

# *Basidiomycetes and Decay in Silver Maple Stands of Central Iowa*

BY  
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**SILVER MAPLE** (*Acer saccharinum* L.) comprises a sizeable portion of the saw-timber volume on commercial forest areas in Iowa, occurring in relatively large, pure, or nearly pure, stands. Among foresters the species has a reputation for being highly susceptible to decay.

The objectives of the present study were to identify the fungi associated with the decay and to investigate factors possibly affecting incidence and progress of heartrot in silver maple. Since the commercial forests of Iowa are in small holdings (Central States Forest Experiment Station 1956), it becomes necessary to use techniques embodying methods other than those requiring the cutting of large forest tracts for sampling of these stands. The development of non-destructive methods for determination of decay, therefore, was made a primary aim of this study.

Two methods appeared to warrant testing, one partially destructive, the other non-destructive. The former entailed the use of a modified increment core-culture technique followed by the felling and internal examination of those trees from which basidiomycetes were successfully isolated. The latter technique, which dealt with radiological investigation of decay, has already been described (Esllyn 1959). Both methods were applicable only to the lower portion of the tree bole and, therefore, to determination of butt decay solely.

## **Literature Review**

*Technique.* The increment borer method used by Rennerfelt (1945) for determination of decay frequency in spruce and

modified by Varner (1948) for similar studies in jack pine was applicable, with further modifications, to the study of decay in silver maple. Varner's technique consisted of removing bark from the area to be bored, moistening the exposed surface with mercuric chloride, and, by means of a previously-disinfected increment borer,

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withdrawing a sterile increment core. Once extracted, the core was placed into a Petri dish containing malt extract agar. The dish was wrapped in wax paper and incubated in the laboratory for 40 days at room temperature. Increment borings were also used to determine occurrence of decay by Arend (1937) in basswood, by Watson, according to Eyre and Lebaron (1944, page 34) in jack pine, and by Heimburger and McCallum (1940) to ascertain extent of butt decay in balsam fir.

Others have used the increment borer successfully in determination of rot deduction from gross volumes (Wagener and Davidson 1954). Brown (1934), for example, observed in aspen that decay diameter in dominant trees at one foot from the ground gave an accurate index of rot percentage in the merchantable stem. The diameters of rot, however, are difficult to determine by increment borings (Hornibrook 1950). Furthermore, estimation of cull based on diameter of decay at one foot cannot be applied in all stands as rot does not always extend that low on the bole.

Progress of decay. That decay is more prevalent and of greater volume in old forest stands than in young stands has been attested to by a number of investigators working with a variety of tree species. This relationship has been attributed to "cumulative risk of wounding" (Meinecke 1916), as well as to increase in relative proportion of heartwood, slower rate of wound healing, and decrease in resistance to decay of the center portion of heartwood (Wagener and Davidson 1954).

Use of crown class, or vigor, as a basis for decay estimations has been investigated for different forest species with varying results. The relationship of rot volume and incidence to crown class varied in incense cedar stands depending upon the area, or site, sampled (Boyce 1920). In Douglas-fir suppression directly influenced decay only in the younger age classes (Boyce 1932). Due to influence of growth rate upon wound healing, vigor-

ously growing trees usually were less prone to infection than slow growing ones (von Schrenk and Spaulding 1909). Meinecke (1922) and Hornibrook (1950) also indicated a relationship between vigor and decay. On the other hand, cull percentage was found to increase with increasing rate of growth in a number of species (McCallum 1928, Kaufert 1935, Garren 1941, Englerth 1942, Spaulding and Hansbrough 1944, Boyce and Wagg 1953).

In other investigations, cull volume increased with increasing rate of growth, although on the basis of percentage of decay no consistent difference or an actual decrease occurred (Bier et al. 1946, 1948; White 1953). Rate of growth was found to contain little or no relationship to volume of decay by other researchers (Wier and Hubert 1918, Schmitz and Jackson 1927, U.S. Forest Service 1932, Hepting 1935, Roth and Sleeth 1939, Buckland et al. 1949, Burns 1955, Fenton and Berry 1956).

Relationship of heart rot to tree diameter has been extensively studied. It has been generally recognized, at least for uneven-aged stands, that increase in decay was associated, albeit indirectly, with increase in tree diameter. For this relationship to hold, a close one must first exist between diameter and age (Buckland et al. 1949), diameter growth being largely a function of age and not a factor directly influencing rate of decay (Weir and Hubert 1918, McCallum 1928, Nordin 1954). In even-aged stands of white pine, diameter was found to be a poor criterion of decay and was thought rather an indicator of vigor (White 1953).

### **Materials and Methods**

Description of study areas. Decay investigations were conducted on bottomland flood plains in the Ledges State Park, and within two areas located on Amana Society land. The Ledges State Park is located centrally in the state, in Boone County. The study plot was situated in an area of the park little used by the general pub-

lic. Forest cover consisted predominantly of silver maple with a fair representation of boxelder and a scattering of large cottonwood and willow trees.

Amana Society lands are located in Iowa County. Of the two areas included within these communities one was situated approximately one mile north of the town of South Amana, and the other about one mile west of the town of Homestead. For convenience, the first area has been designated the South Amana Area and second, the Homestead Area. Both were a part of the bottomland flood plains of the Iowa River and each contained an even-aged stand of silver maple on the lowest elevations which merged into uneven-aged mixed stands as elevation and distance from the river increased. The even-aged portion of both tracts were forested predominantly by silver maple with a scattering of elm and cottonwood, while the uneven-aged portions were a mixture of silver maple, elm, cottonwood, ash, and lesser species. A large number of the smaller maples on all areas grew in clumps and hence appeared to be primarily of sprout origin. However, there was no evidence of parent stumps in any of the three study areas and none of the old stumps present there, or in a recently cutover area, showed a tendency to sprout.

*Selection and marking of trees.* Proceeding through the Ledges Area, each maple encountered that lay within the diameter breast height (dbh) limits of 4.0 to 30.9 inches was numbered with paint. Stems fused at any point below breast height were considered as separate individuals. Crown class and dbh were determined for each tree along with notations of any possible entry points for decay, such as scars, wounds, dead limbs, swollen knots, and decayed attaching stems. Diameters were taken to the nearest tenth inch and grouped by one-inch classes. After tallying a number of trees it became apparent that a large proportion of the sample fell into only a few diameter classes. Accordingly, an attempt was made thereafter to obtain at least ten trees in each

diameter class. Trees falling into diameter classes already adequately sampled were disregarded.

The same sampling technique was applied to the Amana areas with the exception that diameter stratification was initiated immediately. This resulted in more even distribution of diameter classes and in subsequent decrease in overall sizes of both samples.

*Culture technique.* Every tree in the sample was bored at least twice, once to obtain an increment core for age determination, and once for culturing. Both borings were made one foot above ground level to minimize degradation of the butt log by decay or stain fungi. In addition, as past studies have shown that increment bore holes plugged with dowels resulted in fewer cases of decay (Hepting *et al.* 1949, Lorenz 1944), hard maple dowels, soaked in mercuric chloride, were hammered into each bore hole. Hollow trees were rebored for age at breast height. Prior to use, the increment borer and extractor were immersed for a short period in 1:1000 mercuric chloride solution. The age core, extracted first, was examined for signs of decay, then placed in an individual malted milk straw.

The culture method was a modification of that used by Varner (1948). The area to be bored was cleared of loose bark with the belt axe and thoroughly sprayed with mercuric chloride. The sterilized borer was inserted into the tree and a core removed aseptically. By means of a pair of flamed scissors, previously kept sterile in 95 percent ethyl alcohol, a portion of core heartwood was broken off and inserted into a flamed test tube containing malt agar. Flaming was accomplished by means of a portable propane burner. Three heartwood portions were broken off from each core where the heartwood was of sufficient depth and each placed in an individual test tube. Cultures were incubated for at least three weeks at 22°C. Basidiomycetes obtained from such cores were transferred to large test tubes and placed in cold storage.

Trees from which basidiomycetes were isolated, hereafter termed "positive" trees, were tabulated separately from the "negative" trees by diameter and age-crown class groups. Included with the "positives" were trees from which no decay fungi had been isolated, but which had been identified as decayed by examination of age and culture borings. All "positive" trees were cut to determine volume of butt decay and its relationship to crown class, age, and diameter. Once felled, trees were also examined for decay within the first 16-foot log. When present, the extent of decay was measured in lineal feet and associated with its respective infection court. Thirty-five "negative" trees, especially those in lower diameter classes, were cut as further checks on the culture technique.

**Culture identification.** Identification of basidiomycetes isolated from increment cores was attempted through use of a key based on micro- and macroscopic cultural characteristics (Nobles 1948). Each isolate was transferred to a Petri dish containing malt agar and incubated in darkness at 22 degrees centigrade for six weeks, being removed at the end of each week for examination. After four to six weeks each culture was tested on both gallic and tannic acid media for the presence of oxidases.

To aid in identification of various isolates, all conks on or near silver maple, were collected and cultured. Successful cultures were compared with unidentified isolates from increment cores.

## **Results and Discussion**

**Age determinations.** Trees of all diameters were found concentrated most heavily in the 30- and 40-year age groups in the Ledges Area. In the total sample of 375 trees, 240 were in these age classes, while 33 were in the 50-year age class and only two in the 60-year age class.

A total of 203 trees were included in the South Amana sample. Of these

163 lay within the 30-year age class, six in the 20, 16 in the 40, 13 in the 50, three in the 60, and two in the 70-year age class. Trees of all diameters were not found in any one age group although within the 30-year age class they ranged from four to 22 inches.

The sample of 267 trees obtained in the Homestead Area contained a wider distribution of both diameter and age classes than did either of the other two samples. Trees ranged in age from 20 to 125 years, all those above 100 years of age being included together in the tabulation. Totals within each age class were as follows: nine in the 20-year age class, 25 in the 30, five in the 40, 57 in the 50, 96 in the 60, 46 in the 70, 14 in the 80, seven in the 90, and nine in the 100-plus-age group.

### *Sporophores associated with silver maple.*

Fungi found fruiting on, or near, the base of living silver maple included the following species: *Steccherinum septentrionale* (Fr.) Banker, *S. setulosum* (Berk. & Curt.) Miller, *Hericium erinaceus* (Bull. ex Fr.) Pers., *Ganoderma lucidum* (Leyss. ex Fr.) Karst., *P. hirsutus* (Wulf.) Fr., *P. versicolor* (L.) ex Fr., *P. gilvus* Fr., *P. pargamensis* Fr., *P. biennis* (Bull. ex Fr.) Fr., *Volvariella bombycina* var. *bombycina* (Schaeff. ex Fr.) Sing., *Collybia* sp., *Cortinarius* sp., *Schizophyllum commune* Fr., *Coprinus atramentarium* (Bull.) ex Fr., *Pholiota fulva-squamosa* Pk., *Poria* sp.

All species of *Polyporus*, plus *S. commune* and *G. lucidum*, were found growing on dead as well as living trees. In addition, all species of *Polyporus*, with the exception of *P. biennis*, were noted growing only on dead portions of living trees. *S. septentrionale* and *S. setulosum* were found on both living and dead trees outside the study area, while *H. erinaceus* was found on only one of the sample trees and, in this instance, was located within a hole 18 feet high on the bole. *V. bombycina*, in addition to having been collected from a number of decayed pockets on silver maple, was discovered growing from

a previously cut section of one of the "positive" trees. *Polyporus biennis*, *Phloioita fulvo-squamosa*, and *Cortinarius* sp. were found, in all cases, growing on the ground at the butt or a short distance therefrom. *Collybia* sp. and *Poria* sp. were both associated with decayed portions of living silver maples, but their exact relationship to the decay was unknown.

Basidiomycetes found fruiting exclusively on dead, or recently cut, silver maple included: *Polyporus arcularius* (Batsch.) Fr., *P. cinnabarinus* (Jacq.) ex Fr., *P. durescens* Overh., *P. galactinus* Berk., *Pholiota adiposa* (Fr.) Quel. (Fig. 1), *Flammula* sp., *Ganoderma applanatum* (Pers. ex Wallr.) Pat., *Merulius tremellosus* Schrad. ex Fr., *Trametes mollis* (Sommerf.) ex Fr., and *Lentodium squamulosum* Morg.

*Increment borer technique evaluation.* Three of the 35 "negative" trees cut as checks on the field culture technique exhibited signs of decay at one foot. Two of the trees contained off-center decay which had been entirely missed by both borings. The third tree contained intermediate decay below one foot and incipient decay above this level.

While incidence of decay resulting from increment borings was not tabulated in the present study, it was observed that decay was restricted to "cankered" bore holes, i. e. holes that had not callused over properly. Sporophores of *S. commune* and *P. pargamenus* were found at a number of such holes. The plugged bore holes of a few "positive" trees formed moist chambers in which mycelial masses developed from existing decayed wood. In one in-



FIGURE 1. Sporophores of *Pholiota adiposa* and associated decay in a fallen silver maple.



**FIGURE 2.** Growth of *B. nivea* from flamed increment cores.

stance sporophores of the decay fungus, *G. lucidum*, developed at the entrance to each bore hole.

Pathological heartwood was formed as a result of these borings in every section examined. This heartwood followed the course of the bore hole, extending for a short distance on either side. Vertically, pathological heartwood also followed the course of bore holes, extending upward for distances varying from a few inches to over one foot in length. As the vertical distance from the bore hole increased, the pathological heartwood decreased inwardly from the outer edge (McNabb *et al.* 1959, Edgren 1959).

A good deal of trouble was experienced with contaminants in culturing increment cores. This seemed to hold true regardless of the care taken to maintain sterile conditions. As a result it was believed that a number of "contaminants" were natural inhabitants of soft maple wood. The fungus, *Byssochlamys nivea* Westling, a common "contaminant" in the Amana areas, was thought to be in this category. Flaming and reculturing cores over-run by *B.*

*nivea* resulted in the rapid reappearance of the fungus (Fig. 2).

*Incidence and significance of positive trees.* A total of 148, or 39 percent of the trees sampled in the Ledges Area was found, by use of the increment borer culture method, to contain either basidiomycetous fungi or evident signs of decay. The number of "positives" was 49, or 24 percent of the total in the South Amana Area, and 58, or 22 percent in the Homestead Area.

Basidiomycetes were identified by cultural keys in 213 out of the total of 225 "positive" trees (Table 1). The 42 unknowns consisted mainly of trees with extensive decay at the butt from which basidiomycetes had not been isolated and, to a lesser degree, of trees from which the fungi isolated were not identifiable by cultural procedures. In all, 11 different basidiomycetes were identified from silver maple isolations (Table 1).

Most frequently isolated was *Corticium vellereum* Ell. & Crag, which was found to occur in slightly over half of the "positive" trees. *Pholiota adiposa*, the second most frequently isolated fungus, was positively identified with only 14 trees. Individually, volume of decay was greatest in those trees associated with *P. adiposa*, the bulk of the unknowns, and, in a few cases, with *C. vellereum*. From the appearance of decay, however, *P. adiposa* was probably the primary cause of extensive rot in a number of trees located within the latter two categories. On this basis, *P. adiposa* may be considered of major importance with regard to incidence and extent of butt rot in silver maple. *Ganoderma lucidum* was isolated from three trees all of which contained decay. As *G. lucidum* was readily isolated from advanced decay it was not believed responsible for some of the extensive rot encountered in the larger trees from which basidiomycetes could not be isolated. *Trechispora brinkmanni*, isolated from six trees, was associated with decay in only one instance, and its significance was considered uncertain. *Collybia velutipes* was associ-

ated with decay in two of the four trees from which it was isolated. The remaining identified fungi were each isolated from only one tree.

It is of interest to note that of the five fungi, *Armillaria mellea*, *Fomes connatus*, *Ganoderma applanatum*, *Pholiota adiposa*, and *Ustulina vulgaris*, which commonly cause butt rot in sugar maple (Nordin 1954) only *A. mellea* and *P. adiposa* were isolated from silver maple butt logs. Sporophores of *G. applanatum* were present in the Homestead Area but were all growing on dead maple exclusively.

In 124 of the trees from which *C. vellereum* was isolated, no decay was apparent at the one foot level (Table 1). To investigate the possibility that decay might exist below this point, the stumps of five such trees were recut at, or below, ground level. Only two of the recut stumps contained evidence of decay and, in both cases, the rot was confined to overgrown branch stubs. In the 56 trees in which decay was found to be associated with this fungus it varied widely in appearance. The infrequency of associated decay coupled with the variability of decay patterns between affected trees indicated that *C. vellereum* was not primarily a wood-decaying species. Similarly, *C. vel-*

*lereum* was isolated from various types of rot in sugar maple (*Acer saccharum* Marsh) and was believed to have succeeded primary decay fungi (Baxter and Hesterberg 1958; Good 1952; Good and Speirs, In Prep.; Nobles and Nordin 1955). More often in silver maple, however, *C. vellereum* was apparently a primary invader of sound heartwood, rather than a successor to previous fungal tenants. *Trechispora brinkmanni* was isolated from six silver maples, only one of which exhibited decay (Table 1), and may fall into a category similar to that of *C. vellereum* although it has been classified as a white saprot fungus of jack and red pines (Basham 1956) and, in one instance, associated with a trunk decay of aspen (Davidson *et al.* 1959).

A large proportion of the trees inhabited by *C. vellereum* appeared to lie within the intermediate and suppressed crown classes suggesting that some relationship might exist between crown class and incidence of "non-decaying" basidiomycetes. To determine if such existed, the percentage of sound boles inhabited by either *C. vellereum* or *T. brinkmanni*, was tabulated for each crown class (Fig. 3). No significant differences were found to exist at the 5

TABLE 1. Incidence of fungi isolated from silver maple and of associated decay (Ledges, South Amana and Homestead Areas).

| Fungi isolated                    | Total number of positive trees | With visible decay present | Visible decay absent |
|-----------------------------------|--------------------------------|----------------------------|----------------------|
| <i>Corticium vellereum</i>        | 180                            | 56                         | 124                  |
| <i>Pholiota adiposa</i>           | 14                             | 13                         | 1                    |
| <i>Trechispora brinkmanni</i>     | 6                              | 1                          | 5                    |
| <i>Collybia velutipes</i>         | 4                              | 2                          | 2                    |
| <i>Ganoderma lucidum</i>          | 3                              | 3                          | 0                    |
| <i>Polyporus hirsutus complex</i> | 1                              | 0                          | 1                    |
| <i>Polyporus arcularius</i>       | 1                              | 1                          | 0                    |
| <i>Phlebia merismoides</i>        | 1                              | 0                          | 1                    |
| <i>Hericium erinaceus</i>         | 1                              | 0                          | 1                    |
| <i>Fomes fomentarius</i>          | 1                              | 0                          | 1                    |
| <i>Armillaria mellea</i>          | 1                              | 1                          | 0                    |
| Unknowns <sup>1</sup>             | 42                             | 39                         | 3                    |
| Totals                            | 255                            | 116                        | 139                  |

<sup>1</sup>Includes trees decayed at one foot from which no decay fungi were isolated.

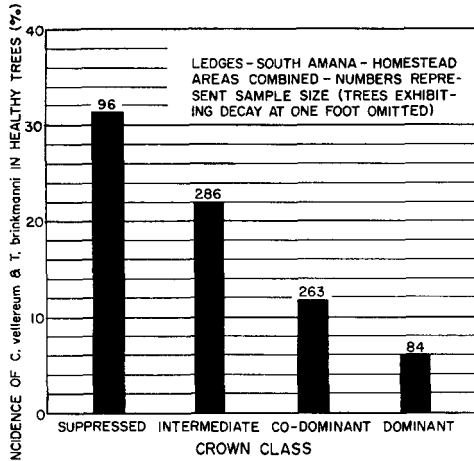


FIGURE 3. Occurrence by crown class of *C. vellereum* and *T. brinkmanni* in non-decayed heartwood of silver maple.

percent level when comparisons were made between suppressed and intermediate classes, and between co-dominant and dominant classes. However, all other comparisonal combinations were found to be highly significant.

*Incidence and extent of butt decay.* Active mycelia of a number of wood-rotting fungi have been found to occur vertically in apparently sound wood of living trees for distances varying from nine inches to six feet beyond visible signs of decay (Welch 1949). However, an average ex-

tension of one to two feet would be expected for these fungi generally (Wagener and Davidson 1954). In the present study, two feet was assumed to have been the maximum vertical penetration of mycelium beyond the last visible signs of decay. As a result, any decay noted within the lowermost three feet of the trunk was considered to have been caused by the fungus cultured from the one-foot level. All decay visible within these limits was subsequently termed "butt rot," regardless of height at which it had gained entrance. The full extent of this rot was measured, regardless of how high it penetrated, and its widest diameter noted. Based on the preceding two measurements, and treating rot columns as cylinders, the cubic-foot volume of decay was calculated individually for each tree. The total number of "positive" trees was not sufficient for an analysis by individual stands so the data were assembled collectively for butt rot by age, crown class, and dbh class.

Incidence of butt rot tended generally to increase with age (Table 2). A similar trend toward increased decay incidence with increasing age was found to occur in sugar maple by Nordin (1954) and he aptly termed this "cumulative hazard of infection."

The percentage of trees containing butt rot was slightly higher in suppressed and

TABLE 2. Relationship of incidence of butt rot to crown class and age (Ledges, South Amana, and Homestead Areas).

| Age Class | Crown Class |                |              |                |             |                |          |                |
|-----------|-------------|----------------|--------------|----------------|-------------|----------------|----------|----------------|
|           | Suppressed  |                | Intermediate |                | Co-dominant |                | Dominant |                |
|           | Basis       | Incidence      | Basis        | Incidence      | Basis       | Incidence      | Basis    | Incidence      |
|           |             | <i>Percent</i> |              | <i>Percent</i> |             | <i>Percent</i> |          | <i>Percent</i> |
| 20-29     | 6           | 16.7           | 9            | 11.1           | 1           | 0              | —        | —              |
| 30-39     | 58          | 15.5           | 146          | 5.5            | 118         | 5.1            | 20       | 0              |
| 40-49     | 25          | 12.0           | 96           | 14.6           | 68          | 8.8            | 17       | 11.8           |
| 50-59     | 18          | 22.2           | 38           | 15.8           | 36          | 11.1           | 10       | 20.0           |
| 60-69     | 6           | 16.7           | 43           | 25.6           | 36          | 11.1           | 16       | 12.5           |
| 70-79     | —           | —              | 9            | 33.3           | 19          | 21.1           | 20       | 10.0           |
| 80-89     | —           | —              | 1            | 0              | 5           | 0              | 8        | 25.0           |
| 90-99     | —           | —              | —            | —              | 6           | 83.3           | 4        | 75.0           |
| 100+      | —           | —              | —            | —              | 5           | 60.0           | 1        | 0              |
| Ave.      |             | 15.8           |              | 15.5           |             | 10.9           |          | 13.5           |
| Total     | 113         |                | 342          |                | 294         |                | 96       |                |

**TABLE 3.** Relationship of butt rot volume to crown class and age in silver maple (Ledges, South Amana, and Homestead Areas).

| Age Class | Crown Class |                             |              |                             |             |                             |          |                             |
|-----------|-------------|-----------------------------|--------------|-----------------------------|-------------|-----------------------------|----------|-----------------------------|
|           | Suppressed  |                             | Intermediate |                             | Co-Dominant |                             | Dominant |                             |
|           | Basis       | Av. butt rot vol. (Cu. ft.) | Basis        | Av. butt rot vol. (Cu. ft.) | Basis       | Av. butt rot vol. (Cu. ft.) | Basis    | Av. butt rot vol. (Cu. ft.) |
| 20-29     | 6           | 0.024                       | 9            | 0.029                       | 1           | .0                          | —        | —                           |
| 30-39     | 58          | 0.027                       | 146          | 0.032                       | 118         | .0                          | 20       | .0                          |
| 40-49     | 25          | 0.002                       | 96           | 0.070                       | 68          | 0.163                       | 17       | 0.452                       |
| 50-59     | 18          | 0.197                       | 38           | 0.257                       | 36          | 0.035                       | 10       | 0.108                       |
| 60-69     | 6           | 0.092                       | 43           | 0.375                       | 36          | 0.354                       | 16       | 0.569                       |
| 70-79     | —           | —                           | 9            | 0.413                       | 19          | 1.991                       | 20       | 0.012                       |
| 80-89     | —           | —                           | 1            | .0                          | 5           | .0                          | 8        | 4.072                       |
| 90-99     | —           | —                           | —            | —                           | 6           | 6.419                       | 4        | 6.551                       |
| 100+      | —           | —                           | —            | —                           | 5           | 0.576                       | 1        | .0                          |
| Total     |             | 0.052                       |              | 0.121                       |             | 0.371                       |          | 0.801                       |
| Basis     | 113         |                             | 342          |                             | 294         |                             | 96       |                             |

intermediate than in co-dominant and dominant classes (Table 2), although none of these differences were statistically significant at the 5 percent level.

A steady trend toward increase in volume of butt rot was shown to exist with increase in age (Table 3) up to the 100-plus-year age class. The average cubic foot volume of rot was less than one within the 20- to 70-year age classes, increasing to approximately 2.3 cubic feet per tree in the 80 and 6.5 cubic feet per tree in the 90-year age class. This figure dropped to an average of 0.5 cubic feet in the 100-plus-year age class. The apparent decrease in volume of butt rot may be due to mortality among highly defective trees 100, or more, years of age. Boyce (1932) and Bier *et al.* (1946) working, respectively, with Douglas-fir and Sitka spruce, found that low decay volumes within older age classes were due to a higher mortality among the decadent, or highly defective, individuals of these classes.

Average butt rot volume was found to increase also with increase in crown class (Table 3). Decay volume increased from 0.05 cubic feet in suppressed trees to a high of 0.80 cubic feet in dominants. This increase is due to expression of age as well as to that of crown class. The age classes above 60 years are scantily, or not at all, represented within lower crown classes

(Table 3). As butt rot volume has been shown to increase with age, the sample of older trees restricted within the higher crown classes tend to raise average volumes of decay for those classes, while averages for the lower crown classes remain static.

There was a tendency toward increase in average butt rot volume with increase in diameter (Table 4); however, it was not so uniform an increase as was ex-

**TABLE 4.** Relationship of butt rot volume to tree diameter in silver maple (Ledges, South Amana, and Homestead Areas).

| Diameter class | Basis (number of trees) | Average volume of butt rot (Cu. ft.) |
|----------------|-------------------------|--------------------------------------|
| 4.0- 5.9       | 75                      | 0.025                                |
| 6.0- 7.9       | 88                      | 0.058                                |
| 8.0- 9.9       | 113                     | 0.029                                |
| 10.0-11.9      | 110                     | 0.159                                |
| 12.0-13.9      | 93                      | 0.054                                |
| 14.0-15.9      | 83                      | 0.082                                |
| 16.0-17.9      | 67                      | 0.098                                |
| 18.0-19.9      | 56                      | 0.395                                |
| 20.0-21.9      | 45                      | 0.288                                |
| 22.0-23.9      | 32                      | 0.484                                |
| 24.0-25.9      | 27                      | 1.509                                |
| 26.0-27.9      | 24                      | 1.420                                |
| 28.0-30.9      | 32                      | 1.925                                |
|                | 845                     |                                      |

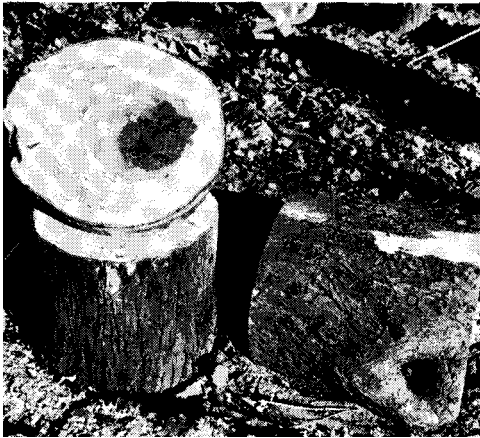


FIGURE 4. Hole in upper bole formed upon disintegration of a former branch and accompanying decay two feet below the defect.

perienced with age (Table 3). Segments of the sample were relatively even-aged and might account for the trend deviations.

*Infection courts and decay indicators.* Decay originating within the first 16-foot log of "positive" trees was traced to its probable source of entry and external evidences of these infection courts were tabulated. A total of 226 defects, which had served as infection courts, were examined on all three study areas and, of these, only 12 were classified as hidden. The remainder were visible externally. Hidden defects included

overgrown decayed branches, sprouts, and wounds. Average height of decay associated with such defects was 2.67 linear feet.

External defects, or decay indicators, were separated into eight different groups and, together with hidden defects, their frequency of occurrence and average associated height of decay were calculated (Table 5). In order of frequency these groups were: swollen knots, seams and scars, open wounds, dead branches, branch stubs, decayed knots, holes, and miscellaneous.

Swollen knots, while most frequently associated with decay, were indicative of rot which was, on the average, limited in extent. This could be attributed to inclusion within one group of all sizes of swollen knots, the more numerous smaller knots being accompanied generally by lesser decay. With increase in size, possibility of decay entering through swollen knots was multiplied due to increased amount of heartwood and added time required for healing. This applied similarly to dead branches, branch stubs, and visibly decayed knots.

Holes in trees were generally found at former branch sites (Fig. 4), or at the butt. The latter were usually due to decay of attached stems (Fig. 5). Again, diameter of the defect would influence spread and extent of decay in the heartwood of the hole. This indicator, though not fre-

TABLE 5. Rot associated with decay indicators and infection courts in silver maple (Ledges, South Amana, and Homestead Areas).

| Infection courts and decay indicators | Frequency<br>$f$ | Percent of Total frequency | Aver. height of Rot per infection (feet)<br>$h$ | $fXh$  | Percent of total of<br>$fXh$ |
|---------------------------------------|------------------|----------------------------|---|--------|------------------------------|
| Swollen knots                         | 60               | 28                         | 1.61  | 96.60  | 17                           |
| Seams and scars                       | 48               | 21                         | 1.98  | 95.04  | 17                           |
| Open wounds                           | 28               | 12                         | 4.56  | 127.68 | 22                           |
| Dead branches                         | 26               | 11                         | 2.52  | 65.52  | 12                           |
| Branch stubs                          | 19               | 9                          | 2.78  | 56.82  | 9                            |
| Decayed knots                         | 18               | 8                          | 0.44  | 7.92   | 1                            |
| Hidden defects                        | 12               | 5                          | 2.67  | 32.04  | 6                            |
| Holes                                 | 11               | 4                          | 5.05  | 55.55  | 10                           |
| Miscellaneous                         | 4                | 2                          | 8.62  | 34.48  | 6                            |
| Totals                                | 226              | 100                        |   | 567.65 | 100                          |

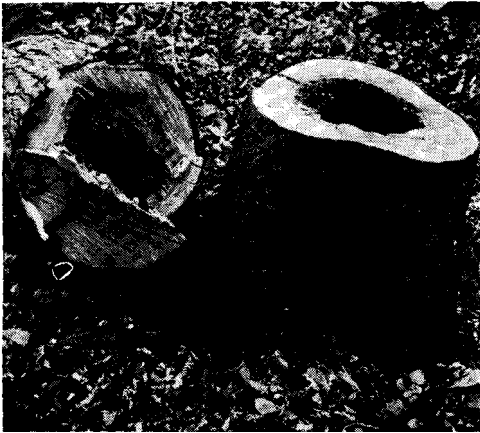


FIGURE 5. Hole at the butt caused by decay of a former attached stem and accompanying rot.

quently found on lower portions of trees, was notable because of the associated high average extent of decay.

Seams (Fig. 6) and scars, together with open wounds, were associated with highly variable amounts of decay as might be expected where defect size may vary by many



FIGURE 6. Seam in silver maple and accompanying decay.

feet. Individually, open wounds accounted for the highest percentage of total rot and were, as a result, of prime importance.

Miscellaneous indicators included attached, decaying stems and trunk grafts, both of which occurred infrequently. Although average extent of rot accompanying these indicators was high, their scarcity relegated them to a position of minor importance.

Fire, the major cause of wounding in the hardwoods of the Appalachian Region (Hepting and Hedgcock 1937) and grazing, an important cause of root and butt wounding in farm woodlots, were not observed in any of the study areas. This may account for the relatively small number of butt wounds encountered.

Invasion courts of *C. vellerum*, inhabiting apparently healthy trees, were not determinable although the lack of basal wounds and frequent presence of overgrown branch stubs indicated possible entry through former branch stubs and other small defects. In sugar maple *C. vellereum* was found predominantly in the upper trunk, and was associated there with frost cracks, dead branches and branch stubs, and scars (Nobles and Nordin 1955).

### Conclusions and Summary

Sporophores of 26 different basidiomycetes (Agaricales) were collected from silver maple trees, or logs, or in duff near standing trees. In addition, 11 basidiomycetes were isolated from living maples, five of which were not included within the above collections. The fungi found to be associated with silver maple included a number which apparently had not been reported previously on this host. These were as follows: *Polyporus arcularius*, *P. cinnabarinus*, *P. galactinus*, *G. lucidum*, *Collybia velutipes*, *Corticium vellereum*, *Copinus atramentarius*, *Lentodium spamulosum*, *Steccherinum setulosum*, *Trechispora brinkmanni*, and *Phlebia merismoides*. If the latter species is combined with *Phlebia radiata* Fr., following Cooke (1956), then this fungus has been reported prior on silver maple.

*Corticium vellereum* was the basidiomycete most frequently isolated from butt heartwood of silver maple; however, 69 percent of the affected trees were devoid of visible butt decay. The fungus appears primarily to be an invader of sound wood, although its isolation from decayed silver and sugar maples indicates it is capable of secondary invasion. *T. brinkmanni* was isolated from six silver maples, but associated with decay in only one of these cases, and may fall, therefore, into a category similar to that of *C. vellereum*. Repeated isolation of basidiomycetes and such non-basidiomycetous fungi as *Byssochlamys nivea* from apparently sound silver maples indicates that a widely diversified microfloral population may exist within such trees without apparent symptomatic expression.

Incidence of *C. vellereum* and *T. brinkmanni* in apparently sound heartwood increased inversely with crown class, i. e., the greatest percentage of invaded trees lay within suppressed and intermediate crown classes. If the primary invasion courts of *C. vellereum* were minor butt defects such as branch stubs, small wounds, etc., then the preponderance of infected trees within lower crown classes might be attributed to their slower rate of growth, or wound healing.

*Pholiota adiposa* was the major cause of extensive butt decay in the silver maple stands studied. While positively isolated from only 14 trees, the appearance of decay in a number of other silver maples from which either no fungus, or *C. vellereum*, had been isolated indicated that *P. adiposa* was the primary decay agency. *Ganoderma lucidum* was isolated from three, and *Collybia velutipes* from two, decayed trees. No other decay fungus was isolated from more than one tree.

A trend toward increase in butt rot volume was associated directly with increase in age, crown, and diameter class. Similarly, incidence of butt rot tended to increase with age, but unlike rot volume, decreased with increasing crown class.

Defects, serving as infection courts for decay fungi, were separated into nine different categories, eight of which were located externally on the bole and could be considered of value as decay indicators. In order of frequency the categories were as follows: swollen knots, seams and scars, open wounds, dead branches, branch stubs, decayed knots, hidden defects, holes, and miscellaneous defects. Highest average heights of decay were associated with miscellaneous defects and holes; however, both were infrequently encountered. Open wounds accounted for the greatest percentage of total decay, followed by seams and scars and swollen knots.

Increment borer-culture techniques may be used for determination of incidence of basidiomycetous fungi and decay at specific points on the lower boles of trees when non-destructive methods are desirable. Analysis of results should, however, include the following reservations: (a) off-center decay, such as that caused by rotted branch stubs, may be entirely missed by the borer; (b) basidiomycetes may be isolated from apparently sound boles so that their presence does not necessarily indicate the presence of decay; (c) fungi isolated from decayed boles are not necessarily primary causal agencies of the decay (appearance of the rot must be considered in this respect); (d) while generally non-destructive in nature, increment borings do provide entrance courts for stain and rot fungi (pathological heartwood formation, which accompanied all borings examined, may form a "bridge" over the sapwood for penetration by heart rot fungi).

Although the method is time-consuming and requires frequent trips to the area of operation, where forested holdings are small in size or where research demands the retention of growing stock, the technique may find application for the following types of studies: (a) surveys for particular butt-inhabiting fungi; (b) incidence of butt decay, or of particular fungi, with respect to factors such as age, diameter, crown class, site, etc.; and, (c)

as a basis for determination of trees within a sample to be cut for decay volume measurements (the method is partially non-destructive in that only a portion of the trees normally cut for such a study would be felled). Until further is known about possible relationships of rot diameters at butt to heights of rot columns for different decay organisms, volume of rot can only be determined by dissection of individual trees.

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