1977

Growth and decay losses in Colorado aspen

Thomas E. Hinds

E.M. Wengert

USDA Forest Service
Research Paper RM-193

October 1977

Growth and Decay Losses in Colorado Aspen

Thomas E. Hinds, Plant Pathologist
and
Eugene M. Wengert, Wood Technologist[1]
Rocky Mountain Forest and Range Experiment Station[2]

[1]Extension Specialist, Virginia Polytechnic Institute and State University, Blacksburg, Virginia; formerly with Forest Products Laboratory, USDA Forest Service, Madison, Wisconsin, stationed at Rocky Mountain Forest and Range Experiment Station, Fort Collins.

[2]Station's central headquarters maintained at Fort Coll'ns, in cooperation with Colorado State University.

Contents

Growth and Decay Losses in Colorado Aspen

Thomas E. Hinds and Eugene M. Wengert

Quaking aspen (*Populus tremuloides* Michx.) stands in Arizona, Colorado, New Mexico, Utah, and Wyoming (fig. 1) contain an estimated 7.1 billion bd ft of sawtimber (Green and Setzer 1974). On favorable sites, aspen yields a greater volume of wood in a shorter period of time than most conifers growing at comparable elevations (Baker 1925, Miller and Choate 1964). Current annual harvest, however, is less than desirable for proper management — only about 10 million bd ft per year in the five-State area. Better utilization is required to maintain the aspen forest and the wildlife habitat, recreation, grazing, watershed, and scenic beauty that it provides.

Decay is one of the factors that limit utilization; even small amounts of decay increase harvesting and processing costs and reduce yields considerably. Therefore, it is important that present and future stands, in which cutting is to be a management tool, be evaluated in terms of expected decay losses.

Only three studies have dealt with aspen defect in the Rocky Mountains. Baker (1925) studied stands in central Utah, but felt that his results generally would be applicable throughout the five-State area. His criteria for site quality and growth and volume tables are still used.

Meinecke (1929) studied similar stands in central Utah to determine the causes of cull and their role in stand management. A study by Davidson et al. (1959) on the type and amount of decay in Colorado aspen revealed that the incidence of decay was considerably lower than that reported by Meinecke.

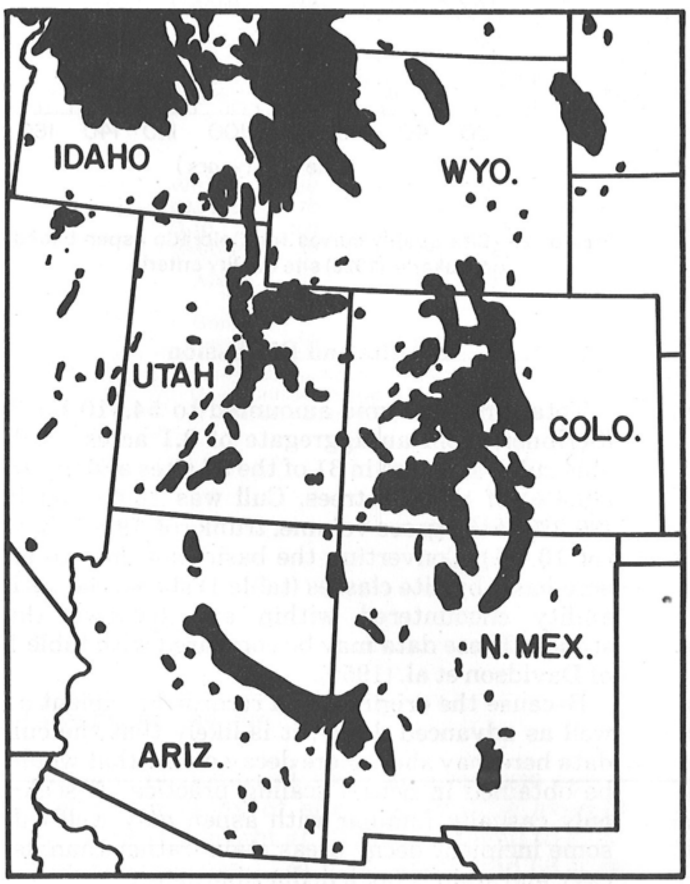

Figure 1.—Range of aspen in the central and southern Rocky Mountains (Little 1971).

The above studies dealt with cubic volumes on the assumption that aspen would be harvested for pulpwood. In view of the principal utilization of Rocky Mountain aspen sawtimber for lumber today, and its anticipated use in the future, we reanalyzed Davidson's data on a linear volume basis.

Procedures

The original data were collected from 976 trees 4.0 in d.b.h. and larger, on 35 plots (mostly 1/10 acre) located throughout western Colorado at elevations between 8,000 and 10,000 ft. The almost pure stands were considered to be among the best in the region (Davidson et al. 1959). In 1954 and 1955, trees were sawn every 4 ft along the merchantable stem to a 4-in d.i.b. (diameter inside bark) top. In 1956, stems were sawn every 8.25 ft. At each saw cut, starting at the stump (1 ft above the ground), d.i.b. and diameter of any decay column were measured. Tree age was determined at stump height. The decay fungi were identified by isolation techniques when the causal fungus was in doubt.

To measure gross and net tree volumes in board feet, the logs were reconstructed into 16.5 ft lengths; we linearly interpolated between measured points when necessary. The logs were then scaled using the National Forest Log Scaling Handbook (USDA Forest Service 1973) procedures as given in paragraphs 22.4 and 22.5 for defect deduction by the squared-defect method and table 2 for Scribner Decimal C volumes. When the defect diameter was the same or nearly the same as the scaling diameter, but did not extend more than 12 ft up the log, the length-deduction method was applied. Decay was assumed to be circular and concentric with the log diameter.

The merchantability standards used in this reevaluation were:

minimum tree d.b.h.:	8 in
minimum top d.i.b.:	6 in
minimum butt log length	16 ft
minimum top log length	8 ft

Of the 976 trees in the original study, 563 trees from 33 plots met these standards (were merchantable from a size standpoint) and are the basis for the information presented here. Although trees on 25 plots were uneven-aged rather than even-aged, the plots were considered typical of the pure aspen stands in Colorado. The site class determination was made on the basis of the dominant trees on the plots.

Baker's (1925) site quality criteria were used in this analysis. The site criteria were plotted as site index curves (fig. 2). Only four curves are shown since he considered trees less than 40 ft tall at maturity as belonging to the unmerchantable-thicket type of aspen of site quality 5.

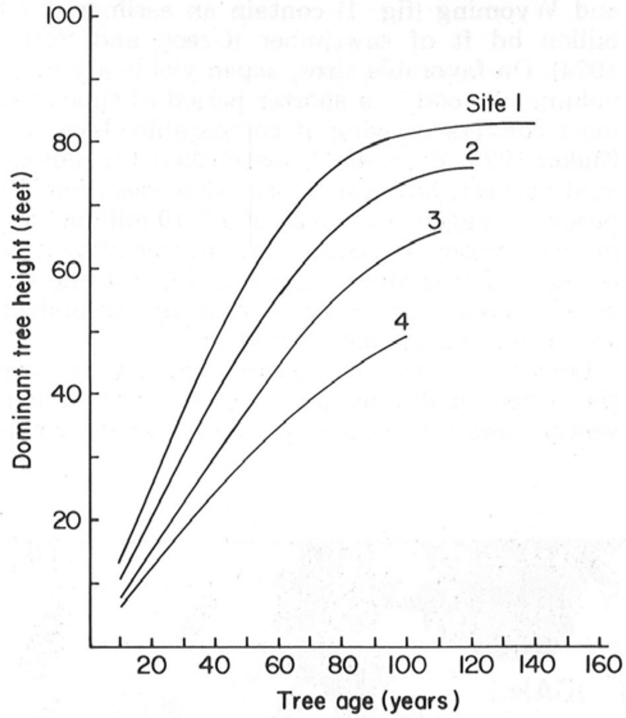

Figure 2.—Site quality curves for Colorado aspen based on Baker's (1925) site quality criteria.

Results and Discussion

Total gross volume amounted to 54,410 bd ft (Scribner) from an aggregate of 3.1 acres. Scalable cull was found in 31 of the 33 sites and in 278 (49.4%) of the 563 trees. Cull was 16,405 bd ft (30.2% of the gross volume: trunk rot 19.8%, butt rot 10.4%). Converting the basic plot data to an acre basis by site classes (table 1) shows the variability encountered within and between the stands. These data may be compared with table 1 of Davidson et al. (1959).

Because the original data recorded incipient as well as advanced decay, it is likely that the cull data here may show more decay defect that would be obtained in actual scaling practice. A scaler only casually familiar with aspen may well call some incipient decay areas stain (rather than decay), and stain is not a deductible defect.

Table 1.—Basic plot data (per acre basis) by site class for merchantable trees in Colorado

Plot No.[1]	No. Trees	Age Range	Age Average	D.B.H. Range	D.B.H. Average	Gross volume	Decay cull Butt	Decay cull Trunk	Decay cull Total
		Years		In		Bd ft	...... Percent	......	
				SITE 1					
SJ-7	290	41-80	67	8.7-12.9	10.2	20,250	12.9	0.0	7.4
SJ-4	220	60-75	68	8.3-13.8	10.1	13,250	35.1	18.0	27.9
SJ-5	240	65-75	72	8.1-12.8	10.2	15,650	10.3	0.0	5.8
G-14	130	61-140	75	8.0-19.6	11.6	12,000	32.9	53.2	40.8
R-16	270	66-124	76	8.0-16.2	9.7	16,950	5.4	6.5	5.9
GM-U-3	210	64-91	77	8.0-13.0	10.5	22,400	12.5	11.4	11.8
G-13	330	70-82	78	8.0-13.2	10.6	25,350	18.7	8.3	14.0
GM-U-4	180	70-133	89	9.5-17.0	13.1	24,250	3.2	6.9	4.9
G-12	150	73-160	100	8.4-15.3	12.0	15,950	34.1	30.3	32.3
R-18	190	97-125	113	9.7-15.5	17.1	21,600	5.7	6.4	6.0
R-21	200	87-138	126	10.2-18.6	14.6	28,700	36.8	19.2	27.5
GM-U-1	170	66-159	141	8.8-22.2	16.6	42,100	73.1	18.0	41.8
GM-U-2	180	162-170	168	14.1-18.2	15.8	44,750	78.5	37.8	52.2
Aver.	212	41-170	91	8.0-22.2	12.0	23,320	31.3	18.2	24.5
				SITE 2					
WR-13	90	52-57	53	8.0-10.9	9.1	3,900	0.0	0.0	0.0
SJ-8	100	57	57	9.0	9.0	5,000	0.0	0.0	0.0
R-17	180	69-72	71	8.2-10.7	9.5	7,800	15.4	3.8	11.5
GM-U-5	320	64-93	73	8.0-14.5	10.5	17,100	9.0	0.0	6.4
WR-12	200	66-115	75	8.0-11.4	9.6	8,800	23.4	5.8	18.2
GM-U-7	220	46-132	89	8.0-15.8	11.3	15,250	18.4	16.2	17.7
GM-U-6	180	75-111	95	10.5-14.6	12.1	14,100	41.5	2.1	28.4
R-19	160	63-126	106	8.7-15.9	12.2	14,750	55.3	47.2	51.9
R-20	100	99-120	107	10.2-18.6	14.2	14,950	1.3	0.0	0.7
GM-U-8	120	54-135	111	8.4-20.7	15.1	16,150	75.3	20.4	52.0
WR-10	220	97-160	113	8.4-13.8	11.1	19,700	36.4	31.6	34.0
WR-11	110	105-125	114	9.8-15.0	12.4	12,200	10.3	20.3	15.6
GM-U-9	170	77-152	126	9.0-16.5	13.5	18,350	52.8	30.3	43.3
G-11	160	112-155	130	9.3-17.8	12.0	15,750	58.0	41.2	49.8
SJ-6	310	130-170	147	8.6-12.6	10.7	26,700	35.9	30.4	33.1
SJ-9	240	138-160	148	8.4-14.4	11.9	26,600	75.8	46.5	60.2
Aver.	180	46-170	105	8.0-18.6	11.5	14,800	36.1	24.8	31.2
				SITE 3					
WR-15	50	96-123	106	10.6-14.2	12.8	4,150	73.1	48.4	63.9
GM-U-12	70	71-160	108	8.3-15.3	14.4	7,600	70.2	51.7	63.2
G-10	160	66-165	113	8.0-19.3	12.6	15,450	61.7	69.6	70.9
GM-U-11	110	84-150	125	9.1-21.2	13.5	12,750	65.3	53.3	60.4
Aver.	97	66-165	115	8.0-21.2	13.2	10,000	69.6	59.0	65.4
Grand Average	182	41-170	99	8.0-22.2	11.9	16,000	36.5	23.1	30.2

[1]SJ — San Juan National Forest
G — Gunnison National Forest
R — Routt National Forest
GM-U — Grandmesa-Uncompahgre National Forest
WR — White River National Forest

Growth and Volume

Height of dominant trees at a specific age is used as an index of site quality. The average dominant tree height at 100 yr was found to be 81 ft on Baker's site 1, 74 ft on site 2, and 63 ft on site 3. Average growth of aspen in Colorado is somewhat greater than that reported by Baker (1925) for Clear Creek, Utah, where trees averaged 10.6 in d.b.h. and 68.5 ft in height at 100 yr on site 1. The average d.b.h., height, gross volumes, and percent decay defect of merchantable

Table 2.—Average d.b.h., height, gross volume, and percent decay defect of merchantable trees[1], by 10-yr age classes

Tree age	Site 1						Site 2					
	D.B.H.	Ht	Cu ft volume	Decay	Bd ft volume	Decay	D.B.H.	Ht	Cu ft volume	Decay	Bd ft volume	Decay
Years	*In*	*Ft*	*Ft³*	*Percent*	*Bd ft*	*Percent*	*In*	*Ft*	*Ft³*	*Percent*	*Bd ft*	*Percent*
50	9.3	60	10.8	0	45	0	(8.1	56	7.3	1	20	0)
60	8.9	64	11.6	3	45	11	9.4	55	9.7	7	35	20
70	10.2	70	15.3	2	70	10	9.6	58	11.3	4	45	15
80	10.7	73	19.1	2	75	11	10.8	60	15.2	0	60	1
90	12.9	77	29.2	2	140	12	11.7	63	18.5	3	70	16
100	(10.9	73	18.1	0	85	0)	12.4	69	22.2	1	105	8
110	12.3	75	23.7	2	110	31	11.8	71	21.8	8	100	22
120	13.2	73	26.1	7	120	16	12.5	68	22.7	15	100	45
130	14.3	78	30.8	10	145	26	11.6	69	19.7	14	90	40
140	16.9	75	44.3	13	230	32	15.3	69	33.8	19	160	60
150	17.5	81	50.5	20	260	51	12.0	71	23.0	14	130	54
160	(16.8	83	54.3	8	290	40)	13.3	72	27.6	15	185	62
170	15.7	90	45.4	14	245	50	(9.4	70	13.4	0	55	0)

[1]*Values in parentheses are based on 3 or less trees from the same site.*

trees by 10-yr age classes found on sites 1 and 2 in the Colorado study are given in table 2.

There was a significant correlation between tree diameter and tree height, but the coefficient of determination was so low that a regression equation for predictive purposes would be useless. However, reliable gross volume tables for individual trees, based on d.b.h. and number of merchantable 16-ft logs, have been constructed from trees in this study by Peterson (1961). Tree volume accuracy based on Peterson's tables was verified by Wengert[3] from tree data collected near Taos, N.Mex. during a tree yield study in 1976.

The gross bd ft (Scribner) and cubic foot volumes per acre, based on average stand age for site classes 1 and 2, found in this study, are given in table 3. These volumes are based on both even-aged and multi-aged unmanaged stands. The sampling was not extensive enough (33 plots) to confidently apply these volumes to all site 1 and 2 stands in Colorado, but they give an indication of volumes that can be expected for nearly pure stands on better sites.

Relationship between Decay, Age, and Site

There was no significant difference in the relationship between tree age and the percent of trees with cull on sites 1 and 2 so they were combined. When the percentage of trees with cull in each 10-yr age class was analyzed, a linear relationship (fig. 3) accounted for the greater part of the variation between trees with cull and age ($r = 0.86$) in stands 40 to 170 yr old. There were not enough data from site 3 for analysis.

[3]*Wengert, E. M. Guidelines for harvesting, utilization and marketing of Rocky Mountain aspen (*Populus tremuloides *Michx.). Manuscript in preparation at Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

Table 3.—Aspen stand gross bd ft (Scribner) and cubic foot volumes per acre (basis: 33 and 35 plots, respectively)

Average stand age	Site 1		Site 2	
	Bd ft[1]	Cu ft[2]	Bd ft[3]	Cu ft[4]
50	(10,500)[5]	2,420	5,400	870
60	(13,300)	2,940	7,300	1,150
70	16,100	3,460	9,100	1,440
80	18,800	3,980	11,000	1,720
90	21,600	4,510	12,900	2,010
100	24,400	5,030	14,700	2,290
110	27,200	5,550	16,600	2,580
120	29,900	6,080	18,500	2,860
130	32,700	6,600	20,300	3,150
140	35,500	7,120	22,200	3,430
150	38,300	7,650	24,100	3,720
160	41,000	8,170	25,600	(4,000)

[1]*Gross volume* $= -3{,}381 + 277.7\,age$, $r = 0.87$
[2]*Cubic foot volume* $= -199 + 52.3\,age$, $r = 0.85$
[3]*Gross volume* $= -3{,}895 + 186.4\,age$, $r = 0.85$
[4]*Cubic foot volume* $= -588 + 28.5\,age$, $r = 0.62$
[5]*Numbers in parentheses extrapolated from original data.*

When the data for percent cull in individual trees were grouped by 10-yr age classes and decay cull plotted as a function of these age classes for Baker's sites 1 and 2, essentially linear relationships were again obtained for the range of ages — 40 to 170 yr (fig. 4). The amount of cull for trees on site 3 averaged 65% between 70 to 150 yr, but the variation was too large to obtain a significant relationship. A summary of figure 4 of the average amount of cull on sites 1 and 2 is as follows:

Tree age	Percent decay cull	
(years)	Site 1	Site 2
60	6	7
80	13	16
100	21	25
120	28	34
140	36	44
160	44	53

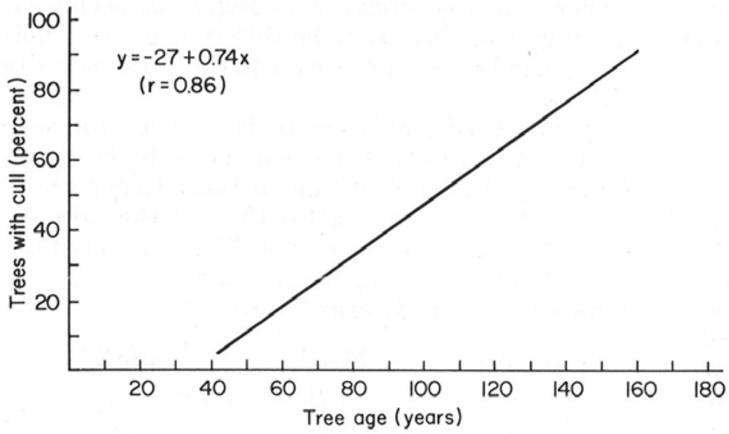

Figure 3.—Relationship between tree age and incidence of decay cull (basis: 524 trees).

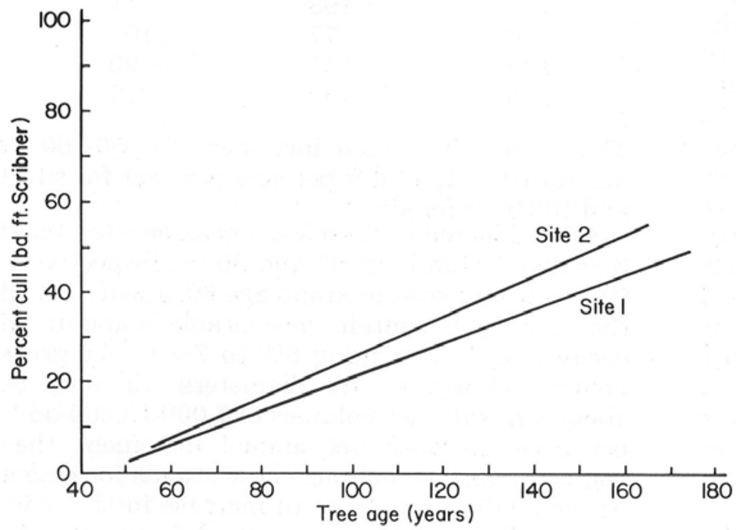

Figure 4.—Relationship between tree age and percent cull on site classes 1 and 2 in Colorado (Basis: 563 trees)
Site 1 percent cull = -17 + 0.38 tree age, r = 0.93
Site 2 percent cull = -21 + 0.46 tree age, r = 0.96.

Because these cull data are based on tree age rather than stand age, the data from figure 4 or the above tabulation must be applied to the actual age of the merchantable trees in a two- or three-aged stand and then summed. For example, a representative two-aged, 10-acre stand on site 1 has 20,000 bd ft in 60-yr-old merchantable trees and 40,000 bd ft in 140-yr-old merchantable trees. The total gross volume is 60,000 bd ft. The cull is 1,200 bd ft (6% of 20,000) from the 60-yr-old trees and 14,400 (36% of 40,000) from the 140-yr-old trees, for a total of 15,600 bd ft of cull or 26% of the stand volume. Note that, if the average cull at age 100 yr had been used (21%), the amount of decay would have been greatly underestimated (12,600 bd ft). Therefore, before these decay data (fig. 4) can be applied to stands, the age distribution of merchantable trees must be known or even-aged stands assumed.

The estimated net volumes per acre by stand age class for sites 1 and 2, based on table 3 stand gross volume, figure 4 cull percentages, and cubic-foot decay estimates of Davidson et al. (1959) are given in table 4. They show the volumes that can be expected on the better sites in Colorado. These tabulations are based on averages, and variation can be expected when the data are applied. For example, high volumes of

Table 4.—Aspen stand estimated net bd ft (Scribner) and cubic foot volumes per acre (based on table 3 stand gross volumes and fig. 4 cull percentages)

Average stand age (years)	Site 1		Site 2	
	Bd ft	Cu ft	Bd ft	Cu ft
50	(10,400)	2,380	5,300	850
60	(12,600)	2,880	6,800	1,120
70	14,600	3,370	8,100	1,380
80	16,300	3,860	9,300	1,630
90	17,900	4,350	10,300	1,880
100	19,300	4,830	11,100	2,110
110	20,400	5,270	11,700	2,320
120	21,300	5,650	12,100	2,520
130	22,000	6,020	12,500	2,710
140	22,500	6,340	12,600	2,850
150	22,800	6,620	12,500	—
160	22,800	6,810	(12,300)	—

butt rot in some older stands may be due to decay following old fire wounds. Trunk rot variation will usually be caused by the presence of *Phellinus tremulae* in the stands.

Merchantable Stands

The aspen stands studied were in site classes 1 to 3 according to Baker's (1925) site classification. Jones' (1966) site index table was also used in this analysis. However, there was no statistical distinction between cull based on Jones' sites 60, 70, and 80, which are roughly comparable to Baker's sites 3, 2 and 1.

The plots in this study were located in medium and old-age stands considered to be typical of the commercial aspen forests in Colorado. Only 8 of the 33 plots were in essentially even-aged stands, and 6 of these were under 80 yr of age (table 1). While a detailed fire history for the stands was not available, the younger stands up to 80 yr are assumed to have originated following fire. There is considerable evidence that stands also originate from causes other than fire. Older stands often tend to deteriorate and break up because of insects, disease, and drought. Sprouting can be sufficient to regenerate the deteriorating older stands. The result is a two-aged stand: a new even-aged class beneath the old stand. Or there may be only a thinning out of the older trees, permitting repeated regeneration to develop as an uneven-aged understory and eventually resulting in a multi-aged stand with normal density at older ages.

Baker (1925) commented on the existence of many uneven-aged stands in the Rocky Mountains, and predicted that — with the elimination of fire — this form of stand would become increasingly prevalent. Data taken in 1960 on five National Forests of Colorado (Hinds 1969) for a canker survey were reviewed to see how prevalent even-aged stands are. The sample plots were established in stands randomly located at mileage points on roads through the aspen type. Only 8 plots in 30 stands were even-aged, and 5 of these were under 100 yr old. When the plot-age data of both studies are combined, only 25% of the Colorado stands previously studied were considered even-aged, and a majority of these were under 100 yr old.

Baker's five site-quality classes probably better describe the older stands that commonly exist in Colorado and Utah today, whereas Jones' site classes, based on even-aged stands, better depict the younger stands. In assessing present aspen stands for cull and merchantability, Baker's site classification is preferable because it distinguishes between the different decay levels — especially between site 3 and the upper two site classes.

If stands of aspen are to be utilized for sawtimber, the rotation age will have to be determined by the length of time it takes to grow merchantable-sized trees rather than by the culmination of net annual increment. The estimated net annual bd ft increment per acre derived from table 4 in this study is as follows:

Stand Age	**Site 1**	**Site 2**
(years)	*. . Bd ft (Scribner) . .*	
60	210	113
80	203	116
100	193	111
120	177	101
140	161	90
160	143	77

The mean net annual increment for 50-160 yr amounted to 184 bd ft per acre per year for site 1 and 102 bd ft for site 2.

Annual increment reached a peak on sites 1 and 2 at about stand age 60 and 80 yr, respectively. On the better sites at stand age 60, about 17% of the trees will contain measurable amounts of decay (fig. 3), averaging 6% to 7% of the gross volume. However, tree diameters will only be about 9 in with net volumes of 7,000-13,000 bd ft per acre. Because net annual increment then begins to decline, holding these stands for longer periods will allow decay to increase in the older trees. Although the net annual increment decreases from age 60, it does not reach the mean until 110 yr on site 1, and 120 yr on site 2. Although decay will be found in 50% to 60% of the trees and amount to 25% to 34%, the average tree diameter will be over 12 in and net volumes should be 12,000 to 20,000 bd ft per acre. It should be brought out that the increase in decay will be greater in the older trees and it is the younger trees with lesser decay entering the merchantable size class which will provide the sound volumes.

Fungi Associated with Aspen Cull

The decay fungi responsible for cull were identified for 74% of the infections, which accounted for 76% of the total 16,430 bd ft cull. Trunk rot was responsible for 66% of the cull volume and butt rot for 34%. The 11 fungi individually responsible for more than 1% of the rot volume and other unidentified rots and their relative importance are shown in table 5.

Table 5.—Fungi associated with aspen cull

Fungus	Infections	Rot volume	Fraction of total gross volume
	.... Percent		
Trunk rots:			
Phellinus tremula (Bond.) Bond. et Boris	22.2	33.8	10.2
Peniophora polygonia (Pers. ex Fr.) Bourd. et Galz.	18.3	14.4	4.4
Libertella sp.	6.2	4.9	1.5
Coriolellus serialis (Fr.) Murr.	.6	1.8	.5
Unidentified brown rot	2.0	1.8	.5
Unidentified white rot	5.9	8.9	2.7
Total trunk rots	55.2	65.6	19.8
Butt rots:			
Collybia velutipes Curt. ex Fr.	9.3	7.6	2.3
Ganoderma applanatum (Pers. ex Wallr.) Pat.	6.2	3.5	1.1
Pholiota squarrosa (Fr.) Kumm.	4.0	2.9	.9
Pleurotus ostreatus (Fr.) Kumm.	1.1	1.9	.5
Polyporus adustus Willd. ex. Fr.	1.7	1.5	.5
Trechispora raduloides (Karst.) Rogers	1.1	2.1	.7
Armillariella mellea (Vahl. ex Fr.) Karst.	3.1	1.9	.5
Unidentified brown rot	7.9	3.4	1.0
Unidentified white rot	10.4	9.6	2.9
Total butt rots	44.8	34.4	10.4
Total trunk and butt rots	100.0	100.0	30.2

Phellinus tremulae (= *Fomes igniarius*) is the most destructive decay organism causing cull in aspen (fig. 5). It was found in 15% of the trees in this study, and was responsible for a third of the cull. The amount of cull attributed to this fungus alone was nearly equal to that of all butt rot cull. Trees infected with *P. tremulae* had an average of 70% cull. Most trees with intensive heart rot have conspicuous fruiting bodies (conks or sporophores) on the trunk. Seventy-five percent of the trees with scalable cull attributed to *P. tremulae* had these external indicators of decay, and the cull averaged 82% of the gross tree volume. Cull in trees without fruiting bodies averaged 40%. The extent of decay associated with sporophores has been reported earlier (Hinds 1963).

Peniphora polygonia (= *Cryptochaete polygonia*), the second most important decay fungus, does not fruit readily on infected trees, consequently there are no external decay symptoms (fig. 5). Decay is usually white with a reddish-brown margin suggestive of an incipient stage. When the decay is exposed on cross cuts, the infected wood seems to be more brittle than normal wood, and the fibers pull out rather than cut cleanly. When sawn lengthwise, the incipient stage does not fall out and is usually considered stained wood, unless the decay is in a well advanced stage. For this reason actual cull is probably much less than that scaled.

Libertella sp. was associated with a white mottle top rot which has an odor similar to green walnut hulls. A red mottle stain with yellow, brown, and green hues usually was associated with the incipient decay. The fungus has been associated with advanced root decay in aspen, and shown to cause a 24% weight loss of sterile aspen root blocks (Ross 1976a). Its associated cull in this study averaged 40% in the infected trees. Both *Libertella* and *P. polygonia* decay are associated with living and dead branches.

Other trunk decay fungi associated with cull were: *Coriollus serialis* (= *Trametes serialis* Fr.), *Daldinia concentrica* (Fr.) Cs. & DeNot., *Polyporus dryophilus* Berk. var. *vulpinus* (Fr.) Overh., and *Sistotrema brinkmanii* (Bres.) J. Erikss. (= *Trechispora brinkmanii* (Bres.) Rogers and Jacks). These fungi caused only slight amounts of cull and they are considered of little consequence.

The incidence of butt rot cull was nearly as great as that attributed to trunk rot. Most butt rot can be eliminated by long butting, however, and total cull is only half as great as that of trunk rot. More species of fungi were associated with butt rot and a larger number of butt rot infections were unidentified.

Collybia velutipes caused the largest amount of butt cull and was the most frequently encountered. Although the average length of decay columns was 10 ft, decay often extended above 16 ft in the older trees and caused an average cull of 35 bd ft. It causes a brown mottle rot which is frequently associated with basal wounds.

Ganoderma applanatum (= *Fomes applanatus*) causes a brown mottle decay not only in the basal part of the stem but also in the large roots (Ross 1976b). It is in almost all aspen stands, and is a major cause of windthrow (Landis and Evans 1975). Fruiting bodies of the fungus, frequently found at the base of an infected tree, indicate butt cull (fig. 6). Length of decay columns average 6 ft, but seldom extended beyond 8 ft, with an average cull of 26 bd ft.

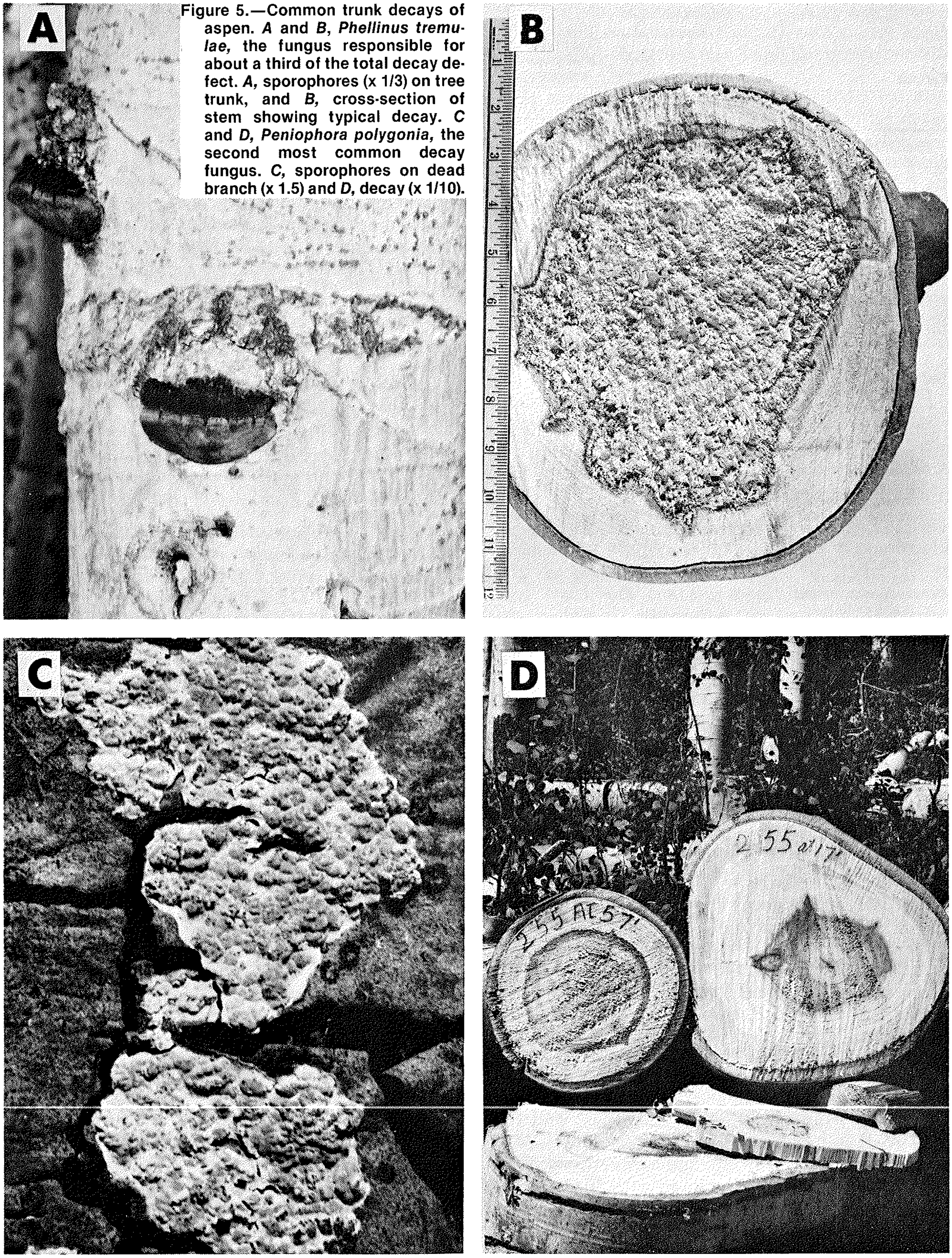

Figure 5.—Common trunk decays of aspen. *A* and *B*, ***Phellinus tremulae***, the fungus responsible for about a third of the total decay defect. *A*, sporophores (x 1/3) on tree trunk, and *B*, cross-section of stem showing typical decay. *C* and *D*, ***Peniophora polygonia***, the second most common decay fungus. *C*, sporophores on dead branch (x 1.5) and *D*, decay (x 1/10).

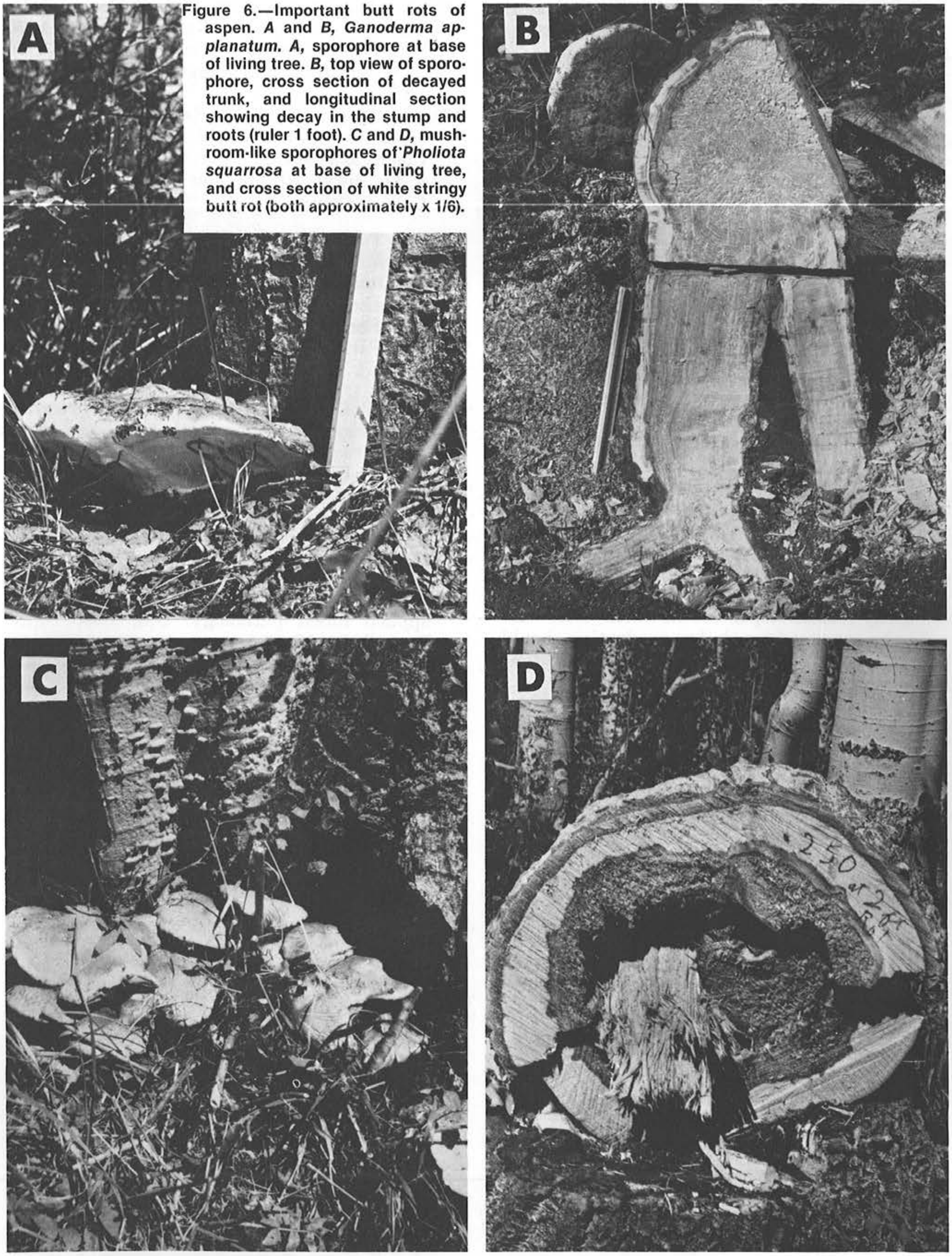

Figure 6.—Important butt rots of aspen. *A* and *B*, *Ganoderma applanatum*. *A*, sporophore at base of living tree. *B*, top view of sporophore, cross section of decayed trunk, and longitudinal section showing decay in the stump and roots (ruler 1 foot). *C* and *D*, mushroom-like sporophores of *Pholiota squarrosa* at base of living tree, and cross section of white stringy butt rot (both approximately x 1/6).

Pholiota squarrosa (fig. 6) and *Polyporus adustus* cause a white, stringy butt rot whereas *Polyporus ostreatus* and *Trechispora raduloides* cause a gray mottle rot. The large white pocket rot of *Armillariella mellea* was frequently associated with old basal wounds. Its actual frequency is probably greater than that shown in table 5 because the fungus is difficult to isolate. It is often mixed with other decay fungi or the decay is so advanced that it is invaded by ants.

Summary

Aspen grows more slowly in the West than in the Lake States, but the aspen stands in the West do not tend to deteriorate and break up at early ages. Colorado aspen begins to reach sawtimber size in about 60 yr, yet holding the stands for a pathological rotation age of 90-120 yr should provide a maximum production of net volumes averaging over 20,000 bd ft per acre on the best sites.

Cull due to decay varies greatly in present unmanaged stands. Many stands are not even-aged, and it is this tree age difference which accounts for much of the cull variation. Decay is usually more prevalent in the older trees; the greater the proportion of older trees in a stand, the greater the decay losses. Aspen on the better sites that are to be managed for timber production should be harvested by clearcutting to insure vigorous sucker production and even-aged development.

The fungi causing cull in the present older stands will likely be found in the younger stands. Their impact on volume losses, however, should not be as great in the regenerated stands, and their relative importance may change when even-aged stands become more prevalent.

Literature Cited

Baker, Frederick S. 1925. Decay of trembling aspen. U.S. Dep. Agric. Bull. 1291, 47 p.

Davidson, Ross W., Thomas E. Hinds, and Frank G. Hawksworth. 1959. Decay of aspen in Colorado. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 45, 14 p., Ft. Collins, Colo.

Green, Alan W., and Theodore S. Setzer. 1974. The Rocky Mountain timber situation, 1970. U.S. Dep. Agric., For. Serv. Res. Bull. INT-10, 78 p., Int. For. and Range Exp. Stn., Ogden, Utah.

Hinds, Thomas E. 1963. Extent of decay associated with *Fomes igniarius* sporophores in Colorado aspen. U.S. For. Serv. Res. Note RM-4, 4 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Hinds, T. E. 1964. Distribution of aspen cankers in Colorado. Plant Dis. Rep. 48:610-614.

Jones, John R. 1966. A site index table for aspen in the southern and central Rocky Mountains. U.S. For. Serv. Res. Note RM-68, 2 p., Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Landis, T. D., and A. K. Evans. 1974. A relationship between *Fomes applanatus* and aspen windthrow. Plant Dis. Rep. 58:110-113.

Little, Elbert L., Jr. 1961. Atlas of United States trees, vol. 1. Conifers and important hardwoods. U.S. Dep. Agric., For. Serv. Misc. Pub. 1146. 9 p., 200 maps. U.S. Govt. Printing Office, Wash., D.C.

Meinecke, E. P. 1929. Quaking aspen: A study in applied forest pathology. U.S. Dep. Agric. Tech. Bull. 155, 34 p.

Miller, Robert L., and Grover A. Choate. 1964. The forest resource of Colorado. U.S. Dep. Agric., For. Serv. Resour. Bull. INT-3, 55 p. Int. For. and Range Exp. Stn., Ogden, Utah.

Peterson, Geraldine. 1961. Volume tables for aspen in Colorado. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn. Res. Note 63, 4 p., Ft. Collins, Colo.

Ross, William D. 1976a. Fungi associated with root diseases of aspen in Wyoming. Can J. Bot. 54:734-744.

Ross, William D. 1976b. Relation of aspen root size to infection by *Ganoderma applanatum*. Can. J. Bot. 54:745-751.

U.S. Department of Agriculture, Forest Service. 1973. National forest log scaling handbook. U.S. Dep. Agric., For. Serv. FSH 2443.71, 193 p. U.S. Govt. Printing Office, Wash., D.C.

Agriculture—CSU, Fort Collins