U.S. FOREST SERVICE RESEARCH NOTE NE-1

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

A SIMPLE DEVICE FOR DEHAIRING INSECT EGG MASSES

The egg masses of some lepidopterous insects are covered by a mat of hairs that for some research purposes must be removed. Doing this by hand is tedious. Besides, the hairs on the egg masses of certain insects such as the gypsy moth (*Porthetria dispar* [L.] and the browntail moth *Nygmia phaeorrhoea* [Donov.]) can cause severe allergic reactions in persons who are exposed to them.

To overcome these difficulties, a mechanical dehairing device has been developed. This device consists of a wide-mouthed 1-quart glass jar, a strainer soldered to a metal rim, a screw cap containing a filter for trapping the hairs and debris, and an air inlet (fig. 1).

The strainer, made of a cup-shaped piece of wire mesh, is soldered to a metal rim insert that fits snugly into the mouth of the jar. The mesh is

NOTICE

This U. S. FOREST SERVICE RESEARCH NOTE is the first of a new series of research publications by the Northeastern Forest Experiment Station. In this new series, which has been adopted as standard for all the Forest and Range Experiment Stations of the U. S. Forest Service, the symbol NE will designate publications of the Northeastern Station.

This new series replaces the Northeastern Station's series formerly known as Forest Research Notes. In like manner, the series of Station Papers previously published by the Northeastern Station will be designated from now on as U. S. FOREST SERVICE RESEARCH PAPERS, and will be identified by the symbol NE and a number.

Figure 1.—The device developed for dehairing egg masses of certain lepidopterous insects. Air forced in through the tube loosens the hairs from the egg masses, and as the air escapes through the perforated cap the hairs are trapped in a filter pad.

of a size to permit passage of the hairs but to prevent passage of the eggs.

The screw cap is perforated with thirty 3/16-inch holes for air outlets. A hole to receive the air inlet tube is also drilled in the cap. This hole is located off center in the cap to create an effective air current inside the jar. A filter pad of cotton, fiberglass, or some similar material is placed inside the screw cap and is held firmly in place by a circular piece of 16-mesh metal screen and a ring-shaped gasket of hard cardboard (fig. 2).

The device is used as follows. The egg masses, dry and preferably broken up to facilitate dehairing, are placed in the jar. Enough to cover the bottom comprises a workable charge. Then the unit is assembled, a flexible tube is attached to the air inlet, and air is forced into the jar.

The air current in the jar agitates the egg masses and separates the hairs and debris from them. The hairs and debris are carried by the air flow to the filter pad, where they are trapped.

The air flow should be regulated so that it will not injure the eggs. In field use portable sources of air can be used, such as an inflated tire tube supplied by a foot-operated pump.

The egg masses are completely dehaired in about 2 minutes. After use, the filter pad is removed and burned (fig. 3).

This device has been used extensively in experimental work at the Forest Insect Laboratory of the U. S. Forest Service Northeastern Forest Experiment Station at New Haven, Conn., and the Bacteriology Department of the University of Connecticut at Storrs, Conn.

Use of the device has facilitated egg counts from gypsy moth egg masses collected in the field and has provided clean dehaired eggs for

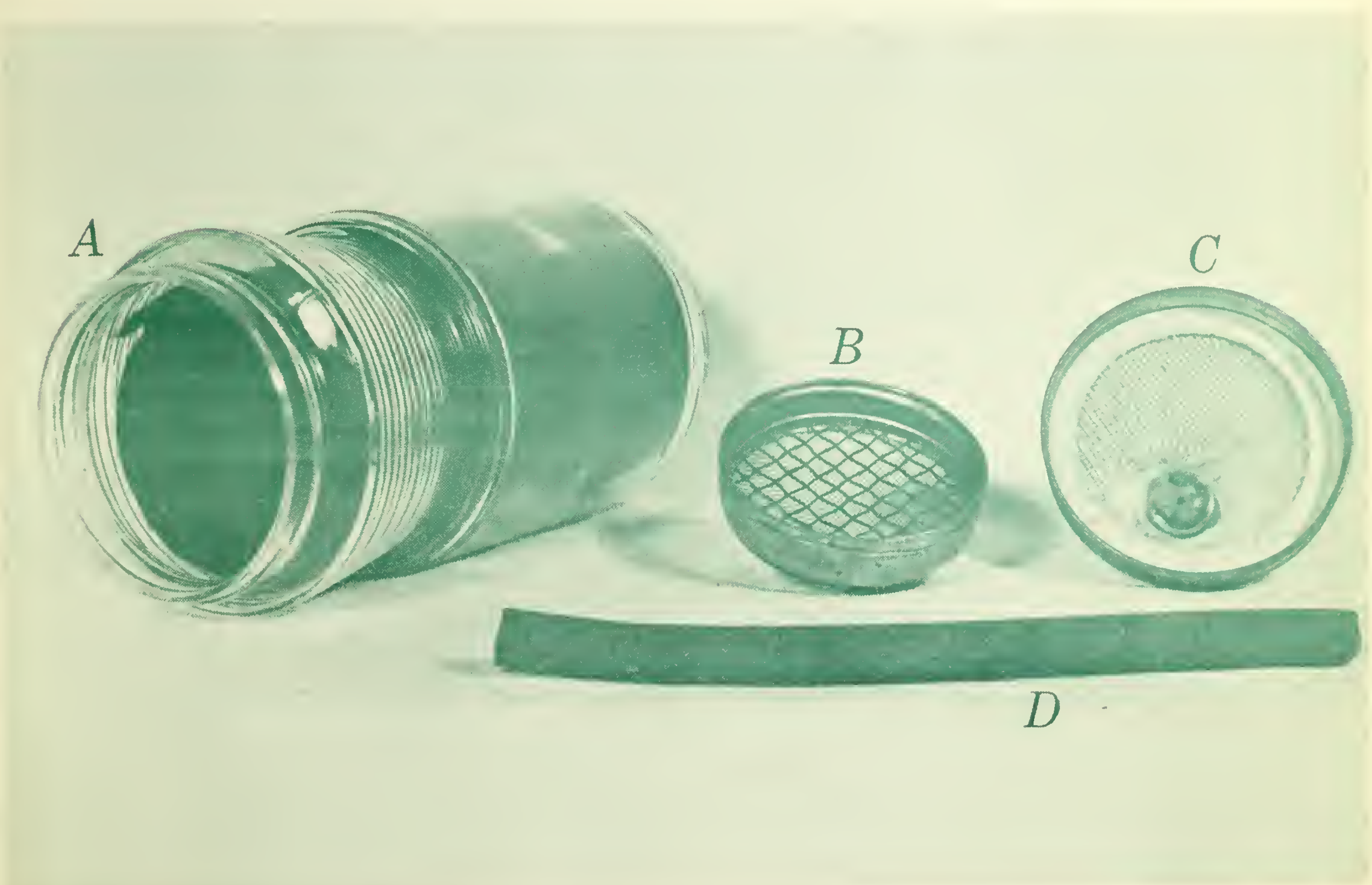

Figure 2.—The parts of the dehairing apparatus. *A*, the glass jar; *B*, the strainer; *C*, the cap with filter pad; and *D*, the air inlet tube.

Figure 3.—Inside of the cap after use, showing the mat of insect hairs trapped on the filter pad.

making special culture media. At the same time it has no doubt lessened the exposure of research personnel to allergenic insect hairs.

In developing this device, the authors made use of common materials available to them, including an instant-coffee jar, a common wire tea strainer, and a tubeless-tire valve stem. Cost of making one dehairing device was about $1.

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[1] Development of the dehairing device was a result of a cooperative research project. Dr. Cosenza, Mr. Boger, and Mr. Dubois are in the Bacteriology Department of the University of Connecticut, Storrs, Conn. Dr. Lewis is an entomologist on the staff of the Forest Insect Laboratory of the Northeastern Forest Experiment Station, New Haven, Conn.

1963

Northeastern Forest Experiment Station

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

A TECHNIQUE FOR SEXING FULLY DEVELOPED EMBRYOS AND EARLY-INSTAR LARVAE OF THE GYPSY MOTH

Because variation in sex ratio is an important factor in the population dynamics of the gypsy moth (*Porthetria dispar*), it is necessary to have some means of determining the ratio of males to females in a population at the beginning of the larval period as well as in the later stages. For determining the sex of fully developed embryos and early-instar larvae, a simple whole-mount microscope technique has been devised. The procedure is as follows:

Alcohol-preserved larvae are placed in an 88-percent liquefied phenol (carbolic acid) solution for a minimum of 2 hours; then they are transferred to an 88-percent liquefied phenol-rose bengal stain solution. The optimum phenol/stain ratio is 99.5/0.5 by weight.

Live larvae and fully developed embryos (with egg chorion punctured or removed) are placed directly in the 88-percent liquefied phenol-rose bengal stain solution.

The larvae are left in the phenol-stain solution for at least 48 hours; punctured eggs require a minimum of 72 hours in the solution. The specimens are then transferred directly to 1- by 3-inch microscope slides. Three specimens can be placed on each slide.

A cover glass is placed over each specimen, and pressure is applied. Under light pressure the integument of the treated insect fractures readily, allowing the internal organs (including the gonads) to flow out through the anal opening or through a break in the abdominal wall.

Each mount is first scanned under low magnification (X 35) to locate the gonads and then under higher power (X 100) to make positive iden-

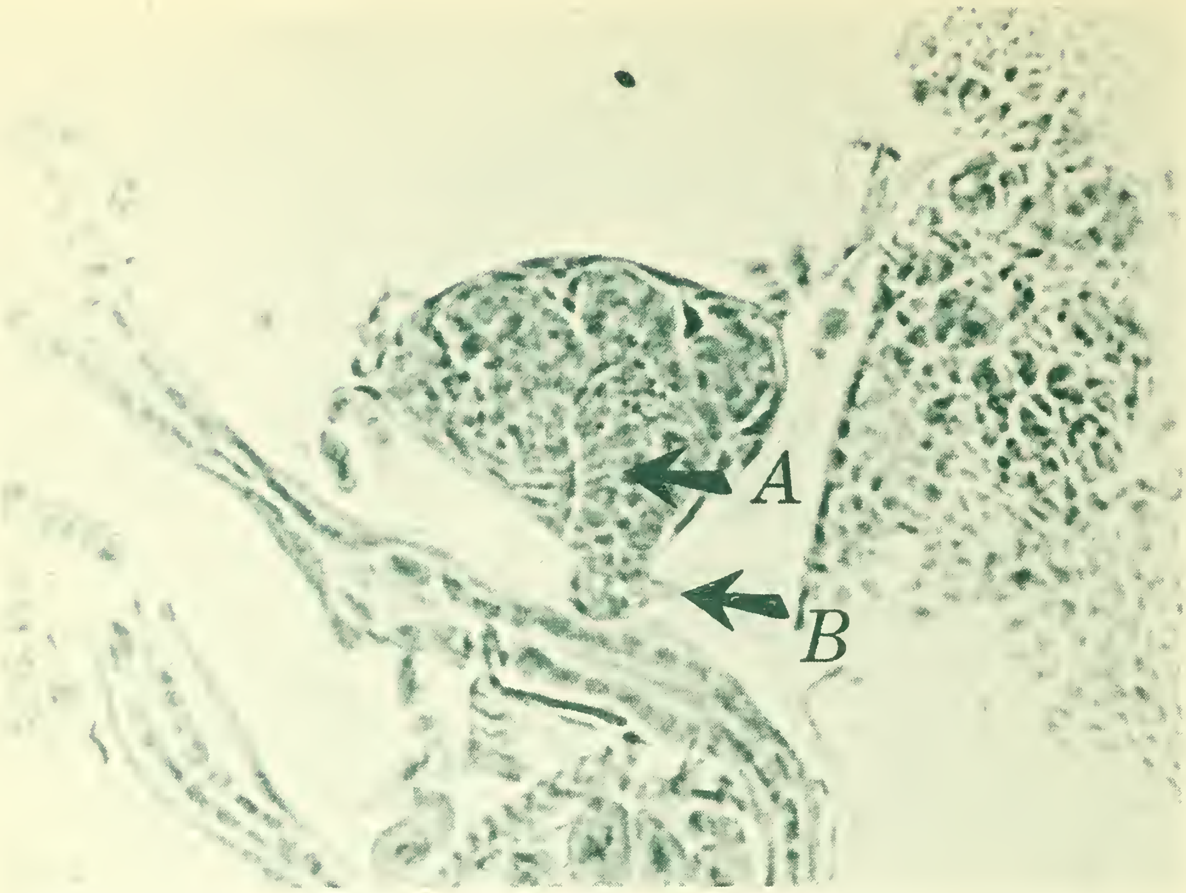

Figure 1.—Ovary of instar I gypsy moth larva (X400). Note the three lobes, the stalk-like outgrowth (A), and the calyx (B).

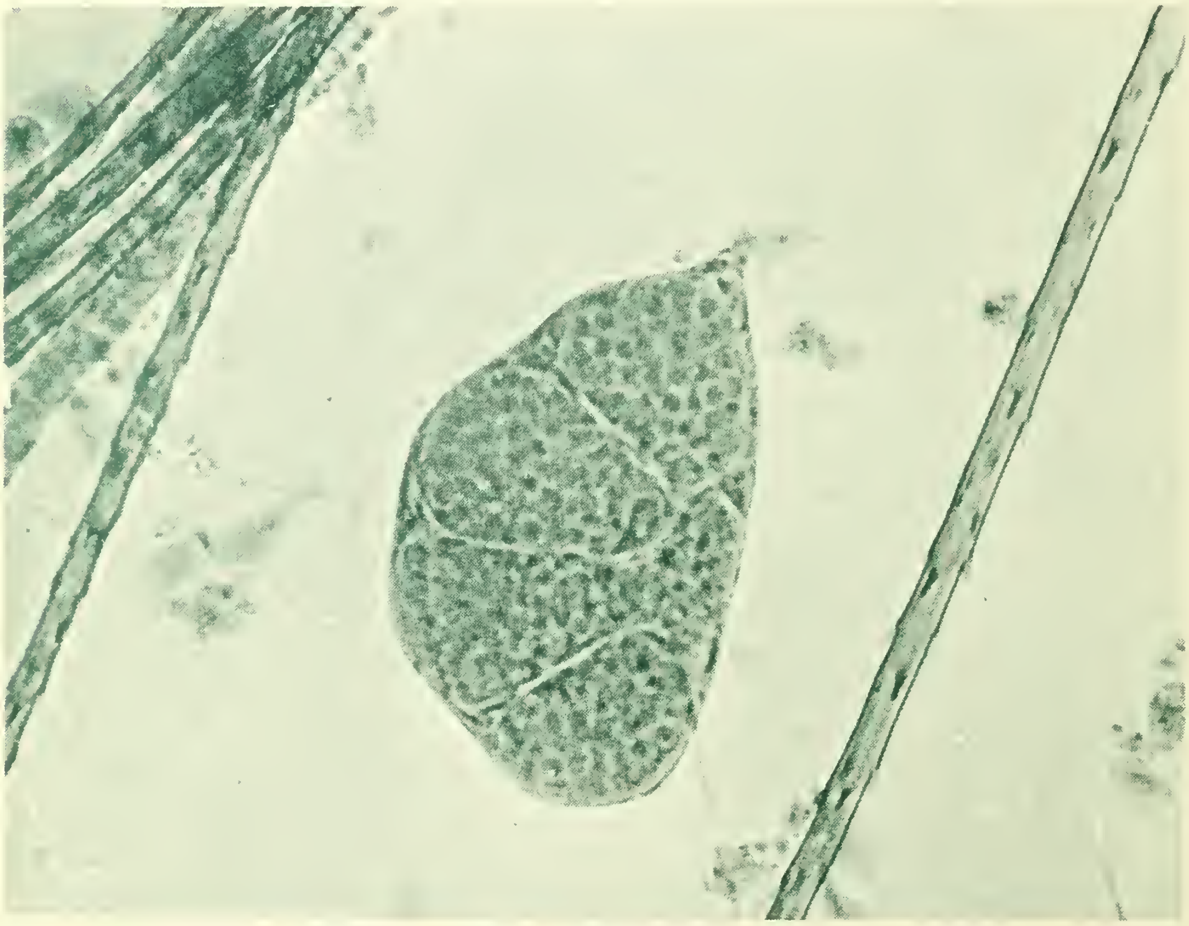
Figure 2.—Testis of instar I gypsy moth larva (X400). Note the four distinct lobes; no stalk-like outgrowth or calyx is present.

tification of the sex. The contrasting characters of the female and male gonads show up clearly.

In the female, the ovaries remain undifferentiated in the embryo and in the hatched first-instar larva. Later in the first instar three definite lobes are formed, which lead to or are connected with a stalk-like outgrowth (fig. 1). Occasionally there appears to be a fourth lobe, but it is apart from the ovarial stalk. The stalk has an enlargement at the distal end, at its junction with the oviduct. This enlargement, or calyx, is normally funnel-shaped and can be seen clearly even in the embryo stage. When pressed between the cover glass and slides, the ovaries present a round to oval-oblong shape.

In the male, the testes consist of four lobes each, all well-defined from the fully developed embryo stage through the later instars (fig. 2). No stalk-like outgrowth or calyx is present. The testes usually appear kidney-shaped.

This technique, which has been used successfully at the Forest Insect Laboratory of the Northeastern Forest Experiment Station at New Haven, Conn., may be applicable to other lepidopterous species.

The mounts can be made in advance; the phenol stain solution will not crystallize. After use, the slides may be washed in running water and used again.

CAUTION: Phenol is highly corrosive to human tissue; so care must be taken in handling it. In case of direct contact with the skin, soap and running water should be applied immediately. The phenol should always be kept in screw-cap glass containers.

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U.S. FOREST SERVICE RESEARCH NOTE NE-3

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

SOME RELATIONSHIPS AMONG AIR, SNOW, AND SOIL TEMPERATURES AND SOIL FROST

Each winter gives examples of the insulating properties of snow cover. Seeds and soil fauna are protected from the cold by snow. Underground water pipes are less likely to freeze under snow cover. And, according to many observers, the occurrence, penetration, and thaw of soil frost are affected by snow cover. The depth of snow necessary to protect soil from freezing will depend, of course, on the air temperature.

For a clearer understanding of the relationship of snow depth to frost, an exploratory study was recently conducted near Laconia, New Hampshire, in which concurrent measurements of air, snow, and soil temperatures were taken and interpreted in respect to each other and to the formation of soil frost.

Methods and Site

Temperatures were measured in the winter of 1960-61 in two level plots in a 30-year-old beech-maple woodlot. The soil was a Shapleigh sandy loam, well-drained and relatively stone-free. The L and F layers in both plots were removed. Three stacks of thermocouples were installed in the soil on each plot at depths of ¼, 3, 6, 12, and 24 inches. Snow was allowed to accumulate on one plot. On the other, snow was shovelled and swept away after each snowfall.

On the snow-plot, a stack of unshielded thermocouples 3, 6, 12, 18, 24, 30, and 36 inches above the ground gave temperature readings within and above the snowpack. A portable, non-recording potentiometer with temperature adjustment was used; a heating coil around the standard cell kept it operable in sub-freezing weather. A thermograph, 4½ feet above the ground between the plots, provided a continuous record of air temperature. Snow depth and density were measured with a Mt. Rose snow tube.

Results

Soil temperatures at the ¼- and 3-inch depths were affected immediately by snow accumulation, beginning December 15. At the 6-inch depth the snow effect was not apparent until December 26. At the two lowest depths the effects did not appear until January 8—about a 3-week lag. Thereafter soil temperatures under snow varied little, the maximum fluctuation at any one depth being about 3°F. The data recorded are graphed in figure 1.

Within the snow pack there is less fluctuation in temperature than at points nearer the snow-air interface or in the air. For example, air temperatures taken concurrently with snow and soil temperatures ranged from 43° to 4°F. (a difference of 39°); and in snow, 12 inches above the ground, temperatures ranged from 34° to 10° (a difference of 24°). In snow 6 and 3 inches above the ground, the difference was only about 10°.

Air, snow, and soil temperatures and their variation from 19 measurements between December 28 and April 6 are compared in table 1. Here again are shown: higher temperatures both within the snow pack and at greater soil depths, a reduced variation in temperature going from air to snow to snow-covered soil, and a greater variation of soil temperature in the bare plot than on the snow-covered one.

On the bare plot, soil temperatures were influenced by concurrent mean daily temperatures only to a depth of about 6 inches. Air-soil temperature

Table 1. — *Air, snow, and soil temperatures and their variation*

Item	Height above soil surface	Temperatures: Mean	Temperatures: Standard deviation	Coefficient of variation
	Inches	*°F.*	*°F.*	*%*
Air	54	23.4	12.9	55
	12	23.5	7.0	30
Snow	6	28.2	3.4	12
	3	30.2	2.0	7

Item	Depth below soil surface	Mean: Snow-covered	Mean: Bare	Standard deviation: Snow-covered	Standard deviation: Bare	Coefficient of variation: Snow-covered	Coefficient of variation: Bare
	Inches	*°F.*	*°F.*	*°F.*	*°F.*	*%*	*%*
	¼	32.0	26.3	0.5	10.4	2	40
	3	32.6	25.5	.4	5.5	1	22
Soil	6	33.6	27.0	.5	4.6	1	17
	12	35.1	29.9	.6	3.1	2	11
	24	36.9	32.7	1.1	2.2	3	7

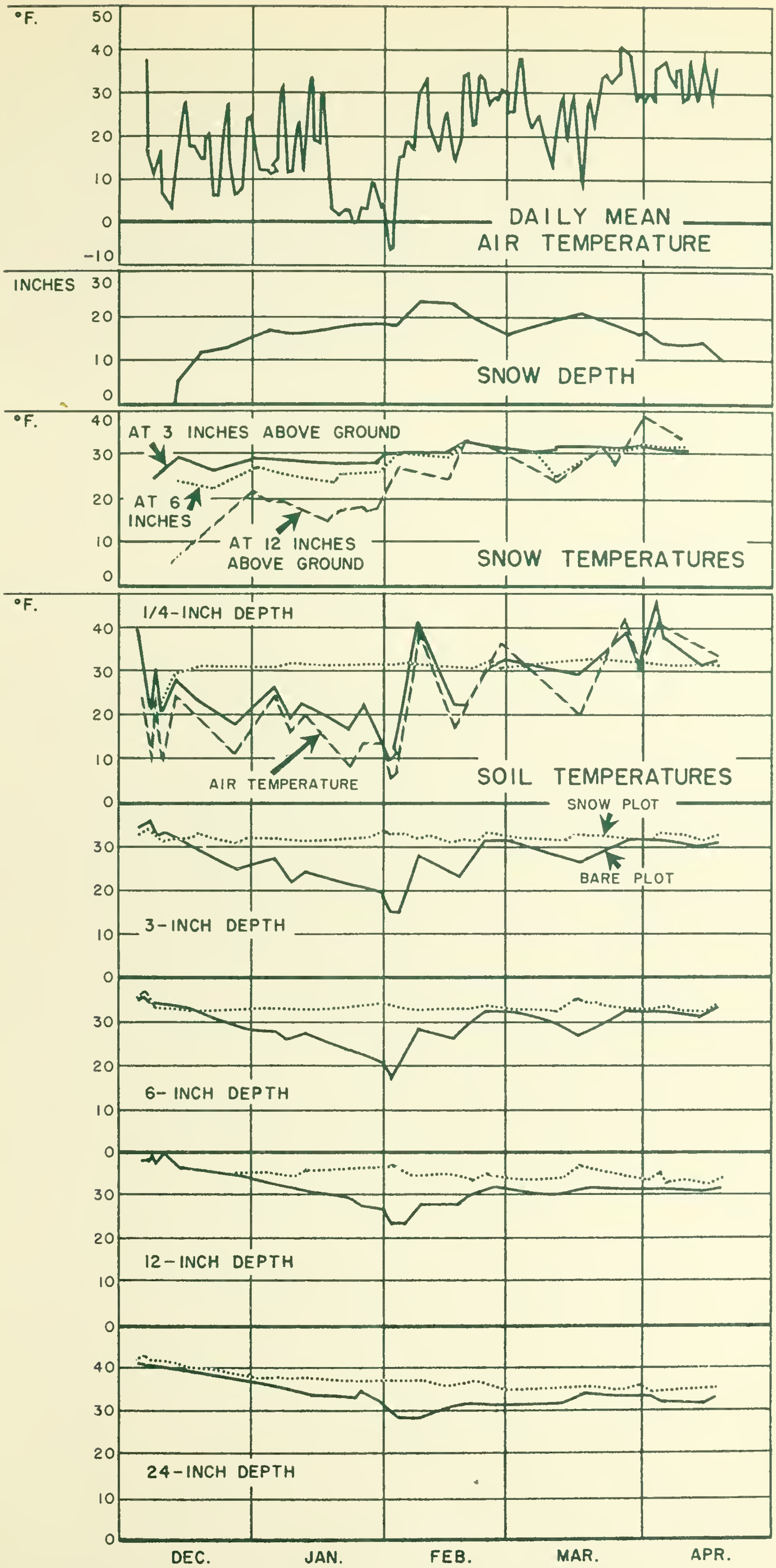

Figure 1. — Air, snow, and soil temperatures and snow depths.

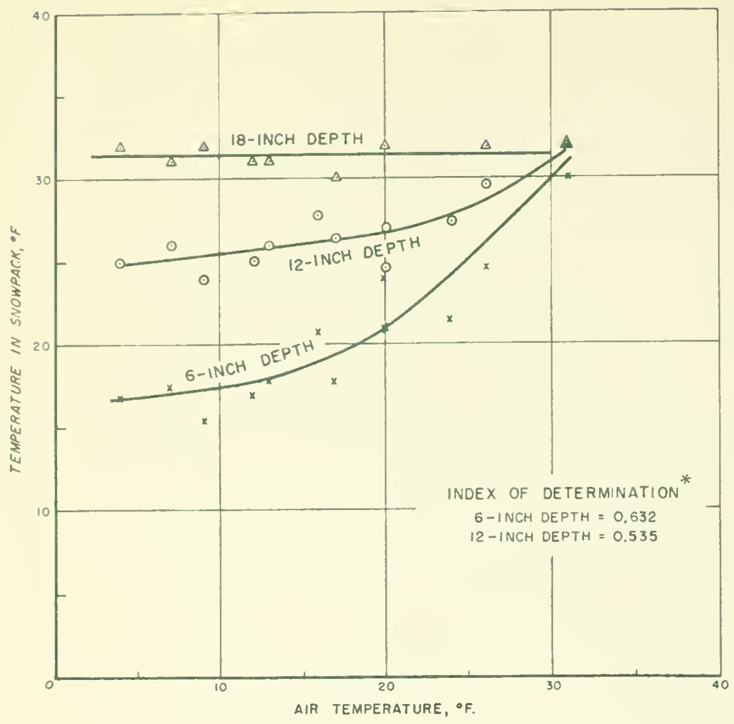

Figure 2. — Temperatures of the snowpack 6, 12, and 18 inches below the surface in relation to air temperature.

*The fraction of the variance in snowpack temperature that is associated with difference in air temperature.

correlation coefficients for the period were 0.85 at 1/4 inch soil depth, 0.63 at 3 inches, 0.49 at 6 inches, 0.16 at 12 inches, and —0.19 at 24 inches.

To determine how much antecedent air temperatures would improve this correlation, mean daily temperatures for antecedent periods ranging in length from 2 to 10 days were determined and their correlation with soil temperatures 3 inches and below was calculated. Correlation increased rapidly up to a 6-day period, with little change thereafter. Correlation coefficients for the 6-day period were 0.85 for 3 inches, 0.76 for 6 inches, 0.51 for 12 inches, and 0.15 for 24 inches.

The relationship of air temperature (average temperature registered by all thermocouples above the snow) to temperatures within the snowpack at 6, 12, and 18 inches is given in figure 2. If freezing at the soil surface occurs at 25°F., as others have reported, then no freezing will occur under 18 inches of snow with air temperatures as low as 4°F. Twelve inches of snow will prevent soil freezing at air temperatures down to 5°F., and 6 inches of snow restricts freezing down to 25°F., under the conditions of this study. These results lend some support to the general observation that snow depths of more than 18 inches will prevent frost penetration of the soil.

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U. S. FOREST SERVICE RESEARCH NOTE NE-4

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA

Experiment Station

ADVANCE REPRODUCTION UNDER MATURE OAK STANDS OF THE NEW JERSEY COASTAL PLAIN

In managing hardwood stands, one of the most important tasks is to secure adequate reproduction of desirable species after harvest cuttings. Natural reproduction is usually relied upon. This can be either advance growth (seedlings or seedling sprouts) or reproduction that becomes established after the cutting. Which one the forest manager should mainly rely upon depends on several factors: relative tolerance of desired and undesired species, abundance of desirable stems and their competitors, logging damage, and cost of different methods of tilting succession to favor preferred species.

On many of the better sites in the New Jersey Coastal Plain, the highly desirable species are oaks, yellow-poplar, and sweetgum. But they are less tolerant of shade than the commonly associated red maple, blackgum, beech, and some other species. Foresters have felt that desirable reproduction was more easily obtained here on well-drained sites than on poorly drained ones.[1] But it has not been clear whether the better reproduction observed on well-drained sites was due to more advance growth, to a greater catch of desired species after cutting, or to less competition.

To determine the influence of soil-moisture conditions on both the amount of desirable advance reproduction and the amount of undesirable competitive growth, a survey of hardwood reproduction under mature oak stands was recently made.

Description of Study

Fifteen mature oak stands, scattered throughout the hardwood section of the New Jersey Coastal Plain, were sampled in the survey. Each stand was fairly well stocked, with no large holes in the canopy.

[1] Smith, Glenn E. Observations on Managing Hardwoods in the Delaware Valley of Southern New Jersey. Jour. Forestry 51: 189-191, 1953.

Selected with the help of State foresters, most of the stands were already marked for cutting.

Five stands were located on each of three moisture conditions: (1) dry sites, on well-drained soils, (2) moist sites, on moderately well to somewhat poorly drained soils, and (3) wet sites, on poorly and very poorly drained soils.

On the dry sites, black, chestnut, and white oaks predominated in the overstories. Understories were relatively short and open. Common shrubs were mountain-laurel, low-bush blueberries, and azalea, with lesser amounts of sweet pepperbush and maple-leaved viburnum. Desirable tree reproduction was chiefly black and chestnut oaks, plus some white oak and Virginia pine, and occasional stems of sweetgum and yellow-poplar. Undesirable species were red maple, dogwood, sassafras, blackgum, black cherry, and gray birch.

On the moist sites, overstories were predominantly northern red oak, with some intermixed white oak. Understories were taller and denser than on the dry sites. In nearly all stands, maple-leaved viburnum was the most common shrub, although sweet pepperbush, southern arrowwood, azaleas, and high- and low-bush blueberries also occurred in abundance. Here desirable tree reproduction included northern red oak, black oak, white oak, sweetgum, and yellow-poplar. Undesirable species were red maple, dogwood, sassafras, hickory, blackgum, and holly.

The wet sites included two conditions of wetness associated with minor topographic differences. The higher ground supported most of the tree and shrub growth. Overstories were composed largely of pin, willow, and swamp white oaks. In the depressions, characterized by thick, usually blackened, leaf litter and by standing surface water during wet periods, the vegetation was relatively sparse. Overstory canopies were thin because most trees grew around, but not in, these spots. Some red maple of second-story stature, and scattered plants of high-bush blueberry, poison ivy, and greenbrier, grew in the depressions. Sometimes dense patches of first-year seedlings of sweetgum or red maple were present.

Understories on the higher ground around the depressions were lush. In some places vegetation was over head-high, and occasionally 50 or more stems were found in a single milacre quadrat. Shrubs predominated. Sweet pepperbush, southern arrowwood, blueberries, and azaleas were most common. Tree reproduction included black, northern red, pin, and swamp white oaks, and sweetgum among the desirable species; red maple, blackgum, beech, holly, and sassafras were common undesirable ones.

In each of the 15 stands, transects of 20 contiguous milacre-quadrats were used to sample the small reproduction up to 1.5 inches d.b.h. Two such transects were studied in each of 12 stands; in the other 3 stands only 1 transect met established standards for uniformity in soil drainage and overstory composition. Reproduction tallies included all trees and shrubs on each quadrat by species and by three height classes: (1) less than 0.5 foot tall, (2) 0.6 foot to 4.5 feet tall, and (3) taller than 4.5 feet but less than 1.6 inches d.b.h. Species and height of the dominant stem on each quadrat were recorded.

Trees and shrubs larger than 1.5 inches d.b.h. were tallied on 0.12-acre plots by species and 1-inch diameter classes. The 0.12-acre plots were 0.6- x 2-chain strips centered on the quadrat transects.

Results

All sites had 800 to 1,100 stems per acre of desirable species in sizes smaller than 1.6 inches d.b.h. (table 1).

Although not differing greatly in numbers per acre, desirable species dominated the understory considerably more on dry sites than on wet ones. On 12 percent of the quadrats on dry sites, 8 percent

Table 1.—*Average number of stems per acre of different types of woody vegetation, by sites*[1]

Type of understory vegetation	Wet sites	Moist sites	Dry sites
Desirable tree species	863	1,071	861
Undesirable tree species	2,274	3,834	3,191
Shrubs (approximate)	25,000	28,000	6,000

[1] Includes all stems less than 1.6 inches d.b.h. With stems 1.6 to 5.5 inches in diameter, values become:

Desirable trees	910	1,104	893
Undesirable trees	2,390	3,965	3,306

Table 2.—*Dominance of different types of woody vegetation in the understory, by sites*[1]

Type of dominant understory vegetation	Wet sites	Moist sites	Dry sites
	Percent	*Percent*	*Percent*
Desirable tree species[2]	3	8	12
Undesirable tree species	17	25	34
Shrubs	72	66	39
None (no woody plants)	8	1	15

[1] Restricted to stems less than 1.6 inches d.b.h.

[2] Seedlings and sprouts.

of those on moist sites, but only 3 percent of those on wet sites, the dominant stem was of a desirable species (table 2). In part, differences in dominance were due to differences among sites in the size of the desirable seedlings: 73 percent of them were taller than 0.5 foot on dry sites, 34 percent on moist sites, and 27 percent on wet sites.

As is obvious from the stand descriptions, species composition in the desirable category varied with moisture conditions. On wet sites sweetgum predominated; on moist sites oaks (as a group) and yellow-poplar were somewhat more common than sweetgum; while on dry sites oaks were most abundant. A percentage breakdown of the desirable species, by sites, is tabulated below for stems less than 1.6 inches d.b.h.

	Wet sites	*Moist sites*	*Dry sites*
Oak species	30	37	69
Yellow-poplar	2	36	11
Sweetgum	68	27	15
Virginia pine	..	..	5

Reproduction of undesirable tree species was more abundant than desirable reproduction on all sites. The undesirable group averaged 2,300 to 3,800 stems per acre (table 1), and dominated 3 to 5 times as many quadrats as the desirable species (table 2). As with the desirable species, the proportion of quadrats dominated by undesirable trees increased with increasing dryness of sites.

Inclusion of stems 1.6 to 5.5 inches in diameter made little difference in numbers per acre (table 1). In that size class undesirable species were still 2 to 4 times as numerous as desirable ones.

Shrubs were much more numerous than tree reproduction on all sites, and usually dominated much larger proportions of the quadrats (tables 1 and 2). Shrubs were taller and denser, and dominated more quadrats on the wet and moist sites than on the dry sites. Fifteen percent of the dry-site quadrats contained no woody plants (table 2). Elsewhere non-stocked quadrats were rare except in the depressions on wet sites.

Shrub competition probably accounts in large part for the small size and infrequent dominance of desirable tree seedlings on the moist and wet soils. As noted earlier, only on the dry sites were a majority of these seedlings taller than 0.5 foot. Here the shrubs were both fewer and shorter, and the tree seedlings had attained greater height despite the less favorable conditions.

Undesirable species were less handicapped by the intense shrub competition on the moister sites, probably because most of them are more tolerant than the desirable species. On the poorly and very poorly drained soils 13 per cent of these undesirables were taller than 4.5 feet, as compared to 11 percent in this size class on the dry sites.

For all sites, the ratio of undesirable to desirable stems in all size classes smaller than 1.5 inches d.b.h. was 3.3 to 1; and the ratio was essentially the same (3.2 to 1) for larger understory trees. These ratios indicate the greater tolerance of the undesirable species and the trend in succession. Unless controlled by cutting and cultural measures to favor preferred species, succeeding overstories in these stands will contain few desirable stems. On dry sites, individual-stem herbicide treatments of undesirable trees larger than 2 inches d.b.h. may be an adequate supplement to harvest cutting.

On the moister sites, more drastic measures will be required to bring through well-stocked stands of desirable species after harvest cuttings. Judicious mistblower applications of herbicide to the low growth and injector treatments of larger stems would seem to be the most feasible method for controlling shrub and weed-tree competition while desirable species are getting established. This may mean that much of the advance reproduction of desirable species may have to be sacrificed. Under these circumstances, new stands would have to be established from seed either just before or just after a harvest cutting is made.

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U. S. FOREST SERVICE RESEARCH NOTE NE-5

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

VARIATION IN RESISTANCE OF HARD PINES TO MOUSE DAMAGE

The most rapid progress in forest-tree improvement will be attained through artificial reforestation with superior genotypes. These trees may be native species, exotics, or hybrid combinations involving several species of diverse origins. Any tree planting creates an artificial situation, which is made even more artificial by the introduction of non-native types. In such situations, pests of various sorts—including certain mammals—may be much more destructive than elsewhere. One of the most neglected fields of inquiry bearing on plantation success concerns the role of mammals, especially rodents.

During the winters of 1959-60 and 1960-61, considerable rodent damage occurred in young hard pine plantations at the Hopkins Experimental Forest in Williamstown, Mass. On many trees the bark was gnawed near the ground line; degrees of damage varied from only slight injury to complete girdling of the stem (fig. 1). The feeding took place mainly during the winter under heavy snow cover. Type of damage, plantation site conditions, and limited trapping operations indicated that the destructive agent was the field mouse *(Microtus pennsylvanicus Ord)*, also called the meadow vole.

Two adjacent plantations on the Hopkins Forest were especially hard hit. The trees in these plantings were all exotics—either accessions of known origin, or open-pollinated or hybrid progenies from exotic species growing in the area around Philadelphia, Pa. Plantation GP-2A-56 contained 24 seedlots, 22 of which were derived from Philadelphia plantings; the other two seedlots were accessions of *Pinus thunbergii* Parl. (Japanese black pine) from Japan and Korea. Plantation GP-2B-56 contained 8 seedlots: one each of *P. sylvestris* L. (Scotch pine) from Scotland, England, Austria, and Switzerland; *P. densiflora* Seib & Zucc. (Japanese red pine) from Japan and Korea; and *P. nigra* Arn. (European black pine) from Italy and from a planting near Philadelphia.

Figure 1.—A stem of Japanese black pine *(Pinus thunbergii)* completely girdled by field mice.

The seedlings were outplanted as 2-0 stock in the spring of 1956. Each plantation consisted of 20 replicated plots, each plot containing one tree from each seedlot represented in the plantation. The individual trees were randomized within plots at 6- by 6-foot spacing. This should have been excellent for the evaluation of mouse damage, since foraging animals were allowed considerable freedom of choice in their diets and could more readily exhibit their true food preferences.

In the spring of 1961, each tree that had been recorded alive in a survival tally in the fall of 1959 was examined for mouse damage done during the two intervening winters.

Analysis and Results

Although there was considerable tree-to-tree variation in severity of damage, simple comparisons of percentages of trees attacked clearly showed the variation in resistance among progenies and progeny groups (table 1).

For purposes of statistical analysis, each planting was divided into four blocks with each block containing five adjacent plots. Percent of trees attacked was calculated for each progeny in each block, based on numbers of trees living in the fall of 1959. (Progeny of the cross *P. thunbergii x P. yunnanensis* were not included in the analysis because of the small number of surving trees in 1959). The analysis of variance was performed on transformed values (arcsin transformation) of the percents of trees attacked. In both plantations there were highly significant differences among progeny groups but no significant differences among seedlots within groups of similar parentage. The range test of Tukey (Snedecor, 1956) was applied to permit comparisons of means from different points in the array.

From the data for plantation GP-2A-56, several statistically and biologically significant comparisons can be made.

The hybrid between *P. thunbergii* and *P. tabulaeformis* Carr. (Chinese pine) was more resistant than pure *P. thunbergii. P. sylvestris* was the most resistant of all species or hybrids in the plantation and was significantly more resistant than the backcross progenies containing roughly ¾ *sylvestris* and ¼ *densiflora* germ plasm. *P. densiflora* was also more resistant than the backcross progenies composed of ¾ *densiflora* and ¼ *thunbergii* germ plasm.

It appeared from our data that each species possesses a certain degree of resistance to attack by the field mouse. For the species and hybrids studied, it is possible to construct a tentative resistance rating scale from most resistant to most susceptible as follows: *P. sylvestris, P. tabulaeformis, P. densiflora, P. thunbergii,* and *P. nigra.*

Table 1.—*Mouse damage by progeny groups, 1959-61 among pine trees planted in 1956*

Species or parentage[1] (*Pinus*—)	Seedlot	Living trees; fall 1959	Trees attacked, spring 1961	
	No.	*No.*	*No.*	*Percent*
PLANTATION GP-2A-56:				
thunbergii x *yunnanensis*[2]	2	5	3	60.0
thunbergii[3]	5	41	22	⎧ 53.6
thunbergii x (*densiflora* x *thunbergii*)	6	82	42	⎨ 51.2
densiflora x (*densiflora* x *thunbergii*)	2	32	14	⎩ 43.7
densiflora	1	10	3	⎧ 30.0
thunbergii x *tabulaeformis*	4	66	13	⎨ 19.7
sylvestris x (*densiflora* x *sylvestris*)	2	40	5	⎩ 12.5
sylvestris	2	34	0	0.0
PLANTATION GP-2B-56:				
nigra	2	38	31	81.6
densiflora	2	34	10	29.4
sylvestris	4	78	4	5.1

[1] In hybrid combinations the species used as the female parent is given first.
[2] Not included in analysis.
[3] Brackets enclose progenies among which the damage was not significantly different at the 5-percent level.

Discussion

The results of our study disagree with findings of Littlefield, Schoomaker, and Cook (1946) in New York. In experimental plantings that included various pines, spruces, and larches, they found Scotch pine to be the species most heavily attacked by field mice. Among other exotic pines represented in both their plantings and ours, Japanese red pine, Japanese black pine, and Chinese pine were listed as more highly favored by mice, whereas Corsican pine *(P. nigra)* was less favored. Cayford and Haig (1961) reported that in Manitoba Scotch pine was highly susceptible to damage by field mice. They observed that minor site variations, particularly as expressed in type and density of ground cover, significantly influenced the degree of mouse attack.

The disparities between the above observations and our own exceed the range of variation in food preferences that might reasonably be expected among different mouse populations of the same species and among different environments, and we cannot satisfactorily explain them. We can only point out some circumstances that may influence the seemingly inconsistent food preferences of mice at different times and places.

Trees do not appear to be a favorite mouse food, and mice probably attack trees only when the supply of more favored foodstuffs is insufficient for the population. And food preferences are relative, varying with the supply of foodstuffs of differing palatability in relation to demand. Plantings of any tree species in large blocks would tend to force mice to utilize the trees that were available if they were at all palatable. Comparisons between species growing on different sites and in blocks of different sizes thus might lead to erroneous conclusions regarding species preferences. In our plantations, the single-tree randomization would seem to have been an optimum design for mouse-preference evaluation. However, in the above-cited New York and Manitoba plantings, the reported species differences in susceptibility to mouse damage cannot be attributed entirely to pure-block plantings. At both places, stripwise mixed plantings of two or more species also were involved, and Scotch pine in such mixtures was consistently damaged more than associated species.

The differences among species and hybrids in susceptibility to mouse damage lead to speculations about the controlling factors—what makes one species more palatable to a mouse than another? In our study the pattern of variation among the various progenies suggests that susceptibility (or resistance) is, at least in part, under genetic control. Since no constant relationship was found between damage and morphological or growth characters, the next logical place to look for a clue was in the chemical constituents of the young pine stems. Interest in a possible chemical basis for resistance was further spurred by the publication of Mirov's (1961) compilation of information on the turpentines in pines.

Oleoresins are found in all living parenchyma cells of pines, but chiefly in the epithelial cells surrounding resin canals in the cortex and wood. Thus the resins are readily encountered by gnawing rodents. Oleoresins are made up of rosin and turpentine. Although the proportions of the component chemicals in the turpentine fraction doubtless vary to some extent, the basic composition of the turpentine is constant within species, and hybrids beween species presumably contain turpentine constituents of both parents. Genetic rather than environmental factors are considered to play the major role in compositional variations.

From our observations and Mirov's turpentine analyses, evidence can be adduced for a hypothesis that accounts for resistance on a chemical basis. The evidence and supporting argument are as follows:

Scotch pine, the most resistant of all the species and hybrids in our study, is the only pine among them that is known to contain the highly reactive terpene, delta-3-carene. This raises the question of whether delta-3-carene is responsible for the resistance.[1] If this terpene is in fact an important factor in mouse resistance, tree-to-tree variability in its relative amounts would help to explain why a few Stoch pine trees were attacked. Also, we might infer that the increased susceptibility of *P. sylvestris* x *(densiflora* x *sylvestris)* resulted from reduction in the percentage of delta-3-carene to a point where it was comparatively ineffective in inhibiting mouse attack.

The question now arises as to the cause of the differences in resistance among the other progenies. Alpha-pinene is common in the turpentines of most pine species, and probably confers no specific capacity for differential behavior among species. However, the amount of alpha-pinene is a guide to the relative proportions of other substances. Damage in the progenies studied follows closely the amount of alpha-pinene in the turpentine: the higher the percent of alpha-pinene, the greater the percent of trees attacked. This relationship also holds true for Virginia pine, as compared to loblolly and pitch pines in Maryland (Fenton 1962): Virginia pine, which has a much higher content of alpha-pinene, was damaged much more by mice.

A hypothesis as outlined above—that delta-3-carene is associated with resistance, and that high percentages of alpha-pinene are associated with susceptibility—obviously is not supported by the observations of Littlefield, et al., and of Cayford and Haig. Therefore this hypothesis can be considered only as a first groping for a

[1] It has been noted that *P. brutia* Ten., a species containing delta-3-carene, is immune to the *Matsucoccus* scale insect; whereas the closely-related *P. halepensis* Mill., with none of this terpene, is susceptible (Mirov, 1961).

clue to the puzzle of what makes a species susceptible or resistant. Its value may lie mainly in stimulating further inquiry into the subject of chemical resistance factors.

More information on the chemistry of the oleoresins would be most helpful. The rosin acids and resenes of the rosin have not been studied intensively. Recent work by the senior author indicates that chemical differences exist between resin produced in the cortex and in the wood. Further research should help to elucidate the relationships existing between tree pests and the resins they encounter in their attack on pine trees.

Literature References

Cayford, J. H., and Haig, R. A.
1961. Mouse Damage to Forest Plantations in Southeastern Manitoba. Jour. Forestry 59: 124-125.

Fenton, Richard H.
1962. Meadow Mice Prefer Virginia Pine. Jour. Forestry 60: 258-260.

Littlefield, E. W., Schoomaker, W. J., and Cook, David B.
1946. Field Mouse Damage to Coniferous Plantations. Jour. Forestry 44: 745-749.

Mirov, N. T.
1961. Composition of Gum Turpentines of Pines. U.S. Dept. Agr. Tech. Bull. 1239, 158 pp.

Snedecor, George W.
1956. Statistical Methods. Ed. 5, 534 pp. Iowa State College Press, Ames, Iowa.

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U. S. FOREST SERVICE RESEARCH NOTE NE-6
1963

Northeastern Forest
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Experiment Station

SOME OBSERVATIONS ON PRECIPITATION MEASUREMENT ON FORESTED EXPERIMENTAL WATERSHEDS

Measurement of precipitation on forested experimental watersheds presents difficulties other than those associated with access to and from the gages in all kinds of weather. For instance, the tree canopy must be cleared above the gage. The accepted practice of keeping an unobstructed sky view of 45° around the gage[1] involves considerable tree cutting. On a level area, trees 30 feet tall around a gage require an opening of about 0.06 acre, and trees 60 feet tall, 0.25 acre; on slopes, the openings required can be much greater. Once cleared, the opening immediately begins to close — almost surreptitiously — so that periodic maintenance is necessary.

Still another problem is the effect of heavy cutting, as a watershed treatment, on precipitation catch. Other concerns are the effect of slope on the catch and whether or not the use of tilted gages for slope correction is justified. Some recent experiences along lines of these last two problems are described below. They are based on work at the Fernow Experimental Forest in West Virginia and at the Hubbard Brook Experimental Forest in New Hampshire.

Precipitation Before and After Watershed Treatment

The watershed-research program at the Fernow Forest required the commercial clearcutting of a 74-acre experimental watershed. Everything salable was removed and only isolated unmerchantable trees were left. The clearcutting exposed the two precipitation gages (standard cans) to

[1] Pereira, H. C., McCulloch, J. S. G., Dagg, M. and others. ASSESSMENT OF THE MAIN COMPONENTS OF THE HYDROLOGICAL CYCLE. East African Agr. and Forestry Jour. 27: 8-15, 1962.

Table 1. — *Reduction in precipitation catch after cutting Watershed 1, Fernow Experimental Forest*

Gage No.	Period	Decrease in catch	
		Inches	*Percent*[1]
11	Annual	1.8	2.9
12	Annual	1.6	2.8
11	December-April	1.5	6.9
12	December-April	.6	3.3

[1] Decrease as percentage of the predicted annual or seasonal value.

Table 2. — *Effect of shielding on precipitation catch, Hubbard Brook Experimental Forest*

Period	Shielded	Unshielded	Difference
	Inches	*Inches*	*Percent*
Growing season 1959	20.31	20.14	0.84
Growing season 1960	25.66	25.68	— .01
Dormant season 1959-60	37.12	34.87	6.45

much greater wind movement and consequently reduced the precipitation catch.

The amount of reduction during the 6-year calibration period was determined by regressing annual and dormant-season catches of each of the two watershed gages — gages 11 and 12 — to gage 14, which was outside the treated area; then the regression was used to predict the expected catch in gages 11 and 12 over the 4-year treatment period. Reductions in catch are shown in table 1.

Timber cutting reduced annual catch by a little less than 3 percent, and the December-through-April catch by 3 to 7 percent. The greater winter differences can be attributed to snowfalls because snow catch is affected more by gage exposure than rainfall catch is.

Similar results were obtained at the Coweeta Hydrologic Laboratory in the southern Appalachians where practically all the precipitation fell as rain. A clearing of two watersheds caused a yearly decrease in catch at three gages of 0.98, 3.06, and 4.14 inches, or 1.4, 4.5, and 6.0 percent respectively. The two largest decreases were statistically significant.[2]

Pertinent to these results is a 3-season comparison of shielded and unshielded gage catch at the Hubbard Brook Experimental Forest in an

[2] Data provided by John D. Hewlett, Coweeta Hydrologic Laboratory, Southeastern Forest Experiment Station.

opening on one of the experimental watersheds. Here shielding had little or no effect on the rainfall catch but increased the snowfall catch by more than 6 percent. Growing- and dormant-season results are given in table 2.

What can one conclude from this? First, that in forest openings windshields should be used if winter precipitation includes significant amounts of snow; second, that windshields should be employed for more accurate rainfall catches when a heavy cutting treatment is planned.

Tilted Gages

Tilted gages for more accurate precipitation catches have been suggested by several workers, most recently and cogently by Hamilton.[3] These gages are tilted (or cut) so that the orifice is parallel to the general slope on which the gage is located. The theory behind this is that the ellipse formed by the angled cut will give a more accurate catch of precipitation that strikes the slope. If the prevailing wind direction during periods of precipitation is into the slope, a tilted gage will have a greater catch than a vertical one; however, if winds come from the opposite direction, the vertical gage will catch more. For calculating true precipitation (the amount that would be received on a horizontal surface), the catch from a tilted gage must be divided by the cosine of the slope angle.

[3] Hamilton, E. L. Rainfall Sampling on Rugged Terrain. U. S. Dept. Agr. Tech. Bul. 1096, 41 pp., illus., 1954.

Table 3. — *Percent increase or decrease of precipitation catch in tilted gages as compared to vertical gages*

Hubbard Brook Experimental Forest, West Thornton, N. H.	Fernow Experimental Forest, Parsons, West Va.[1]	Coweeta Hydrologic Laboratory, Franklin, N. C.[2]	San Dimas Experimental Watershed, Glendora, Calif.[3]
[4]1.3	—0.2	0.7	15.6
[4]3.1	—2.5	—1.6	15.1
[5]2.1	— .3	—3.9	20.8
—	— .5	—3.5	11.8
—	—	—5.3	—
	Percent slope		
24	20-42	38-82	40-105

[1] January-September at 4 sites.
[2] April-September at 5 sites; unpublished data, Southeastern Forest Experiment Station, Asheville, N. C.
[3] Four hydrologic years (October-September), each an average of 22 sites; Hamilton, E. L., Rainfall Sampling on Rugged Terrain. U. S. Dept. Agr. Tech. Bul. 1096, p. 22, 1954.
[4] Growing season (May-October).
[5] Dormant season (November-April).

Using tilted gages at the San Dimas Experimental Watershed in southern California on slopes of 40 to 105 percent, Hamilton found that catches increased 12 to 21 percent over those from vertical gages. The predominate gage aspect was southerly, the direction of most of the storms. At the Coweeta Hydrologic Laboratory and the Fernow and Hubbard Brook Experimental Forests, the effects were much less pronounced and frequently they were opposite (decrease rather than increase) from the California catches (table 3). This suggests that all but one of the Fernow and Coweeta gages were located on leeward aspects whereas the gages at Hubbard Brook were on windward situations. However, prevailing wind directions may or may not be meaningful in mountainous terrain where steep topography can cause precipitation-bearing winds to come from many directions.

What can one conclude from this? Certainly that tilting, as tried in the East, has not shown the differences found in southern California. This is probably due to location of eastern gages in small forest openings with high surrounding vegetation: reduced wind velocities cause the precipitation to fall nearly vertically into the gage. However, precipitation at gage height in San Dimas falls at greater angles to the vertical because of wind velocities attained on the exposed conditions.

The decision as to whether a vertical or tilted gage should be used involves a number of considerations. For instance, it is not so much a choice between gages as it is a choice between systems of gaging. As is well recognized, vertical gages provide an index of precipitation on the watershed. On the other hand, tilted gages, when located on representative slopes and aspects, and when exposed to strong winds, will provide an absolute estimate of total precipitation. Where the index concept is employed, substitution of a tilted gage for a vertical one would hardly be justified: it would provide only a different index.

There are other practical considerations that influence the decision. Tilted gages are more valuable when they are used in sufficient numbers to sample predominant slopes and aspects for a measure of total precipitation on a watershed — a sampling intensity perhaps beyond the resources of most research projects. To date, most watershed experiments have relied on streamflow comparisons using a control watershed rather than on precipitation-streamflow relationships. Therefore the more costly tilted-gage network may not be justified.

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U. S. FOREST SERVICE RESEARCH NOTE NE-7

1963

Northeastern Forest

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Experiment Station

HYBRID POPLAR GROWS POORLY ON ACID SPOIL BANKS AT HIGH ELEVATIONS IN WEST VIRGINIA

In the early 1950s, a region-wide series of hybrid poplar clonal tests was begun in the Northeast to evaluate the performance of 50 selected clones under a variety of site and climatic conditions. The basic test unit was a block of 50 randomized plots—1 plot for each of the 50 clones. In each plot, 16 cuttings were planted at 4-foot spacing.

One of these clonal tests was established by the Northeastern Station in 1951-52 on acid spoil banks from coal strip-mining in northern West Virginia. The spoils where the plantings were made were forbidding sites. Elevation was about 3,500 feet. This windswept mountain country has a cold northern climate, with a frost-free season of about 3 months. The soil material, derived from sandstone and shale, was medium in texture, contained large amounts of coal and rock fragments, and was very compact at the surface.

Two blocks were planted in 1951. Ground limestone at the rate of 2½ tons per acre was applied to the surface of one block at the time of planting; the other block was not treated. In 1952 several additional blocks were planted on the same spoil area. None of the 1952 blocks was limed.

Survival and growth data were recorded annually on the two 1951 blocks for 3 years after planting. Only general observations were made on the 1952 plantings. A final examination of all blocks was made in June 1962. This note summarizes the data and observations.

Results

Survival and growth on the unlimed blocks were poor. On the 1951 unlimed block, average survival for all clones at the end of 3 growing seasons was 20 percent, and average height of the survivors was less than

Figure 1. — The best group of hybrid poplar trees on the unlimed block in 1962 — 11 years after planting.

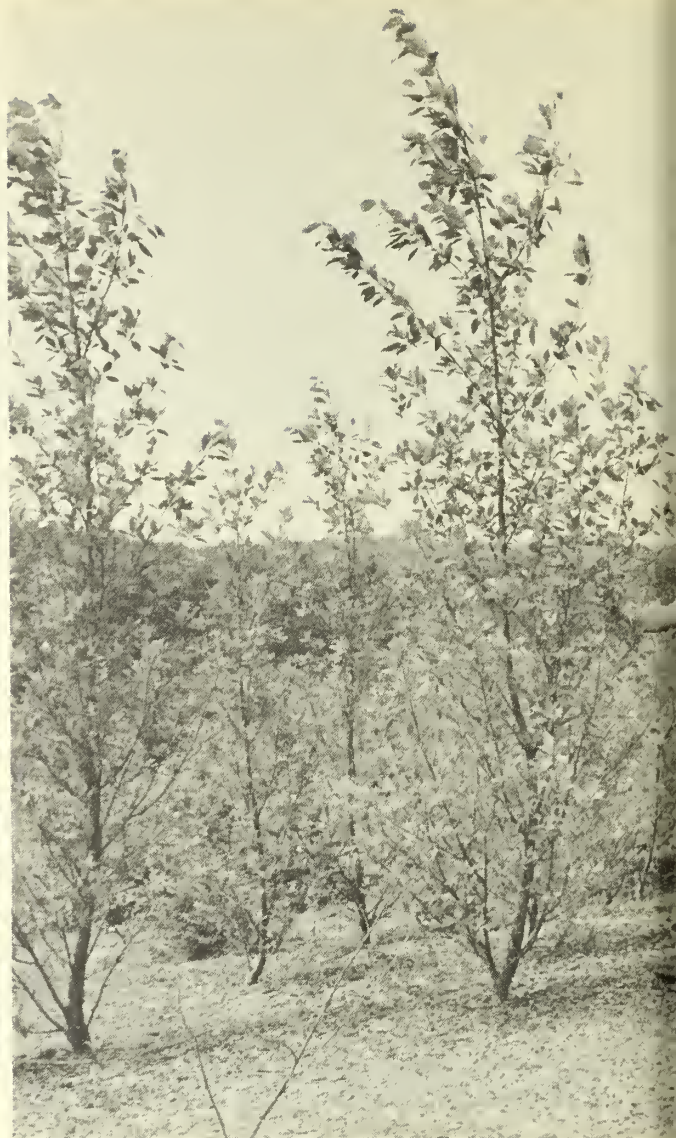

Figure 2. — A good clone—NE-46 —on the limed block in 1962.

1 foot. Many of the original terminals of the survivors had died, and only weak sprouts from near ground level persisted. Clonal differences were only weakly expressed. Only two clones (NE-41 and NE-43) averaged 2 feet or more in height after 3 years; NE-43 was the better of these, averaging 2.8 feet for surviving stems. The variable soil conditions, so typical of spoil banks, probably had more effect on growth and mortality than did clonal differences. Concentrations of waste coal appeared to be particularly unfavorable.

The lime treatment clearly had a favorable effect on the poplars. After 3 years, survival averaged about 80 percent and height averaged about 1.75 feet. Fifteen clones averaged 2 feet or more tall. Clone NE-41 was best, with a mean height of 3.2 feet. Many clonal differences became apparent the first year, and generally they were sustained thereafter. Heights attained on the limed block, though definitely better than on unlimed blocks, still were exceedingly poor in comparison with growth on ordinary agricultural soils.

In 1962—11 years after planting—the effect of liming still was evident in both tree growth and soil pH. At a depth of 1 inch, pH on the limed block was 5.2, as compared to pH 4.6 on the unlimed block.

Living trees on the unlimed block in 1962 averaged less than 3 feet tall, as compared to about 4 feet on the limed block. The tallest tree on the unlimed block had reached 9 feet and a diameter (b.h.) of 0.8 inch (fig. 1). The clone could not readily be identified because the pattern of plots on the ground had been erased by the high mortality. The best tree on the limed block was 16 feet tall and 2 inches in diameter; it was a representative of clone NE-44. Other good clones on this block were NE-41, -42, -43, -46 (fig. 2), -47, and -52. These clones are all hybrids of *Populus maximowiczii.*

In general, survival and growth of the 1952 plantings were about the same after 10 years as described above for the 1951 unlimed plot. However, there were a few instances of markedly better growth that undoubtedly reflect more favorable micro-sites. In one plot, a row of clones planted near the headwall in a moist depression showed much better growth. Several trees of clone NE-42 in this row were 25 to 30 feet tall and 3 to 5 inches in diameter.

In another plot, several unidentified clones showed fully as good growth in 1962 as any clones on the limed plot. These better-growing clones were not in moist depressions; on the contrary, they were on high areas of a somewhat undulating plot. Yet in the same plot there were other areas where no cuttings survived. Apparently the soil on this plot was extremely variable.

Discussion

Lack of moisture and excessive soil acidity appear to be at least part of the reason for the poor development of hybrid poplar in these plantings. The high winds and the stony soil conditions doubtless contribute to the moisture deficiency. Rainfall, which is more than 60 inches a year and well distributed, would be adequate on more hospitable sites.

Compaction of the spoil material probably was another adverse factor. Fresh, loose spoil, if not excessively acid, very likely would have been more favorable than the highly compacted material of the test sites. Soil aeration and water infiltration undoubtedly would be better in looser material, and these conditions would promote more extensive root growth. Although not proposed as a practical measure, we may reasonably speculate that loosening compacted spoils by mechanical means, with incorporation of lime to a depth of 10 to 12 inches, would greatly improve them as sites for poplar growth.

Several comparisons with other species further emphasize that the hybrid popuars are not well suited to the test site:

Red spruce.—This native species, which once clothed West Virginia's high mountain sections with thick vigorous stands, was planted in 1950 on parts of the same spoil area as the poplars. Although a relatively slow-growing species, red spruce from that 1950 planting on and near the 1951 unlimed poplar plot averaged 4 to 5 feet tall—definitely taller than most of the poplars. Survival of the spruce appeared to be good. Despite rather poor color in many trees, indications were that they will continue to grow.

Black and pin cherries.—Scattered trees of these native hardwoods have seeded in naturally on the spoils and generally are growing considerably faster than the poplars.

Poplars on other sites.—Hybrid poplars planted on good bottomland soil at 1,900 feet elevation, only a few miles from the mine-spoil planting site, have grown far better than those on the spoils. Some of the same clones as those on the spoils averaged more than 50 feet tall and 6 inches in diameter at 11 years of age.

Not only was survival and growth of the poplars disappointing on the spoils; but also the trees failed to produce any semblance of a litter or humus layer, and they did not provide enough site protection to encourage native herbs and shrubs to seed in. In most places on the plots the spoil surface in 1962 appeared as bare and desiccated as when the poplars were planted 11 years before.

It remains an open question as to whether hybrid poplars might be recommended for planting on coal-mine spoil banks at the higher elevations, if the material were not notably compacted. But for highly compacted spoils at the higher elevations, such as the test sites here described, this study clearly demonstrates that these poplars should not be planted for revegetation purposes. On such sites, they offer no promise for production of wood products and provide but little site protection.

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U. S. FOREST SERVICE RESEARCH NOTE NE-8

1963

Northeastern Forest

FOREST SERVICE U.S. DEPT. OF AGRICULTURE 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

FIELD TRIAL OF A TREE INJECTOR IN A WEEDING IN WEST VIRGINIA

In June 1960 a 5-acre plot of mixed hardwoods under intensive selection management on the Fernow Experimental Forest in West Virginia was weeded to eliminate poor-quality stems that were competing directly with desirable regeneration. Treatment was confined to stems in the 1- to 5-inch diameter (at breast height) classes.

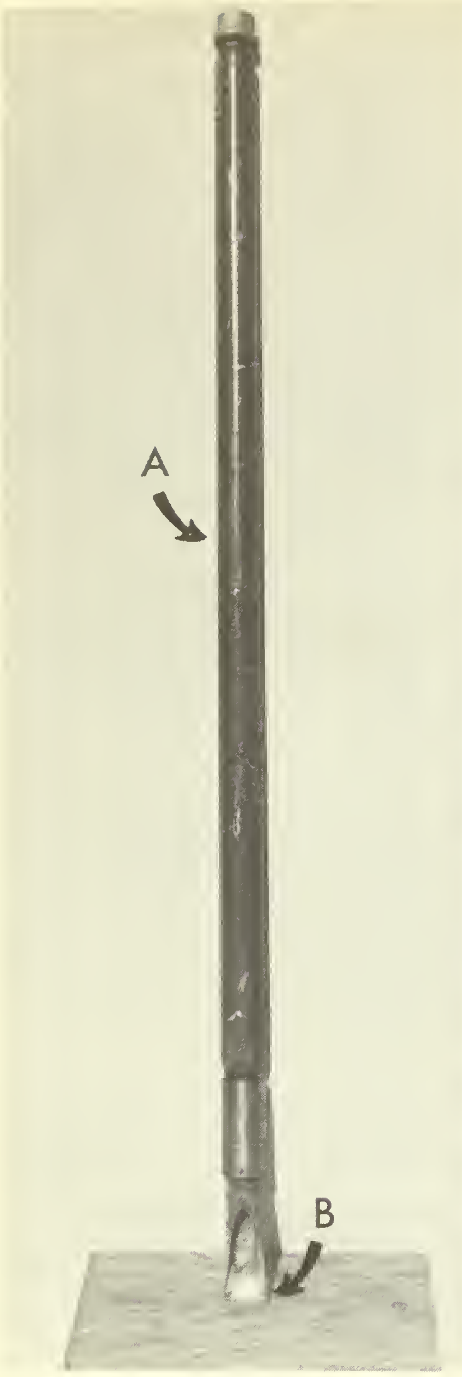
A solution of 2,4,5-T (propylene glycol butyl ether ester) at 40 pounds acid equivalent per 100 gallons in diesel oil was applied in circumbasal cuts, one per inch of tree diameter, with an automatic tree injector. The work was done as a production job, and no special measures were taken to assure exactly uniform applications of the silvicide.

The injector used was a Tree-Di, manufactured by the Parker-Clower Company, Troy, Ala. This device is a 5-foot-long cylinder with a semicircular cutting bit at one end (fig. 1). The silvicide is released from the cylinder by a spring-loaded valve that is actuated by the impact when the cutting bit is struck into the tree stem.

Thirteen species were treated. However, 70 percent of the stems treated were sugar maple (*Acer saccharum* Marsh.) and beech (*Fagus grandifolia* Ehrh.).

After two growing seasons, 134 randomly selected stems were observed to determine kill by species and diameter class. The table shows, by diameter classes, the percentage of kill for all species and for beech and sugar maple separately. None of the dead trees showed any evidence of sprouting.

These results indicate that small stems are easier to kill than large ones. However, this apparent resistance among the larger stems may reflect



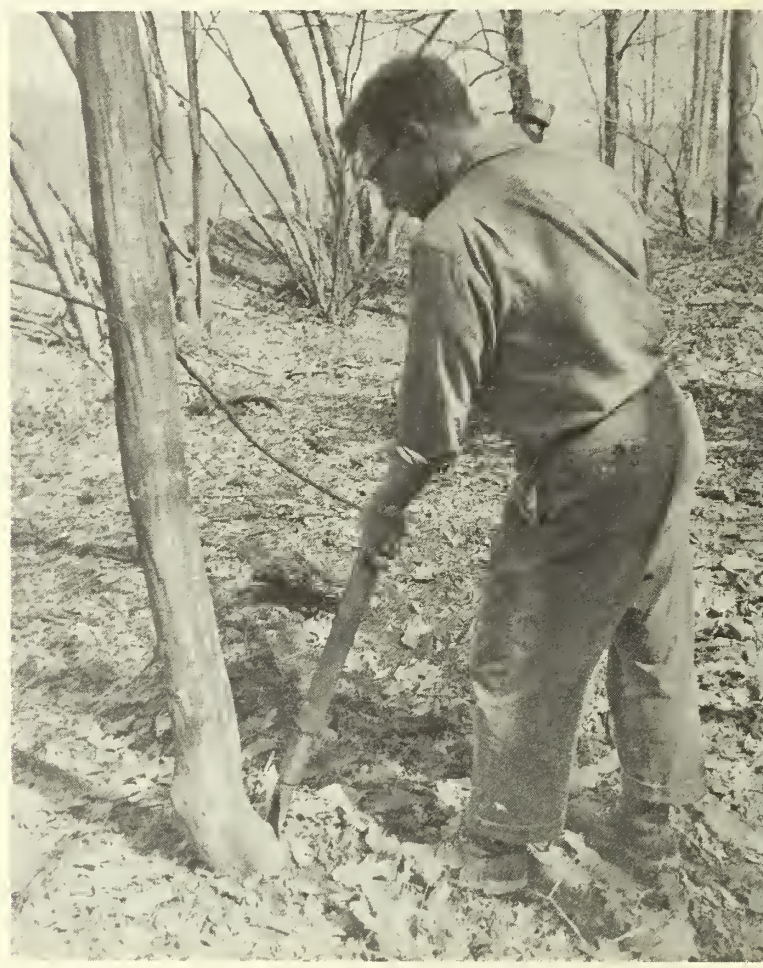


Figure 1. — Left: the silvicide injector. The silvicide in the tube (A) is released by a spring-loaded valve when the semicircular cutting bit (B) is struck into the tree stem.

Right: the injector in use. Injections should be made as near the ground line as possible, with the injector held at a 45-degree angle. The curved bit makes a cup-like wound that prevents runoff of the silvicide.

Figure 2. — Sugar maple is a hard species to kill. In this tree the cambium has survived and proliferated between injector cuts.

Table 1.—*Percentage of kill attained with injector and 2,4,5-T*

D.b.h. class (inches)	All species		Beech		Sugar maple	
	Trees treated	Trees killed	Trees treated	Trees killed	Trees treated	Trees killed
	No.	*%*	*No.*	*%*	*No.*	*%*
1	23	96	5	100	8	87
2	47	64	16	75	23	52
3	37	62	14	57	12	42
4	18	50	3	67	9	22
5	9	44	—	—	6	17
All classes	134	66	38	71	58	47

inadequate treatment. With larger tree size, even spacing of the injector cuts becomes more difficult, particularly in heavy thickets. Several trees encountered during the tally had not received the prescribed number of injections, and the spacing of injections often was irregular.

The average overall kill of only 47 percent of the sapling-size sugar maples indicates that a more intensive treatment is required for adequate control of this species. The treatment used here undoubtedly would be even less effective on trees of pole and sawlog sizes. Kills of sugar maple and other hard-to-kill species probably could be substantially increased by closer spacing of the cuts to make complete or almost complete frills. Also, the use of an injector designed so that the operator could control the dosage per cut might result in better kills.

This test, while limited in nature, does provide useful information for planning future silvicide treatments with injectors in the mountain hardwoods of the northern Appalachian region:

- Sugar maple is difficult to kill and requires relatively intensive treatment.
- Injector cuts probably should be spaced more closely than they were in this test.
- Injectors that provide for operator control of the amount of silvicide per cut might be more effective than the tool that we used.

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U. S. FOREST SERVICE RESEARCH NOTE NE-9

1963

Northeastern Forest

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Experiment Station

EXCESSIVE EXPOSURE STIMULATES EPICORMIC BRANCHING IN YOUNG NORTHERN HARDWOODS

Sudden and excessive exposure of northern hardwood trees often causes growth responses that degrade tree quality, injuries that lead to tree deterioration, or both. The most sensitive and visible tree reaction to increased exposure is the formation of epicormic branches. Such branches may arise along the tree bole from either dormant or adventitious buds in response to some physiological stimulus. Often, but not necessarily always, they are associated with a decline in tree vigor. If they persist, knots develop and log and lumber quality are reduced.

Excessive exposure also may cause twig mortality and top dieback; it may lead to sunscald, snow-bending, glaze damage, and root mortality. In sensitive species such as yellow birch, many trees succumb completely after a few years. Epicormic branching may accompany or, in some cases, may be induced by these various forms of exposure damage (fig. 1).

Clearcutting in small patches (usually less than 1 acre each), which is gaining recognition as a silvicultural system in northern hardwoods for securing a high proportion of yellow and paper birch in the regeneration, has the drawback of suddenly exposing trees on the patch borders. The first patches in old-growth timber expose only mature trees, and epicormic branching here is not of serious concern. But patches cleared in the second and later cuttings adjoin previously cut patches and thus expose borders of young trees. Detrimental effects on these young trees are important because both future growth and timber quality may be impaired.

In a study of patch cuttings on the Bartlett Experimental Forest at Bartlett, N. H., we have become increasingly aware of undesirable aftereffects of exposure. So in 1960 we began a small 1-year study of exposure

Figure 1. — Bent over by snow and afflicted by sun-scald, this 20-year-old sugar maple border tree has produced many epicormic branches.

Figure 2. — A typical border studied, as seen from a newly cut patch; 20-year-old trees on the left, 10-year-old trees on the right.

effects on 10- and 20-year-old border trees. We were concerned primarily with epicormic branches, but noted all manifestations of exposure damage except possible root mortality.

Study Methods

Four borders, each facing a different direction, were chosen in each age class. The borders consisted of the outermost trees growing in previously cut patches that were adjacent to new patches cut in 1960 (fig. 2). In addition to the border trees, unexposed trees were marked along a line 1 chain inside the stand and parallel to the south-facing borders. Five sample trees each of yellow birch, sugar maple, and beech were then chosen at random from each border and from each of the two interior lines. The condition of each sample tree was recorded soon after the cutting in 1960, and again 1 year later. A chi-square test was used to test significance, at the 5-percent level, of differences in numbers of epicormic branches among species, age classes, and exposures.

Most of the tags marking sample trees in the two east-facing borders were missing when the final observations were made, so the following results are based on 15 border trees in each age class instead of the original 20.

Results and Discussion

The exposed south-facing border trees produced significantly more epicormic branches in 1 year than did trees growing 1 chain inside the stands. For both age classes combined, about three times as many epicormic branches were produced by the border trees as by the interior ones.

Direction of exposure showed no consistent effect upon number of epicormic branches. However, direction undoubtedly influences intensity of exposure, and differences in exposure effects other than epicormic branch formation did show up.

Among species, striking differences were observed in the formation of epicormic branches. Yellow birch was by far the most prolific, producing a total of 66 branches among the 30 border trees in the final sample. The sugar maples produced 29 branches; the 30 beeches produced only 5. Expressed as a ratio, the three species rank 13 : 6 : 1 respectively in epicormic-branch production. These differences were significant by chi-square test. The tabulation below shows average numbers of branches per tree by species and age classes (rounded to nearest tenth):

	10-year	*20-year*	*Age classes combined*
Yellow birch	0.9	3.5	2.2
Sugar maple	.2	1.7	1.0
Beech	.3	.1	.2

As this tabulation shows, the 20-year-old birches and maples formed many more branches than the 10-year-old trees; and these differences are significant. However, the differences may not be entirely a physiological effect of age. The older trees, being larger, had more bole surface on which branches might originate, and this size factor in itself may be important. Size almost certainly would be important if the main source of branches was adventitious buds. Even if, as seems likely, the main source of branches is dormant buds, the number of branches might increase with tree size: larger trees offer more area to exposure and possible stimulus of dormant buds by light, heat, and other atmospheric factors; larger trees may have undergone more natural pruning, thus baring the boles and increasing their exposure; and larger trees may have more potentially active buds because of envelopment of more basal branch buds in addition to the original complement of stem buds. So, although tree age may well be a direct factor affecting the number of epicormic branches, it probably functions also as an indirect factor operating through tree size.

Some sun-scald and snow bending also occurred. Sun-scald was most prevalent on 20-year-old sugar maple and beech on the south-facing border. Here it caused extensive death of bark along the tree boles, followed by discoloration of the underlying wood. Three of the five sample trees of sugar maple and one of the five beeches on this border were severely damaged by sun-scald. No sun-scald was observed on yellow birch: the light-colored bark of this species, which would reflect much of the heat and light, possibly was a factor in its resistance to sun-scald damage.

Snow damage was more prevalent on all of the borders than sun-scald, but was not so injurious to the individual trees. Most noticeable on the 20-year-old borders, snow-damaged trees usually were bent over in an arc or in a pronounced lean toward the center of the clearcut patch, no doubt because the mechanical support of adjoining trees on that side had been removed. Most trees damaged by snow seemed likely to recover.

Little top dieback or twig mortality had occurred on these 10- and 20-year-old trees. Though some foliage was discolored, serious crown damage, if it appears at all, probably will not show up until after several growing seasons. Because of the youth and vigor of most of the sample trees, they may adjust to the changed environment without appreciable dieback in the crowns.

Origin of Epicormic Branches

The study afforded an excellent opportunity to explore the origin of epicormic branches. Theoretically, epicormic branches can develop from either dormant or adventitious buds. By definition, a dormant bud is connected to the pith and primary xylem of the parent stem or branch by a strand or trace of pith and primary xylem tissue. As the parent stem or branch grows in diameter, the strand elongates and the bud continues to lie just under the bark. Upon receiving a suitable stimulus, the dormant bud may become active and produce a branch. An adventitious bud, on the other hand, originates in place, usually from the cambium as a result of injury or other stimulus; it has no strand connecting it with the center of the parent stem.

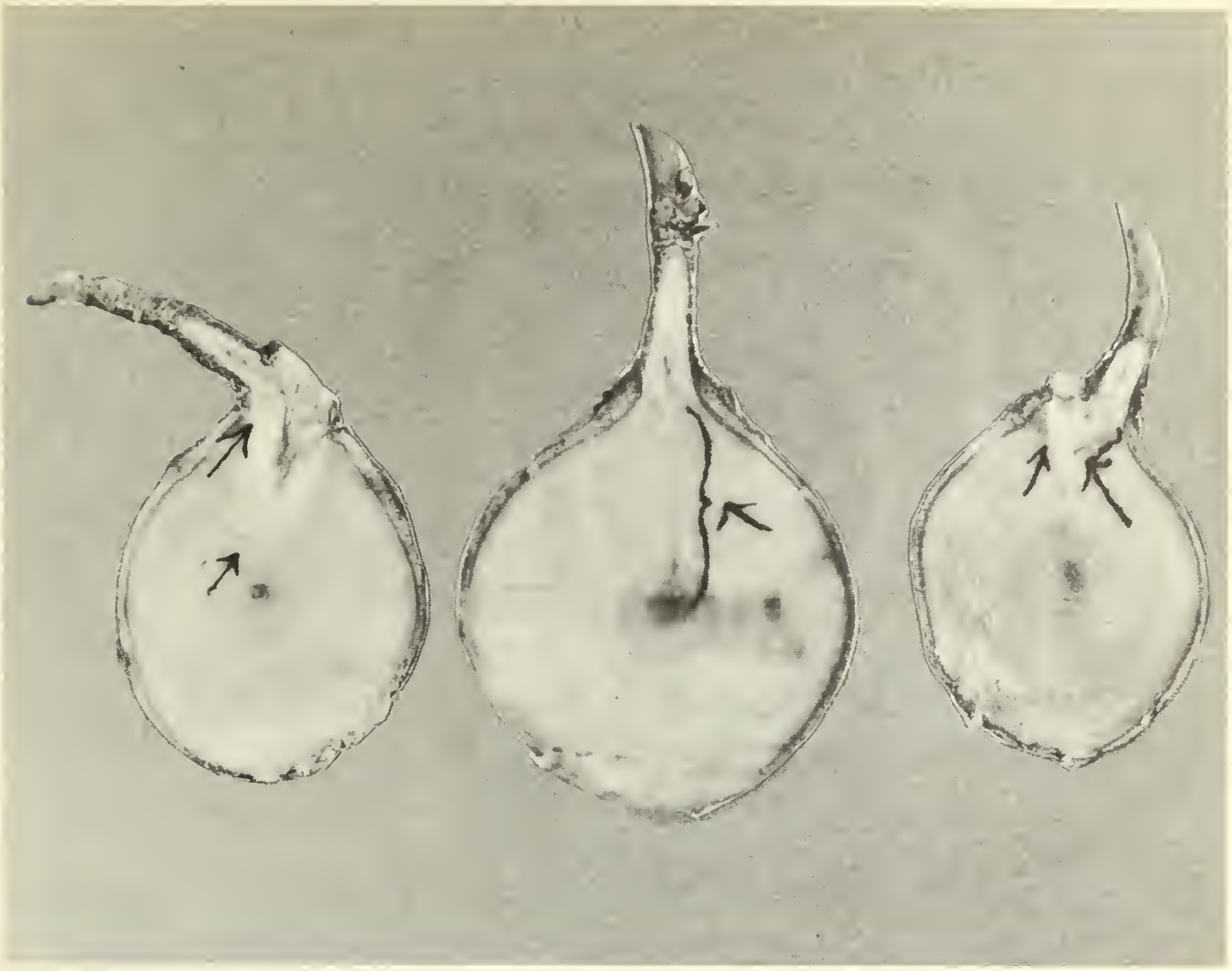

Figure 3. — Cross-sections of yellow birch saplings showing bud strands connecting with epicormic branches. The center section shows a strand originating at the pith of the tree; those on either side show strands originating from old branch knots.

About 30 epicormic branches from several sugar maple and yellow birch saplings from the borders were dissected to determine branch origin. In all cases, including one with cambial injury (sun-scald), the branch was connected to a typical strand extending back into the underlying wood, which confirmed its origin from a previously dormant bud.

However, not all of the bud strands could be traced back to the pith of the parent tree. Particularly in yellow birch, the bud strands of many of the epicormic branches appeared to begin along old branch knots some distance from the pith of the main stem (fig. 3). We could not definitely follow these strands all the way to their origins; presumably they led to old leaf axils at the base of the primary branches that had given rise to the knots. The lower primary branches now were dead and mostly broken off, and the old leaf-axil sites had been enveloped by growth of the main stem, but the axillary buds apparently had maintained their identity and had moved outward as the main stem grew in diameter.

These observations invite a few questions. Does the potential of a tree to form epicormic branches from dormant buds increase with the number of old branch stubs within the tree? Can the number of dormant buds be limited to a significant degree by the early artificial pruning of live limbs? Does the persistence of dormant buds from old branch bases in itself mean that larger trees will produce more epicormic branches than smaller trees?

If all epicormic branches came from dormant buds that had originated on the main stem, the potential of a tree to form such branches would be essentially the same throughout its life. By the same token, if such branches came from adventitious buds or a combination of dormant and adventitious buds, the epicormic-branch-forming potential of a tree would theoretically increase with an increase in the surface area of the tree. If, as our observations indicate, dormant buds from old branch bases persist, the feathering-out potential of a tree may be related to the number of branch stubs within the tree bole. Further study on the origin of epicormic branches should provide some answers to these questions.

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U. S. FOREST SERVICE RESEARCH NOTE NE-10
1963

Northeastern Forest
FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.
Experiment Station

SEVEN-YEAR RESULTS IN MANAGING A SMALL WOODLOT IN SOUTHERN MARYLAND

In the five Maryland counties south of Baltimore, there are 825,000 acres of commercial forest land. About half of this area is estimated to be in true farm woodlands; that is, in small tracts of 40 acres or so that are part of working farms.

Properly managed, these farm woodlands could contribute to the owners' incomes. Unfortunately, few are under any form of management. Many tracts, even though supporting mature timber, lie unused. Others are exploited by high-grading, or by clear-cutting of all merchantable trees. Moreover, in such unmanaged stands, insects, disease, and severe weather take an excessive toll.

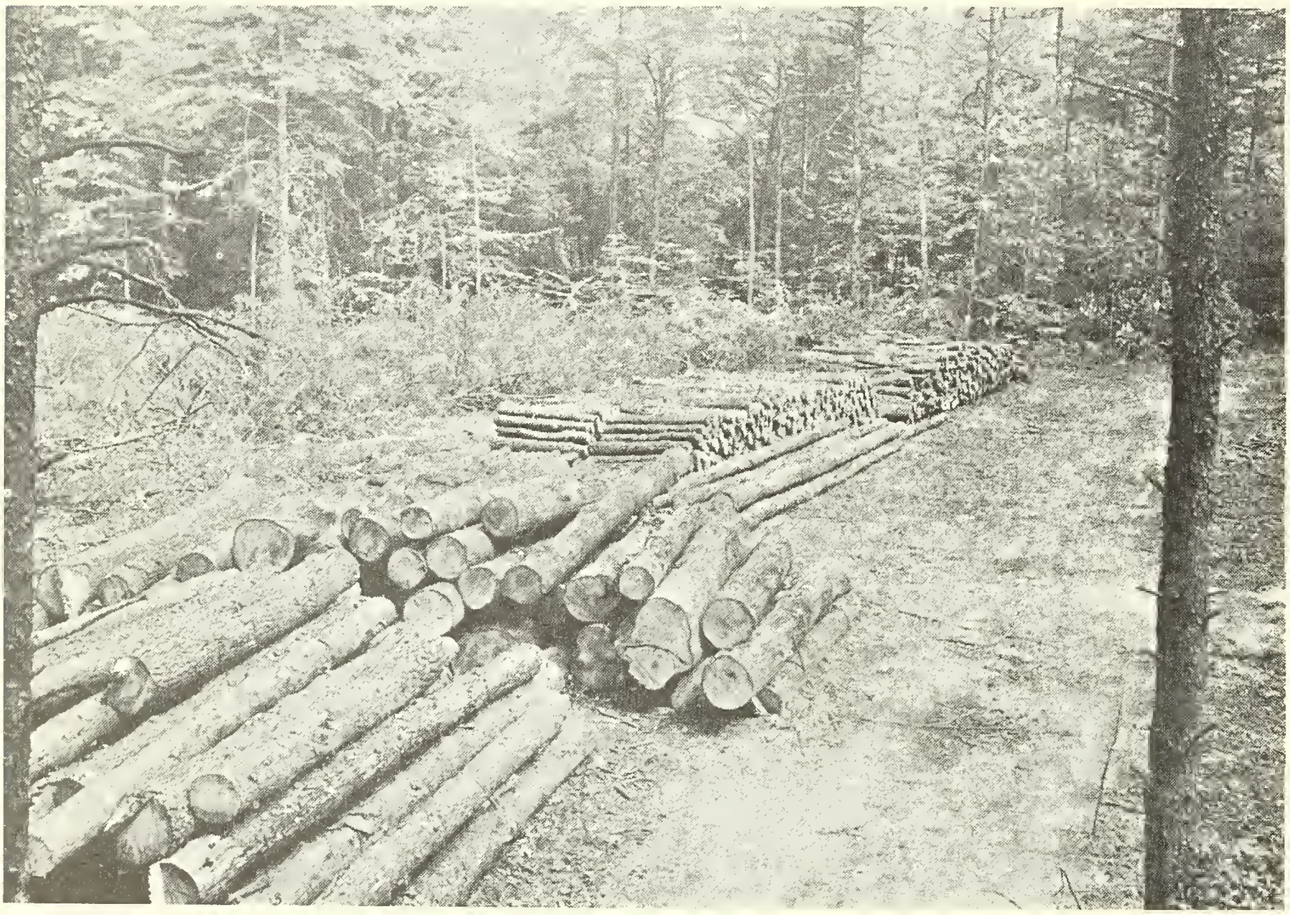
Yet despite past misuse or lack of use, the income and growth potential of southern Maryland's farm woodlands is good. To help demonstrate this fact, the Northeastern Forest Experiment Station in 1954 set aside a 40-acre wooded tract near Beltsville as a farm-woodland demonstration. It was representative of a non-used timber stand. No cuttings had been made in it for at least 40 years; neither had other influences such as fire or storms materially affected the stand. In short, it was reasonably typical of the extensive Virginia pine and mixed hardwood stands of the 5-county area — particularly of stands on poorer-than-average sites.

Three distinct forest types made up the stand: 15 acres in pure pine, principally Virginia pine; 18 acres in pine-oak, mostly pitch pine, southern red oak, and white oak; and 7 acres in pure hardwoods, mostly oaks.

What Was Done

First we had to learn some basic facts about our woodland, such as volume of merchantable timber, composition by species and size classes, and location and area of forest types. These, along with the annual growth rate, were determined. Then a plan of management was prepared. The essence of our system was to harvest annually, or periodically, a volume of merchantable timber about equal to the annual or periodic growth. This was to be supplemented by cultural treatments; these included pine slash disposal and seedbed preparation by burning, control of unwanted hardwoods, planting of pine seedlings, and releasing pine reproduction by weeding.

The silvicultural systems adopted were those that we felt were best suited to managing this woodland. In pure pine, our system was clear-cutting in small patches, based on a 40-year rotation, and supplemented by cultural treatments to reproduce pine in the patches. In pine-oak, our system was selective cutting of about 40 percent of the merchantable



Products cut in 1 year's operation (1954): 3,865 board feet of hardwood sawlogs; 1,795 board feet of softwood sawlogs; 226 lineal feet of pine piling; 77 pine fence posts; 10.1 cords of pine pulpwood; and 7.5 cords of hardwood fuel wood. This first cutting was somewhat heavier than later harvests.

Excellent reproduction of Virginia pine 5 years after clear-cutting a small patch in 1954. Slash was burned in September before seedfall.

volume on a 1-acre block each year, taking the poorest hardwoods first and generally leaving most of the pine for seeding purposes. In pure hardwoods, our system was light selective cutting over the entire 7 acres, taking a few of the larger trees each year, but taking them in groups wherever feasible so as to make larger openings for regeneration.

One final decision remained: who was to harvest the trees and perform the specified treatments? Should we, as a simulated private owner, do the work and sell the products? Or should we take the usual course and sell only stumpage? We already had a 1-man chain saw, a wheeled farm tractor, and miscellaneous small tools; so we decided to do the harvesting and follow-up treatments ourselves, using two men. Most farmers with woodlands either own, or have access to, similar equipment, which we found quite adequate for the job.

The prescribed cuttings and treatments were started in 1954, and repeated annually. The logging job required an average of about 135 man-hours per year, the follow-up treatments an extra 13 man-hours.

What Was Found Out

Each year, a careful record was kept of costs and returns. The volume of all products harvested, and the money received for them at roadside, was recorded (table 1). Labor requirements for the various treatments were kept to the nearest man-hour, and realistic equipment operating costs were charged (table 2). The stumpage values used, which were

Table 1. — Net volume of products cut and sold at roadside, 1954-60

Year	Pine pulpwood	Pine sawlogs	Hardwood sawlogs	Hardwood fuelwood	Pine piling	Fence posts	Peeled hardwood pulpwood
	Units[1]	*1,000 bd. ft.*[2]	*1,000 bd. ft.*[2]	*Units*[1]	*Lineal feet*	*No.*	*Units*[1]
1954[3]	8.067	1.795	3.865	6.000	226	77	—
1955	4.044	.935	2.620	6.990	—	—	—
1956	5.406	2.135	1.140	—	—	—	4.987
1957	5.727	1.015	2.145	—	—	—	3.000
1958	5.687	1.260	1.485	—	—	—	5.344
1959	5.781	.725	1.250	—	—	—	3.500
1960	6.425	—	1.325	—	—	—	3.806
Total	41.137	7.865	13.830	12.990	226	77	20.637

[1] 160 cubic feet each.
[2] International ¼-inch rule.
[3] The 1954 cut unintentionally exceeded annual growth; it was calculated from a preliminary growth estimate that later was found to be too high.

averages of those prevailing in southern Maryland at the time, were: $3 per unit for pine pulpwood, $0.25 per unit for hardwood pulpwood, and $12 per thousand board feet for run-of-the-woods sawtimber.

The costs and returns (table 2) are for the logging operation plus a total of 60 man-hours in chemi-peeling hardwoods for pulpwood from 1956 through 1960. After-logging cultural treatments, averaging 13 man-hours per year, are not included. If done by the owner alone, he could write them off as a time investment only, except for a small outlay for chemicals and hand tools. One person could perform the prescribed treatments — although when burning slash, it would be advisable for two people to be on hand. The 7-year total labor requirements for the cultural treatments were:

	Man-hours
Hardwood control with silvicides	15
Prescribed slash burning	55
Planting pine seedlings	16
Weeding pine reproduction	8

Our inputs, particularly those for cultural work, would not strictly apply to other woodlands. Also, they vary on the same tract from year to year. For example, because of poor seed crops in 1955 and 1956, our pine patch cuttings in those years did not restock well with pine. So

Table 2. — Annual returns, 1954-60

Year	Road value of products[1]	Equipment costs[2]	Net return	Man-hours worked	Returns: Per man-hour[1]	Returns: Stumpage alone
1954	$318.16	$55.95	$262.21	193	$1.36	$82.45
1955	180.33	37.45	142.88	133	1.07	40.81
1956	219.05	36.10	182.95	133	1.38	49.92
1957	193.73	20.80	172.93	103	1.68	43.64
1958	214.45	47.50	166.95	139	1.20	42.72
1959	166.99	45.85	121.14	136	.89	35.01
1960	160.65	32.40	128.25	106	1.21	28.15
Total	$1,453.36	$276.05	$1,177.31	943	—	$322.70
Av./yr.	$207.62	$39.44	$168.20	135	$1.25	$46.10

[1] Includes stumpage.
[2] Rates charged were $1.50 per hour for the wheeled tractor and $0.50 per hour for the chain saw.

16 man-hours were spent in planting these with Virginia and loblolly pines. Also, time spent in slash burning cannot be predicted exactly; ours ranged from 15 man-hours one year to only 4 in another.

Private woodland owners applying cultural practices such as the four listed above are eligible for cost-sharing payments, ranging from 50 to 80 percent of the treatment cost, through the Agricultural Conservation Program (ACP). And forest planting stock is provided at no cost to Maryland landowners.

Discussion

We have shown that a modest income can be realized each year from a small woodland such as the one on which we worked. Our average net roadside return (including stumpage) was $168.20, about $1.25 per man-hour worked. This man-hour return can be realized where the owner and his helper do the harvesting themselves, the way some forest-land owners prefer to operate. However, if the owner had hired two assistants to do all of the work, say for $1.25 per hour each, it is obvious that there would not have been any return left for the owner at all — not even the return from stumpage; so in a situation like this, where the owner is not able to work on the harvesting operation himself, he would be better off to sell his wood products as stumpage and forego the roadside value.

The other objective of our management demonstration was to increase the volume and quality of the growing stock to the site's maximum capacity. This is a more intangible goal; to actually show that the management system was achieving this objective would require a fairly long time — more than 7 years. But we think our efforts were expended in the right direction. For example, except on some parts of the present pure-hardwood site, we felt the pine should be favored over hardwoods. Fifteen acres were already stocked with mature pine in nearly pure stands. We were able for the most part to successfully regenerate the small clear-cut patches with Virginia pine and to control the hardwood competition at small cost. In the selectively cut pine-oak type, we retained most of the healthy pines as a seed source for pine reproduction. What we did remove were hardwoods that definitely had little growth or quality potential. Finally, in the hardwood type, selective removal of large, dominant, but overmature trees certainly provided needed growing space for the younger hardwood understory.

The management systems applied to the three types represented in this woodland can be tentatively recommended for other farm woodlands having similar types and similar stand characteristics. With other types or different stand conditions, some other approach might be recommended. Professional on-the-ground advice may be obtained from county foresters, consulting foresters, and the Extension Service; and published information is readily available from federal and state agencies. Some of the pulp and paper companies also provide advisory services to local forest-land owners.

— RICHARD H. FENTON and RALPH P. BROOMALL*

*At the time this study was made, the authors were on the staff of the Northeastern Forest Experiment Station's research center near Laurel, Md., which since then has been discontinued. Mr. Fenton, a research forester, is now serving at the Experiment Station's research unit at New Lisbon, N. J. Mr. Broomall, a forestry aide, is now serving at the U. S. Forest Service's Forest Disease Laboratory at Beltsville, Md.

U. S. FOREST SERVICE RESEARCH NOTE NE-11

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

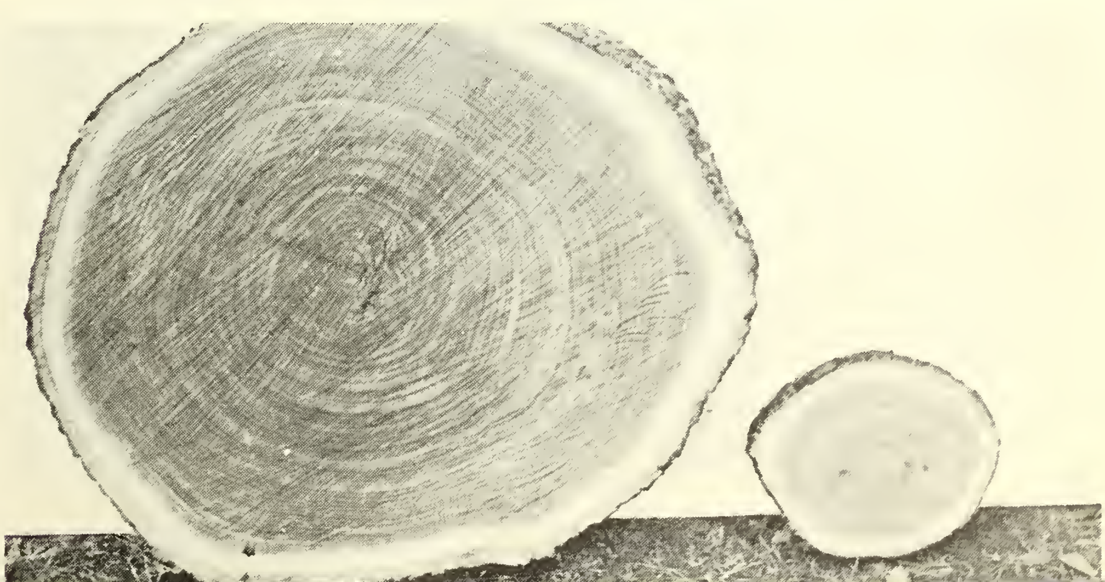
Experiment Station

TREE DIAMETER A POOR INDICATOR OF AGE IN WEST VIRGINIA HARDWOODS

Foresters generally recognize that diameter growth, height growth, sprouting vigor, and seed production are partially related to age; so age often has an important bearing upon silvicultural decisions. But unless past stand histories are fully known, the ages of hardwood trees can be determined only by increment borings, which not only require excessive time but also expose the trees to stain and decay. As an alternative, many foresters assume that for silvicultural purposes tree diameter at breast height is accurate enough as a guide to tree age. For managed even-aged stands, this assumption may hold true. But for unmanaged mountain hardwoods, a recent investigation on the Fernow Experimental Forest, Parsons, West Virginia, has revealed extreme variability in the tree age-d.b.h. relationship (fig. 1).

A random sample of 360 trees, restricted to six species, was selected from trees recently harvested from several hardwood stands. Prior to cutting, these stands exhibited a more or less typical uneven-aged diameter distribution. The cutting removed all stems above 4 to 5 inches d.b.h.

Figure 1.—These two cross-sections cut from red oak stumps illustrate the range in tree size for a given age. Both trees were 55 years old. They grew 40 feet apart on a site-index 60 area.



except a few vigorous high-quality seed trees of desirable species. This type of cutting provided an opportunity for a representative sample throughout a wide range of ages and size classes.

For each sample tree, d.b.h. and number of annual rings at stump height (approximately 1 foot) were determined; and the site index class[1] in which the sample occurred was recorded. Red oak (*Quercus rubra* L.), which was well represented on all three site-index classes covered in this

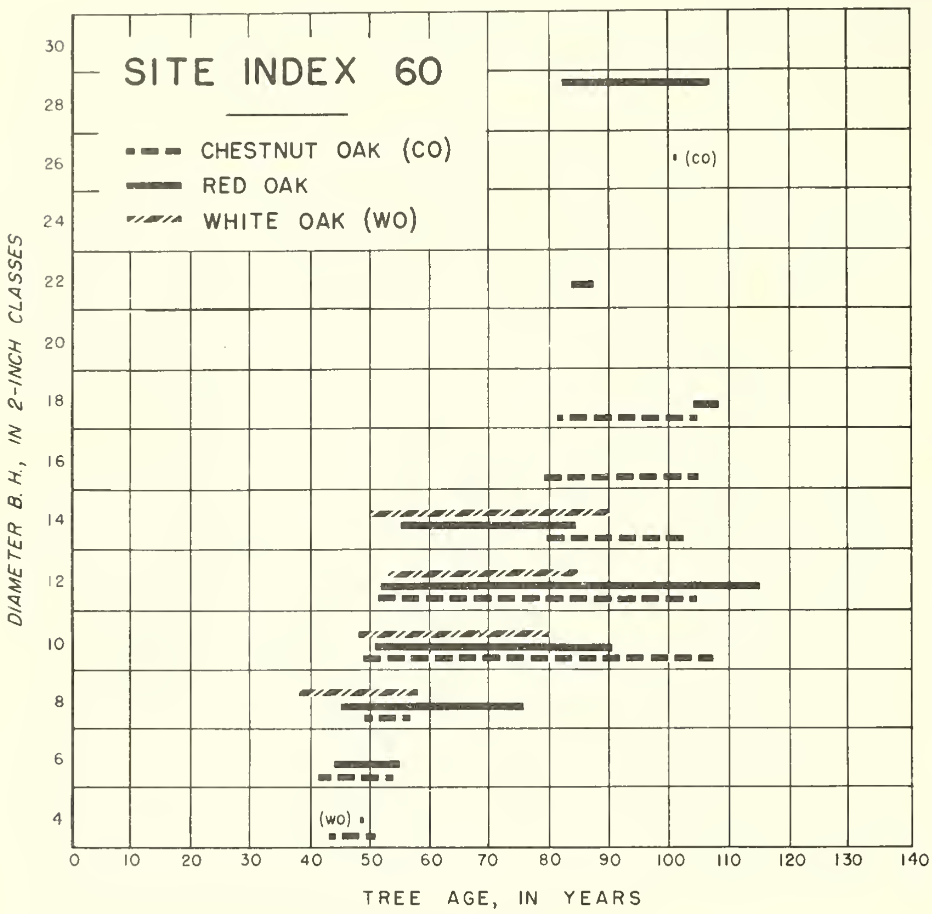
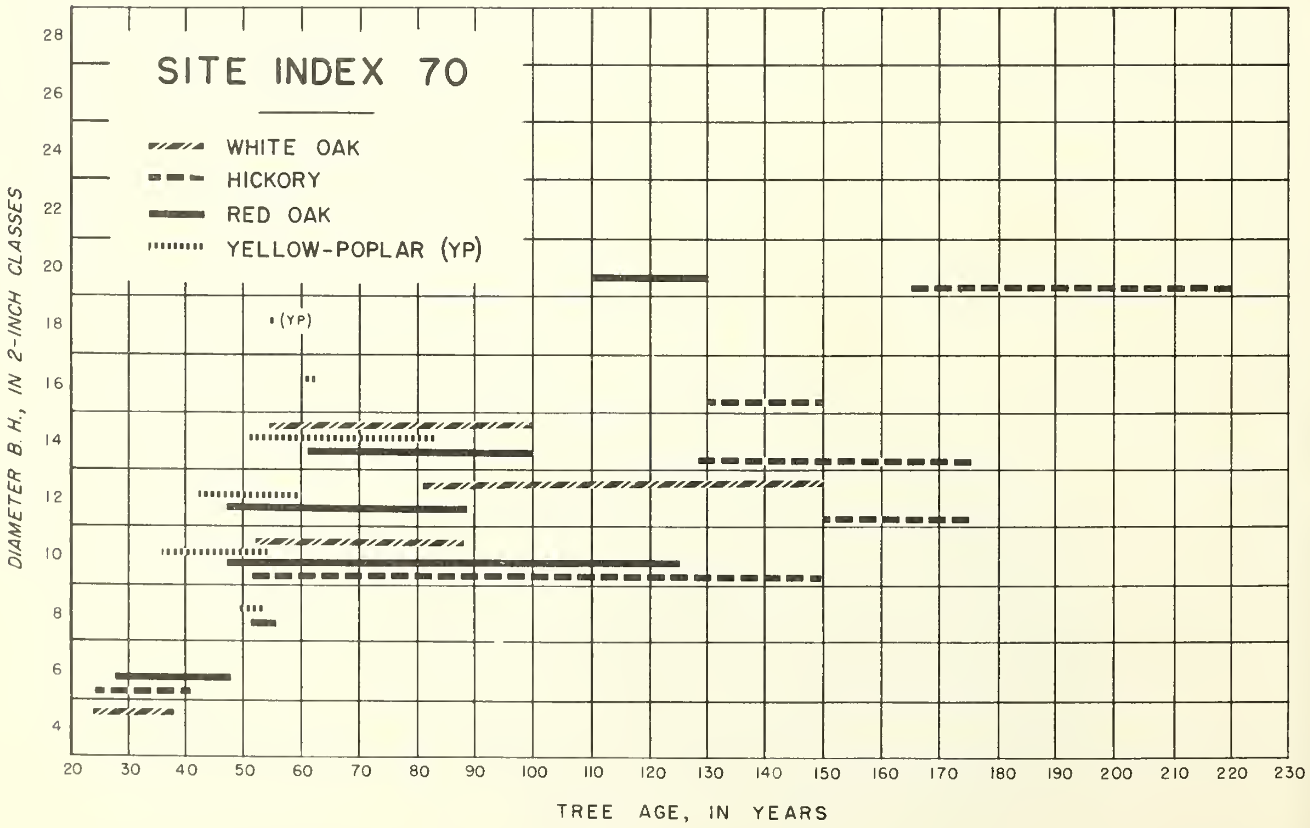


Figure 2.—Range in age by d.b.h. class, site index 60.

Figure 3.—Range in age by d.b.h. class, site index 70.



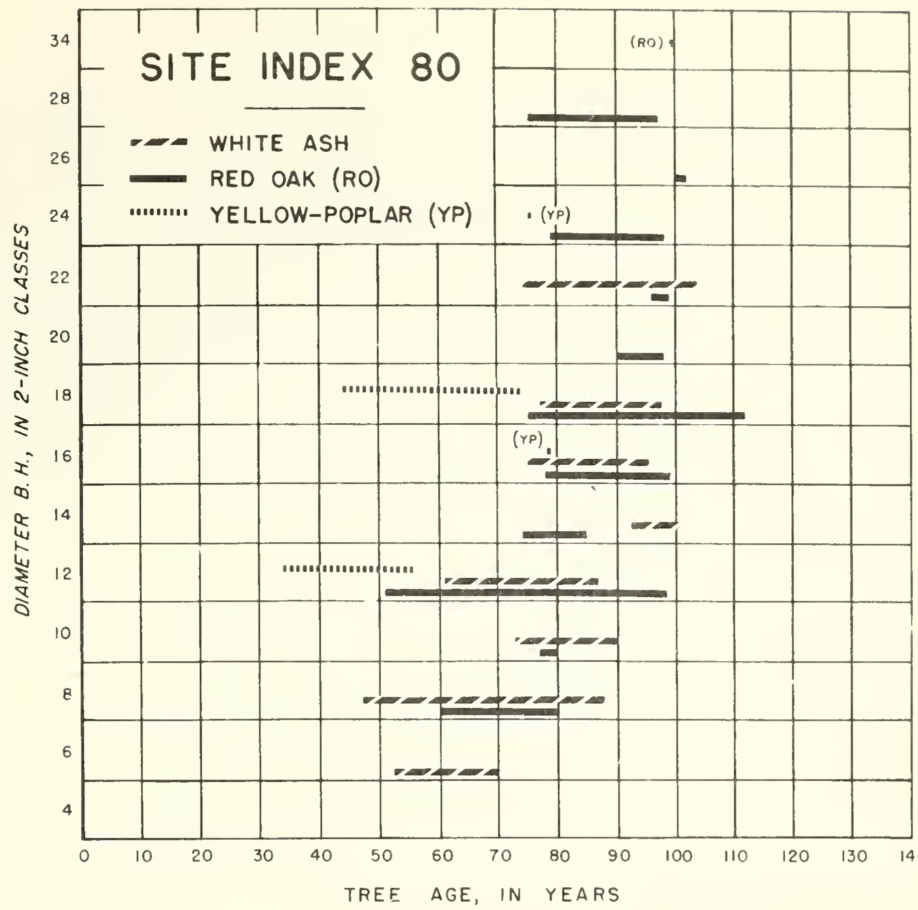


Figure 4.—Range in age by d.b.h. class, site index 80.

study, was the predominant species. The other species were hickory (*Carya* spp.), chestnut oak (*Q. prinus* L.), yellow-poplar (*Liriodendron tulipifera* L.), white oak (*Q. alba* L.), and white ash (*Fraxinus americana* L.).

The results showed that age varies widely within a narrow range of d.b.h. (figs. 2, 3, and 4). For all species and sites, the greatest variability in age generally occurred in the 10-, 12-, and 14-inch d.b.h. classes. The maximum range within any d.b.h. class was 42 to 175 years for 12-inch trees on site index 70. The extreme variability in these middle d.b.h. classes was due to the presence of young thrifty dominants and codominants in mixture with older intermediate and suppressed trees.

Hickory showed the greatest range in age of all species that were studied—no doubt because of its longevity and tolerance. The maximum range for this species in any d.b.h. class was 51 to 150 years for 10-inch trees on site index 70. Red oak, although generally considered to be an intolerant species, was a fairly close second; the maximum spread in age was 47 to 125 years for 10-inch trees on site index 70. Generally speaking, yellow-poplar showed the least range in age within d.b.h. classes of all species. One of the reasons for this may be the relatively narrow total range in age of the yellow-poplar in the study area: nearly all trees of this species came in after heavy cutting of the virgin forests between 50 and

[1] Trimble, G. R., Jr., and Weitzman, Sidney. Site index studies of upland oaks in the northern Appalachians. Forest Sci. 2: 162-173, illus., 1956.

80 years ago. Also, yellow-poplar is very intolerant and usually occurs in even-aged groups.

The relationships between age and d.b.h. were examined from another viewpoint: the maximum range in d.b.h. within any 10-year age class by species and site-index class (figs. 2, 3, and 4). Of all species, red oak exhibited the greatest range in d.b.h. by age class. For the 100-year age class on site index 80, d.b.h. of red oak ranged from 12 to 34 inches. Only a slightly smaller range occurred for red oak in the 80-year age class on site index 60. White oak and hickory showed the least variation of all species in d.b.h. by age class. Apparent differences between species were probably due in part to unequal sample sizes and sampling variation.

Past research in mountain hardwood stands has shown that diameter growth varies by site for trees in the highest two or three vigor classes.[2] But in this study of unmanaged stands, differences in growth rate among sites could not be compared because of the limited amount of data, variable stand histories, and lack of observations on tree vigor. For the same reasons, no comparisons among sites could be made of the variability in the age-d.b.h. relationships.

This study, which is supported by similar findings in northern hardwoods of New Hampshire,[3] clearly indicates that in unmanaged mountain hardwoods, age estimates based solely upon tree d.b.h. must be viewed with caution. The extreme variability of the tree age-size relationship presents for the forest manager questions that bear directly on the successful application of silvicultural practices. For example:

- Will growth responses after silvicultural treatment vary appreciably among trees of the same size but different ages?
- Will the amount and vigor of sprouting be more closely related to tree size or age?

Until research can provide answers to these and similar questions, evaluation of the impact of age and size variability upon silvicultural practices in unmanaged mountain hardwoods must be based to a large extent upon practical experience.

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[2] Trimble, George R., Jr. Relative diameter growth rates of five upland oaks in West Virginia. Jour. Forestry 58: 111-115, illus., 1960.

[3] Blum, Barton M. Age-size relationships in all-aged northern hardwoods. U.S. Forest Serv. Northeast Forest Expt. Sta. Forest Res. Note 125, 3 pp., illus., 1961.

U.S. FOREST SERVICE RESEARCH NOTE NE-12

1963

Northeastern Forest
Experiment Station

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

WHAT HAPPENS TO LIVING CULL TREES LEFT AFTER HEAVY CUTTING IN MIXED HARDWOOD STANDS?

In the Appalachian Mountains, the logging operator usually cuts only those trees that he thinks will yield a profit, and leaves the trees that appear to be unprofitable. Generally these unprofitable trees are either below merchantable size or are culls[1]—trees of merchantable size that contain too little sound material to justify harvesting costs.

In stands that have been burned badly or have suffered repeated high-grading in the past, a large number of the stems may be culls. After logging in such stands, these defective trees threaten the new stand with serious competition. How valid is this threat? What happens to these culls after logging? Do they thrive and develop? Do they merely hang on? Or do they die out? Forest managers in the Appalachian Region would like to have answers to these questions to help determine which culls to kill, and when.

An opportunity to learn something about cull-tree behavior was recently provided by records taken on several commercially clearcut areas on the Fernow Experimental Forest near Parsons, West Virginia, as part of an overall study of management systems for Appalachian hardwoods. Analysis of these records did not provide a complete set of answers on cull-tree behavior, but it did help to define some trends and point up some research needs.

[1] The definition of a cull as used in this study is as follows: any tree 5 to 11 inches d.b.h. that does not have a sound 12-foot section to a 4-inch top inside bark, or, in case the tree is too small to contain 12 feet to a 4-inch top, does not have a potentially sound 12-foot section; any tree over 11 inches d.b.h. (sawtimber tree) that does not scale at least 50 percent sound to an 8-inch top inside bark or does not contain a 16-foot log of sound merchantable material. In addition to rot, sweep or extreme roughness can make a tree a cull.

Our interest in the development of residual culls arose when we observed that many culls died after heavy cutting. It had been the general belief that the opposite might be true: that after heavy release most culls would gain in vigor or at least would persist a long time and would compete with the new stand. These casual observations of heavy mortality among culls led us to attempt a closer evaluation of what was happening.

The Study

The study areas were four compartment-sized units and one 5-acre plot (table 1). These areas, in fact the whole Fernow Forest, were covered by virgin hardwoods until the first logging was done about 1905. Then, between 1949 and 1958, commercial clearcuttings were made; the stands at the time consisted of second-growth Appalachian hardwoods with a heavy admixture of scattered old growth left from the original logging. Volumes per acre in merchantable sawlog-size trees ranged from about 5,000 to 15,000 board feet and averaged 10,000.

The species included the oaks (mostly red, chestnut, and white), sugar maple and red maple, beech, yellow-poplar, black cherry, several hickories, white ash, basswood, sweet birch and a scattering of yellow birch, and a number of minor species typical of Appalachian mountain hardwoods.

The purpose of the cutting was to remove all merchantable trees down to 5.0 inches d.b.h. This objective was more nearly met on some areas than on others (table 1). Cull trees were left intentionally. Logging was done with a crawler tractor and sulky. Trees were winched to main skidroads and skidded tree-length to the deck for bucking.

Immediately after or 5 years after the commercial clearcuttings (table 1), 100-percent inventories were made of the residual stands—stem tallies by d.b.h. class and species for three categories of trees: merchantable, cull, and dead. Cull trees were not permanently marked during the inventories taken immediately after logging; however, they were scribed at the 5- and 10-year cruises. These periodic remeasurements, which revealed changes in numbers of living culls, provided a fairly good indication of cull behavior although more precise information could have been obtained if all individual cull trees had been identified immediately after logging.

Two areas—14-A and 14-B—offered better study opportunities than the other areas because: (1) three periodic inventories were available, immediately after logging and 5 and 10 years later; and (2) fewer merchantable trees were left per acre as a source of new culls to distort the record (table 1).

Table 1.—*The cull-tree study areas*

Area	Size	Site index for oak	Tally period	Culls[1] left after logging		Merchantable trees[1] left after logging	
				Total	Per acre	Total	Per acre
	Acres	*Feet*	*Years*	*No.*	*No.*	*No.*	*No.*
14-A	11.15	77	0, 5, 10	34	3.0	81	7.3
14-B	15.87	67	0, 5, 10	121	7.6	239	15.1
1-A	51.86	75	0, 5	663	12.8	1188	22.9
1-B	22.58	64	0, 5	478	21.2	784	34.7
Plot A	5.0	78	5, 10	([2])	([2])	—	—

[1] Trees over 5.0 inches d.b.h.
[2] The first after-logging cull tally here was made 5 years after logging.

Results

Area 14-A.—The number of culls in all size classes decreased (table 2). Of 6 culls larger than 21 inches d.b.h. on the area immediately after logging, 5 were left at both the 5- and 10-year tallies. Of 27 culls over 11 inches d.b.h., the number dropped to 18 at 5 years and 12 at 10 years. Of 31 culls over 7 inches d.b.h., 20 were left at 5 years and 13 at 10 years. The 6-inch culls were not included because many small culls that were below this size at the time of logging grew up into the 6-inch class during the inventory periods.

Area 14-B.—Cull behavior on this area was much like that on Area 14-A (table 2). The 12 culls over 21 inches d.b.h. that were present immediately after logging declined to 9 at both the 5- and 10-year remeasurements. Of 76 culls over 11 inches d.b.h., the number dropped to 54 at 5 years and to 45 at 10 years. Of 110 culls over 7 inches d.b.h., 66 remained at 5 years and 63 at 10 years.

From these results on these two areas, two important relationships become apparent:

- After heavy cutting, a higher proportion of small culls than of large culls died over the 5- and 10-year periods.

- Losses of cull trees were generally greater during the first 5 years after logging. For trees over 21 inches d.b.h., losses during the first 5-year period equaled those over the entire 10-year period; no additional losses occurred during the second 5-year period. For trees over 11 or 7 inches, losses were greater during the first 5 years than during the second 5 years.

Actual mortality of cull trees might have been somewhat greater than the losses shown (table 2) because a few trees that were classified as merchantable immediately after cutting may have deteriorated later into culls—most likely because of rot development resulting from logging damage.

Plot A.—The cull record on this 5-acre area is complete only for the 5- and 10-year after-logging remeasurements; culls were not tallied immediately after logging. Between the 5- and 10-year periods the number of culls over 21 inches d.b.h. remained at 2; the number over 11 inches d.b.h. declined from 13 to 9; and the number over 7 inches d.b.h. dropped from 26 to 13.

Areas 1-A and 1-B combined.—The 5-year tally on these two areas showed a large number of culls. There were 627 culls over 7 inches d.b.h. compared to 594 immediately after logging. This appeared strange in view of the fact that a number of culls had died during the 5-year period (fig. 1). The explanation apparently is that out of the large number of residual merchantable trees left after logging (table 1), many deteriorated and became culls. This situation prevented any valid quantitative analysis of what happened to the culls after these two areas were logged.

Discussion

A surprisingly large proportion of cull trees died in the period after logging, more in the first 5 years than in the next 5 years. For the two areas for which reliable figures are available (14-A and 14-B combined),

Table 2.—***Change in number of cull trees after logging: Areas 14-A and 14-B***

D.b.h. size class (inches)	Cull trees, years after logging			Change in proportion of culls after 5 years		Change in proportion of culls after 10 years	
	0	5	10				
	No.	*No.*	*No.*	*No.*	*%*	*No.*	*%*
				AREA 14-A			
21	6	5	5	—1	—17	—1	—17
11	27	18	12	—9	—33	—15	—56
7	31	20	13	—11	—35	—18	—58
				AREA 14-B			
21	12	9	9	—3	—25	—3	—25
11	76	54	45	—22	—29	—31	—41
7	110	66	63	—44	—40	—47	—43

Figure 1.—A 15-inch beech that died shortly after logging. This was one of the culls left in Area 1-A.

39 percent of the culls over 7 inches d.b.h. died within 5 years, and 46 percent were dead within 10 years. These heavy losses shortly after logging indicate that the shock of sudden exposure may have been an important factor contributing to cull mortality.

Mortality among small culls was much higher than among large culls. This too indicates that the shock of sudden exposure contributed to cull mortality. The smaller stems had been subordinate trees of low vigor, with a large proportion of shade leaves in their crowns. The larger culls were more vigorous, with a larger proportion of their leaves accustomed to exposure to sunlight. (A large part of the mortality among the big culls was due to windthrow.)

Left unanswered by this study are a number of pertinent questions such as:

- What are the differences among species in the survival pattern of culls? Too few stems by diameter classes were available to permit valid species comparisons.
- Are there characteristics of cull trees—such as vigor class, size, and type of defect—that can be identified and used to predict the probability of survival or the length of time that a cull may survive?
- What is the relationship between residual stand density after logging and cull behavior?

Yet the study provides some useful information for the forester engaged in stand improvement. On the basis of this research, it seems reasonable to recommend that large culls be killed before, during, or immediately after logging—whichever time is most feasible—since few of them will die soon after logging, and few large culls will be destroyed during logging.

For small culls it might be desirable for two reasons to wait 5 years or so before killing them: (1) fewer residual cull stems will need to be killed, because as many as 40 percent may die in the first 5 years after logging, and (2) many additional small trees damaged in logging will have developed toward being culls that obviously need to be removed at the end of 5 years.

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U.S. FOREST SERVICE RESEARCH NOTE NE-13
1963

Northeastern Forest
FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.
Experiment Station

SNOW DEPOSITION AND MELT UNDER DIFFERENT VEGETATIVE COVERS IN CENTRAL NEW YORK

Two-thirds of the annual runoff from watersheds in the Allegheny Plateau of central New York comes from the snow—or snow and rain—that falls in December through April. Although the amounts of precipitation in this period are fairly uniform from year to year, the proportion that falls as snow varies; so does the amount that accumulates on the ground, and its duration and rate of melt. The differences in ground cover also affect snow deposition and melt and the timing and amount of runoff from this snow.

The Study

To determine the relative amounts of snow deposition and melt on open land and under forest stands of different species and densities, snow depth and water equivalent were measured at 23 weekly intervals on the Tully Forest of the State University of New York College of Forestry, 20 miles south of Syracuse, in the winter and spring of 1961-62.

Seven snow courses were laid out to traverse five cover types commonly found on the Allegheny Plateau: (1) open land (unimproved pasture), (2) brushy hardwoods, (3) northern hardwoods, and (4) red pine and (5) Norway spruce plantations. In the brushy-open hardwood type thorn-apple, (*Crataegus* spp.) was the most conspicuous component, but hardwood saplings, berry bushes, and other shrubs were common. The pine and spruce plantations were about 30 years old, and each included both a dense and a thinned stand. The dense stands still exhibited the approximately 6 x 6 feet spacing used in their establishment. The thinned Norway spruce stand had also been pruned. In the all-aged northern hardwood stand, occasional stems 20 inches in diameter at breast height were found.

Each snow course was roughly 100 feet long, divided into 10 equal sampling segments in which sampling points were randomly located. All the courses were within 1 mile of one another at elevations of 1,900 to 2,000 feet on slopes of less than 10 percent, oriented approximately southwest.

Table 1 shows the basal area and sum of diameters derived from a tally of all the trees 1 inch and more in diameter at breast height, on strips 66 feet wide centering on the snow courses, and the average of crown-closure measurements made at each sampling point with a densiometer.[1]

Table 1.—*Cover conditions on snow courses*

Cover type	Basal area	Sum of diameters	Crown density
	Sq. ft./acre	*Inches*	*Percent*
Open land	0	0	0
Brushy hardwoods	31	1,553	2.8
Northern hardwoods	133	2,930	7.6
Red pine, thinned	109	2,486	85.
Red pine, dense	196	5,253	93.
Norway spruce, thinned	163	5,269	94.
Norway spruce, dense	139	5,255	96.

A record of air temperature was obtained from a thermograph and maximum-minimum thermometers exposed at a central location on the Forest. Data for a number of missing days of record were estimated on the basis of the relationship to a nearby Weather Bureau cooperative station at Cortland, N.Y.

The period November 1961 to early April 1962 was one of less than normal precipitation. Most of the months showed small departures from the long-term average, but March had 1.64 inches less precipitation than normal. Not only was the total precipitation less, but the proportion that fell as snow was less than the average of the past 30 years.

[1] Lemmon, Paul E. A SPHERICAL DENSIOMETER FOR ESTIMATING FOREST OVERSTORY DENSITY. Forest Sci. 2: 314-320, 1956.

Results

There was a continuous fluctuation in snow water equivalent throughout the measurement period. Successive weekly measurements indicated snow accumulation, melt, or both. However, there was a general overall increase in water equivalent of the snow on the ground up to March 3 on the open, brushy hardwood, northern hardwood, and thinned Norway spruce plots, and up to March 23 on the others.

Snow accumulation.—In the middle and later winter period snow was most variable on the brushy hardwood site, accumulating most readily here, but also melting fastest. The open plot accumulated less largely because wind blew some snow away; this plot also lost snow readily through melt, a pattern that paralleled that on the brushy hardwood site, but at a lower level. The northern hardwood stand tended to accumulate snow at a slightly lower rate than the brushy stand, and tended to lose it at a slightly slower rate, giving a similar net effect.

Maximum accumulation on hardwood and conifer sites reflects the balance between precipitation, interception, and melt. Average maximum snow water equivalents for the six forest-cover conditions (table 2) are approximately in reverse order of the crown densities of the stands in which they were measured. The accumulation on the brushy site was not significantly different from that under the denser northern hardwoods.

The sum of the positive increments between sampling dates gives an expression of the cumulative effect of cover on snow deposition over the entire season (table 2). This expression is probably a better index of the overall effect of the different cover types than the maximum accumulation on the ground at any one time. Total accumulations under the spruce and dense red pine stands are probably close to the actual values; here most of the snowfall remained on the ground until it was measured. For the hardwood stands, the open site, and the thinned red pine stand the values shown are underestimates, the amount varying inversely with the cover density.

Values of total accumulation for the entire period of the study are inverse to crown density for tree- and shrub-covered sites and show a wider range in values than the maximum accumulation. On the brushy hardwood site the total accumulation for the season is 1.9 times that under the dense spruce, although only 1.6 times as much was present on the ground at the time of maximum accumulation.

Significance of difference.—Analyses of variance of mean water equivalents for each sampling date showed that differences significant at the 5-percent level existed among the cover types whenever there was snow

Table 2.—*Measured snow accumulation, in inches of water*

Cover type	Maximum accumulation on ground	Total accumulation Nov. 30 to April 27
Open land	2.25	6.07
Brushy hardwoods	5.15	9.23
Northern hardwoods	4.90	7.28
Red pine, thinned	4.90	6.44
Red pine, dense	4.05	5.33
Norway spruce, thinned	3.05	5.13
Norway spruce, dense	3.25	4.80

on the ground. Subsequent least significant difference computations generally showed differences between the mean values of all possible pairs to be significant, with few exceptions. For instance, there was no difference between the water equivalents of the thinned and unthinned spruce stands on February 1 and 23 and all through March. Other instances of similar average water equivalents probably do not reflect physical similarities of the stands so much as fortuitously similar results of a number of factors influencing accumulation and dissipation in different degrees.

Ice and snow density.—An unusual but probably not unique occurrence was the presence of solid ice on the soil surface and in the litter under the dense spruce stand from January 4 to the end of the study. This started as a layer of rain that froze in the shallow snow but, once established, did not disappear. The thickness of the ice varied little over the plot, but increased in depth with partial melt and refreezing. There was also a gradual change in the type of ice, from a thin continuous layer to thicker granular ice, and finally to a thick (1½ inch), clear, dense, hard ice. At times there was evidence of meltwater flowing over the frozen surface, as indicated by small channels and by areas where needles were deposited by the moving water, but the ice surface remained intact. The water equivalent of this ice layer is included in all estimates of water equivalent for the dense spruce stand. This ice layer persisted through several days with maximum temperatures over 80°F. A similar layer formed under the thinned spruce stand, but it became discontinuous and disappeared before the end of the study.

Average snow density tended to increase to approximately 30 percent just prior to rapid melt. This is in general agreement with observations made in the Adirondacks and in New Hampshire. The presence of the layer of ice in the spruce stand obscured this relationship somewhat.

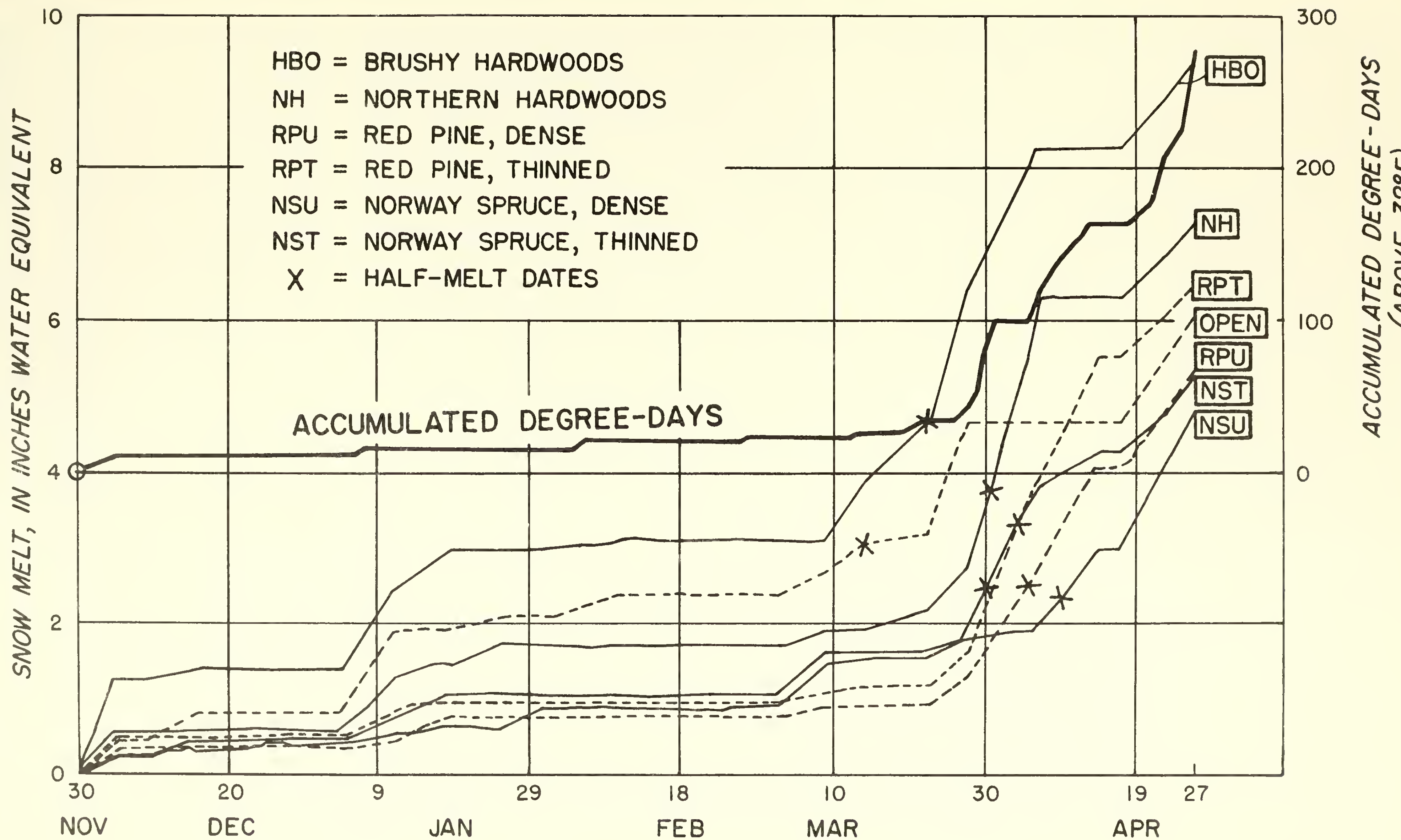

Figure 1.—Cumulative snow melt on the Tully Forest. Southwest aspects, 0 to 10-percent slopes, elevation 1,900 to 2,000 feet.

Half-melt date.—The accumulated degree days and accumulated snow melt shown in figure 1 illustrate the striking differences associated with the different cover conditions. The date when half of the seasonal snow melt has taken place may be related to the prolonged high stream discharge rates during the snow-melt period (a possibility suggested by Arnold Court's half-flow date[2]). For instance, by March 15 and 23, before the first real spring warm spell (which started about March 28), half the seasonal accumulation of snow disappeared in the open and brushy hardwood sites, and the ground was largely bare except for some drifts in the brushy area. The halfway point in the northern hardwoods and thinned spruce was reached about March 31, in the red pine stands about April 4 and 5 and in the dense spruce 5 days later. The most rapid melt of the season occurred under the northern hardwood stand during this period, and extended rapid melt also occurred under the thinned conifers. Under the dense conifers melt was somewhat slower and the more rapid rates occurred later.

Snowmelt runoff.—The longer the snowpack persists, the greater is the likelihood of rapid melt rate and consequent rapid runoff, as the transition from cold winter proceeds into the warmer conditions of spring—greater the likelihood, too, of heavy rainfall swelling snowmelt runoff from the ripe snowpack. It appears that the timing of high temperatures or amounts of rainfall may change the forest's influence on snow accumulation and melt from favorable to unfavorable. When the critical warm period comes early, with large snowpack accumulations in both fields and forests, forests probably contribute less and slower runoff than open areas; when warm weather comes late, with an appreciable snowpack only in forests, the reverse should be true. Consequently, a mixture of forest cover and open areas may provide the best land-use control of snowmelt runoff on the northern Allegheny Plateau.

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[2] Court, Arnold. LARGE MELTWATER FLOWS COME LATER. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Res. Note 189. 8 pp., illus, 1961.

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U.S. FOREST SERVICE RESEARCH NOTE NE-14

1963

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

THIRTEEN-YEAR GROWTH OF SOME GREEN ASH PROVENANCES IN THE NORTHEAST

Green ash (*Fraxinus pennsylvanica* Marsh.) is one of the few native hardwood species that has been planted for afforestation in appreciable numbers in this country. In the Central States this species has been grown mainly on submarginal farmland and on strip-mine spoil banks, while in the Great Plains it has been planted for shelterbelts. In the Northeast, only limited experimental plantings have been attempted.

Ecotypic variation in the Great Plains population was reported by Meuli and Shirley (1937); they recognized three ecotypes based on resistance to artificially induced drought. Wright (1944) also distinguished three ecotypes among collections from the eastern United States and Canada: he found differences in seedling growth rate, petiole color, winter hardiness, time of height-growth cessation, and susceptibility to early frost damage.

This is a report on the growth performance of green ash from several provenances growing in three plantations established in 1951 and 1952 by Dr. Jonathan W. Wright while he was with the Northeastern Forest Experiment Station.

Materials and Methods

Seed was supplied by various cooperators throughout the species' range. Each seedlot was collected from a single mother tree. All but two of the seedlots were labeled by the collectors as *F. pennsylvanica* var. *lanceolata.* However, since Little (1935) does not recognize varieties of *F. pennsylvanica,* we followed his concepts and disregarded the varietal designations.

As received, the seed was stored dry in sealed containers in a refrigerator; later it was moist-stratified for several weeks in the refrigerator before sowing in the spring. The seedlings were grown in the nursery of the Morris Arboretum at Philadelphia, Pa. They were transplanted once and were outplanted as 1-1 stock. Each seedlot in a plantation was represented by 10 seedlings, except for a few lots for which only 8 or 9 seedlings were available. All seedlings in a plantation were completely randomized as single-tree plots.

The first plantation, designated GP-13-51, was installed in 1951 at the Hopkins Experimental Forest at Williamstown, Mass., on a well-drained upland site of Stockbridge loam. The area had been used for agriculture many years before but had reverted to a brush cover with hardhack (*Spirea latifolia* and *S. tomentosa*) predominating. The trees were planted at 8 x 8-foot spacing in plowed strips and were cultivated the first year.

Plantation GP-14-52, established in 1952, was also at the Hopkins Experimental Forest. The soil type here was Amenia loam. This area had been used as hay land for many years and had a heavy grass cover when the plantation was established. Planting was done in rototilled strips at an 8 x 8-foot spacing. The trees were not cultivated or mulched.

The third plantation, GP-1-52, was established in 1952 at the Beltsville Experimental Forest at Laurel, Md. The stock was the same as in GP-14-52 except that one additional Pennsylvania seedlot was included. The soil type was an imperfectly drained Beltsville loam. The area had been under intermittent cultivation for some 300 years and was in a condition of low fertility. The soil had been further depleted by the recent growth and removal of two crops of sod for landscaping purposes. As a result, the soil-type designation may not have been truly indicative of the quality of the site. For the test, the sparse ground cover—mostly seedling Virginia pine—was cleared off and the ash seedlings were planted in plowed furrows at an 8 x 8-feet spacing. All trees were heavily mulched with wood chips.

All plantings were measured in the fall of 1962, when the trees were 13 or 14 years old trom seed. Height and diameter measurements were made only on trees that had not died back and resprouted during the last 5 years. Sprouted trees also were excluded from the survival figures; therefore actual survival was somewhat higher than reported here. Height and survival data were subjected to analysis of variance to ascertain both inter- and intra-provenance differences. In these comparisons, all collections from a given state were considered as a single provenance because, despite some significant variation among seedlots within states, no significant variation among collection localities within states was evident. The range test of Tukey (Snedecor 1956) was used to compare provenance means from different points in the array.

Results and Discussion

The growth of green ash is considered to be highly sensitive to site differences (Hansen and McComb 1958). We took no data on site characteristics other than the general history and condition of each planting area. However, tree growth was markedly better in plantation GP-13-51, which was on a brushy site and was cultivated the first year, than in the other two plantings, which were on grassy or open land and not cultivated (table 1). This superior performance in GP-13-51 is in accord with much other published and general experience, indicating (1) that planted hardwoods usually grow better on land that has been under tree or shrub cover, and (2) that they grow better when cultivated at least through the first year.

Differences in survival among provenances were highly significant in plantation GP-14-52, but not in the other plantations. The inhibiting effect of grass possibly influenced survival in this plantation to some extent, since the trees were neither cultivated nor mulched. The southern progenies had the highest dieback and mortality, perhaps caused by failure to harden off before fall frosts. For the three plantations collectively, 7 percent of the trees had died back during the last 5 years and resprouted: average survival with these trees included was 89 percent; when they were excluded, as was done in preparing table 1, average survival was 82 percent.

The main purpose of this study was to compare the growth of plants from various sources. Some of the differences in height among provenances in both Massachusetts plantings were highly significant. However, no significant differences developed in the Maryland planting. But how meaningful are the observed differences?

These tests suffer from a fault common to many so-called "provenance" tests in that they contain, for some localities, only a single seedlot from a single mother-tree. Other localities are represented by as many as 12 single-tree progenies. Thus these plantations are more like one-parent progeny tests of trees for which origin was the only basis of selection. The difficulties inherent in the establishment of a true provenance test are not unique to green ash, but are encountered with any species that is characterized by sporadic distribution, infrequent seed years, and seed-storage problems. Obviously comparison of provenance samples of such varied composition as those in this study cannot be expected to yield much data of value. Perhaps the only valid conclusion that can be drawn with regard to provenance is that green ash from southern sources is not well adapted to western Massachusetts.

Of greater biological interest, then, is the variation among progenies within localities. The differences in height within provenances (all

Table 1. — *Growth and survival of green ash provenances in three plantations*

State	Seedlots	Survival	Average height [1]	Range in seedlot height averages	Intra-state seedlot differences in height [2]
	Number	*Percent*	*Feet*	*Feet*	
			GP-13-51		
Minn.	1	100	16.6	—	—
Iowa	6	98	15.2	13.1-19.3	*
Mont.	1	100	15.1	—	—
S. D.	3	100	14.3	13.8-15.5	n.s.
Maine	5	93	14.2	12.7-15.1	n.s.
Mich.	1	100	13.7	—	—
Neb.	5	93	13.4	10.5-17.8	**
Ind.	1	78	13.3	—	—
Md.	1	80	11.6	—	—
Ky.	1	60	8.8	—	—
			GP-1-52		
Minn.	3	85	6.5	5.1-7.2	n.s.
Neb.	3	87	5.9	5.2-6.8	n.s.
S. C.	1	100	5.5	—	—
Ind.	12	78	5.4	3.6-6.8	n.s.
Pa.	6	85	5.4	3.4-6.8	n.s.
Tenn.	1	88	4.6	—	—
S. D.	5	91	4.5	3.6-5.0	n.s.
			GP-14-52		
Neb.	3	83	10.2	9.9-10.5	n.s.
Minn.	3	100	9.8	8.2-13.7	**
S. D.	5	89	9.3	7.8-10.9	n.s.
Ind.	12	76	7.0	4.3-11.2	**
Pa.	5	61	6.5	5.4-7.2	n.s.
S. C.	1	44	4.9	—	—
Tenn.	1	12	4.0	—	—

[1] Brackets enclose means that do not differ significantly at the 5-percent level.

[2] n.s. = not significant; * and ** indicate significance at the 5-percent and 1-percent levels, respectively.

sources within a given state) were significant or highly significant in 4 of the 9 cases in the Massachusetts plantings where the provenance was represented by 3 or more seedlots (table 1). In some instances, the range in height within a provenance was nearly as wide as the total range of provenance heights within a plantation.

With respect to early growth in western Massachusetts of the green ash provenances that were sampled, it may be concluded that individual tree variation is at least as important, and perhaps more important, than variation among provenances. This aspect of individual variation in hardwoods has been neglected primarily because of the general lack of interest in hardwood planting. Both the infrequency of good seed years, and the customary practices in seed collection, nursery culture, and plantation establishment, have tended to encourage the use of single-tree test progenies. Such tests have erroneously been used to justify conclusions as to provenance, variety, or even species performance.

A provenance test is essentially a population study. But it is the individual tree, not the population, that must be selected as parent material for genetic improvement. As long as hardwood improvement research is continued on a relatively small scale, the use and maintenance of single-tree progenies in the testing programs is recommended as the most direct method for improvement. In such single-tree progeny testing, the relation between individual-tree variation and geographic variation obviously must be kept in proper perspective. The test results, at best, can only be suggestive of possible provenance differences.

Literature Cited

Hansen, Norman J., and A. L. McComb.
1958. Growth of planted green ash, black walnut, and other species in relation to observable soil-site characteristics in southeastern Iowa. Jour. Forestry 56: 473-480.

Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (Including Alaska). U. S. Dept. Agr. Handbook 41: 472 pp.

Meuli, Lloyd J., and H. L. Shirley.
1937. The effect of seed origin on drought resistance of green ash in the Prairie-Plains States. Jour. Forestry 35: 1060-1062.

Snedecor, George W.
1956. Statistical methods. 5th Ed., 534 pp. Iowa State College Press, Ames.

Wright, Jonathan W.
1944. Ecotypic differentiation in red ash. Jour. Forestry 42: 591-597.

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U. S. FOREST SERVICE RESEARCH NOTE NE-15

1963

Northeastern Forest

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Experiment Station

COST OF MARKING HARDWOOD SAWTIMBER IN WEST VIRGINIA

Marking trees for felling or deadening was one of the important operations when an economic study of forest-management costs and returns was begun in 1959 on a 600-acre management unit of the U. S. Forest Service's Fernow Experimental Forest near Parsons, W. Va. This is a report on the cost of marking for the initial cutting operation.

Study Area

The virgin hardwoods that originally covered the management unit were cut about 1905. The cutting at that time varied from a clear-cutting to a high-grading operation in which the heaviest cutting was done in the most accessible areas and among the most valuable species. Thirty years later the chestnut died and was removed.

By 1959 the stands were composed of second growth and some old residuals (fig. 1). Volumes in trees over 11 inches d.b.h. averaged 8,700 board feet per acre (International ¼-inch rule to an 8-inch top inside bark). Species composition varied: upper slopes and ridge tops bore mostly oak, black gum, sassafras, and black locust; lower slopes and coves bore yellow-poplar, sugar maple, red oak, and other associated high-value species. Site quality varied from fair on the ridges to excellent in some coves.

The unit is being managed by simple practical methods to produce maximum continuous returns. The first few cuttings were designed to be combination harvest and improvement cuttings to remove poor growing stock and encourage desirable reproduction while at the same time paying all operating costs. As forest conditions improve, the cutting operations will approach those typical of the individual-tree or group-selection sys-

Figure 1. — Before marking and cutting, the stand on the management unit consisted of second growth and some old residuals from an earlier cutting.

Figure 2. — The X on this old cull indicates that it is to be deadened.

tems. Woods operations are conducted on this management unit the same as they are conducted on the usual commercial job, and the costs of each activity are determined together with any returns from timber sales.

The Marking Job

Marking for the first cutting was done intermittently over a 3-year period on 448 acres of rugged mountain country where slopes ranged mostly from 30 to 60 percent. The objective was to make a profitable sawtimber cut and to condition or improve the residual stand; present plans call for a second marking and cutting in 15 to 20 years.

Most of the volume marked for the first cutting was in old residuals that had been left from the original cutting of 1905. The only trees below minimum sawlog size (11 inches d.b.h.) that were marked were a few black locusts in the 8- and 10-inch d.b.h. classes, which were harvested for posts. Sawlog-size cull trees were also marked—for deadening.

Marking, a one-man job, was done with a paint gun and commercial tree-marking paint. Merchantable trees to be cut were marked with 1-foot-long paint stripes on two sides of each tree; three stripes were painted on some very large trees. Culls were marked with an X on opposite sides of the tree (fig. 2). Because logging was to be done by the Fernow Experimental Forest logging crew, paint spots were not made on the stumps of marked trees for a compliance check. However, the amount of paint and time required to make stump spots are small and have little influence on marking costs.

The marking on each tree was heavier and more conspicuous than on most commercial jobs. We believe that this additional effort and cost are very worthwhile; less time is lost by fallers looking for the next tree, and fewer marked trees are missed. Although most of the marking was done by a forester, some was done by a well-qualified forestry aid.

Results and Discussion

Marking time was computed from the time the marker left the road until he returned to it. All marking areas in the management unit are within $\frac{1}{2}$ mile of a road, so the travel time on foot was low.

A total gross volume of 1,222,000 board feet (2,700 board feet per acre) was marked for cutting. The average size of the trees marked for cutting was 18 inches d.b.h., and 13 to 14 trees were marked per acre. In addition, 3 culls per acre, averaging 16 inches d.b.h., were marked for deadening.

Marking rates varied from about 3,000 board feet per hour in one area to 10,000 board feet in another—averaging about 5,000 board feet per hour for the entire 3-year operation. Variation in marking time was associated with size of trees marked, number of trees marked per acre, roughness of the terrain, walking distance from the road, and season of the year (marking is slower when the vegetation is in foliage). However, the data for this study were not collected in such a manner that the effect of these factors on marking rates could be accurately evaluated.

Sixty-eight quarts of marking paint were used. On the average, each quart marked 18,000 board feet, or 6.6 acres, or about 89 merchantable trees plus about 20 culls. Cost of paint was negligible—about $1 per can, or less than 1c per tree. And the paint gun, which cost about $16, contributed even less to the marking costs because its purchase price can be spread over thousands of trees.

If we arbitrarily assign a rate of $5 an hour for a forester's time spent in marking (and he provides the paint and gun), then the cost per 1,000 board feet marked would range from about $.50 to $1.70, depending upon marking conditions, and would average about $1 per 1,000 for the entire operation. Considering the fact that marking is one of the most important operations in forest management, this seems to be a modest expenditure.

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U. S. FOREST SERVICE RESEARCH NOTE NE-16
1963

Northeastern Forest
FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.
Experiment Station

TIP-MOTH CONTROL FAILS TO IMPROVE HEIGHT OF PLANTED LOBLOLLY PINES IN A MARYLAND STUDY

Tip moths[1] cause conspicuous damage to loblolly pine reproduction in eastern Maryland, especially on old-field sites. As the number of old-field plantations and the value of forest crops have increased, landowners and managers have become interested in the possibility of controlling this damage and perhaps improving the form and growth of their planted trees.

However, the damage — although conspicuous — has been of questionable importance. For example, Wakeley (*4*) considered tip moths to be only a minor hazard. But on the other hand, studies of tip-moth control by a single spray treatment (*3*) or repeated sprayings (*2*) have shown that in some cases the height growth of loblolly pine can be appreciably increased by such treatments.

To help determine the value of tip-moth control in eastern Maryland, the Northeastern Station and the Maryland Department of Forests and Parks in 1959 started a study in old-field plantations that had been established between the 1957 and 1958 growing seasons. This note summarizes the effect of tip-moth control during the second to fourth growing seasons after planting, the period in which damage to planted seedlings in eastern Maryland is usually the greatest.

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[1] The Nantucket pine tip moth, *Rhyacionia frustrana,* is the primary species in eastern Maryland, but other species, *R. rigidana* in particular (*1*), are probably present in limited numbers.

Study Methods

The three spray treatments originally planned for the study were designed to control, respectively, (1) the first annual brood of tip-moth larvae, (2) the first two broods, or (3) all three broods that might possibly occur in any one year. However, little evidence of a third brood was found during the 3-year period covered by this study; so the third treatment was a duplicate of the second.

For the first treatment, spraying with DDT was done once annually in early May — just before the spring emergence of tip moths. The second and third treatments consisted of an identical May spraying plus another spraying in mid-July just before the emergence of a second flight of moths. The spray was a water emulsion containing 5 percent DDT, applied with a compressed-air sprayer to individual trees.

The 4 blocks in the study were located in 4 separate fields, of 3 to 15 acres, about 3 miles east of Snow Hill in Worcester County. Three of these fields were adjacent; the fourth was about 0.5 mile from the others.

Each block contained 4 plots, 1 for each scheduled treatment and an untreated control. The plots were about 90 feet square, and each contained more than 90 living planted trees in addition to the 2 outer rows of trees that formed an isolation strip. The original spacing between the trees was about 6 by 7 feet.

At the beginning of the study, the seedlings averaged about 1 foot tall. A few seedlings that had been clipped by rabbits were about 0.5 foot, and many of the undamaged seedlings were somewhat more than a foot high.

Results and Discussion

An infestation of tip moths built up rapidly in the study areas. During the summer of 1958 — the year before control treatments began — 0.0 to 2.3 percent of all shoots (terminal and lateral) on the trees in a plot had been injured by tip moths. In 1959, 40 percent of all the tree shoots in 1 control plot were damaged by the first generation of tip-moth larvae, and the damage increased to 68 percent after the second generation had developed. The other 3 control plots showed a less rapid increase: 21 to 46 percent of the shoots were injured by the first 2 generations of larvae in 1959. However, in 1961, 79 to 100 percent of the terminal shoots on the trees in the control plots were damaged during the growing season.

Each spraying operation prevented most of the injury by the tip-moth larvae that developed shortly afterwards. These larvae usually damaged only about 3 percent of the shoots in recently treated plots. However, the sprayings had no apparent effect upon succeeding generations or the degree of infestation in adjacent control plots.

None of the spraying treatments noticeably affected the average height of planted trees as measured in the spring of 1962, 3 years after the treatments were begun. Average height of all the stems in any treatment or the control varied from 7.4 to 8.0 feet, a difference of only 0.6 foot.

Furthermore, the treatments did not appreciably affect the form of the trees in the study. Forked and bent stems appeared at times to be more common among the damaged trees. However, so rapidly did one shoot suppress the other, and so frequently were defects in form overgrown, that no appreciable benefits in form can be attributed to the tip-moth control measures.

However, observations in eastern Maryland do indicate that in some areas tip moths can be more damaging than was observed in this study. In such areas, growth may be severely retarded for 1 or 2 years and appreciable damage to tree form may result. Wherever such severe damage appears to be developing, one or two sprayings for tip-moth control will encourage more rapid recovery of the infested pines and thus should prove to be worthwhile measures.

Literature Cited

(1) Craighead, F. C.
1949. INSECT ENEMIES OF EASTERN FORESTS. U. S. Dept. Agr. Misc. Pub. 657. 679 pp., illus.

(2) Foil, R. R., R. G. Merrifield, and T. Hansbrough.
1961. RESULTS OF TIP MOTH CONTROL ON HEIGHT GROWTH OF LOBLOLLY PINE. La. State Univ. Hill Farm Facts: Forestry 2. 5 pp., illus.

(3) Southern Forest Experiment Station.
1957. 1956 ANNUAL REPORT. U. S. Forest Serv. South. Forest Expt. Sta. 110 pp., illus.

(4) Wakeley, Philip C.
1954. PLANTING THE SOUTHERN PINES. U. S. Dept. Agr., Agr. Monog. 18. 233 pp., illus.

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U. S. FOREST SERVICE RESEARCH NOTE NE-17
1964

Northeastern Forest
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Experiment Station

VARIATION IN SUGAR CONTENT IN A BUDDED SUGAR MAPLE CLONE

The production of maple sugar and maple syrup from the sap of the sugar maple tree (*Acer saccharum* Marsh.) is an important industry in the Northeast, particularly in Vermont and New York. Although it has been recognized for a long time that some trees are sweeter than others — have a higher sugar content in their sap — systematic study of ways to improve sugar production by this species was begun only rather recently.

The need for a practicable way to mass-produce selected sweet or otherwise superior trees by vegetative means became apparent very soon. Vegetative propagation ordinarily is done either by rooting cuttings or by bud- or stem-grafting onto seedling rootstocks, and some studies in rooting sugar maple cuttings have been made.[1] Although vegetative propagation theoretically results in plants that are genetically identical with the parent, the rootstock of grafted plants may induce some deviation from the parent type. Of particular interest in grafting sugar maples is the question: Does the rootstock influence the sugar content of the tree sap?

A study was made to compare the variation in sugar content among young budded trees of a single sugar maple clone with the variation among young seedling trees. Although the clone used in this study was only an average producer, the results may be applicable for any maples budded or grafted on rootstocks of unknown characteristics.

Materials and Methods

All the trees used in this study were located in closely spaced nursery rows at the Adams Nursery in Westfield, Mass. The parent tree (ortet) of the clone, a pyramidal type propagated for ornamental use, was a

[1]Gabriel, William J., Marvin, James W., and Taylor, Fred H. Rooting of greenwood cuttings of sugar maple: effect of clone and medium. Northeast. Forest Expt. Sta., Sta. Paper 144, 14 pp., 1961.

planted specimen in Denton Circle, Springfield, Mass. The rootstocks used in the nursery were wild seedlings of sugar maple that had been lifted bare-rooted and transplanted to the nursery site for budding with the select type. All of the trees were being propagated for eventual sale by the nursery and were used with the owner's permission.

In the spring of 1954, the nursery contained 246 trees that had been budded in August 1950, and several hundred unworked seedlings. The ramets (budded trees) ranged from 3 to 7 feet high in 1954; no height measurements were made on the seedlings. The ramets occupied two rows about 130 feet apart and each of these rows was adjacent to 2 rows of seedlings. These two areas were designated arbitrarily as Section I and Section II.

All 246 ramets were tested for sap sugar; and 87 seedling trees — every tenth tree in the seedling rows — were used for comparison.

Sugar percent was determined with a Zeiss Saccharimeter on drops of sap exuded from holes made with an ice pick. Readings were made to the nearest 0.2 percent. Tests were performed on the budded trees on March 2, March 19, and April 2, 1954. The seedlings and the mother-tree were tested only on the two latter dates. The budded trees were removed from the nursery in 1954, thus eliminating the possibility of future tests.

Results and Discussion

Forty-eight ramets and 34 seedlings were completely dry on all sampling dates. March 19 proved to be a particularly poor day for testing: 71 percent of the ramets and 38 percent of the seedlings that yielded sap at one time or another were dry on that date.

Table 1. — Sugar percent of young clonal and seedling sugar maples

Item	Section I				Section II	
	Seedling (19)[1]		Clonal (39)		Seedling (29)	Clonal (83)
	3/19/54	4/2/54	3/19/54	4/2/54	4/2/54	4/2/54
Range	2.4-5.0	2.2-4.6	2.4-5.2	1.6-3.8	1.6-3.8	1.4-6.8
Average	3.17	2.87	3.74	2.79	2.46	2.90
C[2]	18.5	19.2	20.8	18.5	24.3	29.1

[1]Figures in parentheses are the numbers of trees that gave readings on the dates indicated. No comparison was possible in Section II on March 19 because none of the sample seedlings gave readings.

[2]Coefficient of variation, expressed as a percentage. Coefficients of variation are measures of variation relative to the mean, and are not affected by sample size.

The average sugar percent in the ramets proved to be very close to that of the mother tree. Comparative data for the mother tree and all the ramets that gave readings on the two dates when the mother tree was tested (a total of 52) are tabulated below:

Date	*Mother tree (percent)*	*Ramets (mean percent)*
March 19	3.60	3.49
April 2	3.00	2.72
Average	3.30	3.10

However, more meaningful data are given in table 1, where the range and variability of clonal and seedling tests are listed. It can be seen here that the average sugar percents of seedling and clonal stock are similar. None of the differences between seedling and clonal means for single dates or combined dates, within sections or for both sections combined, was statistically significant by "t" test. Moreover, the coefficients of variation were similar except between sections where somewhat larger coefficients in Section II probably denote more environmental variation than in Section I.

Thus the data show that, for this particular clone budded on seedling stock of unknown parentage, the variation in sugar content among ramets was as great as the variation among seedlings of similarly unknown parentage.

Since identical genotypes may reasonably be expected to show closer similarities to each other than to unrelated genotypes, the failure of ramets of the same clone in our study to conform to this expectation led to speculation as to the cause. One possibility — a remote one in our opinion — is that the rather wide variation among the ramets was associated with their youthfulness, and the variation would have decreased as the trees became older. There was no significant correlation between percent sugar and tree height. Site effects can be discounted in view of the proximity of the trees to each other in each section, and the large differences that often occurred between adjacent trees.

Thus, by a process of elimination, rootstock influence remains as the most likely cause of the variation among the clonal members. The effect of the rootstock in modifying growth and flowering has long been known and utilized in fruit tree production, as with the Malling rootstocks for apples. It does not seem illogical to assume that the rootstock may also influence the amount of sugar in the sap of a sugar maple tree.

Many chemical products of woody plants, such as rubber, quinine, and resin, are end products of metabolism that are rarely, if ever, reused by the plant. However, the sucrose of the sugar maple is both a metabolic product and a food substance; and any influence of the rootstock on the production and utilization of sucrose by the plant is likely to modify the sugar content of the sap. Phenomena such as the appearance of nicotine in the leaves of tomato grafted on tobacco[2] and the production of oleoresin constituents of the scion in the stock of pine grafts[3] may be partially explained by the translocation of enzymes or precursors of products across the graft union. The influence of the rootstock on sugar content in the scion in sugar maple may depend on a simpler quantitative relationship between sucrose production and utilization.

Since variability is inherent in the reproduction of any species from seed, vegetative propagation is a much more reliable way to perpetuate and propagate superior genotypes. However, with sugar maple, vegetative propagation presents problems. In grafted trees, according to the results of our study, the rootstocks may induce an undesirable degree of variability in sugar production. The study was too small for the results to be considered conclusive. But if the present indications as to rootstock influence are confirmed in future tests, grafted stock will be little or no better than seedling stock for reproducing superior trees.

Propagation by cuttings, on the other hand, precludes variation from internal factors. But mass-production techniques have not been perfected. Successful rooting has been accomplished only in mist chambers or by air-layering, and no way has been found for preventing excessive mortality of rooted cuttings during their first winter. These problems with cuttings are under study and are expected to be solved.

If mass-production techniques can be developed, propagation of select trees by cuttings undoubtedly will be the best means for providing uniformly high-yielding trees to the maple sugar industry. Moreover, for certain research purposes, propagation by cuttings will offer definite advantages because the uniformity of genotype thus achieved will permit more accurate appraisal of the effects of environment on sugar production than can be obtained with any other propagation method.

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[2]Dawson, Ray F. Accumulation of nicotine in reciprocal grafts of tomato and tobacco. Amer. Jour. Bot. 29: 66-71, 1942.

[3]Mirov, N. T. Effect of the crown on the composition of oleoresin in pines. Jour. Forestry 43: 345-348, 1945.

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U. S. FOREST SERVICE RESEARCH NOTE NE-18
1964

Northeastern Forest
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Experiment Station

PRODUCTION AND DISTRIBUTION OF SWEETGUM SEED IN 1962 BY FOUR NEW JERSEY STANDS

Although sweetgum (*Liquidambar styraciflua* L.) is one of the most valuable hardwoods in bottomland forests from southern New Jersey and southern Illinois southward, relatively little is known about its production and distribution of seed. Knowledge of both is essential in planning successful measures for reproducing the species. To provide some of the needed information, the Northeastern Forest Experiment Station studied the production and distribution of sweetgum seed in 1962 from four New Jersey stands.

Study Methods

The four stands, in each of which sweetgum was a common or predominant species, were all within a 2-mile radius in Burlington County. They ranged in age from 27 to 42 years, and in average height of dominant trees from 66 to 84 feet. When selected for study in the summer of 1962, all four stands showed promise of a heavy seed crop that fall.

Seed distribution was sampled by paired 1/16-milacre traps spaced along transects extending from within each stand out across an adjoining open field or pasture at a right angle to the stand edge. Each of the open areas was a different cardinal direction (N, E, S, or W) from the stand being sampled. The paired traps inside each stand were placed at 0.1 chain and at 0.25 chain from the edge; those in the open were placed at distances equaling 0.5, 1, 2, and 4 times the height of the dominant trees. All traps were in place before seedfall began.

Fruit Characteristics

Sweetgum seeds are borne in a woody globose head of two-celled beaked capsules (fig. 1). Under favorable conditions two seeds develop in each capsule. However, typical fruits contain many undeveloped seeds that resemble chaff.

The number of developed seeds per fruit appears to vary greatly. The Woody-Plant Seed Manual (U. S. Dept. Agriculture 1948) gives seven or eight as the number of seeds per fruit; and a few observations in southern New Jersey indicate that that number may be about right for very poor crops on isolated trees. However, numbers of seed per fruit may run much higher, especially when seed crops are good. Trenk (1929)

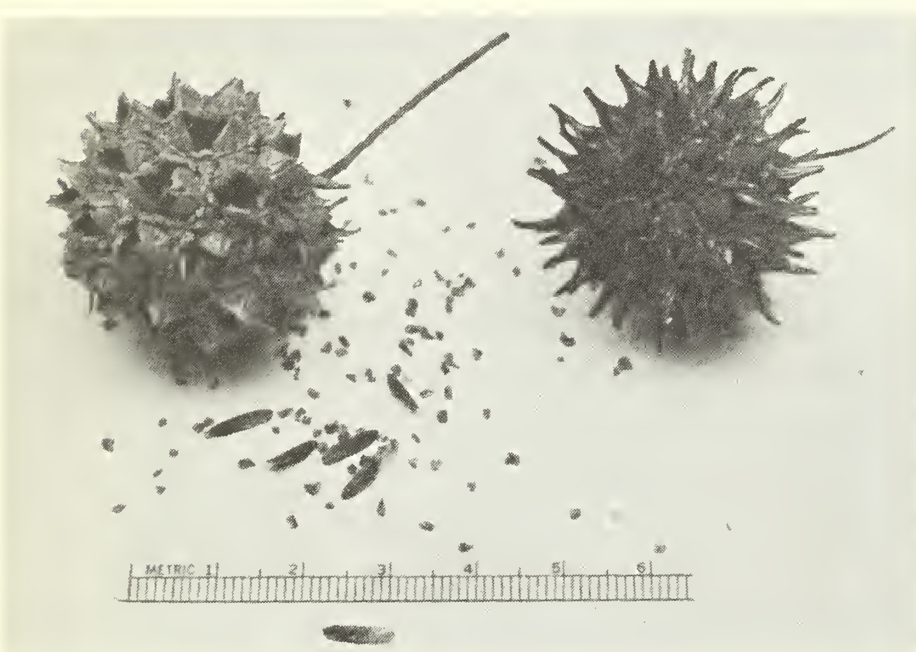

Figure 1.—Open and closed mature fruits of sweetgum. Capsules on the left-hand fruit have opened and released developed seeds and chaff (or abortive seeds). The fruit on the right was wetted, so its capsules are closed.

reported that the fruits usually contain 20 to 50 fertile seeds. In the present study, six fruits collected from the excellent 1962 crop and eight collected from the poor 1963 crop averaged 88 and 61 developed seeds per fruit, respectively. Except for two fruits from one tree in which the seeds were only four percent sound, the developed seed in these two collections averaged 84 percent or more sound.

Amount of Seed Production

In years of good seed crops, dominant trees bear hundreds of fruits, and the best stands must produce several million seeds per acre. Although no measure of total seed production was obtained in this study, the catch under two stands was at the rate of 2.6 to 6.2 million sound seeds per acre (table 1).

Seed production varies greatly among stands. In this study the catch under the most productive stand was 17 times that of the least productive one. These differences seemed to be due mainly to the differences in stand age and composition.

Period of Seedfall

Observed seedfall began on September 20 and was practically completed — about 99 percent — by mid-January. According to seed-trap collections made October 1, semimonthly thereafter until January 18, and a final one in early March, seedfall was mostly light in October and heavy in November; then, except in one stand, it dropped off sharply in December. Only small amounts of seed fell in all stands during January and February (table 2).

Table 1. — *Observed distribution of sound seeds from four sweetgum stands*

Direction of trap line from stand	Seed catch within stand	Proportional catches at distances of —[1]			
		Half stand height	Stand height	Twice stand height	Four times stand height
	Number per acre	*Percent*	*Percent*	*Percent*	*Percent*
East	6,184,000	78	43	18	4
South	2,612,000	136	42	12	1
West	624,000	68	35	8	5
North	372,000	15	13	2	0

[1] Mean catch per trap expressed as a percentage of the mean catch per trap under the stand.

Table 2. — *Catch of sound seed, by stands and periods*

Period	Stand I	Stand II	Stand III	Stand IV	All stands
	Percent[1]	*Percent*	*Percent*	*Percent*	*Percent*[2]
Sept. 20 — Oct. 29	4	26	2	2	5
Oct. 29 — Nov. 26	82(86)	56(82)	41(43)	67(69)	75(80)
Nov. 26 — Dec. 27	11(97)	12(94)	55(98)	25(94)	16(96)
Dec. 27 — Jan. 18	2(99)	5(99)	0(98)	5(99)	3(99)
Jan. 18 — March 13	1(100)	1(100)	2(100)	1(100)	1(100)

[1] Of total caught from that stand. Values in parentheses are cumulative.
[2] Values based on pooled total catches in all four stands.

The rate of seedfall may be very high for short periods. For instance, during one 6-hour period, the catch under one stand was equivalent to 11,900 seeds per acre.

Most of the seeds are apparently released before the fruits fall. In late December about 50 fruits were picked from several trees, and about nine seeds were found in each. Fruits gathered from the ground at the same time contained, on the average, about one seed each. By early March most of the fruits had fallen. Another collection was made from fruits still on the trees at this time, and these fruits contained about one seed each — nearly all of which were sound.

These observations indicate that the absolute end of seedfall may be in April; however, for practical purposes the end can be considered to occur in mid-January.

Effects of Distance and Direction

In the openings near sampled stands, the amount of seed caught per unit area decreased sharply with increased distance from the source. For example, traps at a distance equal to stand height caught less than half as many seeds as traps under the stand. At four times stand height, the proportions fell to 5 percent or less (table 1).

Direction from seed source had surprisingly little effect on seed distribution in comparison with effects observed in previous studies of other species. Among other species, for example, 80 to 85 percent of the seedfall from isolated Atlantic white-cedars in a New Jersey study was on the east side (Little 1950); and in a Maryland study of Virginia pine, four times as many seeds fell on the east side as on the west side of a stand (Sucoff and Church 1960). The usual explanation for these heavier seedfalls on the east side is that the cones are hygroscopic and tend to close during the periods of high humidity or precipitation that commonly are associated with easterly winds, whereas the cones open and shed seed freely during fair weather when the winds generally are westerly.

A similar response to wind and weather conditions was expected from sweetgum, since its fruits also are hygroscopic. However, no such response was discernible in the data from the present study (table 1). The most notable difference related to direction was the smaller catches where the sampling was on the north side. This may be due in this case, at least in part, to the smaller trees and other stand characteristics that account for the comparatively low total seed production by this stand.

If seedfall beyond four times stand height is ignored, 59 to 78 percent of the seeds distributed in the openings fell within stand height. Only 5 to 17 percent landed at distances between two and four times stand height (table 3).

Table 3.—*Apparent distribution of the sweetgum seed that fell in openings outside the stands, by distances from the stands*[1]

Direction of opening from stand	Within half stand height	Between 0.5 and 1 times stand height	Between 1 and 2 times stand height	Between 2 and 4 times stand height
	Percent	*Percent*	*Percent*	*Percent*
East	35	24	24	17
South	41	31	19	9
West	41	25	21	13
North	63	15	17	5

[1] Limited to seed falling in openings within a distance equal to four times stand height.

Sweetgum seeds launched from an adequate height in a favorable wind apparently can travel appreciable distances. In Guttenberg's (1952) study of artificially dispersed seeds, although 96 percent fell within 200 feet of the point of origin, a 100-foot fire tower, some seeds were caught at distances between four and six times the height of the source. None were recovered at greater distances. From the seedlings established around some isolated trees in southern New Jersey, it is evident that enough seed for adequate reproduction may be distributed to at least five times the height of the parent tree. Occasional seeds undoubtedly are transported to far greater distances.

In the present study, no relationship was found between seed soundness and distance from source. At all distances the ratio of sound to unsound seed was about 10 to 1.

Application in Silviculture

Though the information from this study can provide only indications, it does suggest the following tentative guides in managing sweetgum.

- In strip or patch clearcuttings, the width should probably not exceed four times the height of dominant stems in the adjoining stand. When crops are poor, such openings may be too wide if a seed-producing stand is present on only one side. But when crops are good, the seedfall on the outer edge of such openings might be one to four percent of that under the stand, or at the rate of 26,000 to 240,000 sound seeds per acre (table 1).

■ In seed-tree cuttings, two to four trees per acre, if prolific, might be adequate for purposes of regeneration.

Literature Cited

Guttenberg, Sam.
1952. SWEETGUM SEED IS OVERRATED FLYER. Jour. Forestry 50: 844.

Little, S.
1950. ECOLOGY AND SILVICULTURE OF WHITECEDAR AND ASSOCIATED HARDWOODS IN SOUTHERN NEW JERSEY. Yale Univ. School Forestry Bul. 56, 103 pp., illus.

Sucoff, E. I., and T. W. Church.
1960. SEED PRODUCTION AND DISSEMINATION BY VIRGINIA PINE. Jour. Forestry 58: 885-888, illus.

Trenk, Fred B.
1929. SWEETGUM IN MARYLAND. Univ. Md., Md. Forestry Dept. 75 pp., illus.

United States Department of Agriculture.
1948. WOODY-PLANT SEED MANUAL. U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

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U. S. FOREST SERVICE RESEARCH NOTE NE-19

1964

Northeastern Forest

REST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

SECOND-YEAR RESULTS OF HYBRID POPLAR TEST PLANTINGS ON BITUMINOUS STRIP-MINE SPOILS IN PENNSYLVANIA

During the period 1946-49, The Pennsylvania State University established 22 experimental plantings of trees and shrubs on strip-mine spoil banks in the Bituminous Region of Pennsylvania to determine which species were best suited for revegetating such sites. When 10-year growth on the experimental plots was evaluated, a clone of hybrid poplar was found to have outgrown all the other species tested.[1] The performance of this one hybrid poplar suggested that other hybrid poplars might be well adapted for growing on strip-mine spoils, so we planned a screening test of as many hybrid poplar clones as possible to determine which ones were worth further consideration for use in large-scale plantings.

More than 70 hybrid poplar clones are being grown in the Northeast, but some of these exist only in small experimental plots. Enough cuttings for the screening test were available in 1961 from 60 of these clones. In April of that year, test plantings of these 60 clones were made on six strip-mine spoil areas in Pennsylvania's Bituminous Region.[2] This note summarsizes the survival and height growth of the 60 clones after 2 growing seasons.

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[1]Hart, George, and William R. Byrnes. TREES FOR STRIP-MINED LAND. U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 136, 36 pp., illus. 1960.

[2]This study is part of a cooperative effort to investigate all aspects of the problem of revegetating strip-mine banks in Pennsylvania. The cooperating agencies are: The Pennsylvania Department of Forests and Waters; The Pennsylvania Department of Mines and Minerals Industries; School of Forestry, The Pennsylvania State University; Independent Mineral Producers Association; Central Pennsylvania Open Pit Mining Association; West Virginia Pulp and Paper Co.; and Northeastern Forest Experiment Station, U. S. Forest Service.

The Experimental Areas

The plots were established on the six areas at places that had been stripped and graded in accordance with state laws. Each of the six areas was associated with one of the Region's major coal seams.

Samples of spoil material collected from each plot were subjected to textural and acidity tests (table 1). It was evident that the different spoils provide a variety of conditions, especially with respect to acidity, which ranges from pH 3.1 to 5.7. Spoils from the Middle and Lower Kittanning seams (pH 3.1 and 3.3) are the most acid, but the two Clarion spoils (pH 3.6 and 3.7) also are extremely acid. The Lower and Upper Freeport spoils (pH 4.9 and 5.7) are in an acidity range that is considered favorable to tree growth.

Table 1.—*Characteristics of strip-mine spoil material*

Coal-seam	Spoil texture			Texture class	Spoil acidity
	Sand	Silt	Clay		
	Percent	*Percent*	*Percent*		*pH*
Clarion (Clarion Co.)	62	17	21	Sandy clay loam	3.6
Clarion (Clearfield Co.)	61	19	20	Sandy clay loam	3.7
Lower Kittanning	64	17	19	Sandy loam	3.3
Middle Kittanning	41	30	29	Sandy loam	3.1
Lower Freeport	67	17	16	Sandy loam	4.9
Upper Freeport	60	18	22	Sandy loam	5.7

The Clones Tested

Of the 60 hybrid poplar clones tested, four were planted as 1-year rooted cuttings; all others were planted as unrooted and untreated cuttings. Unrooted cuttings were 12 inches long and ranged from ¼ to ½ inch in mid-point diameter.

Parentages of the clones tested are listed in table 2. The clone used by the University in the original plantings was included in the experiment and is designated "X" because its exact parentage is uncertain. However, it is known to be a Northeastern Station clone, and it appears to be either *P. maximowiczii* X *trichocarpa* or *P maximowiczii* X cv. Berolinensis.

Table 2.—*Clone numbers and parentages of hybrid poplars tested on strip-mine spoil areas*

Clone numbers[1]	Parentage
NE-32	*P.* cv. Angulata X cv. Berolinensis
NE-245, -246, -247, 258	*P.* cv. Angulata X *deltoides*
NE-35	*P.* cv. Angulata X cv. Plantierensis
NE-249, -251, -252, -253, -254, -374	*P.* cv. Angulata X *trichocarpa*
NE-12, -302	*P.* cv. Betulifolia X *trichocarpa*
NE-327	*P.* cv. Candicans X cv. Berolinensis
NE-17, -313, 314	*P.* cv. Charkoviensis X cv. Caudina
NE-28, -29	*P.* cv. Charkoviensis X *trichocarpa*
NE-221, -223, -224, -228, -353, -359	*P. deltoides* X cv. Caudina
NE-241, -242	*P. deltoides* X cv. Plantierensis
NE-206, -207, -208, -211, -213, -214, -215, -216, -346, -350	*P. deltoides* X *trichocarpa*
NE-43, -44, -47, -48, -49, -50	*P. maximowiczii* X cv. Berolinensis
NE-53	*P. maximowiczii* X cv. Caudina
NE-52	*P. maximowiczii* X cv. Plantierensis
NE-41, -42, -388	*P. maximowiczii* X *trichocarpa*
NE-277	*P. nigra* X cv. Italica
NE-4, -5, -8, -279	*P. nigra* X *laurifolia*
NE-11	*P. nigra* X *trichocarpa*
X (parentage uncertain)	Either *P. maximowiczii* X *trichocarpa* or *P. maximowiczii* X cv. Berolinensis
PLANTED AS 1-YEAR ROOTED CUTTINGS	
M-86 or NY-3139	Populus robusta (Robusta poplar)
M-87 or NY-3140	Populus species (Siouxland poplar)
M-88 or NY-3141	Populus species (Norway poplar)
NY-2555	Populus canescens (Curly poplar)

[1]NE = Northeastern Forest Experiment Station; M = Michigan; NY = New York.

Methods

At each experimental area, plots were placed on graded and ungraded surfaces of both upper and lower portions of the spoil banks. This plot arrangement was replicated 3 times, giving a total of 12 plots on each area. Clones were assigned at random to each plot, and two cuttings of each clone were placed adjacent to each other within the plots. The spacing was 6 x 6 feet. For some clones, only enough cutting stock was available for one or two replications.

The plots were established between April 11 and 19, 1961. Weather conditions were good during planting and continued good through the first growing season. However, the growing season of 1962 was one of the driest on record.

Survival tallies and height measurements were taken in October 1961 and October 1962. Causes of mortality were noted during each measurement.

Results

Both survival and height varied considerably from bank to bank. To show the differences in clone performance among banks, survival and height of the 10 best clones on each bank are listed in table 3. Ratings were based on both height and survival. Greater emphasis was placed on survival on banks where mortality was heavy and on height where survival was adequate.

As might be expected, some clones appear among the 10 best on several banks, but only NE-388 appears in all 6 lists. Nine clones are listed among the 10 best on 3 or more banks: NE 11, 41, 42, 44, 47, 50, 279, 388, and X. Seven of these clones are hybrids of *P. maximowiczii.*

Survival and height growth varied so much from bank to bank that general statements applicable to performance on all banks are almost impossible. For instance, on the worst bank, survival was less than 25 percent for all but 3 of the 60 clones, whereas on the two best banks survival exceeded 75 percent for all but 3 clones. Height growth was extremely variable too, ranging from less than 1 foot to more than 7 feet.

An attempt was made to relate the performance of the clones to some spoil characteristic. The only factor that showed a close relationship to survival and height growth was bank acidity: height growth and survival generally increased as pH increased (table 4). On the two most acid banks, mortality not only was high during the first year, but also continued to occur during the second year. Survival of the 10 best clones dropped from 25 percent at the end of the first year to 18 percent at the end of the second year on the Middle Kittanning spoil and from 43 percent to 37 percent on the Lower Kittanning spoil. Even greater drops in survival were noted in clones not listed among the 10 best. Very little second-year mortality occurred on the other four spoils.

To get a better measure of the effects of grading and slope position than would be provided by averages of all clones, data were averaged for a selected group of 13 clones that were consistently among the better ones in all replicates in all areas. Average survival for this group was 63 percent on the graded portions of the banks and 53 percent on

Table 3.—*Survivals and heights of 10 best hybrid poplar clones on each spoil area*

Clarion Clarion Co.			Clarion Clearfield Co.			Lower Kittanning		
Clone	Survival	Height	Clone	Survival	Height	Clone	Survival	Height
	%	*Ft.*		%	*Ft.*		%	*Ft.*
11	75	2.2	11	63	2.8	4	33	1.5
42	71	3.3	29	69	2.8	41	25	3.9
43	67	2.5	42	75	2.8	42	25	1.8
44	67	2.5	44	86	2.5	216	30	2.9
47	100	2.0	47	75	2.4	241	67	1.5
49	87	2.5	50	79	2.9	251	40	1.4
252	71	2.3	214	63	2.4	253	43	1.4
279	100	3.2	279	87	2.4	327	27	3.6
388	63	3.2	388	63	2.9	359	50	2.0
X	58	3.0	X	75	3.4	388	29	3.0
Ave.	76	2.7	—	74	2.7	—	37	2.4

Middle Kittanning			Lower Freeport			Upper Freeport		
Clone	Survival	Height	Clone	Survival	Height	Clone	Survival	Height
	%	*Ft.*		%	*Ft.*		%	*Ft.*
50	17	0.6	11	100	4.2	8	100	7.9
207	17	.4	41	100	5.3	11	100	7.6
214	13	1.0	42	100	4.5	41	100	8.5
216	17	.4	44	96	4.0	42	100	6.3
223	25	.6	47	100	4.0	47	100	8.5
249	13	1.0	50	95	3.8	53	100	6.5
277	13	1.0	208	100	4.0	224	100	6.3
279	25	.6	314	86	4.6	228	83	7.7
302	18	.8	388	100	3.5	388	96	6.3
388	25	.4	X	91	4.0	X	96	6.5
Ave.	18	0.7	—	97	4.2	—	98	7.2

the ungraded outslopes. This difference was statistically significant at the 5-percent level. Sliding rocks were the most common cause of the higher mortality on the outslopes. Survival on upper and lower slopes was almost identical.

Heights for the same 13 clones were averaged for all but the Lower and Middle Kittanning banks, where poor survival made statistical tests

Table 4.—*Average survival and height of the 10 best hybrid poplar clones on each spoil area as related to spoil acidity*

Coal-seam	Average spoil acidity	Survival	Height
	pH	*Percent*	*Feet*
Middle Kittanning	3.1	18	0.7
Lower Kittanning	3.3	37	2.4
Clarion (Clarion Co.)	3.6	76	2.7
Clarion (Clearfield Co.)	3.7	74	2.7
Lower Freeport	4.9	97	4.2
Upper Freeport	5.7	98	7.2

impossible. On the other four areas, average height on the outslopes was 3.6 feet, which was significantly greater than the average of 3.2 feet attained on the graded portions. Thus, as in other species studied, grading has a slightly depressing effect on height growth.[3] However, hybrid poplars reacted just the opposite of most species in one respect—response to slope position. Average height of the 13 clones was significantly greater on upper slopes than on lower slopes (3.5 vs. 3.3 feet).

Discussion

Two growing seasons is an inadequate period of time to evaluate the performance of individual clones, but striking differences in growth among spoil areas are already evident. Spoil acidity appears to be the most decisive factor. Evidently poor survival may be expected on spoils more acid than pH 3.6. Although the average height of 2.7 feet attained by the 10 best clones on the 2 Clarion spoils (pH 3.6 and 3.7) is not considered good growth for hybrid poplars, it still exceeded the growth of 10 other species that had been planted on these same spoil areas.

Other factors also may affect the performance of hybrid poplars on strip-mine spoils. Compaction of the spoil by grading reduces height growth by a small amount. Moisture relationships and the vagaries of weather undoubtedly account for some of the variation in survival and height growth. To what extent the dry weather of 1962 increased mor-

[3]Davis, Grant, and Rex E. Melton. TREES FOR GRADED STRIP-MINE SPOILS. Pa. State Forest School Res. Paper 32, 4 pp., 1963.

tality or hindered height growth is difficult to determine. However, it is relevant to note that the supervisor of a state nursery where hybrid poplar cuttings are produced reported a definite reduction in height growth in his unirrigated beds in 1962. Any instances of mortality, reduced vigor, or increased susceptibility to disease due to long-range effects of the drought will be noted in future observations.

It is of some interest that none of the 4 clones planted as rooted cuttings was listed among the 10 best. This means that, genetically, these clones were not so well adapted to the sites as some others. But their relatively low rating also indicates that rooted cuttings do not possess any great advantage over unrooted ones — at least not enough advantage to justify the extra expense of growing and planting them.

In summary, the early results from this test of hybrid poplars are encouraging. It appears that a number of the clones will be suitable for revegetating all but the most acid spoil banks. Obviously it is still too early to draw conclusions as to the ultimate value of hybrid poplars on mine spoils in Pennsylvania. Only time will tell which clones, if any, can maintain rapid growth and resist disease and insect attacks to the degree necessary to develop into productive forest stands.

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U. S. FOREST SERVICE RESEARCH NOTE NE-20
1964

Northeastern Forest
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Experiment Station

EVALUATION OF THE TROUGH-TYPE RAIN GAGE

Although infrequently used, the trough-type rain gage has been described as aerodynamically the most efficient of gages (Hayes and Kittredge 1949). This applies only to the commercial semicircular eave-gutter type of trough and not to troughs rectangular in cross-section. The latter, as well as the upright cylindrical type of gage, produces greater disturbances in the rain-bearing wind stream.

A major advantage of any type of trough gage is its readily adjustable area of catch. Troughs have been used that range in width from 4 inches to 9 inches and in length from 24 inches to 80 feet. A trough gage 4 inches wide and 12.56 inches long has the same surface area as a standard 8-inch cylindrical gage. Larger troughs with greater areas are particularly useful in throughfall studies, as they can be used to measure a composite of rainfall and drip from a variety of canopy conditions.

Dr. W. C. Lowdermilk apparently was the first to design and install a trough gage—in 1929 in southern California. Trough gages were later examined critically in two comparative rain-gage investigations, both in California (Storey and Hamilton 1943, Hayes and Kittredge 1949). In both investigations trough gages showed up well, probably better than any others, including shielded and tilted gages. But they never caught on.

Experience with Trough Gage

Since 1929 the use of the trough gage has generally been restricted to interception studies, and it was such a study that occasioned this analysis. Our interception studies were begun in 1950 at the Delaware-Lehigh Experimental Forest (Dilldown Watershed) and the Pocono Experimental Forest in northeastern Pennsylvania, using half-round trough gages 6 by 36 inches. These gages were used to measure through-fall under vegetation and rainfall in the open.

In 1952 several Weather Bureau Standard rain gages were placed adjacent to trough gages in the open. To our dismay, it soon became evident that the trough gages were catching less rain than the standard gages. The most obvious explanation for this was that some of the rain splashed out of the troughs. The strong winds accompanying summer storms probably blew away part of the spray from raindrops bouncing on the relatively flat bottom of the trough.

This hypothesis was tested in the summer of 1953. A number of new trough gages were made, having 3-inch vertical sides above the semicircular cross-section, to contain the splash. A high trough was exposed along with a low trough and a standard gage at several locations. At one location, four additional low troughs were oriented in the four cardinal directions, to detect any effect of direction. During each storm the resident observer noted the prevailing wind direction.

The first test was informative: the catches in the high trough were not significantly different from those in the standard gage, but those in the low trough were significantly less. No effect of direction was apparent. Inadvertently, however, the directional troughs had been placed so that they sloped from 5 to 19 percent. After slope corrections had been applied, a pattern appeared: the greater the slope, the larger the catch of rainfall.

Accordingly the test was rearranged and enlarged in 1954. The directional troughs were all given the same slope (5 percent), and four other low troughs were lined up in one direction (south) with varying slopes. The pattern detected the preceding year was confirmed: no effect of direction of slope but a correlation with percent of slope.

Regressions were calculated, using the following general equation as a model:

$$Y = a + b_1X + b_2XS$$ in which

Y = Amount per storm as measured in the standard gage, in inches.
X = Amount caught in any low trough, in inches.
S = Slope of the low trough, in percent.

Covariance analysis showed no difference between the 1953 and 1954 data; in fact, all three coefficients were essentially identical. Therefore, the data for the 2 years were pooled and the following equation was calculated:

$$Y = 0.011 + 1.073X - 0.00319XS \qquad [1]$$

Both variables were highly significant at the 1-percent level. This equation will be used to correct trough-gage measurements (in the open) for a forthcoming paper on interception.

Why The Discrepancy?

The reader may wonder why the results of these analyses do not agree with the findings of earlier investigators. In both studies (Storey and Hamilton 1943; Hayes and Kittredge 1949) trough gages gave an excellent measure of rainfall. A reasonable explanation for the discrepancy is available.

In both earlier studies the terrain was steep: Rain Gage Hill, the site of the 1943 study, has slopes ranging between 30 and 40 percent, according to Hamilton (1954); the area for the 1949 study, in Strawberry Canyon, was a 40-percent slope. And in both studies the troughs were placed parallel to the slope. But in our studies the terrain was nearly level and the troughs sloped only enough to provide drainage. The trough slopes, measured so that corrections could be calculated, ranged between 5 and 20 percent.

At these low slope angles, some of the raindrops would either bounce and splash out or be blown out of the trough. When raindrops hit a sloping surface, however, they do not bounce vertically; instead they are deflected into the trough. This explanation is reinforced by Equation 1: the XS interaction accounts for the slope effect. For example, a catch of 3.00 inches in a trough sloping at 5 percent results in an estimate of 3.17 inches of actual rainfall. On a 20-percent slope, the estimate is 3.03 inches. If the equation were extrapolated to a 25-percent slope, there would be little or no difference between the actual catch and the estimated catch. In other words, if the trough slopes 25 percent or more, its catch provides an accurate measure of rainfall. This probably explains the accuracy of the gages in the California studies.

Trough Gages Under a Canopy

A further study was made to determine if our throughfall trough gages had been catching an accurate sample. At the Pocono Experimental Forest, in large pole-size northern hardwoods, six positions for throughfall troughs were established. High troughs were set in three positions and ordinary low troughs in three others. A new arrangement of the troughs was randomly made after each storm.

A similar series of positions was selected for throughfall testing in scrub oak at the Dilldown Watershed. Here the troughs could not be moved readily, so three splash guards were fabricated to set on the ordinary trough gages and to simulate high troughs. After each storm the splash guards were moved to a randomly selected new arrangement.

The results were inconclusive. In the high forest, no significant differences were found between the high-trough and low-trough catches. In the scrub-oak area, however, some of the positions showed significantly higher catches when the splash guards were installed. In view of the fact that rain dripping from a high forest canopy did not splash out of the troughs, it seems doubtful that drip from low scrub-oak cover could have been lost. We suspect that the splash guards bulged enough to make a greater catch area than we measured.

Conclusions

The conclusions to be drawn from this study can be stated in words of caution. The trough gage, although aerodynamically efficient, may allow a part of the rain to splash and be lost unless the gage is sloped more than 25 percent. If such slope cannot easily be maintained, other means must be taken to prevent or contain the splash. It can be contained by built-up sides, but at the expense of aerodynamic efficiency.

Another idea, although not tested, is to use a V-shaped trough rather than a semicircular trough. The bottom angle of the V should be between 90° and 120°. As there are no horizontal surfaces, the drops could not bounce vertically, and there should be no splash from the sloping sides of the V.

One other caution: the sides of the trough gage are relatively flexible, and this flexibility affects the surface area of the orifice. If this area changes or cannot be measured accurately, the sample will be in error. Some type of reinforcing should be added to the long sides of a trough gage.

Literature Cited

Hamilton, E. L.
1954. RAINFALL SAMPLING ON RUGGED TERRAIN. U. S. Dept. Agr. Tech. Bul. 1096, 41 pp., illus.

Hayes, G. L., and J. Kittredge.
1949. COMPARATIVE RAIN MEASUREMENTS AND RAIN-GAGE PERFORMANCES ON A STEEP SLOPE ADJACENT TO A PINE STAND. Trans. Amer. Geophys. Union 30: 295-301.

Storey, H. C., and E. L. Hamilton.
1943. A COMPARATIVE STUDY OF RAIN-GAGES. Trans. Amer. Geophys. Union 24: 133-141.

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U.S. FOREST SERVICE RESEARCH NOTE NE-21

1964

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Experiment Station

HOW TO MAKE A WIND-MOVEMENT RECORDER FROM ANY SPARE DRUM-TYPE RECORDER

The automatic recording of wind movement is sometimes essential to experiments in forestry and watershed-management research. Wind-movement data are often obtained by periodic reading of the anemometer dial, but occasionally data are required for variable intervals and at times when observations cannot be made easily. Instruments designed to record wind movement are being manufactured, but they are multiple-stage recorders and are expensive. To our knowledge, no instrument is made for the sole purpose of recording wind movement. So we devised an easy and inexpensive way to convert any drum-type recorder into a wind-movement recorder.

The study that occasioned the need for such a device required the measurement of wind movement at several places for the period 10 a.m. to 10 p.m. daily, including weekends. Two recording rain and snow gages, Weather Bureau type, were temporarily available; so we converted them to record continuous wind movement. When they are needed again for recording precipitation, they can be reconverted in a few minutes.

Figure 1 shows the base and the weighing mechanism of the rain gage converted to record wind movement. The weighing platform has been immobilized by turning down the stop screws, and the linkage has been removed from the pen-arm shaft. Parts A, B, and C have been added.

Part A is a piece of 16-gage sheet metal about 1½ inches wide and 20 inches long, bent to fit between the arms of the weighing mechanism.

It has been drilled to allow the pen arm shaft to pass through it; the shaft also helps to hold it in position. A hole has been drilled in the rain-gage base to accept the bolt holding the sheet-metal support.

The U-shaped part, B, also made of 16-gage sheet metal, keeps the counterweight, D, from falling down. It will swivel and thus is adjustable to control the amount of pen travel. Part C is an electromagnet;

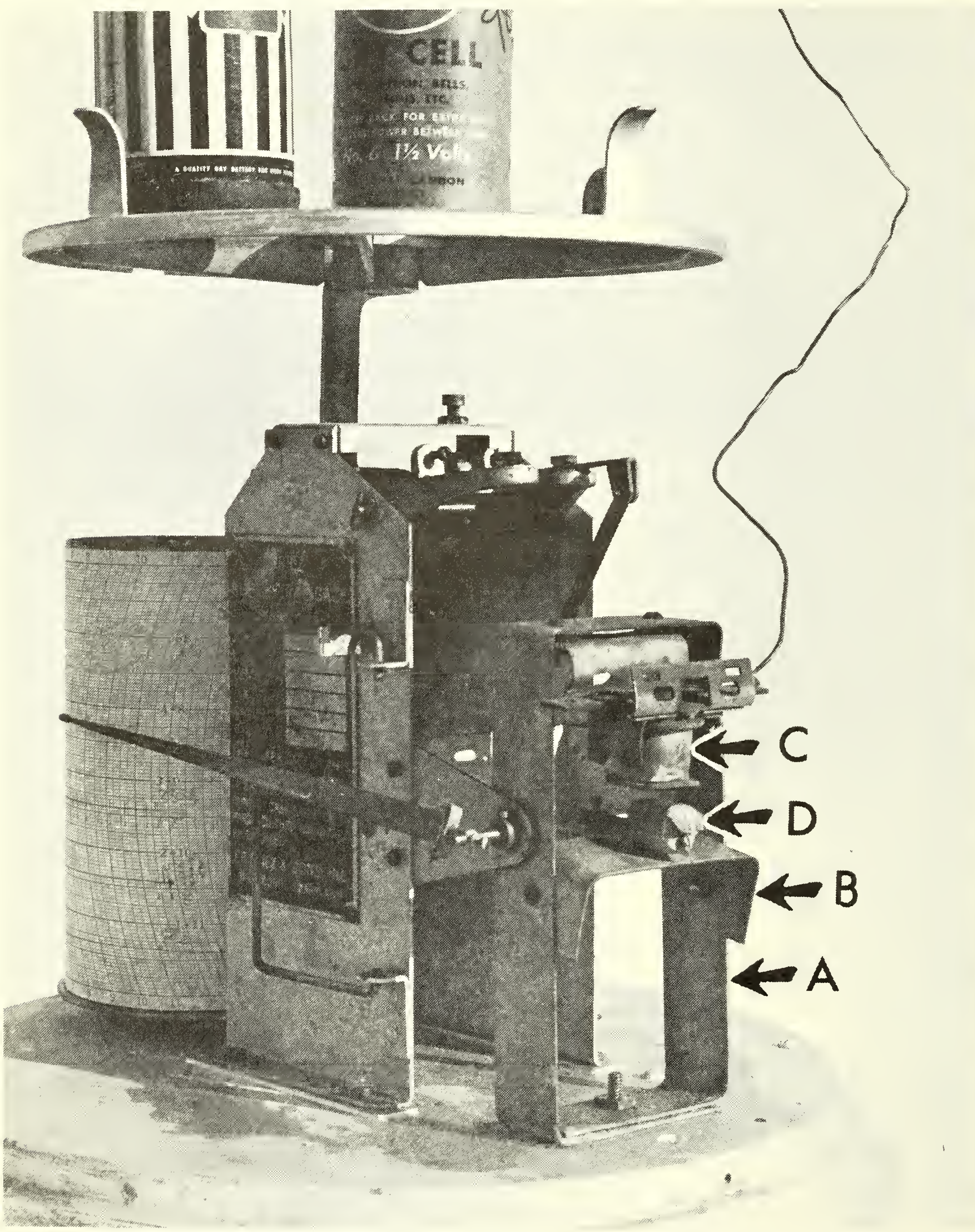

Figure 1.—A rain gage converted to record wind movement. For description of lettered parts, see text.

this one was taken from an old automobile relay, but any kind of low-voltage electromagnet will suffice.

The counterweight, D, is wrapped with masking tape to keep it from sticking to the magnet. In some gages the counterweight is made of lead and is not attracted magnetically. If so, it should be replaced with a steel counterweight, or it may be wrapped with a piece of sheet steel to make it attractive to the magnet.

A low-voltage electromagnet can usually be energized sufficiently with two $1\frac{1}{2}$-volt dry cells. If line current is available, a low-voltage transformer can be used. The voltage should be as low as possible to prevent sparking and damage to the anemometer points.

The dry cells are connected in series with the anemometer contacts and the electromagnet. When the anemometer contact points close, the electromagnet is activated, lifting the counterweight and lowering the pen, thus making a vertical mark on the chart. Each vertical mark represents 1 mile of wind movement, and the marks are totaled to provide a measurement of wind movement for the period desired, as read from the time scale on the chart.

A variety of time scales are available for this model of recording rain gage: 6, 12, 24, 48, 96, and 192 hours. In the study described, 96-hour gears and charts were employed, requiring servicing twice weekly. One chart may be used for 3 or 4 traces by moving the pen arm up or down. The set screw should be tightened just enough so that the pen arm can turn on its shaft with moderate pressure.

When wind speeds are too great for recording each mile at the slower chart-drum speeds, clock speed can be increased, or the anemometer dial can be modified to cause contact once every 2 miles or once every 5 miles. The outer anemometer dial has 10 fingers, which close the electrical contacts once each mile of wind movement. At one location, we removed all fingers from the dial except those at 0 and 5; the record then consisted of a mark every 5 miles, sufficient to provide a reliable average in miles per hour. The dial itself is left intact so that total wind movement between visits may be read from the odometer, providing a check on the chart record.

As the only pertinent parts of the recorder for this purpose are the chart drum and the pen-arm assembly, any recording instrument that has these components is suitable for recording wind movement. We also adapted a spare hygrothermograph for this purpose. Although both the recording rain gage and the hygrothermograph are fairly expensive instruments, they are often temporarily available, are much less expensive than the standard recorder for wind movement, and may be reconverted to their original use without difficulty.

If no instrument is available, the necessary parts may be purchased separately for about $80 and mounted on a heavy wooden or metal base. A parts list with approximate prices follows:

1 piece 16-gage sheet metal 1½ x 26 inches	$ .50
1 electromagnet	2.00
15 feet bell wire, plastic covered	.25
Assorted nuts and bolts	.25
2 dry cells, No. 6	1.90
(Or 1 bell transformer, 6-volt)	(1.75)

The above parts may be purchased locally or from a mail-order catalog. The following parts, needed if no spare instrument is available, may be obtained from one of several instrument makers. Names will be furnished upon request.

1 clock with chart cylinder	$71.00
1 pen-arm shaft	1.50
1 pen-arm assembly with bracket	4.50
1 pivot	1.00
1 counterweight	.75

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U. S. FOREST SERVICE RESEARCH NOTE NE-22

1964

Northeastern Forest

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Experiment Station

COLLAR CRACK OF BIRCH

The name "Collar crack" is suggested for a condition of birches observed in the past 4 years during field studies of forest disease problems in the White Mountains of New Hampshire. The first close observations of this condition were made during the summer of 1963. This is a report on those observations and an explanation of the possible cause.

The symptoms observed were vertical cracks from a few inches to several feet long at the bases of yellow birch (*Betula alleghaniensis* Britt.) and paper birch (*B. papyrifera* Marsh.) trees (fig. 1). On some trees the base is so weakened that windthrow results (fig. 2). On other trees the crowns become thin and the leaves chlorotic as the dead areas around the basal cracks coalesce and girdle the tree.

The affected trees were usually concentrated in certain areas, but some were found scattered. Affected trees were found on dry hillsides as well as on moist, flat, low land. Many such trees were found on the Bartlett Experimental Forest and throughout the Saco River area on the eastern slopes of the White Mountains. (But no affected trees were found on the Hubbard Brook Experimental Forest, on the western slopes of the mountains.)

Observations

The affected trees were most abundant on sites having more than 50 percent softwoods — especially fir. On some of these sites more than half of the birch trees were affected. A study of the history of one such site of about 5 acres on the Bartlett Experimental Forest revealed that the land had once been cleared for farming and the trees that later grew

Figure 2. — Many affected trees break at the base during storms. *Armillaria mellea* is fruiting on the root of this tree.

Figure 1. — Vertical cracks at the base of this paper birch tree indicate root and butt decay.

on the land were cut for fuelwood and other purposes at frequent intervals.

Basal cracks were noted on trees ranging in size from 4 to 18 inches d.b.h., on sprouts and single stems, and on trees on hummocks and in depressions. Small cracks just beginning to form were seen on small young trees as well as on large old specimens. Some cracks were very large, and in them were found fruiting bodies of the principal fungi that cause decays in birch: *Pholiota* sp., *Fomes igniarius* var. *laevigatus,* and sterile conks of *Poria obliqua.* Basal cracks were noted on many dead windthrown trees.

Roots of several trees were dug and examined after the trees were cut for study. The humus and soil were dug away from many shallow roots on trees that were not cut. The decay varied from small areas on the undersides of the roots to completely decayed large roots. Every tree that had basal cracks had some root decay.

Sections were cut from decayed roots and from decayed and discolored areas in the butts. In the laboratory, *Armillaria mellea* (fig. 3) was isolated consistently from the decay in the sample root sections. Although this fungus was isolated from the decays in some of the butt sections, other decay fungi were isolated more commonly. An unidentified dark nonsporulating fungus was isolated from the dark zone lines in the decay caused by *A. mellea* (fig. 3).

Figure 3. — *Armillaria mellea* growing in culture from chips of decayed wood. Rhizomorphs often form in culture. The black fungus was isolated from the dark zone lines in the decay.

Figure 4. — Fruiting bodies of the honey mushroom, *Armillaria mellea.*

Figure 5. — *Armillaria mellea* at the base of a living yellow birch.

Figure 6. — Mycelial fans of *A. mellea* 6 feet up the stem of a living yellow birch.

During the latter half of September, fruiting bodies of *A. mellea* — commonly called the honey mushroom — were abundant throughout the forest (fig. 4). Because the fungus forms rhizomorphs — black stringy strands of fungus tissue — the common name of the disease caused by this fungus is "shoestring root rot." The fruiting bodies were found on the roots and bases of many of the trees that had been studied earlier (fig. 5). They were found in the cracks as high as 3 feet above the base. Very few rhizomorphs were found on the dead areas on the living trees.

On the Bartlett Experimental Forest, more than 50 trees were observed that had basal cracks and the fruiting bodies of *A. mellea* either on the roots or on the base. Fruiting bodies were observed also on an equal number of affected trees in many areas along the eastern part of the Kancamagus Highway near Conway, New Hampshire.

White fans of fungus tissue were found under recently killed bark patches as high as 6 feet above the bases of some trees. These mycelial fans were a few inches from living tissues (fig. 6). A dull red liquid oozed from spots in the dead and dying bark. Small insect holes were commonly observed near the centers of the wet spots.

Discussion

A wide variety of woody plants throughout the world are attacked by *A. mellea.* (See Leaphart, Charles D. *Armillaria root rot.* U. S. Dept. Agr. Forest Pest Leaflet 78, 8 pp., illus., 1963.) The fungus generally is thought to become an aggressive parasite only after other factors have weakened the host.

Our observations suggest that *A. mellea* is the cause of the root rot on the birch trees examined, that the rot is usually followed by cracking at the tree base, and that other decay fungi invade the trees through the basal cracks after *A. mellea* has ceased to grow upward in the butt.

An extensive study was not made, but on the basis of the information gathered it is recommended that trees with basal cracks be cut and used as soon as possible. Decay fungi entering through the cracks cause a rapid decrease in the value of the tree and also cause the base of the tree to be so weakened that the chances for windthrow are increased.

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U. S. FOREST SERVICE RESEARCH NOTE NE-23

1964

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Experiment Station

FREQUENCY OF STREAMFLOW MEASUREMENTS REQUIRED TO DETERMINE FOREST TREATMENT EFFECTS

Most of the stream-discharge records for our experimental watersheds are taken by continuous measurements. But the question arises: are continuous measurements necessary to determine effects of forest treatments? Or could treatment effects be determined by measurement of discharge at intervals, say, once a day or once a week?

Data collected on our Fernow Experimental Forest in West Virginia offered a good opportunity to test this possibility. The control-watershed approach was and is used on the Fernow. After a 6-year calibration period, treatments were applied, and results were tested for significance of treatment effects. All analyses were based on continuous records.

Analysis

For the analysis reported in this note, data from two watersheds — a commercial clearcutting and a control watershed — were utilized. Treatment effects were compared for these six frequencies of measurement: (1) continuous; (2) daily; (3) semi-weekly or 3½-day (Monday and Thursday); (4) weekly or 7-day (Monday); (5) semi-monthly or 15-day (the 8th and 23rd); and (6) monthly or 30-day (the 15th).

Treatment effects included these ten measurements of water yield: (1) annual discharge, (2) growing-season discharge (May-October), (3) dormant-season discharge (November-April), (4) May discharge, (5) June discharge, (6) July discharge, (7) August discharge, (8) September discharge, (9) October discharge, and (10) low flow — number of days in year with discharge below 0.05 cubic feet per second per square mile (csm.).

With 6 frequencies and 10 kinds of treatment effect, 60 separate analyses were involved. All data analyzed were in area-inches except for the low-flow data, which were in number of days. Storm flows or peak flows were not considered in these analyses. They might better be studied by installation of crest gages and would thus present a somewhat different problem from that treated here.

First, stage and csm. were tabulated for each day at midnight. Midnight was chosen for convenience; any other time would have worked as well. It was decided that the nuisance of using different randomly selected times for each day would offset any theoretical advantage of that method. Tabulations were made for 6 calibration years and for 3 years after start of treatment.

Next, estimated flows by month, season, and year were prepared for each watershed, using each frequency of measurement. For example, for the 30-day frequency it was assumed that flow at midnight on the 15th represented average flow for the month. This led to some strange estimates. For example, discharge for the month of October 1954 on the control watershed was estimated at 74 area-inches by the 30-day frequency method.

Prediction equations were prepared. For each, the smallest difference required to show significance was computed. The 5-percent level of significance was used and a one-tailed test was assumed (the area under only one end of the probability curve was considered). One assumption was made: the value for the control in the treatment year being tested would not differ from the corresponding mean value for the calibration period by more than one standard deviation.

Table 1. — ***Annual discharge in area-inches, by frequency of measurement, control watershed***

Water-year	Frequency of measurement					
	Continuous	Daily	3½-day	7-day	15-day	30-day
1951-52	25.95	24.70	21.09	21.16	21.91	26.26
1952-53	18.02	18.11	19.08	16.11	27.35	17.42
1953-54	17.93	18.99	17.32	17.91	18.12	27.38
1954-55	28.74	29.15	24.87	22.90	22.57	86.74
1955-56	22.97	22.25	23.96	20.38	18.47	25.34
1956-57	33.49	34.70	29.21	33.19	33.69	17.96
Mean	24.52	24.65	22.59	21.94	23.68	33.52

Results

Annual discharges for the 6 calibration years on the control watershed, as determined by the different frequencies of measurement, are given in table 1. The same discharges expressed as percentages of the values determined by continuous measurement are shown in table 2. For the

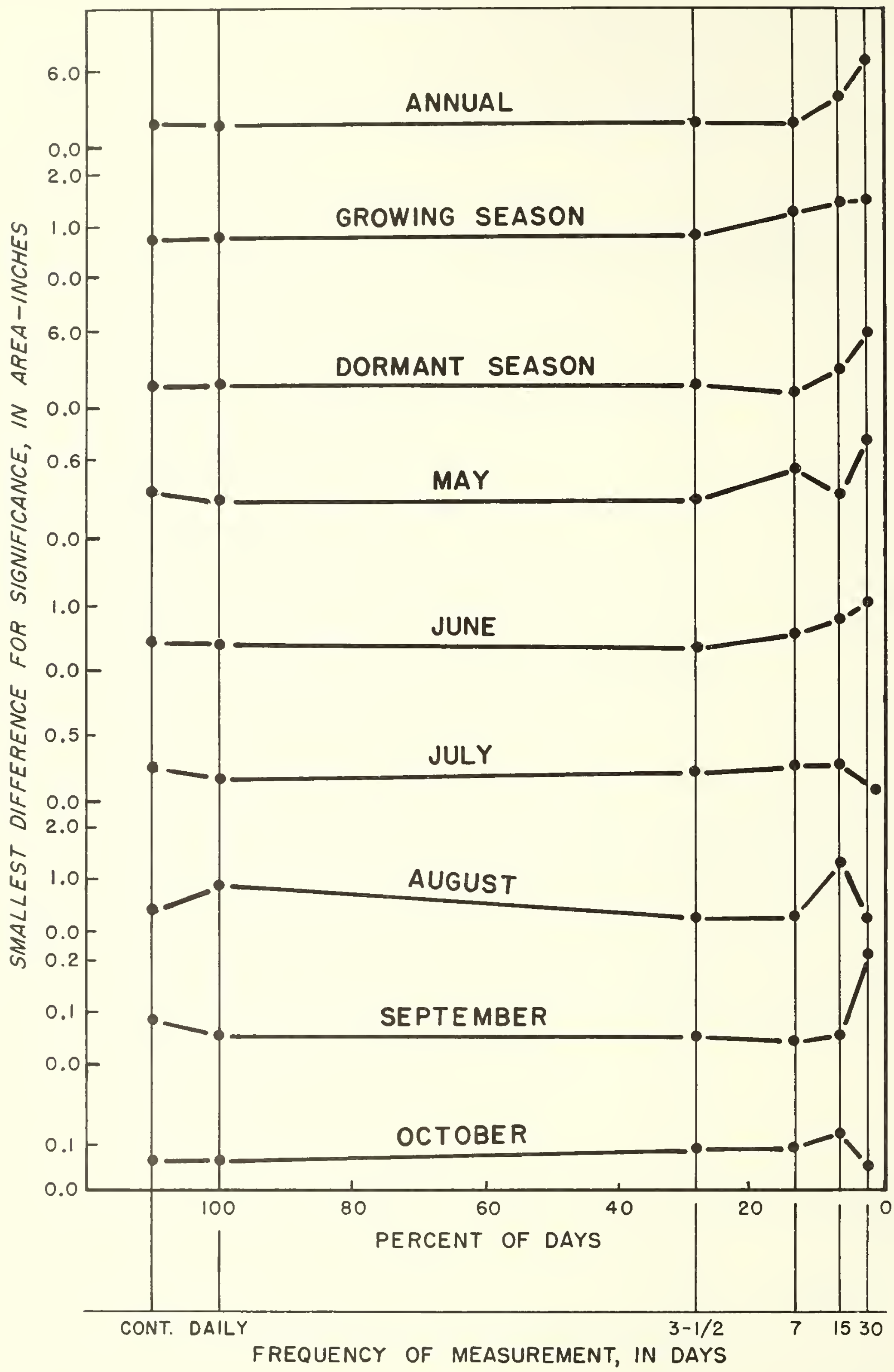
Table 2. — *Annual discharge by frequency of measurement, as percentage of discharge determined by continuous measurement, control watershed*

Water-year	Frequency of measurement				
	Daily	3½-day	7-day	15-day	30-day
1951-52	95	81	82	84	101
1952-53	100	106	89	152	97
1953-54	106	97	100	101	153
1954-55	101	87	80	79	302
1955-56	97	104	89	80	110
1956-57	104	87	99	101	54
Mean	101	92	89	97	137

Table 3. — *Discharge in area-inches by month, season, and year, based on different frequencies of measurement, control watershed, water-year 1955-56*

Period	Frequency of measurement					
	Contin-uous	Daily	3½-day	7-day	15-day	30-day
May	1.24	1.26	0.82	0.94	0.49	3.53
June	.61	.59	.52	.69	.36	1.76
July	.34	.38	.29	.44	.10	.18
August	1.56	1.42	1.97	.51	.44	1.21
September	.03	.03	.03	.02	.07	.01
October	.03	.05	.07	.02	.01	.03
Growing season	(3.82)	(3.72)	(3.70)	(2.62)	(1.47)	(6.72)
November	0.36	0.37	0.34	0.25	0.98	0.81
December	1.27	1.33	.95	1.35	.71	.39
January	2.53	2.39	2.77	4.61	.44	.39
February	7.11	6.87	8.77	6.61	3.18	8.35
March	5.41	5.11	5.43	3.01	8.21	7.34
April	2.47	2.46	2.00	1.93	3.48	1.34
Dormant season	(19.15)	(18.53)	(20.26)	(17.76)	(17.00)	(18.62)
Year	22.97	22.25	23.96	20.38	18.47	25.34

Figure 1. — Smallest difference for significance for various frequencies of measurement.



6 years, the daily estimates ranged from 95 to 106 percent of the continuous-measurement record; 30-day estimates ranged from 54 to 302 percent.

Similar data for months and seasons in one water-year are given in table 3. Generally, estimates based on daily measurement are fairly close to the continuous-measurement discharges; for less frequent measurements, the estimates are not so close.

Table 4. — *Number of significant changes due to treatment in the 3 years after start of treatment, for 6 measurement frequencies*

Data analyzed	Frequency of measurement					
	Continuous	Daily	$3\frac{1}{2}$-day	7-day	15-day	30-day
1 Annual	3	3	2	2	1	1
2 Growing season	3	3	2	3	2	1
3 Dormant season	0	0	0	0	0	0
4 May	0	0	1	1	1	0
5 June	1	1	1	1	0	1
6 July	3	3	2	2	2	2
7 August	2	0	2	2	0	1
8 September	2	3	2	3	3	2
9 October	3	3	3	3	3	3
10 Low flow	3	3	3	3	3	3
Sum	20	19	18	20	15	14
Significant and valid[1]	20	18	17	18	13	14
Significant but not valid[1]	0	1	1	2	2	0

[1]Assuming results of continuous record are standard and correct.

Figure 1 shows the smallest differences required to show significance for most of the analyses. The lines on the graph are almost horizontal until the 15- or 30-day frequencies.

Tests of significance using the measured values (by the different methods) in the 3 years after start of treatment are shown in table 4. In 30 tests, the continuous record showed 20 significant values. The daily and $3\frac{1}{2}$-day records showed close to the same results. And the 7-day record also showed 20 significant values. The 15-day and 30-day record showed 15 and 14 significant values, respectively.

The last two lines in table 4 are based on the debatable assumption that significant results of the discontinuous measurements are valid only if the continuous record showed significant results in the corresponding analysis. As can be seen, in almost all cases when the discontinuous method showed significance, the continuous record substantiated it. The 30-day record showed 14 significant changes, and 14 corresponded to significant results by the continuous record.

The yes or no of significance is only part of the story. Quantitative estimates of the amount of change due to treatment are also important.

Table 5 presents, for the first water-year after completion of treatment, the estimates of increases in discharge after treatment, and their fiducial limits. For annual discharge, estimates by both continuous and 30-day measurement indicated significant increases. However, the estimated in-

Table 5. — *Increase in discharge following treatment as determined by different frequencies of measurement, in area-inches, water-year 1958-59*

Data analyzed	Frequency of measurement					
	Continuous	Daily	3½-day	7-day	15-day	30-day
Annual	5.09 ± 1.50*	5.47 ± 1.58*	4.22 ± 1.71*	4.21 ± 1.73*	2.30 ± 4.26	8.39 ± 6.18*
Growing season	4.40 ± 0.98*	4.47 ± 0.96*	4.17 ± 0.98*	3.67 ± 1.52*	4.21 ± 2.72*	7.76 ± 1.36*
Dormant season	0.60 ± 2.01	1.21 ± 1.69	0.61 ± 1.76	0.50 ± 1.05	—0.40	—0.44
May	0.09 ± 0.33	0.18 ± 0.26	0.27 ± 0.31	0.41 ± 0.54	0.21 ± 0.34	0.32 ± 0.71
June	1.27 ± 0.35*	1.60 ± 0.36*	0.99 ± 0.29*	0.75 ± 0.51*	—0.26	1.81 ± 1.45*
July	1.60 ± 0.64*	1.65 ± 0.43*	0.78 ± 0.30*	1.33 ± 0.30*	3.17 ± 1.83*	3.17 ± 0.10*
August	1.14 ± 0.65*	0.47 ± 0.95	1.12 ± 0.25*	0.65 ± 0.25*	0.96 ± 1.78	2.92 ± 0.35*
September	0.46 ± 0.07*	0.46 ± 0.05*	0.40 ± 0.06*	0.48 ± 0.05*	0.76 ± 0.05*	0.07 ± 0.02*
October	0.16 ± 0.05*	0.16 ± 0.05*	0.15 ± 0.08*	0.17 ± 0.08*	0.13 ± 0.11*	0.10 ± 0.04*
	Number of days of discharge below 0.05 csm					
Low flow	—38 ± 13*	—38 ± 8*	—41 ± 28*	—48 ± 38*	—30 ± 11*	—64 ± 26*

*Significant at 5-percent level.

crease based on continuous measurement was 5.09 ± 1.50 inches, and based on 30-day measurement the estimate was 8.39 ± 6.18 inches. Obviously the continuous-measurement estimate in this example was much better.

Discussion

The results are encouraging. Perhaps discontinuous measurements may be used to determine treatment effects. But four qualifications must be made.

First, the records for this comparison were based upon carefully constructed gaging stations, painstaking maintenance, and meticulous data collection. If daily or weekly measurements had been done at a station with a shifting control or with inaccurate measurement of head, results might have been quite different.

Second, the treatment tested (clearcutting) was a drastic one, with sizable treatment effects. If a less severe treatment had been made, results might not have been so promising.

Third, the significance of effects here depends largely on the 6-year calibration period. In many administrative studies it might not be feasible to wait 6 years before treatment. Perhaps a full-scale assault upon the problem of time-serial correlation is in order; or, to put it another way: How can we get more than one "n" in a year?

And fourth, simultaneous measurement at both watersheds was assumed. In actual practice, the time of measurement on the two would probably differ slightly because of the travel time between measurements.

The results suggest that, under some situations, much might be learned from relatively few measurements. For instance, for the Fernow clearcutting, weekly measurements in September and October by themselves would have been rewarding.

Values in the control and treated watersheds were not so well correlated during or immediately after a storm as they were at other times. Depending on objectives, a rule for a 7-day measurement program might be to avoid measurement within 24 hours after a storm of a given magnitude — say 0.50 inch.

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U. S. FOREST SERVICE RESEARCH NOTE NE-24

1964

Northeastern Forest

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Experiment Station

THE IMPORTANCE OF DEW IN WATERSHED-MANAGEMENT RESEARCH

Many studies, using various methods, have been made of dew deposition to determine its importance as a source of moisture. For example, Duvdevani (1947) used an optical method in which dew collected on a wooden block was compared with a set of standardized photographs of dew. Potvin (1949) exposed diamond-shaped glass plates at 45° to ground level, so that condensed dew ran into a graduate. Lloyd (1961) studied amount and duration of dew by using polystyrene blocks mounted on a balance linked to a 7-day continuous recorder. Craddock (1951) devised a sub-groundlevel balance and recorder to give continuous records of dewfall on a soil mass or a plant surface at groundlevel; and the Craddock recorder was later — in 1954 — improved upon by Jennings and Monteith.

The formation of dew is generally limited to clear nocturnal periods when exposed surfaces are cooling and have temperatures below the dewpoint of the surrounding air. Visible dew comes from three separate sources: (1) true dewfall, or condensation of water vapor from the atmosphere; (2) distillation, or condensation of water vapor from transpiring leaves or warmer, sufficiently moist soils; and (3) guttation, or exudation of liquid from certain parts of leaves (Slatyer and McIlroy 1961). Only the first source, dewfall, represents a direct addition of moisture to the plant-soil system.

Either artificial or natural collection surfaces can be used to measure dewfall and distillation. However, some scientists feel that artificial objects do not indicate the correct amount of dew received. Angus (1959) and Slatyer and McIlroy (1961) advocated weighing an isolated representative portion of the natural surface as the most reliable method of determining dew deposition.

Is Dew Important?

The Fernow Experimental Forest, near Parsons, West Virginia, where watershed-management research is being carried on, has been observed to be an area where dew deposition is heavy. The question arose: Is dew deposition important enough as a source of moisture to be considered in our watershed-management studies?

So in the summer of 1962 an exploratory study of dew deposition was made in an open area on flat bottomland adjacent to the Fernow Experimental Forest headquarters. The purposes of the study were: (1) to determine the general magnitude of dew deposition, and (2) to test the feasibility of using a modified recording rain gage for measuring dew.

To use a natural surface for measuring dew deposition, the rain gage was modified to accommodate a section of live turf (fig. 1). The turf was held on a plate, 17.89 inches in diameter, supported on a pedestal in the bucket of the gage. The turf plate provided a deposition area five times as large as the rain-gage orifice, causing the scale on the

Figure 1.—Recording rain gage modified to measure dewfall. The live turf was used to provide a natural surface for collecting dew.

Table 1. — *Dew deposition in an open area adjacent to Fernow Experimental Forest headquarters*

Period (1962)	Accumulation for period	Occurrence of dew deposition	Average measurable deposit	Maximum dew deposition during period
	Inches	*No. days*	*Inches*	*Inches*
May	0.030	19	0.0016	0.004
June	.051	19	.0027	.005
July	.044	19	.0023	.005
August	.055	23	.0024	.005
September	.032	13	.0025	.005
October	.030	10[1]	.0030	.007
November[2]	.017	8	.0021	.004
May-November	.259	111	.0024	.007

[1]Totals for October do not include 10 days of missing record caused by instrumentation difficulties.
[2]November values include frost deposition.

recorder chart to be magnified by five. The chart drum was equipped with a 96-hour gear, and dew deposition could easily be read from the chart to the nearest 0.001 inch.

Increases in moisture caused by dew deposition could be differentiated from those caused by rainfall by the nature of the pen trace. Dew deposition caused slow, gradual rises: rainfall caused more rapid and generally larger rises. General weather observations also aided in chart interpretation.

Measurement Values

Dew measurement values for May through November 1962 are shown in table 1. Total monthly dew deposition ranged from 0.017 to 0.055 inch, and the total for the 7-month period was 0.259 inch. Maximum daily accumulation during the 7-month period was 0.007 inch. Dew or frost was recorded on 111 of the 200 days of record.

A visual observation of the occurrence of dew showed that there were usually 3 to 6 days in each month when dew formed but was not recorded by the gage. Assuming that deposition on each of these days amounted to 0.0005 inch — half the amount that would show on the recorder — the maximum unrecorded amount in any month would be 0.003 inch. This was considered negligible.

In most instances, deposition began registering on the dew chart by 9 p.m. Maximum accumulation was usually reached between 6 and 7 a.m., and the dew usually evaporated by 9 a.m. Most of the November deposition was observed to be frost. Frost formation followed the same pattern as dew, with the possible exception that it formed later in the evening. Water content of the frost formations did not differ greatly from that of the dew deposits.

The average daily dew deposit was relatively uniform for the 7 months of record, ranging from 0.0016 to 0.0030 inch. During July, August, and September the average deposition for the nights when dew occurred was 0.0023, 0.0024, and 0.0025 inch, respectively. The total deposition for these 3 months was 0.131 inch, or 1.2 percent of the 10.76 inches of precipitation that occurred during the period.

A dew study reported by Lloyd (1961) revealed that the nightly averages for the same 3 months in 1958 in an open area in northern Idaho were 0.0069, 0.0033 and 0.0036 inch. The total deposition for these 3 months in northern Idaho was 0.39 inch, or 13 percent of the 2.96 inches of rainfall that occurred during the period.

Since the height of the collection surface on the Fernow dew gage was 3 feet above ground level, the question arose as to how much variation occurred between the dew deposition at ground level and on the gage. Lloyd (1961) showed that dew deposition at 5 feet height was about twice that at 1 foot. Deposition at 2 feet was halfway between that at 1 and 5 feet, and maximum deposition occurred at 10 feet. Baumgartner (1956) found dew deposition in the open at 1 meter to be more than twice that at ½ meter; maximum depostiion was at 1½ meters and was more than 3 times the ½ meter amount. Both of these studies showed a tendency for dew deposition to be greater at several feet above ground level — indicating that the Fernow dew gage may have shown higher totals than actually occurred at ground level.

In our study, dew deposition was measured only in the open. Results shed little light on what might occur under, within, or at the top of the forest canopy. Geiger (1959), writing on dew in the forest, states that "Most of the dew, as I have several times been able to observe, is deposited on the upper surface of the crown, decreasing continuously and decidedly downward into the inside of the stand. Above the crown, the deposition of dew was so great at times that it required several hours of sunshine to complete its evaporation." Lloyd (1961) found no dew deposition under a closed forest canopy, and observed heavy dew on top of a closed canopy of alder.

The extent to which night depositions of dew retard evapotranspiration on the following day is still uncertain. And the possibility of dew entering the plant system is another point of controversy. These two points are not explored here, although they bear on the importance of dew in the hydrologic cycle.

Conclusion

The total amount of dew measured in the open at the Fernow Experimental Forest headquarters was not large. The total for August, the month of maximum deposition, was 0.055 inch — only 1 percent of the mean August precipitation (5.7 inches).

In any month, the error in precipitation measurements on most small experimental watersheds very likely exceeds 0.055 inch. Thus the amount of dew at this location is probably not large enough to warrant its being measured in watershed-management studies.

The modified rain gage appears to be capable of measuring deposition for comparison with precipitation, streamflow, soil moisture or other watershed measurements, but perhaps is not accurate enough for basic studies of dewfall.

Literature Cited

Angus, D. E.
1959. Agricultural water use. In advances in agronomy. v. 11, pp. 33-35, illus. Amer. Soc. Agron. New York and London.

Baumgartner, Albert.
1956. Untersuchungen über den Wärme- and Wasserhaushalt eines jungen Waldes. Deut. Wetterdienst. Ber. 5 (28): 4-53.

Craddock, J. M.
1951. An apparatus for measuring dewfall. Weather 6: 300-308.

Duvdevani, S.
1947. An optical method of dew estimation. Roy. Met. Soc. (London) Quart. Jour. 73: 282-296.

Geiger, Rudolf.
1959. The climate near the ground. 332 pp. Harvard Univ. Press, Cambridge, Mass.

Jennings, E. G., and J. L. Monteith.
1954. A sensitive recording dew-balance. Roy. Met. Soc. (London) Quart. Jour. 80: 222-226.

Lloyd, Merle G.
1961. The contribution of dew to the summer water budget of northern Idaho. Amer. Met. Soc. Bul. 42: 572-580.

Potvin, A.
1949. A simple method of dew measurement. Forestry Chron. 25: 52-53.

Slatyer, R. O., and I. C. McIlroy.
1961. Practical microclimatology. UNESCO, Commonwealth Sci. and Indus. Res. Organ., Australia. Ch. 6, 24 pp.

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U. S. FOREST SERVICE RESEARCH NOTE NE-25

1964

Northeastern Forest

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Experiment Station

COOPERATIVE TEST PLOTS PRODUCE SOME PROMISING CHINESE AND HYBRID CHESTNUT TREES

In attempts to find a chestnut tree that is resistant to the blight fungus *Endothia parasitica,* Asiatic chestnuts have been imported and grown in this country, and tree breeders have worked to produce hybrid trees that might be suitable substitutes for the blight-susceptible American chestnut, *Castanea dentata,* in timber and nut production.

These efforts during the past 30 years have produced a number of hybrid trees; and one Chinese chestnut from Nanking (accession number PI-58602) has proved to be superior in blight resistance, tree form, growth rate, and nut production. To compare the hybrid trees with this Chinese chestnut, 15 cooperative test plots were established by the senior author. The plots were on private, state, and Federal land.[1]

Two plots were established in the spring of 1947 in Connecticut (Litchfield County), and Tennessee. Subsequently, plots were established in Alabama, Arkansas, Connecticut (Tolland County), Illinois, Michigan, Missouri, New Hampshire, New York, Ohio, Pennsylvania, South Carolina, and West Virginia. A total of 1,746 trees were planted: 500 hybrids from Glenn Dale, Md.; 705 hybrids from Hamden, Conn.; and 541 Chinese trees from Glenn Dale.

[1]The authors thank the many institutions and agencies on whose lands the 15 cooperative plots were established. And they gratefully acknowledge the splendid cooperation and assistance given by the many field cooperators in preparing and maintaining the test sites and in collecting data over the years.

The Glenn Dale hybrids were developed by Russell B. Clapper and his associates in the U. S. Department of Agriculture's Division of Forest Pathology. The Connecticut hybrids were developed by the late Arthur H. Graves and his colleagues, first at the Brooklyn Botanic Garden and later (1947-62) at the Connecticut Agricultural Experiment Station. The Chinese chestnut seedlings, also grown at the Glenn Dale nursery, were PI-58602 and a few replants of Chinese chestnut 55984 from Yunan Province.

Table 1.—*Location and planting detail of 15 chestnut-tree plots*

Plot No.	Location	State	County	Established	Trees planted: Hybrids: Hamden	Trees planted: Hybrids: Glenn Dale	Trees planted: Chinese Glenn Dale	Trees planted: Total
				Year	*No.*	*No.*	*No.*	*No.*
1	Great Mountain Forest	Conn.	Litchfield	1947	50	23	58	131
2	Norris Dam, TVA	Tenn.	Anderson	1947	51	22	55	128
3	Antioch College	Ohio	Greene	1948	25	37	17	79
4	Table Rock State Park	S. C.	Pickens	1948	66	19	34	119
5	National Wildlife Refuge	Ill.	Williamson	1949	25	49	25	99
6	County Recreation Park	Pa.	Montgomery	1949	25	49	25	99
7	Russ Forest	Mich.	Cass	1951	50	39	13	102
8	Nathan Hale Farm (A)	Conn.	Tolland	1951	42	0	48	90
9	Nathan Hale Farm (B)	Conn.	Tolland	1951	49	0	49	98
10	Ouachita National Forest	Ark.	Polk	1952	58	30	20	108
11	Boys' Industrial School	W. Va.	Taylor	1953	50	49	50	149
12	Guntersville Dam, TVA	Ala.	Marshall	1954	50	50	50	150
13	State College of Forestry	N. Y.	Onondaga	1954	50	49	51	150
14	Sinkin Experimental Forest	Mo.	Dent	1954*	64	34	46	144
15	Abbott State Forest	N. H.	Hillsboro	1955	50	50	0	100
	Total	—	—	—	705	500	541	1,746

*All plots were planted in the spring except the plot in Missouri, which was planted in December.

Methods

At each location the trees were planted on forest land of above-average hardwood site quality. These were sites where various plant indicators suggested that chestnut might do well. These sites were characterized by deep, fertile, and well-drained soils with a covering of leaf litter and humus (Diller 1950).

One fairly reliable plant indicator, common to most of the areas, was yellow-poplar (*Liriodendron tulipifera*). Accordingly, the planting sites were chosen where yellow-poplars either were already established or might be expected to make good growth.

Before planting, all native overstory trees 2 inches d.b.h. and larger were girdled. In most plots saplings less than 2 inches d.b.h. were left standing. Subsequent maintenance was necessary on all the plots. In one Ohio plot all volunteer woody vegetation was cut back to the ground. On a few sites, herbaceous vegetation and some of the lesser woody species invaded the area and suppressed the planted trees.

Table 1 gives the location and planting detail for each plot. Originally it was hoped that 150 trees could be planted in each plot — 50 hybrids each from the Connecticut and the Maryland sources, and 50 Chinese chestnuts from Maryland. But because some hybrid chestnut seedlings were damaged at the nurseries the total number of trees planted per plot varied from 79 to 150.

Connecticut plots A and B did not receive any Glenn Dale hybrids, and the New Hampshire plot did not receive any Glenn Dale Chinese. All other plots were planted with the Hamden and Glenn Dale hybrids, and the Glenn Dale Chinese in varying numbers.

All the plots were planted in the spring except the Missouri plot, which was planted in early winter. The trees were planted randomly at a spacing of 10 x 10 feet.

In August and September 1963 the 15 plots were inspected and the 20 to 25 most promising trees in each plot were measured for height and d.b.h. Because of differences in site, year of establishment, and the diverse genetic constitution of the hybrids, it was impossible to make a formal statistical analysis of the growth measurements.

Results

All the trees that had averaged at least 2 feet in height growth per year are listed in table 2, along with their source, age, and pedigree. The 67 trees that met this requirement represented about 4 percent of

Table 2.—*Chestnut trees in test plots that averaged at least 2 feet height growth per year*

Connecticut hybrids

Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.
		Years		*In.*	*Ft.*
Conn.	40	18	JAxOP	5.9	37
Tenn.	252	18	JAxOP	3.8	37
Pa.	E51	16	CxJ.JA	4.4	35
Pa.	E56	16	CxJ.JA	4.1	35
Ill.	B79	16	ACxJC	4.5	32
Ill.	B22	16	J.CA	3.0	32
Conn. (A)	11-4	14	AxC.JA	3.8	31
Conn. (A)	14-2	14	ACxC	2.9	29
Conn. (B)	12-2	14	J.JAxC	3.7	35
Ark.	64	13	C**	4.0	37
Ark.	37	13	CxJA**	4.0	28
Ark.	82	13	CxJA**	3.4	26
Ark.	21	13	C**	3.5	26
Ark.	36	13	CxJA**	3.1	28
W. Va.	78	12	AxC.JA	4.3	32
W. Va.	125	12	AxC.JA	3.4	32
W. Va.	74	12	JAxC	3.3	28
W. Va.	8	12	C.JAxC.JA	1.9	26
W. Va.	127	12	JAxC	2.2	24
W. Va.	144	12	JAxC	2.3	24
Mo.	150	10	JAxC	2.0	21

Glenn Dale Chinese

Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.
		Years		*In.*	*Ft.*
S. C.	F67	17	58602	6.6	40
S. C.	F26	17	"	4.9	35
S. C.	F84	17	"	4.8	37
Pa.	F14	16	"	4.1	33
Ill.	B59	16	"	5.3	40
Ill.	B69	16	"	4.7	33
Ill.	B70	16	"	3.8	36
Ill.	B1	16	55984	3.3	33
Conn. (B)	1-2	14	58602	3.5	33
Conn. (B)	3-5	14	"	3.4	33
Conn. (B)	5-2	14	"	3.3	33
Conn. (B)	4-5	14	"	3.2	31
Conn. (B)	1-4	14	"	2.9	30
Conn. (B)	4-7	14	"	2.9	28
Conn. (B)	5-5	14	"	2.2	30
Ark.	44	13	"	3.3	26
W. Va.	9	12	"	3.4	38
W. Va.	15	12	"	3.3	34
W. Va.	45	12	"	3.3	30
W. Va.	16	12	"	3.0	38
W. Va.	135	12	"	3.0	28
W. Va.	14	12	"	2.6	32
W. Va.	47	12	"	2.5	26
W. Va.	43	12	"	2.3	28
W. Va.	73	12	"	2.3	28
Ala.	45	11	"	3.0	23
Mo.	38	10	"	1.9	21

Glenn Dale hybrids

Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.
		Years		*In.*	*Ft.*
S. C.	F31	17	CxCJ	6.3	35
S. C.	F21	17	AhOP	6.2	40
S. C.	F22	17	AhOP	5.0	40
S. C.	F36	17	AhOP	4.5	37
Pa.	E40	16	AOP	5.4	37
Pa.	E44	16	—	3.9	35
Pa.	E87	16	CxC	4.7	35
Pa.	F2	16	CxC	4.1	33
Ill.	B26***	16	CAxA	7.3	45
Ill.	B56	16	CxH	5.3	37
Ill.	B23	16	CAxC	2.9	33
W. Va.	80	12	CAxC	2.6	26
W. Va.	79	12	CAxH	2.5	26
W. Va.	148	12	CAxC	2.5	30
W. Va.	147	12	CAxC	2.1	24
W. Va.	19	12	CAxC	2.0	24
Ala.	31	11	CxC	3.3	27
Ala.	52	11	CxC	2.5	24
Mo.	59	10	CAxCA	2.4	21

*Trees were 1-3 years old when planted. Age is given as number of growing seasons on plot plus 1.
**Grafted trees. All on Chinese rootstock except Ark 64, which is a Chinese on Japanese rootstock. A = American, *Castanea denta;* C = Chinese, *C. mollissima;* J = Japanese, *C. crenata;* H = Henry, *C. henryi;* h = hybrid; OP = open-pollinated.
***Most outstanding hybrid tested.

the original number planted in the 15 plots. No trees in Michigan, New Hampshire, New York, and Ohio plots grew this well. The arbitrary height-growth yearly increment failed to furnish clues to the more important limiting factors for the poorer plots.

By far the most outstanding hybrid tested, tree B26, is located in the Illinois plot. It measured 7.3 inches d.b.h. and 45 feet in height — an annual growth of 0.43 inches d.b.h. and 2.6 feet height — in 17 growing seasons from seed (Clapper 1963). This tree has recently been named *Clapper chestnut* by Little and Diller (1964).

The pedigrees of the hybrids listed in table 2 are for the hybrids planted originally. Most trees that were highly susceptible to the blight fungus succumbed within 4 or 5 years. But by no means have all the susceptible trees been killed. For instance, many other miscellaneous plantings in which the Connecticut hybrid A x C.JA was represented became infected and were killed by the blight; so it can be predicted that some of the Connecticut hybrids of similar pedigree also will become blighted.

Grafted chestnut trees from Connecticut, planted in the Arkansas plot, have done well. Two of the trees, Ark 37 and Ark 36, are grafts of two hybrids recently described by Jaynes and Graves (1963) as C2 (Sleeping Giant chestnut) and C4. Both trees were grafted on Chinese rootstock. The surprisingly unexpected increased height (and d.b.h.) increment, which resulted when hybrid chestnut scions were grafted onto certain Chinese chestnuts as rootstocks, was not discovered until the Arkansas plot was inspected in September 1963.

The Chinese chestnut trees planted among the hybrids grew nearly as well as the hybrids. But the preliminary results indicate that not all the individual Chinese trees of seedling origin are fully resistant to the blight. In fact, canker incidence was as high among the Chinese trees as among the hybrids in some plots.

Discussion

Earlier miscellaneous planting of Asiatic chestnut trees demonstrated that Chinese and hybrid chestnut trees exhibit vigorous growth on forested land when not in severe competition from other tree species. However, the percentage of vigorous trees — those averaging approximately 2 feet height growth per year — is believed to be too small to warrant large-scale forest-tree plantings of seedlings for timber production because they could not maintain dominance in competition with the volunteer hardwood species among which they would be planted.

The 27 Chinese trees listed in table 2 represent 5 percent of those planted, and presumably some of these trees will have inherently poor form, or will not be fully resistant to the blight fungus. However, for wildlife plantings, where nut production rather than timber is the primary objective, the Chinese chestnut PI-58602 seedlings may be worthwhile.

Planting seedling chestnut trees for timber production will not be feasible until, either through selection or through breeding, forms are developed that will yield a higher percentage of vigorous, blight-resistant, well-formed trees. As soon as inexpensive vegetative-propagation techniques are developed for chestnut, the very best individual trees can be propagated and used to establish plantations.

Because chestnut is a vigorous sprouter and responds well to coppicing, an area generally needs to be stocked only once. After the first harvest no replanting, as a rule, would be necessary.

The pedigrees of the hybrids shown in table 2 reveal the different approaches used by Clapper and Graves in attempting to obtain the same goal of producing a blight-resistant forest tree. Clapper used first- and second-generation crosses of Chinese and American chestnuts mainly, and backcrosses of the F_1 progeny to the parent species. A few of his crosses, with the Chinese timber-chinkapin (*C. henryi*) and certain intercrosses of Chinese, also showed promise.

Graves, on the other hand, to assure that his crosses would possess sufficient blight resistance, relied heavily upon various combinations of three chestnut species: the American, the Chinese, and the Japanese (*C. crenata*). Sixteen — or possibly 18 — of the 21 Connecticut hybrids listed are combinations of Chinese, Japanese, and American (CJA). The reason for the uncertainty is that some of Graves' crosses were open-pollinated and the parentage is not definitely known.

No attempt is made here to discuss all the reasons for discrepancies in growth rates in the different plots. Some of the contributing factors — such as site, year of planting, and genotype — have been mentioned. Another factor was transplant shock. Certain hardwoods require several years to recover from such shock, and this may be one reason for the poor initial height growth in the New York and New Hampshire plots, which were established as recently as 1954 and 1955, respectively. Still another factor, competition, was apparently an important limiting factor in the Michigan and New York plots. Weather was also an obvious factor: snow damaged the trees of the northern plot in New Hampshire.

Gypsy-moth defoliation was apparently an important limiting factor in the Litchfield, Conn., plot.

The reasons for the slow growth of trees in the Ohio plot were less apparent. Competition from all woody vegetation was eliminated soon after establishment. Possibly encroaching herb and grass cover, or the more alkaline Ohio soil, adversely affected seedling growth.

However, perhaps the most noteworthy finding is not the differences in growth rates — from whatever causes — but the fact that all 15 plots contain some promising trees 9 to 17 years after planting.

Some pertinent questions have been raised by this study: Can satisfactory trees be selected from within a single species — the Chinese chestnut — that possess blight resistance, have good timber-tree possibilities, and yield heavy crops of nuts? Or, can superior trees that meet the above requirements be developed more readily through species hybridization? How resistant are Chinese chestnut seedlings to the chestnut-blight fungus when the trees are grown in competition with other forest-tree species? Among the many large chestnut trees that are beginning to bear in the 15 plots, will certain crosses consistently produce superior offspring? What is the relationship of growth and tree form to blight susceptibility?

Many of the trees in the 15 test plots are still too young and too small for a critical evaluation of their future forest-tree characteristics and nut-bearing capabilities. On the other hand, at least 40 hybrids and 27 Chinese chestnut trees already are showing vigorous growth, excellent forest-tree form, and apparent resistance to the blight. However, a more critical evaluation of all the hybrid trees by geneticists and tree breeders is needed.

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Literature Cited

Clapper, Russell B.
1963. A promising new forest-type chestnut tree. Jour. Forestry 61: 921-922, illus.

Diller, Jesse D.
1950. The planting and care of blight-resistant chestnuts for forest trees. U .S. Dept. Agr. Div. Forest Path. Spec. Release 15, 6 pp., illus.

Jaynes, Richard A., and Arthur H. Graves.
1963. Connecticut hybrid chestnuts and their culture. Conn. Agr. Expt. Sta. Bul. 657, 29 pp., illus.

Little, Elbert L. Jr., and Jesse D. Diller.
1964. "Clapper chestnut," a hybrid forest tree. Jour. Forestry 62: 109-110, illus.

U. S. FOREST SERVICE RESEARCH NOTE NE-26

1964

Northeastern Forest
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Experiment Station

GERMINATION, SURVIVAL, AND FIRST-YEAR GROWTH OF BLACK CHERRY UNDER VARIOUS SEEDBED AND SUPPLEMENTAL TREATMENTS

In Pennsylvania and New York there are 2,350,000 acres of plantable land that could be utilized for growing timber for future needs.[1] Much of this plantable land lies on the Allegheny Plateau — a region that is eminently suited to growing black cherry (*Prunus serotina* Ehrh.). On the Allegheny National Forest alone, 26,000 acres are classed as plantable. Besides this, the even-aged management program recently adopted on the Forest calls for clearcutting about 3,000 acres each year. Although these cut areas are expected to regenerate naturally for the most part, some of the acreage very likely will require artificial restocking.

Because black cherry is the most valuable timber tree on the Allegheny Plateau, methods for establishing this species on the plantable lands and on the clearcuttings hold particular interest. However, the planting of hardwood species has not generally been successful anywhere in the Northeast. Direct seeding of hardwoods has not been tried extensively; a few trials in the past with black cherry on the National Forest were not successful. Nevertheless, we need a reliable method for regenerating black cherry artificially; and, in terms of probable costs and general feasibility, direct seeding offers considerable promise. So a study was undertaken to determine some of the effects of seedbed and certain supplemental treatments on black cherry germination and first-year growth on an open, grassy site.

[1]United States Forest Service. TIMBER RESOURCES FOR AMERICA'S FUTURE. U. S. Forest Serv. Forest Resources Rpt. 14, 713 pp., 1958.

The Study

The study site was an old field on the Irvine Demonstration Forest near Warren, Pennsylvania. A rank cover of mixed grasses, goldenrod, and other forbs was present. The soil is a moderately well to somewhat poorly drained silt loam. The site is similar to much of the open land on the Allegheny Plateau.

Ripe seed for the study was collected September 17, 1961. It was cleaned by mashing the fruits in a potato ricer under running water. The cleaned seed was then spread to air-dry until October 5. At that time, part of the seed was sown in the fall seeding phase of the study. Another portion of the same batch of seed was stratified in sand out of doors over winter for use in the spring seeding phase. This seeding was done on April 18, 1962.

The study involved 20 treatment combinations. These were applied in a randomized block design consisting of 4 blocks of 20 plots each for each sowing season. The plots were 3 by 3 feet, and were contiguous within blocks.

The 20 treatments were combinations of 5 methods of seedbed preparation and 4 supplemental treatments. The seedbed preparations were:

1. No treatment.
2. Scarified—surface litter mixed with soil.
3. Spaded—surface litter turned under.
4. Scalped—plants and surface litter removed.
5. Burned—surface litter consumed by fire; ashes left in place.

Each plot was sown with 25 seeds at 6-by-6-inch spacing. A template was used to facilitate even spacing. Seeds were embedded flush with the soil surface on all seedbeds except the spaded ones; there they were placed about 1/4 inch deep.

The supplemental treatments were:

1. No treatment.
2. Vegetation clipped twice during the growing season at seedling height, to simulate machine mowing.
3. Fertilized with slow-acting magnesium ammonium phosphate of 8-40-0 analysis at the rate of 1 ounce per plot. In the fall seeding, the fertilizer was simply dropped through the holes of the template after the seed had been sown. In the spring seeding, the appropriate amount of fertilizer was placed in a hole punched about 3 inches deep at each seed spot before sowing.
4. Fertilized and clipped—combination of treatments 2 and 3 above.

Observations of total germination were made once each week during June and the first 2 weeks of July. Thereafter, germination was checked once every 4 weeks until leaf fall in October. The height of the tallest seedling on each plot was measured to the nearest 1/10 inch in October.

Analysis of variance was used to test differences in germination and first-year height growth. The arcsin transformation was used on germination percentages. The figures for the tallest seedling on each plot were used in the analysis of height growth. Orthogonal comparisons were made for both germination and height data. Because season of sowing was not randomized in the layout of plots, it could not be tested statistically.

Results

Germination. — Germination on all prepared seedbeds averaged 22 percent in the fall seeding and 17 percent in the spring seeding, or about 20 percent for both seasons combined. On the untreated beds, the figures for fall and spring seeding were 3.5 and 3.0 percent respectively (table 1). In the statistical analyses for each season, the four seedbed preparations combined were significantly (1-percent level) better than no preparation in both instances. There were no significant differences among the four preparation methods.

Height growth. — First-year height growth was relatively poor under all treatments, and the differences when reduced to averages were not striking (table 1). Because the table values are based upon the one

Table 1.—Average germination and first-year height growth, by treatment groups

Treatment	Fall sowing		Spring sowing	
	Germination	Height	Germination	Height
	Percent	*Inches*	*Percent*	*Inches*
Seedbed preparation:				
None	3.5	2.3	3.0	2.2
Scarified	21.0	2.4	17.7	2.3
Spaded	20.0	4.0	18.5	3.2
Scalped	25.0	3.3	16.2	2.4
Burned	21.2	2.5	16.5	2.3
Supplemental treatments:				
None	—	2.3	—	2.0
Clipped	—	2.2	—	2.0
Fertilized	—	4.4	—	2.9
Clipped and fertilized	—	3.3	—	3.3

tallest seedling in each plot, mean heights for all seedlings would have been even less than those values.

Analyses of the height data showed some significant differences among treatments in both the fall and spring seedings. All differences mentioned below were significant at the 1-percent level except where noted otherwise:

1. Growth was better on spaded plots than on scarified plots. Mean heights were 4.0 inches and 2.4 inches respectively on the fall plots, 3.2 inches and 2.3 inches on the spring plots (the latter difference was significant only at the 5-percent level).
2. Growth was better on fertilized spaded plots than on spaded plots with no fertilizer. Mean heights were 5.9 inches and 2.4 inches respectively on the fall plots, 4.6 inches and 2.2 inches on the spring plots. No growth response to fertilizer was evident on the other seedbeds.
3. Growth was better in the spring seeding on plots that were spaded, fertilized, and clipped than on similar plots that were not clipped. Mean heights were 6.2 inches and 3.0 inches respectively.

Clipping showed no significant effect on the fall-sown spaded and fertilized plots, nor on plots in any other treatment combination in either season.

Seedling survival. — The numbers of seedlings present after one and two growing seasons depended mostly upon the number that germinated. Some mortality of course occurred, but it was rather evenly distributed among treatments. Well over half of the original seedlings still survived after 2 years (table 2).

The spaded seedbeds showed a tendency toward lower survivals than seedbeds treated otherwise; and the number of seeds germinated revealed a similar pattern (table 2). Except for the check plots, survivals were highest on the scalped seedbeds and lowest on the spaded ones. At the end of the second summer, 78 and 73 percent of the seedlings were still living on scalped beds in the spring and fall seedings, respectively, compared to 51 and 52 percent on the spaded beds.

Discussion

The poor seedling establishment on the study plots is believed to be due to a combination of seed losses to rodents and poor germination caused by not covering the seed enough to prevent drying. A few seeds that became so dry that they returned to dormancy were missed by the rodents and then germinated the second spring. Other seedings and

Table 2.—Percentage of germination and survival, based on number of seeds sown, by seedbed treatments and season for each sowing

Treatment	Germination		Survival			
			Spring sowing		Fall sowing	
	Spring sowing	Fall sowing	1st season	2nd season	1st season	2nd season
None	3.0	3.5	2.0	2.0	3.0	1.2
Scarify	17.7	21.0	13.5	11.0	16.5	12.2
Spade	18.5	20.0	11.0	9.5	14.0	10.5
Scalp	16.2	25.0	13.5	12.5	22.5	18.2
Burn	16.5	21.2	11.5	6.8	18.8	16.0
All plots	14.4	18.2	10.3	8.4	15.0	11.6

sand-flat tests with portions of the same batch of seed demonstrated that the seed was good: germinations as high as 73 percent were obtained.

The poorer germination in the untreated plots, as compared to all treated plots, is believed to have been due mainly to drying of the seed. Even though the seeds were pressed into contact with the litter or living plant crowns on the soil surface, this loose material probably allowed the seeds to dry excessively.

Height growth of the seedlings obviously was poor. Competition from the grass and associated broadleaf plants undoubtedly was an important limiting factor. This effect of competition was strikingly demonstrated on some extra seedbeds that were hand-weeded throughout the growing season. These beds, which adjoined the study plots and were seeded at the same time, produced cherry seedlings up to 32 inches tall the first summer without fertilizing or any other treatment.

The response of black cherry to weeding was similar to that reported for hybrid poplars by Schreiner.[2] He found hybrid poplars to be particularly susceptible to the inhibiting effect of grass and other weeds: trees could not be successfully established on old fields without eliminating the sod and weeding for at least 1 year. Experimental evidence indicated that the inhibiting effect of grass on hybrid poplars involves something more than mere competition for moisture and nutrients.

[2]Schreiner, Ernst J. Variation Between Two Hybrid Poplars in Susceptibility to the Inhibiting Effect of Grass and Weeds. Jour. Forestry 43: 669-672, 1945.

The herbaceous species on our study plots recovered quickly in all treatments. The first-year recovery was somewhat less on the scalped plots where roots, stolons, and seeds in the surface layer of soil were physically removed, but it was not enough less to noticeably affect growth of the cherry seedlings. The clipping and fertilizing treatments definitely did not provide the essential conditions for good seedling growth.

It appears that drastic reduction and continued suppression of the herbaceous competition for at least 1 year—and perhaps longer—are required. Repeated cultivation is one proven way of accomplishing this. However, the necessary weed control might also be achieved with herbicides; and this possibility is being explored in current studies.

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U. S. FOREST SERVICE RESEARCH NOTE NE-27

1965

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Experiment Station

WHITE PINE PRUNING AND BRANCH GROWTH

A better understanding of the growth responses of young trees to silvicultural treatments is essential for intensive management programs for juvenile stands. At the juvenile stage, the effect of silvicultural treatment on main-stem development is much greater than it would be later.

In a study conducted on the Massabesic Experimental Forest, it was learned that the growth rate of residual branches of young white pine (*Pinus strobus* L.) was not affected by pruning intensity. It was also found that, when main-stem growth rate had recovered after pruning, the cross-sectional area of branches per unit of main-stem volume still was smaller than on unpruned trees.

Barrett and Downs[1] showed how growth rate of white pine stems is affected by pruning intensity. They found that growth was reduced in proportion to the severity of the pruning, but that the growth reductions were temporary. Our study provides some of the details of the recovery process.

The Study

The study was begun in 1959 to determine how pruning influences residual branch growth. At that time a natural 12-year-old stand of white pine was thinned to spacings of either 6 or 12 feet. Twenty-seven trees averaging 9 feet tall and 1.1 inches in diameter at breast height were selected at each spacing. They were listed in order of branch area

[1]Barrett, Leonard I., and Albert A. Downs. GROWTH RESPONSE OF WHITE PINE IN THE SOUTHERN APPALACHIANS TO GREEN PRUNING. Jour. Forestry 41: 507-510, 1943.

per foot of height. Branch area is the total cross-sectional area of branches, in square inches, as measured about 1 inch from the main stem of the tree. The 27 trees in each spacing were then divided into 9 groups of 3, and the 3 trees in each group were randomly assigned among 3 pruning intensities: removal of none, one-third, or two-thirds of the branch area.

However, upon re-measurement after pruning, the pruned trees were found to fall into 3 rather distinct intensity classes in which approximately 40, 55, or 70 percent of the branch area had been removed. This happened because entire whorls of branches were either cut or left; hence some trees in the original lighter category lost more branches, and some trees in the more severe category lost fewer branches, than had been specified. These trees together made up an intermediate group in which the branch area actually removed was about 55 percent. The regrouping provided 6 trees pruned at each of the above intensities, plus 9 unpruned controls, at each spacing. The 40-, 55-, and 70-percent intensities were designated as light, moderate, and severe pruning, respectively.

Two average-size branches on each tree were selected for measurements of length and diameter. These branches were in the lowest remaining whorl on the trees originally scheduled for removal of two-thirds of the branch area. On other trees the selected branches were in the whorl that occupied a comparable position. These branches were numbered, and each was marked at the diameter measurement point.

The length and diameter of these average branches were measured in 1959, 1960, 1961, and 1962. Diameters of all other branches were measured at the same time. Main-stem diameters were also measured: at the center of the internode nearest stump height, at 3 feet above ground level, then at 4-foot intervals, and at midpoint of the shorter top section. Main-stem volume was determined from these measurements.

Results

Branch growth. — Analyses of variance were made, comparing growth in length and diameter of the selected branches of the 6 pruned trees in each pruning-intensity group with branch growth of the 9 unpruned trees in the same spacing class. No significant differences in growth of residual branches over the 3-year period were attributable to pruning. However, growth of the selected branches was somewhat greater on trees growing at the wider spacing (table 1).

Main-stem growth. — Growth rates in 1960 were reduced by pruning, roughly in accord with the amount of branch area removed. By 1962,

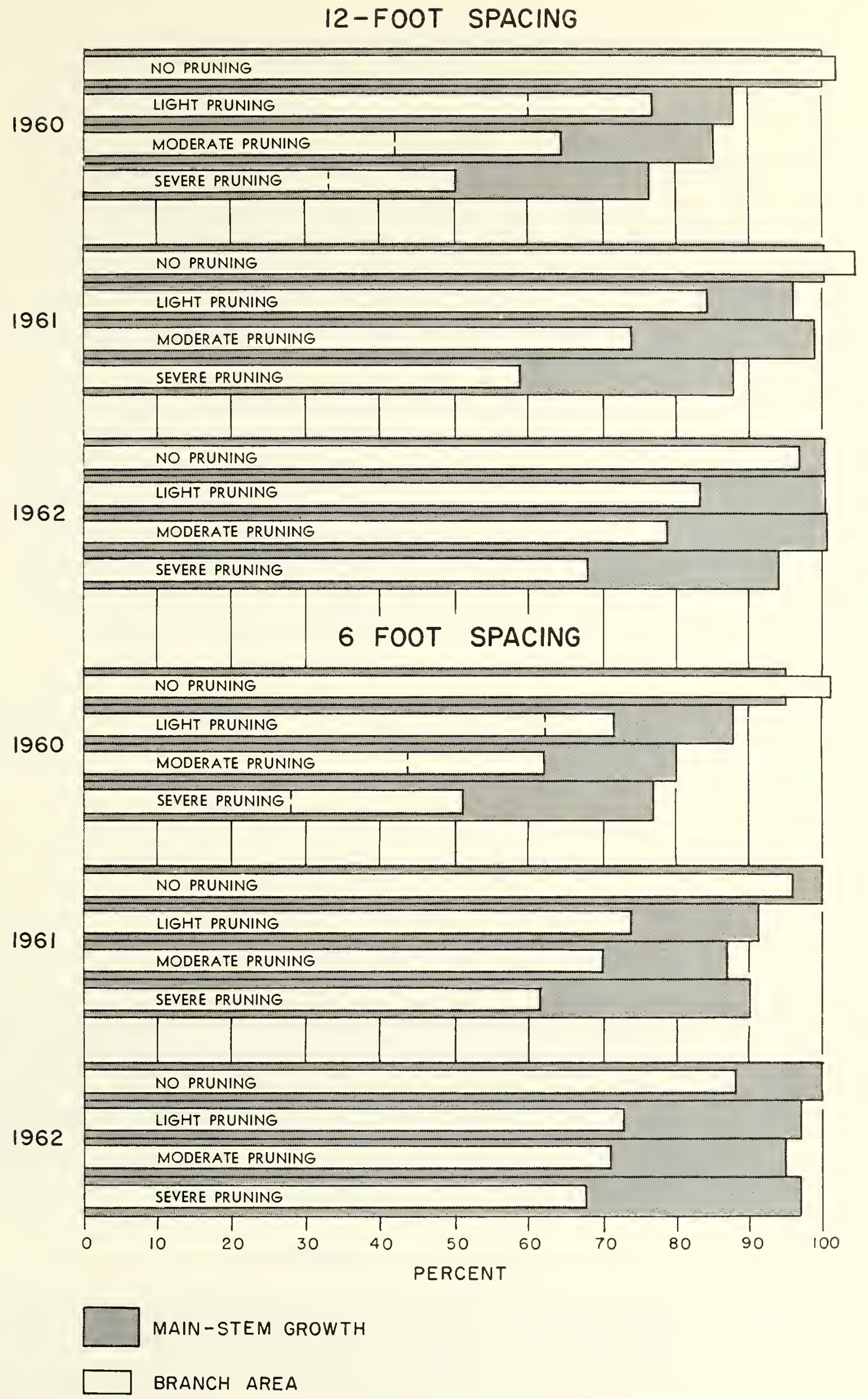

Figure 1. — Relative main-stem growth and branch area per 100 cubic inches of main-stem volume, by treatments and years. Unpruned trees at 12-foot spacing provide the standards for comparison in each year's data. Main-stem growth of these trees is assigned a value of 100 percent. Branch area/stem volume ratios are expressed in percent of the curved values shown in figure 3; hence the bars for the unpruned trees at 12-foot spacing do not read exactly 100 percent. Broken horizontal lines in the 1960 bars show values immediately after pruning in 1959.

Table 1. — Growth of selected branches

Pruning intensity[1]	Spacing	Average length 1959	Average length 1962	Growth	Average cross-sectional area 1959	Average cross-sectional area 1962	Growth
	Ft.	*In.*	*In.*	*In.*	*Sq. in.*	*Sq. in.*	*Sq. in.*
Unpruned	6	27	52	25	0.15	0.44	0.29
	12	28	59	31	.17	.52	.35
Light	6	31	56	25	.21	.44	.23
	12	29	56	27	.20	.53	.33
Moderate	6	28	52	24	.16	.41	.25
	12	27	50	23	.17	.53	.36
Severe	6	24	46	22	.14	.40	.26
	12	30	55	25	.23	.69	.46

[1]Light, moderate, and severe pruning represent removal of approximately 40, 55, and 70 percent of the branch area, respectively.

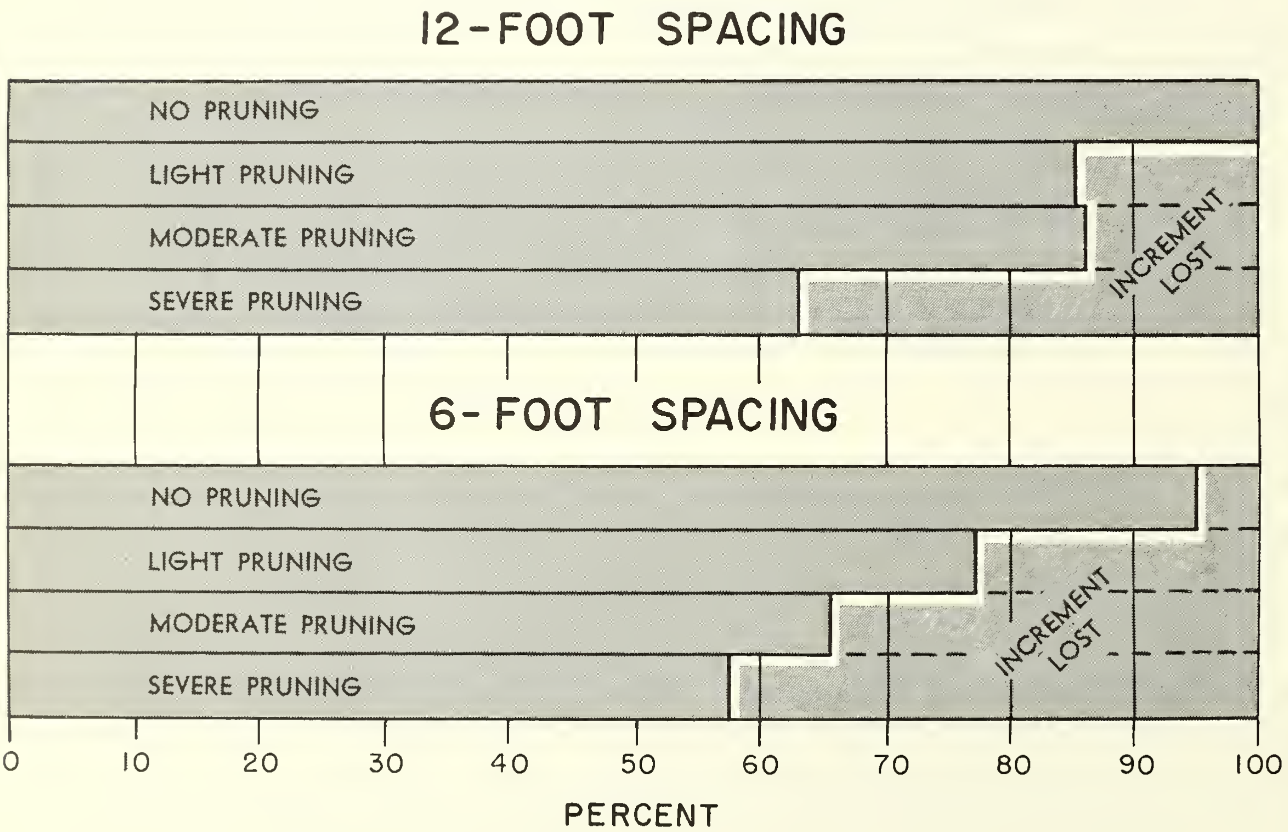

Figure 2. — Relative main-stem volumes and loss of increment at the end of 3 years. Unpruned trees at 12-foot spacing are assigned a value of 100 percent as the standard for comparison.

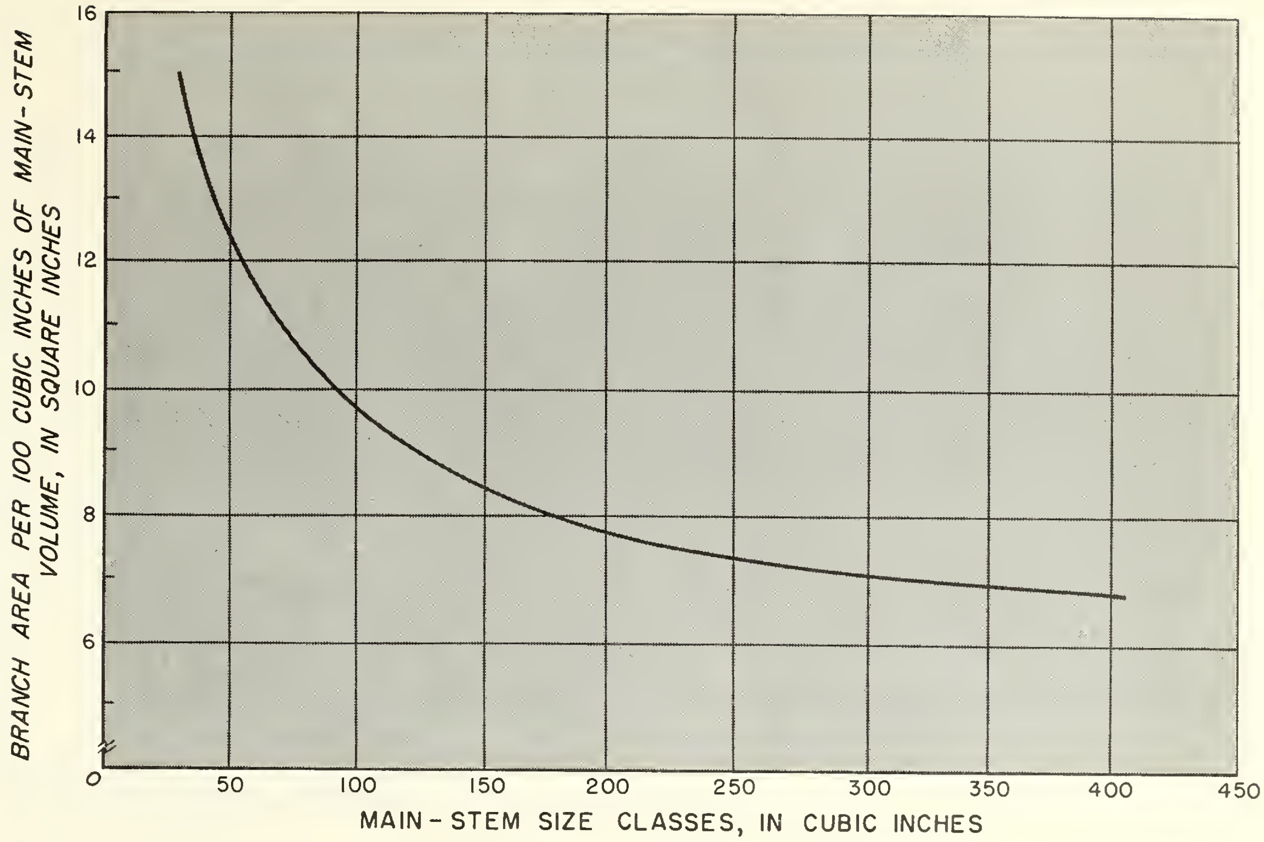

Figure 3. — Square inches of branch area per 100 cubic inches of main-stem volume, by size classes of unpruned trees growing at 12-foot spacing.

growth rates had recovered or almost recovered to the level shown by unpruned trees at 12-foot spacing; the groups that had not made complete recovery fell only slightly short of it (fig. 1). However, the data for 1961 indicate a generally slower rate of recovery among trees at the 6-foot than at the 12-foot spacing.

Although growth rates had practically recovered by 1962, a net loss in volume had resulted from the pruning, and this loss was greater at the closer spacing (fig. 2). The losses ranged from 14 to 37 percent over the 3-year period. The bar-graph data in figure 2 are based on the 3-year volume increases per unit of volume present in 1959. For unpruned trees at 12-foot spacing, which provided the base for comparison, there were 4.5 cubic inches of main-stem volume in 1962 for each cubic inch in 1959. If, for example, the lightly pruned trees at 6-foot spacing had increased at the same rate, they would have grown from 82 cubic inches in 1959 to 369 cubic inches in 1962. But they grew to only 286 cubic inches, or 78 percent of 369; hence the loss in potential volume was 22 percent.

Branch area and main-stem volume relationship. — For individual unpruned trees growing at 12-foot spacing, each year's branch-area value per 100 cubic inches of main-stem volume was plotted over total main-stem volume. The resulting curve (fig. 3) showed a consistent relationship between main-stem volume and branch area per unit volume.

By considering these curved values as normal branch area per unit of main-stem volume, it is found that main-stem growth rate recovers while branch area is still only 70 or 80 percent of normal (fig. 1). The inference can be drawn that some portion of the branch area of unpruned trees is contributing little or nothing to main-stem growth.

The balance between amount of crown and volume of main-stem characteristic of unpruned trees is, of course, altered by pruning. Since branch growth rate after pruning remains essentially unchanged while main-stem growth rate is reduced, the growth trend in trees after pruning is toward re-establishment of the original balance between crown and stem. However, that balance is not fully regained.

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U. S. FOREST SERVICE RESEARCH NOTE NE-28

1965

Northeastern Forest

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Experiment Station

LOW AVERAGE BLISTER-RUST INFECTION RATES MAY MEAN HIGH CONTROL COSTS

The Northeastern Forest Experiment Station, in cooperation with Federal and State forest-pest-control agencies, undertook a survey of blister-rust infection rates in the white pine region of the East during 1962 and 1963. Those engaged in blister-rust-control activities will not be surprised at the survey's results. We found that infection rates were significantly higher in high-hazard climatic zones than elsewhere. Hazard maps prepared by Charlton (1963) were used as the basis for delineating climatic hazard zones.

Control efforts also influence the rate of infection; and our survey showed that infection rates were uniformly low, regardless of climatic hazard, for some years after a control treatment. In addition, there was some evidence that infection rates tend to decline from north to south within hazard zones. The average rate of infection estimated for the East as a whole was about one-half the average rate reported for the Lake States.

However, the average infection rate for an area or a group of stands is only part of the story. More important for control activities is the frequency of serious injury. Most pine stands can absorb modest numbers of blister-rust fatalities without serious reduction of eventual yields. Control efforts are aimed at stands where infection is more serious. Our survey showed that, in groups of stands with low average infection rates, only 1 stand in 100 may now be experiencing serious blister-rust losses, while almost half of the stands in groups with high average infection rates may suffer serious losses.

Where average infection rates are low, then, control personnel must examine a large number of areas to find one that needs control. Since finding stands that need control is part of the cost of control, it would seem that control could be very expensive indeed in areas of generally low hazard. In response to this situation, blister-rust-control organizations drop from their control programs pine areas subject to little infection; and surveillance procedures on the remaining pine acreage are tailored to hazard conditions so that surveillance is most intensive where the chance of significant damage is greatest.

Survey Sampling and Analysis

Some 279 blister-rust-control areas[1] were chosen for examination throughout the thirteen Eastern States. This sample was distributed among the various states as shown in table 1. Within each state, control areas to be sampled were chosen at random from lists of all control areas regardless of their control history, current control status, or climatic environment. Only areas with a history of Ribes eradication were sampled in North Carolina, Tennessee, and Georgia.

Each sample area was subsampled to establish its infection rate by examining 200 saplings and/or pole-size pines, 100 located along each of two parallel lines transecting the area. Randomly distributed 10-tree clusters were used in most sample areas in New York, and 100-tree clusters were used in North Carolina, Tennessee, and Georgia. A count was kept of the sample trees that had contracted a fatal blister-rust infection during a 5-year sample period, 1952-56. In addition, information was obtained on sample area location and size, and on control history in most cases.

Five of the 279 sample areas were discarded because infection counts were incomplete. Forty-two others, many of them in Virginia, had never had a Ribes population nor any infection; so they were discarded. The remaining 232 areas, all with a history of Ribes eradication, were grouped by hazard zone and by 2 classes of control-treatment history (table 2).

Areas from the low- and medium-hazard zones were considered together, because preliminary analysis showed that infection rates were very similar for these two hazard zones. A north-south breakdown was made of each hazard zone, corresponding to Forest Service Region 8

[1]The cooperative blister-rust control program has resulted, over the years, in a comprehensive mapping of white pine stands throughout the range of the species. The total forest area stocked with pine is subdivided into work areas, variously called road blocks, grids, or control areas, to facilitate control operations. These are referred to here as control areas.

and the northern and southern zones of Forest Service Region 7. The states making up each of these three geographic areas are shown in table 1.

Two simple classes of control-treatment history were recognized as a further breakdown. Sample areas that had received no examination or treatment for 10 years before the sample period (1952-56), nor during the first 3 years of the sample period, were separated from blocks that had received some sort of examination or control treatment between 1942 and 1954. Treatment history was not available for a few areas, so some sample areas are not included in this breakdown.

Table 1. — *Distribution of blister rust sample blocks, by states*[1]

State	Total pine acreage	Areas sampled	Pines examined
	Acres	*No.*	*No.*
FOREST SERVICE REGION 7			
Northern Zone:			
Maine	983,136	48	9,600
New Hampshire	1,313,909	63	12,600
Vermont	174,039	9	1,800
Massachusetts	579,987	29	5,800
New York	695,024	22	4,400
Connecticut	109,761	5	1,000
Rhode Island	64,018	0	0
Total	3,919,874	176	35,200
Southern Zone:			
Pennsylvania	106,725	5	1,000
New Jersey	3,771	0	0
Delaware	242	0	0
Maryland	74,079	4	800
Virginia	800,492	40	8,000
West Virginia	340,127	17	3,400
Kentucky	48,179	0	0
Total	1,373,615	66	13,200
FOREST SERVICE REGION 8			
North Carolina	736,880	22	4,400
South Carolina	64,192	0	0
Tennessee	770,118	12	2,400
Georgia	544,478	3	600
Total	2,115,668	37	7,400
Total, all states	7,409,157	279	55,800

[1]Only states with significant acreages of white pine are listed.

Table 2.—*Number of control areas sampled and average rates of fatal blister-rust infection for the 5-year period 1952-56, by climatic hazard zone, geographic location, and treatment history*

Item	All sample areas	Discarded areas	Areas with a history of Ribes eradication[1]					
			Retained areas	Trees infected	Areas treated, 1942-54	Trees infected	Areas not treated	Trees infected
	No.	*No.*	*No.*	*%*	*No.*	*%*	*No.*	*%*
High-hazard areas	134	27	107	1.5	67	1.0	28	2.7
R-7 northern zone	60	1	59	1.5	39	.8	8	5.9
R-7 southern zone	55	26	29	2.4	19	2.1	10	2.8
R-8	19	0	19	.0	9	.0	10	.1
Low and medium-hazard areas	145	20	125	.7	72	.5	43	.9
R-7 northern zone	116	11	105	.8	59	.6	36	1.1
R-7 southern zone	11	8	3	.0	1	.0	2	.0
R-8	18	1	17	.0	12	.0	5	.0
All areas	279	47	232	1.1	139	0.8	71	1.6

[1]Exact treatment history was not determined for some sample areas, so the numbers of areas listed under each treatment history classification do not total, in some cases, to the number shown under "All retained areas."

Results

Table 2 shows the average rates of infection found for various groupings of control areas. The number of sample areas upon which each infection-rate estimate is based is also shown. Medium- and low-hazard conditions for the southern zone of Region 7 are not well represented in this sample. The other control-area groups are adequately represented.

The average 5-year rate of fatal blister-rust infection among all sample areas with a history of Ribes eradication was 1.1 percent, which is somewhat less than one-half the average rate found by King (1958) for the Lake States. However, rust infection is not generally or evenly distributed in all pine stands, but is highly localized. About two-thirds of the sample areas, although they had a history of Ribes eradication, had no fatal infections on sample trees dating from the 5-year sample period. And 50 percent of the trees found to have fatal infections were concentrated on 12 of the 232 sample areas—half the injury was on 5 percent of the area.

Control areas in the medium- and low-hazard zones did not have high average rates of infection, nor did control areas in the high-hazard zone that had received an inspection or treatment within 10 years of the sample period (table 2). These groups had average 5-year infection rates of 1 percent or less, with the exception of recently treated high-hazard areas in the southern zone of Region 7.

Interpretation

From these survey results, idealized estimates of the incidence of blister-rust infection were made (table 3). Three control-area categories, defined by hazard zone and treatment history, are suggested, along with the average rate of fatal infection to be expected for areas in each category.

However, average infection rate is not a very meaningful statistic, because few control areas will actually experience this average rate. Rather, some areas in any category will remain free of injury for 5 years, while others will be heavily infected. Table 3 also shows the proportion of control areas in each category that can be expected to have infection rates higher than 2½ percent during the 5-year period, based on the survey data. Only 1 out of 100 category-1 areas will develop serious rates of infection during the next 5 years. But 10 percent of category-2 areas, and 45 percent of category-3 areas, are likely to be seriously injured by blister rust in the immediate future.

This means that a large number of areas that do not need treatment have to be examined in order to find a category-1 area that does need treatment. It takes a large investment in examination to locate areas needing control in this category. For this reason, control is much more expensive for category-1 areas than for areas in other categories. The same, of course, is true of category-2 areas as compared to areas in category 3.

Table 3. — *Idealized estimates of blister-rust incidence*

Control area category	Average 5-year infection rate anticipated	Proportion of areas that are expected to have rate in excess of 2½%
	%	%
1. Areas without a Ribes population or where no infection has been noted for two or more consecutive examinations.	([1])	1
2. Areas in Region 8; in low- and medium-hazard zones of Region 7, or in the Region 7 high-hazard zone if they have been treated in the last decade.	1	10
3. Areas in the high-hazard zone of Region 7 that have not received treatment during the last decade and where Ribes are known to occur.	4	45

[1]Close to zero.

Looked at in this way, hazard zone-treatment history categories are useful primarily in indicating the likelihood of encountering control areas that will require Ribes-eradication treatment, rather than in indicating the rates of infection to which these areas will be subject.

Using This Information

The Northeastern Forest Experiment Station, in cooperation with others, has undertaken a series of research studies to provide economic evaluations of various silvicultural and protection activities in eastern white pine. On the protection side, an analysis of white-pine weevil control has been completed (Marty and Mott 1964) and a similar study dealing with blister-rust control is now under way.

Blister-rust control has been carried on for many years in the East by state pest-control agencies in cooperation with the U. S. Forest Service. As a part of its technical contribution to this cooperative program, the Forest Service plans to develop and make available improved control standards or guides—guides that will help to identify those areas of pine that promise adequate financial returns for blister-rust-control expenditures. The information developed by this infection-rate survey will contribute directly to formulating these guides.

Literature Cited

Charlton, John W.
1963. Relating climate to eastern white pine blister rust infection hazard. U. S. Forest Service Eastern Region, Upper Darby, Pa. 38 pp., illus.

King, D. B.
1958. Incidence of white pine blister rust infection in the lake states. U. S. Forest Service Lake States Forest Expt. Sta., Sta. Paper 64, 12 pp., illus.

Marty, Robert, and D. Gordon Mott.
1964. Evaluating and scheduling white pine weevil control in the Northeast. U. S. Forest Serv. Res. Paper NE-19, 56 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

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U. S. FOREST SERVICE RESEARCH NOTE NE-29

1965

Northeastern Forest
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Experiment Station

ACCURACY IN STREAMFLOW MEASUREMENTS ON THE FERNOW EXPERIMENTAL FOREST

Measurement of streamflow from small watersheds on the Fernow Experimental Forest at Parsons, West Virginia was begun in 1951. Stream-gaging stations are now being operated on 9 watersheds ranging from 29 to 96 acres in size; and 91 watershed-years of record have been collected. To determine how accurately streamflow is being measured at these stations, several of the important factors that influence the accuracy of the records have been studied.

The factors studied were grouped into the following four categories: (1) stream-gaging instrumentation, (2) stage-discharge relation, (3) manual checking of stage, and (4) compilation of data.

Stream-Gaging Instrumentation

The gaging stations on the Fernow Forest are sharp-crested 120° V-notch weirs with either FW-1 or A-35 water-level recorders. Accurate measurement with the 120° V-notch weir requires that: (1) the weir blade be sharp, smooth, and clean; (2) the upstream face of the cutoff wall be vertical and as smooth as possible; (3) the nappe, to be fully aerated, should touch only the upstream edges of the weir blade; and (4) the velocity of approach should be less than 0.5 foot per second (King 1954 and Thomas 1957).

To satisfy these conditions, care in construction and periodic maintenance are required. On the Fernow Forest, the weir blades are frequently checked for irregularities and rust damage, and repairs are made when needed. To ensure proper aeration of the nappe, the cutoff walls have been shaped so that the water falls freely below the notch, leaving an air space under the waterfall. Weir basins have been constructed with sufficient width, length, and depth to slow velocity of approach. Silt and debris accumulations in the weir basin are removed at least annually. Checks of velocity of approach made in the weir basins with a pygmy current meter have shown that the velocity was usually below the 0.1 foot per second starting velocity of the meter or well below the recommended maximum velocity of approach of 0.5 foot per second.

Stage-Discharge Relation

A rating table showing quantity of flow for stages up to 2.0 feet has been prepared for each of the Fernow weirs. The rating is based on the formula $Q = 4.43H^{2.449}$ (Q is the discharge in cubic feet per second and H is stage in feet) as determined by Hertzler (1938). According to Thomas (1957) there is general agreement among experimenters that stages of less than 0.20 foot will not produce reliable results when the usual discharge formulas are used. This is due in part to the tendency of the nappe to adhere to the weir blade at low stages. Accordingly, the Fernow rating tables were volumetrically checked at low stages and necessary adjustments were made. The maximum stage for rating-table adjustment for any single weir was 0.58 foot, and several weirs required adjustments for stages up to 0.25 foot. For two of the nine weirs in operation, checks indicated that the formula could be used without adjustment.

The procedure for adjusting the rating tables was to compare the averages of series of volumetric check measurements at given stage heights with the standard formula values. If appreciable differences (more than 5 percent) did not occur between the two sets of values, the standard value was used. For weirs in which appreciable differences occurred, the rating tables were adjusted up to the stage where the adjusted rating closely approached the standard rating, by picking discharge values from a curve fitted to the check points (fig. 1).

Adjusting the rating curve naturally improves the accuracy of streamflow records. However, sources of error still exist: (1) the plotted points are affected by both sampling and measurement error; and (2) the smoothed portion of the curve from which the adjusted rating table values are taken is fitted free-hand between the averages of series of volumetric check points. Thus some of the average check points are above or below the curve, causing a small error in the adjusted values at these points.

As an example of the error introduced by sampling and measurement,

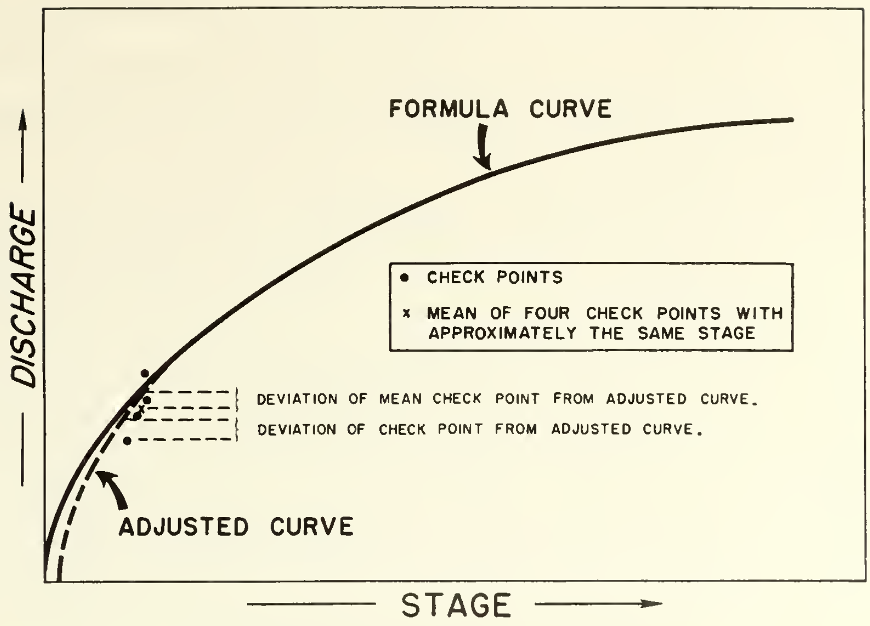

Figure 1. — Schematic drawing of the standard or formula rating curve, the adjusted curve, plotted check points, and mean check points.

the mean of 6 check measurements made at Fernow weir 8 while the stage was 0.207 feet was 0.0854 c.f.s.; the standard deviation was 0.0010 c.f.s. and the standard error of the mean was 0.0004 c.f.s. If the actual or true discharge for this stage is 0.0010 c.f.s. (one standard deviation) higher or lower than the mean of the check measurement, it would make a difference of 1.2 percent or 86 cubic feet of water per day. The necessity of rating a weir is brought out by the fact that discharge for the stage of 0.207 (using Hertzler's formula) is 0.0936 c.f.s., which is 9.6 percent or 906 cubic feet per day higher than the mean of the check measurements.

There is no really good method for determining the error introduced when fitting the adjusted portion of the rating curve to the volumetric check points. About the best that can be done is to compare the deviation of the check points and the adjusted curve values in use, realizing that this is biased because in most instances the curve was based on the check points. A comparison of this type for Fernow weir 8, which required an adjustment in the rating curve up to a stage of 0.58 foot, showed that adjusted-curve values ranged from 99.5 to 105.9 percent of the check points, with most of the values being close to 100 percent. The adjusted values ended up slightly on the standard-curve side of the check points because of the conservative approach used in adjusting; that is, care was used not to overadjust. Since the deviations between check points and adjusted values occur at low stages, they do not represent large differences in streamflow totals. A test of the effect of deviations between volumetric-check values and adjusted-curve values upon streamflow totals for watershed 8 showed that annual streamflow, using the adjusted-curve values, was 0.13 area-inches higher or 100.3 percent of the total obtained when using check-point values.

Thus it appears that errors in streamflow totals due to deviations in check points and adjusted-rating-table values can safely be estimated at less than 0.5 percent. Deviations between check points and true discharge caused by sampling and measurement error are also estimated to cause less than 0.5 percent error in streamflow totals. Each of the above-mentioned errors is cumulative in nature (although they may partially compensate each other), and it is important that they be kept as small as possible.

Manual Check of Stage

On the Fernow Forest, the continuous-discharge measurements made with the water-level recorders are checked manually, usually weekly, using a hook gage mounted on a metal reference bar over the weir basin. If the hook-gage reading and chart stage differ by more than 0.003 foot, the recorder is adjusted and the previous week's chart is corrected.

Sources of error that must be guarded against to insure accurate hook-gage readings include improper location of the reference bar, changes in reference-bar heights, malfunction of the hook gage, rough water or wave action, and human error in reading the gage.

Location of the reference bar should be far enough upstream to prevent any effect of surface contraction caused by the water falling over the weir blade. This does not present any problem on the Fernow, as all reference bars are located at least 2.5 times the depth of the notch upstream from the cutoff wall, as recommended by King (1954).

There has been some slight change in height of the reference bars at several of the weirs since installation. Periodic checks of the correction factor (differences between bottom of V-notch and zero reading on hook gages) have shown these changes to be gradual and, for any one weir, in one direction. Since the changes are small (usually less than 0.002 feet per year) streamflow records for the period before checking are not corrected, causing the records to be in error by a small amount (in the general magnitude of 0.001 foot). Tests with the Fernow data have shown that a correction factor in error by 0.002 foot causes annual streamflow to be in error by approximately 1 percent.

Human error in reading the hook gage must also be considered. At present the weekly checks on the water-level recorder are based on one hook-gage reading unless the need for a check reading is indicated by an appreciable difference between the hook-gage reading and the recorder pen trace. For the most part, human errors are compensating as opposed to previously discussed errors, which have been cumulative.

Generally the manual checking of stage would seem to cause less than a 1 percent error in streamflow totals, most of which is due to changing reference-bar heights.

Compilation of Data

Compilation of data is a broad term that includes all operations from marking and tabulation of charts to the computation of discharge totals. These operations are fully described in Proceedings of the Watershed Management Research Conference, (Northeastern Forest Experiment Station 1962).

Factors that affect data compilation include both human errors and errors inherent in the methods being used. Human errors are most likely to occur in those operations that require estimating (for example, picking the mean water level for a segment of the hydrograph). However, the differences between the estimated and actual values are usually small and, being compensating, do not amount to significant values. Actual mistakes in compilation are more difficult to evaluate: a good checking system helps to keep mistakes at a minimum.

Most of the errors in method are confined to the conversion of stage readings to discharge. The point-picking method used on the Fernow involves determining the mean stage for a selected time interval and calculating the discharge from the mean stage. The error involved in this procedure is due to the fact that the mean stage does not correspond exactly to the average discharge of the interval. This is a cumulative error (indicating less discharge than actually occurs); and its magnitude depends upon the stage changes within the time interval concerned. At present the permissible-rise table designed to keep errors in the mean discharge at less than 2 percent is being used. A study of the Fernow data has shown that, on the average, only 39 percent of the permissible rise is used, which would mean that the error due to this source is considerably less than 2 percent, and may safely be estimated to be 1 percent or less.

Many of the procedures used in the compilation of Fernow streamflow data have been added to increase accuracy. These include correcting the pen trace for (1) debris and ice in the V-notch, (2) chart expansion, (3) time, and (4) gage-height errors; and checking each of the various procedures. Also, gage heights are read from the chart to the nearest

Table 1. — Area-inch streamflow values for Fernow watershed 7, water-year 1959-60, eliminating various correction operations or using modifications of present compilation procedures

(In area-inches)

Period	Actual values using present methods	No corrections made for —					Totals with elimination of checking of compilations	Totals if gage height read to nearest 0.005 foot
		Time errors	Gage-height errors	Debris and ice errors	Chart expansion	Anything		
Growing season (May - Oct.)	4.245	4.245	4.274	4.357	4.241	4.398	4.295	4.254
Dormant season (Nov. - Apr.)	25.264	25.264	25.356	25.503	25.069	25.495	25.107	25.239
Annual	29.509	29.509	29.630	29.860	29.310	29.893	29.402	29.493
ACTUAL VALUE MINUS OTHER VALUES (DIFFERENCES)								
Growing season	....	0	+0.029	+0.112	−0.004	+0.153	+0.050	+0.009
Dormant season	....	0	+0.092	+0.239	−0.195	+0.231	−0.157	−0.025
Annual	....	0	+0.121	+0.351	−0.199	+0.384	−0.107	−0.016

0.001 foot. Table 1 shows the effects of eliminating pen-trace corrections on annual and seasonal streamflow totals for watershed 7. Errors in time that are caused by improper recorder operation or mistakes in setting the pen did not change the streamflow totals when they were corrected. Corrections for gage-height errors and for debris or ice in the V-notch amounted to 0.121 and 0.351 area-inch respectively for the water-year (out of an annual runoff of 29.509 area-inches). Elimination of chart-expansion corrections caused the annual total to be in error by 0.199 area-inch.

On the Fernow, each step in the compilation of data is checked, most often by someone other than the person doing the original work. The elimination of checking procedures on watershed 7, as shown in table 1, would have caused the annual streamflow to be in error by about 1/10 area-inch. Most of the errors were found during the dormant season, when streamflow is most variable. Table 1 also shows the results of reading gage heights to the nearest 0.005 foot instead of the present method of 0.001 foot. As might be expected, changes in streamflow totals were small.

Generally the amounts of streamflow involved in the various correction and checking operations and in reading the gage height to the nearest 0.001 foot are small. However, the corrections can amount to large percentages during periods of very low stage, when a small absolute difference in flow represents a high percentage of total flow. Since many of the Fernow results are dependent on daily flow values, most of these procedures that provide additional accuracy are necessary.

Conclusions

A summary of the estimates of percentage error in annual streamflow values caused by the various factors studied in this report is as follows:

Source of error	*Estimate of percentage error in annual streamflow values*
1. Deviation of mean check points from true values plus deviation of adjusted curve from mean check points	1.0
2. Error in manual check of stage	1.0
3. Errors in methods used in compilation of data	1.0
Total of estimate from various sources	3.0

It is realized that the total of 3.0 percent is a rough estimate and that it cannot, on the basis of the data given, be stated that annual Fernow streamflow measurements are within 3 percent of being correct. The estimates have been assigned maximum values, and in most cases the total error due to these sources is probably something less. Also the above errors may compensate for each other. On the other hand, additional sources of error, which have not been evaluated, may add to the estimated percentages. To be on the safe side it might be concluded that Fernow streamflow values are in error in the neighborhood of not more than 3 to 5 percent.

The total estimate of error in stream discharge affects the determination of results of watershed treatments. The errors in measurement, together with the lack of perfect natural correlation between watersheds when the control-watershed approach is used, cause errors of estimate in prediction equations. Following treatment, the magnitude of change in discharge that is needed to establish statistical significance increases with the magnitude of the error of estimate.

Literature Cited

Hertzler, R. A.
1938. Determination of a Formula for the 120-Degree V-Notch Weir. Civil Engin. 8: 756-757, illus.

King, H. W.
1954. Handbook of Hydraulics. Ed. 4, 563 pp., illus. McGraw-Hill, New York.

Northeastern Forest Experiment Station.
1962. Proceedings, Watershed Management Research Conference on Collection and Compilation of Streamflow Records. U. S. Forest Serv. Northeast. Forest Expt. Sta. 55 pp. Laconia, N. H.

Thomas, Charles W.
1957. Common Errors in Measurement of Irrigation Water. Amer. Soc. Civil Engin. Proc. Paper 1362. 23 pp.

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U. S. FOREST SERVICE RESEARCH NOTE NE-30

1965

Northeastern Forest
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SPECIES COMPOSITION CHANGES UNDER INDIVIDUAL TREE SELECTION CUTTING IN COVE HARDWOODS

In the past, uncontrolled clearcutting on many of the good to excellent hardwood sites[1] in the Appalachians has resulted in forest stands composed of the so-called cove hardwoods, a high proportion of which are intolerant species. Characteristically these stands run heavily to yellow-poplar (*Liriodendron tulipifera* L.), northern red oak (*Quercus rubra* L.), black cherry (*Prunus serotina* Ehrh.), basswood (*Tilia americana* L. and *T. heterophylla* Vent.), white ash, (*Fraxinus americana* L.), and sugar maple (*Acer saccharum* Marsh.); and the first three species generally make up more than half the stems in the overstory. Other trees commonly found in the mixture are red maple (*A. rubrum* L.), beech (*Fagus grandifolia* Ehrh.), sweet birch (*Betula lenta* L.), white oak (*Q. alba* L.), chestnut oak (*Q. prinus* L.), hickory (*Carya* spp. Nutt.), and cucumbertree (*Magnolia acuminata* L.).

In recent years large areas of cove hardwoods have been placed under some type of forest management. In many cases the system used consists of frequent light cuttings based on individual tree selection. It would appear that such cuttings would eventually convert the stands to an all-aged condition. This raises the question: What will be the long-range effect on species composition?

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[1] Site indexes 70 and upwards for oak according to Schnur, G. Luther. YIELD, STAND AND VOLUME TABLES FOR EVEN-AGED UPLAND OAK FORESTS. U. S. Dept. Agr. Tech. Bul. 560, 88 pp., illus., 1937.

Work done on our Fernow Experimental Forest near Parsons, West Virginia, points up two obvious trends: (1) the proportion of sugar maple will increase appreciably and consistently; and (2) the proportion of yellow-poplar, red oak, and black cherry will probably decrease to a point where these species are no more than minor components of the stands. The observations and experience upon which the above statements are based are discussed below.

Selection Cuttings on the Fernow

For 10 years — 15 years in two instances — tree selection has been practiced in hardwood stands on good sites on the Experimental Forest. Cutting cycles of 5 to 20 years are being followed. On some of the study areas two selection cuts have already been made. All together, the study covers 11 cutting areas totaling 211 acres. The record begins with original observations in the stands before logging and includes at least two post-cutting measurements.

At the inception of the study, in 1949, all the stands were 40- to 50-year-old second growth with a scattering of old-growth trees left when the area was logged around 1905. The overstory, except the old-growth stems, was made up predominantly of intolerant cove hardwoods. The few stems of advance reproduction (trees 1 to 5 inches d.b.h.) that were present in 1949 consisted of the very tolerant sugar maple and beech — 60 percent; the tolerant basswood and mid-tolerant sweet birch, red maple, white ash, and hickories — 25 percent; and all other species — 15 percent (table 1). These other species were mostly hophornbeam (*Ostrya virginiana* (Mill.) K. Koch.), yellow birch (*Betula alleghaniensis* Britton), oaks, elm (Ulmus spp. L.), and black gum (*Nyssa sylvatica* Marsh.).

Our tree-selection cuttings left an average post-logging basal area of about 80 square feet per acre in trees over 5 inches d.b.h. Although the stands perhaps could have been safely cut back another 10 or 15 square feet, cutting to less than about 60 square feet of basal area per acre would have invited epicormic branching with resulting log degrade, and would have retarded the board-foot growth rate.

In marking for cutting, the emphasis was on overmature and mature trees in the larger diameter classes, and on poor-risk trees and trees of poor quality potential in all merchantable size classes. No deliberate attempts were made to create openings for reproduction (although some were created incidentally): the objective was to harvest individual trees. Many foresters in the Appalachian area follow similar marking practices.

Table 1. — *Ten-year changes in species composition of understory and pole-size stems under tree-selection cutting in cove hardwoods, expressed in average numbers of stems per acre and proportions of all stems, by size classes*

Species and proportions	Stems in original stand				Stems in 10-year stand			
	1 foot tall to 1 inch d.b.h.	1 - 5 inches d.b.h.	6 inches d.b.h.	8 inches d.b.h.	1 foot tall to 1 inch d.b.h.	1 - 5 inches d.b.h.	6 inches d.b.h.	8 inches d.b.h.
Sugar maple — number	848.0	146.0	6.0	2.1	2649.0	178.0	10.5	3.5
Percent total stems	49.0	37.3	10.1	5.5	47.0	43.0	22.4	12.5
Beech — number	376.0	87.1	1.7	1.2	1102.0	73.6	2.2	1.2
Percent total stems	22.0	22.3	2.9	3.1	20.0	17.8	4.7	4.3
Sweet birch — number	25.0	41.0	8.2	3.7	230.0	29.7	6.0	3.3
Percent total stems	2.0	10.5	13.8	9.6	4.0	7.2	12.8	11.8
Red maple — number	72.0	40.6	5.2	2.3	99.0	25.4	6.7	2.8
Percent total stems	4.0	10.4	8.8	6.0	2.0	6.1	14.3	10.0
Group 1[1] — number	74.0	18.0	8.1	5.5	460.0	33.1	5.8	4.0
Percent total stems	4.0	4.6	13.7	14.4	8.0	8.0	12.5	14.4
Group 2[2] — number	332.0	58.3	30.1	23.6	1066.0	74.2	15.6	13.1
Percent total stems	19.0	14.9	50.8	61.5	19.0	17.9	33.3	47.0
Total stems	1727.0	391.0	59.3	38.4	5606.0	414.0	46.8	27.9

[1] Basswood, white ash, and hickories.

[2] All other species.

Reproduction after Cutting

A surge of reproduction always followed cutting on the study areas.[2] For example, before cutting, an average of 1,730 stems per acre 1 foot tall to 1 inch d.b.h. was found. Five years after cutting there were 7,600 stems. While sugar maple and other more or less tolerant species predominated, cutting did bring in some of the intolerant hardwoods, especially in the larger openings. After 10 years, three-fourths of the trees of miscellaneous other species (group 2 in table 1) in the 1-foot tall to 1-inch d.b.h. range were yellow-poplar and black cherry — about 800 stems. However, because of rapidly increasing overhead foliage density and/or a decrease in tolerance with age, most of these intolerant stems subsequently die or stagnate badly. Sugar maple, which is ideally adapted to selection management under a schedule of frequent light cuts, thrives. In general, tallies taken 5 and 10 years after cutting showed substantial gains in the proportion of sugar maple up to 12-inch d.b.h. sawlog size (table 2). With the passing of time the proportion of sugar maple can be expected to increase throughout all size classes.

Heavier cutting on a tree-selection basis, by opening up the canopy, would bring in and perpetuate more of the desirable intolerants such as yellow-poplar. However, selection cutting heavy enough to do this would understock the stand and, as stated previously, probably would result in lowered log quality and a reduced board-foot growth rate. In other words, individual tree selection, when carried out with due consideration for maintenance of log quality and optimum board-foot growth rates, is not appropriate for managing stands of such desirable intolerants as yellow-poplar and black cherry, or even stands of the somewhat more tolerant red oak.

Future Stands

On the basis of the Fernow study we can make some predictions about the future species composition of these stands.

We are going to have a lot more sugar maple — eventually 50 percent or more of the trees will probably be of this species. While the tabular values (tables 1 and 2) are weighted for the 11 study areas, the trends are the same on each individual area: increasing proportions of sugar maple in each diameter class during the 10-year period.

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[2] Trimble, G. R., Jr., and George Hart. An Appraisal of Early Reproduction After Cutting in Northern Appalachian Hardwood Stands, U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 162, 22 pp., illus., 1961.

Table 2. — *Trend of sugar maple increase under tree-selection cutting in cove hardwood stands, expressed in average numbers of stems per acre*

Size class of stems	Original stands			5 years later[1]			10 years later[1]		
	Sugar maple	All commercial species	Percent sugar maple	Sugar maple	All commercial species	Percent sugar maple	Sugar maple	All commercial species	Percent sugar maple
	No.	*No.*	*%*	*No.*	*No.*	*%*	*No.*	*No.*	*%*
1 foot tall to 1 inch d.b.h.	848.0	1727.0	49.0	4193.0	7596.0	55.0	2649.0	5606.0	47.0
1 - 5 inches d.b.h.	146.0	391.0	37.0	155.0	329.0	47.0	178.0	414.0	43.0
6 inches d.b.h.	6.0	59.3	10.0	7.1	45.5	16.0	10.5	46.8	22.0
8 inches d.b.h.	2.1	38.4	5.5	2.6	29.2	8.9	3.5	27.9	12.5
10 inches d.b.h.	.9	29.4	3.1	.9	21.6	4.2	1.5	21.4	7.0
12 inches d.b.h.	.5	17.7	2.8	.5	16.7	3.0	.7	17.3	4.0

[1] Stands were cut after original measurements and were retallied 5 and 10 years later.

Beech, another intolerant, will also persist under selection management; but because it does not seed as prolifically as sugar maple, and because it will be discriminated against in marking on account of its generally poor form, beech will probably not become a very important component of future stands.

Sweet birch and red maple, which characteristically occur on these sites, will persist under tree-selection cutting.

The tolerant basswood and mid-tolerant white ash and hickory appear to do reasonably well under tree-selection systems. Because basswood and ash are desirable species, they will be favored in marking and will undoubtedly form a part of the future stands — perhaps as much as 20 percent.

The yellow-poplar, black cherry, and red oak that predominated at the beginning of the study period probably will shrink to less than 20 percent in the future all-aged stands.

A number of factors will influence the species proportions that will exist in the future on these good sites under all-aged silviculture. Among them are: species occurrence, as affected by topography, geography and past history; differences in site quality within the range of site conditions that support cove hardwoods; and differences in marking practices under the tree-selection system. However, in those parts of the Appalachian area where sugar maple commonly occurs, the stands resulting from continued tree-selection cutting will be composed more or less as follows:

Species	*Percent*
Sugar maple	50 - 75
Yellow-poplar, black cherry, red oak	5 - 20
Beech, sweet birch, red maple, basswood, ash, hickory	20 - 40
Others	5 - 10

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U. S. FOREST SERVICE RESEARCH NOTE NE-31

1965

Northeastern Forest
Experiment Station
FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

EFFECTS OF STORAGE TREATMENTS ON THE RIPENING AND VIABILITY OF VIRGINIA PINE SEED

In a study at the Beltsville, Md., Experimental Forest in 1953 and 1954, the seed of Virginia pine (*Pinus virginiana* Mill.) became at least 45 percent viable 8 weeks before the natural opening of cones. Because seedfall in that locality usually starts during the first or second week of November, it was concluded that cone collecting could begin there safely in early September (*1*).

However, the patterns of viability before seedfall differed in the 2 years. In 1953 viability tended to increase between early September and the beginning of seedfall in November, whereas in 1954 viability peaked at 86 percent on September 7 and then declined to 37 percent on October 25.

The 1954 pattern of viability was not only at odds with the 1953 results, but also with data obtained in studies on other species of pine (*2, 3, 4*). Hence it seemed advisable to take another look at the development of seed viability in Virginia pine. This was done with seed of the 1960 crop, again on the Beltsville Forest.

The 1960 study included not only the pattern of viability before seedfall, but also 6 treatments of seed collected at weekly intervals during the ripening period. These treatments involved varying lengths of dry storage at 25° to 28° C. and 5° C., and varying periods of wet storage at 5° C.

Methods

Seed collection.—Seed for the 1960 study was collected from 10 Virginia pines at 7-day intervals between July 26 and November 15, when seedfall began. The trees, growing in an old-field stand, were largecrowned, about 16 years old, and fruiting abundantly. Five cones were cut from each tree on each collection date. The cones were gathered from different parts of each crown to avoid any possible bias due to effects of cone position.

The 50 cones in each collection were mixed to insure randomness among later subsamples. Average specific gravity was determined within an hour after the cones were collected.

Seed extraction.—The seed in 25 randomly selected cones from each 50-cone sample was hand-extracted within 24 hours after collection for use in 5 of the 6 storage treatments. Extraction was done by pulling back each cone scale and carefully easing out the seeds. The cones were not predried nor preheated.

In the remaining treatment, which called for storage of cones under room conditions, relatively little hand extraction was necessary.

Treatments.—The 6 storage treatments of cones and seeds are tabulated below, in number of days:

Treatment	*Dry storage of cones at 25°-28° C.*	*Storage of seeds*	
		Dry at 5° C.	*Wet at 5° C.*
I	0	0	0
II	0	0	2
III	0	0	5
IV	0	0	14
V	21-154	56	2
VI	0	94-207	2

Dry storage of seeds was in tightly stoppered vials.

Germination tests. — In all treatments, after seeds were extracted, mixed, and subjected to any scheduled dry storage, 100 apparently sound seeds were placed on damp, shredded peat moss in each of 2 or 3 plastic germinating dishes. Dishes of seeds exposed to wet storage were sealed and stored at 5° C. for the proper number of days. After the completion of any scheduled wet storage, seeds of all treatments were exposed for 2 hours to 160 foot-candles of cool-white fluorescent light. Then the dishes were sealed and placed in a dark oven held at 25° ± 1° C., which Toole *et al.* (*6*) had suggested as the temperature most conducive to the germination of Virginia pine seed.

Germination was tallied in each dish at 7, 14, 25, and (usually) 46 days after the seeds were placed in the oven. After the last examination, all ungerminated seeds were cut to determine soundness so that viability could be expressed as percent of sound seed. A seed was counted as germinated if its radicle extended 5 mm. or more, and an ungerminated seed was regarded as sound if endosperm tissue was visible (even though

Table 1. — *Percent germination of sound Virginia pine seeds, by collection dates and storage treatments*[1]

Collection date		Specific gravity of cones	Storage treatment I	II	III	IV	V	VI
July	26	1.06	0	0	0	0	—	0
Aug.	2	1.06	0	0	0	0	—	0
	9	1.05	0	0	0	0	—	0
	16	1.02	0	0	0	0	4	0
	23	1.07	0	0	0	0	35	25
	30	1.07	7	2	3	4	73	76
Sept.	6	1.07	5	7	8	7	81	82
	13	1.03	29	33	22	39	76	61
	20	1.04	65	65	57	75	83	72
	27	.99	87	79	86	84	69	70
Oct.	3	.99	83	86	81	65	79	87
	11	.99	82	88	66	72	53	84
	18	.94	67	79	71	84	60	91
	25	.91	53	62	67	78	73	72
Nov.	1	.89	61	79	72	83	75	73
	8	.78	86	85	81	78	81	85
	15	.60	78	84	82	91	82	89
Average (all values)			41	44	41	45	54[2]	57
Average (September 13 to November 15)			69	74	68	75	73	78

[1]Each value was based on two 100-seed samples, except in treatment V, in which three 100-seed samples were tested.
[2]Missing values for the first three collection dates, for which germination was not tested, were assumed to be zeros.

rotted). In treatments V and VI, observations on germination were terminated after 25 days because rot was becoming prevalent in the ungerminated seeds.

Results

Viability prior to seedfall. — The 1960 results confirmed earlier findings: (1) that Virginia pine seed becomes sufficiently viable 2 months before seedfall to warrant collecting for routine use; and (2) that some seeds mature even earlier (table 1).

The 1960 results also were in accord with the 1953 observations of Church and Sucoff on Virginia pine (*1*) and with reported observations on other pines (*2, 3, 4*) that, once high viability is reached, it tends to remain high until seedfall. After September 20, 1960, there were no consistent variations in the percent of seed that germinated (table 1). The decline in germination observed by Church and Sucoff after September 7 in 1954 seems illogical and is unexplainable.

Table 2. — *Percent of total germination occurring within 7 days, by collection dates and storage treatments*

Collection date		Storage treatment					
		I	II	III	IV	V	VI
Aug.	16	—	—	—	—	11	—
	23	—	—	—	—	41	33
	30	14	40	20	0	71	50
Sept.	6	0	0	0	0	89	59
	13	36	21	17	11	58	57
	20	12	17	23	28	76	79
	27	41	68	79	69	86	69
Oct.	4	70	80	87	81	74	76
	11	85	98	100	96	73	88
	18	80	99	99	99	57	87
	25	73	98	99	98	49	65
Nov.	1	90	97	98	97	79	56
	8	83	97	99	98	84	69
	15	75	90	73	98	77	69

Treatment effects on seed germination.—The amount of germination varied with pregermination treatment, but not always as expected. Toole *et al.* (6) had reported that imbibition of moisture at 5° C.—that is, cold wet storage—increased the germination of Virginia pine seed. In our study, cold wet storage (treatment II-IV) increased germination only slightly, if at all, over germination of seeds that did not receive such a treatment (treatment I) (table 1). However, the values in table 1 are for total germination; germination during the first 7 days was, in fact, somewhat increased by a few days of cold wet pregermination treatment.

This quicker germination induced by cold wet storage was especially evident in the samples collected after October 1. For example, the proportion of total germination that occurred within 7 days often approached 100 percent in these later collections in treatments II-IV but fell between 70 and 90 percent in treatment I, which differed only in the omission of cold wet storage (table 2).

Prolonged dry storage had more effect than wet storage on total germination, especially among seeds collected before September 20. For example, in the September 6 collection, treatments I-IV, which provided no dry storage, showed less than 10-percent germination, as compared to 81 or 82 percent under treatments V and VI, which included dry storage (table 1). Prolonged dry storage advanced the collection date at which high seed germination occurred by about 3 weeks.

Prolonged dry storage seemed first to favor and then to hinder rapid germination. For seeds collected prior to October 1, quicker germination usually occurred among those that had undergone such storage (treatments V-VI compared to treatments I-IV), but for seeds collected after October 1 a reverse relationship was apparent (table 2).

Cone maturity and germination. — The cones became physiologically mature during the latter part of September. Maturity was indicated by a change in cone color from green to dark purple during the third week of the month, and by a drop in specific gravity below 1.0 in the cones collected on September 27. Before that date specific gravities had ranged from 1.02 to 1.07—with the high of 1.07 appearing in late August and persisting through early September.

Once the specific gravity had dropped below 1.0, there was no consistent effect of date of collection on the germination of sound seeds (table 1).

Seedling abnormalities.—Schubert (5) has described seedling abnormalities associated with prematurely collected, though viable, seeds of western species of pine, so an attempt was made to determine whether similar abnormalities would develop from prematurely collected seeds of Virginia pine. Extra seeds from treatment VI were used, and 18 seedlings from each of the 13 collections of viable seeds were grown in clay pots. The seedlings were observed for 37 days after germination started. No abnormalities associated with early cone collection appeared.

Discussion

The 1960 study confirmed 1953 and 1954 findings that, at least 2 months before natural seedfall, Virginia pine seeds ripen on the trees sufficiently to be capable of germination.

The 1960 data also indicate that seeds that have been collected early continue to ripen off the trees under certain storage conditions. Prolonged cold dry storage in closed containers, with or without prior storage in cones at room temperatures, apparently favors the ripening and subsequent germination of seed collected between August 30 and September 20. Such storage is easily provided and could be a routine practice with seed collected for use in forest nurseries.

If cold dry storage is not available, cone collections should be delayed until cones are mature. This time can be determined by a change in cone color from green to purple, and by a drop in specific gravity of the cones to 1.00 or less.

No adequate guide other than calendar date is available for determining when cone collections may be started for seeds that are to be after-ripened by cold dry storage. Because this date may be affected by location and climate, the results of this study should not be applied outside southern Maryland without allowing for some local verification.

None of the storage treatments tried in the 1960 study gave the absolute maximum in germination of sound seeds. Cutting tests indicated that 89 to 100 percent of all lots were sound. Germination, even when based on *sound* seeds (table 1), usually reached maxima of only 86 to 91 percent. Possibly better control of seed-rotting organisms would have increased these values.

Literature Cited

1. Church, Thomas W., Jr., and Edward I. Sucoff.
1960. Virginia pine seed viable two months before natural cone opening. U.S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 102, 4 pp.
2. Fowells, Harry A.
1949. An index of ripeness for sugar pine seed. U.S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 64, 5 pp.
3. McLemore, B. F.
1959. Cone maturity affects germination of longleaf pine seed. Jour. Forestry 57: 648-650.
4. Maki, T. E.
1940. Significance and applicability of seed maturity indices for ponderosa pine. Jour. Forestry 38: 55-60.
5. Schubert, Gilbert H.
1956. Effect of ripeness on the viability of sugar, jeffrey, and ponderosa pine seed. Soc. Amer. Foresters Proc. 1955: 67-69, illus.
6. Toole, V. K., E. H. Toole, S. B. Hendricks, H. A. Borthwick, and A. G. Snow, Jr.
1961. Responses of seeds of *Pinus virginiana* to light. Plant Physiol. 36: 285-290, illus.

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U. S. FOREST SERVICE RESEARCH NOTE NE-32

1965

Northeastern Forest

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Experiment Station

HOW TO DETERMINE SEASONING DEGRADE LOSSES IN SAWMILL LUMBERYARDS

Sawmill operators generally recognize the problem of defects due to air-drying hardwood lumber, but they often fail to realize how much these seasoning losses cost in money, time, and wasted lumber.

A recent study revealed that degrade losses in the air-drying of red oak averaged more than $10 per 1,000 board feet in the central Appalachian region.[1] This figure included only the decrease in lumber value due to reductions in grade from seasoning defects. The cost of rehandling or remanufacturing the degraded boards would have represented an additional loss that was not calculated in the study.

Yet seasoning degrade losses of less than $2 per 1,000 feet were found at more than half the mills sampled, which indicated that most seasoning degrade can be eliminated. A dollar saved in degrade losses is at least as beneficial to the lumber producer as a dollar increase in lumber prices.

The results of this study indicate the need for sawmill operators to determine the degrade losses in their operations. Such information would be useful in determining what improvements in lumber-drying practices are necessary to reduce losses to acceptable levels.

A method by which the individual operator can make periodic determinations of air-seasoning degrade losses is suggested here. The procedure is inexpensive because the necessary information can be obtained by the lumber inspector during normal grading operations and does not require extra men or equipment. The system has been tested at a number of Appalachian sawmills with excellent results.

[1] Results of an unpublished study involving a random sample of 329,000 board feet. Data on file at the Forest Products Marketing Laboratory, Princeton, West Virginia.

Procedure

Seasoning degrade is determined at the time air-dry lumber is being prepared for shipment. The procedure is not difficult: it can be applied by any competent hardwood lumber inspector without seriously interrupting normal grading operations.

Care should be taken to distinguish between seasoning defects and other types of defects. For example, a shake that becomes evident after air-drying should not be counted as a seasoning defect; neither should defects resulting from logging damage, insect damage, and milling or handling.

But splits, checks, warp, and stain (except mineral stain) are all seasoning defects. The diagrams below (fig. 1) illustrate how seasoning defects can lower the grade and value of lumber.

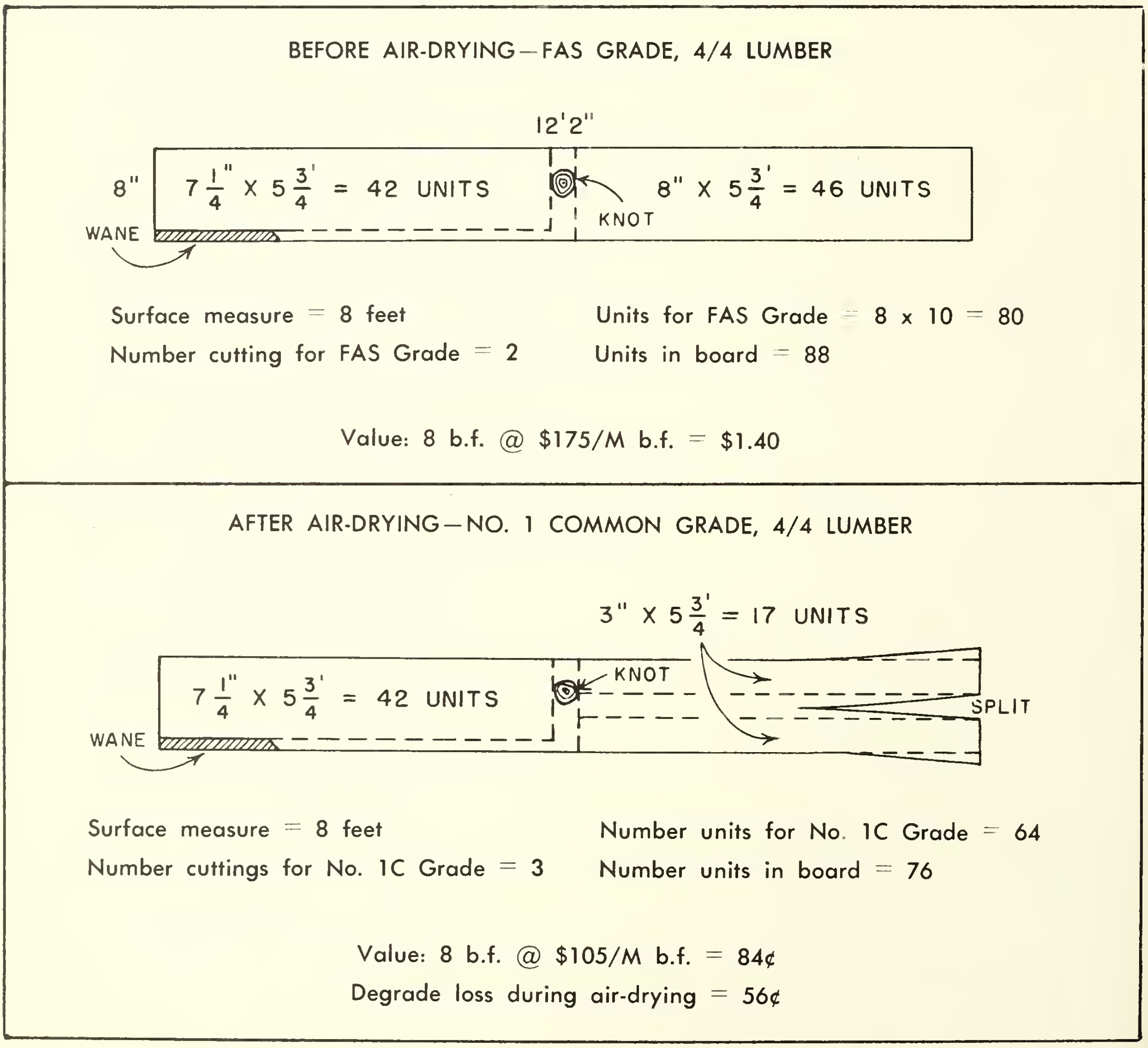

Figure 1.—How seasoning defects can lower the grade and value of lumber.

Although it is often possible to improve a degraded board by ripping or trimming, no allowance should be made for this in the degrade determination. Each board should be evaluated in its present condition, and not in its potential remanufactured condition.

Selection of Sample

Each mill manager should first determine how much lumber he needs to sample to obtain a reliable estimate of air-drying losses. A 5-percent sample of shipments by species is usually adequate for evaluating the drying practices at large operations, provided the samples are selected at random and represent lumber piled for seasoning over the entire year. On the other hand, 30 percent of all lumber shipped should be checked on very small operations. The following tabulation provides suggested sampling levels for yards of different sizes.

Yard size: Volume shipped per year (M bd. ft.)	*Sample size, by species (percent)*
5,000 and over	5
2,500 — 4,999	10
1,500 — 2,499	15
750 — 1,499	20
500 — 749	25
Up to 499	30

Special checks are often needed to determine the amount of seasoning degrade that is occurring in sections of air-drying yards that have recently been modified; additional checks are beneficial for determining needed improvements for sections of yards that consistently show more degrade than others. In any event, tests for degrade should be frequent enough to provide the mill manager with up-to-date knowledge of the lumber drying performance of his yard.

Normally, the sample should include all the lumber in a particular shipment. This simplifies the sampling procedure, as the shipping tally sheet then becomes the basis for figuring degrade loss per 1,000 board feet. Degrade loss for a single stack of lumber can be determined, if desired, by recording separate shipping tallies and degrade data for each stack.

Grading and Tallying

The technique for determining degrade is essentially that of dual-grading the air-dry boards, a research method developed by the U.S.

Forest Products Laboratory. This method eliminates the need for grading the green lumber and then regrading it when dry to determine grade losses. The procedure is as follows:

1. Determine the present grade of each air-dry board and tally it in the usual manner on the lumber shipping tally sheet.
2. Determine whether the board contains seasoning defects, and if so, whether the present grade of the board is lower than it would have been if the seasoning defects were not present.
3. If the board has been degraded one or more grades by seasoning defects, record the degrade information on the Degrade Tally Sheet as follows:

DEGRADE TALLY SHEET

Original green grade[2]	*Air-dry grade*[3]	*Volume (bd. ft.)*[4]	*Type defect*[5]
FAS	No. 1C	8	Split
FAS	No. 2C	9	Check
No. 1C	No. 2C	6	Warp
No. 1C	No. 3AC	5	Stain

[2] The estimated green grade of the degraded board at the time of stacking for air-seasoning.
[3] The actual air-dry grade of the degraded board when inspected at time of shipping.
[4] The air-dry volume of the degraded board.
[5] The major seasoning defect responsible for degrading the board.

Calculation of Degrade Losses

After dual-grading of a shipment of lumber, the information on all the tally sheets should be summarized to determine the following:

1. The total volume of lumber in the shipment.
2. The volume of lumber degraded in each grade change category. For example, from FAS to No. 1C; from No. 1C to No. 2C; from FAS 1FC to No. 2C, etc.

This information is then combined with lumber values by grades to prepare the degrade loss summary, as in the following example:

DEGRADE LOSS SUMMARY

Potential grade & value/M bd. ft.	*Actual grade & value/M bd. ft.*	*Value difference M bd. ft.*	*Volume degraded (bd. ft.)*	*Degrade loss*
(1) FAS ($175)	No. 1C ($105)	$ 70	80	$ 5.60
(2) FAS ($175)	No. 2C ($68)	107	180	19.26
(3) No. 1C ($105)	No. 2C ($68)	37	80	2.96

Total degrade loss = $27.82
Total volume graded, bd. ft. = 4,125
Average degrade loss/M bd. ft. = $ 6.74

This example indicates (1) that 80 board feet were degraded from FAS to No. 1 Common; (2) that 180 board feet were degraded from FAS to No. 2 Common; and (3) that 80 board feet were degraded from No. 1 Common and No. 2 Common.

The volumes in each grade change category are multiplied by the appropriate value differences per 1,000 board feet to obtain the total loss for each category. The average degrade loss is based on the total volume in the shipment. In the above example, a total degrade loss of $27.82 occurred in a shipment that contained 4,125 board feet, which meant an average seasoning degrade loss of $6.74 per 1,000 board feet ($27.82 divided by 4.125).

Evaluating Causes of Degrade

A summary of the volume of lumber degraded by each major type of seasoning defect can be helpful in determining the nature of improvements needed in the air-drying yard. This data should be taken from the degrade-tally sheets and recorded on the following form:

VOLUME DEGRADED, BY TYPE OF DEFECT

Sample number	*Split (bd. ft.)*	*Check (bd. ft.)*	*Warp (bd. ft.)*	*Stain (bd. ft.)*
1	120	180	30	30
2	100	130	27	20

In this example, the large proportion of degrade loss was due to splits and checks, while only minor degrade resulted from warp and stain. This indicates that the lumber dried rapidly, but that it was not protected sufficiently from the weather.

Research studies conducted at Appalachian hardwood sawmill lumber-yards show that the lack of proper lumber-stack roofing is the major cause for surface checking; and that too few stickers in the stacks is the major cause for splitting. Poor sticker alignment and poor bunk alignment are the major causes of warp (cup, crook, bow, and twist), although the lack of roofing also causes warp in the top layers of lumber in the stacks.

Stain was not found to be a major degrade problem in drying red oak, although some cases of sticker stain were found where drying conditions were poor and where wide, green stickers were used.

In their approximate order of importance, the principal causes of the four types of seasoning degrade found at the sawmill lumberyards are listed below:

Split

1. Too few stickers.
2. Lack of roofing or poor roofing.
3. Stickers not flush with ends of boards.

Check

1. Lack of roofing.
2. Board edges exposed at bunk spaces.
3. Stickers not flush with ends of boards.
4. Too rapid drying due to exces-ive exposure of lumber stacks.

Warp

1. Poor sticker alignment.
2. Poor bunk alignment.
3. Lack of sufficient stickers.
4. Foundation out of level.
5. Thick and thin lumber in same course in stack.

Stain

1. No chemical dip.
2. Use of green stickers.
3. Use of wide stickers.
4. Base of piles too low.
5. Grass and weeds growing between stacks.
6. Poor yard orientation or location.

Unavoidable Degrade Losses

A certain amount of seasoning degrade is unavoidable in drying lumber in open yards. Research investigations have not determined the precise allowable degrade losses by species and thicknesses of lumber. However, rough guidelines can be established for the major hardwood species in the Appalachian region. In general, air-drying practices should be improved if degrade tests at the lumberyard show consistently greater losses than indicated in the following:

Species	*Thickness*	*Allowable losses in percent of air-dry lumber value*
White and red oak	4/4 and 5/4	1.0
White and red oak	6/4 and 8/4	2.0
Poplar, basswood, and cucumber	4/4 and 5/4	.5
Poplar, basswood, and cucumber	6/4 and 8/4	1.0
Maple and beech	4/4 and 5/4	2.0
Maple and beech	6/4 and 8/4	3.0

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Selected References

Devine, John.

(n.d.) PRODUCTION KILN DRYING. Quality Printers, Inc. Memphis, Tenn., 151 pp., illus. (Available from the Moore Dry Kiln Co., Jacksonville, Fla.)

Peck, E. C.

1956. AIR DRYING OF LUMBER. U.S. Forest Prod. Lab. Rpt. 1657. 21 pp., illus. Madison, Wis.

Rasmussen, E. F.

1961. DRY KILN OPERATORS MANUAL. U.S. Dept. Agr. Handbk. 188, 197 pp., illus.

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J. S. FOREST SERVICE RESEARCH NOTE NE-33

1965

Northeastern Forest

EST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY PA

Experiment Station

ATLANTIC WHITE-CEDAR BEING ELIMINATED BY EXCESSIVE ANIMAL DAMAGE IN SOUTH JERSEY

Atlantic white-cedar, which grows in the swamps of the New Jersey Pine Region, is a prized timber species. Most areas now growing white-cedar have been clearcut 4 or 5 times since 1700. In contrast, the associated swamp hardwoods—red maple, blackgum, and sweetbay—rarely produce wood that is valuable enough to harvest.

In bygone days white-cedar was used for shingles, siding, boat boards, posts, poles, and similar products. Today it is not much used for shingles or siding, but is still used for posts, poles, and boat boards, and much of it now goes also into paneling and into rustic furniture and fences. The dense stands that this species forms provide not only a valuable timber crop, but also an aesthetic attraction to tourists and an excellent habitat for wildlife, especially deer.

Present evidence clearly shows that, because of excessive damage by wild animals, white-cedar is not forming new stands in many areas after clearcuttings or killing wildfires. Rabbits clip the small seedlings, and deer so relish the twigs and foliage as winter browse that, in areas where the deer population is high, many white-cedars are killed and the survivors are reduced to stunted bushes.

Effects of the excessive deer pressure on white-cedar reproduction are shown by a small study established on the Wharton Tract in September 1955. The study site was a swamp where a stand of white-cedar trees

Figure 1.—Ten years after the fire: left—fenced plot; right—unfenced plot. The two foreground cedars in the fenced plot are about 12 feet tall, and many others are taller than the man.

ranging from 3 to 7 inches d.b.h. had been killed during a large wildfire in July 1954. In September 1955, two small plots, each about 20 feet square, were established; one plot was fenced against deer and the other was left open. Tallies of twenty-five 1/4-milacre quadrats in each plot showed an abundance of white-cedar reproduction at that time: 210,720 seedlings per acre in the fenced plot and 111,520 seedlings in the companion unfenced plot. All quadrats in the fenced plot and 96 percent of those in the unfenced plot were stocked to white-cedar.

Nine years later the fenced plot still had more than 57,000 white-cedar seedlings per acre, and 96 percent of the 1/4-milacre quadrats were stocked. But in the unfenced plot the number of white-cedars had dropped to

1,440 per acre, and only 20 percent of the quadrats still had white-cedar seedlings. Already the number and distribution of seedlings in the unfenced plot were too poor to form a well-stocked stand.

Height differences were even more marked. The average height of the tallest white-cedars on stocked quadrats in the fenced plot in 1964 was 7.6 feet, as compared to 1.5 feet in the unfenced plot. On the basis of 1,600 well-distributed dominants per acre (the number of trees often found in well-stocked merchantable stands 45 to 50 years old), the difference was even more marked: the average height of these dominants in the fenced plot was 10.3 feet, or about 7 times the height of the browsed and mutilated dominants in the unfenced plot (fig. 1).

The differences between the two plots in white-cedar stocking and growth are attributed to deer. In both plots rabbits clipped many of the seedlings, but rabbits do not uproot the young plants, and they seldom clip stems more than 3 years old. Deer continue to browse white-cedar trees as long as they can reach the foliage. They also uproot many small seedlings because they tend to jerk the twigs sharply when browsing, and the young seedlings are poorly anchored in the moss and soupy peat of the swamps.

The importance of deer browsing in white-cedar regeneration is shown not only by these two small plots, but also by the regeneration developing in other swamps that were burned during the same 1954 wildfire. Even though this fire covered 19,500 acres and thus provided a tremendous amount of fresh browse in pine seedlings, pine and hardwood tree sprouts, and shrub sprouts, the pressure on white-cedar regeneration has been overwhelming. We estimate that about 500 acres of white-cedar stands were killed by this fire, and our observations indicate that the white-cedar reproduction starting on these sites in 1955 ran around 150,000 seedlings per acre. Today little of this reproduction can be found. Only in rare spots, as where a tangle of windthrown fire-killed trees has provided protection, do white-cedars occasionally give promise of being a part of the next stand.

The evidence is incontrovertible that excessive deer browsing is now eliminating Atlantic white-cedar from many swamps in the New Jersey Pine Region where the species had maintained itself fairly successfully through three centuries of the white man's cuttings and fires.

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U. S. FOREST SERVICE RESEARCH NOTE NE-34

1965

Northeastern Forest

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Experiment Station

PATTERN OF DEFECT ASSOCIATED WITH STEM STUBS ON NORTHERN HARDWOODS

Decay and discoloration are the principal defects that reduce quality of northern hardwoods in New England. We need to know how to minimize these defects in young growing stock, and how to recognize them in merchantable trees. To determine accurately the amount of internal defect in trees, we must know the quantitative relationships between external signs on stems and the losses within them. The purpose of this note is to point out the defect pattern associated with dead stubs of main stems that persist on living northern hardwoods.

The leading shoots of young trees may be killed by disease, insects, suppression, and mechanical injuries. New leaders often form from lateral branches or from adventitious buds on the live stem below the killed portion. The dead stem section deteriorates until a stub is all that remains.

In early stages, stem stubs can be differentiated easily from branch stubs by their acute angle from the main stem and by their occurrence near abrupt bends in stems (fig. 1). As stem stubs decay and drop off and as the trees straighten, it becomes increasingly difficult to identify the stubs as remains of old main stems.

During studies of decay and discoloration in northern hardwoods in the White Mountains of New Hampshire, more than 1,000 trees were dissected longitudinally and examined, and the relation of internal defects to external indicators was established. It was easy to differentiate old

Figure 1.—Stem stubs on (left to right) yellow birch, red maple, and sugar maple. On the sugar maple a crack formed below the stub as callus enveloped it.

Figure 2.—Dissection of the stems shown in figure 1. Most of the defect associated with stem stubs advanced downward into tissues that were present when the main stems died.

stem stubs from branch stubs in the dissected sections. The pith below the stem stub was in a straight line with the stub and differed from the curved path of the pith in branch stubs and in the new main stem formed above the stem stub (fig. 2). In a few trees studied, the stem stub was decayed completely, leaving behind a hole in the stem (fig. 3).

Stem stubs were most common between 6 and 16 feet above the ground, and stub diameters were usually less than 5 inches. Cracks sometimes formed above and below the stubs (fig. 2). Defect associated with stem stubs advanced downward faster in yellow birch and slower in sugar maple than in other species (fig. 2).

Decays and discolorations that advanced from stem stubs into living tissues in the stem were limited usually to those tissues present when the leaders died. Because of this, most of the defect advanced downward. When a large lateral branch below the killed terminal became the new main stem, defect advanced also into those tissues present when the terminal died. If decay and discoloration later developed in the new main stems and spread downward, it sometimes joined defects arising from stem stubs. This was more common with discoloration than with decay (fig. 4).

Figure 3.—A hole in a yellow birch that formed when the stem stub decayed away.

Figure 4.—Dissection of the tree shown in figure 3. Discoloration advancing downward joined the discoloration around a hollow column. This column indicated the location of the old main stem. Decay did not advance into the new main stem.

Figure 5.—Dissection of a paper birch, showing the black sterile growth of *Poria obliqua* on a stem stub. This fungus infects new main stems.

A common exception to the above defect pattern was caused by *Poria obliqua* infecting stems through stem stubs. This fungus readily invaded tissues formed after the leader died, including the new main stem (fig. 5).

These observations indicate that defects associated with stem stubs usually advance downward and that the diameters of defect columns in trees are approximately the diameters of the stem stubs.

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U. S. FOREST SERVICE RESEARCH NOTE NE-35

1965

Northeastern Forest
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Experiment Station

ARTIFICIAL LIGHT SOURCES DIFFER IN EFFECT ON BIRCH SEEDLING GROWTH

The use of artificial lights to grow tree seedlings for research and even for commercial uses is becoming common. With this has come an increasing awareness that not all types of artificial lights produce the same results (2, 3, 5). The presence or absence of particular wavelengths in the light source may cause large differences in height growth and morphological development that are separate from the effects of light intensity.

Fluorescent lamps, although good for relatively high-intensity, uniformly-distributed light with a minimum of heat, are usually deficient in one or more of the important wavelength bands. Their output in the far-red band is extremely low, and the different types of lamps vary greatly in spectral distribution in the visible region. In most facilities for growing plants under artificial light, some type of fluorescent lamp is used as the primary light source, and incandescent bulbs are added to provide the far-red component.

In recent years, fluorescent tubes designed specifically for plant growth have appeared on the market. The output of these tubes is highest in the red and blue regions, which are the regions of greatest absorption by chlorophyll. They were designed to produce maximum photosynthesis and to enhance vegetative and reproductive growth in general. The assumption is often made that plants grown under these special fluorescent tubes will not require supplemental incandescent energy.

While setting up a light facility for growth of yellow and paper birch seedlings, the question naturally arose as to which of the many available light sources would produce best results. A simple experiment was therefore set up to test three different flourescent tubes, both with and without an incandescent supplement.

Study Methods and Materials

Six light compartments were constructed, using banks of six 8-foot fluorescent tubes in each compartment. Light baffles on the sides of each compartment permitted air flow through the compartment while restricting stray light. The three kinds of tubes used were the cool-white type, the warm-white type, and the tubes especially designed for plant growth, which bear the trade name Gro-lux.[1]

For each tube type two compartments were set up, one illuminated with fluorescent lamps alone, and one with three 25-watt incandescent bulbs in addition. Yellow birch and paper birch seedlings were grown from seed in Hoaglands No. 2 nutrient solution in a sand-vermiculite supporting medium. There were 3 seedlings in each pot, and 8 pots of each species for each treatment. Photoperiod was 20 hours. After 3 months' growth, seedling height, dry weight of roots, and dry weight of tops were determined. The analysis of variance was used for tests of significance.

Light-intensity measurements were taken under the various sources with a Model 501-M photometer with type-D phototube (Photovolt Corp.), filtered to limit the instrument's response to the visible region of the spectrum. Although the response of this phototube is not exactly equal at all wavelengths, it is nearly so, and is satisfactory for comparisons between treatments. The measurements revealed only minor differences in total visible energy emission by the three types of fluorescent tubes. For purposes of this study, their output is considered equal. It would be equivalent to about 800 foot-candles if measured under the cool-white tubes with a conventional illumination meter (such as Weston Model 756). The incandescent supplemental illumination increased energy emission in the visible region by an average factor of 1.25.

The relative spectral distribution of the three fluorescent tubes is shown below (adapted from Bulletins 0-205 and 0-236, Sylvania Lighting Products), in percent of total emission:

	Wavelength in millimicrons		
	380-490 Violet & blue	*490-590 Green & yellow*	*590-700 Red & orange*
Gro-lux	37.0	15.6	46.0
Warm white	18.3	44.1	36.0
Cool white	28.6	43.3	26.4

[1] All tubes were manufactured by Sylvania Lighting Products. Mention of particular commercial products should not be considered as endorsement by the U.S. Department of Agriculture or the Forest Service.

Results

Supplemental incandescent illumination resulted in significantly greater height growth (0.01-level) and top dry weight (0.05-level) with all fluorescent tubes (table 1 and fig. 1), but it did not significantly affect root dry weight. Seedling height and root dry weight differed under the three types of fluorescent tubes (0.05-level of significance) as follows:

- Yellow birch height was less under Gro-lux tubes than under the warm white or cool white fluorescents, both with and without the incandescent supplement.
- Paper birch root dry weight was lower under warm white fluorescents than under the other tube types, both with and without the incandescent supplement.
- Yellow birch root dry weight was lower under warm white fluorescents in the absence of supplemental incandescent illumination; with the incandescent supplement, the differences were not significant.

Part of the increased growth that occurred under incandescent supplemental illumination probably was due to the higher light intensity. Although the light measurements that were taken were not adequate for accurate evaluations of this effect, a simple calculation will permit rough

Table 1.—Average seedling heights and dry weights under various light sources

Species and tube type	Height[1]		Top dry weight[1]		Root dry weight[1]	
	0	+	0	+	0	+
	Inches		*Grams*		*Grams*	
Paper birch:						
Gro-lux	4.1	5.8	0.48	0.63	0.37	0.34
Warm white	4.2	6.2	.39	.56	.20	.26
Cool white	4.0	6.9	.55	.68	.37	.44
All tubes	4.1	6.3	.48	.63	.31	.35
Yellow birch:						
Gro-lux	2.8	4.5	.30	.37	.23	.21
Warm white	5.1	8.0	.35	.60	.14	.25
Cool white	3.7	7.2	.28	.63	.21	.37
All tubes	3.8	6.6	.31	.54	.20	.28

[1] 0 and + signs denote without and with supplemental incandescent illumination, respectively.

comparisons. The growth figures obtained with no incandescent supplement were raised by a factor of 1.25 — the amount of additional illumination obtained from the incandescents (table 2). This adjustment theoretically eliminates light intensity as a factor; growth differences remaining should therefore be due either to differences in the spectral distribution of the light sources or to experimental error. The adjustment is based on the assumption that growth is proportional to light intensity over the range between the compensation point and the saturation point. Although growth rates vary with species, light source, and other factors, the assumption of a nearly proportional increase with light intensity appears commonly in the literature; it is especially well supported by curves of growth over light intensity such as those of Dunn and Went (4) for tomato.

Although statistical tests of these crude estimates are not appropriate, the figures in table 2 suggest that the incandescent illumination itself, apart from intensity effects, accounted for much of the increased height growth that occurred in both species under the incandescent supplement. The independent effect of incandescent illumination on dry weight was less pronounced. It may have been an important factor in the greater top dry weight in yellow birch. The other dry-weight categories show little evidence of such an effect.

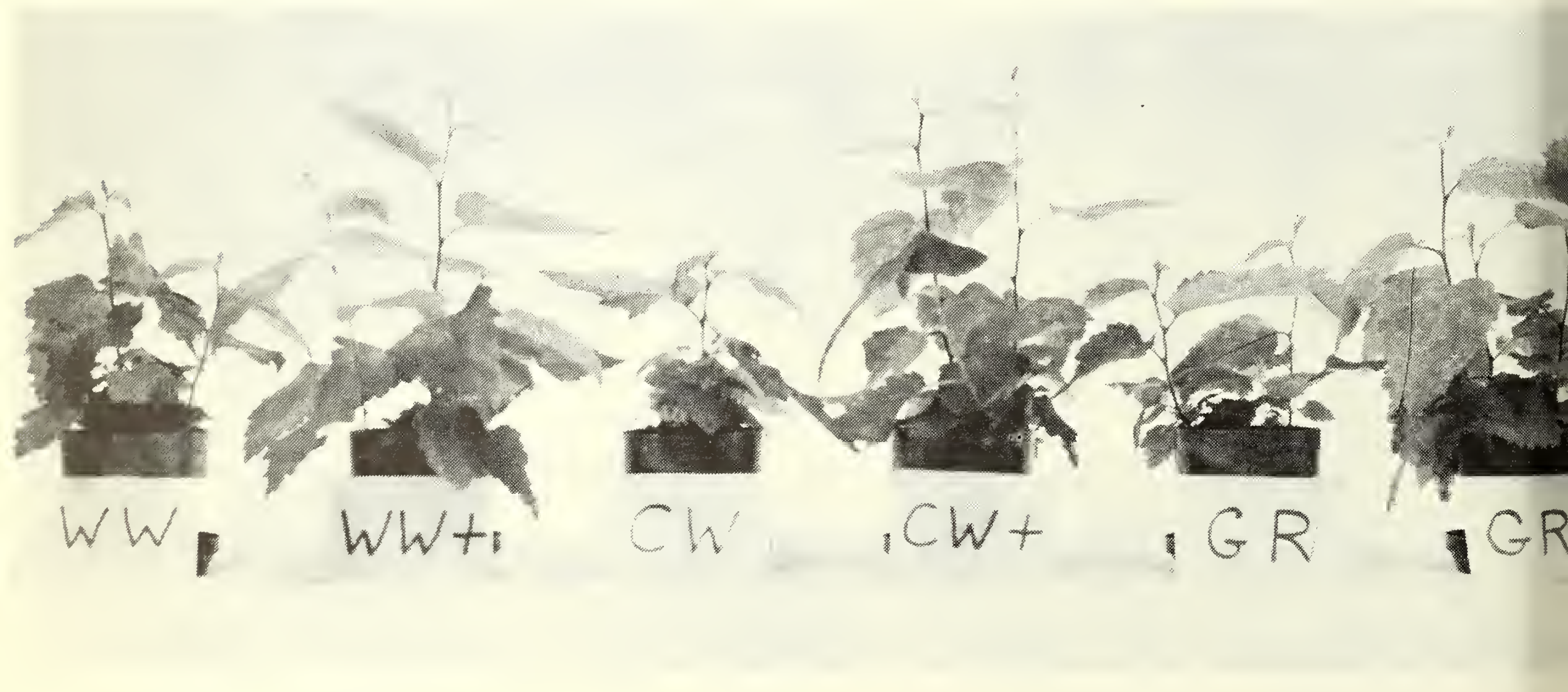

Figure 1.—Paper birch seedlings grown under 6 artificial light sources. From left to right: warm white fluorescents; warm white fluorescents plus incandescents; cool white fluorescents; cool white fluorescents plus incandescents; Gro-lux fluorescents; Gro-lux fluorescents plus incandescents.

Table 2.—Average seedling heights and dry weights adjusted to represent equal light intensities[1]

Species	Height[2]		Top dry weight[2]		Root dry weight[2]	
	0	+	0	+	0	+
	Inches		*Grams*		*Grams*	
Paper birch	5.1	6.3	0.60	0.63	0.39	0.35
Yellow birch	4.8	6.6	.39	.54	.25	.28

[1] Averages shown in table 1 for treatments without the incandescent supplement were raised by a factor of 1.25.
[2] 0 and + signs denote without and with supplemental incandescent illumination, respectively.

Discussion

The special fluorescent tubes (Gro-lux) did not produce better growth of birch seedlings than the other tubes in spite of their high energy output in the regions of maximum chlorophyll absorption. Presumably yellow-green light is utilized in photosynthesis by birch seedlings to a much greater extent than is suggested by the spectral absorption characteristics of chlorophyll. This is known to occur in some plants and is believed to be due to absorption and transfer of light energy to chlorophyll by other pigments (5).

Height growth was actually inhibited under the Gro-lux tubes. Seedlings under these lights were shorter, but possibly stockier, than those under the other tubes. Supplemental incandescent light was more essential for height growth with the Gro-lux tubes than with the others. This seems logical in view of the interacting and compensating effects of the red and far-red portions of the spectrum, which regulate shoot elongation in many plants; shoot elongation is promoted by far-red radiation and inhibited by red radiation (1). Hence, the greater height growth with incandescents is due to their relatively high output of far-red radiation, as compared to the fluorescents. Gro-lux tubes, because of their high output of red light, would tend to inhibit stem elongation more than the others. Even with incandescent supplemental illumination, the ratio of far-red to red would be lower under the Gro-lux tubes.

The effect of incandescent lights on dry matter production is not entirely clear. Theoretically, the far-red radiation obtained from incandescent bulbs should have little or no effect on the amount of photosynthate produced; it should simply alter the way in which this photosynthate is distributed; i.e., it should determine whether the seedlings will be tall and spindly or short and stocky. Paper birch followed this theoretical pattern with increased height but normal dry weight when given supplemental incandescent illumination. Yellow birch, however, increased in both height and shoot dry weight with the incandescent supplement. Reasons for this are not apparent, but similar dry-weight increases resulting from incandescent bulbs also have been reported elsewhere (4).

For use in a plant growth facility, cool-white fluorescents with an incandescent supplement seem best for growing seedlings of yellow and paper birch. The more expensive Gro-lux bulbs, although perhaps having advantages for other species or for other purposes, were less satisfactory for our needs.

Literature Cited

1. Butler, W. L., and Robert J. Downs.
1960. Light and Plant Development.
Sci. Amer. 203 (6): 56-63.

2. Downs, Robert J.
1957. Photoperiodic Control of Growth and Dormancy in Woody Plants. In Physiology of Forest Trees: 529-537. Ronald Press Co., New York. 678 pp.

3. Downs, Robert J.
1958. Effects of Photoperiod and Kind of Supplemental Light on Vegetative Growth of Pines. Forest Sci. 4: 185-195.

4. Dunn, Stuart, and F. W. Went.
1959. Influence of Fluorescent Light Quality on Growth and Photosynthesis of Tomato. Lloydia 22: 302-324.

5. French, C. S., and Violet M. K. Young.
1956. The Absorption, Action, and Fluorescence Spectra of Photosynthetic Pigments in Living Cells and in Solutions. In Radiation Biology, vol. 3: 343-391. McGraw-Hill Book Co.

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U. S. FOREST SERVICE RESEARCH NOTE NE-36

1965

Northeastern Forest

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Experiment Station

MARKET OPPORTUNITIES FOR TREATED WOODEN GUARDRAIL POSTS IN WEST VIRGINIA

At present practically no wooden guardrail posts are being installed along West Virginia's highways. Neither are concrete posts. Only steel posts are being used in new highway construction despite the fact that wooden posts that have been properly treated with a decay-preventing preservative are entirely acceptable to the State Highway Department. Furthermore, treated wooden posts are reported to provide as good or better service than posts made of steel or concrete (1, 2, 3).

West Virginia State Road Commission officials say that, up to the construction year 1946, wooden posts of naturally decay-resistant species (primarily black locust) were used almost exclusively for new highway construction in the State. But between 1946 and 1958 decay-resistant wooden posts became scarce and were gradually replaced by concrete guardrail posts in new construction. Steel guardrail posts were not used in West Virginia until 1958. Since then steel has been used almost exclusively in the State, despite the Highway Department's eventual acceptance of treated wooden posts in 1960.[1]

The Study

Concerned over this loss of a market for wooden posts, the Forest Products Marketing Laboratory of the U.S. Forest Service has made a study to determine why wooden guardrail posts are not being used in the State. Approximately 28,000 posts are installed in the State per year.

[1] A number of species and treatments are acceptable for treated wooden posts, most commonly creosote or osmasalt treated southern yellow pine.

Designs for each State road project specify the type of guardrail to be installed. There is no choice here. However, in most cases, the contractor bidding for the project may choose and prepare his bid for either treated wood, primed steel, galvanized steel, or concrete guardrail posts to support this guardrail. Since the contractor chooses the type of post to be installed, it is apparent that he is primarily responsible for the fact that wood is no longer used for guardrail posts in West Virginia.

Since road-construction contracts are awarded on the basis of competitive sealed bids, the contractor must consider the comparative in-place costs of the four types of guardrail posts in making his choice. The study was designed in part to determine these costs.

Initial investigations determined that guardrail erection in West Virginia is generally subcontracted to one of four firms in the State who have the necessary equipment and experience to handle this type of work. Two of the firms are located in West Virginia; the other two are in neighboring states. Officials of each of these firms were personally interviewed in the spring of 1964 to determine their comparative in-place costs for the four types of guardrail posts as well as other factors affecting their choice of posts.

Results

The four firms interviewed accounted for virtually all of the guardrail erection contracted for by West Virginia in 1963. The work is usually contracted a year in advance, meaning that projects let in 1963 are accomplished during 1964. With the exception of one small job, all of the contractors bid steel guardrail posts. About 40 percent of the posts used in 1963 were primed steel and 60 percent were galvanized steel.

Contractors said that treated wood and concrete guardrail posts are generally set in the same manner. The procedure is as follows: a crew first lays out the posts at specified intervals along the installation site, a truck-mounted auger then drills the holes, the post is set in the hole, and the hole is backfilled with hand shovels and then tamped either by hand or machine. One contractor installs the wooden posts first and then slopes the top and drills for the rail, but wooden posts are usually purchased pre-drilled and sloped. All concrete posts are purchased pre-drilled and sloped.

A setting crew for wooden or concrete posts usually consists of seven or eight men. When unfinished wooden posts are used, an additional man is required to slope the tops, drill holes for the guardrail bolts, and treat these holes with a preservative. Three contractors indicated that

Table 1.—Comparative costs of treated wood, primed steel, galvanized steel, and concrete guardrail posts in West Virginia, 1964

(In dollars per post)

Item	Treated wood[1]		Primed steel[2]		Galvanized steel[3]		Concrete[4]	
	Average	Range	Average	Range	Average	Range	Average	Range
Purchase price[5]	2.50	2.50	4.84	4.75-5.00	5.68	5.25-5.85	3.75	3.25-4.50
Butt treating	—	—	.13	.09- .20	—	—	—	—
Painting	—	—	.12	.05- .20	—	—	—	—
Sloping & drilling	.26	.25- .29	—	—	—	—	—	—
Setting	2.03	1.87-2.35	.45	.35- .52	.45	.35- .52	2.03	1.87-2.35
Total	4.79	4.62-5.13	5.54	5.24-5.72	6.13	5.74-6.32	5.78	5.12-6.39

[1] Post dimensions: 7 inches at small end, length 6 feet. Treatment: 8 pounds per cubic feet creosote oil or .55 pounds retention dry cromated zinc chloride, pentachlorophenol, or osmosalt chemical.

[2] 8½ pounds per lineal foot.

[3] Weight of galvanizing—2 ounces per square foot.

[4] Reinforced and precast in accordance with designs.

[5] Delivered to the installation site.

a crew of this size generally sets 80 wooden or concrete posts per 8-hour day; one contractor said 100 posts per day.

In contrast, both primed and galvanized steel posts are nearly always set with a truck-mounted driver. Prior to driving, primed steel posts are butt-treated with an asphalt paint. The primed steel posts also require two coats of white paint after setting. Galvanized steel posts require no treatment or painting before or after erection.

A setting crew for steel posts generally consists of five or six men. A crew of this size usually sets about 240 steel posts per day. One contractor said that his daily production averages nearly 290 posts.

To summarize, it is apparent from the size of crew required and daily production rate that wooden and concrete posts cost considerably more to install than steel posts. Based on average crew wages and daily production, the average installation cost is $2.03 for a wooden or concrete post, but only 45c for a galvanized steel post and 70c for a primed steel post.

However, the initial cost of a treated wooden post is considerably less than for either of the other three types. And, despite higher setting costs, the total in-place cost of a treated wooden guardrail post is still approximately 75c to $1.34 less than the in-place cost of a primed steel, galvanized steel, or concrete guardrail post (table 1).

It should be noted that there were other cost factors that were not measured. Equipment costs as well as the rate at which the guardrail can be hung were considered equal for all four types of post. The contractors indicated that this assumption is generally true and were unable to provide meaningful cost differentials among the four types of post. Thus, the absolute costs reported in table 1 may vary but the relative cost relationships should hold true.

Discussion

It is apparent that the in-place cost of treated wood guardrail posts is considerably less than the in-place cost of any of the other three types of guardrail posts. Then why are all of the contractors using steel posts, not wood?

In answer to this question, all contractors stated that their choice of post is governed mainly by production considerations. Guardrail installation normally represents but a small portion of the total cost of the road project. The cost of installing guardrail posts is a less important consideration than integrating the installation job with the other necessary jobs in building a highway.

Guardrail erection is normally the last operation on a road project.

It is usually August before the guardrail subcontractor can begin erection work. And this work must be completed before inclement weather begins in November. Because of the greater time required to install wooden posts — and the increasing uncertainties involved, such as possible default of contract — the contractors apparently choose the type of post that can be installed most quickly in this short erection season.

Since speed of installation is the contractors' primary reason for using steel posts, efforts should be directed at improving setting techniques and increasing the number of wooden posts that can be set per day. None of the contractors have tried driving wooden posts. Perhaps at least some of the installations with more favorable driving conditions would permit driving wooden posts and a corresponding daily production increase. Although it is highly unlikely that the driving of wooden posts will ever equal the daily installation of steel posts, the elimination of one or two men from the setting crew could bring the comparative setting costs more in line.

There are other possibilities that should be investigated. Perhaps setting crews could be reorganized or enlarged. Or perhaps the use of additional crews or equipment is feasible to eliminate bottlenecks and speed up production.

Some contractors mentioned alignment difficulties with each of the different types of posts. Perhaps this problem could be alleviated by drilling the holes for the guardrail bolts and sloping the tops after the posts have been set. At this point, it should be noted that many technologists question the need for sloping well-treated wooden posts, at least in regard to durability. In addition to permitting an easier alignment of holes, this system would permit the post to be topped at the proper height in instances when the post could not be set to the desired depth. Wooden posts are clearly better suited than steel or concrete for field modifications of this type.

Finally, any extension of the guardrail-erection season should favor the use of wooden posts. The contractors indicated that they usually have slack periods during the spring and summer months and must schedule their operations as dictated by the prime contractor. If the guardrail subcontractor were given additional time to complete installations, his concern could switch to lower cost installations. And, for any one guardrail installation project, the use of treated wooden posts should result in lower costs. To accomplish this extension of contract time, closer cooperation between the prime contractor and the guardrail subcontractor is apparently needed.

These are some of the factors that could have a significant effect on the use of wooden guardrail posts in West Virginia. Additional research, perhaps even field tests and demonstrations, is needed to determine the feasibility of these various alternatives.

Literature Cited

1. Beaton, J. L., and R. N. Field.
   1959. DYNAMIC FULL SCALE TESTS OF MEDIAN BARRIERS. Calif. Div. Highways, 20 pp., illus.

2. Blew, J. Oscar Jr.
   1961. WHAT CAN BE EXPECTED FROM TREATED WOOD IN HIGHWAY CONSTRUCTION. U.S. Forest Serv. Forest Prod. Lab. Rpt. 2235, 16 pp., illus.

3. Hobbs, L. H.
   1962. USING WOOD FOR GUARDRAIL POSTS—AN ANALYSIS FOR THE NORTH CAROLINA STATE HIGHWAY AND PUBLIC WORKS COMMISSION. N. C. State College School Forestry, 23 pp.

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J. S. FOREST SERVICE RESEARCH NOTE NE-37

1965

Northeastern Forest

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Experiment Station

A FIELD TEST OF PROCEDURES FOR EVALUATING AND SCHEDULING WHITE-PINE WEEVIL CONTROL

Procedures have recently been developed that permit economic and biological information to be integrated in making decisions about the need for control against the white-pine weevil, and in scheduling control in young white pine plantations.[1] The procedures are based upon studies of the magnitude of economic losses that result from weevil attack in white pine and upon studies of the temporal and spatial pattern of weevil attack. The profitability of control can be determined by economic projections to maturity of values saved by control and of the costs of control.

The studies upon which the procedures are based were conducted in the last decade in New England, New York, and Pennsylvania. In 1964 a field test of the accuracy and applicability of these procedures throughout this area and Virginia was conducted by the Branch of Forest Pest Control (now Branch of Forest Protection), Eastern Region, U. S. Forest Service, in cooperation with several States, private individuals, and the Northeastern Forest Experiment Station.

Plots were established in 32 white-pine plantations. Data were collected in each stand on: site quality, tree height, height-growth rate, number of trees per acre, and the number of trees that had never been weeviled in each of the last 4 years. The proportion of never-weeviled trees was calculated for each year, 1961-64.

To use this method in making control decisions, a target height is selected up to which weeviling is to be prevented (one or two log lengths

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[1]Marty, Robert, and D. Gordon Mott. EVALUATING AND SCHEDULING WHITE-PINE WEEVIL CONTROL IN THE NORTHEAST. U. S. Forest Serv. Res. Paper NE-19, 56 pp., 1964. Northeast. Forest Expt. Sta., Upper Darby, Pa.

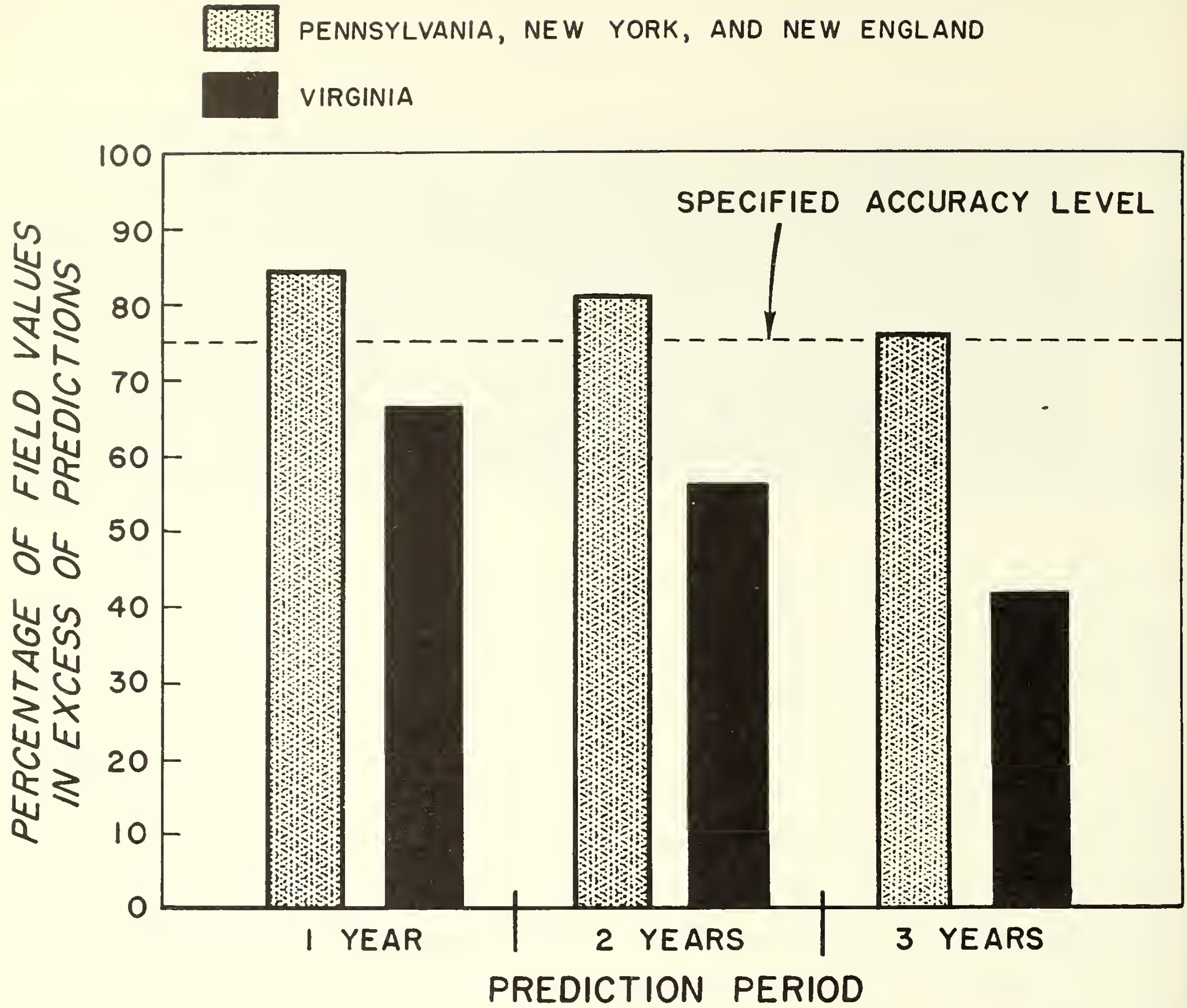

Figure 1.—Percentage of cases in which observed proportion of never-weeviled trees was greater than predicted proportions (75 percent is expected as a result of the accuracy level provided in the prediction tables).

plus an allowance for trim and weeviling) on a specified number of trees per acre. The number of years required for the stand to reach this target height is predicted from the current growth rate and present height.

Whether a sufficient number of unweeviled trees (specified as a management goal) will remain after this number of years as a result of the normal progress of the weevil infestation can be determined from a set of tables developed for this purpose. If the number of never-weeviled trees is predicted by the tables to fall below the number required, before these trees attain the target height, control is indicated. Alternatively, if a sufficient number of never-weeviled trees is predicted to survive to the target height, control is not needed. And if more than 5 years are predicted for the trees to grow to the target height, an evaluation must be made again in the future. The data collected in this field test permit the accuracy of these tables to be tested.

The tables prepared by Marty and Mott allowed one out of four predictions of the proportion of never-weeviled trees to be less than actual field experience. That is, three out of four field experiences would result in the survival of more than the predicted number of never-weeviled trees for each prediction period, and only one out of four would result in less than the predicted number. Prediction periods of 1, 2, and 3 years were used in this test of the method, in which predicted values were compared with the field record. The results are summarized in figure 1.

The predictions (fig. 1) were in close accord with the actual field-test results for New England, New York, and Pennsylvania. However, for Virginia the tables obviously do not predict actual field experience; and damage developed more rapidly than in the area for which the tables were designed.

For each of the 25 New England, New York, and Pennsylvania stands, the need for control and its profitability could be determined from the prediction tables developed by Marty and Mott. Management objectives vary among pine producers: rotation ages, stocking requirements at maturity, the bole length to which control is to be practiced, and the cost of control are by no means uniform. In these 25 stands, 200 unweeviled trees per acre — involving butt-log (18 feet total) protection only, and control costs of \$3, \$4, and \$6 per acre per treatment — were assumed as management conditions for purposes of comparison among the stands. The profitability of weevil control depends as well upon whether the investor is willing to accept projections that assume rising stumpage values or prefers to assume stable stumpage values.

Of the 25 stands, 4 presently contain less than the target number of never-weeviled trees. The outcome is uncertain in 8, and these will need future examination. Control is required in 11 within the next 5 years to maintain the required number of trees until target height is attained; and 2 of the stands will reach target height without requiring control.

In the 11 stands that require control action within the next 5 years, the profitability of control has been calculated. This will depend upon the form of ownership, whether stable or rising stumpage values are assumed, and the cost of control. Three combinations of ownership and stumpage-value assumptions have been made: public ownership with rising stumpage values, private ownership with rising stumpage values, and private ownership with stable stumpage values. In addition, three control costs have also been assumed (table 1).

In summary: the prediction tables proposed by Marty and Mott for use in evaluating and scheduling white-pine weevil control in young white

Table 1.—Distribution of 11 stands requiring weevil control, by profitability class, assuming a variety of ownerships, stumpage values, and costs of control treatment

Profitability class (rate of return on control costs)	Public ownership, rising stumpage, and treatment cost per acre of —			Private ownership, rising stumpage, and treatment cost per acre of —			Private ownership, stable stumpage, and treatment cost per acre of —		
	$3	$4	$6	$3	$4	$6	$3	$4	$6
6 percent or more	5	4	—	4	—	—	—	—	—
5 to 6 percent	5	4	—	1	4	—	4	—	—
4 to 5 percent	1	3	5	6	4	—	4	5	—
3 to 4 percent	—	—	4	—	3	8	3	3	4
Less than 3 percent	—	—	2	—	—	3	—	3	7

pine plantations have been tested on 32 stands throughout New England, New York, Pennsylvania, and Virginia. The tables correctly predict the course of weevil infestations within the confidence level specified in all of this area except Virginia. As a result of the evaluation in the stands for which the procedures are appropriate, roughly one-half of the stands were found to require control to achieve management objectives; and in all cases where it was needed, control would be profitable.

However, profitability varied from near zero to over 6 percent. The greatest return would be realized from the stands in public ownership with rising stumpage values and low control costs. In contrast, over half the stands (assuming private ownership, stable stumpage values, and high control costs — $6 per acre per treatment) would be expected to yield less than 3 percent profit.

The actual values saved by control ranged from $165 to $575 per acre. These amounts, of course, represent the percentage returns discussed above and must not be taken as indicative of present investment values. Further work is in progress to develop these procedures for natural stands of white pine and to improve the field sampling technique.

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J. S. FOREST SERVICE RESEARCH NOTE NE-38

1965

Northeastern Forest
Experiment Station

REST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

INSECT-INDUCED CRYSTALLIZATION OF WHITE PINE RESINS. I. WHITE-PINE WEEVIL[1]

In breeding programs designed to produce insect-resistant plants, a serious obstacle to progress often is the lack of efficient selection and testing criteria. Natural infestations of some insects are large and severe enough to allow selection of resistant plants directly from the natural plant population. However, the attacks of the white-pine weevil (*Pissodes strobi* Peck), the major pest of eastern white pine (*Pinus strobus* L.), are limited to a small proportion of the trees in a stand or plantation in any given year. Moreover, weevil attack is influenced by the interaction between several environmental factors and the growth rate of the tree. Yet a single successful attack during the first 15 or 20 years of a tree's life may ruin it for quality lumber production. Obviously a definite need exists for criteria by which the relative resistance of white pine trees to this insect can be determined.

Differences in the properties and quantities of the oleoresins produced by pines have long been thought to affect their resistance to certain insect pests. A copious flow of liquid resin seems to function as a defense against those insects that burrow into the tree's tissues. The manner in which such insects cope with these oleoresins is not clearly understood. However, two recent papers point up the possibility that a secretion from the insect may cause the resins to crystallize and thus be inactivated as a deterrent to attack.

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[1] See also: Santamour, Frank S. Jr. INSECT-INDUCED CRYSTALLIZATION OF WHITE PINE RESINS. II. WHITE-PINE CONE BEETLE. U. S. Forest Serv. Res. Note NE-39, 5 pp., 1965.

Harris (1960) collected small drops of vomitus from larvae of the European pine shoot moth (*Rhyacionia buoliana* Schiff.) and mixed this with resin (pine species and source of resin not specified). The mixture of vomitus and resin emulsified readily and hardened into crystals within a few hours. Untreated resin remained sticky for several weeks. Although resin crystallization in different pine species was not compared, it was suggested that the variation in susceptibility to attack may be related to the ease of resin emulsification.

Yates (1962) found that the resin exuded from the tips of cut branches of some pine species could be induced to crystallize by placing live larvae of two *Rhyacionia* species in the resin droplets. The resins of shortleaf and loblolly pines — species susceptible to attack by these tip moths — were readily crystallized, while resins of the resistant longleaf and slash pines showed no crystallization. Control tips of all species remained resinous after 24 hours. Although crystallization normally occurs more rapidly in the susceptible species, it was assumed that the faster-than-normal crystallization on the test tips was caused by the presence of the larvae. Yates stressed the implications of this phenomenon for insect control and the development of insect-resistant strains of pine. A further report on this work (Anonymous 1962) stated that the relationship between insect physiology and resin crystallization had not been determined.

In 1962, a study was begun by the Northeastern Forest Experiment Station to determine the extent to which oleoresin crystallization in various white pine species and hybrids might be induced by larvae of the white-pine weevil.

Materials and Methods

Trees used in this study were selected, mainly on the basis of availability, from ornamental specimens in the Philadelphia area, and from plantations established by the Northeastern Forest Experiment Station at Washington Crossing, New Jersey, and at Williamstown, Massachusetts. The older ornamental trees could not be rated accurately for past weeviling, and the New Jersey plantation was not subject to weevil attack. Therefore data on weeviling were obtained only from trees growing in Massachusetts.

Oleoresin was collected in June, in two ways: from the wood and from branch tips. Wood resin was obtained by drilling 5/8-inch holes slightly upward through the bark into the sapwood, and fitting glass vials into the holes to collect the resin. After 24 hours the vials were removed. Cortical or shoot resin was collected with an attenuated eye-dropper from freshly cut lateral branches of the current year. All collections were stored in stoppered glass vials at room temperatures, and were tested within 1 to 3 days.

It was assumed that the shoot resin from cortical resin canals of young branches would be more like the resin encountered by larvae in nature than would wood resin. Therefore the two types of resin were kept separate and were tested separately throughout the study.

Larvae of the white-pine weevil were collected from naturally-infested stems of eastern white pine and were utilized while still in a fresh condition. Larvae of other *Pissodes* species and hybrids were obtained from cultures maintained by the Station's Forest Insect Laboratory.

The experimental procedure was as follows. First, a large drop of resin was removed from the vial and placed on a clean glass slide by means of a glass rod. Next, the head and some adjoining thoracic tissue were removed from active larvae by means of a sterilized razor blade. This tissue was then placed in the resin and macerated and mixed with it, using the same glass rod. The slide was then placed in an electric oven at 100° F. and examined at various intervals. A control was used for each test.

In addition, some tests were conducted in which whole unmacerated larvae, larval skin, larvel guts, pupal heads, or fresh frass were used.

Nature and Behavior of Resins

Some background information about the resins themselves is appropriate before discussing the results of the tests with weevil larvae.

Oleoresin can be considered as a supersaturation of rosin in turpentine (Smith 1964). The rosin is composed chiefly of resin acids, and the natural crystallization of oleoresin is the result of precipitating resin acids out of solution. The resin acids are a related group of about 7 to 9 monobasic acids that have the empirical formula C_{20} H_{30} O_2. The degree of natural crystallization of oleoresin probably depends on both the total resin content and the proportions of the various acids in the mixture. Baldwin *et al* (1958) stated that crystallization of a given resin acid from rosin (residues left after steam distillation of turpentine) may occur when the resin acid makes up about 30 percent or more of the weight of the rosin. The crystallization of one acid will bring down other resin acids. Knowledge about the qualitative and quantitative relationship of resin acids is limited to the wood oleoresins of the chief turpentine-producing species (longleaf pine and slash pine). No information is available about resin acids in shoot resin. The resin-acid content of pine oleoresins deserves further study.

Natural crystallization.—Crystallization of oleoresin is a natural phenomenon that is expressed in varying degrees in most pine species. Wood resins of some hard pines (subgenus Diploxylon) are particularly precocious in this regard: crystallization may occur in collecting vials during a 24-hour collecting period. However, the wood resins of the soft or white pines seldom exhibit rapid crystallization: of 19 trees of 9 species from which wood resin was collected in this study, the resin from only one, a specimen of *P. parviflora* Seib. & Zucc. (Japanese white pine), showed crystallization during the first week after collection. Resin from another *P. parviflora* did not crystallize during 2 months' storage. Only six wood resins, representing five species, had crystals present after storage for 2 months.

Shoot resins, in contrast, tended to crystallize rapidly in storage. Crystals were observed in most shoot resins within 4 to 12 days after collection. However, no crystals were formed after 1 year in shoot resins of *P. griffithii* McClel. (Himalayan white pine), *P. koraiensis* Sieb. & Zucc. (Korean white pine), *P. peuce* Griseb. (Macedonian white pine) X *griffithii,* and *P. peuce* X *strobus;* and these resins did not react with crushed larval heads. Retarded natural crystallization (2 months) was noted in shoot resins of *P. flexilis* James (limber pine) and *P. ayacahuite* Ehrenb. (Mexican white pine) X *P. griffithii,* both of which showed moderate test crystallization. Thus it appears that the degree of insect-induced crystallization may be related to natural crystallization. Yates (1962) also found that species whose shoot resin crystallized more rapidly in nature gave stronger crystallization reactions under the influence of insects.

Solubility.—All of the wood oleoresins used in this study were completely soluble in methanol, ethanol, and acetone. However, the shoot resins did not all exhibit total solubility. When equal volumes of solvent were added to a sample of shoot resin, a white flocculent material began to settle out. This material did not dissolve completely even when the proportion of solvent to resin was as high as 10 to 1, although some resins were more soluble in acetone than in the other solvents. When the solvent was allowed to evaporate slowly in an open container, the white material redissolved in the resin. The nature of this white material is under investigation.

Monoterpenes.—Preliminary analyses for terpene composition were run by gas chromatographic methods on the shoot and wood resins of some of the trees used in the study. This work was done by Richard H. Smith of the U. S. Forest Service, Pacific Southwest Forest and Range

Table 1.—Monoterpene composition of shoot and wood oleoresins of two pine trees[1]

Component	*Pinus strobus* Wood	*Pinus strobus* Shoot	*P. griffithii* Wood	*P. griffithii* Shoot
	Percent	*Percent*	*Percent*	*Percent*
α—pinene	53.1	58.4	93.8	25.9
β—pinene	42.3	34.9	4.2	36.1
Δ—3—carene	—	—	.9	—
myrcene	1.2	1.0	.7	35.9
limonene	1.2	1.2	.4	—
camphene	1.7	3.5	—	.9
β—phellandrene	.4	1.0	—	1.2

[1] Data supplied by Richard H. Smith, Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service.

Experiment Station, Berkeley, California. Results for one eastern white pine and one Himalayan white pine are given in table 1.

In the eastern white pine, the two types of resin agree fairly closely in monoterpene composition. The shoot resins of four other eastern white pines, two of which were weeviled and two not weeviled, did not differ substantially in composition from the eastern white pine shoot resin. However, in the Himalayan white pine, the shoot resin differed markedly from the wood resin. The possibility that similar differences occur in other species or individuals suggests that published material on the turpentine composition of only the wood oleoresins of pines cannot be used in determining host-pest relationships for insects that primarily attack bark, buds, or perhaps even cones.

Results and Discussion

Crystallization reactions of the resins to the crushed heads or other parts of weevil larvae were observed and rated on a numerical scale after 4 hours. The ratings were as follows:

0—No crystals, or no increase in crystallization over the control.

1—Few crystals; resin clear and sticky.

2—About ¼ crystallized; resin clear and sticky.

3—About ½ crystallized; resin clear and sticky.

4—Some crystals; resins clear, hard, and dry.

5—Crystallization practically complete; resin white, opaque, hard, and dry.

Results of the tests with crushed larval heads in the resins of various white pine species and hybrids are given in table 2. Although not all shoot

Table 2.—Crystallization ratings of white pine resins after 4 hours' contact with crushed heads of weevil larvae

Species or hybrid,[1] *Pinus*—	Resin	
	Wood	Shoot
ayacahuite	0	5
cembra	0	—
flexilis	0	3
griffithii	0	0
koraiensis	0	0
monticola	0[2]	5
parviflora	0[2]	—
peuce	0, 2	5
strobus	0[2]	5[3]
ayacahuite X *strobus*	0	5
ayacahuite X *griffithii*	—	3
griffithii X *parviflora*	0	—
peuce X *griffithii*	—	0
peuce X *strobus*	—	0
strobus X *griffithii*	0	5
strobus X *parviflora*	—	5

[1] In hybrid combinations female parent is listed first.
[2] A few crystals were noted in 1 specimen after 24 hours.
[3] Variation among trees is discussed in the text.

resins crystallize under the test conditions, a much stronger tendency to crystallize was evident among the shoot resins than among the wood resins.[2]

Several of the species and hybrids (table 2) were represented by two or more trees. Responses of individual trees are noted only when the behavior of their resins differed from the general pattern.

Strong crystallization reactions were induced by pupal heads, larval skin, and fresh frass, as well as by larval heads of the weevil. A weak to moderate reaction (rating 2 to 3) was induced by larval guts.

When the whole live larvae were placed in drops of shoot resin of eastern white pine, limited crystallization occurred near the larvae but the resin was still sticky after 12 hours. No crystallization took place in a similar trial with shoot resin of Himalayan white pine.

Larvae of *Pissodes approximatus* Hopk. and of a hybrid weevil, *P. strobi* X *approximatus,* were used in standard tests on eastern white pine resins. Strong crystallization reactions occurred in shoot resin and weak reactions (rating 1 to 2) in wood resin. Larvae of *P. affinis* Rand. induced

[2] In limited tests, the wood resins of *Picea abies* (L.) Karst. (Norway spruce) and *P. asperata* Mast. were readily crystallized.

moderate crystallization (rating 3) in shoot resin and weak crystallization in wood resin of the tree hybrid *P. strobus* X *griffithii.*

Meaningful observations on natural resistance of exotic pine species to our native weevil have been hampered by the limited number of plantings within the optimum range of the insect, and by the imperfectly understood but probably important role that environment and growth rate may play in apparent resistance. Of the two species in which shoot oleoresin was tested and failed to crystallize, Himalayan white pine was considered to be fairly resistant by McAloney (1943) and by Wright and Gabriel (1959). However, Lemmien and Wright (1963) reported that this species was more heavily weeviled than eastern white pine in southern Michigan. *P. koraiensis* was considered to be less susceptible to weevil than eastern white pine (Wright and Gabriel 1959).

Two other species, *P. peuce* and *P. monticola* Dougl. (western white pine), have also been mentioned as possible genetic sources of resistance. Shoot oleoresins of both species were readily crystallized in the presence of crushed heads of weevil larvae. Moderate crystallization occurred in the resins of two trees of *P. flexilis,* a species that McAloney (1943) reported as commonly weeviled and Wright and Gabriel (1959) reported as seldom weeviled.

The lack of resin crystallization for two of the species hybrids deserves special mention. These two trees, both of which were derived from crosses on the same individual *P. peuce* and were growing near each other in Williamstown, Massachusetts, point up the fact that slow- or non-crystallizing resins do not always denote weevil resistance. One of the trees, a specimen of *P. peuce* X *strobus,* showed evidence of past unsuccessful weevil attack and might be considered resistant. The other tree, a hybrid of *P. peuce* X *griffithii,* had been weeviled four times since 1953.

Perhaps the only conclusion to be drawn from both the observational information on weeviling and the resin crystallization tests of exotic species is that much more work is needed. Since it is likely that resistance to weevil is an individual rather than a specific characteristic, large numbers of trees would have to be investigated and tested for resistance.

Shoot resin was collected from 11 eastern white pines in the present study. Eight of these trees were derived from controlled intraspecific crosses among known parents, and three were of unknown parentage. The eight trees were part of a 47-tree plantation of intraspecific hybrids, which have been studied in relation to weevil resistance (Santamour 1964). Six of the 47 trees had not been weeviled. The above-mentioned eight trees included the six unweeviled trees and two others that had been weeviled.

In the tests, both of these weeviled trees and three of the unweeviled ones showed maximum crystallization of shoot resins after 2 hours. The shoot resins of the three trees of unknown parentage, none of which had been weeviled, likewise crystallized readily. However, the other three unweeviled trees among the eight of known parentage gave test reactions rated 0, 1, and 2 after 4 hours and 1, 2, and 4 after 24 hours, thus showing some degree of resistance to insect-induced crystallization of their shoot resins.

The relationship between weevil-induced resin crystallization and known or suspected susceptibility to weevil attack is not clear. Although most of the trees whose resin did not crystallize in the test either had not been weeviled or showed evidence of past unsuccessful weevil attack, the crystallization-resistant *P. peuce* X *griffithii* hybrid was heavily weeviled. When shoot resin from this hybrid was being collected some branches were found that produced very little resin. It may be that the susceptibility of this tree is the result of low resin production under certain conditions. Although the data presented here are somewhat scanty, the study of the crystallization reaction and its causes offers a promising lead for further research.

Literature Cited

Anonymous.
1962. OLEORESIN CRYSTALLIZATION STUDY. U.S. Forest Serv. Southeast Forest Expt. Sta. Ann. Rpt. 1962: 58.

Baldwin, Doris E., Virginia M. Loeblich, and Ray V. Lawrence.
1958. ACIDIC COMPOSITION OF OLEORESINS AND ROSIN. Chem. & Eng. Data Ser. 3: 342-346.

Harris, P.
1960. PRODUCTION OF PINE RESIN AND ITS EFFECT ON SURVIVAL OF *Rhyacionia buoliana* (SCHIFF.) (LEPIDOPTERA: OLETHREUTIDAE). Canad. Jour. Zool. 38: 121-130.

Lemmien, Walter, and Jonathan W. Wright.
1963. HIMALAYAN WHITE PINE IN SOUTHERN MICHIGAN. Mich. Agr. Expt. Sta. Quart. Bul. 45: 618-621.

MacAloney, H. J.
1943. THE WHITE PINE WEEVIL. U.S. Dept. Agr. Circ. 221, 31 pp.

Santamour, Frank S., Jr.
1964. IS THERE GENETIC RESISTANCE TO WHITE PINE WEEVIL IN *Pinus strobus?* Northeast. Forest Tree Improve. Conf. Proc. 11: 49-51.

Smith, Richard H.
1964. VARIATIONS IN THE MONTERPENE COMPOSITION OF PONDEROSA PINE WOOD OLEORESIN. U.S. Forest Serv. Res. Paper PSW-15. 17 pp. Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif.

Wright, Jonathan W., and William J. Gabriel.
1959 POSSIBILITIES OF BREEDING WEEVIL - RESISTANT WHITE PINE STRAINS. U.S. Forest Serv. Northeast. Forest Expt. Sta. Sta. Paper 115, 35 pp.

Yates, Harry O., III.
1962. INFLUENCE OF TIP MOTH LARVAE ON OLEORESIN CRYSTALLIZATION OF SOUTHERN PINES. U.S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 174, 2 pp.

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U. S. FOREST SERVICE RESEARCH NOTE NE-39

1965

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

INSECT-INDUCED CRYSTALLIZATION OF WHITE PINE RESINS. II. WHITE-PINE CONE BEETLE

The white-pine cone beetle (*Conophthorus coniperda* (Schwarz)) can cause extensive damage to cones of eastern white pine (*Pinus strobus* L.) and can severely hamper natural reproduction of this species (Graber 1964). This insect also will be a potential pest of seed orchards for the production of genetically superior seed if and when such orchards are established. It may be assumed that in certain areas, and for certain purposes, these seed orchards will contain white pine species that are exotic to the Northeast, or are hybrids of *P. strobus* and exotic species. Knowledge about the relative vulnerability of non-native species to this insect is extremely limited.

It was noted, when dissecting beetle-infested conelets, that the resin appeared to be crystallized into small globules throughout the conelet. Several recent studies (Harris 1960; Yates 1962; Santamour 1965) have indicated that attacking insects may induce resin crystallization. Because of the possibility that the observed crystallization was caused by the insect and that differences in resin crystallization may be indicative of relative resistance to insect attack, a study was undertaken to determine the effect of the cone beetle on crystallization of the resins of a number of white pine species and hybrids.

Oleoresin from cortical canals of young shoots appeared to be similar to that found in the cortex of conelet peduncles, and therefore shoot oleoresin was used in this study. Both cortical resins were incompletely soluble (white flocculent material settled out) in methanol, ethanol, and acetone; whereas wood (xylem) resin was completely soluble (Santamour 1965).

Materials and Methods

Oleoresin was collected in April 1964 as it exuded from cortical resin ducts of freshly-cut 1-year-old branches. Generally this collection was made with an attenuated eye-dropper, but in certain free-flowing species the resin was simply allowed to drip into the collecting vial. Resin was stored in screw-capped glass vials at room temperature. One vial of each resin sample was left undisturbed for study of natural crystallization; resin from the other vial was used in the tests described below within 3 days after collection.

The trees from which oleoresin was collected included native eastern white pine from New Hampshire and a number of exotics and hybrids growing in plantations of the Northeastern Forest Experiment Station and the Cabot Foundation of Harvard University. The kind permission of the Cabot Foundation to use its exceedingly valuable material is gratefully acknowledged.

Conelets of native white pine that were infested with the cone beetle were collected in November 1963 from the ground beneath an open stand of this species in New Salem, Massachusetts. The conelets were stored in a paper bag in a refrigerator. Conelets were broken apart manually to collect the beetles, and only those beetles that were alive and uninjured were used in the experiments.

Tests of insect-induced crystallization were made by macerating the severed head and thorax of the adult beetle in a drop of resin on a clean glass slide. The slide was then incubated at 100° F. and test reactions were determined after 4 hours. Slides bearing a drop of untreated resin were included in each test as controls. In addition, the whole live beetle, macerated abdomen, and frass from fresh attacks were used in resin of *P. strobus* and *P. griffithii* McClel. (Himalayan white pine). A positive test was one in which the resin crystallized into a hard, white, dry mass within 4 hours.

Several tests of beetle attack were also made in the laboratory. For these tests, freshly-cut pine branches bearing 1-year-old conelets were placed with their bases in water, and healthy adult beetles were liberated in the area around the conelet.

The beetles were not separated by sex for either the crystallization tests or the attack studies. Godwin and ODell (1965) found that although males did not initiate attacks in the spring, young males that had not overwintered were as likely to initiate attacks in the summer as were young females. The male-female sex ratio (1:2) found by Godwin and ODell in overwintered conelets would suggest that more females than males were used in the present tests.

Results and Discussion

The results of crystallization tests of macerated beetle heads (and thoraxes) on shoot resins of various white pine species and hybrids are given in table 1. Generally, only one tree of a given species or hybrid was used in the tests. Exceptions were *P. strobus* (6 trees); *P. peuce* Griseb. (Macedonian white pine) (2 trees); and *P. peuce* X *strobus* (5 trees).

Macerated head and thorax, macerated abdomen, whole live beetle, and fresh frass were equally effective in inducing crystallization of *P. strobus and P. griffithii* resin. However, crystallization induced by whole beetles was limited to the area around the beetle.

All the resins that crystallized in the presence of cone beetles—with one exception—also crystallized during undisturbed storage. Yates

Table 1.—*Occurrence of natural and insect-induced crystallization of white pine shoot resins*

Species or hybrid, *Pinus*—	Natural crystallization	Test crystallization
Series Cembrae:		
koraiensis	0	0
Series Flexiles:		
flexilis	0	0
reflexa	0	0
armandi	0	0
Series Strobi:		
ayacahuite	+	+
griffithii[1]	+	+
lambertiana[1]	0	0
monticola	0	0
parviflora	+	+
peuce[1] (2 trees)	0,0	0,0
strobus (6 trees)	+,+,+,+,+,+	+,+,+,+,+,+
ayacahuite X O.P. (probably *monticola*)	0	+
ayacahuite X *strobus*	+	+
peuce X *griffithii*	0	0
peuce X *strobus* (5 trees)	0,0,+,+,+	0,0,+,+,+
monticola X *parviflora*	+	+
monticola X *strobus*	+	+
strobus X *griffithii*	+	+

[1]Grafted on *P. strobus*.

[2]Female parent is listed first in hybrid combinations.

(1962) and Santamour (1965) have previously pointed out that resins that have a tendency toward natural crystallization also crystallize more readily in the presence of insects. The one exception to this generalization was a single individual of an open-pollinated progeny of *P. ayacahuite* Ehrenb. (Mexican white pine) that, upon morphological examination, was determined to be a hybrid with *P. monticola* Dougl. (western white pine). The relationship between natural and induced crystallization is not clear at present.

All of the pine species whose resin crystallized in the present tests belonged to the series Strobi of the pine subgenus Haploxylon. Of the non-reactive species in this series, *P. lambertiana* Dougl. (sugar pine) has not been successfully crossed with any other member in the series and does not grow well in the Northeast. *P. monticola* has been grown to a small extent in the Northeast and hybrids between this species and *P. strobus* have shown many desirable traits. However, the resistance of *P. monticola* to insect-induced resin crystallization was not exhibited in the control-pollinated hybrids that were tested. On the other hand, *P. peuce* appeared to be capable of transmitting its crystallization resistance to its interspecific progeny. Four of the five *P. peuce* X *strobus* hybrids tested were siblings from the same non-crystallizing female parent, and the resin from two of these did not crystallize. The same *P. peuce* female was also involved in the hybrid *P. peuce* X *griffithii,* the resin of which also resisted crystallization in the tests.

In the laboratory tests with live beetles on pine branches bearing 1-year-old conelets, several successful attacks occurred. Of four beetles placed on fresh branches of *P. strobus* on April 13, 1964, one beetle started to enter the base of a conelet almost immediately, and had completely disappeared in 3 hours. By the next morning, another beetle had entered the base of a peduncle. Successful attacks also were made on conelets of two *P. peuce* X *strobus* hybrids after the branches had been in the laboratory for 3 days. The resin of one of these hybrids crystallized readily in the standard test and also showed natural crystallization; the resin of the other hybrid did not crystallize under either circumstance. However, we cannot be sure that either the attacks or the behavior of the resins in these hybrids was strictly normal because of the possibility that the branches underwent physiological disturbances during the 3-day test period. Such disturbances, if they occurred, could have resulted in abnormal host-pest relationships. None of the attacking beetles emerged during the 2 weeks when the branches were kept under observation.

It is not known whether the insect-induced crystallization reaction of shoot resins indicates resistance to the white-pine cone beetle or not. However, the results suggest that at least two of the species (*P. monticola* and *P. peuce*), which should be used extensively in any breeding program for resistance to the white-pine weevil, may also contribute some degree of resistance to the white-pine cone beetle.

Literature Cited

Graber, Raymond E.
1964. Impact of the white-pine cone beetle on a pine seed crop. Jour. Forestry 62: 499-500.

Godwin, P. A., and T. M. ODell.
1965. The life history of the white-pine cone beetle, Conophthorus coniperda (Schwarz). Ent. Soc. Amer. Ann. 58: 213-219, illus.

Harris, P.
1960. Production of pine resin and its effect on survival of Rhyacionia buoliana (Schiff.) (Lepidoptera : Olethreutidae). Canad. Jour. Zool. 38: 121-130.

Santamour, Frank S., Jr.
1965. Insect-induced crystallization of white pine resins. I. White-pine weevil. U.S. Forest Serv. Res. Note NE-38, 8 pp. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Yates, Harry O., III.
1962. Influence of tip moth larvae on oleoresin crystallization of southern pines. U.S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 174, 2 pp.

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J.S. FOREST SERVICE RESEARCH NOTE NE-40

1965

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

PRE-COMMERCIAL THINNING NOT RECOMMENDED FOR VIRGINIA PINE STANDS IN SOUTHERN MARYLAND

Virginia pine *(Pinus virginiana* Mill.) normally develops such dense stands on suitable sites, as in old fields, that thinning would seem to be a good silvicultural practice. Seedling stands may have 10,000 or more stems per acre, and stands 20 years old may still contain 2,000 trees. Even though rapid differentiation of crowns occurs in this intolerant species, resulting in early suppression of many stems and much mortality, thinning still might be expected to favor the development of greater volumes or more valuable products.

However, the results from past studies of thinning Virginia pine have been somewhat conflicting, and consequently do not provide firm guides to desirable types of thinning, or even to the advisability of thinning. In North Carolina, Slocum and Miller (1953) released 6-year-old crop trees and 9 years later found that they contained more than twice the volume of unreleased crop trees. But after a 15-year-old stand was thinned, little difference in the growth of released and unreleased crop trees occurred in 14 years. Several other authors (Bramble 1953, Whitesell and Pickall 1956, and Williamson 1953) also concluded that thinning had to be done while stands were young if any appreciable growth response were to be obtained.

In contrast, Rushmore[1] thinned 15-, 25-, and 30-year-old stands and got not only a growth response, but essentially the same response, at all three ages — about 0.4 inch more radial increment in 10 years in released than in unreleased crop trees. And in Virginia, Hoekstra and Hutchinson

[1] Rushmore, F. M. THINNING VIRGINIA PINE IN MARYLAND — A 10-YEAR EXPERIENCE. Unpublished report, Northeast. Forest Expt. Sta., 1949.

(1963) found that the first-year responses in diameter growth of released Virginia pines 10-14, 15-19, 20-24, and 25-29 years old were comparable, varying only between 0.05 and 0.07 inch among all the sampled ages.

Even if individual-tree responses were similar over a range of ages, the overall effects of thinning ordinarily would differ with stand age because of varying amounts of storm damage. Windthrow is particularly common in partially cut stands of pole-size or larger Virginia pine. Thinned stands of sapling-size trees are highly susceptible to damage by ice or wet snows. Consequently, the results reported by some authors (Slocum and Miller 1953, and Fenton and Bond 1964) suggest that, if thinning is to be done in Virginia pine, only pre-commercial thinning at an early age — preferably around 5 to 7 years — should be considered.

To provide some additional information on the response of young Virginia pine stands to thinning, the Maryland Department of Forests and Parks and the Northeastern Forest Experiment Station started a study in Maryland's Cedarville State Forest in 1953, using stands 7 and 17 years old. In both age classes thinning to 900 trees per acre versus no thinning was compared. Methods and 10-year results are summarized below.

Study Methods

Blocks of plots were located in well-stocked pure stands of both ages on well-drained sandy loam soils. At the start of the study the 17-year-old stand contained about 2,900 stems per acre and the 7-year-old stand about 9,500 stems per acre.

When the treated plots were thinned to 900 trees per acre, the resultant spacing was about 7 feet. Residual trees were at least codominant before thinning. Cut stems were lopped and the slash was scattered. In the control plots an equal number of trees in the dominant-codominant crown classes were marked for future comparisons of mortality and growth.

The plots in both stands were small, and they were clustered rather than randomized by treatment. In the 17-year-old stand a group of four 0.05-acre plots, with a 0.5-chain isolation strip around each one, was thinned; four untreated plots of the same size were in a group 1 chain away. The arrangement in the 7-year-old stand was similar, except that only two treated plots and two check plots were established.

Diameters (b.h.) of crop trees were measured to the nearest 0.1 inch at the time of establishment and after 5 and 10 years. Heights of the 10 tallest crop trees per plot (equivalent to 200 trees per acre) were measured in each plot of the 7-year-old stand in each tally, but only in the 10-year remeasurement of the older stand. In the last tallies, some of the

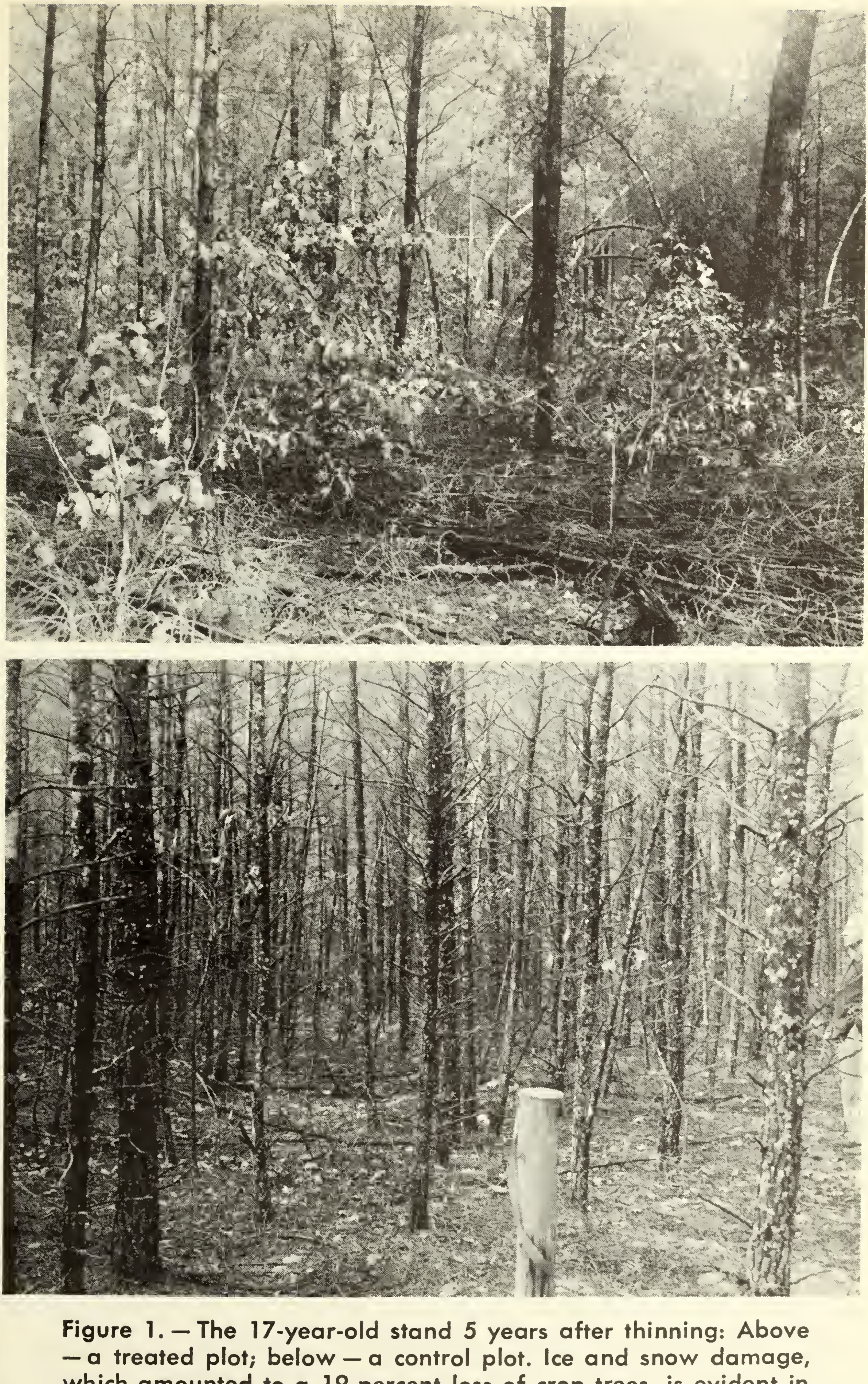

Figure 1. — The 17-year-old stand 5 years after thinning: Above — a treated plot; below — a control plot. Ice and snow damage, which amounted to a 19-percent loss of crop trees, is evident in the thinned plot and absent in the other. Note also that a hardwood understory has developed in the thinned plot but not in the unthinned plot.

larger trees that had not been originally selected in the control plots were also measured.

The data have been summarized on the basis of 900 and 200 crop trees per acre. The 900 stems are roughly equivalent to the stocking in stands when harvested for pulpwood, and 200 is about the number of trees that would be left if allowed to grow to sawlog size.

Mortality

The 10-year mortality among the 900 crop trees in the 17-year-old thinned stand was severe, averaging 31 percent as compared with 14 percent in unthinned controls. More than half of the loss in the thinned plots occurred in the first 5 years, and most of it was due to destructive weather (fig. 1). In the control plots all the mortality of selected trees occurred in the second 5-year period and is attributed to competition.

In the 7-year-old stand, losses in the thinned plots were only 4 percent during the 10-year period. The four trees that comprised this loss were clustered, which suggests bark beetles as the probable cause of death. In contrast, the 10-year losses among selected trees in the control plots were equivalent to 270 trees per acre, or 30 percent. Less than one-fourth of this mortality occurred during the first 5 years.

The comparative mortality of crop trees in our thinned stands agrees with the findings of Slocum and Miller (1953) in North Carolina. They concluded that thinning is not practical in stands 12 or more years old, largely because of the hazards of ice and wind damage.

Diameter and Basal-Area Growth

900 crop trees per acre. — Surviving crop trees in the 17-year-old stand made 50 percent more diameter growth during the 10-year period in the thinned plots than in the unthinned ones (1.5 inches versus 1.0 inch). However, because of greater mortality in the thinned plots, basal-area growth of the crop trees did not differ appreciably on a per-acre basis: 25.1 versus 22.8 square feet per acre for thinned and unthinned plots, respectively (table 1, A).

In the 7-year-old stand the situation was reversed: here the high mortality was in the check plots. As in the 17-year-old stand, the trees in the thinned plots gained appreciably more in diameter in 10 years than the selected crop trees in the check plots — 2.3 inches versus 1.7 inches (table 2, A).

However, many of the originally selected trees in the check plots were

Table 1. — Ten-year changes on thinned and unthinned plots in a 17-year-old Virginia pine stand

(Based on a stocking of 900 crop trees per acre after thinning and an equal number of comparable trees marked on the unthinned plots: A — in terms of all survivors among the selected crop trees; B — in terms of the 200 largest trees per acre)

Stand age	Thinned			Unthinned		
	Trees per acre	Average diameter (b.h.)	Basal area per acre	Trees per acre	Average diameter (b.h.)	Basal area per acre
Years	*No.*	*Inches*	*Sq. ft.*	*No.*	*Inches*	*Sq. ft.*
		A. 900 CROP TREES PER ACRE				
17	900	3.2	49.6	900	3.0	45.0
22	725	4.2	69.3	900	3.6	64.0
27	625	4.7	74.7	775	4.0	67.8
10-year changes:	—275	1.5	25.1	—125	1.0	22.8
		B. 200 LARGEST TREES PER ACRE				
17	200	4.1	18.6	200	4.0	17.0
22	200	5.4	31.8	200	4.8	25.1
27	200	5.9	37.7	200	5.2	29.7
10-year changes:	0	1.8	19.1	0	1.2	12.7

not among the largest trees 10 years later. When we disregard the original selections and pick the largest trees in numbers to match survival in the thinned plots (860 trees per acre), we find that these trees had grown fully as well as the thinned ones. Their average 10-year increase in diameter was 2.3 inches — the same as for the thinned trees. And their increase in basal area per acre was 52.8 square feet — slightly more than the 50.5 square feet registered by the thinned trees. Thus, despite the apparent growth benefits from thinning, when thinned and unthinned stands as a whole are compared, thinning did not result in any real gain.

200 largest trees per acre. — The 200 largest trees per acre (at the time of each tally) showed greater average response to thinning than did all survivors of the 900 trees per acre. Mortality was not a factor when considering the 200-tree group. Consequently, in the 17-year-old stand, the 10-year growth in both diameter per tree and basal area per acre was

Table 2. — Ten-year changes on thinned and unthinned plots in a 7-year-old Virginia pine stand

(Based on a stocking of 900 crop trees per acre after thinning and an equal number of comparable trees marked on the unthinned plots: A — in terms of all survivors among the selected crop trees; B — in terms of the largest 200 trees per acre among original selections)

	Thinned			Unthinned		
Stand age	Trees per acre	Average diameter (b.h.)	Basal area per acre	Trees per acre	Average diameter (b.h.)	Basal area per acre
Years	*No.*	*Inches*	*Sq. ft.*	*No.*	*Inches*	*Sq. ft.*
		A. 900 CROP TREES PER ACRE				
7	900	1.2	6.8	900	1.4	10.2
12	860	2.7	35.0	840	2.6	31.6
17	860	3.5	57.3	630	3.1	33.2
10-year changes:	—40	2.3	50.5	—270	1.7	23.0
		B. 200 LARGEST TREES PER ACRE				
7	200	1.6	2.6	200	1.9	4.1
12	200	3.4	12.7	200	3.6	14.1
17	200	4.4	21.4	200	4.3	20.0
10-year changes:	0	2.8	18.8	0	2.4	15.9

about 50 percent more in the treated plots than in the controls (table 1, B). Differences in the 7-year-old stand were much less — only about 16 percent more in diameter growth and 18 percent more in basal-area growth in the treated plots (table 2, B).

Differences in height growth in this stand were minor: the thinned trees increased from 13.2 to 27.5 feet in the 10-year period, and the unreleased trees increased from 14.0 to 29.6 feet.

Discussion and Conclusion

The results from this study do not warrant a recommendation for thinning Virginia pine stands at either of the represented ages. In the stand thinned at 17 years, the individual trees showed an appreciable increase in growth, but on a per-acre basis this response was offset by greater mortality on the thinned areas, largely because of lowered resistance to storm damage. In the younger stand, the trees of the thinned plots and the largest trees of the unthinned plots did not differ much in either individual diameter growth or basal-area growth per acre. In view of these results and the fact that Virginia pine is primarily a pulpwood species, non-commercial thinnings such as were made in this study do not seem to be justified in similar dense stands of southern Maryland.

Militating further against thinning is the increased development of hardwood understories when the pine overstory is reduced, as is evident in figure 1. This would definitely increase the cost of reproducing pine after harvest cutting.

Literature Cited

Bramble, William C.
1953. Early thinnings of Virginia pine. Pa. State Forest School Res. Paper 19, 4 pp., illus.

Fenton, Richard H., and Adna R. Bond.
1964. The silvics and silviculture of Virginia pine in southern Maryland. U. S. Forest Serv. Res. Paper NE-27, 37 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Hoekstra, P. E., and J. G. Hutchinson.
1963. First-year results indicate Virginia pine responds to thinning. U. S. Forest Serv. Res. Note SE-14, 2 pp., illus. Southeast. Forest Expt. Sta., Asheville, N. C.

Slocum, G. K., and W. D. Miller.
1953. Virginia pine. N. C. Agr. Expt. Sta. Tech. Bul. 100, 52 pp., illus.

Whitesell, C. D., and A. J. Pickall.
1956. The present status of Virginia pine and Virginia pine-hardwood management in Maryland. Md. Dept. Res. and Ed. Ref. 56-8. 7 pp.

Williamson, M. J.
1953. Young Virginia pine responds to thinning and pruning. Jour. Forestry 51: 129.

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U.S. FOREST SERVICE RESEARCH NOTE NE-41

1965

Northeastern Forest

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY, PA.

Experiment Station

SUSTAINED WINTER STREAMFLOW FROM GROUNDMELT

The watersheds of the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire are among the few small gaged watersheds for which continuous winter streamflow records are obtained while deep snow covers the area. Records show that a remarkably steady flow of between 0.006 and 0.025 area-inch of water per day leaves the watershed in spite of snow depths up to 6 feet and air temperatures often continuously below 10°F. Wisler and Brater (1959) stated that streamflow of about 0.01 area-inches/day (0.025 cm/day) arises from groundmelt, which is defined as melt of snow by heat transferred from the soil to the bottom surface of the snowpack. Gold (1957) gave measured soil-heat flux data corresponding to a groundmelt of 0.071 cm/day under about 12 inches of snow for February and March 1955 at Ottawa, Ontario. Calculations from soil temperature gradients and thermal conductivity led to groundmelt estimates of 0.01 to 0.02 inches/day at the Central Sierra Snow Laboratory (Corps Engineers, 1956). This note presents data verifying the groundmelt theory for Hubbard Brook.

Sustained Winter Streamflow

The gaged Hubbard Brook watersheds range in size from 30 to 200 acres and have a forest cover of second-growth northern hardwoods. Winter hydrographs show a steady, low-volume streamflow through even the coldest, snowiest winters. Table 1 shows daily streamflow in area-inches for Hubbard Brook watersheds 1 and 3 for the winters of 1961 and 1963, in which no midwinter thaw occurred. Streamflow on the two watersheds is consistent on a unit-area basis even though watershed 1 is 29.2 acres and watershed 3 is 104.7 acres in size. Snow depth was about 20 inches

Table 1. — **Measured streamflow on Hubbard Brook watersheds 1 and 3, in inches/day**

Date	1961		1963	
	Watershed 1	Watershed 3	Watershed 1	Watershed 3
Jan. 5	0.015	0.015	0.015	0.015
Jan. 15	.012	.011	.015	.015
Jan. 25	.010	.008	.012	.015
Feb. 5	.006	.007	.012	.013
Feb. 15	.007	.008	.012	.013
Feb. 25	.188*	.204*	.012	.015
Mar. 10	—	—	.012	.013
Mar. 20	—	—	.023*	.022*

* Beginning of snowmelt period.

throughout January and early February 1961 and ranged from 15 inches in early January 1963 to 50 inches by mid-March.

The steep watersheds, shallow soils, and tight bedrock preclude the existence of extensive groundwater bodies, so it is not likely that this sustained flow arises from groundwater (Hewlett and Hibbert, 1963).

It is logical that this water originates as groundmelt of the snow pack. Because the soil is warmer at increasing depths in the winter, heat is conducted up to the soil surface, where it is used to melt snow. Since these soils are nearly always saturated by autumn rain, the snowmelt water passes through the soil and reaches the stream. Flow of water in the soil is not impeded by concrete frost formation because this type of frost is practically non-existent (Hart, Leonard, and Pierce, 1962).

If the groundmelt theory is correct, the measured streamflow should be equal to the heat flux from the ground minus the heat flux up through the snow, all divided by the heat of fusion of water. The heat fluxes are the products of the respective temperature gradients and thermal conductivities.

Soil Temperature Profiles

Soil-temperature profiles have been obtained near the foot of watersheds 1 and 3 at weekly intervals throughout the year for several years. These temperatures have been measured with thermistors to the nearest Fahrenheit degree at seven depths and at two separate locations.

Figure 1 presents profiles (average of both locations) obtained in 1961 and in 1963. A straight line has been drawn through the points (except 36 inches) for each date. The slopes of these lines represent the average temperature gradient, which does not change too much in the winter months with depth or with time. The February 11, 1963, gradient of about 0.25° F./inch or 0.05° C./cm can be chosen as typical of this data.

Soil-Heat Flux

The thermal conductivity of a soil can be calculated by the method given by DeVries (1963). If we assume a soil temperature of 2° C. and volume percentages appropriate to Hubbard Brook as follows: quartz 20%, other minerals 25%, water 15%, air 40%, then the thermal conductivity will be 1.97×10^{-3} cal cm^{-1} sec^{-1} $°C^{-1}$. If we use a temperature gradient of 0.05° C./cm, a heat of fusion of 80 cal/g — and with 86,400 sec/day — we have an equivalent melt by soil conduction $= 0.05 \times 1.97 \times 10^{-3} \times 86{,}400/80 = 0.106$ cm of water/day. The melt contribution of stored heat resulting from gradual lowering of soil temperature can be estimated using a heat capacity of 0.38 cal cm^{-3} $°C^{-1}$ (DeVries) and a temperature drop of 1° F. in the top 20 inches in 30 days, or 0.55° C. in 50 cm in 30 days. Thus the equivalent melt is $0.55 \times 50 \times 0.38/(30 \times 80) = 0.004$ cm/day, which is a small but significant contribution.

The heat lost upward through the snowpack when the air temperature is less than 32° F. can be calculated for a typical condition by using a

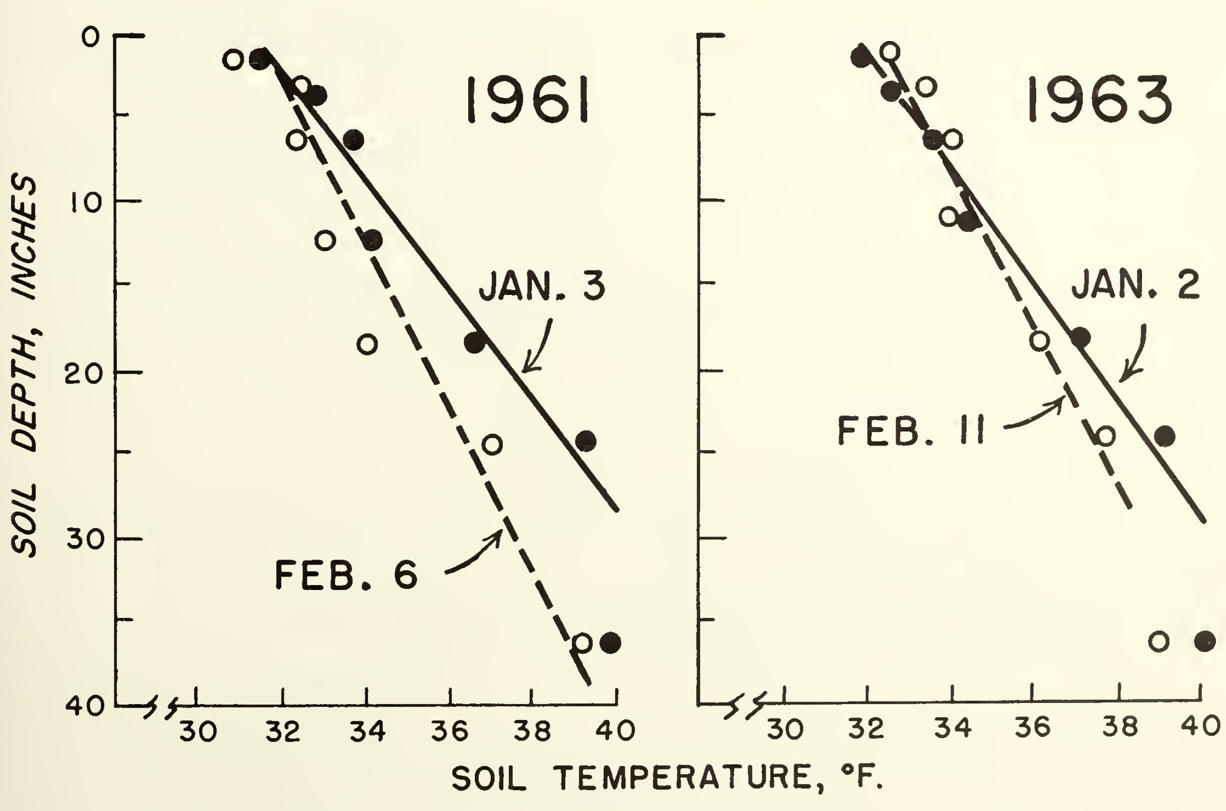

Figure 1. — Soil temperatures at various depths under snow.

thermal conductivity of 0.00032 cal cm^{-1} sec^{-1} $°C^{-1}$ for a snow density of 0.2 (DeVries). An air temperature of 14° F. (10° C. temperature difference) above 30 inches (75 cm) of snow gives an amount of melt which does not occur, since the heat is lost by conduction through the snow, of $0.32 \times 10^{-3} \times 10 \times 86{,}400/(75 \times 80) = 0.046$ cm/day.

The fraction of the soil-heat flux lost by snow conduction can vary from 0 to 1 with variations in snow depth and density and air temperature. The remainder is used in groundmelt. In normal years the heat flux from the ground decreases as the ground cools and the temperature gradient decreases (fig. 1). In 1963, increasing snow depth reduced the fraction of heat lost to the air and increased the fraction for groundmelt, which tended to maintain a constant amount of groundmelt. In 1961, the unusually shallow snowpack allowed the groundmelt fraction of the heat supply to remain constant instead of increasing; thus, as the total heat supply decreased, groundmelt and streamflow decreased.

Our groundmelt approximation from thermal considerations is $0.106 + 0.004 - 0.046 = 0.066$ cm/day. Measured streamflow of 0.015 inch/day or 0.038 cm/day is comparable. Considering the nature of the estimates made in the temperature-profile method, these values are as close as can be expected. Sustained winter streamflow can here certainly be explained by groundmelt of the snow cover.

Literature Cited

DeVries, D. A.
1963. THERMAL PROPERTIES OF SOILS. *In* Physics of plant environment, W. R. van Wijk, ed., pp. 210-235. John Wiley & Sons, New York.

Gold, L. W.
1957. INFLUENCE OF SNOW COVER ON HEAT FLOW FROM THE GROUND. Proc. Internatl. Assoc. Sci. Hydrol. 11th Gen. Assembly, Toronto, 4: 13-21.

Hart, George, Raymond E. Leonard, and Robert S. Pierce.
1962. LEAF FALL, HUMUS DEPTH, AND SOIL FROST IN A NORTHERN HARDWOOD FOREST. U. S. Forest Serv. Northeast. Forest Expt. Sta. Res. Note 131, 3 pp.

Hewlett, John D., and Alden R. Hibbert.
1963. MOISTURE AND ENERGY CONDITIONS WITHIN A SLOPING SOIL MASS DURING DRAINAGE. Jour. Geophys. Res. 68: 1081-1087.

United States Corps of Engineers.
1956. SNOW HYDROLOGY. U. S. Army Corps Engin., North Pacific Div., Portland, Oreg., pp. 176-179.

Wisler, C. O., and E. F. Brater.
1959. HYDROLOGY. 408 pp. John Wiley & Sons, New York.

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. S. FOREST SERVICE RESEARCH NOTE NE-42

1965

Northeastern Forest

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Experiment Station

ADDITION OF PHOSPHORUS TO SUBSOIL PROMOTES ROOT DEVELOPMENT OF YELLOW BIRCH

Pot-culture studies have indicated that roots of yellow birch (*Betula alleghaniensis* Britton) develop more prolifically in humus than in sandy mineral soil (Hoyle 1965; Winget *et al.* 1963; Redmond 1954; and Tubbs 1963). This situation has also been observed during root-excavation studies (Redmond 1957; Spaulding and MacAloney 1931). Results of these studies generally indicated that soil temperature, soil moisture, and bulk density were not limiting factors in mineral horizons. Better root development in humus, and in mineral soil with high organic matter content, suggested that nutrient conditions were critical in sands. However, Tubbs (1963) did not obtain a rooting response after fertilizing mineral soil.

The problem remained: to clarify whether or not subsoil nutrient deficiency inhibits root development of yellow birch. The purpose of the work reported here was to study how root development of yellow birch in a sandy subsoil is affected by nitrogen (N), phosphorus (P), and potassium (K) in the presence or absence of limestone.

Methods

Plastic pots were filled with B_{23} horizon material collected from a Hermon soil under second-growth northern hardwoods on the Bartlett Experimental Forest in the White Mountains of New Hampshire. The Hermon soil is a well-drained sandy loam developed from granitic till. The subsoil is very acid, high in exchangeable aluminum, and low in clay and exchangeable bases. For a more detailed description of this soil see Hoyle (1965).

Combinations of nutrient salts were prepared for two series of pots. Dolomitic limestone was mixed with soil in half the pots at the rate of 2,000 pounds/acre. This gave a limed and unlimed series of pots variously treated with nitrogen, phosphorus, and potassium (table 1). Nitrogen was supplied as NH_4Cl (320 pounds N/acre), phosphorus as NaH_2PO_4 (187 pounds P/acre), and potassium as KCl (363 pounds K/acre). Salts for each treatment were weighed and dissolved in 250 ml. of distilled water.

Three yellow birch seedlings with four true leaves present were lifted from germination trays and planted in each pot. The pots were set under artificial lighting (cool-white fluorescent plus incandescent) using a 21-hour photoperiod.

Soil moisture was maintained at field capacity with distilled water.

Table 1.—*Schedule of nutrient salt treatments*

Limed series	Unlimed series	Treatment designation
NPK	NPK	Complete
NP	NP	Minus K
NK	NK	Minus P
PK	PK	Minus N
None	None	Check

Table 2.—***Height and weight of yellow birch seedlings grown in Hermon subsoil variously treated with nitrogen (N), phosphorus (P), and potassium (K)***

Nutrient treatment	Average height[1] of stems	Total weight[1] of stems/pot	Total weight[1] of roots/pot
	mm.	*mg.*	*mg.*
Unlimed series			
NPK	73.3	108.0	213.2
NP	61.3	54.0	112.3
NK	58.3	70.5	75.7
PK	88.3	217.5	683.1
Check	54.7	53.2	82.1
Limed series			
NPK	140.0	362.0	784.5
NP	82.7	167.4	216.4
NK	48.3	40.0	63.2
PK	102.7	425.2	894.4
Check	62.7	94.0	124.7

[1] Basis: 3 seedlings.

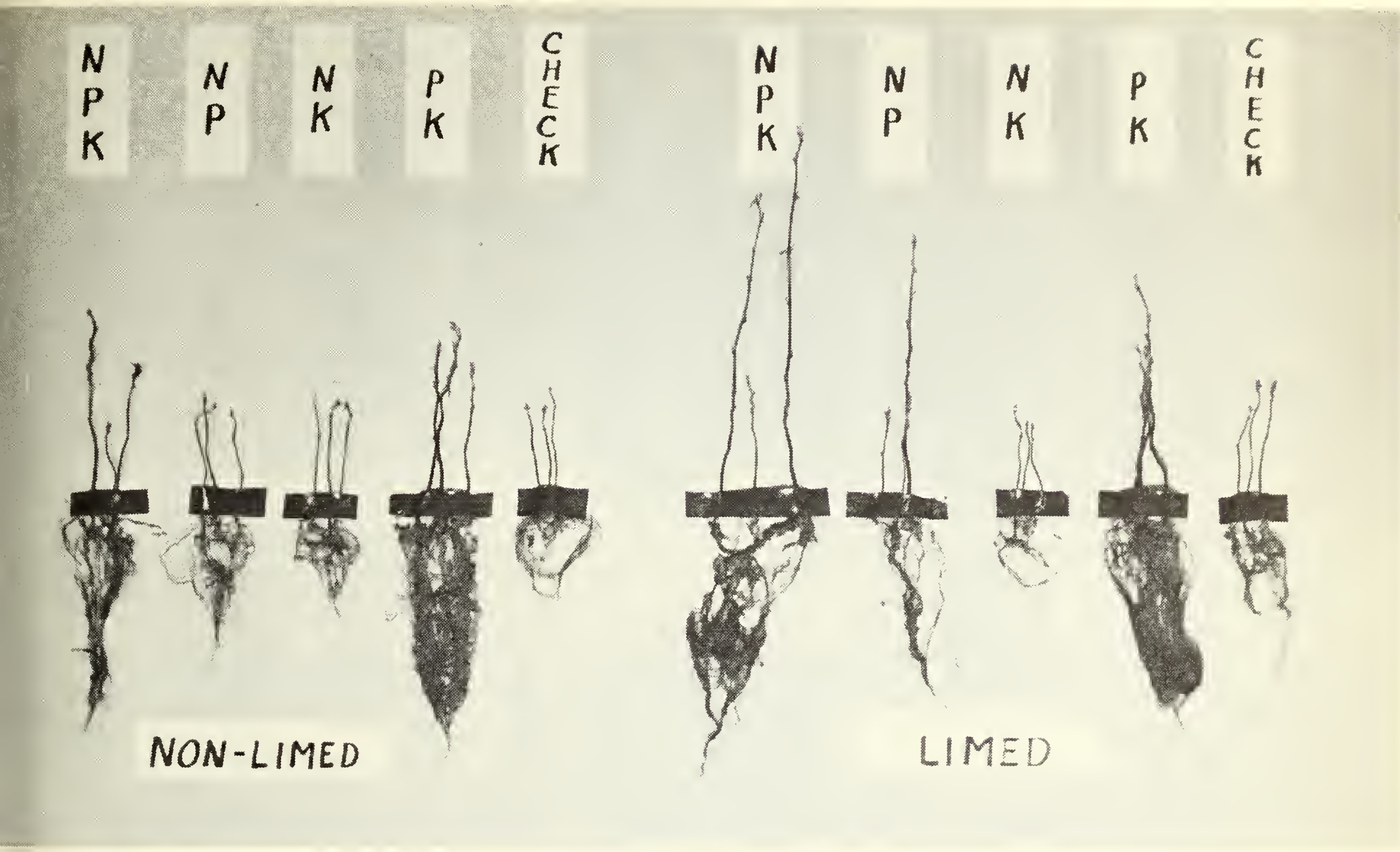

Figure 1.—Root development of yellow birch seedlings in limed and unlimed subsoil variously treated with nitrogen (N), phosphorus (P), and potassium (K).

Five-ml. aliquots of the various nutrient salt solutions were diluted to 10 ml. and first applied to the pots 8 days after planting. This procedure was continued for 3 additional weeks. Thereafter, larger undiluted aliquots were applied with greater frequency to complete the nutrient treatments. After 70 days, all plants were washed from the soil, oven-dried, and measured.

Results

Seedling development. — Results of nutrient additions are illustrated in figure 1. Absolute data are given in table 2, and relative gains in figure 2. Stem weights are for stems only and do not include leaf weights.

Poorest stem and root development occurred in the NK (minus P) treatment for both the limed and unlimed series. Greatest stem and root weights were recorded for the PK treatment in each series; seedling stem and root weights of the NPK treatment were slightly less. Possibly the high level of supplied N interacted with P to reduce gains. Some secondary response to N was suggested by the greater stem height and larger leaf development of seedlings in the NPK treatment, limed series.

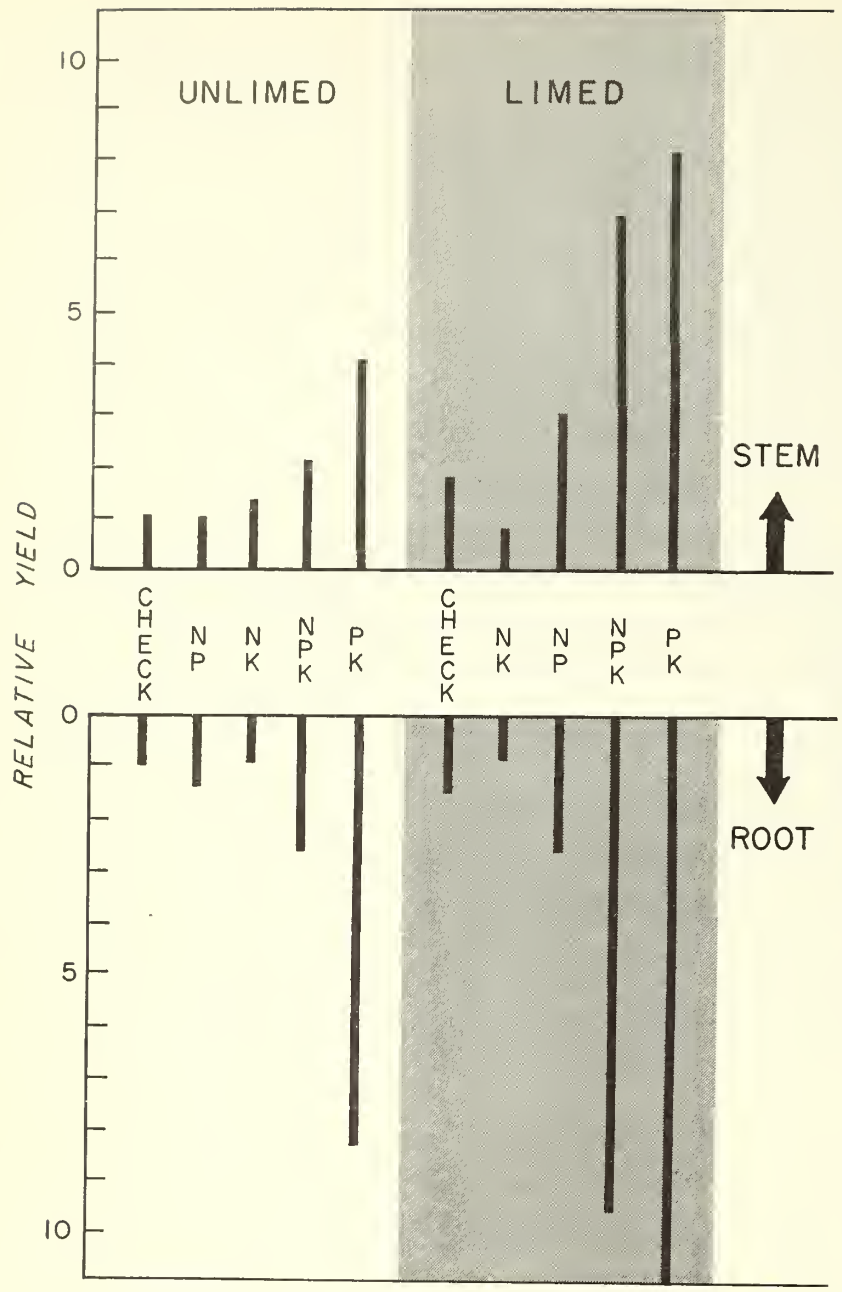

Figure 2.—Relative yield of stem and root weights. The data have been normalized, taking the unlimed check as 1.

Response to added P was greater for all treatments in the limed series than in the unlimed series (figs. 1 and 2). In the absence of tissue analyses, the reasons for this are not clear.

Though additions of P to this subsoil improved growth of yellow birch seedlings, optimum growth[1] was not achieved. Length of internodes and size of leaves on all treatments were less than normal. In addition, the leaves of the seedlings, especially those in the unlimed series, showed marginal necrosis, varying degrees of chlorosis, and curling.

Soil microflora. — A green mat of microflora developed on the soil surface of all pots receiving P, but not on those without P (NK and check) in both series. The microflora consisted of green algae (Chloro-

[1] Assuming growth of yellow birch in humus would be near optimum, a height of about 380 mm. in 70 days is possible (Hoyle 1965).

phyta). Two forms, spherical and cylindrical, were prevalent. It was interesting to note that P in this subsoil could also be limiting to the growth of microflora as well as higher plants.

Discussion and Conclusions

This study suggests that a deficiency of P in the Hermon subsoil may limit the root development of yellow birch seedlings. This interpretation offers a plausible explanation of why natural stands of yellow birch growing on this soil generally display only sparse rooting in the deeper horizons. Having obtained a rooting response to P applications under laboratory conditions, we might reasonably expect that subsoil treatment with P in the forest would stimulate root development of yellow birch when other factors are not restrictive. Research in Canada indicates that subsoil moisture and temperature under northern hardwood forest conditions generally are not limiting in well-drained soils (Fraser 1957a and 1957b; Redmond 1957). However, additional pot-culture studies in controlled environments, plus complementary field experiments, are needed to document these preliminary findings, and to achieve greater understanding about response to P and possible secondary responses to other nutrients.

Response to added P in the Hermon subsoil is probably due to: (1) small total amounts of P because of mineralogical composition; (2) presence of P in unavailable forms; and (3) toxic levels of aluminum (Al). Soil analyses by the author indicated that 2.1 to 0.3 milliequivalents/100 g. (A to C horizon) of exchangeable aluminum are present. High levels of available Al can be taken up by plants and precipitate P in the roots. In this acid subsoil (pH 5.2), Al has probably combined with native P to form insoluble aluminum phosphates. Phosphorus for plant use is thus greatly reduced or tied up completely, depending on the severity of conditions in the soil. To some extent, iron (Fe) will also fix phosphorus in this way.

Phosphorus deficiency in acid soils can be alleviated by P fertilization and liming. Addition of phosphate fertilizer reduces the level of exchangeable Al and increases the immediate supply of P. Liming induces release of bound P that occurs naturally in the soil by two processes. First is the hydrolysis of inorganic Fe and Al phosphates; second is an increase in the rate of mineralization of organic P. Liming may also increase availability of some micro-elements.

In our study, both of these practices were effective. Phosphorus supplied to the unlimed soil induced better growth than that of the controls.

However, additional P and liming together yielded further improvement. Since this subsoil contained little or no exchangeable Ca, liming may also have had some effect by supplying Ca in the role of a plant nutrient as well as soil conditioner.

These results are important for two reasons. First, previous studies by other workers have not clearly indicated why yellow birch roots develop poorly or not at all in mineral horizons of forest soils. Inadequate moisture, temperature, or nutrients were thought to be limiting, but no clear demonstration of these limitations was given. Work described in this paper indicates that the problem lies in the realm of soil fertility, and that P is the major limiting nutrient.

Second, it should be pointed out that this subsoil P deficiency and/or Al toxicity is severe and critical. Without some kind of treatment to alleviate the condition, seedling mortality is very high on mineral subsoil. Survivors maintain a marginal existence. The effect of this condition in the subsoil on large established trees in the forest is not known. For young stands in clearcut areas, superficial layers (humus and A horizon) of the forest soil probably satisfy the P requirements of yellow birch; but with increasing size and greater demands, inadequate P nutrition might possibly develop.

At present there are large gaps in our knowledge about the nutritional requirements of yellow birch and the extent to which our forest soils can satisfy these needs. Successful management of yellow birch is contingent upon closing these gaps in our knowledge about forest soil fertility and its effects on tree growth.

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Literature Cited

Fraser, D. A.
1957a. Ecological studies of forest trees at chalk river, ontario, canada. III. Annual and seasonal march of soil moisture under a hardwood stand. Canada Dept. North. Affairs and Natl. Resources, Forestry Branch, Forest Res. Div. Tech. Note 55, 15 pp.

Fraser, D. A.
1957b. Ecological studies of forest trees at chalk river, ontario, canada. IV. Annual and seasonal march of soil temperature on several sites under a hardwood stand. Canada Dept. North. Affairs and Natl. Resources, Forestry Branch, Forest Res. Div. Tech. Note 56, 15 pp.

Hoyle, Merrill C.
1965. Growth of yellow birch in a podzol soil. U. S. Forest Serv. Res. Paper NE-38, 14 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.

Redmond, D. R.
1954. Variations in development of yellow birch roots in two soil types. Forestry Chron. 30: 401-406, illus.

Redmond, D. R.
1957. Observations on rootlet development in yellow birch. Forestry Chron. 33: 208-212.

Spaulding, Perley, and H. J. MacAloney.
1931. A study of organic factors concerned in the decadence of birch on cut-over lands in northern new england. Jour. Forestry 29: 1134-1149, illus.

Tubbs, Carl H.
1963. Root development of yellow birch in humus and a sandy loam. U. S. Forest Serv. Res. Note LS-33, 2 pp., illus. Lake States Forest Expt. Sta., St. Paul, Minn.

Winget, C. H., T. T. Kozlowski, and S. Sasaki.
1963. Effect of seedbed and water stress on seed germination and seedling growth of yellow birch. Univ. Wis. Forestry Res. Note 88, 5 pp.

U. S. FOREST SERVICE RESEARCH NOTE NE-43
1966

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SUCCESS OF CAMPGROUNDS STUDIED AS GUIDE TO RECREATION PLANNERS

As part of its forest recreation research, the Northeastern Forest Experiment Station in the summer of 1964 made a survey of all privately owned campgrounds in New Hampshire, in cooperation with the New Hampshire State Planning Project. The purpose of the survey was to find out what characteristics of campgrounds — and campground management — lead to success.

A total of 108 campground owners were interviewed. Information collected during these interviews included data on size of investment, method of financing, management costs, and volume of business since opening. Each campground owner was also questioned about his business outlook and his attitudes toward further development of camping facilities on public lands in the State (LaPage and Foster 1965).

To provide an objective basis for comparing campgrounds, a "successful" campground was arbitrarily defined as one that had been used to more than 50 percent of its capacity during the preceding year. Attendance figures for 1963 were available for 85 enterprises, or 96 percent of the private campgrounds that were in business that year. Of these, 37 were found to be successful according to our definition, and 48 were unsuccessful.

Although defining success in this way ignores past attendance trends as well as important differences in managerial objectives and efficiency, several interesting comparisons were made. The 37 more successful campground enterprises were those that were well established, were built near lakes, contained 70 or more family units, and were located in either the central or southern part of the State (tables 1 to 4).

The 48 less-successful enterprises, besides being those that were new, small, and dry, also included 11 out of 13 owners who did not expect to remain in business through the next 5 years, and 27 out of 36 owners who did not plan to expand their operations within the next 3 years.

Interpreting These Findings

Expressing a campground's annual attendance in terms of the percentage of capacity use received may provide a reasonably good index of comparative success for any single year; but the venture's ultimate success will depend on more than its gross volume of business. However, since annual attendance is the raw material for success, the factors that influence it are well worth examining.

The direct relationship of enterprise age to success (table 1) should not be taken to mean that success follows the simple establishment and aging of a camping enterprise. In addition to reflecting a probable increase

Table 1. — Percentage of successful enterprises,[1] by age of campground development

Years in business	No.	Percentage successful
1-3	34	24
4-6	30	43
Over 6	21	76

[1] Campgrounds that averaged more than 50-percent of capacity use throughout the 1963 camping season.

Table 2. — Percentage of successful enterprises, by size of campground development

Size of enterprise[1]	No.	Percentage successful
Small	53	31
Large	22	78

[1]Campgrounds containing 70 family units or more were classed as large; those containing fewer than 70 units were classed as small.

Table 3. — Percentage of successful enterprises, by type of on-site attraction

Attraction[1]	No.	Percentage successful
Lake	35	60
River	32	44
Non-water	18	28

[1] All bodies of water irrespective of size, including farm ponds, were classed as lakes. Similarly the category of rivers includes small streams.

Table 4. — Percentage of successful enterprises, by geographic location within the State

Region[1]	No.	Percentage successful
Northern	29	20
Central	43	53
Southern	13	62

[1] See figure 1 for locations of the three regions.

Table 5. — Proportion of successful and unsuccessful campgrounds that had investments of more than $10,000, and had 70 or more developed family units, according to the number of years in operation

Campground age (years)	Proportion that had investments of $10,000 or more		Proportion that had 70 or more developed family units in 1963	
	Successful	Unsuccessful	Successful	Unsuccessful
1-3	4 out of 8	8 out of 22	3 out of 7	2 out of 22
4-6	9 out of 13	5 out of 17	7 out of 12	2 out of 14
Over 6	10 out of 15	1 out of 5	9 out of 15	1 out of 5

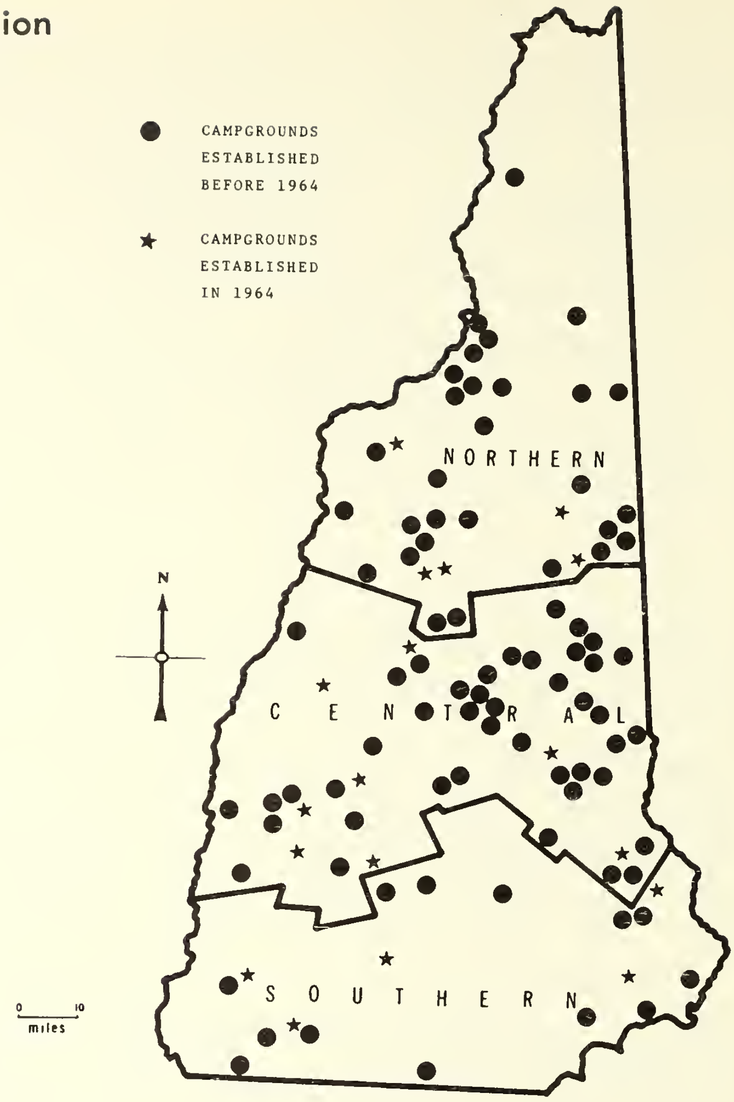
in popularity, campground age is also an expression of the changes that take place in the enterprise and in its management over time. The older and more successful campgrounds have large investments as well as numerous individual family units. The less-successful ventures demonstrated no significant change in either their developed capacity or dollar investment with age (table 5).

Though campground size (table 2) has much to do with success, its importance depends upon regional campground location. Out of 23 small campgrounds in the northern region of New Hampshire, 22 were unsuccessful; while 5 out of 6 larger ventures in the same region were successful. In the central region, the success of small campgrounds improved to 9 out of 21, and 12 out of 15 large ones reported attendances in excess of 50 percent of their 1963 capacity. Campground size seemed to be of least importance in the southern region, where the proportion of successful small campgrounds was 6 out of 8.

The variable impact of size on success undoubtedly results, in part, from differences in the size and nature of the camping demand from one region to another (fig. 1). For example, the average length of visit for campers in each region was found to be: southern, 2 days; central, 5 days; and northern, 3 days. Regions that are characterized by a demand for transient campsites probably encourage the development of fewer large, expensively equipped, family-vacation type enterprises.

An analysis of visit length and frequency at these same private campgrounds suggests that visit patterns are characteristics of the regional market, and are therefore not always subject to manipulation by campground owners. Short visits in the northern part of the State, with its established tourist potential, may be due to a scarcity of warm-water swimming; while in the southern region the short visit may be due more to the region's

Figure 1.—The regional distribution of the campgrounds studied.



accessibility for short (2-3 day) trips from nearby population centers.

The relationship of success to the presence of a water attraction at the campground (table 3) appears to be direct and strong. Yet, in comparing both large and small water-oriented campgrounds, the success ratio strongly favors the larger ventures. Among water-oriented campgrounds containing fewer than 70 family units, only 31 percent were successful, as opposed to 76 percent of the larger campgrounds having comparable water attractions.

Although the absence of a water attraction shows a fairly persistent association with unsuccessful enterprises, the presence of water is no guarantee of success in any of the three regions of the State (table 6). The success of non-water-based campgrounds in the central region can probably be attributed in part to the relative abundance of public beaches in that part of the State. In the southern region, where short visits are the rule, camping enterprises probably do not need to have either the number or the variety of recreational opportunities that are required of major vacation campgrounds.

In addition to size, age, location, and a water attraction, three other characteristics set the successful campgrounds apart from their less successful competitors. Camper visits averaged more than twice as long at the more successful enterprises (4½ days). A majority of successful campgrounds (54 percent) had a predominately advance reservation clientele, as opposed to 38 percent of the less successful ones. And the successful enterprises were more than twice as likely to be members of the New Hampshire Campground Owner's Association (49 percent vs. 19 percent).

Table 6.—Number of successful and unsuccessful campgrounds, according to the presence or absence of a water attraction, by regional location.

Region	Type of attraction	Number successful	Number unsuccesful
Northern	Water-oriented	6	14
	Non-water-based	—	10
Central	Water-oriented	20	16
	Non-water-based	3	3
Southern	Water-oriented	6	5
	Non-water-based	2	—
Total	Water-oriented	32	35
	Non-water-based	5	13

The ways in which advance reservations and extended visits might influence enterprise success are self-evident. However, the relationship between association membership and campground success is probably not a causal one because a member campground is generally indistinguishable from any other campground. Both association membership and enterprise success are probably the results of a keen business interest and energetic management. Member campgrounds apparently do receive a larger volume of business than would be expected on the basis of their numbers. Of 1,000 questionnaires voluntarily completed by private campground visitors during 1964, two-thirds originated at member campgrounds. However, only one-third of New Hampshire's private campgrounds belong to the New Hampshire Campground Owner's Association. This striking disparity in response rates indicates either better survey cooperation from owners who are association members, or the existence of a greater volume of business at association campgrounds.

Application to Campground Planning

Defining success in terms of a minimum of 51 percent occupancy, although analytically useful, may not be entirely realistic. McCurdy and Mischon (1965) reported that among 12 private campgrounds situated along the Ohio River, none exceeded 35 percent occupancy in any year since its construction. Holcomb, Conklin, and Winch (1963), and Riviere (1964), recommend that prospective campground developers in the eastern United States base their projected costs and income on a 50-percent level of occupancy, and not more than 60 percent. With these guidelines, marginal occupancy would certainly have to be something less than 50 percent.

A campground owner who can realize 50-percent occupancy, for a season-long average, will probably find that his venture has been economically successful, provided his operating and development costs have been kept to a minimum. However, in highly developed vacation regions such as central and northern New Hampshire, intensive management and its resultant high operating costs may be unavoidable if a campground is to compete effectively.

In further defense of the 50-percent occupancy definition of success, it is noteworthy that most of the campgrounds in this analysis were either very well, or very poorly, patronized. Only 13 of the 85 enterprises reported average 1963 occupancy levels of 50 percent.

Although there is undoubtedly some disagreement in what should be considered a successful occupancy level for private campgrounds, the general relationships found in this study can reasonably be expected to apply regardless of the definition of success used.

In attempting to predict the probability of success for new campgrounds, there are in these findings several strong clues concerning situations to be avoided. For example, the chances of obtaining a successful occupancy level at small, dry, campgrounds are poor in all parts of the State. And in the northern region, the odds against establishing a successful campground are impressive regardless of the combined effects of size, attraction, and investment.

But there are exceptions. And although these exceptions may be due to the quality of a special attraction, or the energy of a developer, they are also partly a result of factors external to the enterprise. For example, differences in regional success rates reflect not only variable market sizes and competitive conditions, but also differences in public policy. The fee (or absence of a fee) at publicly developed campgrounds, and the geographic distribution of public camping areas, can undoubtedly have even more significant effects upon private campground success than any of the factors included in this analysis.

Because of the continually increasing pressures for development of forest recreation enterprises on private lands, a better understanding of these inter-relationships is needed now. To provide sound and workable guides for the development of these enterprises, further studies have been planned by the Forest Service — not only of the New Hampshire camping market but of other Northeastern recreation markets as well.

Literature Cited

Holcomb, C. J., H. E. Conklin, and F. E. Winch, Jr.
1963. Opportunities for Private Campgrounds as an Alternative Use of Land. Va. Polytech. Inst. Agr. Ext. Serv. Circ. 72, 16 pp.

LaPage, W. F., and S. H. Foster.
1965. The Private Campgrounds of New Hampshire. N. H. State Planning Project Study Rpt. 7, 62 pp. Concord.

McCurdy, D., and R. Mischon.
1965. Small Woodland Recreation. Line Project Rpt. of the U. S. Forest Serv. Central States Forest Expt. Sta. project rpt., 8 pp.

Riviere, Bill.
1964. How to Build and Operate Private Family Campgrounds. 49 pp. Kalmbach Publishing Co., Milwaukee.

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U. S. FOREST SERVICE RESEARCH NOTE NE-44
1966

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GYPSY MOTH EGG-MASS DENSITY AND SUBSEQUENT DEFOLIATION

The relationship between insect density and subsequent defoliation is usually important among the many factors involved in deciding if, when, and where to take control action against a defoliator such as the gypsy moth. Unfortunately, the proportion of the foliage that will be removed by a defoliator in any given place and year depends not only upon the number of insects that are present, but also upon a number of other variables. Thus a particular insect density does not determine a particular defoliation level. Rather, an array of defoliation levels may result from that density; and all that one can say, unless he has quantified these other determining variables, is that each particular defoliation level within this array will have a particular probability of occurrence.

In the years 1911 to 1931, records were taken annually by personnel of the now defunct Melrose Highlands, Mass., gypsy moth laboratory on the number of egg masses present on 264 0.18-acre plots, and on the subsequent defoliation of each tree within these plots. Several published papers were based on these records,[1, 2] but the relationship between egg-mass density and subsequent defoliation was not analyzed and presented in a way that could be used in practice. Therefore I have analyzed the association between defoliation and egg-mass density that was found in the Melrose plots during the years when density tended to be high and

[1] Minott, C. W., and I. T. Guild. SOME RESULTS OF THE DEFOLIATION OF TREES. Jour. Econ. Ent. 18: 345-348. 1925.
[2] Baker, W. L. EFFECTS OF GYPSY MOTH DEFOLIATION ON CERTAIN FOREST TREES. Jour. Forestry 39: 1017-1022. 1941.

defoliation was generally evident (between 1911 and 1922), in a way that may prove to be helpful in reaching control decisions.

Procedure

Apparently the 264 observation plots were selected to represent as wide a range of environmental conditions as possible.[3] During the first few years an actual tally was made of the egg clusters observed on each tree, and a separate count was made of those found within the remainder of the plot. By the fall of 1916, however, an estimating procedure was adopted. This procedure was not described in detail. A defoliation estimate was also recorded every year for each individual tree. This latter value was the average of the independent estimates of at least two experienced observers.[4]

For my analysis the annual egg-mass counts for each plot were converted to a per-acre basis, and a mean percentage defoliation was calculated from the estimates for the oak trees in that plot. These data were then compiled in a frequency matrix, using five categories of current egg-mass density, two categories of trend in egg-mass numbers, and four defoliation categories.

Both the procedures for gathering the original data and the methods of data conversion that were used here allow for sampling bias — for example, in the initial selection of observation plots, in the method of estimating both egg-mass density and defoliation, and in the restriction of this analysis to defoliation of oaks only. These limitations will be discussed later.

Results

The number of egg masses per acre at the start of the generation is only a crude approximation of insect density in the larval stages when defoliation takes place. One reason for this is that the number of eggs per egg mass is highly variable. We know from a previous study[5] that the number of eggs per egg mass at the start of any given year is inversely correlated with the number of egg masses per acre at the start of the preceding year. Therefore, we can forecast current defoliation more accurately by using

[3] Guild, I. T. SUMMARY OF THE OBSERVATION POINT PROJECT FROM 1911 TO 1928. Unpublished report on file at the Forest Insect and Disease Laboratory, West Haven, Conn. 1929.

[4] Guild, I. T. FORECASTING GYPSY MOTH DEFOLIATION. Unpublished report on file at the Forest Insect and Disease Laboratory, West Haven, Conn. 1928.

[5] Campbell, R. W. THE ANALYSIS OF NUMERICAL CHANGE IN GYPSY MOTH POPULATIONS. Manuscript in preparation, 1965.

both egg-mass density at the start of the current year and egg-mass density at the start of the preceding year than by the use of the former variable alone.

The frequency matrix derived from these data is shown in table 1. To read this matrix:

1. Determine the appropriate category of current egg-mass density per acre (0 to 500; 501 to 1,000; 1,001 to 1,500; 1,501 to 2,500; 2,501 +).
2. Determine whether the trend in egg-mass density from the preceding year to the current year was downward, or stable or upward.
3. Read the frequency of occurrence of each defoliation category (less than 25%, 25.1 to 50.0%; 50.1 to 75.0%; 75.1%+).

Suppose, for the moment, that table 1 accurately portrays the frequency of defoliation in each listed category that one would find in an average year. Further, suppose that one is able and willing to state for various field situations: (1) A tolerable defoliation level. (2) An acceptable risk of being wrong — that is, of not identifying a particular condition as intolerable when, in fact, it will be.

Given these assumptions, table 1 provides a basis for deciding, within a given risk level, whether or not a given area should be chosen for treatment. Consider two areas as an example.

Area 1 is a wooded public picnic site, and area 2 is a private woodlot under management for fuel wood production. It is decided that for area 1 a condition of not more than 25-percent defoliation will be tolerated, and that this tolerable level should not be exceeded more than 1 time out of 10. For area 2, it is decided that not more than 50-percent defoliation will be tolerated, and that the risk of error should not exceed 1 time in six.

To facilitate a decision on area 1, the data that were shown in table 1 have been regrouped in the form shown in table 2. Note that this regrouping consisted of simply summing (in column 2) the defoliation frequencies that had been listed separately in columns 2, 3, and 4 of table 1. As indicated, only the first value listed, 0.072, is less than the stipulated risk level of 0.10. Thus, area 1 should be left untreated only when there are fewer than 500 egg masses per acre in the current year and the number found is less than that recorded the year before.

A similar regrouping of the data in table 1 will facilitate a decision on area 2 (table 3). In this case, column 1 of table 3 is equal to the sum of columns 1 and 2 of table 1, and column 2 of table 3 is equal to the sum of columns 3 and 4 of table 1.

For area 2, control would always be initiated when current density is greater than 2,500 egg masses per acre. Control would never be initiated when current density is less than 500 egg masses per acre. Control would be initiated at densities between 500 and 2,500 egg masses per acre only when the current density is greater than or equal to the egg-mass density of a year ago.

Table 1. — Frequency of various ranges of percent defoliation of oaks in a year, as related to egg-mass densities per acre at the start of that year and trend in egg-mass density from preceding year to current year

Current number of egg masses per acre	Trend in egg-mass density from preceding year to current year	Frequency of defoliation at percentage rate of — (basis: No. observations)				Total No. observations
		0 to 25.0	25.1 to 50.0	50.1 to 75.0	75.1 to 100	
0-500	Down	0.928 (90)	0.051 (5)	0.021 (2)	0.000 (—)	— 97
	Stable or up	.813 (26)	.062 (2)	.094 (3)	.031 (1)	— 32
501-1,000	Down	.791 (49)	.145 (9)	.032 (2)	.032 (2)	— 62
	Stable or up	.673 (33)	.103 (5)	.163 (8)	.061 (3)	— 49
1,001-1,500	Down	.838 (31)	.054 (2)	.027 (1)	.081 (3)	— 37
	Stable or up	.621 (18)	.103 (3)	.172 (5)	.104 (3)	— 29
1,501-2,500	Down	.639 (39)	.197 (12)	.049 (3)	.115 (7)	— 61
	Stable or up	.500 (25)	.220 (11)	.160 (8)	.120 (6)	— 50
More than 2,500	Down	.560 (42)	.213 (16)	.120 (9)	.107 (8)	— 75
	Stable or up	.286 (55)	.198 (38)	.172 (33)	.344 (66)	— 192

Table 2. — Frequency of oak defoliation in two categories (0 to 25% and over 25%) in a year, egg-mass densities per acre at the start of that year, and trend in egg-mass density from preceding year to current year (from table 1)

Current number of egg masses per acre	Trend in egg-mass density from preceding year to current year	Frequency of defoliation at percentage rate of —	
		0 to 25.0	25.1 to 100
0-500	Down	0.928	0.072
	Stable or up	.813	.187
501-1,000	Down	.791	.209
	Stable or up	.673	.327
1,001-1,500	Down	.838	.162
	Stable or up	.621	.379
1,501-2,500	Down	.639	.361
	Stable or up	.500	.500
More than 2,500	Down	.560	.440
	Stable or up	.286	.714

Table 3. — Frequency of oak defoliation in two categories (0 to 50% and over 50%) in a year, egg-mass densities per acre at the start of that year, and trend in egg-mass density from preceding year to current year (from table 1)

Current number of egg masses per acre	Trend in egg-masses density from preceding year to current year	Frequency of defoliation at percentage rate of —	
		0 to 50.0	50.1 to 100
0-500	Down	0.979	0.021
	Stable or up	.875	.125
501-1,000	Down	.936	.064
	Stable or up	.776	.224
1,001-1,500	Down	.892	.108
	Stable or up	.724	.276
1,501-2,500	Down	.836	.164
	Stable or up	.720	.280
More than 2,500	Down	.773	.227
	Stable or up	.484	.516

Discussion

Percentage defoliation of oak by the gypsy moth in the years covered by this analysis was directly related to egg-mass density at the start of each year, and inversely related to the trend in egg-mass density from the preceding year. Although these relationships were not close enough to provide a useful predictive equation, a frequency matrix such as table 1 does indicate that rather clear-cut expectations of given defoliation levels can be calculated when broad categories are used.

The original defoliation estimates taken by the Melrose personnel may be somewhat lower than the actual defoliation that occurred, since these estimates, from 1916 onward, were all made during one extended trip to all of the plots. Some of the trees in severely defoliated plots may have produced a new flush of foliage by the time this visit was made. On the other hand, the gypsy moth tends to defoliate oaks more severely than most of the other species in a stand. For this reason, it seems likely that the percentage defoliation values that were used in deriving table 1 are probably higher than the average defoliation for all species in the plots.

Finally, it seems clear from our studies in northeastern New York State[5] that sparse gypsy moth populations often receive more members than they lose during the major dispersion period of the insect, which occurs during the first larval instar. Such net gains in larval numbers might account for some of the severe defoliation that was recorded even when the number of egg masses in the plot at the start of the current year was low. Of course there are other variable factors, not accounted for here, that may have altered the relationship between egg-mass density and resultant defoliation.

Since adequate data on more recent gypsy moth infestations are lacking, the accuracy of table 1 for forecasting current conditions has not been determined. With suitable data, we could check the predictive accuracy of the results shown here. And, more important, a much broader-based guide for control decisions could be developed.

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U. S. FOREST SERVICE RESEARCH NOTE NE-45
1966

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AERIAL SPRAYING OF LOW-GRADE HARDWOOD STANDS WITH 2,4,5-T IN WEST VIRGINIA

Aerial application of herbicides to poor hardwood stands shows promise of being an effective aid in converting stands of low-grade hardwoods to conifers in West Virginia. Many of the sites now occupied by low-grade hardwoods are incapable of producing quality hardwoods — even under good management — and are generally much better suited to certain conifers, particularly the native pine.

This report describes the results of an aerial application of herbicide by helicopter to the hardwoods on such a site where partial conversion to white pine by aerial seeding is planned. The study was carried out on the Monongahela National Forest in cooperation with the timber management staff and the District Ranger personnel of the Marlinton Ranger District. The National Forest provided the land, supervised the cutting, paid for the aerial spraying, and assisted in the field measurements.

Study Area

The treated area consisted of two cutover plots and two uncut plots, each 8 acres in size, located near each other on a steep (average 55 percent) southwest-facing slope near Huntersville, West Virginia. Site index for the area was about 55 feet for oak.

Before the two plots were cut, the stand was well stocked with about 75 square feet of basal area per acre in trees over 5 inches d.b.h. Stand age was about 69 years. The species composition was: northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), chestnut oak (*Q. prinus* L.), and scarlet oak (*Q. coccinea* Muenchh.) — 40 percent; shagbark hickory (*Carya ovata* (Mill.) K. Koch) and mockernut hickory (*C. tomentosa*

Nutt.) — 22 percent; sugar maple (*Acer saccharum* Marsh.) — 9 percent; flowering dogwood (*Cornus florida*) — 8 percent; downy serviceberry (*Amelanchier arborea* (Michx. f.) Fern.) — 5 percent; Virginia pine (*Pinus virginiana* Mill.) and pitch pine (*P. rigida* Mill.) — 4 percent; red maple (*Acer rubrum* L.) — 3 percent; and other species — 9 percent.

On the two logged plots, all trees down to about 5 inches d.b.h. had been cut and skidded out for pulpwood between February and August 1963.

Application of Herbicide

On August 15, 1963, the four plots were sprayed by helicopter with 2 pounds of 2,4,5-T acid equivalent per acre in oil (1/3 gallon of a 6-pound-per-gallon iso-octyl ester formulation in 4.5 gallons of No. 2 fuel oil). The spray was applied through a conventional boom-type spray rig mounted on the helicopter. Weather conditions were ideal during the operation; the day was calm and visibility was excellent. Total spraying time was 50 minutes, which included 4 trips to the landing area, 2 miles distant, for reloading.

As a check on the distribution of the herbicide and penetration through the canopy, twenty-five 4- by 5-inch oil-sensitive cards were placed in a line at 20-foot intervals from the bottom of the slope to the top in each plot. The cards on the cutover plots were heavily spattered with oil droplets, indicating good coverage. All cards on the uncut areas were lightly spattered, indicating good coverage of the area and heavy retention of spray in the tree canopy.

Results

A year later, in August 1964, the plots were checked to determine the effectiveness of the herbicide treatment. On the cutover plots, most of the small scattered trees left after logging were dead but most of the stumps of cut trees were sprouting. On the uncut plots, the trees were tallied by species in 2-inch diameter classes under four degrees of crown damage, following the method of Roe.[1] The tallies were taken on 16 permanent 1/20-acre subplots in each of the two uncut main plots. The crown damage classes used were:

Dead = more than 80% defoliated.
Severe = 50 to 80% defoliated.
Light = 20 to 50% defoliated.
None = less than 20% defoliated.

[1] Roe, Eugene I. MEASURING THE RESULTS OF AERIAL SPRAYING WITH HERBICIDES FOR FORESTRY PURPOSES. U. S. Forest Serv. Lake States Forest Expt. Sta. Tech. Note 492, 2 pp. 1957.

Figure 1. — General condition of overstory trees 1 year after aerial spraying with 2,4,5-T.

In addition, the number of spray-killed understory stems below 1.0 inch d.b.h. was tallied on a 1/100-acre subplot at each sampling point.

The overall killing effect of the spray on the overstory was good (fig. 1). It was most effective on the four oak species: more than 90 percent of the trees were dead or severely defoliated. Red maple, black locust, and basswood were the next most susceptible group: 69 percent dead or severely defoliated. Sugar maple was intermediate: 39 percent dead or severely defoliated. The hickories, serviceberry, dogwood, and crataegus were only slightly affected. Pitch pine and Virginia pine showed no damage (table 1).

No relationship between tree size and susceptibility to the spray treatment was apparent. The highly susceptible oaks were deadened in all size classes and the more resistant hickories were about equally resistant in all size classes. About 9 percent of the stems below 1.0 inch d.b.h. — chiefly mountain laurel, witch hazel, serviceberry, dogwood, and small tree seedlings — were deadened on the unlogged plots.

Table 1. — *Effectiveness of aerial spray, by species*

Species	Trees examined	Damage class			
		Dead	Severe	Light	None
	No.	%	%	%	%
White oak	176	88	4	4	4
Hickories	95	18	5	5	72
Serviceberry	71	25	13	21	41
Red and scarlet oaks	69	91	—	4	5
Virginia and pitch pines	58	—	—	—	100
Chestnut oak	48	79	11	5	5
Sugar maple	41	39	—	15	46
Dogwood	23	22	—	4	74
Red maple	13	69	—	8	23
Black locust	10	90	—	—	10
Hophornbeam	11	18	10	27	45
Crataegus	11	—	—	9	91
Witch hazel	10	90	—	—	10
Basswood	6	83	—	—	17

Discussion

Partial conversion of hardwood stands to pine requires that some method be employed to reduce the hardwood competition. In uncut stands similar to those on our study area, aerial application of 2,4,5-T shows promise of being such a method. This treatment appears especially promising where the stands are composed chiefly of oaks. However, one spraying does not bring about much reduction of the understory, as most of the chemical is caught in the tree crowns.

In this study the herbicide was applied in late summer and white pine seeds were sown the following spring (1964). No data on the success of the seeding are yet available. However, it is recognized that the undisturbed forest floor is a relatively unfavorable seedbed for pine, and that catches of seedlings are likely to be light under these conditions.

Also, by hindsight, we suspect that the sequence followed in the trial was a poor choice because the released understory is likely to take over the site before any pine seedlings starting from the seeding have become well enough established to hold their own. A follow-up treatment probably will be required to release these pines.

A better sequence might be to seed first, and delay the herbicide treatment a few years until an adequate number of pine seedlings are established. Released from the overstory at this stage, many of the pine seedlings could be expected to compete successfully with the understory vegetation.

On cutover areas, the logging, besides removing most of the overstory, creates better seedbed conditions to the extent that mineral soil or intermixed soil and humus are exposed. However, unless the stumps are individually treated, rampant sprouting will follow the cutting. The spray treatment applied shortly after the logging in our study did not inhibit sprouting to any substantial degree, and a follow-up treatment probably will be necessary.

As in unlogged areas, timing may be the key to success. It now appears that seeding should be done at once on cutover areas to take advantage of the improved seedbeds, but that the spraying should be delayed 4 or 5 years. By that time the sprouts will have made considerable growth and will be susceptible to foliage treatment. One treatment then should suffice to release the pines.

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U. S. FOREST SERVICE RESEARCH NOTE NE-46
1966

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CUTTING HARDWOOD CANTS CAN BOOST SAWMILL PROFITS

The markets for hardwood lumber are now strong, and sawmill profits are increasing. But this favorable market-price situation is the exception rather than the rule. Usually hardwood sawmill operators are confronted with ever-decreasing profit margins. During the past decade, while lumber prices have remained relatively constant, most logging and sawmilling costs have increased from 30 to 45 percent.[1, 2]

To stay in business, lumbermen have had to modernize their equipment and reorganize their lumber-production techniques for more efficient operation. Despite the recent increase in hardwood lumber prices, many hardwood lumbermen are still searching for opportunities to increase their profit margins.

One of the most promising opportunities for increased income is the manufacture of cants from the low-grade heart portion of sawlogs. A cant is a large timber, cut by the headsaw, for structural use or for further reduction into lumber by another saw in the same mill. Usually a cant contains the knotty heart of the log.

Although these heart sections of sound Appalachian hardwood sawlogs may be free of scale defects such as decay, shake, and split, they usually contain grade defects that reduce the quality of lumber sawed from them. This lumber often sells for less than the cost of manufacture: losses may range up to $30 per 1,000 board feet.

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[1] Martens, David G. LOG GRADES — A KEY TO PREDICTING SAWMILL PROFITS. South. Lumberman. 210 (2612): 29-34, illus., 1965.

[2] Sarles, R. L. TEN-YEAR CHANGES IN SELECTED LOGGING AND SAWMILLING COSTS. South. Lumberman. 210 (2620): 28-30, illus., 1965.

Since there are a variety of market outlets for cants as solid timbers, one method of reducing these losses would be to saw the low-grade heart sections of logs into cants instead of 1-inch boards. Three possible advantages of thicker cuttings were foreseen: (1) a reduction in saw-kerf loss, (2) a reduction in sawing time per log, and (3) an improvement in lumber quality.

A Study of Cants

To determine how much volume and product value could be increased by sawing sawlog hearts into cants rather than 1-inch lumber, a study of cant production was made recently by the U. S. Forest Service's Forest Products Marketing Laboratory at Princeton, W. Va.

To make these comparisons, we diagramed to scale on cross-section paper 12 cant sizes and superimposed on each diagram the largest volume in 1-inch lumber that could be sawed from each size of cant (fig. 1). The end dimensions of the 12 cant sizes studied ranged from 4 by 4 inches to 8 by 8 inches.

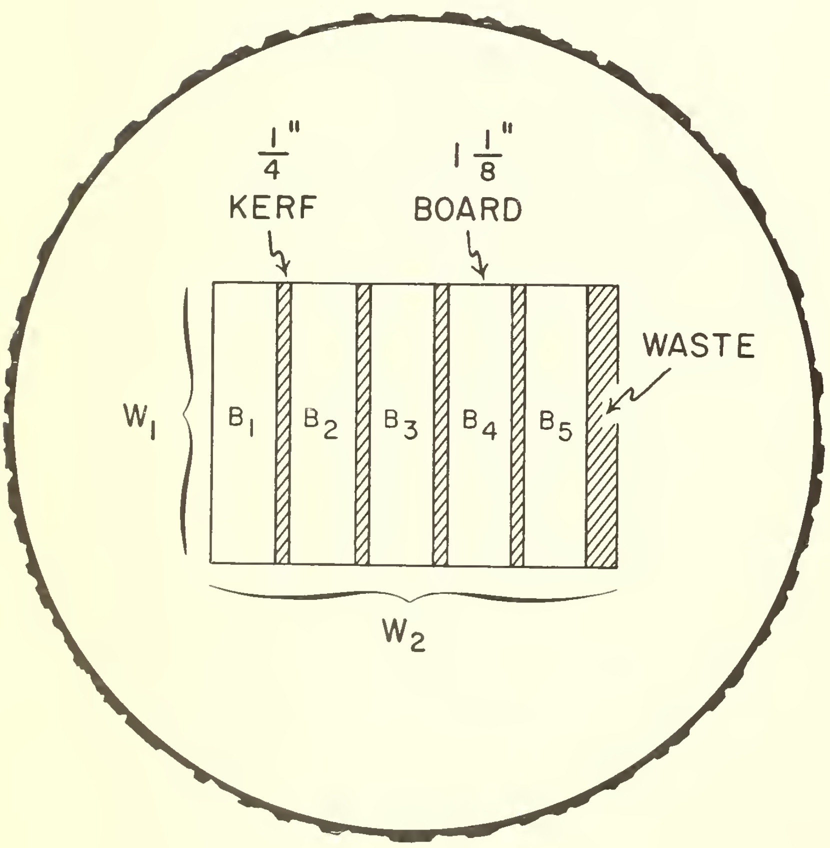

Figure 1. — Log cross-section, showing recovery of 1-inch lumber in a 5-by-7 cant.

$$\text{Cant volume} = \frac{W_1 \times W_2 \times L}{12}$$

$$\text{1-inch volume} = \frac{n\,(B \times W_1) \times L}{12}$$

W_1 = cant width (inches)
W_2 = cant depth (inches)
L = length (feet)
B = 1-inch board nominal thickness
n = number of boards in cant

To obtain log-conversion data, we made a time study at a local sawmill. For one group of logs, we recorded the time required to saw 1-inch lumber, whereas for another group of logs we recorded the time required to saw each log into lumber and a cant.

In our study, we defined the experimental conditions precisely. The following assumptions were made:

1. Each cant log would be sawed to develop the maximum volume of 2 Common and Better grade lumber from the outer part of the log, whereas the portion of the log containing lumber of grades 3A Common and poorer would be made into cants and sold as timbers.

2. Each lumber log would be sawed to develop the best grade of 1-inch lumber in all portions of the log, including the heart.

3. All logs would be 12 feet long and would have both a gross and net log volume of 100 board feet. Log scale would equal lumber tally for board logs.

4. All nominal 1-inch boards would have an actual board thickness of $1\frac{1}{8}$ inches after sawing to allow for shrinkage.

5. Sawmill production rate would be 1,700 board feet per hour of 1-inch lumber with a $\frac{1}{4}$-inch saw kerf. The mill would operate at full capacity for 8 hours per day.

6. Green lumber and cant prices would be: (a) $100 per 1,000 board feet for lumber in the combined grades of 2A Common and Better; (b) $58 per 1,000 board feet for grades 3A Common and poorer in the heart center portion of a log; (c) $50 per 1,000 board feet for cants, regardless of end dimension.

7. Total lumber-manufacturing costs would be $80 per 1,000 board feet, consisting of $20 per 1,000 board feet for stumpage plus $30 for logging and $30 for milling.

8. Cant manufacture would require no sawing time because the cant is the log portion left after high-grade lumber is removed.

9. The daily production of 1-inch lumber would be the same regardless of whether logs were sawed into boards or whether both boards and cants were produced.

10. Sufficient logs would be available for uninterrupted mill production even though cant manufacture requires a greater daily volume of raw material.

11. All logs would be of uniform size, shape, and quality and would be suitable for cant manufacture.

Analytical Procedures

To obtain a reasonably accurate estimate of the economic benefits from producing 1-inch lumber or producing both 1-inch lumber and cants, we had to evaluate the entire production sequence. This included the following factors: (1) volume yields for both boards and cants, including overrun and kerf losses; (2) proportionate sawing times for board logs and cant logs for all cant sizes tested; (3) delivered cost of extra raw material used when sawing cants because of greater daily volume output; (4) monetary returns from green cants and grouped lumber grades.

An abbreviated illustration of our analytical procedures is presented in table 1. This example applies to only one size of log and cant. The log is $14\frac{1}{2}$ inches in diameter, 12 feet long, and has a net yield of 100 board feet in nominal 1-inch lumber. The cant end dimensions are 5 inches by 7 inches, and this 12-foot timber has a net volume of 35 board feet. Data for individual logs have been expanded to a daily basis to provide a more vivid comparison between the two log-conversion techniques.

Table 1. — Sawing 1-inch lumber versus sawing lumber and cants: a comparison of daily yields, sawing times, production costs, and income

Item		Lumber log	Cant log
Lumber yield per log:			
2 Common and Better	*board feet*	75	75
3A Common and Poorer	*board feet*	25	—
Cant yield per log	*board feet*	—	35
Total volume per log	*board feet*	100	110
Sawing time per log	*minutes*	3.50	2.63
Logs sawed hourly	*number*	17.14	22.81
Logs sawed daily	*number*	137	182
Extra raw material for cant production	*logs*	—	45
	board feet	—	4,500
Daily volume yields:			
2 Common and Better	*board feet*	10,275	13,650
3A Common and Poorer	*board feet*	3,425	—
Cants	*board feet*	—	6,370[1]
Total	*board feet*	13,700	20,020
Daily gain from sawing cants	*board feet*	—	6,320[1]
Daily production costs:			
Lumber, all grades: 13.7 M at $80/M		$1,096.00	$1,096.00
Purchase extra logs: 4.5 M at $50/M		$ —	$ 225.00
Total		$1,096.00	$1,321.00
Daily gross income:			
Lumber: 2A Common and Better @ $100/M		$1,027.50	$1,365.00
3A Common and Poorer @ $58/M		$ 198.65	$ —
Cants: 6.37 M @ $50/M		$ —	$ 318.50
Total		$1,226.15	$1,683.50
Daily net operating income (Gross income — production costs)		$ 130.15	$ 362.50
Daily gain in operating income from sawing cants		$ —	$ 232.35

[1] The slight variation between cant gain and cant yield is due to elimination of fractional logs and to imperfect fit for cants.

Results

Volume yields are increased when sawlog hearts are sawed into cants instead of 1-inch lumber. Volume is saved because there is less waste from sawdust. In an earlier study to compare the feasibility of sawing crossties and/or 1-inch lumber from 8½-foot logs, Lane and Fechner[3] showed that the board-foot yield from logs sawed into ties was about one-third greater than the yield of logs sawed into lumber. This difference in yield between tie logs and lumber logs was considerably greater than the volume differences observed in our study. But our log size was larger and most of our cants were smaller than the ties used in Lane and Fechner's study. So our increased volume yield from cants would understandably be less.

The graphic placement of boards and saw kerfs upon the ends of the 12 different cant sizes showed that product volume would be 4 to 18 board feet greater than if these cants had been sawed into 1-inch lumber (table 2). However, the proportional increase in volume from cant cutting was not uniform among the 12 sizes tested. Variation occurred because certain

[3] Lane, Paul H., and Gilbert H. Fechner. SAWED TIE PRODUCTION IN THE TENNESSEE VALLEY REGION. Cross Tie Bull. 32 (12): 9-22, 1951.

Table 2. — Comparison of cant volume and 1-inch lumber yield that can be sawed from 12-foot cants of various end dimensions

Cant end dimensions	Cant volume	4/4 lumber yield	Volume difference	Proportionate volume increase from cants
Inches	*Board feet*	*Board feet*	*Board feet*	*Percent*
4 x 4	16.0	12.0	4.0	25.0
4 x 5	20.0	15.0	5.0	25.0
4 x 6	24.0	18.0	6.0	25.0
5 x 5	25.0	15.0	10.0	40.0
5 x 6	30.0	20.0	10.0	33.3
5 x 7	35.0	25.0	10.0	28.6
6 x 6	36.0	24.0	12.0	33.3
6 x 7	42.0	30.0	12.0	28.6
6 x 8	48.0	36.0	12.0	25.0
7 x 8	56.0	42.0	14.0	25.0
7 x 9	63.0	45.0	18.0	28.6
8 x 8	64.0	48.0	16.0	25.0

cant sizes could not be completely converted into boards without some waste other than saw kerf.

Theoretically, the gain from sawing cants should be 25 percent because there is a 1/4-inch kerf for each 1 inch board. But boards are cut 1-1/8 inches thick to allow for shrinkage; and when some cant sizes were diagramed, there were some cuttings that could not be counted as standard 1-inch lumber (fig. 1). In these situations the percentage gain from cant cutting was greater than in those situations where cants could be resawed into 1-inch boards with no waste other than kerf.

Although the reduction in saw-kerf waste is the most obvious source of overrun in cant manufacture, it is not the most important factor in obtaining the greater volume yields from logs sawed into cants. The greatest volume gain comes from the reduction in sawing time. Since cants are the parts of sawlogs left over after all grade lumber has been removed, they require no sawing time.

Theoretically, sawing time is directly proportional to volume sawed. For example, if a 5-by-7-inch cant contains 25 board feet of 1-inch lumber

Table 3. — Daily net operating income from 1-inch lumber production compared to daily net operating income from sawing logs into both cants and 1-inch lumber

(12-foot lengths)

Cant end dimension (inches)	Daily net operating income[1]		
	1-inch lumber	1-inch lumber plus cants	Gain from cants
4 x 4	$205	$307	$102
4 x 5	188	314	126
4 x 6	170	324	154
5 x 5	188	354	166
5 x 6	159	359	200
5 x 7	130	363	233
6 x 6	136	381	245
6 x 7	101	393	292
6 x 8	67	402	335
7 x 8	32	439	407
7 x 9	15	498	483
8 x 8	—2	487	489

[1] Difference between the value of lumber produced daily and the total cost of daily production. Lumber selling costs are not included. Values are to the nearest dollar.

and this cant is sawed from a log yielding 100 board feet of 1-inch lumber, the assumed gain from reduced sawing time would be 25 percent. However, in sawing it is customary to turn factory-grade sawlogs to obtain the maximum volume of high-quality lumber from the outer part of each sawlog face. Each turn requires time that could otherwise be spent in sawing. Therefore, the gain from sawing a cant, rather than 1-inch lumber, is slightly less than the proportion of the total log volume represented by that cant.

The effect of reduced sawing time is by far the most significant factor in obtaining the increased daily volume yield from cants. For instance, overrun from saw-kerf savings amounted to only 10 board feet per log or a total daily gain of 1,820 board feet. But the volume gained from reduced sawing time was 2½ times greater because each day an extra 4,500 board feet of logs were purchased and processed to maintain full sawmill operating capacity.

Of course the most important benefit from sawing cants is the increased income derived from this milling procedure. The manufacture of cants permits a hypothetical increase in daily gross income ranging from $102 to $489 (table 3). These figures are based upon optimum theoretical conditions where all logs are suitable for cant manufacture, all No. 3A Common lumber in the log is confined to the cant, and only one cant size is cut per 8-hour shift. The monetary savings accrue from three sources: (1) cant volume overrun from kerf savings, (2) daily volume gain due to less sawing time per log, and (3) general improvement in the quality and value of 1-inch lumber.

Conclusions

Under optimal theoretical conditions, gross sawmill operating income can be increased through cant manufacture by nearly $500 per day. In practice, however, the economic gains from cant manufacture will be considerably less: perhaps only 10 to 20 percent of the theoretical maximum. Some of the factors that control this potentially greater income are suitability of logs for cant manufacture, cant size, and market potential.

Sawmill operators can expect a greater overrun when sawing cants than when sawing 1-inch lumber. This overrun develops from the savings in kerf volume that would normally be wasted as sawdust when sawing standard lumber thicknesses.

Cant manufacture permits a substantial reduction in sawing time. Theoretically, cants require no conversion time because they are byproducts left after the better grades of lumber have been removed.

The time saved when sawing cants will provide daily volume gains that are considerably greater than the volume gained from cant overrun associated with saw kerf.

Since grade defects are frequently concentrated in the heart section of hardwood sawlogs, the average lumber quality produced by a sawmill will improve if hearts are sawed into cants. Only the better portions of the log will be sawed into 1-inch lumber. Thus average lumber value will increase because the lower grades will have been eliminated. Nor will there be a concomitant reduction in total dollar yield from cants because unit cant values remain nearly static within the range of the most commonly used sizes.

The high profit potential from cant manufacture should encourage hardwood sawmill operators to consider both the manufacture of lumber and cants. When factors such as log quality, mill capacity, and market potential have been thoroughly analyzed to show that cant production is feasible, this milling technique may provide the extra profits so urgently needed.

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U. S. FOREST SERVICE RESEARCH NOTE NE-47

1966

Northeastern Forest

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AVERAGE GROWTH RATES IN SOUTHERN MAINE

In the 1950s a cooperative study was made to obtain accurate growth information about the spruce-fir forests of northern Maine and New Hampshire. The results of that study were published in 1961.[1]

Recently a second study was completed to obtain growth rates for the forests of southern Maine (fig. 1). This is a report on the results of that study.

Both of these studies were made by the Northeastern Forest Experiment Station in cooperation with a group of timberland owners. The cooperators in the southern Maine study were: Dead River Co.; Diamond-Gardner Corp.; T. L. Dickson; Eastern Pulp Wood Co. & St. Croix Paper Co.; Hudson Pulp and Paper Co.; National Packaging Corp.; Oxford Paper Co.; Penobscot Chemical Fibre Co.; Penobscot Development Co.; Prentiss and Carlisle Co.; Scott Paper Co.; Eastern Fine Paper and Pulp Division, Standard Packaging Corp.; St. Regis Paper Co.; and S. D. Warren Co.

Purpose

The purpose of the study in southern Maine was to obtain average net[2] growth rates in gross cubic-foot volume for 24 stand classifications. The classifications are those used by many of the cooperators in estimating volume of standing timber. They consist of four species groups, three

[1] Bickford, C. Allen, Franklin R. Longwood, and Robert Bain. AVERAGE GROWTH RATES IN THE SPRUCE-FIR REGION OF NEW ENGLAND. U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 140, 23 pp., 1961.

[2] Net growth = accretion + ingrowth — mortality.

Figure 1. — The study area included roughly the southern half of Maine—11 counties and parts of 4 others.

height classes, and two density classes, as follows:

Species group. — The composition class was based on plurality of gross cubic-foot volume for sawtimber and poletimber stands, and number of stems for seedling-and-sapling stands. The species groups were: (1) pine; (2) other softwood; (3) mixed wood; and (4) hardwood.

Height. — Height class is the average total height of dominants and codominants. The height classes used in this study were: (1) 0 to 30 feet; (2) 30 to 50 feet; and (3) 50 feet or more.

Density. — Density class is the percent of crown cover in dominants and codominants. The two density classes used were: (1) 35 to 75 percent and (2) 75 to 100 percent.

A landowner who uses these classifications can arrive at an average growth rate for his tract. The variances given in this report for the stand classifications enable calculation of sampling error as a measure of reliability.

Data Collection and Results

The proposed field work in southern Maine included remeasurement of forest-survey plots by the cooperating companies. Using aerial photographs, all plots were classified into species group, height class, and density class by an experienced forest-survey photo interpreter. Four hundred plots were remeasured as of October 14, 1964; and 321 of these plots have

Table 1. — Average net growth per year in gross volume and associated variances by stand class

Species group	Stand class: Height	Stand class: Density	Net growth per acre per year	Plots	Variance of an individual observation (plot)	Standard error of average net growth
	Feet	*Percent*	*Cubic feet*	*Number*		*Cubic feet*
Pine	0-30	35-75+	39.3	4	4018.58	31.7
		75+	—	—	—	—
	30-50	35-75	37.2	8	3733.67	21.6
		75+	86.7	9	1804.26	14.2
	50+	35-75	27.0	8	3401.07	20.6
		75+	65.2	12	4415.98	19.2
Other softwood	0-30	35-75	22.5	9	1002.23	10.6
		75+	34.4	6	1601.11	16.3
	30-50	35-75	56.0	32	6806.69	14.6
		75+	65.6	21	2318.54	10.5
	50+	35-75	39.2	9	2049.32	15.1
		75+	51.9	17	3180.88	13.7
Mixed wood	0-30	35-75	26.6	7	439.42	7.9
		75+	38.5	2	3784.50	43.5
	30-50	35-75	47.7	31	2571.65	9.1
		75+	53.0	13	1903.22	12.1
	50+	35-75	29.3	15	1895.34	11.2
		75+	60.8	19	2770.51	12.1
Hardwood	0-30	35-75	21.1	15	1356.22	9.5
		75+	4.1	6	26.27	2.1
	30-50	35-75	15.2	25	630.84	5.0
		75+	43.5	20	3515.74	13.3
	50+	35-75	39.2	15	1553.09	10.2
		75+	49.7	18	1252.39	8.3

been used by the Northeastern Station to obtain the average growth rates and variances presented in table 1. The remaining plots either had been heavily cut or were obviously in error and therefore were considered unsuitable for growth calculations. Plots were measured during periods of dormancy to simplify conversion of periodic increment to average annual growth. The period between measurements averaged 5 years.

Application

Two examples are presented below to show how the forest landowner can apply these growth data.

EXAMPLE 1

Purpose. — The landowner wishes to obtain an estimate of growth for a 63,300-acre tract in southern Maine.

Method. — First he stratifies the tract by aerial-photo delineation into classes corresponding to those used in this study. When this is done, he can then obtain his estimate of growth by applying the average growth rates from table 1 to the specific breakdown of area.

Table 2. — Example of estimation of total net cubic-foot growth

Stand class: Species group	Stand class: Height	Stand class: Density	Area	Area	Average net growth	Total net growth
	Feet	*Percent*	*Acres*	*Proportion of Total*	*Cubic feet*	*Cubic feet*
Pine	0-30	35-75	0	—	—	—
		75+	0	—	—	—
	30-50	35-75	0	—	—	—
		75+	5,100	0.081	86.7	442,170
	50+	35-75	4,500	.071	27.0	121,500
		75+	6,800	.107	65.2	443,360
Other softwood	0-30	35-75	2,100	.033	22.5	47,250
		75+	0	—	—	—
	30-50	35-75	8,400	.133	56.0	470,400
		75+	6,200	.098	65.6	406,720
	50+	35-75	0	—	—	—
		75+	2,100	.033	51.9	108,990
Mixed wood	0-30	35-75	0	—	—	—
		75+	0	—	—	—
	30-50	35-75	9,400	.148	47.7	448,380
		75+	4,100	.065	53.0	217,300
	50+	35-75	0	—	—	—
		75+	2,000	.032	60.8	121,600
Hardwood	0-30	35-75	1,500	.024	21.1	31,650
		75+	0	—	—	—
	30-50	35-75	2,200	.035	15.2	33,440
		75+	2,100	.033	43.5	91,350
	50+	35-75	4,700	.074	39.2	184,240
		75+	1,100	.033	49.7	104,370
Total	—	—	63,300	1.000	—	3,272,720

Result. — Calculation of the growth estimate is shown in detail in table 2. The last column represents the product of the area in acres and growth in cubic feet. These values are the estimates of total annual growth for each of the 24 classes. The sum of these values — 3,272,720 cubic feet — is the estimated annual net growth for the landowner's tract, in gross cubic-foot volume.

The proportions of area shown in table 2 could have been used to calculate the portion of growth-per-acre attributable to each class. The sum of these growth rates would be 51.7 cubic feet, the average growth per acre for the tract.

EXAMPLE 2

Purpose. — Assuming that the forest area of the southern Maine region is 10 million acres and that the 321 remeasured plots are a simple random sample of this region, growth calculations can be made in the same manner as in example 1.

Method. — For purposes of this example, the area within each class is assumed to be consistent with the area represented by the numbers of plots within the class. Numbers of plots in column 2 of table 3 and average growth rates in column 3 were obtained from table 1. The area breakdown in column 4 was obtained from numbers of plots in column 2.

Result. — Calculated average annual growth rates per acre of forest area are shown in column 6. The sum of column 6 is the estimated annual net growth of all species in the region — 44.02 cubic feet per acre. The estimated total growth is 440.2 million cubic feet.

Calculation of Sampling Error

Sampling error, although sometimes viewed by the nonmathematician as overly complicated, is usually the only unbiased measure of confidence attached to an estimate. Taken one step at a time, sampling errors are easily calculated and interpreted. For instance, the sampling error of average growth from the stratified estimate is calculated as

$$S_{\bar{x}} = \sqrt{\sum \left(\frac{P_i^2 \, S_i^2}{n_i} \right)}$$

in which

P_i = the proportion of area within the class

S_i^2 = the variance of the class

n_i = the number of plots within the class.

For example 1, refer to table 2: square the proportion and multiply by the variance from table 1; divide by numbers of plots from table 1; sum over all 15 classes and obtain the square root of this sum.

Table 3. — Example of calculation of mean cubic-foot growth and its sampling error for all species

1			2	3	4	5	6	7	8	9
Species group	Stand class: Height	Stand class: Density	Plots	Average growth	Area	Variance	Proportion times average growth	Col. 4 times col. 5	Col. 4 times col. 7	Col. 8 divided by col. 2
	Feet	*Percent*	*Number*	*Cubic feet*	*Proportion of Total*		*Cubic feet*			
Pine	0-30	35-75	4	39.3	0.012	4018.58	0.472	48.223	0.579	0.144750
		75+	0	—	.000	—	—	—	—	—
	30-50	35-75	8	37.2	.025	3733.67	.930	93.342	2.334	.291750
		75+	9	86.7	.028	1804.26	2.428	50.519	1.415	.157222
	50+	35-75	8	27.0	.025	3401.07	.675	85.027	2.126	.265750
		75+	12	65.2	.037	4415.98	2.412	163.391	6.045	.503750
Other softwood	0-30	35-75	9	22.5	.028	1002.23	.630	28.062	.786	.087333
		75+	6	34.4	.019	1601.11	.654	30.421	.578	.096333
	30-50	35-75	32	56.0	.100	6806.69	5.600	680.669	68.067	2.127094
		75+	21	65.6	.065	2318.54	4.264	150.705	9.796	.466476
	50+	35-75	9	39.2	.028	2049.32	1.098	57.381	1.607	.178556
		75+	17	51.9	.053	3180.88	2.751	168.587	8.935	.525588
Mixed wood	0-30	35-75	7	26.6	.022	439.42	.585	9.667	.213	.030429
		75+	2	38.5	.006	3784.50	.231	22.707	.136	.068000
	30-50	35-75	31	47.7	.097	2571.65	4.627	249.450	24.197	.780548
		75+	13	53.0	.040	1903.22	2.120	76.129	3.045	.234231
	50+	35-75	15	29.3	.047	1895.34	1.377	89.081	4.187	.279133
		75+	19	60.8	.059	2770.51	3.587	163.460	9.644	.507579
Hardwood	0-30	35-75	15	21.1	.047	1356.22	.992	63.742	2.996	.199733
		75+	6	4.1	.019	26.27	.078	.499	.009	.001500
	30-50	35-75	25	15.2	.078	630.84	1.186	49.206	3.838	.153520
		75+	20	43.5	.062	3515.74	2.697	217.976	13.515	.675750
	50+	35-75	15	39.2	.047	1553.09	1.842	72.995	3.431	.228733
		75+	18	49.7	.056	1252.39	2.783	70.134	3.928	.218222
Total	—	—	321	—	1.000	—	44.02	—	—	8.221980

Using pine (height = 30 to 50, density = 75+), to illustrate:

$$\frac{[\ (0.081)^2\ (1804.26)\ ]}{9} = 1.315306$$

This result is the contribution for that one class. The sampling error for all classes is the square root of the sum of 15 such numbers. For example 1, it was calculated to be 4.040 cubic feet. As indicated by the symbol, this applies to the mean value per acre previously calculated to be 51.7 cubic feet. The error for the property as a whole is obtained by multiplying 4.040 by 63,300 acres. For these data the sampling error is 255,732 cubic feet. Expressed in percent, this error is 7.8.

For example 2, refer to table 3. Column 7 lists the product of proportion and variance; these entries are then multiplied by the respective proportions to obtain $P_i^2\ S_i^2$ as column 8 entries. Next, division by number of plots provides the entries of column 9, which are summed to give 8.221980. The square root of this sum is 2.867, which is the standard error — or sampling error — of the mean. It is 6.5 percent of X = 44.02. The corresponding sampling error for the region is 28,670 million cubic feet (6.5 percent of 440,200,000 cubic feet).

Briefly, here is how the sampling error indicates reliability. Example 1 provided an average net growth rate of 51.7 cubic feet per acre per year with a sampling error of 7.8 percent. The probability that a new estimate would fall within 7.8 percent of 51.7 cubic feet is approximately 68 percent. This means that the odds are 2 to 1 that if the study were repeated the new estimate of net growth would be between 47.7 and 55.7 cubic feet (51.7 ± 4.0). Increasing the size of this interval would increase the corresponding probability, and vice versa. For example, the odds are 19 to 1 that a new estimate of net growth would be between 43.7 and 59.7.

Evaluation

As in the growth study conducted in northern Maine and New Hampshire, average growth rates are somewhat higher than was previously assumed. It must be kept in mind, however, that mechanical defect and decay incidence is not reflected in these averages other than in the effect they have upon the components of growth in gross volume.

Usable estimates of net growth can be obtained for a particular property only if these averages are applied to areas delineated in the same manner as those used in this study. Some classes are represented by fewer plots than others and would be expected to yield estimates with less reliability. This will be reflected in the sampling error. Users of these data are urged to make use of the sampling-error calculation procedure as an index of the value of each estimate made.

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U. S. FOREST SERVICE RESEARCH NOTE NE-48

1966

Northeastern Forest

EST SERVICE, U. S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA.

Experiment Station

SITE INDEX OF DELAWARE-MARYLAND SWEETGUM STANDS IN RELATION TO SOIL CHARACTERISTICS

Intensive forest management requires knowledge about the differences in productivity of land areas or sites. The suitability of management systems and stand treatments often depends on the potential of the particular site in question. For example, conversion of low-value stands to another species may be economically feasible on the best sites, but not on the poor ones. To provide the guides needed for management decisions, sites must be grouped into quality classes on the basis of studies that relate site productivity to measurable site characteristics. Local studies are usually required, because factors important in one region often prove to be relatively unimportant in another.

Relationships between the site index of New Jersey sweetgum stands and soil and water-table characteristics were described in a 1963 publication[1]. That study was subsequently extended to Delaware and Maryland; this report describes results from the extended study.

Study Methods

Study methods used in the Delaware and Maryland Coastal Plain were essentially the same as those used in New Jersey[1]. Sweetgum blight, heavy cutting, and age eliminated many prospective stands from study; only 25

[1] Phillips, John J., and Marco L. Markley. SITE INDEX OF NEW JERSEY SWEETGUM STANDS RELATED TO SOIL AND WATER-TABLE CHARACTERISTICS. U. S. Forest Serv. Res. Paper NE-6, 25 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1963.

suitable areas were located. Of these, only one was in Delaware; and it had a muck soil, so it too was eliminated from all subsequent analyses based on mineral-soil characteristics. Of the other 24 areas, 6 were located on Maryland's Eastern Shore and 18 on the Western Shore.

Groundwater wells were established in all of the Delaware and Maryland plots so that depth to groundwater and fluctuations in this depth could be measured.

Results

Groundwater relationships.—Because of droughts in 1963 and 1964, groundwater levels in the Delaware and Maryland plots were lower than those measured in the New Jersey study. Groundwater levels dropped below the well bottom (42 inches) early in the summers of both 1963 and 1964, eliminating any chance of relating groundwater and site index in the Delaware-Maryland plots.

Soil factors and site index.—The first step in the analysis was to test the equation developed earlier for mature soils in New Jersey[1] on the 12 Maryland plots that had similar soils. The New Jersey equation seemed adequate for 10 of these plots: the average difference between predicted and measured site index for the 10 plots was 6.7 feet, 1 foot more than the standard error of estimate found in the New Jersey study. The two Maryland plots that differed widely in site index from the value predicted by the New Jersey equation had subsoil silt contents in excess of 50 percent. This is much more silt than was found in the New Jersey or other Maryland plots, where average silt contents were 18 and 27 percent respectively. However, the inclusion of correction factors based on silt content of the subsoil did not appreciably improve the accuracy of the equation.

The second step in the analysis was to combine data from all plots (except those on muck) in the three states. In this analysis, height of the sampled trees was used as the dependent variable, rather than site index. The resulting equation was:

$$\text{Height} = 98.5 - \frac{1310}{\text{age}} - 9.7X_1 + 0.51X_2 + 0.19X_3 - 4.2X_4 - 3.5X_5$$

where:

Age = number of rings at breast height plus 3.

X_1 = 0 for alluvial soils with silt contents of less than 50 percent in the B_2 horizon; or 1 for all residual soils and for alluvial soils with silt contents of 50 percent or more in the B_2 horizon.

X_2 = percent of clay in the B_2 horizon.

X_3 = percent of fine sand in the B_2 horizon.

X_4 = 0 where silt content of the B_2 horizon is 16 percent or more; or 1 where this silt content is 15 percent or less.

X_5 = 0 where the depth to a tight B_2 horizon is 13 inches or more; or 1 where this depth is 12 inches or less.

The multiple correlation coefficient for this equation is 0.87 and the standard error of estimate is between 5 and 6 feet. While the equation accounts for 75 percent of the variation found in the average height of the sampled trees, about 45 percent of this is due to age and only 30 percent is due to the soil factors that were included in the equation.

On the basis of the study samples, this equation would predict productivity within a 10-foot class (± 5 feet) for 60 percent of the sites. For the remainder, values would be less accurate. Height of trees on one sample plot differed from the predicted value by 17 feet, and in 10 other plots it varied by 10 or 11 feet. Nevertheless the equation may be a useful guide for estimating site productivity for sweetgum on alluvial soils in all three states. For residual soils in Delaware and Maryland, this equation is much more accurate than the earlier New Jersey equation.

To facilitate use of this new equation, table 1 has been computed for predicted values of site index (base age of 50 years).

Site index by soil groups.—Site-index values are listed by soil groups, drainage classes, and types in table 2. Although there was considerable variation in site index within classes, the values presented here may be useful as a guide for estimating site index.

Alluvial soils were often very good sites for sweetgum, with site index generally between 85 and 95. Coarse-textured nonglauconitic deposits in New Jersey ran lower (77-82), as did some of the Bibb soils in Maryland.

Mature residual soils were moderate to good sites for sweetgum. Values on the very poorly drained Portsmouth loam varied little from the average of 85 feet. Greater variation occurred on the moderately well-drained Woodstown loam (78 to 93) ; and the sole value for Rutledge (78) was 18 feet higher than the single New Jersey plot that fell in that soil series. The only Fallsington plot also had a much higher value in Maryland than in New Jersey; its value was 88 compared to 58 and 64 for the two New Jersey plots.

Muck soils were normally low in productivity. But where drainage has been improved, sweetgum may have a relatively high site index—85 on one study plot.

Table 1.—Predicting sweetgum site index on soils of the Delaware-Maryland-New Jersey Coastal Plain[1]
(In feet at 50 years of age)

A

Clay in B_2 horizon (percent)	Alluvial soils with silt contents in B_2 horizon of— 50 percent or more	Alluvial soils with silt contents in B_2 horizon of— 16-49 percent	Alluvial soils with silt contents in B_2 horizon of— 15 percent or less	Residual soils with silt contents in B_2 horizon of— 16 percent or more	Residual soils with silt contents in B_2 horizon of— 15 percent or less
5	65	75	71	65	61
10	68	77	73	68	64
20	73	82	78	73	69
30	78	88	83	78	74
40	83	93	88	83	79
50	88	98	94	88	84
55	—	100	96	91	86

B

Fine sand in B_2 horizon (percent)	Depth to tight B_2 horizon: 13 inches or more	Depth to tight B_2 horizon: 12 inches or less
5	+1	−2
10	+2	−2
20	+4	0
30	+6	+2
40	+8	+4
50	+10	+6
60	+11	+8
70	+13	+10
75	+14	+11

[1] First obtain base value in A; then correct as indicated in B. Estimated site index is the result of adding these two values.

Conclusions

In this study, neither individual soil characteristics used in regression equations nor soil types recognized in the National Cooperative Soil Survey proved to be precise indicators of site productivity for sweetgum stands in New Jersey, Delaware, and Maryland. However, estimates of site productivity made from information in this report should still be useful to practicing foresters. Best estimates can be made on the following basis:

- All soils: the site index values given here by soil type may be used as a guide in estimating site index.

Table 2.—Site index for Maryland and Delaware sweetgum stands by soil groups, drainage classes, and soil types

Soil groups, drainage classes, and soil types	Site-index values *Feet*
MATURE RESIDUAL SOILS	
Moderately well drained:	
Adelphia-Donlonton loam or fine sandy loam[1]	74, 90
Donlonton-Keyport loam	76
Donlonton silt loam	78
Keyport fine sandy loam	80
Woodstown loam	78, 84, 93
Poorly drained:	
Fallsington fine sandy loam	88
Very poorly drained:	
Portsmouth loam	83, 85, 87
Rutlege sandy loam	78
ALLUVIAL SOILS	
Bibb silt loams	74, 75, 81, 82, 90, 94
Johnston loamy fine sand	96
RECENT ALLUVIAL DEPOSITS	
Well drained (Fluctuating water table)	87
Poorly drained[2]	84, 90
MUCKS	
Mucks	68, 85

[1] Where two type names are used, the soil is an intergrade between the two.
[2] The value 90 is on a deposit showing greensand influence.

- Alluvial soils and recent alluvial deposits: the prediction equation presented here should be useful for estimating site index in all three states, although it predicts within a 10-foot site-index class ($\pm$ 5 feet) on only about 75 percent of the sites.

- Mature residual soils: for mature soils in New Jersey, the equation previously reported[1] will give slightly more accurate predictions than the one offered in this paper. For mature residual soils in Delaware and Maryland, the equation presented in this paper gives more reliable results.

— JOHN J. PHILLIPS[2]

[2] When this study was made, the author was associate soil scientist on the staff of the Northeastern Forest Experiment Station's research unit at New Lisbon, N. J. At present he is on the staff of the Wisconsin Public Service Commission, Madison, Wis.

U. S. FOREST SERVICE RESEARCH NOTE NE-49

1966

Northeastern Forest

FOREST SERVICE, U. S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA.

Experiment Station

DEFECTS IN BIRCH ASSOCIATED WITH INJURIES MADE BY *XYLOTERINUS POLITUS* SAY.

The purpose of this note is to give a brief pictorial description of the internal defects in paper birch (*Betula papyrifera* Marsh.) and yellow birch (*B. alleghaniensis* Britt.) that are associated with external signs of infestation by the ambrosia beetle *Xyloterinus politus*[1] (fig. 1). The information was gained during studies of trees growing in the White Mountains of New Hampshire.

Adult beetles usually bore through lenticels in trees weakened earlier by mechanical wounds, living agents, and other causes (fig. 2). Apparently when certain infested trees do not die, the beetles depart, leaving behind the galleries they have made, approximately 1/16 inch in diameter. These wounds initiate processes that result in discoloration (fig. 3). Bacteria and fungi often enter through the wounds, where they contribute to the discoloration processes. The fungi may even cause decay when conditions are favorable.

The extent of internal defects arising from beetle infestation depends primarily on (1) the number of beetle holes, and (2) the extent and location of the internal defects already present in the tree at the time of attack.

There are three general patterns of defect: (1) spindle-shaped islands of discoloration (vigorous trees, light infestation) (fig. 3 and 4); (2) irregular patches of discoloration resulting from coalescence of many islands of discoloration, and sometimes further coalescence of such discoloration with large central discoloration already in the tree (medium

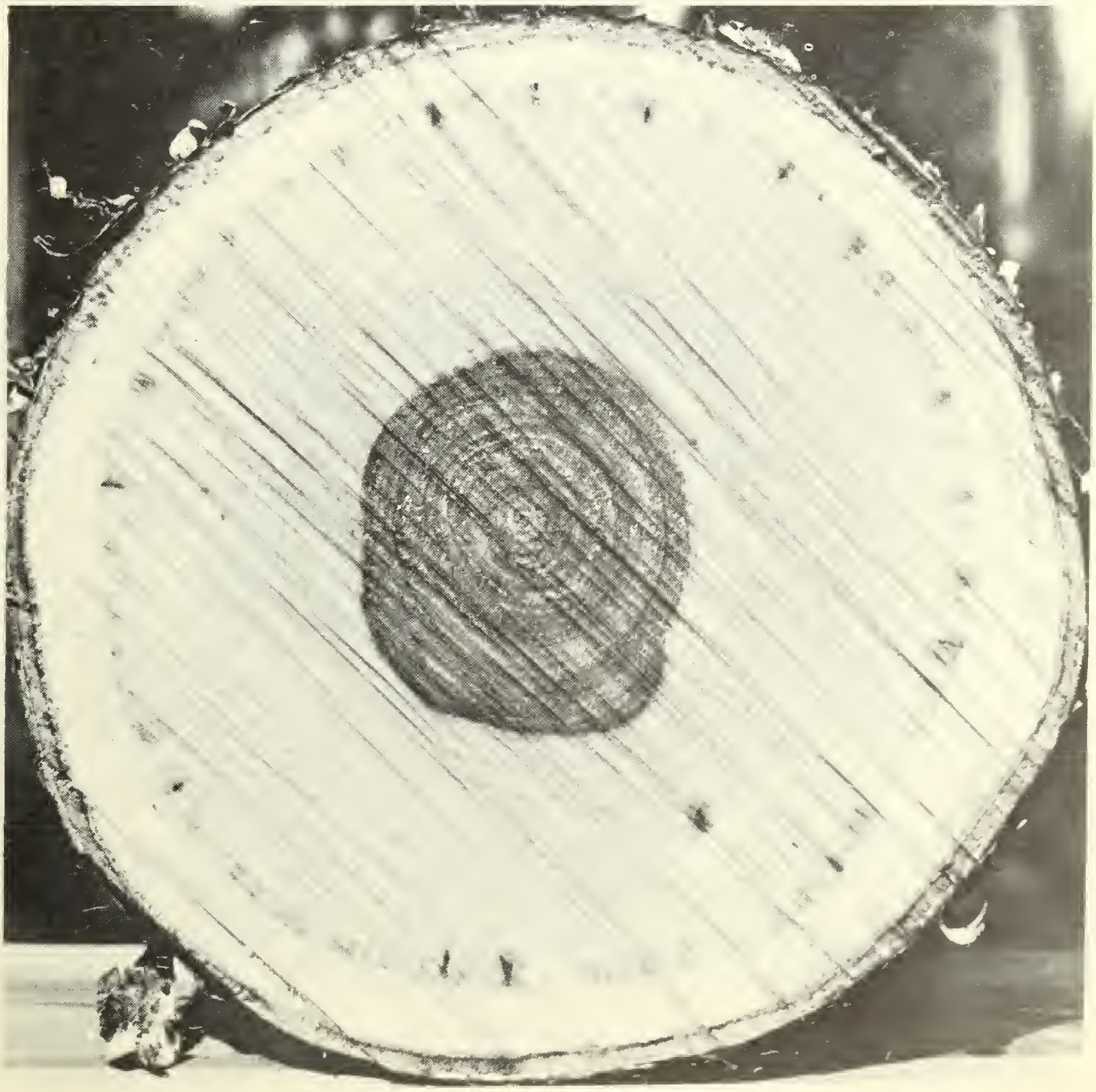
[1] The author is indebted to Dr. Jack Krall of the New York State University College of Forestry at Syracuse for identifying the beetle.

Figure 1. — Ambrosia beetles (Xyloterinus politus).

Figure 2. — Small holes in lenticels of birch tree indicate attack by X. politus.

Figure 3. — Small islands of discoloration associated with a light infestation of X. politus.

Figure 4. — Cross-section of islands of discoloration. The wood that formed subsequent to infestation remained white, while the wood present at the time of infestation was a dull pink (except the dark red-brown central discoloration that was present before insect attack).



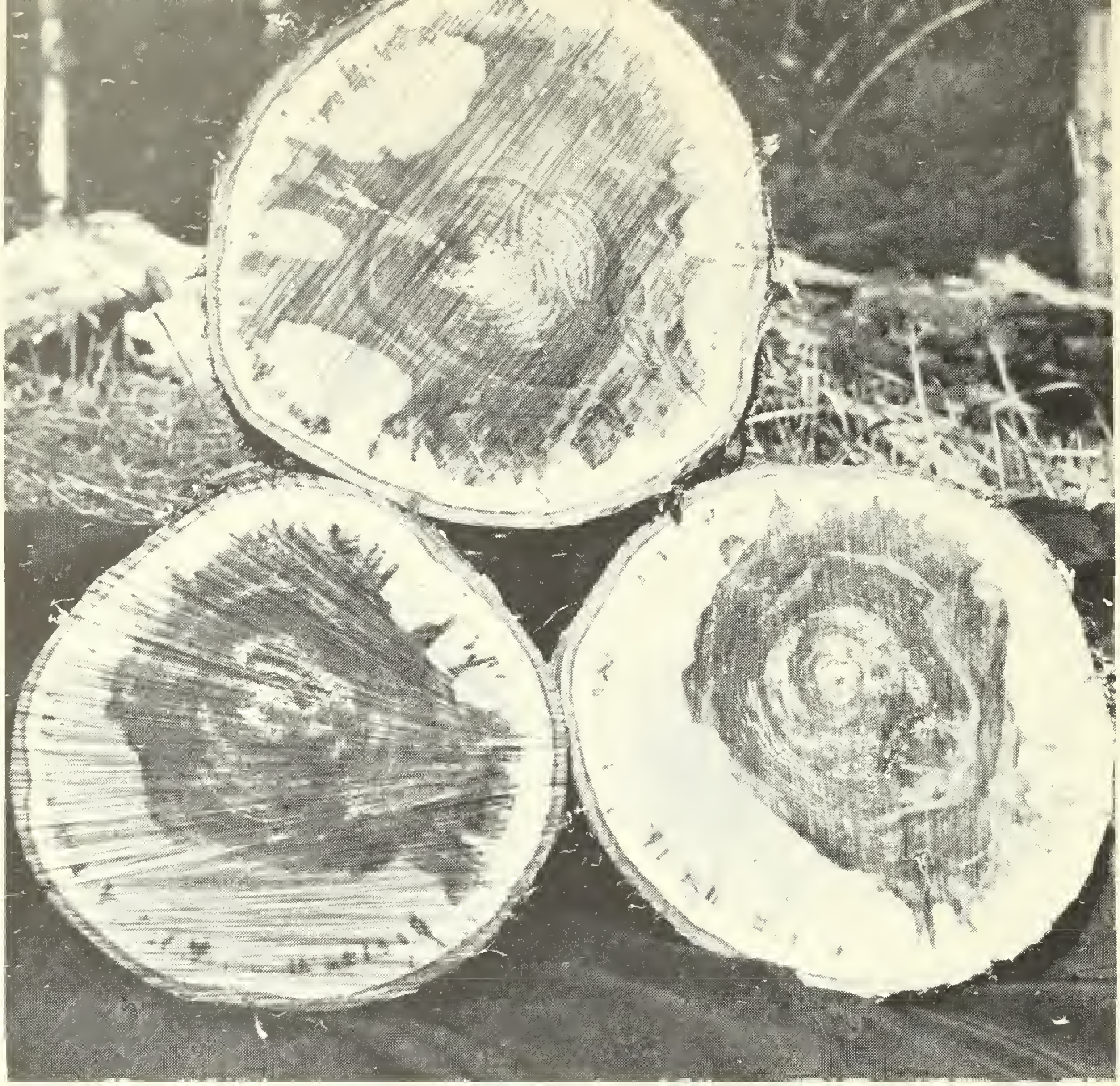


Figure 5. — A jagged pattern of defect associated with a medium infestation. The injured annual ring is distinct in the lower samples. Small dots of discoloration in the upper sample indicate a light recent infestation.

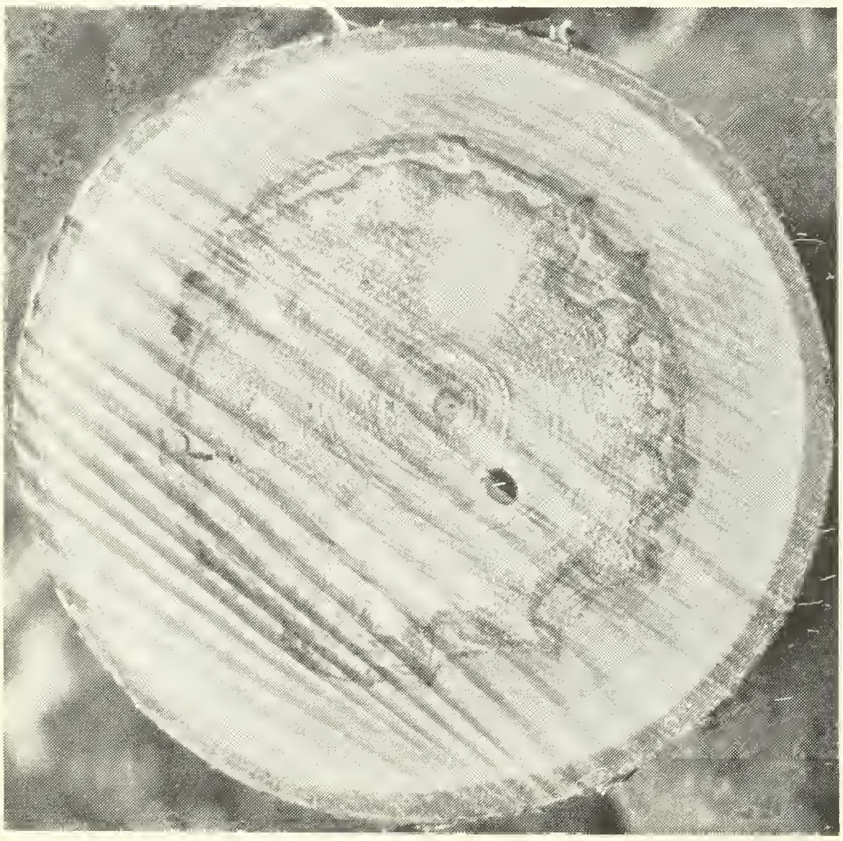
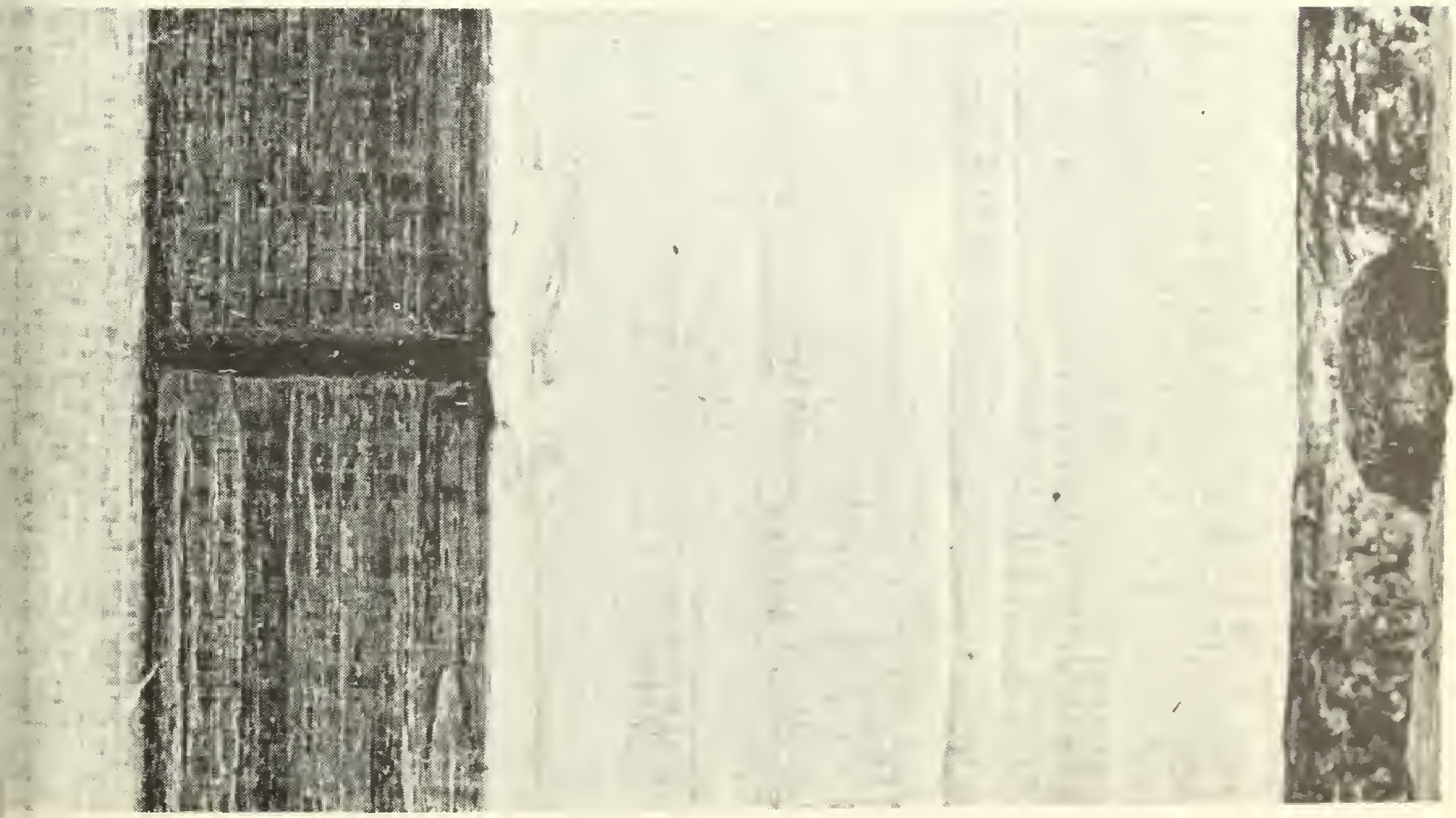


Figure 6. — Decay and discoloration associated with a severe infestation. A circular pattern resulted when the defects joined.

Figure 7. — Nodule-like growths of callus tissue around beetle holes inflicted 40 years ago.

Figure 8. — In this radial view of a sectioned tree, an excavation formed by the removal of the bark nodule around the beetle hole, made over 40 years ago and subsequently carried outward on the bark, is directly in line with the gallery now deeply buried within the tree. The radial extent of the discoloration conforms to the length of the gallery. In cross-sections such discolorations appear as spindle-shaped islands (see figs. 4 and 5).



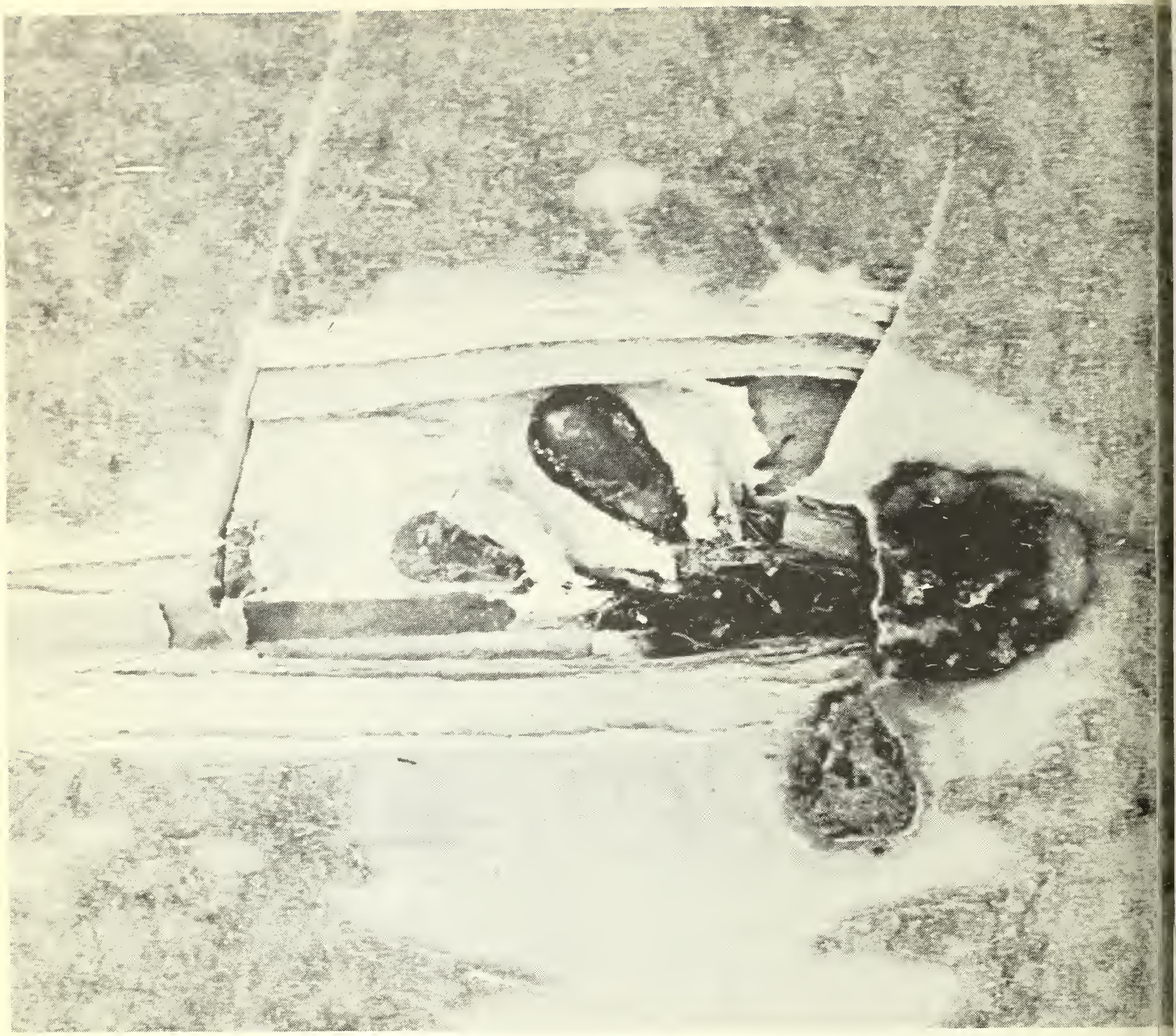


Figure 9. — A Xylococculus betulae colony that gained entrance to the inner bark through the beetle hole in the lenticel.

infestation) (fig. 5); and (3) continuous patterns, forming a circle in cross-section and sometimes including decay (severe infestation) (fig. 6).

Beetle holes in lenticels are carried outward on the bark as the tree grows and can remain visible for over 40 years (fig. 7). They serve as reliable signs of internal defect (fig. 8), and the number of holes serves to indicate the extent of defect.

The defects are compounded when the holes are inhabited by the scale insect, *Xylococculus betulae* (Perg.) Morrison (fig. 9). These insects expel their saccharine excrement through long wax tubes that protrude from their bodies out through the holes in the bark. Their feeding retards the healing processes. Woodpeckers searching for scale insects as food further disrupt the healing processes when they tear the bark to expose the insects.

The patterns of defects described here are similar to those occurring in sugar maples (*Acer saccharum* Marsh.) that have sapstreak disease. Observations by the author suggest that ambrosia beetles play a role in sapstreak disease of maples also.

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U. S. FOREST SERVICE RESEARCH NOTE NE-50

1966

Northeastern Forest

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Experiment Station

BACTERIA OF LIVING AND DEAD LARVAE OF *PORTHETRIA DISPAR* (L.)

A preliminary study of the bacteria associated with living and dead larvae of the gypsy moth (*Porthetria dispar* (L.)) was undertaken to determine what types of micro-organisms may be associated with disease in this insect. Specific objectives of this study were to enumerate the types of aerobic bacteria, and if possible to further elucidate the role of disease-causing micro-organisms in the population dynamics of this insect (Campbell 1963). In addition, information was taken to determine if there was a gross relationship between the habitat of the insect and the microflora encountered.

Although many bacterial genera and species from other insects have been described in qualitative studies, only scant information is available about the resident or transitory population of the gypsy moth. In the first phase of this investigation, Dubois[1] used media containing plant and insect tissues to isolate the maximum number of aerobic bacterial types present. None of the devised media was found to be better than trypticase soy agar, which is employed routinely for the cultivation of bacteria.

The authors, along with other insect pathologists, realize that the framework of any survey is based upon the availability and suitability of selective media. In this sense the experimental design was restrictive. By employing trypticase soy agar aerobically, they eliminated the possibility of isolating anaerobes and other fastidious micro-organisms. Thus this investigation dealt only with bacteria capable of growth under the stated conditions.

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[1]Normand R. Dubois. U. S. Forest Serv., NE. Forest Exp. Sta., Forest Insect Res. Div. Quart. Rep. July-Sept. 1961. 14 pp., New Haven, Conn.

Materials and Methods

Cultures. — Collections of gypsy moth larvae were made in Schenectady County, New York, in the summers of 1961, 1962, and 1963. A total of 345 isolates were obtained from 196 dead instar IV-VI larvae, 58 living instar V larvae, and 17 dead larvae that had been parasitized (containing the parasite maggot).

Isolation procedures. — Of the 345 bacterial isolates investigated, 251 were obtained from the dead larvae, 69 from the living larvae, and 25 from the parasitized larvae.

Each dead larva was surface-treated for 5 minutes in a 0.5-percent Clorox solution that contained 0.01 percent Tween 80.[2] The larva was rinsed five times with sterile water, and 1 ml. of the final rinse was plated on trypticase soy agar (TSA) to assure sterility of the larval surface. Each treated larva was macerated with a sterile glass rod in 1 ml. of sterile water. A loopful of the crushed material was streaked on TSA and incubated aerobically at 28°C. for 24 hours.

After visible growth had occurred on the plates, all colonies that appeared different were transferred to TSA slants. Stock cultures were maintained on TSA at 4°C.

Site descriptions. — In an effort to determine if bacterial isolations were related to a particular ecological area, 55 dead and 54 living larvae of those mentioned above were collected in three forest sites for which pertinent descriptive data were taken (Campbell 1963).

Site E was primarily a dry site with well-drained soil. White oak *(Quercus alba* L.) was the predominant tree species, with red oak *(Quercus rubra* L.) and pignut hickory *(Carya glabra* (Mill.) Sweet) next in abundance. The undergrowth was sparse.

Site F was along a well-drained ridge, neither wet nor dry. Red and white oak predominated, with an understory of witch hazel *(Hamamelis virginiana* L.) and hophornbeam *(Ostrya virginiana* (Mill.) K. Koch).

Site H, classified as a wet site, had 8 inches of organic muck lying directly over an impermeable layer. Swamp white oak *(Quercus bicolor* Willd.) and red maple *(Acer rubrum* L.) were the predominant tree species, with little shrub cover.

Identification of isolates. — Colonial, morphological, and physiological characteristics of the microbial isolates were determined by standard

[2]Mention of a particular commercial product should not be construed as an endorsement by the U. S. Department of Agriculture or the Forest Service.

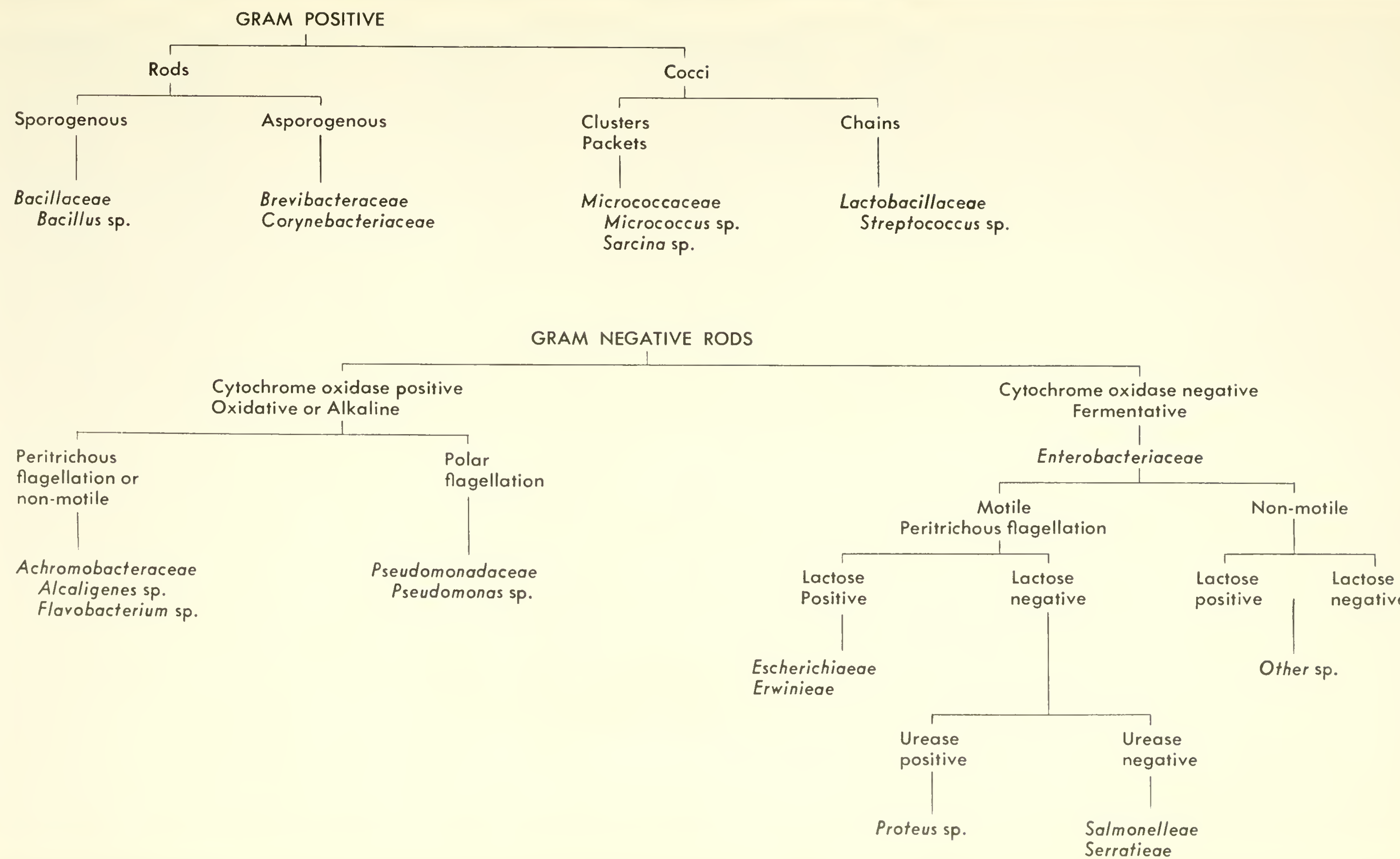

Figure 1. — General scheme for identifying bacterial isolates.

bacteriological techniques as described in the *Manual* of the American Society of Microbiologists (1957), unless otherwise indicated.

Colonial characteristics were determined from 48-hour cultures on TSA plates or slants.

Morphological observations were made by using bright-field and phase-contrast illumination. Motility and cell arrangement were determined from hanging-drop preparations of 12-hour trypticase soy broth cultures. Flagellar arrangement was detected according to the method of Leifson (1951). Gram stains were made according to the method of Kopeloff and Beerman. Endospore stains were made by steaming cells with 5 percent aqueous malachite green and counterstaining with 1-percent aqueous safranin.

The anaerobic fermentation of glucose was detected by using a method of Hugh and Leifson (1953). Lactose fermentation was detected in Phenol red lactose broth (BBL). Cytochrome oxidase was determined using Kovacs' method (1956). Urease activity at 37°C. was detected in urea broth (BBL).

Bacterial types were identified according to a stepwise scheme outlined in figure 1. The investigators are well aware of the shortcomings of such a procedure, but for the purpose of this survey it was deemed adequate. No attempt was made to identify the isolates according to species, except where noted.

Results and Discussion

Bacterial types isolated from dead, living, and parasitized gypsy moth larvae are shown in table 1. No striking difference appeared in frequency of isolation of a particular bacterial group between living and dead larvae except in the case of the family *Enterobacteriaceae.* Of the isolates from dead larvae, 26.7 percent were members of this family; whereas only 1.4 percent of the isolates from living larvae were members of this group. The significance of this information is not clear, but there is a possibility that members of this family may be responsible for some disease in the larvae. *Proteus myxofaciens* n. sp. is a member of this group and might be associated with disease in the insect, although this microbe in itself is not pathogenic for gypsy moth larvae.[3]

Members of the genus *Bacillus* accounted for 44.9 and 43.4 percent of the isolations from living and dead larvae, respectively. Four cultures of

[3]Podgwaite, John D. PROTEUS MYXOFACIENS N. SP. ISOLATED FROM GYPSY MOTH LARVAE. M.S. Thesis, University of Connecticut, 58 pp. 1965.

Table 1. — Bacterial isolations from gypsy moth larvae

Organism	Number of isolates from larvae				Percent of total isolations			
	Dead	Living	Para-sitized	Total	Dead	Living	Para-sitized	Total
Pseudomonadaceae	5	1	0	6	2.0	1.4	0	1.7
Pseudomonas sp.	5	1	0	6	—	—	—	—
Achromobacteraceae	10	1	0	11	4.0	1.4	0	3.2
Alcaligenes sp.	8	1	0	9	—	—	—	—
Flavobacterium sp.	2	0	0	2	—	—	—	—
Enterobacteriaceae	67	1	17	85	26.7	1.4	68.0	24.6
Escherichieae	14	1	8	23	—	—	—	—
Paracolobactrum sp.	7	0	0	7	—	—	—	—
Other sp.	7	1	8	16	—	—	—	—
Proteeae	48	0	8	56	—	—	—	—
P. myxofaciens	16	0	0	16	—	—	—	—
Providence strains	12	0	4	16	—	—	—	—
Other sp.	20	0	4	24	—	—	—	—
Erwinieae, Serratieae, Salmonelleae	5	0	1	6	—	—	—	—
Micrococcaceae	14	5	1	20	5.6	7.2	4.0	5.8
Micrococcus sp.	12	4	1	17	—	—	—	—
Sarcina sp.	2	1	0	3	—	—	—	—
Brevibacteriaceae, Corynebacteriaceae	10	7	0	17	4.0	10.1	0	4.9
Lactobacillaceae	36	23	6	65	14.3	33.3	24.0	18.8
Streptococcus sp.	24	17	6	47	—	—	—	—
S. faecalis	12	6	0	18	—	—	—	—
Bacillaceae	109	31	1	141	43.4	44.9	4.0	40.9
B. thuringiensis types	4	0	0	4	—	—	—	—
Other Bacillus sp.	105	31	1	137	—	—	—	—
Total	251	69	25	345	100.0	100.0	100.0	100.0

a crystalliferous *Bacillus,* pathogenic for gypsy moth larvae, were isolated and will be reported elsewhere.

The other major group of bacterial isolates was of the genus *Streptococcus.* Certain motile pigmented streptococci from this survey have already been reported as potential pathogens by Cosenza and Lewis (1965). These micro-organisms may be responsible for natural mortality in gypsy moth populations.

Sixty-eight percent of the isolates from parasitized larvae were members of the family *Enterobacteriaceae,* and 24 percent were streptococci. Any attempt to associate these groups with parasitization, on the basis of the data available, would be premature.

Table 2 lists some of the same bacterial isolates shown in table 1 that were isolated from larvae for which we had specific site information. A

Table 2. — Bacteria isolated from larvae associated with site information

Organism	Living larvae from site —				Dead larvae from site —				Total bacterial types per site from site —		
	E	F	H	Total	E	F	H	Total	E	F	H
Pseudomonadaceae	0	0	1	1	0	1	2	3	0	1	3
Pseudomonas sp.	0	0	1	1	0	1	2	3	—	—	—
Achromobacteraceae	0	0	0	1	1	1	1	3	2	1	1
Alcaligenes sp.	1	0	0	1	1	0	1	2	—	—	—
Flavobacterium sp.	0	0	0	0	0	1	0	1	—	—	—
Enterobacteriaceae	0	1	0	1	7	7	8	22	7	8	8
Escherichieae	0	1	0	1	4	2	1	7	—	—	—
Paracolobactrum sp.	0	0	0	0	0	1	1	2	—	—	—
Other sp.	0	1	0	1	4	1	0	5	—	—	—
Proteeae	0	0	0	0	3	5	7	15	—	—	—
P. myxofaciens	0	0	0	0	1	2	3	6	—	—	—
Other sp.	0	0	0	0	1	3	2	6	—	—	—
Erwinieae, Serratieae, Salmonelleae	0	0	0	0	0	0	0	0	—	—	—
Micrococcaceae	2	1	2	5	2	0	1	3	4	1	3
Micrococcus sp.	2	1	1	4	2	0	1	3	—	—	—
Sarcina sp.	0	0	1	1	0	0	0	0	—	—	—
Brevibacteriaceae, Corynebacteriaceae	4	2	0	6	2	1	0	3	6	3	0
Lactobacillaceae	12	2	3	17	7	2	2	11	19	4	5
Streptococcus sp.	12	2	3	17	6	1	1	8	—	—	—
S. faecalis	0	0	0	0	1	1	1	3	—	—	—
Bacillaceae	6	10	15	31	11	3	9	23	17	13	24
Bacillus sp.	6	10	15	31	11	3	9	23	—	—	—

sufficient number of isolates were not available to ascertain if there were any significant differences in the types of bacteria isolated from larvae collected in the different sites. It appeared (table 2) that only one group, the streptococci, differed in frequency of isolation from different sites, most of the streptococcal isolates being from larvae collected in site E.

Literature Cited

American Society of Microbiologists.
1957. MANUAL OF MICROBIOLOGICAL METHODS. 305 pp. McGraw-Hill Book Co., Inc., New York.

Campbell, Robert W.
1963. THE ROLE OF DISEASE AND DESICCATION IN THE POPULATION DYNAMICS OF THE GYPSY MOTH *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae.) Can. Entomol. 95: 426-432.

Cosenza, Benjamin J., and Franklin B. Lewis
1965. OCCURRENCE OF MOTILE, PIGMENTED STREPTOCOCCI IN LEPIDOPTEROUS AND HYMENOPTEROUS LARVAE. J. Invert. Pathol. 7: 86-91.

Hugh, R., and E. Leifson.
1953. THE TAXONOMIC SIGNIFICANCE OF FERMENTATIVE VERSUS OXIDATIVE METABOLISM OF CARBOHYDRATES BY VARIOUS GRAM NEGATIVE BACTERIA. J. Bacteriol. 66: 24-26.

Kovacs, N.
1956. IDENTIFICATION OF *Pseudomonas pyocyanea* BY OXIDASE REACTION. Nature [London] 178: 703.

Leifson, Einar.
1951. STAINING, SHAPE, AND ARRANGEMENT OF BACTERIAL FLAGELLA. J. Bacteriol. 62: 377-389.

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