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Decay of Aspen in Colorado

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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CONTENTS

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Quaking aspen (Populus tremuloides Michx.) stands are extensive in the central Rocky Mountains. The species reaches its maximum development in the mountains and high mesas west of the Continental Divide in Colorado (Baker, 1925). On the better sites aspen yields a greater volume of wood in a shorter period than most of the conifers growing at comparable elevations.

The present study was undertaken to determine the relationship of decay in stands in different areas and of different ages.

REVIEW OF PREVIOUS WORK

Baker (1925), who made a study of aspen in the central Rocky Mountains, states: "It is found that while growth is more rapid in New England, deterioration and decay take place earlier, so that the maximum and average sizes are about the same in the two regions and stands are very similar." Likewise, growth is more rapid in the better aspen areas of the Lake States, but deterioration is also more rapid there. Baker, who set up a criterion of site quality based on height growth, states that aspen grows on a wide variety of soil types.

The studies of Meinecke (1929) in one locality in Utah indicate that most of the rot in aspen was caused by Fomes igniarius var. populinus (Neu.) Campb.[2/] and F. applanatus (Pers. ex Wallr.) Gill. Decay was minor in the younger age classes and increased with age. Decay accounted for 18 percent of the gross volume in the 101- to 110-year age class, and 41 percent in the 121- to 130-year class.

Schmitz and Jackson (1927), working in Lake States aspen, regarded trunk rot caused by F. igniarius as the primary loss, but they also recognized Armillaria mellea (Fr.) Quel. and F. applanatus as important decay fungi.

2/ This fungus is hereafter abbreviated F. igniarius.

Schrenk and Spaulding (1909) point out that in New England, as well as in Colorado and New Mexico, it is almost impossible to find stands of any age that are free from F. igniarius.

Russian investigators have conducted many studies on the decay of European aspen (Populus tremula L.) which is closely related to P. tremuloides. Ankudinov (1939) who reviewed the earlier Russian work on this subject states that, as in North America, F. igniarius is the most important decay fungus. He reports that there was no consistent relationship between the amount of decay and site quality, or between decay and individual tree dominance. To minimize decay losses, Ankudinov recommends: (1) controlling the stand density by early thinning, and (2) eliminating stems that are injured, insect damaged, or broken topped, thus removing those most susceptible to F. igniarius.

Riley (1952) reported on the decay of aspen in Ontario caused by F. igniarius. In stands up to 70 years old no relation between decay and site could be demonstrated where cubic foot volumes were used, but a slightly higher percentage of cull occurred on the poorer sites when the trees were measured in board feet. Basham (1958), also working in Ontario, reported that three types of heart rots were important: white spongy rot caused by F. igniarius, yellow stringy rot caused by Radulum casearium (Morgan) Lloyd, and stringy butt rots from which several fungi, notably Pholiota spectabilis Fr. and A. mellea, were isolated. A pronounced relationship between age and decay was found. The relationship between decay and soil conditions was less pronounced although trees on drier sites were somewhat more decadent than those on moist ones.

LOCATION AND TYPE OF STANDS SAMPLED

Samples for the present study were all located in western Colorado in stands considered to be among the best in the region. The work was carried out in the summers of 1954, 1955, and 1956.

Sample plots were at elevations between 8,000 and 10,000 feet, where aspen frequently occurs in almost pure stands. At the lower limits serviceberry, scrub oak, and in some places Douglas-fir and ponderosa pine may be intermixed, while at the higher elevations there is often an understory of spruce and subalpine fir. The better aspen stands in Colorado have abundant undergrowth of herbaceous plants, which is considered excellent forage for sheep. The climatic, soil, and moisture requirements for aspen in the central Rocky Mountain region are discussed by Baker (1925).

METHODS

Study plots of typical commercial aspen forests were located in old and medium-aged stands. Isolated small patches of aspen were not sampled nor were stands at the lower elevations where growth is poor and commercial values are marginal. The mensurational data were taken to correspond with current practices for pulpwood sales in this area. Either 1/10- or 1/20-acre plots were used, depending on the time available. All trees over 4.0 inches d.b.h., and a few below this limit, were felled and dissected. The trees were cut into 4- or 8-foot bolts to a minimum top diameter of 4.0 inches d.i.b.[2] Where decay was encountered, the bolts were further dissected to determine the extent of decay. Samples for isolation were removed from decay infections where the causal fungus was in doubt. Age was determined from sample disks taken at stump height and later examined in the laboratory with a binocular microscope. Wood volume was calculated for each bolt by Smalian's formula. Rot volumes were calculated in the same way except that where rot ended within a bolt it was treated as a cone.

RESULTS

A total of 976 trees was dissected on 35 plots in 5 national forests in western Colorado (fig. 1). Decay was found in 517 trees (53.0 percent) and averaged 8.4 percent of the total gross volume on the plots studied. Trunk rots accounted for 5.0 percent of the gross volume, and butt rots 3.4 percent. The basic plot data by site classes are given in table 1. The aspen stands studied were in site classes 1 to 3, according to Baker's (1925) site classification. The average height of dominant trees at 100 years is 81 feet on site 1, 74 feet on site 2, and 63 feet on site 3. Nine of the plots were two-aged rather than even-aged, and on these each age class was analyzed separately.

3/ About 60 percent of the trees were felled in 1954 and 1955 when 4-foot bolts were cut. In 1956, trees were cut into 8-foot bolts except the top bolt was 4 feet if it was too small to yield an 8-foot bolt. A trimming allowance of 0.25 foot was used for all bolts. The trimming allowance was not included in the volume totals for the 1954 and 1955 work but it was included for the trees cut in 1956. These variations in technique should have little effect on the overall results, which at best, can only be considered as indicative of general trends. Because of the great variation in the amount of decay in plots in the same age and site class, the slight deviations due to different techniques should be of little significance in determining rot percentages.

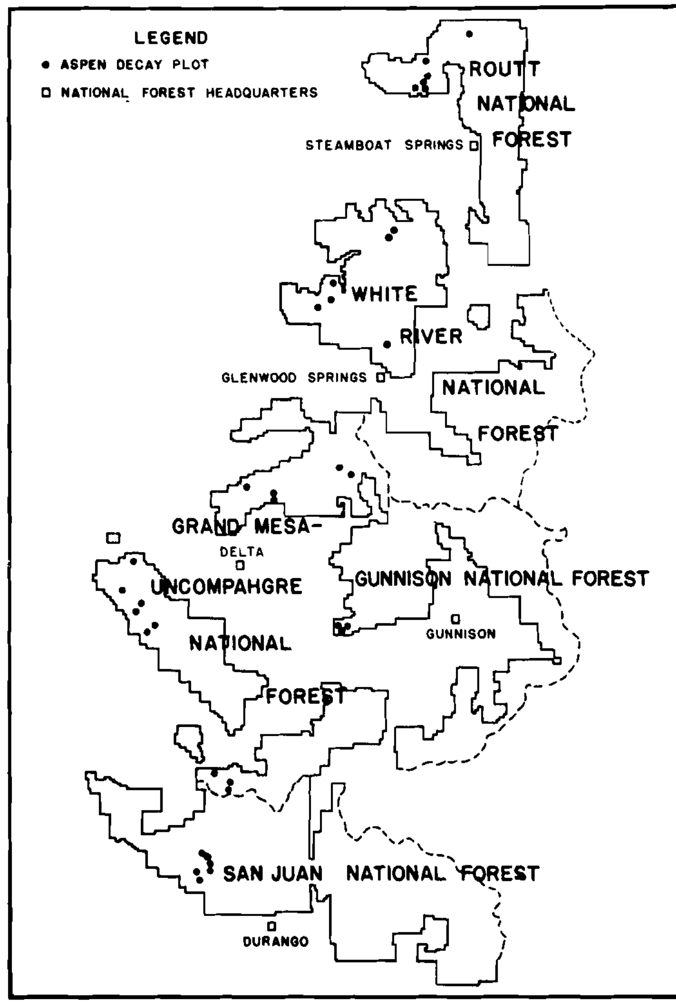
Table 1. --Basic plot data by site classes

Plot No. [1/]	Tree basis	Average age	Average d.b.h.	Total gross volume	Decay: Butt	Decay: Trunk	Decay: Total
	Number	Year	Inches	Cubic feet	- -	Percent	- -
			SITE 1				
SJ-7(b)	22	41	6.7	123.8	0	0.8	0.8
WR-13	53	52	6.9	256.1	0	1.9	1.9
G-14	33	58	7.6	240.7	0.2	4.7	4.9
GM-U-1(b)	23	63	6.1	89.6	3.2	2.0	5.2
G-12(b)	19	66	7.8	174.3	2.0	3.5	5.5
SJ-4	25	68	9.7	321.2	2.5	3.3	5.8
R-16	50	70	8.1	476.6	.8	.4	1.2
SJ-5	27	72	9.9	380.4	.4	1.1	1.5
SJ-7(a)	27	73	9.8	406.6	1.3	0	1.3
GM-U-3	30	74	9.0	493.7	1.8	.8	2.6
G-13	34	77	10.5	620.9	.8	1.1	1.9
GM-U-4	21	86	12.1	540.7	.7	1.0	1.7
R-18	19	114	12.3	448.3	.2	1.7	1.9
G-12(a)	6	119	14.1	200.7	.7	5.8	6.5
R-21	10	126	14.9	291.1	1.9	10.4	12.3
GM-U-1(a)	16	150	17.3	811.2	16.8	.5	17.3
GM-U-2	18	170	15.8	833.9	9.0	6.0	15.0
Total or average	433	78	10.5	6,709.8	3.9	2.4	6.3
			SITE 2				
SJ-8	19	55	6.0	66.7	1.4	1.6	3.0
GM-U-8(b)	29	57	6.3	96.0	.2	.5	.7
R-19(b)	12	65	7.2	59.5	1.3	6.7	8.0
R-17	27	69	7.6	173.5	.4	3.2	3.6
GM-U-5	39	72	9.9	488.1	.1	2.2	2.3
WR-12	26	73	9.3	254.2	1.8	1.7	3.5
GM-U-6	28	73	10.0	365.7	4.0	1.0	5.0
GM-U-7	28	83	10.3	420.9	.2	3.3	3.5
R-20	10	107	14.2	299.9	.1	0	.1
WR-10	24	110	10.7	486.2	.6	9.5	10.1
G-11	17	112	11.7	369.0	7.1	8.9	16.0
R-19(a)	13	115	12.8	277.9	2.1	21.0	23.1
WR-11	10	115	12.5	238.4	.5	3.9	4.4
GM-U-9	21	116	12.0	442.1	6.0	2.9	8.9
GM-U-8(a)	8	135	18.2	352.0	19.0	3.0	22.0
SJ-9	11	152	11.8	246.3	2.5	19.9	22.4
SJ-6	32	153	10.5	566.1	1.7	9.4	11.1
Total or average	354	93	10.6	5,202.5	3.3	6.1	9.4
			SITE 3				
WR-14	40	53	5.2	75.6	1.0	.8	1.8
WR-15(b)	9	59	4.8	9.5	0	3.1	3.1
GM-U-11(b)	12	63	5.6	21.4	0	5.3	5.3
GM-U-12(b)	14	66	6.8	68.4	.1	1.9	2.0
GM-U-10	60	66	5.8	113.6	.2	2.0	2.2
G-10(b)	23	66	6.6	75.4	1.5	6.0	7.5
WR-15(a)	5	104	12.5	92.8	4.1	12.1	16.2
GM-U-11(a)	10	130	14.0	280.1	1.2	22.6	23.8
GM-U-12(a)	4	130	17.4	149.1	5.5	10.5	16.0
G-10(a)	12	131	13.8	328.8	2.6	22.0	24.6
Total or average	189	73	9.2	1,214.7	2.2	14.2	16.4
Grand total or average	976	82	9.3	13,127.0	3.4	5.0	8.4

1/ SJ = San Juan National Forest (plots established in 1954 or 1955)
WR = White River National Forest (plots established in 1954 or 1955)
G = Gunnison National Forest (plots established in 1956)
GM-U = Grand Mesa-Uncompahgre National Forest (plots 1-3 established in 1954 or 1955; plots 4-12 established in 1956)
R = Routt National Forest (plots established in 1954 or 1955)

Two-aged stands are indicated by lower-case letters in parentheses. For example, on plot SJ-7 there were 22 trees in the 41-year class [SJ-7(b)] and 27 averaging 73 years old [SJ-7(a)].

Figure 1. --Map of western Colorado showing the location of the 35 aspen decay plots.



A detailed fire history for the aspen areas was not available. However, the younger stands up to 80 years are approximately even-aged and are assumed to have originated following fire. There is considerable evidence that stands also originate from causes other than fire. For instance, many of the older stands (80 to 120 years or older) tend to break up rapidly because of disease, insects, or drought. Sometimes the result is a new even-aged stand, or there may be only a thinning out of the older stems, permitting sprouts to develop as an even-aged understory.

RELATIONSHIP BETWEEN DECAY AND AGE

The relationship between the amount of decay and stand age is shown in figure 2. Although there is little relationship between decay and site class for the younger stands, the differences are

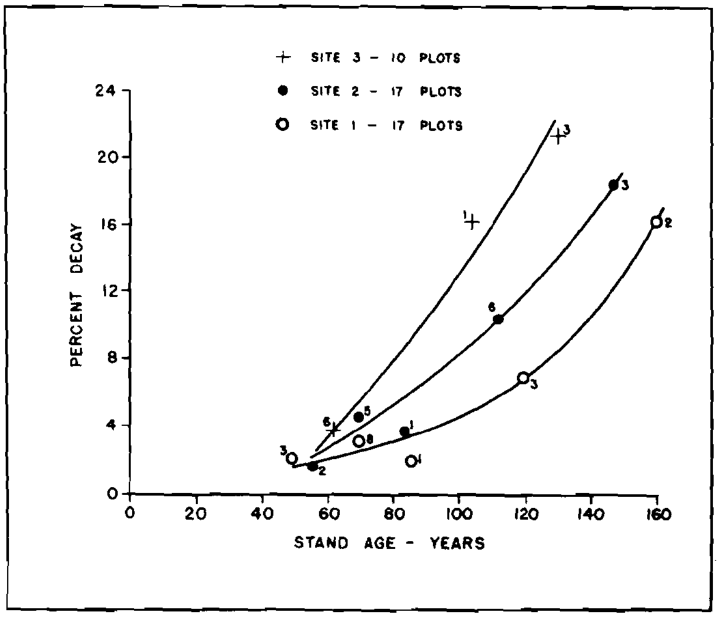


Figure 2. --Relationship between percent decay and age on three site classes.

marked in stands over 100 years old. The decay curves in figure 2 should be considered tentative because of the great variation in decay in some plots of comparable ages and site classes. A summary from figure 2 of the average amount of decay in stands of different ages on the 3 sites is as follows:

Stand age in years	Percent decay Site 1	Site 2	Site 3
60	2	3	3
80	3	5	7
100	4	8	13
120	7	12	19
140	11	17	27

The amount of decay in stands under 40 years old was negligible on all 3 sites. In 100-year-old stands, decay averaged 4 percent on site 1, 8 percent on site 2, and 13 percent on site 3.

Some of the variations in decay in plots of comparable ages and sites can be explained, but others cannot. For instance, the high volume of butt rot in some of the older plots is due to decay following fire wounding about 80 years ago. Some of these old wounds were still open and extended to a considerable height on the trunks. In other older stands the wounds had not been so severe and although decayed, had become almost completely healed over in the 80-year period. Fire wounds were not common in any of the stands under 85 years old. One of the main reasons for variations in rot volume was that F. igniarius was rare or absent in some stands.

The incidence of decay in Colorado aspen is considerably lower than that reported by Meinecke (1929) for this species in one locality in northern Utah:

Age class in years	Percent decay: Utah Sites 1 and 2	Percent decay: Colorado Sites 1 and 2
91-100	11	6
101-110	18	7
111-120	26	9
121-130	41	11

Basham (1958) noted that for aspen in Ontario the ratio of butt rots to trunk rots was highest on the driest sites. In the present study in Colorado, butt rots amounted to 62, 35, and 13 percent of all decay volume on sites 1, 2, and 3, respectively.

FUNGI ASSOCIATED WITH ASPEN DECAY[4/]

Identifications of the decay fungi were made for 60 percent of the infections; these accounted for 69 percent of the total decay volume as shown below. The figures are based on 672 decay infections and a decay volume of 1,145.8 cubic feet.

Type of decay	Infections (Percent)	Decay volume (Percent)
Identified decays:		
Trunk rots	39	52
Butt rots	21	17
	60	69
Unidentified decays:		
Trunk rots	11	17
Butt rots	29	14
	40	31

4/ The authorities for the scientific names of the fungi found in this study are given in table 2.

Identified decays accounted for 75 percent of the trunk rot volume but only 55 percent of the butt rot volume. The 17 decay fungi identified and their relative importance are shown in table 2. Some of the fungi listed require further study for positive identification, and there are undoubtedly others that cause decay but have not yet been identified.

Table 2.--Fungi associated with identified aspen decays

Fungus	Infections		Decay volume	
	Number	Percent	Cu. ft.	Percent
Trunk rots:				
Cryptochaete polygonia (Fr.) Karst.	114	28.3	75.7	9.6
Fomes igniarius var. *populinus* (Neu.) Campb.	104	25.9	466.9	59.1
Libertella sp.	38	9.5	36.2	4.6
Polyporus dryophilus Berk. var. *vulpinus* (Fr.) Overh.	3	.7	12.1	1.5
Daldinia concentrica (Fr.) Cs. & DeNot.	2	.5	.5	.1
Trechispora brinkmannia (Bres.) Rogers & Jacks.	1	.3	8.3	1.0
Total trunk rots	262	65.2	599.7	75.9
Butt rots:				
Collybia velutipes Curt. ex Fr.	48	11.9	78.7	10.0
Fomes applanatus (Pers. ex Wallr.) Gill.	32	8.0	49.8	6.3
Pholiota squarrosa (Fr.) Kummer	18	4.5	20.2	2.5
Coniophora sp.	14	3.5	.5	.1
Pleurotus ostreatus (Fr.) Kummer	9	2.2	13.7	1.7
Polyporus adustus Willd. ex Fr.	7	1.7	4.4	.6
Trechispora raduloides (Karst.) Rogers	5	1.2	19.5	2.5
Armillaria mellea (Fr.) Quel.	3	.7	Trace	--
Polyporus pargamenus Fr.	2	.5	Trace	--
Tricholoma unifactum Peck	1	.3	3.3	.4
Radulum casearium (Morgan) Lloyd	1	.3	Trace	--
Total butt rots	140	34.8	190.1	24.1
Total trunk and butt rots	402	100.0	789.8	100.0

More species of fungi were isolated from butt decay than trunk decay, although the number of decay infections was about the same in each category. Trunk rots accounted for about two-thirds of the total decay volume; butt rots, one-third. In this study *F. igniarius* and *Cryptochaete polygonia* were classified as trunk rots, although in the case of *F. igniarius* especially, the rot was sometimes concentrated in the butt. *Collybia velutipes* was usually isolated from butt rot, but is known to invade trunk wounds of some tree species.

Of the six species classed as trunk decays, C. polygonia (fig. 3) was isolated and identified most frequently (28 percent of identified infections). A preliminary account of this fungus from Colorado aspen was given by Davidson and Hinds (1958). Since C. polygonia does not fruit readily on infected living trees, it could be identified only from isolations. There were many additional decay infections that appeared to be this fungus, but which were not positively identified either because of failure to obtain a culture or the isolate was of a secondary non-decay species.

Decay caused by C. polygonia was white, often with a reddish-brown margin. The decay was usually suggestive of an incipient stage and never appeared to be in an advanced stage of disintegration. When it was exposed on cross cuts with a power saw, the infected wood seemed to be more brittle than normal wood and the fibers were pulled out rather than cut cleanly. Entrance was almost entirely through branch stubs. Incipient decay of F. igniarius (fig. 3) can be distinguished from that of C. polygonia only when the black marginal line, usually characteristic of the former, is present. F. igniarius caused much greater volume loss than any of the other decay fungi (59 percent of the volume associated with identified decays). In stands younger than about 80 years, both the proportion of trees infected and the amount of decay per tree was low.

Trees infected by F. igniarius had an average of 25 percent decayed volume. This average includes incipient infections in young trees so the volume of decayed wood in the older stands where sporophores are present is somewhat higher.

Polyporus dryophilus var. vulpinus, which causes a white pocket trunk rot, was isolated only three times. These infections were from older trees. Daldinia concentrica was present in two living trees but it caused little decay.

F. applanatus seems to be the most important butt and root rot, chiefly because it results in windthrow. The rot is white mottled and it was consistently concentrated in the large roots and basal part of the stem (fig. 4). In almost all aspen stands observed, there were numerous trees that had blown over while still alive. Nearly all these had roots rotted off by F. applanatus. The decay affects both sapwood and heartwood but usually does not extend far above stump height. The principal courts of entry are not known in detail, but presumably are in the roots, since above-ground wounds were not associated with this decay.

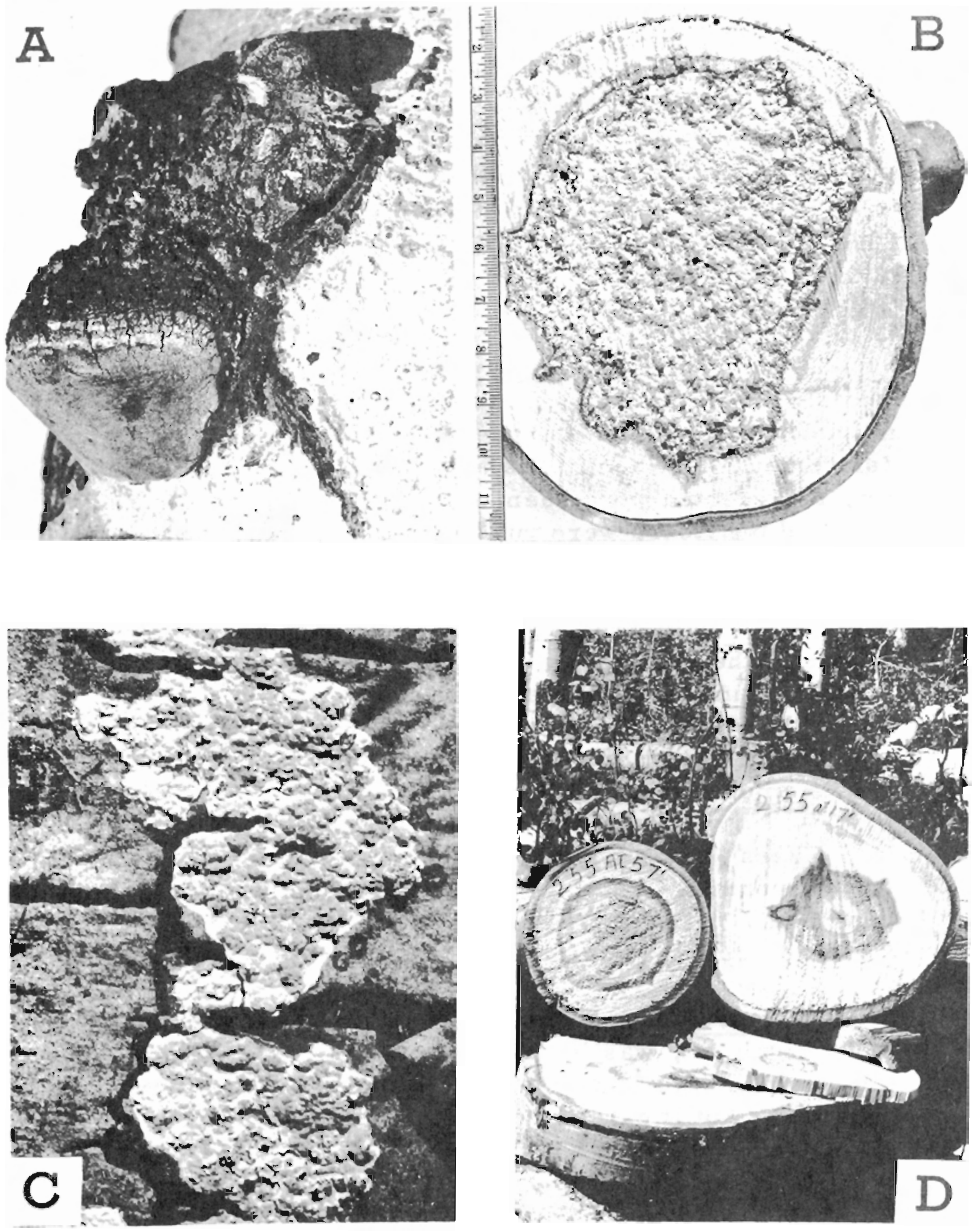


Figure 3. --Important trunk decays in aspen. A and B. Fomes igniarius var. populinus, the fungus responsible for about 60 percent of the total decay. A. Sporophore (X 9/10), and B. Cross section of stem showing typical decay (X 1/3). C and D. Cryptochaete polygonia, the fungus that was isolated most frequently but caused only about 10 percent of the total decay. C. Sporophores on dead branch (X 1-7/10) and D. Decay (X 1/10).

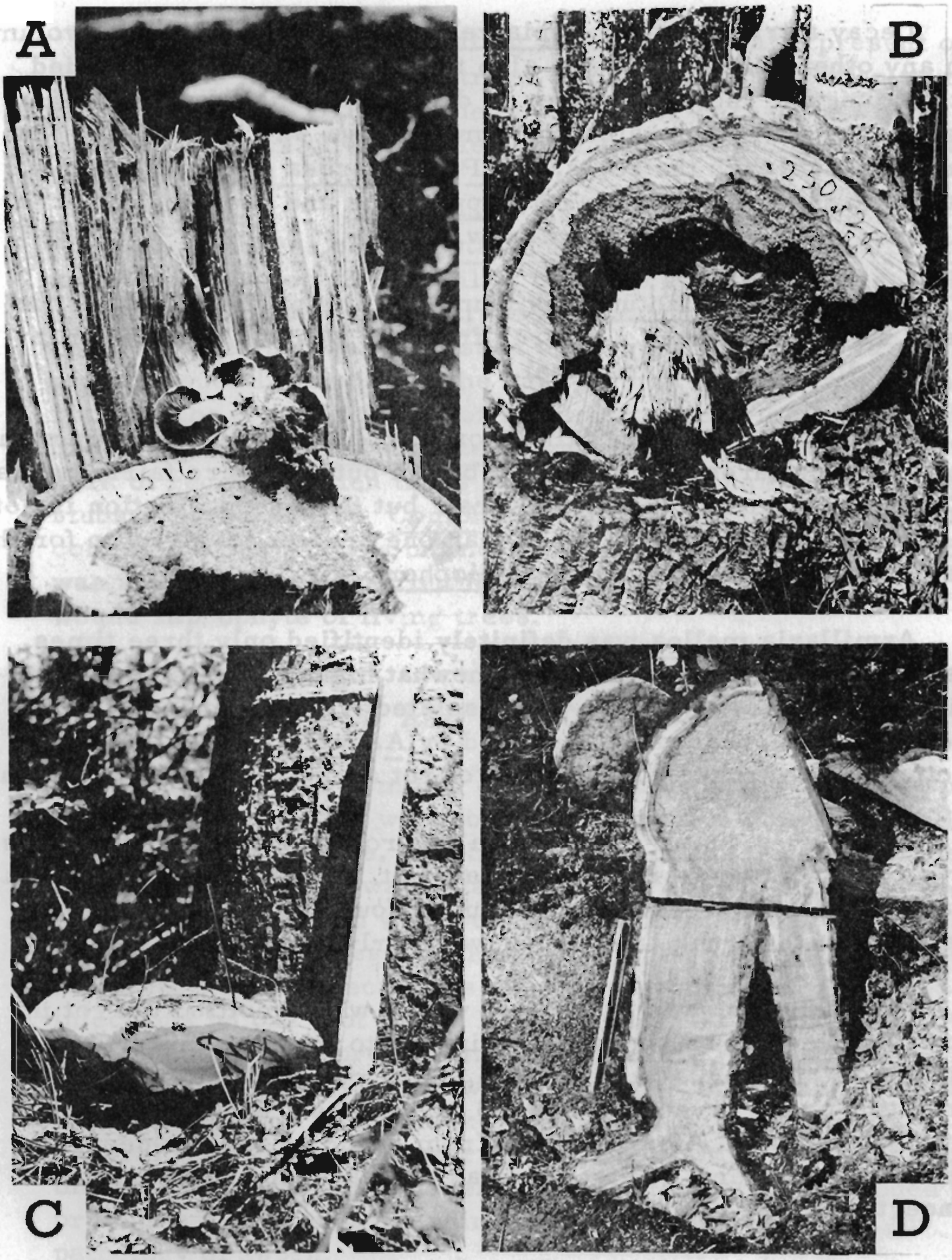


Figure 4. --Important butt rots in aspen. A and B. Sporophores and decay of Pholiota squarrosa (both approximately X 1/6). C and D. Fomes applanatus, a butt rot that also acts parasitically and causes weakening of the roots and windthrow. C. Sporophore at base of living tree (X 1/6). D. Top view of sporophore, cross section of decayed stem, and longitudinal section showing decay in the stump and roots (X 1/12).

Decay attributed to Collybia velutipes had a larger total volume than any other butt rot. It was also the most frequently identified butt rot fungus. Incipient stages of decays associated with Pholiota squarrosa and F. applanatus are similar (fig. 4). Entrance of both seems to be through the roots, but P. squarrosa does not act as a parasite to the same extent as F. applanatus and does not result in weakening and subsequent windthrow.

Tricholoma unifactum was found fruiting on the ground at the base of an infected tree. Cultures from the sporophores and from the rot in the tree were identical.

Brown butt rots were fairly common, especially in young stands. Some of the cultures obtained from brown butt rot were fairly typical of Coniophora puteana (Schum.) Karst. but their identification is not yet certain. There may be more than one species involved so for the present they are grouped under Coniophora sp.

Armillaria mellea was definitely identified only three times. Its actual frequency is probably somewhat higher as this fungus is difficult to isolate. No fungi were isolated from a number of decay infections that appeared to be caused by A. mellea. The identified infections were from small pockets of rot associated with basal wounds.

Polyporus adustus occurs as a sap rot associated with wounds but was not isolated from typical heart rot. Pleurotus ostreatus was isolated from nine trees. It was usually found as a heart rot in the lower part of the trunk, and decay was fairly extensive.

Libertella sp. was associated with a white mottled top rot in 38 trees. This decay has an odor similar to green walnut hulls. Cultures of this fungus have a dense, buff, cottony mat, with dark sporulating areas developing after 3 to 4 weeks. Etheridge and Laut (1958) isolated Libertella sp. from sound as well as decayed aspen wood in Alberta so its status as a decay-producing organism is uncertain.

SPOROPHORES OF ASPEN DECAY FUNGI

Most trees with extensive F. igniarius decay had conspicuous fruiting bodies on the trunk (fig. 3-A). The number of such fruiting bodies, which usually form at old branch stub traces, is an indication of the longitudinal spread of decay inside the trunk.

Fomes applanatus fruiting bodies are usually present on the bases of the infected living trees (fig. 4-C) but are often so near the base as to be partly hidden by grass or herbaceous plant growth or leaf litter. Fruiting bodies continue to develop after the trees are windthrown.

Sporophores of *Pholiota squarrosa* (fig. 4-A) and *Tricholoma unifactum* develop on the soil at the base of infected trees. *Pleurotus ostreatus* and *Collybia velutipes* frequently fruit on dead standing or down trees but were not seen on living trees. The latter were most frequently formed at the base of the trunks or from dead roots. The fruiting bodies of *Daldinia concentrica* were seen on one living tree. *Cryptochaete polygonia* fruits abundantly on the bark of recently fallen trees and only occasionally on dead branch stubs of living trees. *Coniphora puteana* sporophores have been collected on aspen logs but not on living trees. *Polyporus adustus* was also found on logs, but in a few instances it appeared to be a wound saprophyte of living trees.

WETWOOD AND ASSOCIATED DEFECTS

Wetwood is a common defect in many hardwood tree species. In some aspen stands wetwood infections were common, while in others they were rare. No information on the possible influence of wetwood on decay was obtained in this study. Wetwood was commonly associated with wood borers and in these instances decay was rarely present. However, when wetwood was associated with wounds, decay was usually present also. Wetwood infections on one plot on the Routt National Forest appeared to be associated with prominent frost cracks. However, other stands in the same vicinity with a high proportion of wetwood infections had no frost cracks. Bacteria cause wetwood in several tree species (Carter 1945), but no study was made on the cause of wetwood in aspen. More information is needed to provide a better understanding of the role of wetwood in the pathology of aspen.

SUMMARY

A total of 976 aspen trees over 4.0 inches in diameter were felled and dissected on thirty-five 1/10- or 1/20-acre plots on 5 national forests in western Colorado. Decay was found in 53 percent of the trees and accounted for 8.4 percent of the gross volume. There was a definite relationship between stand age and decay and between site quality and decay. In 50-year-old stands the average amount of decay (cubic foot basis) was less than 2 percent on sites 1, 2, and 3. In 100-year-old stands, the decay averaged 4, 8, and 13 percent for sites 1, 2, and 3, respectively. Identified decays accounted for about two-thirds of the total decay volume. Cryptochaete polygonia was the most frequently isolated decay fungus (28 percent of identified infections) but Fomes igniarius var. populinus caused the greatest volume loss (59 percent of decay associated with identified infections). Most of the butt rot was caused by Collybia velutipes, Fomes applanatus, and Pholiota squarrosa. C. velutipes was associated with the greatest volume of butt decay, and it was also the most frequently isolated butt rot fungus. F. applanatus is important as it is a root parasite and causes weakening and windthrow.

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