7 |
| | 30 | 7–9 | 8.1 | 16 | 0.3–2.3 | 0.9 | 13.4 | 10.6 | 9.1 | - |
| | 31 | 3–5 | 3.7 | 20 | 0–0.6 | 0.1 | 8.0 | 6.7 | 6.1 | 4.0 |
| | 32 | 4–7 | 6.3 | 19 | 0.1–1.1 | 0.7 | 13.1 | 11.3 | 7.9 | - |

[1]*Tallest sucker in each of 20 milacre plots.*
[2]*Stem less than 4.5 feet at breast height.*

Table A-2.—Number of isolations and number of microorganisms, including sterile isolation attempts, obtained from the stems of aspen suckers.[1]

| Microorganism | Black stain | Brown stain | Wetwood | Decay | Cankers | Total |
|---|---|---|---|---|---|---|
| Sterile | 9 | 60 | 87 | 4 | 16 | 176 |
| Unidentified | 16 | 16 | 17 | | 2 | 51 |
| Bacteria | 1 | 23 | 57 | 3 | 6 | 90 |
| *Pleurostromella* sp. | | 17 | 25 | | 1 | 43 |
| *Dothiora polyspora* Shear & Davidson | 7 | 3 | 6 | | 7 | 23 |
| *Cytospora chrysosperma* Pers. ex Fr. | 2 | 4 | 6 | | 5 | 17 |
| *Rhinocladiella* sp. | 1 | 8 | 7 | 1 | | 17 |
| *Flammulina velutipes* (Curt. ex Fr.) Sing. | | 11 | 3 | 3 | | 17 |
| *Sirodothis populnea* (Thum.) Sutton & Funk | | 6 | 5 | | 2 | 13 |
| *Candida* sp. | 1 | | 12 | | | 13 |
| *Peniophora polygonia* (Pers. ex Fr.) Bourd. et Galz. | | 6 | 5 | | | 11 |
| *Phoma* sp. | 1 | 5 | | | 1 | 7 |
| *Actinomycetes* | | 3 | 2 | | | 5 |
| *Gliocladium* sp. | | 1 | 2 | | | 3 |
| *Leptographium* sp. | | | 3 | | | 3 |
| *Ceratocystis alba* DeVay, Davids. & Moller | | 2 | 1 | | | 3 |
| *Gonatobotryum* sp. | | 2 | 1 | | | 3 |
| *Graphium* sp. | | 1 | | | 1 | 2 |
| *Verticillium* sp. | | | 2 | | | 2 |
| *Penicillium* sp. | | 1 | 1 | | | 2 |
| *Cephalosporium* sp. | | | 2 | | | 2 |
| *Phialophora* sp. | | 1 | 1 | | | 2 |
| *Ceratocystis crassivaginata* Griffin | | | 1 | | 1 | 2 |
| *Hypoxylon mammatum* (Wahl.) Miller | | 2 | | | | 2 |
| *Phellinus tremulae* (Bond.) Bond. et Borris | | 2 | | | | 2 |
| *Trechispora* sp. | | | 2 | | | 2 |
| *Libertella* sp. | | | 1 | | | 1 |
| *Moniliella* sp. | | 1 | | | | 1 |
| *Tropospora* sp. | | | 1 | | | 1 |
| *Coniothyrium* sp. | | | 1 | | | 1 |
| *Armillaria* | | | | 1 | | 1 |
| *Ganoderma applanatum* (Pers.: Wallr.) Pat. | | 1 | | | | 1 |
| Total | 38 | 172 | 211 | 12 | 43 | 476 |

[1]*More than one organism was frequently obtained from a single isolate.*