Bulletin 412 July, 1938

A SURVEY OF DISEASES AND DEFECTS IN CONNECTICUT FORESTS

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CONTENTS

existed in the forest as shown by the type map. (Figure 87). The success with which this was done is shown in Table I in which the percentage of plots located in the different forest types is shown in comparison with the acreage (percent) actually in those types as determined from the type map.

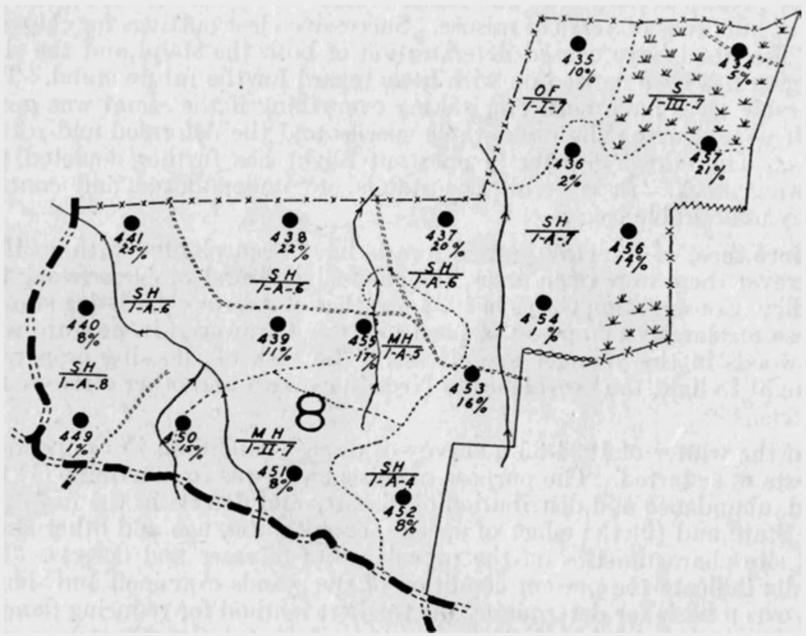

FIGURE 87. Type map of compartment 8, Hartland Hollow Block, Tunxis Forest. Type symbols and location of plots shown by number (434-441 and 449-457). The percent below each plot represents the number of trees bearing one or more Nectria cankers.

ACKNOWLEDGMENTS: The Survey was started late in 1934 by R. C. Lorenz, technician E. C. W. Division of Forest Pathology, and Thad J. Parr, then project superintendent E. C. W., Connecticut. It was taken over in March, 1935, by the senior author who gave the project general supervision, worked up the data and wrote the manuscript. The junior author supervised the field work and assisted wth the manuscript. The entire work was carried out as a project of the Emergency Conservation Work and Civilian Conservation Corps. Perley Spaulding, Division of Forest Pathology, identified fungi and read the manuscript. T. J. Grant, E. C. W. Division of Forest Pathology, was very helpful in criticizing the manuscript, particularly regarding Nectria. State Forester A. F. Hawes, Connecticut, and J. S. Boyce, Yale University, criticized the manuscript. W. G. Mayer, D. J. Falvey, A. J. Hunyadi and W. C. Spellman carried out the field work. W. C. Spellman and O. A. Kelsey did very effective work in the field and in the laborious task of summarizing the data. The authors are under the deepest obligation to these men, without whom the survey would have been impossible. To W. L. Slate, director, and W. O. Filley, forester, Connecticut Agricultural Experiment Station, and A. F. Hawes, State forester, grateful acknowledgment for permission to publish.

TABLE I. PLOTS LAID OUT COMPARED WITH ACREAGE BY FOREST TYPES

Designation	Old Field (percent)	Swamp (percent)	Oak Ridge (percent)	Mixed Hardwoods (percent)	Softwood-Hardwood (percent)	Softwood (percent)	Plantations (percent)	Total (percent)
Plots	4.3	3.4	4.0	73.1	14.5	0.7	0	100
Acreage	7.5	3.5	2.3	65.3	12.9	0.2	8.3	100
Deviation	-3.2	-0.1	+1.7	+7.8	+1.6	+0.5	-8.3	0

The forest types were sampled in practically the same proportion in which they existed in the forest. This was true for each one of the four forests sampled as well as the average of the four forests. There was a tendency to lay out proportionately fewer plots in the old field type and in the plantations than exist in nature. This was due to the small value and transient character of the old field type and the lack of sizeable trees in the plantations. Conversely, a larger proportion of plots was laid out in the mixed hardwoods type.

A comparison of the proportion of plots laid out in each age class also showed a very close agreement with the actual acreage found in the forests.

Although no hard and fast system of cruise lines and plot locations was followed, the authors are convinced that the results give as true a picture of the conditions in the areas sampled as time limitations permitted.

A typical portion of a type map with the plot locations is shown in Figure 87.

Forest Types

The forest types as recognized in Connecticut State Forests are as follows:

SYMBOL	NAME	DESCRIPTION
OF	**Old Field**	chiefly gray birch or red cedar with other species coming in on abandoned fields or pastures.
S	**Hardwood Swamp**	chiefly red maple and yellow birch on wet soil.
O	**Oak Ridge**	chiefly scarlet and chestnut oaks on dry shallow-soiled ridges.
MH	**Mixed Hardwoods**	either "northern hardwoods"; beech, birch and maple, or "southern hardwoods"; red oak, ash, maples, basswood, birches, tulip, oaks and hickories—a frequent and abundant forest type.
SH	**Softwood—Hardwood**	a mixture of softwood and hardwood species ranging from 20 percent of the one and 80 percent of the other, to 80 percent of the one and 20 percent of the other.
SW	**Softwood**	chiefly hemlock, pine or southern white cedar making up over 80 percent of the stand with or without hardwoods in mixture.

SYMBOL	NAME	DESCRIPTION
P	Plantation	chiefly coniferous planting—most of it done in recent years.

AGE CLASSES

I— 0—20 years
II—21—40 years
III—41—60 years
IV—61—80 years
A—All ages

YIELDS PER ACRE:

1— 0—2000 Board Feet
2—2000—5000 Board Feet
3—5000—plus Board Feet

CROWN DENSITY

0.0—1.0 from open to a complete canopy.

A symbol, $\frac{\text{MH}}{\text{1-II-.7}}$, means that the stand is of the mixed hardwoods type, with a yield of from 0 to 2000 board feet per acre, is 21 to 40 years old and has a crown density of 0.7 of complete canopy.

All plots were .1 acre in area, 66 feet square and were laid out at the rate of one plot for each 11 acres sampled. Quarter-inch rope with knots at 66-foot intervals was used to determine the bounds of the plot. The angles were laid out with a hand compass. Corner trees were marked with a band of white paint and on one of them the plot number was painted for possible future relocation. Rope was then trailed back and forth across the plot dividing it into lanes 15 to 20 feet wide. These narrow lanes made possible the tallying and examination of each tree on the plot without the danger of duplication or omission. All stems one inch D.B.H. and larger were carefully examined for disease and defect and the diameter breast high, crown class and species of all trees were recorded. The age and height of one tree from each of the dominant, codominant and intermediate crown classes were obtained. A form sheet was filled out for each plot giving general as well as specific information. (Figure 88)

The field work was carried out by foremen trained in forestry, using one or two crews of two or three men each. At intervals the work of each foreman was checked in the field by the junior author for accuracy and completeness of both field work and records. This supervision assured a uniformly high quality of work, particularly on the four forests intensively surveyed: Tunxis, Pachaug, Meshomasic and Cockaponset. At the close of the field work the data sheets and maps from each forest were assembled, and the tabulation of the data and the preparation of the manuscript was done at one central office.

Some of the earlier work was not sufficiently detailed to be used in all tabulations. The species composition and the percentage Nectria cankered was determined on 12 forests (Figure 86), 20,460 acres being sampled with 1852 plots. All other results are based on data from 1256 plots, covering 13,780 acres on the four forests, or on only one of these forests.

CONNECTICUT FOREST DISEASE STUDY

Plot No.: 173 Forest: Pachaug Block: Plainfield Comp. 4 Area: 1-10 acre Slope: Gentle
Exposure: South Forest Type: MH-II Density: .8 Plot Site: II Topography: Lower slope
Soil: Fresh—sandy loam—shallow—rocky well drained
Total number of trees on plot: 94 % Diseased: 16 Observer: Tilbe Date: 11-20-35
Data by: Curran
Heights: Dom. Red Oak 35′-33 yrs., CD White Oak 32′- 32 yrs. Notes by: Bedurtha
Int. White Birch 28′- 27 yrs. Foreman in charge: Mayer

TREE									CANKER			
SPECIES	Hgt.	DBH	Age	Origin	Crown	Condition	Disease and Type	Other Defects	Bearing	Hgt.	Fruiting	REMARKS
1. Scarlet Oak		2.9	15	Sprout	CD	Good	Nectria(2)		SE	0′	Abundant	
									NW	0′	Scarse	
2. White Oak		2.1	13	Seed.	S	Fair	Nectria	Mech. injury	All pts.	2′	Abundant	Ent. Mech. in.
3. Red Maple		1.7		Sprout	S	Fair	Butt Rot			0-3′		
4. Scarlet Oak		3.6	20	Sprout	CD	Good	Nectria		SE	0′	None	
5. Scarlet Oak		4.0	22	Sprout	CD	Good	Nectria		NE	0-1′	Sparse	
								Frost crack	W	0-1′		
6. Red Oak		7.5	39	Sprout	D	Fair	Strumella		All pts.	6-7′	None	Stub 2.0″
								Frost crack	NE	0-1′		
7. Scarlet Oak		4.2	24	Sprout	D	Good	Nectria		SE	0′	None	
8. Black Oak		2.7	19	Sprout	S	Good	Nectria		NW	0-1′	Abundant	
							Strumella		NW	0-1′	None	
9. Hickory		2.0		Sprout	S	Good	Lesions(7)		All pts.	4′		
10. Scarlet Oak		3.8		Sprout	D	Good	Trunk rot			4′	None	Dead stub
11. Scarlet Oak		3.8	18	Sprout	D	Good	Strumella		SE	4′	None	Stub 1.7″
12. White Oak		4.8	19	Sprout	D	Good	Nectria		N	0-1′	Abundant	Ent. butt rot
							Butt rot			0′	None	Dead stump
13. Black Oak		3.2	25	Seed.	CD	Good	Nectria		E	0′	Abundant	
14. Red Maple		1.1		Sprout	S	Good	Borer		W	6′		
								Mech. injury	W	3′		Rubbing
15. Gray Birch		1.8	21	Seed.	I	Good	Nectria		S	12′	None	

Red Oak 2″-1 CD, 3 I; 3″-2 CD, 3 I; 4″-3 D
White Oak 1″-6 S; 2″-3 I, 5 S; 3″-1 D, 6 CD; 4″-2D, 1 CD, 1 I
Scarlet Oak 2″-1 I; 3″-4 CD, 2 I; 4″-3 D, 2 CD; 5″-2 D; 6″-1 D
Red Maple 1″-2S; 2″-1 CD, 3 I, 1 S; 3″-2 CD
Gray Birch 1″-5 S; 2″-2 S; 3″-1 CD, 1 I
Hickory 1″-1 I, 4 S; 2″-1 I, 1 S
Black Oak 1″- 1 S; 3″-1 CD

FIGURE 88. Sample Disease Survey form used in this study.

DESCRIPTION OF FORESTS EXAMINED

AREA COVERED

The four forests intensively examined are located over the State in such a way that they are fairly representative of the State as a whole. (Figure 86). About 75 percent of the Tunxis and Meshomasic forests was covered by the survey and about 25 percent of the Pachaug and Cockaponset forests. One plot was laid out for each 11 acres of area examined. The total number of trees examined was 98,420, on 1256 tenth-acre plots. (Table II).

Table II. Area Covered by the Disease Survey

Forest	Area Examined (acres)	One plot per (acres)	Number plots examined	Number trees examined
Tunxis	4480	12	376	29,421
Pachaug	2500	12	214	19,419
Meshomasic	4300	10	419	32,356
Cockaponset	2500	10	247	17,224
TOTALS—AVERAGE	**13,780**	**11**	**1,256**	**98,420**

SPECIES COMPOSITION

The number of trees one inch D.B.H. and over, found on the plots examined, averaged 784 per acre. There was some variation among the different forests:

Pachaug	907 per acre	Meshomasic	772 per acre
Tunxis	782 per acre	Cockaponset	697 per acre

The statement is made (Hawes 1933) that there are no fully stocked natural forests in Connecticut due in most cases to the death of the chestnut. Just what is full stocking in Connecticut forests is difficult to determine, since it varies with age, species and site quality. The figures given above are based on all forest types and age classes, hence they represent the average condition found on the state forests sampled. Although the older age classes may be understocked, the outlook for better stocking in the future is good. The average basal area per acre for all forests was 81.1 square feet with the four forests ranging as follows:

Tunxis	106.8 sq. feet per acre	Meshomasic	66.8 sq. feet per acre
Cockaponset	87.4 sq. feet per acre	Pachaug	56.8 sq. feet per acre

The average D.B.H. of all trees examined, determined by the basal area method, was 4.4 inches. The average for each forest was:

Tunxis	5.0 inches	Meshomasic	4.0 inches
Cockaponset	4.8 inches	Pachaug	3.4 inches

Heights are discussed under site quality, and age under Nectria canker in relation to age.

By Basal Area

The species composition of the stands examined on the four forests is shown in Table III. The average of the four forests indicates that red maple is the species having the greatest basal area, forming 17.1 percent of the stand. It is followed by red oak with 11.0 percent, hemlock 10.3 percent, and white oak 10.0 percent. (Figure 89). Red maple, however, is not the most abundant species on any single forest; hemlock, scarlet oak, red oak, and white oak being most abundant on the Tunxis, Pachaug, Meshomasic and Cockaponset forests respectively. The species have been divided into two groups: **Large Tree Species** which grow to large size and most of which are of lumber or cordwood value; **Small Tree Species** which are small trees of little or no lumber or cordwood value, many of which are considered as weed trees.

The basal area of that part of the population eight inches D.B.H. and over, expressed as percent of the total basal area for that species, is given in Table III and in Figure 89. This varies from 59.2 percent on the Tunxis with its abundance of large hemlock to 34.2 percent on the Pachaug. The average for the four forests was 51.2 percent. The **Small Tree Species** form a small proportion of the stands in each forest and they naturally have few or no trees in the eight-inch and over D.B.H. class.

The oaks form a large part of the stands in the three southern forests, while maples, birches and softwoods form a large part of the stands in the northern forest (Tunxis). On the four forests 36.1 percent of the basal area of the stands was formed by oaks, with maples 19.6 percent, birches 15.3 percent and softwoods 12.7 percent in the order named. These four groups form 83.7 percent of all the stands examined.

[7]The common names and scientific names of trees and shrubs as they are used in this Bulletin are listed on page 558. The authorities for these names are according to Sargent's "Manual of the Trees of North America," 2nd edition, 1921, for the trees; and Gray's "New Manual of Botany," 7th edition, 1908, for the shrubs.

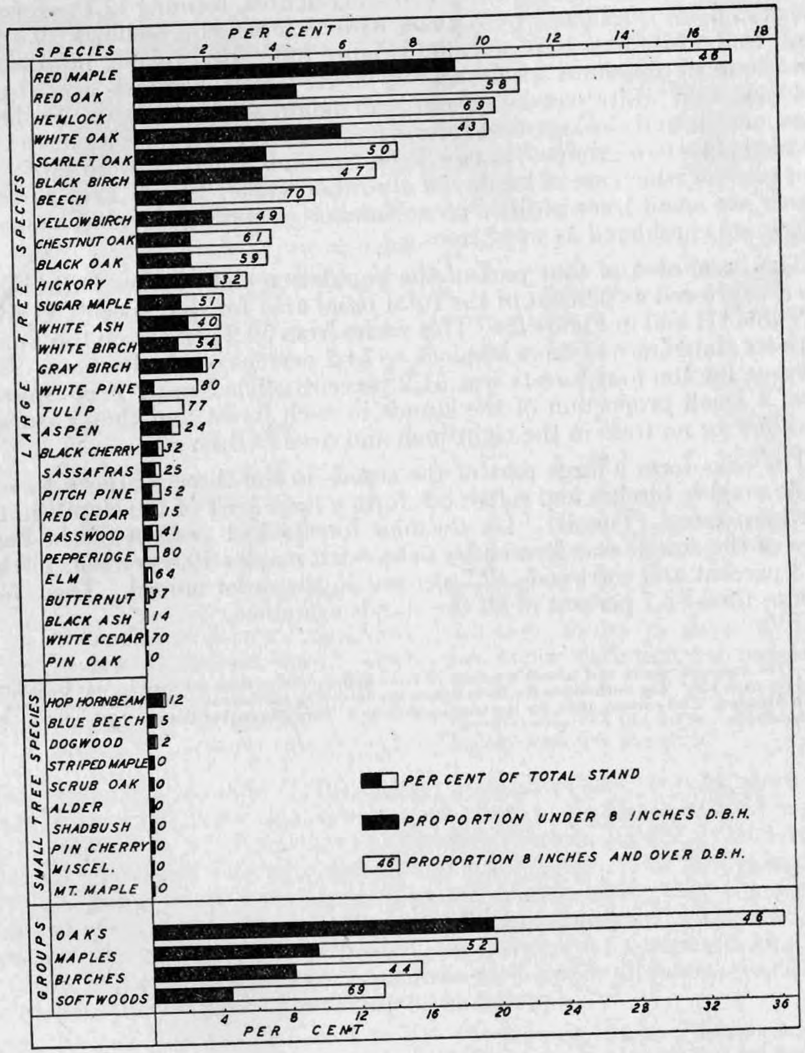

FIGURE 89. Species composition of the four forests—Basal Area. The entire bar represents the percentage of the population made up of the species indicated. The black part of the bar represents the proportion (percent) of the basal area in trees under 8 inches D.B.H. The white part of the bar and the figure in it represents the proportion (percent) of the basal area in trees 8 inches and over D.B.H.

TABLE III. SPECIES COMPOSITION OF THE FOREST—BASAL AREA

SPECIES	TUNXIS		PACHAUG		MESHOMASIC		COCKAPONSET		FOUR FORESTS	
	Percent of total stand	Percent trees 8″ and over	Percent of total stand	Percent trees 8″ and over	Percent of total stand	Percent trees 8″ and over	Percent of total stand	Percent trees 8″ and over	Percent of total stand	Percent trees 8″ and over
Large tree species:										
Red Maple	24.3	52.0	11.1	30.4	13.3	36.4	12.0	45.7	**17.1**	46.1
Red Oak	5.7	70.7	7.4	36.6	**20.3**	52.9	11.3	65.7	**11.0**	58.0
Hemlock	**25.0**	69.0	0.02	89.7	0.3	67.0	1.9	67.3	**10.3**	69.0
White Oak	0.5	34.8	25.0	31.4	14.2	41.3	**13.5**	56.8	**10.0**	42.7
Scarlet Oak	0.0	....	**26.6**	36.3	8.4	57.0	9.7	61.3	**7.5**	49.6
Black Birch	5.4	52.8	1.9	46.4	9.0	33.3	9.8	56.9	**6.9**	46.7
Beech	9.8	73.2	1.0	30.4	0.6	36.1	4.6	69.8	**5.1**	70.2
Yellow Birch	4.5	53.4	1.8	52.6	4.2	38.6	5.1	51.4	**4.2**	48.9
Chestnut Oak	2.0	54.8	0.0	....	4.3	65.9	8.8	59.0	**3.8**	61.3
Black Oak	0.01	59.0	3.7	43.3	7.1	53.2	6.3	71.8	**3.7**	58.7
Hickory	0.2	52.9	3.8	30.4	5.1	20.9	5.5	44.5	**3.1**	31.8
Sugar Maple	4.6	55.0	0.1	0.0	0.9	32.5	1.6	45.8	**2.4**	51.2
White Ash	2.9	50.9	1.2	46.7	2.5	23.7	1.5	29.3	**2.3**	39.6
White Birch	5.6	52.9	0.3	88.2	0.2	65.3	0.06	86.7	**2.3**	54.1
Gray Birch	1.3	9.6	3.3	3.5	3.1	5.3	0.8	20.5	**1.9**	7.2
White Pine	2.8	90.0	3.2	48.1	0.4	86.5	0.06	56.3	**1.6**	79.3
Tulip	0.2	67.8	0.01	0.0	2.2	75.3	2.3	79.1	**1.2**	76.8
Aspen	0.8	41.3	2.1	12.2	1.4	12.7	0.6	38.2	**1.1**	23.8
Black Cherry	1.3	36.0	0.3	19.2	0.3	21.7	0.1	0.0	**0.6**	31.8
Sassafras	0.2	47.3	0.2	0.0	0.5	14.6	1.0	23.6	**0.5**	24.6
Pitch Pine	0.0	....	4.1	51.7	0.01	0.0	0.03	100.0	**0.5**	52.0
Red Cedar	0.1	0.0	0.2	16.0	0.5	2.7	1.0	25.7	**0.44**	14.6
Basswood	0.6	48.3	0.0	....	0.3	24.1	0.2	28.6	**0.43**	40.7
Pepperidge	0.2	85.7	0.4	86.6	0.24	41.8	1.0	86.1	**0.43**	80.1
Elm	0.3	67.8	0.2	96.0	0.22	32.6	0.05	90.1	**0.25**	64.0
Butternut	0.02	96.6	0.01	0.0	0.11	20.1	0.1	33.7	**0.09**	37.4
Black Ash	0.0	....	0.3	16.0	0.02	0.0	0.0	....	**0.04**	13.7
White Cedar	0.0	....	0.04	70.4	0.0	....	0 0	....	**0 01**	70.3
Pin Oak	0.0	....	0.02	0.0	0.0	....	0.0	....	**0.01**	0.0
TOTALS & AVERAGES	**98.33**	**60.3**	**98.50**	**34.8**	**99.70**	**43.0**	**99.00**	**57.2**	**98.80**	**52.3**

TABLE III. SPECIES COMPOSITION OF THE FOREST—BASAL AREA—Concluded

SPECIES	TUNXIS Percent of total stand	TUNXIS Percent trees 8" and over	PACHAUG Percent of total stand	PACHAUG Percent trees 8" and over	MESHOMASIC Percent of total stand	MESHOMASIC Percent trees 8" and over	COCKAPONSET Percent of total stand	COCKAPONSET Percent trees 8" and over	FOUR FORESTS Percent of total stand	FOUR FORESTS Percent trees 8" and over
Small tree species:										
Hop Hornbeam	1.2	12.5	0.4	0.0	0.09	29.2	0.02	0.0	0.5	11.8
Blue Beech	0.02	0.0	0.1	0.0	0.1	10.9	0.44	4.4	0.2	5.1
Dogwood	0.001	0.0	0.5	5.6	0.06	0.0	0.53	0.0	0.2	1.8
Striped Maple	0.21	0.0	0.0	...	0.0	...	0.0	...	0.13	0.0
Scrub Oak	0.0	...	0.4	0.0	0.01	0.0	0.0	...	0.05	0.0
Alder	0.08	0.0	0.09	0.0	0.03	0.0	0.0	...	0.04	0.0
Shadbush	0.07	0.0	0.008	0.0	0.003	0.0	0.0	...	0.03	0.0
Pin Cherry	0.08	0.0	0.0	...	0.0	...	0.0	...	0.03	0.0
Miscellaneous	0.003	0.0	0.002	0.0	0.007	0.0	0.01	0.0	0.01	0.0
Mountain Maple	0.006	0.0	0.0	...	0.0	...	0.0	...	0.01	0.0
TOTALS & AVERAGES	1.670	8.8	1.50	1.9	0.30	1.2	1.00	2.0	1.20	6.7
Averages—all species		59.2		34.2		42.8		56.4		51.2
Species groups:										
Oaks	8.2	65.0	63.2	34.7	54.4	51.4	49.6	62.0	36.1	52.4
Maples	29.2	52.1	11.3	30.0	14.2	36.3	13.5	45.7	19.6	45.7
Birches	16.8	49.8	7.3	29.5	16.4	29.8	15.6	53.3	15.3	43.5
Softwoods	27.8	70.9	7.7	49.5	1.1	45.0	3.1	53.5	12.7	68.7
TOTALS & AVERAGES	82.0	59.4	89.5	34.8	86.1	45.0	81.8	57.5	83.7	44.0

Miscellaneous species are sumac, witch hazel, willow, black walnut, apple, sycamore and spruce.

By Number of Stems

Although forest composition by basal area gives one a clearer picture of the size and number of the different species, the number of stems is of greater importance from the standpoint of incidence of disease and defect. Considering the number of stems one inch D.B.H. and larger of each species, red maple is definitely the most abundant, forming 20.6 percent of all the stems examined. (Figure 90). Moreover it leads in each forest except the Pachaug, where white oak is somewhat more abundant, due to a large number of small white oak stems even in older stands. The **Small Tree species** form a larger proportion of the forests, in number 4.0 percent, than in basal area, 1.2 percent.

The actual number of stems examined of each species is also given in Table IV as a basis for comparing one forest with another, but chiefly so one may have a basis for judging the value of observations concerning any given species. In every case in this bulletin where any information about a species is given, whether it be the number of Nectria cankers, the number of frost cracks, the number of broken tops or the number of decayed trees, the number of trees examined to secure that information is given in Table IV. Thus, for example, any information based on the examination of 20,309 stems of red maple is of more value than that based on the examination of 36 black ash or 17 mountain maple. Similarly any statement based on 277 white oak examined on the Tunxis is less reliable than one based on the examination of 4,874 white oak on the Pachaug. The number of stems examined will not be repeated in subsequent tables but unless otherwise stated these figures will apply to data throughout the bulletin.

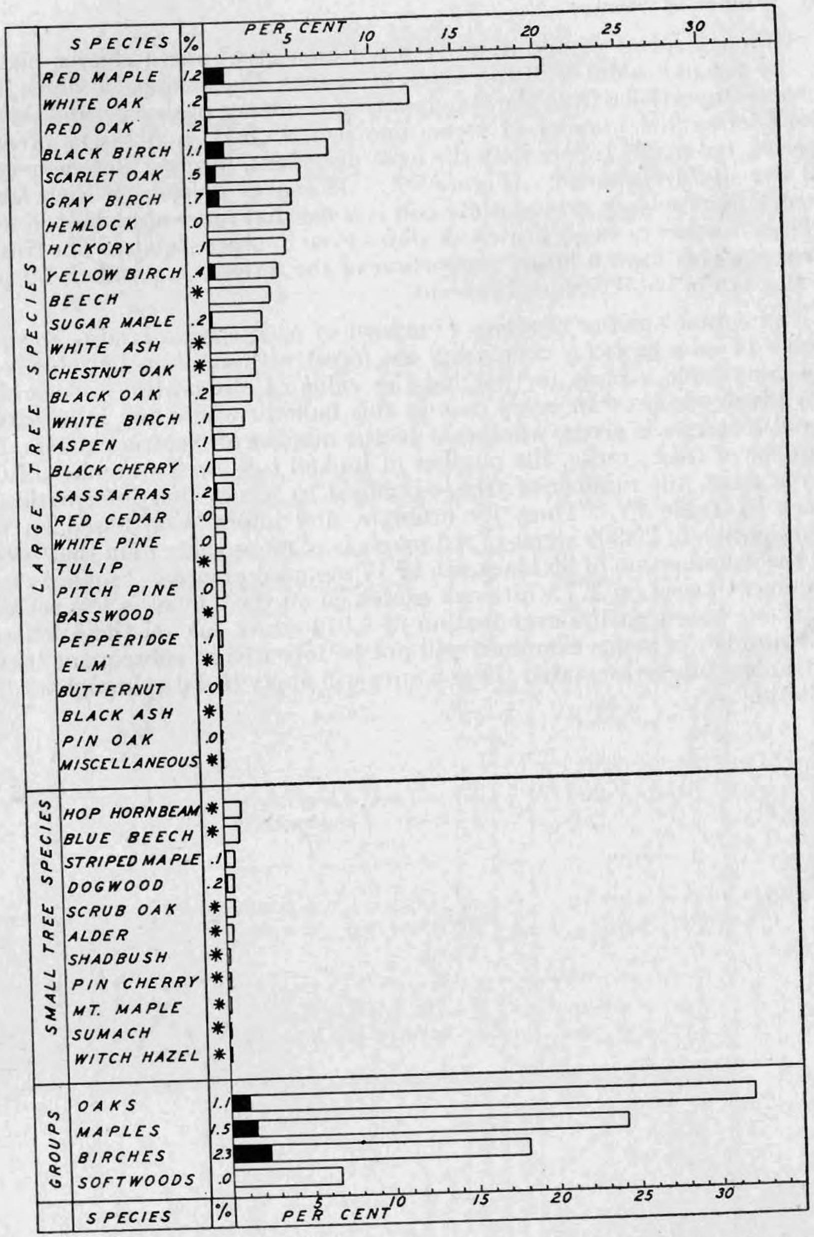

FIGURE 90. Species composition of the four forests—Number of stems; also percent of total population Nectria cankered. The entire bar represents the percent of the total population made up of the species indicated. The black part of the bar and the figure to the left represent the percentage of the total population made up of the Nectria cankered individuals of the species indicated. The asterisk means less than 0.1 percent.

TABLE IV. SPECIES COMPOSITION OF THE FOREST—NUMBER OF STEMS

SPECIES	TUNXIS Number trees examined	TUNXIS Percent total stems	PACHAUG Number trees examined	PACHAUG Percent total stems	MESHOMASIC Number trees examined	MESHOMASIC Percent total stems	COCKAPONSET Number trees examined	COCKAPONSET Percent total stems	FOUR FORESTS Number trees examined	FOUR FORESTS Percent total stems
Large tree species:										
Red Maple	7354	25.0	3558	18.3	6415	19.8	2982	17.3	20,309	20.6
White Oak	277	0.9	4874	25.1	4722	14.6	2226	12.9	12,099	12.3
Red Oak	1331	4.5	1034	5.3	4417	13.7	1495	8.7	8277	8.4
Black Birch	2063	7.0	179	0.9	3056	9.5	1640	9.5	6938	7.4
Scarlet Oak	0	0.0	3222	16.6	1481	4.6	974	5.7	5677	5.7
Gray Birch	856	2.9	1818	9.4	2169	6.7	223	1.3	5066	5.1
Hemlock	4577	15.6	2	0.01	42	0.1	223	1.3	4844	4.9
Hickory	64	0.2	884	4.6	2410	7.5	1291	7.5	4649	4.7
Yellow Birch	1558	5.3	222	1.2	1375	4.2	962	5.6	4117	4.2
Beech	2400	8.2	261	1.4	239	0.7	770	4.5	3670	3.7
Sugar Maple	2248	7.6	51	0.3	368	1.1	389	2.3	3056	3.1
White Ash	1020	3.5	152	0.8	1195	3.7	414	2.4	2781	2.8
Chestnut Oak	505	1.7	0	0.0	735	2.3	1318	7.5	2558	2.6
Black Oak	2	0.01	568	2.91	1199	3.7	568	3.3	2337	2.4
White Birch	1685	5.7	9	0.05	40	0.1	4	0.02	1738	1.8
Aspen	281	1.0	467	2.4	401	1.2	87	0.5	1236	1.2
Black Cherry	592	2.0	176	0.9	343	1.1	47	0.3	1158	1.2
Sassafras	143	0.5	86	0.4	522	1.6	363	2.1	1114	1.1
Red Cedar	107	0.4	36	0.2	268	0.8	216	1.3	627	0.6
White Pine	206	0.7	299	1.5	27	0.09	14	0.08	546	0.5
Tulip	65	0.2	1	0.01	260	0.8	190	1.1	516	0.5
Pitch Pine	0	0.0	436	2.2	1	0.01	1	0.01	438	0.4
Basswood	268	0.9	0	0.0	87	0.3	34	0.2	389	0.4
Pepperidge	23	0.08	27	0.1	92	0.3	82	0.5	224	0.2
Elm	54	0.2	7	0.03	61	0.2	6	0.03	128	0.1
Butternut	7	0.02	4	0.02	43	0.1	18	0.1	72	0.08
Black Ash	0	0.0	33	0.2	3	0.01	0	0.0	36	0.04
Pin Oak	0	0.0	9	0.05	0	0.0	0	0.0	9	0.01
Misc. Softwoods	0	0.0	4	0.02	1	0.01	0	0.0	5	0.01
TOTALS	27,686	94.11	18,419	94.90	31,972	98.82	16,537	96.04	94,614	96.04

Table IV. Species Composition of the Forest—Number of Stems—Concluded

SPECIES	TUNXIS Number trees examined	TUNXIS Percent total stems	PACHAUG Number trees examined	PACHAUG Percent total stems	MESHOMASIC Number trees examined	MESHOMASIC Percent total stems	COCKAPONSET Number trees examined	COCKAPONSET Percent total stems	FOUR FORESTS Number trees examined	FOUR FORESTS Percent total stems
Small tree species:										
Hop Hornbeam	756	2.6	159	0.8	78	0.24	10	0.05	1003	1.0
Blue Beech	29	0.1	94	0.5	176	0.54	484	2.8	783	8.8
Scrub Oak	0	0.0	490	2.5	22	0.07	0	0.0	512	0.5
Dogwood	1	0.01	236	1.2	37	0.11	192	1.1	466	0.5
Striped Maple	463	1.6	0	0.0	0	0.0	0	0.0	463	0.5
Alder	239	0.8	16	0.08	49	0.15	0	0.0	304	0.4
Shadbush	124	0.4	2	0.01	4	0.01	0	0.0	130	0.12
Pin Cherry	99	0.3	0	0.0	0	0.0	0	0.0	99	0.10
Mountain Maple	17	0.06	0	0.0	0	0.0	0	0.0	17	0.02
Misc. Hardwoods	7	0.02	3	0.01	18	0.06	1	0.01	29	0.02
TOTALS	1,735	5.89	1,000	5 10	384	1.18	687	3.96	3,806	3.96
GRAND TOTALS	29,421	100.00	19,419	100.00	32,356	100.00	17,224	100.00	98,420	100.00
Species groups:										
Oaks	2,115	7.2	10,197	52.5	12,576	38.9	6,581	38.2	31,469	32.0
Maples	10,082	34.3	3,609	18.6	6,783	21.0	3,371	19.6	23,845	24.2
Birches	6,162	20.9	2,228	11.5	6,640	20.5	2,829	16.4	17,859	18.1
Softwoods	4,890	16.6	777	4.0	339	1.1	454	2.6	6,460	6.6
TOTALS	23,249	79.0	16,811	86.6	26,338	81.5	13,235	76.8	79,633	80.9

* Miscellaneous softwoods are white cedar and spruce. Miscellaneous hardwoods are sumac, witch hazel, willow, black walnut, apple and sycamore.

There was considerable variation between the different forests, particularly the Tunxis Forest and the Pachaug Forest. The Tunxis had a large proportion of maples, 34.3 percent, birches 20.9 percent and softwoods 16.6 percent, characteristic of the northern hardwood, beech-birch-maple forest with a mixture of hemlock. The other three forests, particularly the Pachaug, are characteristic of the southern hardwood type with an abundance of oaks, 52.5 percent, and a small number of maples, 18.6 percent, birches 11.5 percent and softwoods 4.0 percent. Hickory likewise was scarce on the Tunxis, 0.2, compared with the Pachaug, 4.6. Beech was abundant on the Tunxis, 8.2, and not on the Pachaug, 1.4. Striped maple and mountain maple were restricted to the Tunxis. It must be borne in mind that the absence of a species or a disease or defect from any of the forests is not necessarily indicative of the fact that it does not exist in that forest, but only that it has not been encountered on the plots examined, which are but a small proportion of the total area covered in the survey. However, since the number of plots on each forest was quite large and they are distributed uniformly over the area sampled, the distribution given is indicative of the actual abundance of all but the rarer species.

This variation in species composition from forest to forest must be considered in determining the amount of Nectria and Strumella infection and the treatment that can best be applied.

The species composition of the twelve forests examined was tabulated and found to be so similar to that of the four forests presented in Table IV that it has been omitted. This similarity indicated that the averages for the four forests are quite representative of the State as a whole.

FREQUENCY DISTRIBUTION OF SPECIES

The number of plots, out of the total of 1256 examined, on which each species occurred, was determined and expressed as a percentage frequency figure. This percentage frequency is shown in Table V. A high percentage means wide general distribution throughout the forest.

Red maple was present on the greatest number of plots, 91 percent, followed by red oak with 71 percent, white oak 67 percent, black birch with 65 percent and hickory, 47 percent. White ash, 42 percent, was present on a larger number of plots than might have been expected from its relative scarcity. It is, however, widely and generally distributed, though not in quantity.

At the other end of the scale, occurring on only a few plots, were elm 3 percent, butternut 4 percent, red cedar 6 percent, and white pine 8 percent.

TABLE V. PERCENT FREQUENCY OF OCCURRENCE OF SPECIES

SPECIES	Number plots species occurred on	Per-cent of total	SPECIES	Number plots species occurred on	Per-cent of total
Large tree species:					
Red Maple	1149	91	Pepperidge	100	8
Red Oak	891	71	Basswood	99	8
White Oak	840	67	White Pine	95	8
Black Birch	813	65	Red Cedar	74	6
Hickory	594	47	Butternut	49	4
White Ash	524	42	Elm	40	3
Yellow Birch	490	39	Pitch Pine	32	3
Scarlet Oak	472	38	Miscellaneous	12	1
Gray Birch	441	35			
Black Oak	429	34	**Small tree species:**		
Sugar Maple	338	27	Hop Hornbeam	163	13
Beech	337	27	Blue Beech	136	11
Hemlock	320	26	Dogwood	127	10
Black Cherry	290	23	Striped Maple	85	7
Chestnut Oak	221	18	Shadbush	54	4
Sassafras	213	17	Scrub Oak	45	4
Aspen	209	17	Alder	43	3
White Birch	196	16	Miscellaneous	24	2
Tulip	157	13	Pin Cherry	13	1

Miscellaneous Large Tree Species are black ash, pin oak, white cedar and spruce.
Miscellaneous Small Tree Species are mountain maple, sumac, witch hazel, willow, apple, black walnut and sycamore.

RESULTS

The result of examining 98,420 trees in four forests of the State was a fuller knowledge of the kind, abundance and species incidence of the various diseases and defects found in the forest than has ever been available heretofore. Since Nectria cankers were so abundant, on 5721 living trees, particular attention was paid to this disease and its characteristics. Its relation to its hosts, its relation to the stand and to the site were studied. It was found on a larger number of trees than any other disease or defect. Strumella cankers, decay, frost cracks, top damage due to ice storms and drought, mechanical injuries due to logging and rubbing, miscellaneous lesions, borer injury, fire scars and other minor types of injury were found and are discussed in the following pages.

All diseases and defects that could be noted by observation of the living trees were recorded. No cultures nor dissections were made, hence some of the obscure and non-typical cases of Nectria or Strumella may have been overlooked. Likewise the extent of decay could only be judged from outward appearance. Probably much decay was not visible from the outside and could only have been detected by dissection. Such a dissection study would be desirable. No defects in the form of the bole, such as lean, crook, sweep, limbiness or crotch were recorded.

Particular emphasis has been placed on the relation of disease or defect to species. Data referring to the abundance of a disease or defect on a given forest is chiefly of limited and local value. Data referring to species, however, is of more general value and application since it can be used in Connecticut or in nearby localities in proportion as that species occurs in the forest under consideration.

In tabulating the data, an individual tree was recorded as having Nectria but once even though it had more than one Nectria canker on it. But if it had Nectria and also a broken top, it was recorded under each defect. Thus the summation of all diseases and defects will be too high because of the duplications recorded. The amount of this duplication was not great, however, averaging 3.0 percent for all the forests. That is, on the 17,665 trees having defects, there were 21,727 diseases or defects recorded. Most of the trees had but one defect while a small number had two, three or even four.

The results here recorded are based on large numbers of trees examined and large numbers of defects encountered. Their chief value lies in giving a dependable picture of average conditions over a wide area in the several forest types and age classes as they exist in the forests of Connecticut. As the tabulation of results progressed, it was often evident that if only one forest had been examined some very plausible and attractive theories could have been formulated. With a larger amount of information, apparently good explanations for conditions in one forest were exploded by data from another. Hence if the conclusions here given are sometimes tentative and qualified, it is because the abundance of data makes a cautious statement advisable rather than too small an amount making it necessary.

Averages in all cases are based on the actual numbers involved and are never the average of averages. That is, all averages are weighted averages. Hence, in a table such as Table XVI, the average for the four forests for black oak, as an example, is based on the actual percent of that species examined, which were diseased, rather than on a straight average of the sum of 2.3, 0.3 and 3.2.

Unless otherwise stated in the legends and captions, all figures and tables are based on data from 1256 plots on four forests.

NECTRIA CANKER

The cankers on various hardwood species caused by *Nectria coccinea* and other species of *Nectria* vary widely in appearance. The typical appearance is a round or oval sunken pit with flaring edges of broken bark and rolls of callus tissue. The bare wood exposed in the middle of the canker usually shows concentric ridges or layers where the cambium has been killed back by the slow and intermittent advance of the fungus. These ridges are concentric around a central area which is usually the remains of a dead branch stub through which the fungus probably gained entrance to the stem. The shape of the cankers varies from greatly elongated forms sometimes occurring on maple, through oval forms on basswood, to forms which are much wider than high and resemble wire fence injury. This last is characteristic of scarlet oak. Sometimes the cankers are covered either by callus growth (Grant 1936) as often happens in sugar

The scientific names and authorities for the various species of fungi mentioned in this Bulletin are according to Boyce, J. S., Forest Pathology, McGraw-Hill, New York, 1938, and will not be listed here.

maple, or by dead bark as in black and yellow birch. The fruiting bodies, when present, are reddish, rounded structures the size of a pinhead, scattered around the edges of the canker. The presence of fruiting bodies positively identifies the canker as Nectria, but in most cases fruiting bodies are not present. Many cases were encountered in the field where no fruiting bodies were found. If these cases looked like Nectria cankers, based on the experience of the foreman in charge of the crew and also of the supervising technician, they were so classified.

Nectria Canker in Relation to Host Species

Percentage of Species Cankered

The frequency with which various hardwood species are infected with Nectria canker varies with the locality. Welch (1934) reports heavy infections of basswood in parts of New York, yellow and black birch in Vermont, paper birch in New Hampshire and red and black oak in Connecticut. Black walnut is frequently infected in Virginia, Ashcroft (1932). Spaulding *et. al.* (1936) list as commonly cankered in New England: red maple, yellow birch, sweet (black) birch, and to a lesser extent gray birch, paper (white) birch, sugar maple, mountain maple, red oak, black oak and large-toothed aspen. He lists the following species as not commonly cankered: white ash, white oak, American elm, hickory, basswood and scarlet oak.

The number of trees of each species infected with Nectria cankers found in the four forests is given in Table VI and Figure 91. There is some variation within a species between the different forests but if the relative ranking of the species in each forest is observed it will be seen that the average for the four is fairly consistent. Thus pepperidge ranks 1, 3, 4, 1 on the four forests, black birch 3, 1, 1, 5, and sassafras 8, 4, 2, 2. Here, as elsewhere in this bulletin, the average for the four forests is a weighted average.

Red maple, 5.7 percent, does not appear to be cankered as frequently as Spaulding (1936) suggests. It should be moved down in the list next to sugar maple. Its abundance in the stand, hence the frequency with which its cankers are encountered, as discussed under *Percent Total Stand Cankered*, probably accounts for its being considered so heavily infected. Mountain maple, 58.8 percent, was found on the Tunxis only and in small numbers, hence its high percentage of Nectria infection may not be characteristic of the species farther north. Black birch is heavily infected, 15.4 percent, in all forests. Scarlet oak is frequently cankered, 9.6 percent, in the three forests in which it occurs. It ranks close to black oak, 9.1 percent, and should be moved up next to it. Red oak, on the other hand, is not frequently cankered, 2.3 percent, and ranks near white oak, 1.2 percent. Basswood is moderately cankered, 5.4 percent. Variations among the four forests in amount of infection of the different species are evident, but for Connecticut the ranking of the species given in Table VI is believed to be representative of the State as a whole.

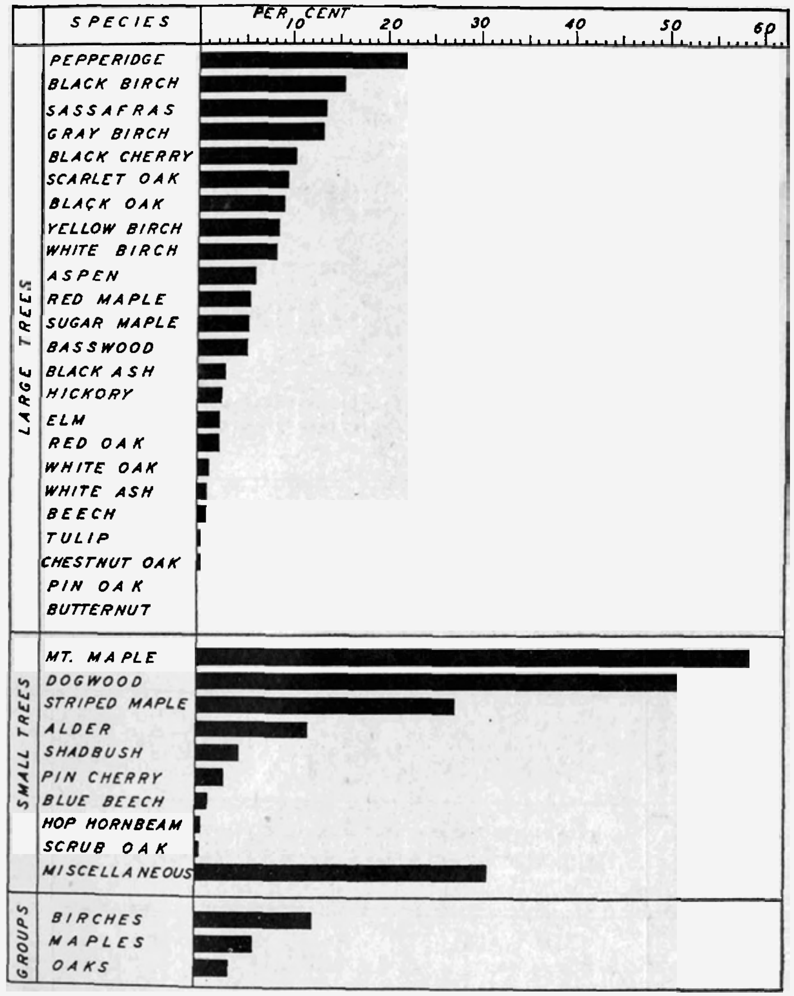

FIGURE 91. Number of trees of each species (in percent) infected with Nectria canker.

TABLE VI. PERCENT OF SPECIES CANKERED BY NECTRIA AND PERCENT TOTAL STAND CANKERED BY NECTRIA

SPECIES	TUNXIS		PACHAUG		MESHOMASIC		COCKAPONSET		FOUR FORESTS	
	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered
Large tree species:										
Pepperidge	25.7	*	33.3	0.1	15.2	*	24.4	0.1	21.9	0.1
Black Birch	11.9	0.8	42.9	0.4	21.2	2.0	5.8	0.6	15.4	1.1
Sassafras	4.2	*	24.4	0.1	17.0	0.3	9.9	0.2	13.6	0.2
Gray Birch	13.6	0.4	10.1	0.9	16.6	1.1	5.4	0.1	13.3	0.7
Black Cherry	1.0	*	37.5	0.3	13.1	0.1	4.3	*	10.3	0.1
Scarlet Oak	...	..	11.5	1.9	6.9	0.3	7.6	0.4	9.6	0.5
Black Oak	0.0	0.0	13.2	0.4	8.7	0.3	8.3	0.3	9.1	0.2
Yellow Birch	11.9	0.6	9.9	0.1	9.7	0.4	1.5	0.1	8.6	0.4
White Birch	8.1	0.5	33.3	*	12.5	*	0.0	0.0	8.3	0.1
Aspen	3.6	*	4.5	0.1	10.2	0.1	4.6	*	6.1	0.1
Red Maple	8.0	2.0	10.7	2.0	2.1	0.4	1.7	0.3	5.7	1.2
Sugar Maple	6.8	0.5	7.8	*	3.2	*	0.3	*	5.6	0.2
Basswood	6.3	0.1	...	...	3.4	*	2.9	*	5.4	*
Black Ash	...	...	3.0	*	0.0	0.0	...	...	2.8	*
Hickory	0.0	0.0	4.5	0.2	2.4	0.2	2.1	0.2	2.7	0.1
Elm	0.0	0.0	42.9	*	0.0	0.0	0.0	0.0	2.3	*
Red Oak	2.2	0.1	2.7	0.1	2.9	0.4	0.5	*	2.3	0.2
White Oak	0.4	*	2.5	0.6	0.5	0.1	0.2	*	1.2	0.2
White Ash	0.1	*	5.3	*	1.8	0.1	0.0	0.0	1.1	*
Beech	0.6	0.1	1.5	*	0.0	0.0	1.2	0.1	0.8	*
Tulip	0.0	0.0	0.0	0.0	0.4	*	0.0	0.0	0.2	*
Chestnut Oak	0.2	*	...	...	0.0	0.0	0.3	*	0.2	*
Pin Oak	...	...	0.0	0.0	...	...	...	...	0.0	0.0
Butternut	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Softwoods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS & AVERAGES	5.5	5.2	7.8	7.4	6.0	5.9	1.9	2.4	5.6	5.4

TABLE VI. PERCENT OF SPECIES CANKERED BY NECTRIA AND PERCENT OF TOTAL STAND CANKERED BY NECTRIA—Concluded

SPECIES	TUNXIS		PACHAUG		MESHOMASIC		COCKAPONSET		FOUR FORESTS	
	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered	Percent of species cankered	Percent total stand cankered
Small tree species:										
Mountain Maple	58.8	*	...	...	...	...	...	...	58.8	*
Dogwood	0.0	0.0	16.1	0.2	37.8	*	89.1	1.0	47.9	0.2
Striped Maple	27.6	0.4	...	...	...	...	...	..	27.6	0.1
Alder	0.0	0.0	87.5	0.1	44.9	0.1	...	..	11.8	*
Shadbush	1.6	*	0.0	0.0	100.0		...	...	4.6	*
Pin Cherry	3.0	*	...	...	...	...	...	...	3.0	*
Blue Beech	0.0	0.0	2.1	*	4.0	*	0.0	0.0	1.2	*
Hop Hornbeam	0.3	*	1.3	*	2.6	*	0.0	0.0	0.5	*
Scrub Oak	...	..	0.4	*	0.0	0.0	...	...	0.4	*
Miscellaneous	28.6	*	66.7	*	27.8	*	0.0	0.0	31.0	*
TOTALS & AVERAGES	8.5	0.5	6.0	0.3	14.1	0.2	24.9	1.0	11.4	0.4
GRAND TOTAL & AV.	5.7	5.7	7.7	7.7	6.1	6.1	3.4	3.4	5.8	5.8
Species groups:										
Birches	11.1	2.3	12.8	1.5	17.3	3.5	4.3	0.7	12.5	2.3
Maples	8.7	3.0	10.7	2.0	2.1	0.4	1.5	0.3	6.1	1.5
Oaks	1.5	0.1	5.9	3.1	2.8	1.1	2.1	0.8	3.6	1.1
TOTALS & AVERAGES	8.7	5.4	7.9	6.6	6.4	5.0	2.4	1.8	6.6	4.9

Softwood species are hemlock, red cedar, white pine, pitch pine, white cedar and spruce.
Miscellaneous species are sumac, witch hazel, willow, black walnut, apple and sycamore.

* — less than 0.1 percent of total stand cankered.

A most striking fact is brought out in Figure 91. The so-called weed species such as mountain maple, dogwood and striped maple are frequently infected and, although they make up only a small proportion of the total stand, they can form a source of inoculum which may help to infect more valuable species. Hence they should, wherever practicable, be removed in the course of improvement cuttings.

Considering the species groups, the birches are most frequently infected, 12.5 percent, ranking in the order black, gray, yellow and white. Maples are less frequently infected, 6.1 percent, ranking in the order mountain, striped, red and sugar; while oaks are least infected, 3.6 percent, ranking in the order scarlet, black, red, white, scrub, chestnut and pin. Softwoods are not attacked.

In addition to the list of genera infected by Nectria given by Welch (1934) the present study has added *Cornus, Alnus, Hamamelis, Salix* and *Platanus*.

Percentage of Total Stand Cankered

In the above paragraphs the number, in percent, of the individual trees of each species which had one or more cankers was discussed. This varied, for example, from 58.8 percent in the case of mountain maple with 10 cankered trees out of 17 individuals examined, to 5.7 percent in the case of red maple with 1157 cankered trees out of 20,309 individuals examined. Because of the extreme variation in the abundance of the different tree species, which variation has no relation to how frequently they are cankered, a truer picture of the actual abundance of the cankered trees in relation to the total population, or stand, examined can be obtained by determining the "percentage of the total stand cankered". Thus red maple with 1157 cankered trees out of a total population of 98,420 trees examined has a percent total stand cankered of 1.2 percent, whereas mountain maple with 10 cankered trees out of a total population of 98,420 has less than 0.1 percent total stand cankered. This total is recorded in Table VI and the averages are shown graphically in Figure 90.

Cankered trees of red maple form 1.2 percent of the entire number of trees examined (total stand) while cankered black birch forms 1.1 percent, followed by gray birch 0.7 percent, scarlet oak 0.5 percent, yellow birch 0.4 percent, sassafras 0.2 percent, black oak 0.2 percent, sugar maple 0.2 percent, red oak 0.2 percent, and white oak 0.2 percent.

The **Small Tree Species** are usually present in such small numbers that although they are heavily infected they usually form less than 0.1 percent of the cankered trees encountered. Dogwood 0.2 and striped maple 0.1 are somewhat higher.

Therefore the Nectria cankers most frequently encountered in the average forest are on red maple and black birch. That is, out of 100 cankered trees encountered in the average Connecticut forest 20 would be red maple and 18 would be black birch; the remainder would be scattered among several species.

The cankered birches made up 2.3 percent of the total stand, maples 1.5 percent and oaks 1.1 percent, or 4.9 percent out of the total of 5.8 percent for all species.

Frequency Distribution of Nectria Canker

By Plots

Almost every article on Nectria canker stresses the fact that its distribution is very irregular. That is, certain stands, no matter what their species composition, are heavily cankered while other closely adjacent stands of the same species composition may have little or no canker. This was found to be true of the forests examined in this survey. Figure 87 indicates how variable may be the amount of Nectria infection. The percentage figures indicate the number of cankered trees on each plot. Plots closely adjacent to each other have such percentages as: 1, 8, 15, 8, 11, 25, 22, 17, 8, 16, 20, 1 etc.

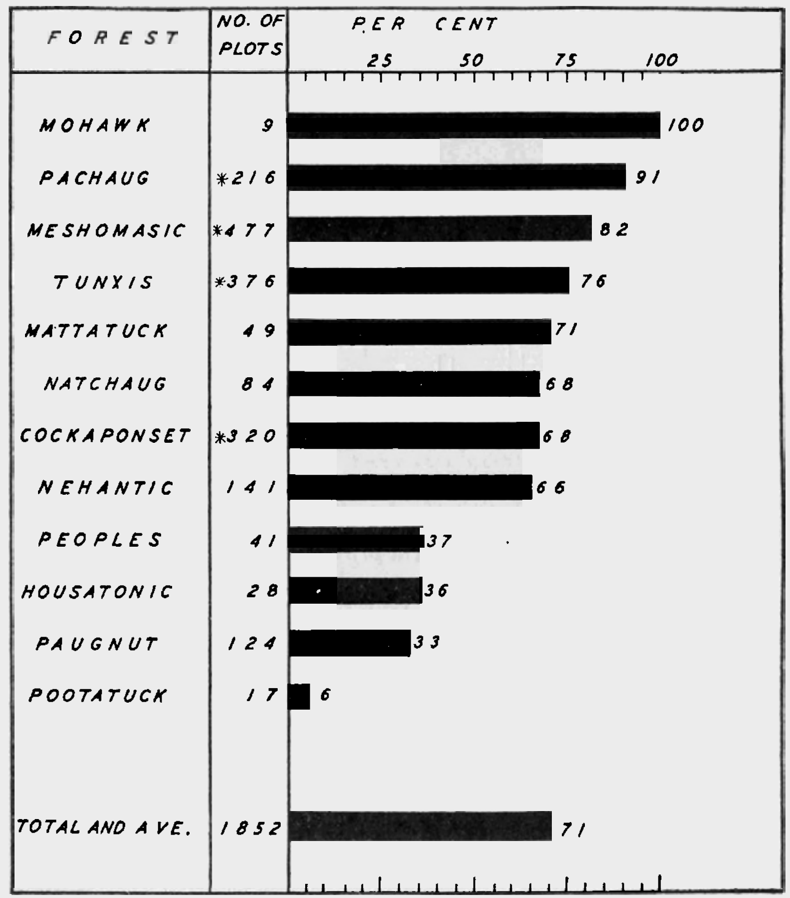

FIGURE 92. Number of plots examined (in percent) which have one or more Nectria cankers—by forests.

The fact remains, however, that Nectria cankered trees are very *widely* and very *generally distributed* throughout a stand, even though they are not *uniformly distributed.* Figure 92 shows, for example, that of 216 plots laid out at random in all forest types and age classes over an area of 2500 acres at Pachaug alone, 91 percent had *one or more* Nectria cankered trees on them. Similarly the Meshomasic had cankers on 82 percent of the plots, Tunxis 76 percent and Cockaponset 68 percent. Any disease which can be found on from 91 to 68 out of 100 plots laid out at random must be quite generally distributed.

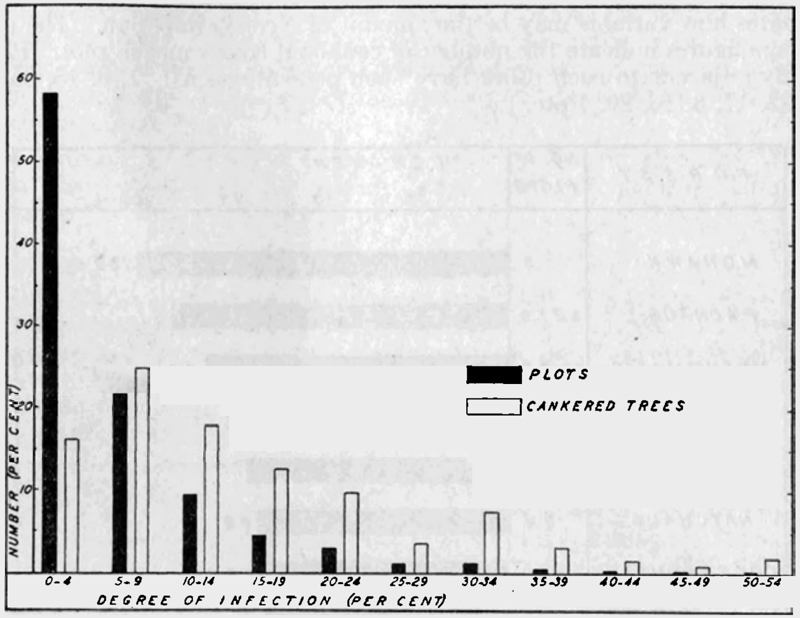

FIGURE 93. Frequency distribution of plots (in percent) of different degrees of Nectria infection in relation to number of Nectria cankered trees on those plots. Black bar—percent of plots. White bar—percent of Nectria cankered trees.

Frequency distribution based on whether a plot *has* or *has not* Nectria cankered trees on it (Figure 92) gives little idea of the distribution of different *amounts* of Nectria cankers. Figure 93 shows that the percentage of infection by Nectria cankers has a very skewed distribution. That is, 58.1 percent of the plots have only 16.2 percent of the Nectria cankered trees, or roughly 80 percent of the plots have 40 percent of the cankered trees. (Table VII). On the other end of the scale, 2.4 percent of the plots have 14.8 percent of the cankered trees.

TABLE VII. PERCENT FREQUENCY OF OCCURRENCE OF DIFFERENT DEGREES OF INFECTION BY NECTRIA

Degree of infection (percent class)	Plots examined		Total cankered trees		Total trees per plot (average)	No. cankered trees per plot (average)
	number	percent	number	percent		
0—4	730	58.1	927	16.2	78	1.3
5—9	270	21.5	1413	24.7	85	5.4
10—14	118	9.4	1036	18.1	77	9.1
15—19	57	4.5	721	12.6	81	13.2
20—24	38	3.0	561	9.8	60	15.3
25—29	14	1.1	217	3.8	66	16.4
30—34	14	1.1	423	7.4	99	31.6
35—39	7	0.6	177	3.1	73	26.6
40—44	4	0.3	92	1.6	72	24.3
45—49	2	0.2	51	0.9	61	26.5
50—54	2	0.2	103	1.8	101	53.0
TOTALS & AVERAGES	**1256**	**100.0**	**5721**	**100.0**	**79**	**4.7**

By Species:

Some species are cankered on many of the plots on which they occur. This was true of mountain maple 100 percent, dogwood 80 percent, scarlet oak

TABLE VIII. PERCENT FREQUENCY OF OCCURRENCE OF NECTRIA CANKERS BY SPECIES

SPECIES	Plots on which species occurred	Plots on which species were cankered		SPECIES	Plots on which species occurred	Plots on which species were cankered	
Large tree species	No.	No.	percent		No.	No.	percent
Scarlet Oak	472	205	43	Tulip	157	0	0
Black Birch	813	314	39	Butternut	49	0	0
White Birch	196	64	33	Pin Oak	1	0	0
Gray Birch	441	140	32				
Red Maple	1149	358	31	**Small tree species:**			
Black Oak	429	130	30	Mountain Maple	1	1	100
Pepperidge	100	30	30	Dogwood	127	102	80
Sassafras	213	61	29	Striped Maple	85	34	40
Yellow Birch	490	139	28	Alder	43	10	23
Black Ash	9	2	22	Pin Cherry	13	3	23
Black Cherry	290	62	21	Shadbush	54	5	9
Sugar Maple	338	67	20	Scrub Oak	45	3	7
Aspen	209	34	16	Blue Beech	136	5	4
Hickory	594	94	16	Hop Hornbeam	163	5	3
Red Oak	891	129	14	Miscellaneous	23	6	26
Basswood	99	12	12				
White Oak	840	89	11	**Species groups:**			
Beech	337	21	6	Birches	1940	657	34
White Ash	524	25	5	Maples	1573	460	29
Elm	40	2	5	Oaks	2899	561	19
Chestnut Oak	221	5	2	Softwoods	523	0	0

' Miscellaneous species are sumac, witch hazel, willow, black walnut, apple, sycamore and spruce.

43 percent, striped maple 40 percent, and black birch 39 percent. (Table VIII). On the other hand, chestnut oak 2 percent, hop hornbeam 3 percent, blue beech 4 percent, elm 5 percent, and white ash 5 percent, are not usually cankered on the plots on which they occur. The species groups show a frequency of occurrence of Nectria canker of birches 34 percent, maples 29 percent and oaks 19 percent.

Location of Nectria Cankers

Height on the Trunk

Most Nectria cankers are located on the main trunk of the tree not far above the ground. The location varies greatly with the different species groups. In the oaks 97 percent of the cankers were located within 8 feet of the ground, in the maples 86 percent and in the birches 51 percent. Furthermore, in oaks practically 100 percent of the cankers were located within 16 feet of the ground, maples 99 percent and birches 82 percent. (Figure 94). This location of the cankers affects the value of the butt log.

In oaks the cankers are often located so close to the ground that they are within stump height, hence do not cause any cull unless decay has entered and gone up the bole. In sugar maple most of the Nectria cankers are located at the base of the tree, while in red maple their location is more variable. Beech 99 percent, hickory 92 percent, and white ash 91 percent have most of their cankers located within four feet of the ground, like the oak. Pepperidge 66 percent, aspen 76 percent, sassafras 67 percent, black cherry 82 percent, pin cherry 60 percent and basswood 78 percent have a smaller proportion of their cankers within four feet of the ground and resemble the maples and birches in that respect. The location of cankers on the different species of oaks examined was very similar. The same was true of the birches.

Andrews (1935) reported 75 percent of the cankers within the first 5 feet of bole, 90-97 percent in the first 10 feet, and 96-99 percent in the first 20 feet. He claimed that this data held constant within a species regardless of crown class and height and from this concluded that cankering occurred early in the life of the tree.

In the birches the dominant trees apparently continued to develop cankers at higher levels later in life. Aside from these cankers at higher levels most of them appear to start early in the life of the tree.

Plot exposure had no effect on the height of occurrence of the cankers.

Branch Cankers

Cankers were found on the branches of only 4.8 percent of those trees which had one or more cankers. This is a small number considering that the branch cankers are usually few and small. The cankers noted were those which could be seen from the ground and some may have been missed. *Branch cankers* were seen on only half of the species on which cankers were found. (Table IX).

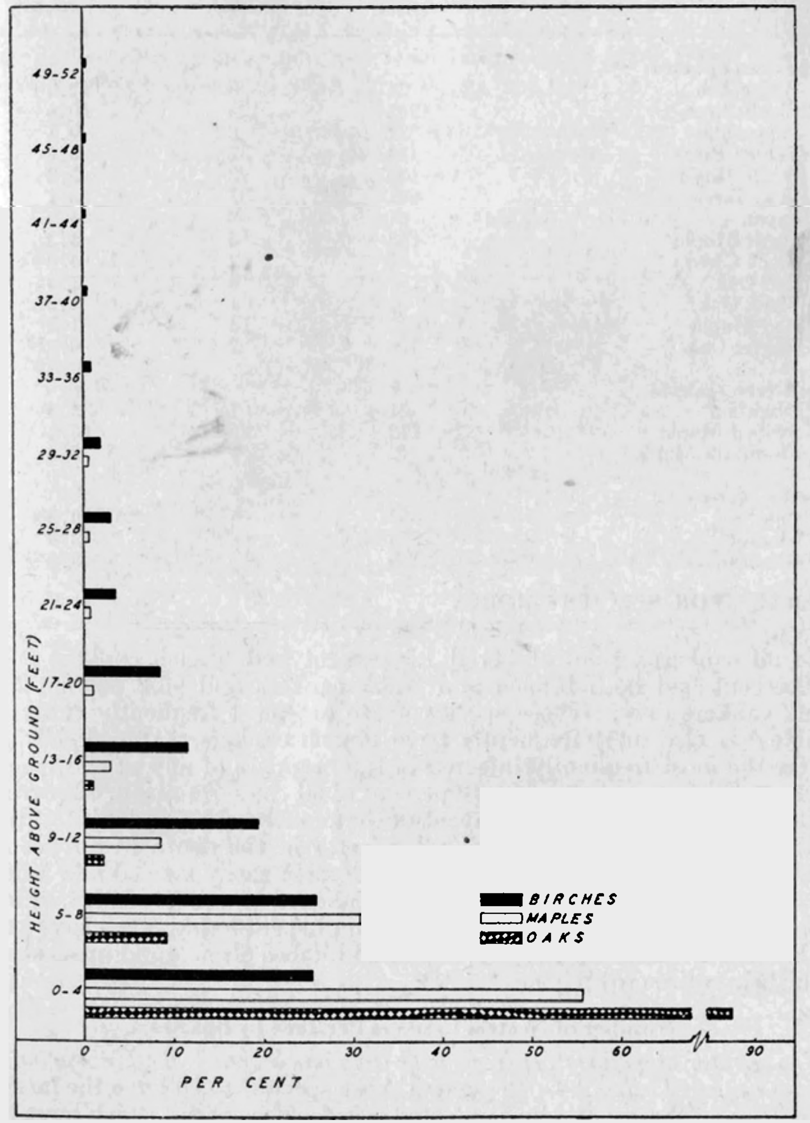

FIGURE 94. Location of Nectria cankers—height above ground.

TABLE IX. SPECIES HAVING BRANCH CANKERS

SPECIES	Number cankered trees	Trees with branch cankers number	percent
Large tree species:			
White Ash	24	3	12.5
Black Birch	1202	128	10.6
Pepperidge	22	2	9.1
Yellow Birch	416	37	8.9
White Birch	150	8	5.3
Gray Birch	691	35	5.1
Aspen	61	3	4.9
Sugar Maple	188	8	4.3
Black Cherry	50	2	4.0
Red Oak	159	3	1.9
Black Oak	85	1	1.2
Red Maple	1037	13	1.2
Scarlet Oak	478	2	0.4
Small tree species			
Dogwood	21	7	33.3
Striped Maple	172	26	15.1
Mountain Maple	12	1	8.4
Species groups			
Oaks	863	—	0.6
Maples	1574	—	3.0
Birches	2459	—	8.5
AVERAGE FOR SPECIES GROUPS			4.8

Of all cankered trees observed 1.1 percent had branch cankers only, 3.7 percent had both branch and trunk cankers and 95.2 percent had trunk cankers only. Those species which are most frequently cankered (Table VI) also most frequently have branch cankers. The birches are by far the most frequently infected in the branches of any of the species groups. Birches accounted for 18 percent of all trees examined, 42 percent of the cankered trees and 75 percent of the branch cankers. This location of the cankers may be a contributing factor in the death of birches by Nectria canker. The smaller branches are more easily girdled and killed. By gradual loss of the crown the tree is weakened and finally killed. Field observation indicates that dying yellow and black birches often have part of their crown killed by girdling, and dead birches often stand up as stubs with their entire crown gone.

Number of Nectria Cankers Per Tree by Species

The number of cankers per tree varies from one to many, the average for all species cankered being 2.9. In general those species which have the largest proportion of their individuals infected are also the species which have the greatest number of cankers per tree. There are some exceptions such as scarlet oak and aspen. Among the **Large Tree Species** black birch has 4.6, sassafras 4.6 and pepperidge 3.7, the largest number of cankers per tree. Next comes yellow birch with 3.3, gray birch with 3.3 and white birch with 2.8 (Table X). Mountain maple has 3.7 and striped maple 3.2, the largest number per tree among the **Small Tree Species.**

Of the species groups, birches have the greatest number of cankers per tree, 3.9, followed by maples, 2.2, and oaks, 2.0, in the same order as the percentage of trees infected (Table VI).

The frequency of occurrence of the number of Nectria cankers per tree (Table XI) shows a relatively greater percentage of the oaks and maples with one to two cankers per tree than birches, and a relatively smaller percentage with three and more cankers per tree.

TABLE X. NUMBER OF NECTRIA CANKERS PER TREE

SPECIES	Weighted average number of cankers per tree	SPECIES	Weighted average number of cankers per tree
Large tree species		**Small tree species:**	
Black Birch	4.6	Mountain Maple	3.7
Sassafras	4.6	Striped Maple	3.2
Pepperidge	3.7	Dogwood	1.6
Yellow Birch	3.3	Alder	1.4
Gray Birch	3.3	Pin Cherry	1.3
White Birch	2.8	Hop Hornbeam	1.2
Black Cherry	2.8	Shadbush	1.2
White Ash	2.6	Blue Beech	1.1
Hickory	2.3	Scrub Oak	1.0
Sugar Maple	2.3	Miscellaneous	2.4
Red Oak	2.2	**AVERAGE**	2.1
Scarlet Oak	2.1	**AVERAGE—ALL SPECIES**	2.9
Red Maple	2.1		
Basswood	2.1		
Elm	2.0	**Species groups:**	
Black Oak	1.9	Birches	3.9
Aspen	1.8	Maples	2.2
White Oak	1.6	Oaks	2.0
Beech	1.4		
Chestnut Oak	1.0		
AVERAGE	3.0		

Miscellaneous species with Nectria are witch hazel, sumac, willow and apple.

TABLE XI. PERCENT FREQUENCY OF NUMBER OF NECTRIA CANKERS PER TREE

Number of cankers	BIRCHES Percent of trees	MAPLES Percent of trees	OAKS Percent of trees	ALL SPECIES Percent of trees
1- 2	50.4	75.0	79.0	65.7
3- 4	21.1	14.5	13.4	16.9
5- 6	10.7	5.1	4.4	7.2
7- 8	6.3	2.6	2.0	4.0
9-10	4.4	1.2	0.8	2.4
11-12	2.7	0.7	0.1	1.4
13-14	1.5	0.4	0.0	0.8
15-16	1.2	0.2	0.2	0.6
over 16	1.7	0.3	0.1	1.0
TOTALS	100.0	100.0	100.0	100.0

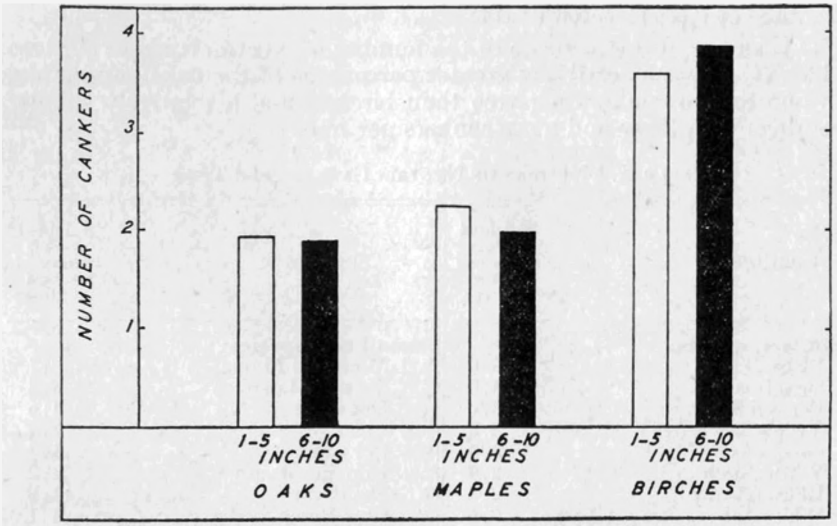

Figure 95. Number of Nectria cankers per tree in relation to diameter classes. Diameter classes 1-5 inches and 6-10 inches.

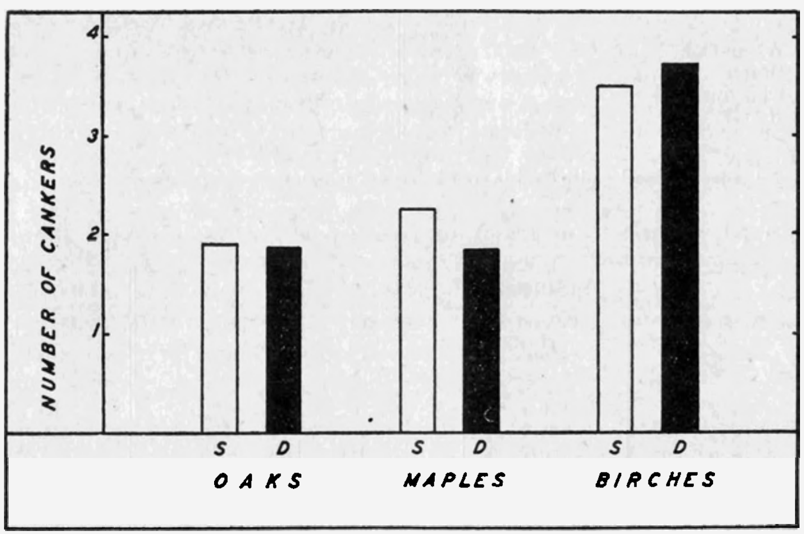

Figure 96. Number of Nectria cankers per tree in relation to crown classes. S—Suppressed—includes both suppressed and intermediate crown classes. D—Dominant—includes both codominant and dominant crown classes.

Andrews (1935) states that the greatest number of Nectria cankers per individual occurred in the lowest diameter and crown classes. He adds, however, that this may be due to species differences at that stage of development, as sugar maple was very abundant in the stand examined. It formed 60 percent of the entire population examined and an even larger percentage of the small diameter classes.

The above statement is borne out by the data here presented as far as the maples and oaks are concerned but not for the birches. The maples have a decreased number of cankers per tree with increased diameter (Figure 95) and in the upper crown classes (Figure 96). The same is true in the case of the oaks. In birches, however, the reverse is true; that is, the larger, more dominant birches have a greater number of cankers per tree than the smaller, suppressed birches. This order is exactly the same for the number of cankers per tree as it is for the number (percentage) of trees infected with Nectria cankers (Figures 97 and 98).

Fruiting of Nectria Cankers

During the course of the field work on the Tunxis Forest the Nectria cankers located less than six feet from the ground were examined for evidences of fruiting. These data (Table XII) indicate that fruiting was greater in the spring season than at any other time, which substantiates part of the findings of Welch (1934). Welch, however, found an increase in fruiting in the fall also. The examinations made from September to November, 1935, do not bear this out but a dry summer season may have been unfavorable to fruiting. The observations were not continued over a sufficient period of time to give conclusive results on that point. Spaulding *et al.* (1936) report a very definite increase in fruiting with increased moisture of the habitat but present no data on the seasonal fruiting of cankers on standing trees.

Table XII. Amount of Fruiting of Nectria Cankers in Relation to Season (Tunxis Forest 2200 Cankers)

Date	Amount of fruiting (percent) Abundant	Sparse	None	Number of cankers
January–March	50	6	44	103
March–June	13	6	81	157
June—September	13	5	82	198
September–November	10	7	83	812
November–January	7	3	90	930
Averages and Total	11	5	84	2200

The amount of fruiting at any time was not large, an average of 84 percent showing no fruiting whatever, while 5 percent of the cankers examined were fruiting sparsely and 11 percent abundantly.

Avenues of Entrance of the Nectria Organism

More than 1700 Nectria cankers on the Tunxis Forest were observed to determine the possible avenue of entrance of the organism. In many cases it could not be determined with certainty and these were discarded.

Of those which could be determined, the largest number, 45 percent, had evidences of an old branch stub apparently in the center of canker development through which the organism seems to have entered. About 20 percent were associated with borer injury, 10 percent with frost cracks, 9 percent with rubbing injuries, 8 percent with miscellaneous lesions and 8 percent with mechanical injuries. Often callus folds, dead bark or decay of the exposed wood in the center of the canker obscures the possible point of entry. These data agree in part with the avenues of entrance as given by Grant (1936). He lists as causes: rubbing, 8 percent; crotches of living branches, 15 percent; branch stubs, 56 percent; and unknown, 21 percent. Regarding branch stubs he says, "Regardless of exact point of entrance the data show that branches were important as avenues of entrance for Nectria into the host."

Effect of Nectria Cankers on Host Species

Damage to the individual tree infected by one or more Nectria cankers depends on its size, vigor, species and degree of infection. Spaulding (1936) says, "Nectria cankers sometimes kill trees outright but far the greater number cause weakening or crippling, leading to premature death or wind breakage." Welch (1934) states that because the spread of fungus is slow, often less than .5 inch a year, "the danger of killing by girdling is not very great". He concludes that it is chiefly a menace because it opens a wound to decay, often leading to the heartwood through a dead branch stub. Andrews (1935) suggests that damage may be serious in small trees in which girdling and death can be quickly brought about, and points out that this is what happens to the side branches through which the disease enters. He specifically states, "In larger sizes very little evidence of inhibition of growth by well developed cankers could be found". Sometimes vigorous trees of certain species can overgrow the canker, but there still remains either a defect or an area of decay which may increase in size.

No special study of the growth rate of cankered trees was made but very frequently dead trees bearing Nectria cankers were found. The size and species of these trees was noted. Whether the tree died because of the presence of Nectria cankers could not, of course, be determined with certainty in all cases, but observers were requested to list as dead with Nectria cankers only those trees where it seemed reasonably sure that Nectria was either the primary cause or a contributing cause of the death.

With this limitation in mind, the data is sufficiently clear cut to be of value in comparing the species groups. (Table XIII).

TABLE XIII. PERCENT OF NECTRIA CANKERED TREES THAT WERE DEAD—(BY SPECIES GROUPS)

D.B.H. class (inches)	Oaks	Maples	Birches
1–2	9.1	13.5	10.2
3–4	3.1	8.6	14.1
5–6	1.3	13.5	10.6
7–8	0.6	4.8	13.6
9–10	0	0	8.7
Averages	3.2	10.7	10.3

The data in Table XIII was obtained by recording, for example, the number of Nectria cankered maples in the one and two-inch D.B.H. class (993) and the number of dead cankered maples in the same D.B.H. class (134) and determining the percentage dead, 13.5. A very much larger percentage of oaks was dead with Nectria cankers in the small sizes than in the larger sizes. This tendency was not so evident in maples where the figures were quite high in both classes. In birches the percentage dead with Nectria was practically as large in the seven to eight and nine to ten-inch classes as it was in the one to two-inch class. The oak group was in striking contrast with the birch group. The weighted average D.B.H. of the cankered trees in each species group was: birches 3.7 inches, oaks 2.5 inches and maples 2.1 inches.

Most of the oaks found dead with Nectria cankers were small; hence the disease may act to weed out many small trees in the stand. In maples, many small trees were dead with Nectria cankers, but there were also some in the middle-size classes. In birch, Nectria cankers were frequently destructive both to the small and also to the large trees. Observation in the field indicates clearly that many large, yellow, black and white birch are so infected by many Nectria cankers as to kill them. Observation indicates that the maples seem to be able to overgrow the Nectria cankers, while in birches this does not appear to occur. In oaks, although there are many severe basal cankers on large trees, death does not seem to result nor is breakage evident.

Nectria Canker in Relation to Age of Infected Trees

The age of the trees infected with Nectria cankers was determined in the field by increment borings. The distribution of age classes is probably similar for healthy and cankered trees, hence these data (Table XIV) indicate what age classes were prevalent in the forests examined. The greatest number of cankered trees were 16 to 20 years old, followed by the 11 to 15-year class and the 21 to 25-year class. Insufficient data were available on the ages of the healthy trees on the plots, hence the percentage of infection by age classes could not be determined.

A comparison of the species groups by 25-year age classes shows that the younger birches are less often infected than the maples and oaks, but that in the older classes (26 to 50 and 51 to 75) the birches are more often infected than the maples and oaks. These results are similar to those discussed under the effect of Nectria cankers on host species. Many of the birches become infected while young and are not able to overcome the infections and apparently continue to develop new cankers as they become older, hence more of the older trees are cankered and eventually they may be killed by the disease. The maples become heavily infected while young, and a number of them die at this time and also to some extent when older. However, many are able to outgrow the disease, hence the older maples are found to be less frequently infected. The oaks become heavily infected when young and many die. Those that survive do not outgrow their cankers nor do they apparently become more frequently infected as they become older.

Table XIV. Age of Trees Cankered by Nectria

Age class	Number trees cankered	All species (percent)	Oaks (percent)	Maples (percent)	Birches (percent)
1– 5	52	1.0	0.4	1.0	1.0
6–10	428	8.6	5.8	10.3	6.6
11–15	951	19.1	16.8	25.1	15.5
16–20	1107	22.1	25.4	25.0	21.4
21–25	727	14.6	18.0	15.2	14.4
Sub-total	**3265**	**65.4**	**66.4**	**76.6**	**58.9**
26–30	486	9.7	10.0	8.9	11.0
31–35	361	7.2	8.7	4.1	8.8
36–40	283	5.7	5.7	3.4	6.9
41–45	174	3.5	2.2	3.2	4.7
46–50	133	2.7	3.3	1.3	2.9
Sub-total	**1437**	**28.8**	**29.9**	**20.9**	**34.3**
51–55	76	1.4	1.3	0.5	2.0
56–60	59	1.2	0.9	0.3	1.3
61–65	54	1.1	0.7	0.7	1.3
66–70	39	0.8	0.2	0.3	1.1
71–75	23	0.5	0.3	0.3	0.3
Sub-total	**251**	**5.0**	**3.4**	**2.1**	**6.0**
76–80	8	0.2	0.0	0.2	0.2
81–85	9	0.2	0.2	0.1	0.2
86–90	6	0.14	0.1	0.0	0.2
91–95	1	0.02	0.0	0.0	0.1
96–100	2	0.04	0.0	0.0	0.05
Sub-total	**26**	**0.60**	**0.3**	**0.3**	**0.75**
over 100	8	0.2	0.0	0.1	0.05
GRAND TOTAL	4987	100.0	100.0	100.0	100.00

Nectria Canker in Relation to Diameter of Trees

The diameter of all trees, whether healthy or diseased, was measured. This made it possible to determine the percentage of all the trees in a given diameter class which were infected by Nectria cankers. The number above 10 inches D.B.H. was small; hence the data were not used in Figure 97. In the birches there is a very definite rise in the proportion of Nectria

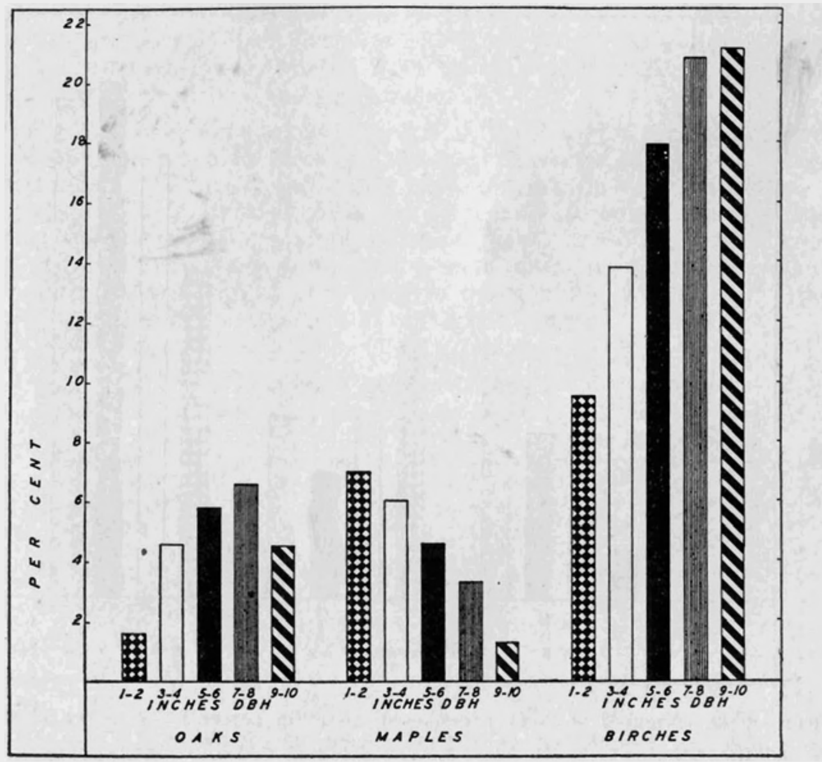

Figure 97. Number of Nectria cankered trees (in percent) by diameter classes. Diameter classes 1-2 inches, 3-4 inches, 5-6 inches, 7-8 inches and 9-10 inches.

cankered trees with increase in diameter. In the maples there is as definite, though not as great, a decrease with increase in diameter. The oaks show a slight increase in infection with increase in diameter. These data point to conclusions similar to those discussed under Nectria canker in relation to age of infected trees.

Nectria Canker in Relation to Crown Class

The crown class of the trees infected with Nectria canker was compared with the crown class of the healthy trees. The results are shown in Figure 98 which should be compared with Figure 97. The dominant and codominant birches are more frequently cankered than the intermediate and suppressed. In the maples this is reversed; that is, the dominant and codominant trees are less frequently infected than the intermediate and suppressed. Apparently the vigorously growing trees, which are usually

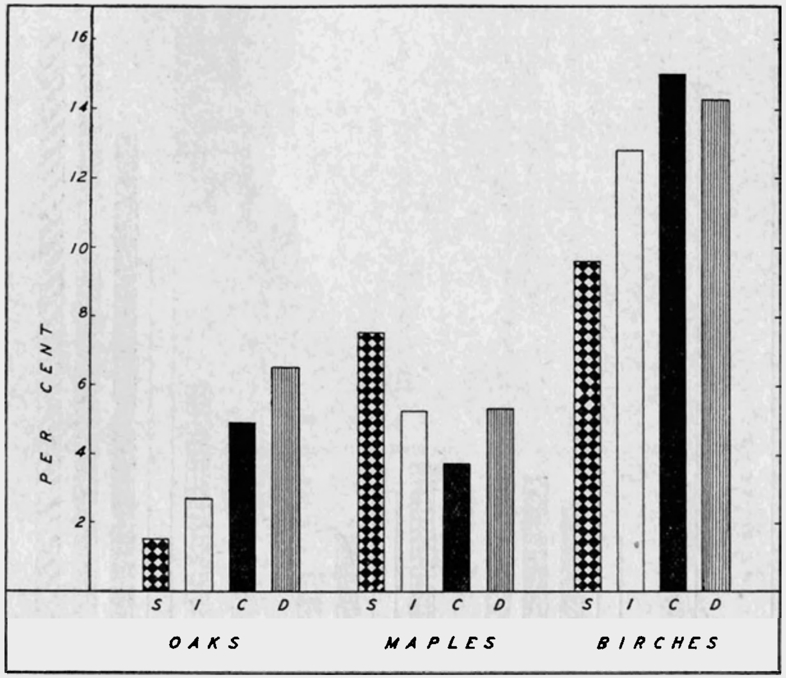

FIGURE 98. Number of Nectria cankered trees (in percent) by crown classes. S—suppressed, I—intermediate, C—codominant, D—dominant.

in a dominant position, are able to outgrow the disease. The oaks resemble the birches showing a larger amount of infection in the dominant and codominant classes than in the suppressed and intermediate classes.

An examination of the data for the individual species other than oaks, birches and maples shows that beech, hickory, alder, basswood and pepperidge have a greater amount of Nectria in the higher crown classes than in the lower, resembling the birches. Aspen, black ash, sassafras and black cherry have a lesser amount of Nectria in the higher crown classes than in the lower, resembling the maples.

Nectria Canker in Relation to Origin of Tree

There was no relation between the origin of the tree, whether sprout or seedling, and the amount of Nectria canker.

Nectria Canker in Relation to Forest Type

Since forest types vary in species composition and in habitat factors, they would be expected to vary in the amount of Nectria infection. This has been shown to be the case in Connecticut forests (Table XV). The Hardwood Swamp type had the greatest number of infected trees, 12.1 percent, probably because of the abundance of red maple and yellow birch, two heavily cankered species, and poor growing conditions in the swamp type. Observation has shown that the hardwood swamp type is usually composed of poor quality trees having Nectria cankers as well as decay, lesions, dead tops and other defects.

The old field type had a large amount of Nectria, 10.4 percent, because of the abundance of gray birch and the open character of many of the old field stands. The mixed hardwoods type, found on a variety of sites, is composed of a large number of species, some heavily cankered, others not. The large number of the immune softwoods cause the softwood-hardwood type and the softwood type to have a small amount of Nectria canker. The oak ridge type with its abundance of chestnut oak, hickory and other oaks also ranked low in the amount of Nectria canker.

TABLE XV. NECTRIA CANKERS IN RELATION TO FOREST TYPE

Forest type	Symbol	Trees Examined (Number)	Trees cankered	
			(Number)	(Percent)
Swamp Hardwood	S	2209	267	12.1
Old Field	OF	4130	428	10.4
Mixed Hardwoods	MH	75527	4294	5.7
Softwood-Hardwood	SH	12961	530	4.1
Oak Ridge	O	2518	90	3.6
Softwood	SW	618	20	3.2

Nectria Canker in Relation to Density of Stand

The total number of trees per plot averaged 79 but there was no consistent difference in number of trees on the lightly diseased plots compared to the heavily diseased plots. Since the average number of trees per plot was based on all types and age classes, the number of stems would not necessarily indicate the actual density of the stand unless the age of the stand was known.

The same applies to a basal area per plot figure; hence no attempt was made to determine a correlation between basal area and percentage of trees infected with Nectria canker.

The density of the canopy on each plot was judged by the observer and rated according to the usual system of 0.1 to 1.0, from a very open canopy (0.1) to one in which the crown cover is complete (1.0). The data for density 0.1 and 0.2 are too few to be of any value. The number of plots in each canopy density class and the percentage of Nectria infection follows:

Crown density class	Number of plots	Average percent Nectria infection
1- 2	6	(plots too few)
3- 4	53	7.4
5- 6	290	6.5
7- 8	775	5.5
9-10	130	3.4

There is a slight but definite trend toward decreasing Nectria infection with increasing density of the canopy. (Figure 99). These facts would lend weight to Grant's (1936) suggestion that a densely stocked stand where the side branches are small and few in number would seem to be

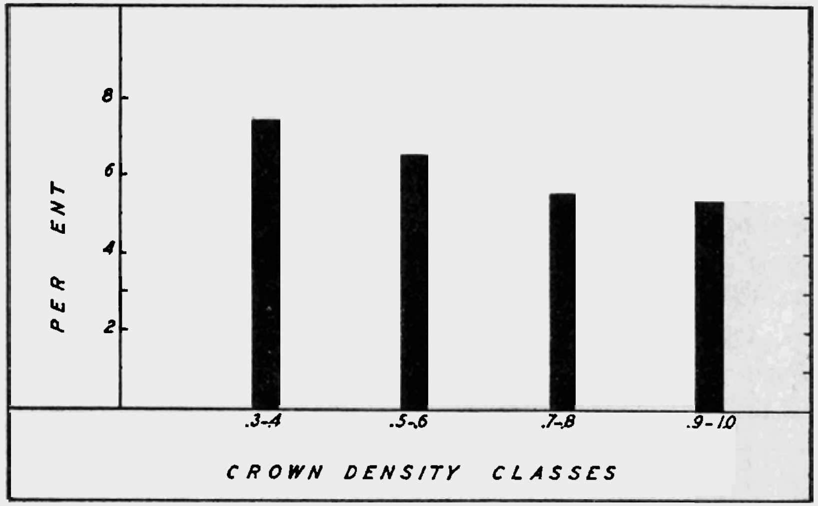

FIGURE 99. Nectria infection in relation to crown density classes. Crown density classes, .3-.4, .5-.6, .7-.8 and .9-1.0.

desirable from the point of view of minimizing Nectria canker formation on young stems. The rapid healing over of small wounds left by the early pruning of side branches would be desirable. Hence any silvicultural practices tending to produce dense young stands would be beneficial from the standpoint of reducing Nectria infection.

Nectria in Relation to Age of Stand

The amount of Nectria on plots located in different age classes of forest stands was determined. The data varied so widely that no reliance could be placed on averages obtained from all the forests. Previous history and species composition of the stand, as well as other possible factors, enter in to obscure any effect which age of the stand may have.

Likewise large numbers of the plots were in uneven aged stands with a varied mixture of ages.

Nectria in Relation to Plot Exposure

The direction of facing of nearly 3000 Nectria cankers on the Tunxis Forest in relation to the exposure of the plot was determined. There was no correlation evident. About the same average number of cankers were found on each exposure. Neither was the direction of facing of the cankers affected by plot exposure.

Nectria in Relation to Site Quality

The field crews designated each plot examined as good (I), medium (II) or poor (III) site. This designation was an ocular estimate based on the height, age, vigor and appearance of the trees of the plot. The exact height-age of a dominant and a codominant tree on each plot was obtained in the Tunxis Forest. This data, when averaged according to site classes, gave a height at a classification age of 50 years of:

Site I –53 feet
Site II –48 feet
Site III–40 feet

A comparison of the four forests indicated that species composition has a very marked effect on the relation between site and amount of Nectria infection since oaks and hickories, comparatively lightly infected species, are more prevalent on the poorer sites than are birches and maples.

Examination of seven frequently cankered species was made on the Tunxis Forest. *The percentage of trees infected with Nectria cankers was greater on the poor sites than it was on the good sites.* (Figure 100). This difference was particularly marked in the four species of birch where Site III had 28 percent Nectria infection, Site II, 17 percent and Site I, 10 percent. Striped maple also showed a difference while sugar maple and red maple showed little difference.

Many other factors beside site quality determine the percentage of Nectria infection, chief among them being species composition of the stand and past history of the stand. Hence care must be used to give proper weight to the species composition of the stand under consideration, as well as its site quality.

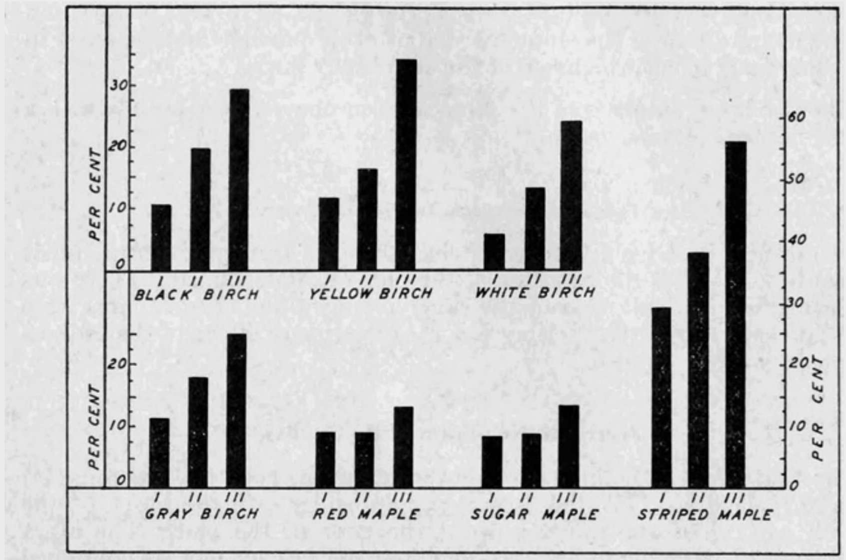

FIGURE 100. Effect of site quality on number (in percent) of Nectria cankered trees of seven species. (Tunxis Forest-376 plots). I—good site, II—medium site, III—poor site.

Discussion

The oaks, maples and birches constitute three-fourths of the trees found in the four forests examined. These species groups, together with the immune softwoods, account for most of the tree population. The oaks form a large percentage, 32.0, of the total population, but since they are not frequently cankered by Nectria, 3.6 percent, the cankered individuals form only a small part of the total population, 1.1 percent, (Figure 101). In contrast, the birches form a smaller percentage, 18.1 of the total population, but since they are frequently cankered by Nectria, 12.5 percent, the cankered individuals form a relatively large part of the total population, 2.3 percent. The maples are intermediate between the oaks and the birches.

The Tunxis Forest contrasts with the other three forests in having few oaks and many maples. Several forests have more Nectria cankered oaks than they have Nectria cankered maples.

In an effort to determine just what the conditions were on the severely Nectria cankered plots, all plots which had 15 or more percent of Nectria cankered trees were analyzed. The number in each forest was: Tunxis 38, Pachaug 27, Meshomasic 40, and Cockaponset 10.

Since suppressed trees would likely drop out of the stand in the course of time, these would probably never enter into the final crop unless man

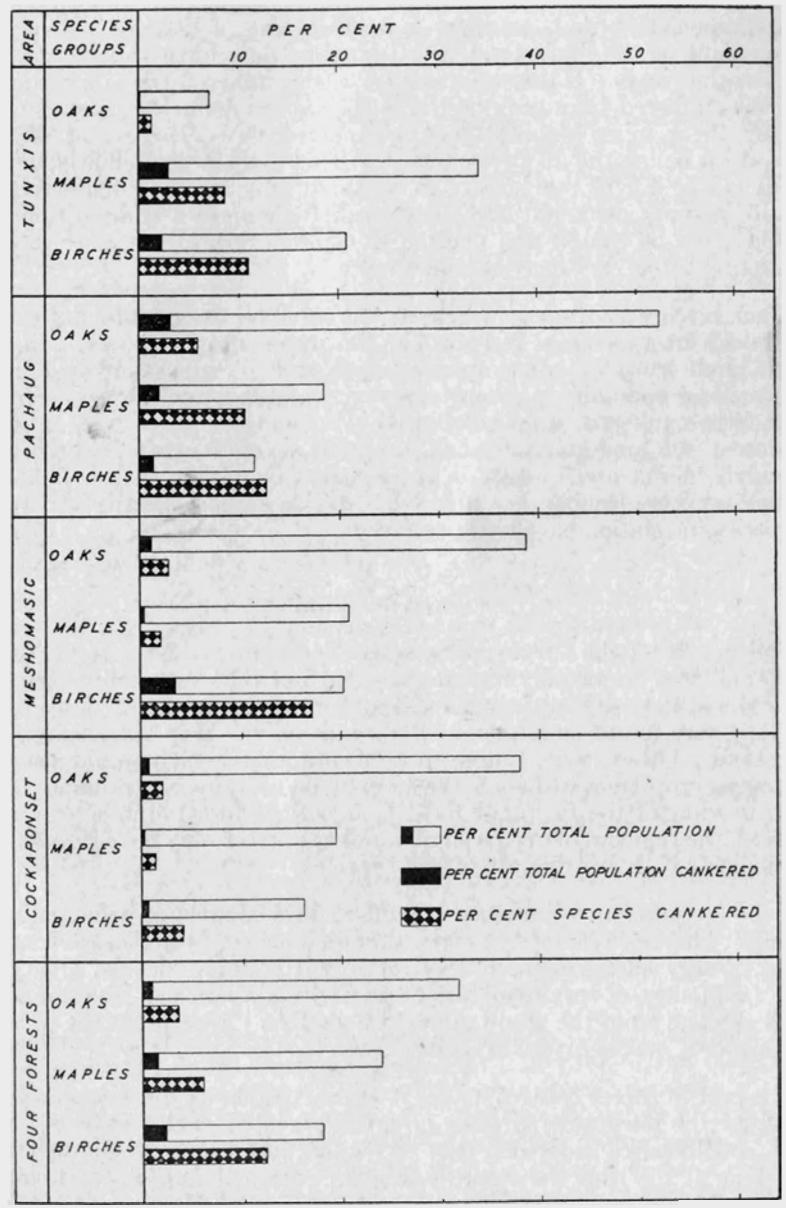

FIGURE 101. Comparison of species groups with regard to species composition of the forest: percent of species Nectria cankered and percent of total population Nectria cankered. Entire white bar—percent of the total population made up of the species group indicated. Black part of bar—percent of total population made up of Nectria cankered trees. Cross-hatched bar—per cent of the species cankered.

favored them in his silvicultural operations. Likewise trees such as gray birch, aspen, dogwood, sassafras and others are of little or no value as components of the final stand, although they may have value as trainers and in other ways. If the suppressed Nectria cankered trees of all species, and the cankered trees of undesirable species are deducted from the plots having 15 or more percent Nectria cankered trees, 75 percent of these plots drop below the 15 percent limit. This drop is particularly marked in the old field type due largely to cankered gray birch. Such stands are usually heavily cankered and because of their species composition they should often be cut off and planted to conifers. In other cases sassafras was found to be very heavily cankered.

Black birch was often very heavily cankered on these plots, not only in the lower crown classes but also in the upper crown classes. In fact, black birch leads all other species which were Nectria cankered in the dominant or codominant crown classes. Dominant red maples were also frequently cankered, especially on the Pachaug forest where, although the forest was predominantly oak, the most severe Nectria cankering was in stands in wet areas heavy in red maple. Dominant yellow birch and scarlet oak were frequently cankered. All this emphasizes the importance of species in relation to Nectria canker.

Control Measures

The results of the survey indicate that in Connecticut forests Nectria cankered trees are usually not so abundant but that they can be removed from the stand without injurying it to any great extent. Many of the cankers were found on suppressed trees which would in time pass out of the stand. Others were found on inferior species which would never be chosen as crop trees although they might be of value as trainers. However, in view of the fact that most Connecticut forest stands are understocked, the removal of even a small number of trees may be of importance, particularly if those trees are of good species.

Since Nectria is a wind-borne organism, it is capable of wide and rapid spread. Therefore *complete, permanent* elimination of the disease from the stand is, very likely, impossible. Certainly it is impracticable. The presence, frequently, of very small branch cankers makes the present elimination of all cankers from the stand almost impossible. An abundance of wind-borne spores makes future infection likely.

The cost of direct control makes it impracticable to go through a stand solely for the purpose of girdling or cutting Nectria cankered trees. Such work should be considered a part of regular stand improvement practice and done at the time the stand is treated. Since the presence of cankers causes weakening and slowing up of the growth rate, deformation, breakage and possible death, or cull and possible decay entrance, trees with Nectria cankers should not be chosen as crop trees. There are small spots in Connecticut forests where cankered trees are so numerous it is necessary to choose some crop trees with cankers. In that case, preference should be given to those species such as the oaks and maples which do not usually succumb to Nectria canker, and to such individuals as have cankers

located high up in the tree, where they will not cause cull in the butt log or, less desirable, near the ground where they will cause little or no cull. Few trees with basal cankers seem to break over or die, but rot often does enter. Hence such trees should be chosen only as a last resort.

The abundance of Nectria cankers on certain of the weed species, such as striped and mountain maples, dogwood and alder, the inoculum from which is capable of infecting more valuable species, Spaulding *et al* (1936), make it desirable to cut these infected weed trees whenever they are encountered in the course of regular silvicultural work. The elimination of these cankered weed species and as many of the cankered timber species as practicable will lessen the amount of inoculum and thus lessen the chances for infection of the remaining stand.

Both the present and future value of a stand, and the use to which it will be put, determine the kind and amount of control work that should be done (Grant 1937). If a stand is of poor quality, it is not worth expending much effort in the reduction of Nectria canker. If the stand is to be used largely for water shed protection, wild life protection or recreation, not much time or money need be expended in the control of Nectria canker. Stands intended primarily for timber production, particularly saw logs, should be well cared for. Considerable time spent on Nectria control in such stands is justifiable.

Since dense, rapidly growing stands on good sites are most apt to be free of Nectria infection, any silvicultural practices which produce dense stands of young trees which self-prune early in life to a considerable height on sites favorable to healthy and rapid growth, are to be favored. If these practices are followed by weeding and thinning to continue rapid growth, the amount of Nectria canker should be at a minimum. In a word, good silviculture is good Nectria control.

1. **The elimination of Nectria cankered trees should be carried out in connection with regular stand improvement work.**
2. **Girdle, or better cut down and utilize, all cankered trees if this practice does not open up the stand too much. If it does, leave some of the cankered trees as trainers.**
3. **Do not choose trees with Nectria cankers as crop trees.**

STRUMELLA CANKER

Cankers caused by *Strumella coryneoidea* are very characteristic in appearance and are found chiefly on the oaks. The cankers are more elongated than those caused by *Nectria* and have successive ridges of callus growth making a concentric pattern around a branch stub or crotch where entry usually occurs. The fungus kills back the callus, enlarging the canker, and the dead, exposed wood finally decays and sloughs off. Excessive growth opposite the canker gives a characteristic bulge to the tree trunk which serves to spot the disease at a distance. The disease often kills the tree or causes it to break off at the canker.

Strumella cankers were found sparingly on all four forests. The Tunxis Forest had very few cankers because of the small amount of oak present. Only 215 Strumella cankers were found, or 0.2 percent of all trees examined. Of the 31,469 oaks examined, 194 or 0.6 percent had Strumella cankers,

(Table XVI). This is a relatively small number compared with the Eli Whitney Forest in southern Connecticut where from 1 to 5 percent of the oaks were cankered by Strumella. (Bidwell and Bramble, 1934).

TABLE XVI. PERCENTAGE OF TREES INFECTED BY STRUMELLA CANKERS

SPECIES	Tunxis	Pachaug	Meshomasic	Cockaponset	Four Forests
Black Oak	...	2.3	0.3	3.2	1.5
Scarlet Oak	...	1.1	0.1	1.5	0.9
Scrub Oak	...	0.8	...	...	0.8
Red Oak	0.2	1.8	0.3	1.4	0.7
Chestnut Oak	...	...	0.3	0.7	0.4
White Oak	...	0.5	...	0.7	0.3
Hickory	...	0.1	0.04	0.5	0.2
Beech	...	0.4	...	0.3	0.08
Red Maple	...	0.3	...	...	0.05
AVERAGE	0.01	0.5	0.06	0.5	0.2
All Oaks	...	...	...	...	0.6

Black oak was most frequently cankered 1.5 percent, followed by scarlet oak 0.9 percent, scrub oak 0.8 percent, red oak 0.7 percent, chestnut oak 0.4 percent and white oak 0.3 percent. The ranking was practically the same on each of the four forests. Bidwell and Bramble (1934) give the relative frequency of infection on one area as red and black oak 13.9 percent, scarlet and pin oak 5.0 percent, and chestnut and white oak 3.1 percent.

Most of the cankers were located on the lower part of the bole, 69 percent within 8 feet of the ground and 94 percent within 16 feet of the ground. (Figure 102).

This location renders cull all or part of the most valuable butt log.

The cankers varied in length from one foot to eight feet, the weighted average length being 1.8 feet.

Length (feet)	Percent	Length (feet)	Percent
1	57	5	2
2	24	6	1
3	9	7	0.5
4	6	8	0.5

Average 1.8

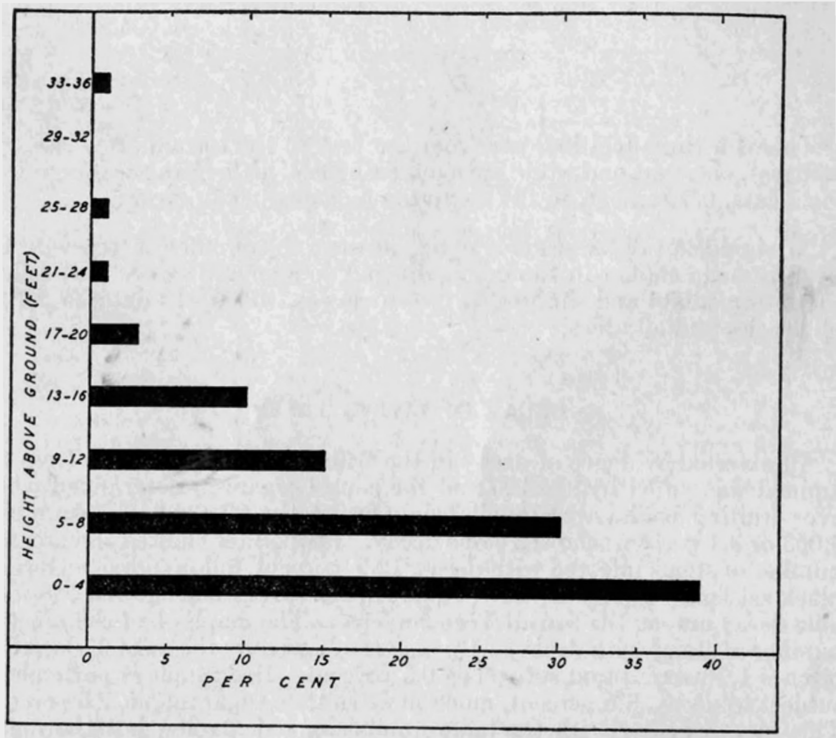

FIGURE 102. Location of Strumella cankers, height above the ground.

The larger trees were more frequently infected with Strumella cankers than the smaller trees. The average of all species examined was:

D.B.H. (inches)	Percent cankered
1- 5	0.2
6-10	0.5
11-15	0.4

This held for all species infected. The larger trees bore cankers which were plainly older and larger than those on smaller trees. This points to early infection accompanied by some deaths among the less vigorous, smaller trees, resulting in a relatively greater amount of infection in the remaining larger trees.

Infected black, scarlet and red oak apparently do not die out very freely in the young size classes, or else infection occurs later in the life of the tree, for we find the following percentages of Strumella cankering:

D.B.H. (inches)	Percent cankered
1– 5	0.6
6–10	1.7
11–15	1.6

This is a three-fold increase from the first to the second size class. In contrast, chestnut and white oaks increase very little from the one to five-inch class, 0.3 percent, to the six to ten-inch class, 0.5 percent.

No significant difference was noted between the number of trees infected by Strumella canker in the dominant and codominant crown classes and the intermediate and suppressed crown classes. This was determined for all species and all areas.

DECAY OF LIVING TREES

All external evidence of decay in the trunk or branches of the trees examined was noted by species, and the causal organism determined wherever fruiting bodies were available. Out of the 98,420 trees examined, 3,063 or 3.1 percent, showed some decay. Pepperidge showed the greatest number of stems infected with decay, 12.9 percent, followed by butternut, black ash, pin oak, beech etc. (Table XVII). Dogwood showed considerable decay among the **Small Tree Species.** The maples had the greatest number of stems with decay, 5.1 percent, followed by the oaks 2.5 percent, birches 1.9 percent and softwoods 0.5 percent. Red maple is particularly subject to decay, 5.6 percent, much more so than sugar maple, 2.5 percent. This fact, together with the large number of red maples, put the maple group at the top with regard to decay.

A comparison of the different species on the four forests showed considerable variation in the number of trees decayed. For example, red maple, present in all forests in large numbers, showed the following percentage of decayed individuals:

Tunxis	4.4 percent	Meshomasic	4.2 percent
Pachaug	6.7 percent	Cockaponset	11.4 percent

The same was true of many of the other species. The average of all species on the four forests was:

Tunxis	2.0 percent	Meshomasic	2.3 percent
Pachaug	4.2 percent	Cockaponset	5.2 percent

Where fruiting bodies were present it was possible to identify the organism causing the decay. The fungus most frequently encountered was *Fomes connatus*, causing about three-fourths of all the named decays. Red

TABLE XVII. PERCENTAGE OF LIVING TREES HAVING DECAY

SPECIES	Percent	SPECIES	Percent
Large tree species			
Pepperidge	12.9	White Pine	0.7
Butternut	11.1	Pitch Pine	0.5
Black Ash	11.1	Black Cherry	0.4
Pin Oak	11.1	Hemlock	0.1
Beech	5.9	Miscellaneous	10.0
Red Maple	5.6		
Sassafras	4.0	**Small tree species**	
Scarlet Oak	3.8	Dogwood	10.5
Hickory	3.5	Shadbush	3.8
White Ash	3.2	Blue Beech	3.6
Black Oak	3.1	Hop Hornbeam	2.3
Yellow Birch	2.7	Alder	0.7
Tulip	2.7	Scrub Oak	0.6
Sugar Maple	2.5	Striped Maple	0.2
White Oak	2.5	Pin Cherry	0.0
Black Birch	2.1	Mountain Maple	0.0
Chestnut Oak	2.0	Miscellaneous	4.2
Basswood	1.8		
Aspen	1.6	**AVERAGE–ALL SPECIES**	3.1
Red Cedar	1.6	**Species groups**	
Red Oak	1.5	Maples	5.1
Gray Birch	1.3	Oaks	2.5
White Birch	1.3	Birches	1.9
Elm	0.8	Softwoods	0.5

Miscellaneous species are white cedar, black walnut, spruce, sycamore, willow, sumac, witch hazel and apple.

maple was most frequently infected by this fungus. Beech, pepperidge, sugar maple, black and yellow birch, hickory, white, red, scarlet and black oaks are also susceptible. The sterile form of *Fomes igniarius*, (sometimes called *Fomes nigricans* in the United States) was the second most abundant fungus encountered, making up 13 percent of the named decays. Yellow and white birch were by far the most frequently infected with *F. nigricans*, followed by black birch, gray birch, red maple and beech. Other fungi less frequently found were: *Daedalia quercina*, *Armillaria mellia*, *Polyporus hispidus*, *Fomes igniarius*, *F. applanatus*, *F. fomentarius* and *F. fraxinophilus*.

Decay enters the tree in a large number of ways: through fire scars, insect injuries, logging injuries etc. The longer the tree lives, the longer it will be subjected to accidents which destroy its bark and expose its wood to the entrance of decay organisms. All trees examined were arranged by size classes, and the number of trees showing decay in each size class was determined. All species showed a decided advance in the number of trees decayed with increase in size. For all species figures were as follows:

D.B.H.	Percent decayed	D.B.H.	Percent decayed
1– 5 inches	2.5	11–15 inches	8.0
6–10 inches	5.6	over 15 inches	14.7

This increase for the species groups is shown in Figure 103. The data in the 16 inches and over class are sometimes inadequate, hence there are irregularities in the figures for maples and birches.

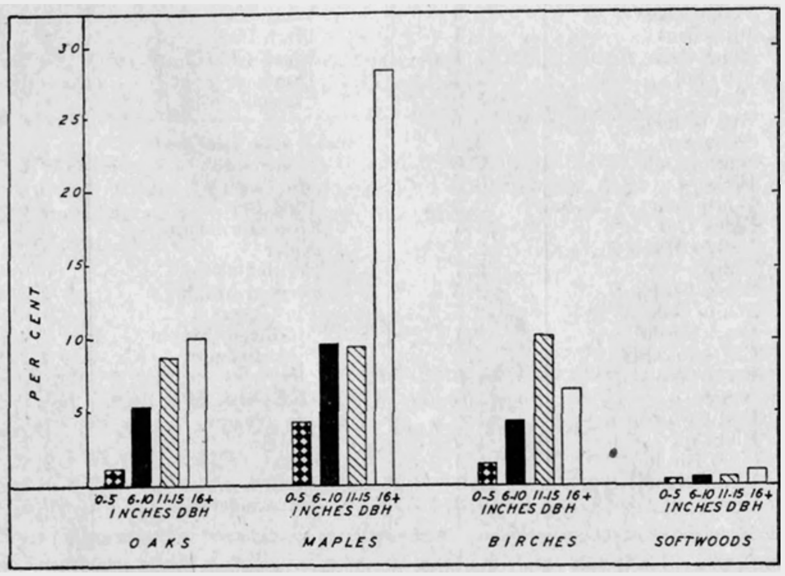

FIGURE 103. Effect of Diameter on the number (percent) of living trees with decay. Diameter classes 0-5 inches, 6-10 inches, 11-15 inches and 16 inches and over.

Most of the decay occurred near the ground in both small trees, one to seven inches D.B.H., and large trees, eight inches and over D.B.H. (Figure 104). In the small trees, of all species, 93 percent of the decay was within 8 feet of the ground and 99 percent within 16 feet. In the large trees, of all species, the decay was located somewhat higher on the tree, 77 percent occurring within 8 feet of the ground and 91 percent within 16 feet.

It must be kept clearly in mind that the length of the decayed area and the cull here discussed refers to what can be seen in the standing tree. No dissections were made to determine internal decay. Limstrom and Kuenzel (1937) conclude that about twice as many trees in the stands are defective as can be detected by observation of external appearance, and that actual extent of decay is about twice what can be seen from the outside. They record a cull of from 8.2 percent in small poles to 31.6 percent in trees over 9.6 inches D.B.H. of the total merchantable board foot or cubic foot volume.

Location and extent of the visible decay determined the amount of cull in this study. If a tree showed external evidence of decay from one to two feet above the ground, cull was considered as one lineal foot of the log; six to eight feet above ground, seven feet; nine to ten feet above the ground as one foot, since an eight-foot log could be cut below the cull.

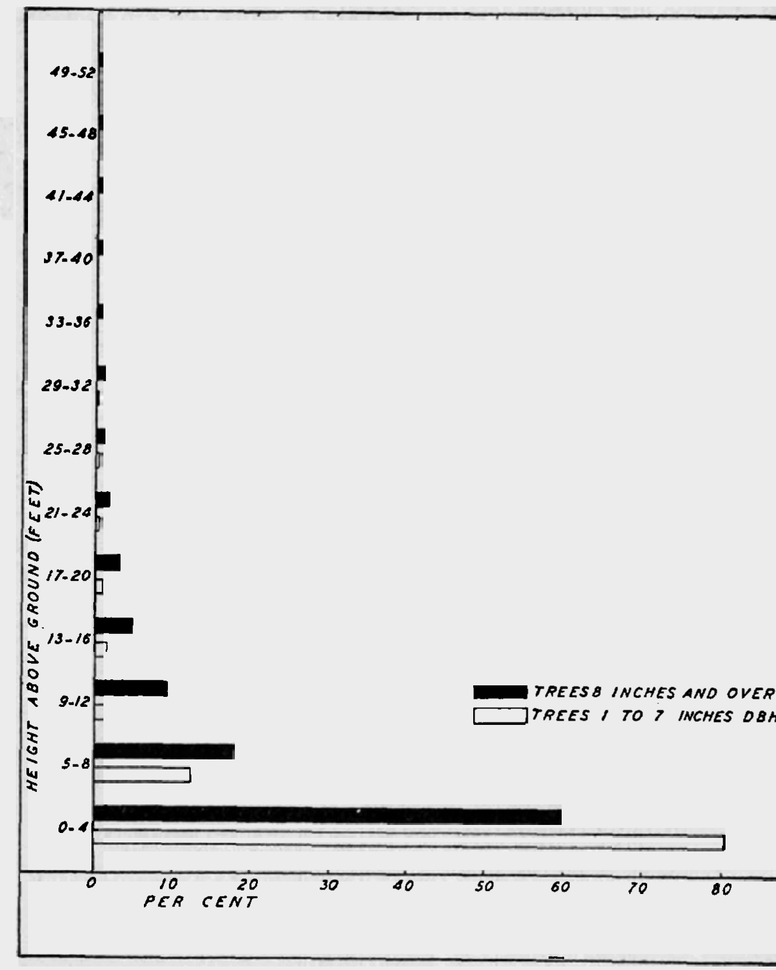

FIGURE 104. Location of Decay—height above the ground. Black bar—trees 8 inches and over D.B.H. White bar—trees 1-7 inches D.B.H.

Considering a sound healthy tree as capable of producing a 20-foot log, the percentage of cull was figured on that basis. That is, of 162 trees having decay, the extent and position of this decay was such as to make it necessary to cull 939 lineal feet of log. These same 162 trees, if healthy, would produce 3240 lineal feet of log. The cull was therefore 29 percent. If the average length of log produced was less than 20 feet, the cull would, of course, be higher than 29 percent. The percentage of cull was deter-

TABLE XVIII. AMOUNT OF LINEAL FEET OF CULL DUE TO DECAY—BASED ON 20 LINEAL FEET OF LOG PER TREE

	TUNXIS		PACHAUG		MESHOMASIC		COCKAPONSET		FOUR FORESTS	
	1 to 7 inches D.B.H.	8 inches and over D.B.H.	1 to 7 inches D.B.H.	8 inches and over D.B.H.	1 to 7 inches D.B.H.	8 inches and over D.B.H.	1 to 7 inches D.B.H.	8 inches and over D.B.H.	1 to 7 inches D.B.H.	8 inches and over D.B.H.
Number of trees with decay	371	162	670	143	619	137	647	190	2307	632
Lineal feet of logs	7,420	3,240	13,400	2,860	12,380	2,740	12,940	3,800	46,140	12,640
Lineal feet of cull	1,139	939	1,383	413	1,501	433	1,805	775	5,828	2,560
Percent cull	15.4	29.0	10.3	14.4	12.1	15.8	13.9	20.4	12.6	20.3

mined separately for the small trees, one to seven inches D.B.H., and the large trees, eight inches D.B.H. and over, for each forest. (Table XVIII). The large trees had more cull in every case, varying from 4 percent to 14 percent more. The average cull for the four forests was 12.6 percent for the small trees, and 20.3 percent for the large trees, or 14.3 percent for all trees.

No attempt was made to determine cull by species, since it was assumed that the cull would vary according to the frequency with which the species was decayed. (Table XVII).

The weighted average length of visible decay for all forests and all species was 2.2 feet, while the weighted average length of cull was 2.9 feet.

This cull figure applies only to those trees showing decay, hence the cull for the entire stand would be 14.3 percent of 3.1 percent (the percentage of trees with decay). For the small trees this would be .4 percent and for the large trees .6 percent. This cull figure is for visible decay only and does not include Nectria, Strumella or frost cracks. In comparison with the cull due to frost cracks, the cull due to decay is greater close to the ground. This would point to logging injuries and fire scars as points of entrance for the fungus.

The Connecticut forests sampled would appear to be relatively free from decay even if the amount found is doubled to take care of invisible decay, at least in comparison with some of the Missouri forests. The serious factor is that decay in the relatively young stands of Connecticut will increase as the stands become older and may become much more serious than at present.

FROST CRACKS

Radial splits in the trunk and large branches of trees, known as frost cracks, are caused by sudden changes in temperature and especially very severe cold. They occur in winter, chiefly during extremely cold winters such as that of 1933-34 in Connecticut. Stone (1912) states that they were very common during the cold winter of 1903-1904 in Massachusetts and that elm is more liable to frost cracks than other varieties.

During the course of the survey 2,522 trees were found to have one or more frost cracks, or 2.8 percent of all the trees examined. Scarlet oak, black ash, black oak and red maple are most frequently frost cracked (Table XIX) among the **Large Tree Species**, and striped maple, shadbush and dogwood among the **Small Tree Species**. A large number, 17 percent, of the trees which have frost cracks have more than one. Basswood, blue beech, and white birch are most liable to have multiple cracks. Considering the species groups, the oaks have the largest number, 3.9 percent, with maples 3.7 percent, softwoods 2.1 percent, and birches 1.2 percent having fewer trees cracked. (Figure 105).

Frost cracks range from less than one foot to as much as 45 feet in length. The average length (weighted average) for all frost cracks was 2.7 feet. The longest cracks were found on elm, black birch and hemlock.

(Table XIX). The length of the frost cracks was least in oaks and greatest in birches, just the reverse of the percentage having frost cracks. (Figure 105). Some individual trees seem to be structurally weak and have from 5 to 15 frost cracks facing in all directions and at different heights on the bole.

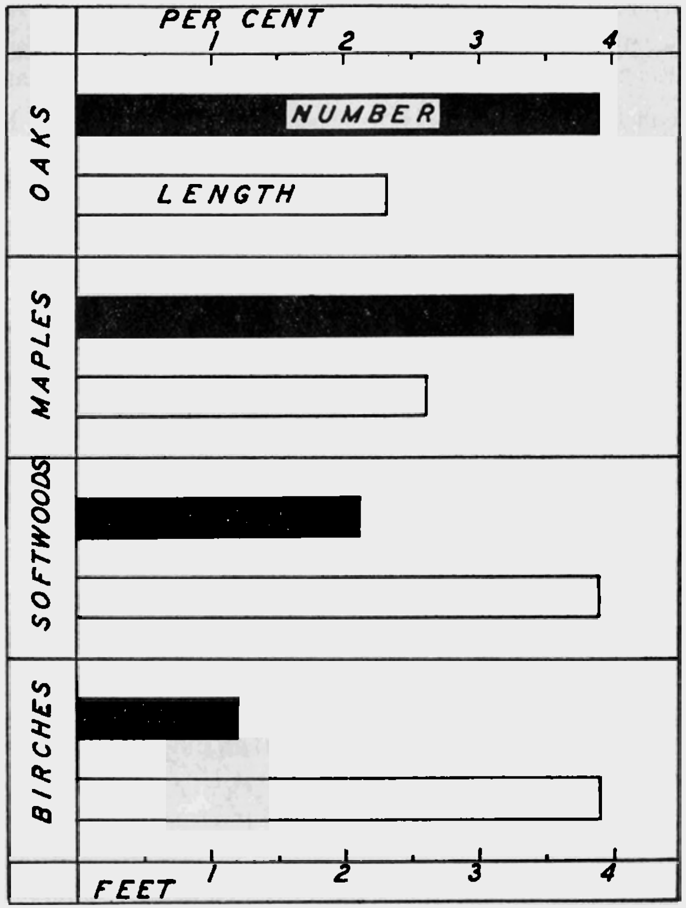

FIGURE 105. Length (in feet) of frost cracks and number (in percent) of trees with frost cracks—by species groups.

TABLE XIX. FROST CRACKS IN RELATION TO TREE SPECIES

SPECIES	Trees with frost cracks (percent)	Cracked trees with multiple cracks (percent)	Length of cracks (feet)
Large tree species			
Scarlet Oak	5.9	17.5	2.2
Black Ash	5.6	0.0	1.0
Black Oak	4.8	15.3	2.4
Red Maple	3.9	18.2	2.7
Red Oak	3.6	16.6	2.3
White Oak	3.3	17.3	2.4
White Birch	3.3	25.8	3.0
Butternut	3.1	0.0	1.0
Basswood	2.8	30.0	1.7
Tulip	2.6	23 1	2.7
Hemlock	2.5	13.1	4.0
Pepperidge	2.5	20.0	2.4
Beech	2.1	15.9	3.4
Aspen	1.9	9.1	2.3
Sugar Maple	1.8	19.6	2.2
Hickory	1.6	12.0	2.8
Black Birch	1.5	18.3	5.1
Chestnut Oak	1.5	22.5	3.5
Yellow Birch	1.3	17.0	3.0
Sassafras	1.1	9.1	2.1
White Ash	0.8	10.0	3.5
Elm	0.8	100.0	7.0
White Pine	0.6	0.0	2.0
Black Cherry	0.5	20.0	3.8
Pitch Pine	0.5	0.0	1.5
Gray Birch	0.3	7.1	2.4
Other species	0.0	0.0	0.0
Small tree species:			
Striped Maple	8.9	20.0	1.3
Shadbush	5.5	16.7	1.4
Dogwood	3.9	5.6	3.2
Hop Hornbeam	1.4	7.7	3.0
Scrub Oak	1.2	0.0	1.8
Blue Beech	0.9	28.6	3.0
Other species	0.0	0.0	
AVERAGES—ALL SPECIES	**2.8**	**17.0**	**2.7**
Species groups:			
Oaks	3.9	17.0	2.3
Maples	3.7	18.3	2.6
Birches	1.2	17.8	3.9
Softwoods	2.1	12.5	3.9

It is interesting to note that oaks are most frequently frost cracked and birches least frequently; the oaks have the shortest cracks and birches the longest. The oaks seem to be unable to adjust themselves to rapid changes of temperature, hence crack often, but their wood structure is such that the cracks are short. The tendency to crack may be correlated with the late leafing out of the oaks in contrast with the early leafing out of the birches.

The larger trees were more frequently frost cracked than the smaller ones:

D.B.H. (inches)	Percent frost cracked	D.B.H. (inches)	Percent frost cracked
1— 5	1.9	11—15	10.2
6—10	6.7	over 15	13.3

Similarly, the dominant trees were slightly more subject to frost cracking than the trees in the lower crown classes. The average of all species gave the following percentages of frost cracked trees in each crown class:

Dominant	6.2 percent	Intermediate	4.6 percent
Codominant	5.6 percent	Suppressed	2.9 percent

The birches showed this relation more strikingly than did the other groups.

The greater amount of cracking in the larger diameter classes and upper crown classes seems to substantiate the findings of Busse (1910) who claims that wind acting on the larger-crowned, more dominant trees, exerts a tension which, coupled with tensions already present due to temperature differences between the inside and outside of the tree, brings about the radial splitting known as frost cracking. He claims that old, stout-rooted, broad-crowned trees split most frequently and, in younger stands, usually the stoutest members split.

More than 80 percent of the frost cracks on all species were located within the first eight-foot log. The height above the ground of over 2,700 frost cracks was recorded in the four forests. This was done by tabulating the frost cracks in each four-foot section in which they appeared; thus a 4 to 12-foot frost crack was recorded in the three lowest sections: 0 to 4, 5 to 8 and 9 to 12. The location for all species was as follows:

0— 4 feet above ground	61.8 percent	21—24 feet above ground	1.2 percent
5— 8 feet above ground	20.7 percent	25—28 feet above ground	0.6 percent
9—12 feet above ground	8.3 percent	29—32 feet above ground	0.5 percent
13—16 feet above ground	4.0 percent	over 32 feet above ground	0.3 percent
17—20 feet above ground	2.6 percent		

There were, however, marked differences between the different species and species groups. Sugar maple has a greater number of cracks close to the ground while red maple had them scattered more frequently at higher

levels. Red oak among the oaks had 95 percent located within four feet of the ground. The oaks as a group had 81 percent within the first four feet, compared to 43 percent in the birches. In birches a relatively larger number of cracks were located at the higher levels than in the oaks. Maples resemble the birches closely. This is shown graphically in Figure 106. Hickory resembles oak, having most of its cracks close to the ground. White ash, beech, basswood, hemlock, aspen and tulip resemble the birches.

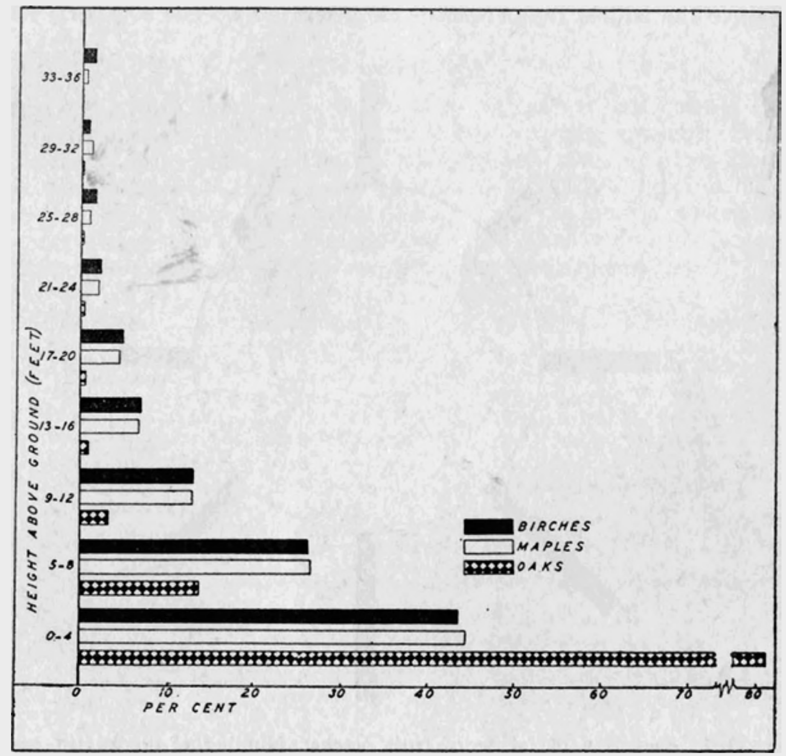

Figure 106. Location of frost cracks—height above the ground—by species groups.

Since frost cracks do not damage the log severely, the resulting cull is not great and varies with the closeness of utilization and the skill of the sawyer. Most frost cracks do not penetrate deeply. Many heal over but nevertheless cause a defect in the wood. Most trees have but two or three feet of the log frost cracked and, since most of these cracks are close to the ground, the actual cull averages 3.7 lineal feet for each tree. Frost cracks serve, however, as a point of entrance for decay organisms, and in the field some were observed to be invaded by wood rotting fungi, chiefly *Fomes connatus*.

Stone (1912) states that frost cracks are almost always found on the sunny side of the tree, generally toward the south. The direction of facing of 2729 frost cracks was noted. The average of all species indicates a distinctly greater number facing the southerly and southwesterly directions. (Figure 107). Many trees, 6.3 percent of all, had several frost cracks listed as facing in "all directions" and these were eliminated from the direction count. Some frost cracks are found in each compass direction but the greatest number face the south, west and north. The afternoon winter sun strikes the bole and warms the trunk most on the south, southwest and west sides of the tree. This is followed by rapid cooling at night and, since the widest temperature changes occur on the southerly side of

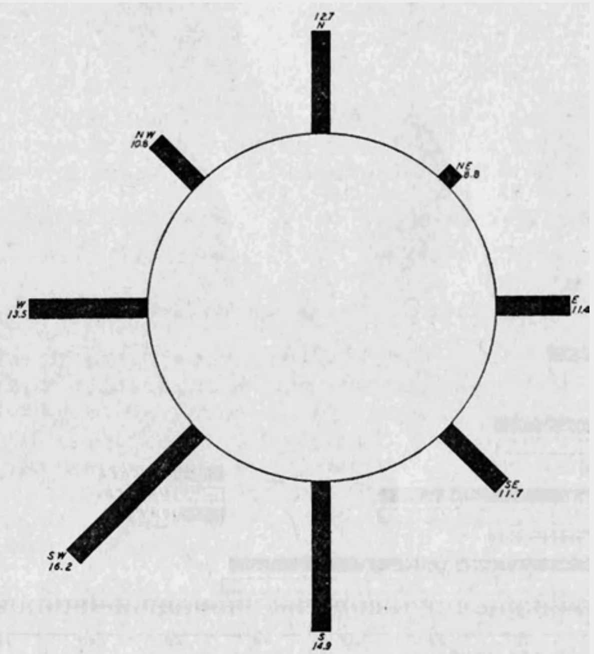

FIGURE 107. Direction of facing of frost cracks. Number of cracks (in percent) facing the eight compass directions indicated.

the tree, the largest number of frost cracks are found on that side. The large number found on the north side may be partly due to the tendency of the observer to read north, east, south and west more frequently than the in-between directions, or they may be partly due to cold winds from the north cooling off that side of the tree very rapidly.

The irregular character of the forest with its various slopes, exposures, holes in the canopy and chances for reflected heat probably accounts for the fact that many of the cracks are on the northerly, easterly and northwesterly sides of the tree. Stone's (1912) observation that frost cracks are almost always found on the sunny side of the tree indicates he probably observed only open grown shade trees since he also says elm is particularly susceptible to cracking, a fact not substantiated by our observations.

Each of the four forests had the greatest number of cracks to the south or southwest. The different species groups also favor these directions except the birches, which have the largest number of cracks facing the north followed by the east, the west and the south.

The relation between number of trees with frost cracks and the exposure of the plots on which they grew was determined for 799 trees on the Tunxis Forest. There was no relationship; that is, there were no more frost cracked trees on plots facing the south and southwest than on plots facing in any other direction. Probably many other factors enter in to obscure any effect of exposure on number of cracks.

TOP DAMAGE

Breakage within the crowns of the trees examined was usually due to glaze or sleet storms although logging injury was also present. Most of this damage occurred on the Tunxis Forest where a severe glaze storm on November 26-29, 1921, occurred. This storm broke the tops out of mand trees. The species most frequently damaged were in general weak-woodey or slender-twigged species. Damage by top breakage averaged 1.6 percent for all species examined. Those most frequently damaged were:

SPECIES	Percent damaged	SPECIES	Percent damaged
Black ash	11.1	Beech	2.7
Basswood	4.4	Sugar maple	2.4
Elm	3.9	White birch	2.0
Hemlock	3.6	White ash	1.7
Red maple	3.4	Black birch	1.4
Hop hornbeam	3.4	Butternut	1.4
Yellow birch	3.0	Striped maple	1.1
Black cherry	2.9		

The oaks were less frequently damaged:

SPECIES	Percent damaged	SPECIES	Percent damaged
Red oak	0.6	Hickory	0.4
Tulip	0.6	Sassafras	0.2
Chestnut oak	0.5	Dogwood	0.2
Gray birch	0.5	Scarlet oak	0.2
Aspen	0.5	White oak	0.1
Pepperidge	0.4	Black oak	0.1
White pine	0.4		

In general, this agrees with the results of Downs (1938) except for hemlock which he lists as resistant to breakage. It is likely that much of the breakage observed in hemlock on the Tunxis was due to injury received during logging off of the overstory.

A different type of injury characterized by a dying of the tops occurred in 0.3 percent of the trees examined. Much of this was probably caused by drought. The oaks were most frequently affected. This dieback in oaks was previously studied by the junior author and found occurring on oaks in Connecticut hardwood stands. Other species such as black ash, butternut, basswood, sugar maple, black birch, white ash, black cherry and beech were found to have a small amount of dying back of the tops. Black ash often dies back under Connecticut conditions.

MECHANICAL INJURIES

Injuries brought about through logging operations, rubbing of one tree against another; falling trees or other mechanical causes have been grouped under the heading of mechanical injuries. They affect 1.7 percent of the trees examined. They afford a means of entrance for decay organisms. The weak-wooded, thin-barked species tend to be more frequently affected than other species. Those most frequently injured were:

Basswood	5.1 percent	Beech	2.3 percent
White pine	2.9 percent	Black birch	1.9 percent
Red maple	2.8 percent	White birch	1.7 percent

Those less frequently injured were:

Chestnut oak	0.6 percent	White oak	1.1 percent
Black oak	0.7 percent	Scarlet oak	1.3 percent
Red oak	0.8 percent	Hemlock	0.9 percent

MISCELLANEOUS LESIONS

On many trees in the forest there are small oval lesions where the bark has died and the dry, hard wood is exposed. They occur chiefly on the lower part of the bole. What causes them is not known, probably there is a variety of causes. They are present, nevertheless, in considerable numbers and since they all furnish a point of entrance for decay fungi they are a potential danger. The most striking fact was their wide universal distribution in all the forests sampled. Out of the 98,420 trees examined, 3,533 trees, or 3.6 percent, had one or more of these lesions. The second striking fact was that hickory and red maple were by far the most frequently affected, 11.0 and 8.7 percent respectively. This was true of each of the four forests. They were followed by:

Blue beech	6.8 percent	Striped maple	3.4 percent
Beech	3.7 percent	Red oak	3.1 percent
Scarlet oak	3.7 percent	Black oak	2.3 percent
Aspen	3.6 percent	Sugar maple	2.2 percent

BORER INJURY

Injury by borer was evident in several cases but was almost confined to red and sugar maple which made up 95 percent of the cases. Red maple had 4.4 percent of its number infested and sugar maple 0.8 percent. The average for all species was 1.0 percent. Decay, *Fomes connatus*, was in a few cases associated with maple borer injury.

FIRE SCARS

About 1.0 percent of the trees examined had evidence of fire scars at their base. This number may not represent the average amount of fire scarring in the forest, since burns on the State Forest are usually clear cut, shortly after the fire, and planted to conifers. Such areas were not sampled. Recent light burns which might not yet be cut were probably not sampled by the observer. However, since the areas mentioned are small in extent, the figure of 1.0 percent is probably but slightly below the true average. The figures as given do not necessarily represent the relative susceptibility of the various species. This is shown by the frequent scarring of the oaks, 1.3 percent, a much more resistant group than maples or birches. The generally drier character of the southern and eastern forests, where oak is abundant, probably accounts for the greater amount of fire scarring of the oaks. Relative susceptibility could be obtained only by comparing the various species under uniform conditions as to intensity and time of year of the burn.

The figures do, however, represent the conditions as they exist on the state forests at the present time.

The species most frequently fire scarred were:

SPECIES	Percent	SPECIES	Percent
Scarlet Oak	1.9 percent	Yellow Birch	1.0 percent
Aspen	1.4 percent	Sassafras	1.0 percent
Pepperidge	1.4 percent	Tulip	1.0 percent
Red Oak	1.3 percent	Black Birch	0.8 percent
Black Oak	1 3 percent	Hickory	0.8 percent
Red Maple	1.1 percent	Basswood	0.8 percent
White Oak	1.1 percent	Elm	0.8 percent
White Ash	1.1 percent	Shadbush	0.8 percent
Pitch Pine	1.1 percent	Chestnut Oak	0.6 percent
Gray Birch	1.0 percent	Sugar Maple	0.4 percent

The oaks were most frequently scarred, 1.3 percent, followed by:

Maples	1.0 percent	Birches	0.8 percent
	Softwoods	0.2 percent	

Most of the fire scars were from one to two feet in length and were nearly always located at the base of the tree.

DISCUSSION

The summation of all the diseases and defects encountered in the survey showed 22.1 percent of the trees affected, (Table XX). This figure included about 3 percent of duplication, where a tree had two or more defects and was listed under each. That is, an individual tree might have had Nectria canker and also a broken top. It would be listed under both headings. Deducting this amount of duplication we find that about 19 percent of the total tree population examined had one or more defects. This does not include such bole defects as lean, crook, branchiness or fork, which would raise the figure considerably. These defects, coupled with an abundance of poor species present in the stands, make the problem of picking an adequate number of crop trees per acre a difficult one.

The damage to the tree and to the stand varies with the different defects and must be borne in mind in judging their seriousness. The most abundant species in the forest are arranged in Table XXI according to the prevalence of each of eight different diseases and defects. Picking the five highest species in each defect, we find that red maple has a considerable number of the six defects listed: decay, frost cracks, top damage, mechanical injury, lesions and fire scars. Scarlet oak also has an abundance of the following six: Nectria, Strumella, decay, frost crack lesions and fire scars. Beech is next with four, and sassafras, aspen, black oak and red oak with three each. From the standpoint of diseases and defects **only**, we find that these species are undesirable, while white birch, white ash and sugar maple are comparatively free of defects. Keeping in mind the varying seriousness of the different defects, a general idea of the relative value of the different species can be obtained.

TABLE XX. SUMMARY OF DISEASES AND DEFECTS.

Disease or Defect	Number of Trees Defective	Percent
Nectria canker	5721	5.8
Miscellaneous Lesion	3533	3.6
Decay	3063	3.1
Frost Crack	2522	2.8
Top Damage	1921	2.0
Mechanical Injury	1684	1.7
Borer Injury	963	1.0
Fire Scar	935	1.0
Strumella Canker	215	0.2
Miscellaneous	1170	1.2
Total	21,727	22.1

Many factors determine the value of a species in forestry, chiefly the utility of its wood and its reproductive ability. One of these factors is its susceptibility to diseases and defects. Table XXI helps to evaluate the principal species in Connecticut forests from the standpoint of this factor.

TABLE XXI. SUMMARY OF DISEASES AND DEFECTS OF THE MOST ABUNDANT TREE SPECIES

SPECIES	Number Trees	Percent of Stand	DISEASES AND DEFECTS (percent)							
			Nectria Canker	Strumella Canker	Decay	Frost Cracks	Top Damage	Mechanical Injuries	Lesions Misc.	Fire Scars
Red Maple	20309	20.6	5.7	0.05	5.6	3.9	3.6	2.8	8.7	1.1
White Oak	12099	12.3	1.2	0.3	2.5	3.3	0.9	1.1	1.2	1.1
Red Oak	8277	8.4	2.3	0.7	1.5	3.6	1.2	0.8	3.1	1.3
Black Birch	6938	7.4	15.4	....	2.1	1.5	1.8	1.9	0.6	0.8
Scarlet Oak	5677	5.7	9.6	0.9	3.8	5.9	0.6	1.3	3.7	1.9
Gray Birch	5066	5.1	13.3	....	1.3	0.3	0.5	1.2	1.1	1.0
Hemlock	4844	4.9	...	....	0.1	2.5	3.7	0.9	0.02	0.2
Hickory	4649	4.7	2.7	0.2	3.5	1.6	0.7	1.2	11.1	0.8
Yellow Birch	4117	4.2	8.6	....	2.7	1.3	3.3	1.1	0.5	1.0
Beech	3670	3.7	0.8	0.08	5.9	2.1	3.1	2.3	3.7	0.2
Sugar Maple	3056	3.1	5.6	....	2.5	1.8	2.8	1.1	2.2	0.4
White Ash	2781	2.8	1.1	....	3.2	0.8	2.1	1.3	1.0	1.1
Chestnut Oak	2558	2.6	0.2	0.4	2.0	1.5	0.7	0.6	0.5	0.6
Black Oak	2337	2.4	9.1	1.5	3.1	4.8	0.5	0.7	2.3	1.3
White Birch	1738	1.8	8.3	....	1.3	3.3	2.2	1 7	0.6	...
Aspen	1236	1.2	6.1	....	1.6	1.9	0.7	3.4	3.6	1.4
Black Cherry	1158	1.2	10.3	....	0.4	0.5	3.3	1.5	2.0	0.1
Sassafras	1114	1.1	31.6	....	4.0	1.1	0.4	2.4	1.0	1.0

SUMMARY

1. A field survey of diseases and defects in Connecticut forests was made from 1934 to 1936. The survey covered twelve forests, four of them intensively.

2. Tenth-acre plots were laid out in practically all forest types and age classes in the proportion in which they existed in the forests examined.

3. Nearly 14,000 acres of forest were sampled with 1256 plots, one plot for each 11 acres. Over 98,000 trees were examined.

4. An average of 784 trees, one inch D.B.H. and over, was found per acre of forest with an average D.B.H. of 4.4 inches, and an average basal area of 81.1 square feet per acre.

5. On the basis of basal area, red maple, red oak, hemlock, white oak and scarlet oak were the most abundant species. About 50 percent of the basal area of all species was in trees eight inches and over D.B.H.

6. On the basis of number of stems, red maple, white oak, red oak, black birch and scarlet oak were the most abundant species.

7. The oaks formed 32 percent, maples 24 percent, birches 18 percent and softwoods 7 percent of the number of stems present in the four forests.

8. The northern forest (Tunxis) was heavy in maple, hemlock, birch and beech while the southern forests (Meshomasic, Cockaponset and Pachaug) were heavy in oaks and hickories.

9. The percent frequency distribution of red maple was highest, this species appearing on 91 percent of the plots; red oak 71 percent, white oak 67 percent; black birch 65 percent and hickory 47 percent.

10. Cankers caused by *Nectria* spp. were the most abundant defect encountered. They occurred on 5.8 percent of all trees examined. Pepperidge 21.9 percent, black birch 15.4 percent, sassafras 13.6 percent, gray birch 13.3 percent and black cherry 10.3 percent were the species most frequently cankered.

11. Birches were most frequently Nectria-cankered, 12.5 percent, in the order black, gray, yellow and white. Maples were less frequently cankered, 6.1 percent, in the order mountain, striped, red and sugar. Oaks were least infected, 3.6 percent, in the order scarlet, black, red, white, scrub, chestnut and pin.

12. Several weed species, such as mountain maple, 58.8 percent, dogwood 47.9 percent and striped maple 27.6 percent, were frequently infected with Nectria and may serve as a source of infection for more valuable species.

13. Red maple 1.2 percent and black birch 1.1 percent, because they are so abundant in the stand and are also rather heavily infected, were the most frequently encountered Nectria-cankered species in the forest. Out of every 100 cankered trees encountered, 20 would be red maple and 18 would be black birch.

14. Nectria cankered trees were **widely** and **generally** distributed throughout the forest but they were not **uniformly** distributed, being very abundant in some limited areas and very sparse in others.

15. Eighty percent of the lightly Nectria cankered plots contained 40 percent of the cankered trees, while 2.4 percent of the heavily infected plots contained 14.8 percent of the cankered trees.

16. Most of the Nectria cankers were located low on the bole of the tree. In the oaks 97 percent, in the maples 86 percent and in the birches 51 percent were located within eight feet of the ground.

17. Nectria cankers seem to start early in the life of the tree except in the birches where their location at high levels also indicates infection later in the life of the tree.

18. Nectria cankers on the branches occurred on only 4.8 percent of the trees which were cankered. They were most abundant on the same species on which cankers appeared most frequently: black birch, pepperidge and yellow, white and gray birch.

19. The number of individual Nectria cankers per tree averaged 2.9 for all species. The birches had the greatest number per tree, 3.9, followed by maples, 2.2 and oaks, 2.0.

20. The maples and oaks showed a greater number of trees having one to two Nectria cankers than birches; while birches showed a greater number of trees with three to many cankers than maples or oaks.

21. There is a decrease in the number of Nectria cankers per tree with increased diameter and in the upper crown classes in the case of maples and oaks. The reverse is true in the case of birches.

22. Eighty-four percent of the Nectria cankers examined were not fruiting at all; 5 percent were fruiting sparsely, and 11 percent abundantly. An increased fruiting was noticed in the spring but not in the fall.

23. Many Nectria cankers were associated with old branch stubs as a possible avenue of entrance while others were associated with borer injury, frost cracks, rubs and mechanical injuries. The avenue of entrance could not be determined in many cases.

24. The number of dead trees on which there were Nectria cankers indicated that, in birches particularly, Nectria may be the cause of death. More large sized dead birch trees with cankers on them were found than either maples or oaks. Oaks seem often to be killed by Nectria cankers when young; maples seem to be able to outgrow the disease while birches often die from Nectria canker attacks.

25. Sixty-five percent of the Nectria infected trees were under 25 years old. A greater number of older birches were cankered than either older oaks or older maples.

26. Birches and oaks show a greater amount of Nectria cankering with increased diameter, whereas maples show a lesser amount.

27. Birches and oaks show a greater amount of Nectria cankering in the higher crown classes, whereas maples show a lesser amount.

28. Origin of the tree, whether sprout or seedling, had no effect on the amount of Nectria canker.

29. The hardwood swamp type had the greatest percentage of trees with Nectria cankers followed by the mixed hardwood type, old field type and the softwood-hardwood and softwood types.

30. There was a slight decrease in the amount of Nectria infection with increased density of the crown canopy.

31. There was no relation between amount of Nectria infection and the age of the stand.

32. There was no relation between Nectria cankering and plot exposure.

33. In the case of seven species examined there was a greater amount of Nectria infection on poor sites than on good. This was particularly pronounced in the birches.

34. Comparing the species groups, birches made up the smallest percentage of the total population but the largest percentage of the species Nectria-cankered, and also of the total population cankered. Oaks were just the opposite, making up most of the stand but the least of the species Nectria cankered and of the total population cankered. Maples were intermediate between birches and oaks.

35. Cankers caused by *Strumella coryneoidea* affect 0.2 percent of the total tree population and 0.6 percent of all oaks examined. The oaks ranked in the order of decreasing infection: black, scarlet, scrub, red, chestnut and white.

36. Sixty-nine percent of the Strumella cankers were located within eight feet of the ground.

37. Strumella cankers ranged from one to eight feet in length, the weighted average length being 1.8 feet.

38. The larger trees were more frequently infected with Strumella cankers than the smaller trees. There was no difference in the amount of infection between the upper and lower crown classes however.

39. Decay was found in 3.1 percent of the living trees examined. The maples showed the greatest number of stems with decay, 5.2 percent, followed by oaks, 2.5 percent, birches 1.9 percent, and softwoods, 0.5 percent.

40. Pepperidge, 12.9 percent, beech 5.9 percent, red maple 5.6 percent, and sassafras 4.0 percent are particularly subject to decay.

41. *Fomes connatus* was the most frequently encountered fruiting decay attacking chiefly red maple.

42. There was an increase in percentage of trees decayed with increase in diameter.

43. Most of the decay was close to the ground, 77 percent occurring within eight feet of the ground in the case of the larger trees, eight inches D.B.H. and over.

44. The cull due to visible decay was, 4 percent of the small tree population and .6 percent of the large tree population.

45. Frost cracks were found on 2.8 percent of the trees examined. Oaks had the largest number (percent) of trees with frost cracks but had the shortest cracks. Birches had the smallest number (percent) with frost cracks but the cracks were longest. The average length of frost cracks was 2.7 feet.

46. The larger trees and those in the upper crown classes were more frequently frost-cracked than the smaller, lower crown class trees.

47. Over 80 percent of the frost cracks are located within eight feet of the ground.

48. The greatest number of the frost cracks were found on the south and southwest sides of the trees.

49. Top damage, due to ice storms, was present in 1.6 percent of the population. The species are listed in the order of frequency of top damage. Die-back due to drought was also encountered.

50. Mechanical injuries due to logging operations and other causes occurred on 1.7 percent of the stand.

51. Lesions, borer injury and fire scars were encountered in varying numbers.

52. Red maple, scarlet oak and beech are subject to many different defects while white birch, white ash and sugar maple are relatively free from defects.

53. About 19 percent of the trees in the average forest had one or more defects or diseases.

Common and Scientific Names of Trees Encountered in the Disease Survey

COMMON NAMES	SCIENTIFIC NAMES
Alder	—*Alnus incana*
Apple	—*Pyrus malus*
Ash, Black	—*Fraxinus nigra*
Ash, White	—*Fraxinus americana*
Aspen	—*Populus grandidentata* and *P. tremuloides*
Basswood	—*Tilia glabra*
Beech	—*Fagus grandifolia*
Beech, Blue	—*Carpinus caroliniana*
Birch, Black	—*Betula lenta*
Birch, Gray	—*Betula populifolia*
Birch, White	—*Betula papyrifera*
Birch, Yellow	—*Betula lutea*
Black Walnut	—*Juglans nigra*
Butternut	—*Juglans cinerea*
Cedar, Red	—*Juniperus virginiana*
Cedar, White (Southern)	—*Chamaecyparis thyoides*
Cherry, Black	—*Prunus serotina*
Cherry, Pin	—*Prunus pennsylvanica*
Dogwood	—*Cornus florida*
Elm	—*Ulmus americana* and *U. fulva*
Hemlock	—*Tsuga canadensis*
Hickory	—*Carya* spp.
Hop Hornbeam	—*Ostrya virginiana*
Maple, Mountain	—*Acer spicatum*
Maple, Red	—*Acer rubrum*
Maple, Striped	—*Acer pennsylvanicum*
Maple, Sugar	—*Acer saccharum*
Oak, Black	—*Quercus velutina*
Oak, Chestnut	—*Quercus montana*
Oak, Pin	—*Quercus palustris*
Oak, Red	—*Quercus borealis*
Oak, Scarlet	—*Quercus coccinea*
Oak, Scrub	—*Quercus ilicifolia*
Oak, White	—*Quercus alba*
Pepperidge	—*Nyssa sylvatica*
Pine, Pitch	—*Pinus rigida*
Pine, White	—*Pinus strobus*
Sassafras	—*Sassafras officinale*
Shadbush	—*Amelanchier* spp.
Spruce	—*Picea* spp.
Sumac	—*Rhus* spp.
Sycamore	—*Plantanus occidentalis*
Tulip	—*Liriodendron tulipifera*
Willow	—*Salix* spp.
Witch Hazel	—*Hamamelis virginiana*

The authority for these names is according to Sargent's "Manual of the Trees of North America,", 2nd edition, 1921 and Gray's "New Manual of Botany," 7th edition, 1908.

LITERATURE

Abell, C. A. Influence of glaze storms upon hardwood forests in the southern Appalachians. Jour. Forestry, **32**:35-37. 1934.

Andrews, S. R. The incidence of Nectria canker in the sugar maple-beech-yellow birch type near Kane, Pennsylvania. Thesis in Library Yale School of Forestry, New Haven, Conn. 1935.

Anon. Information on Nectria canker disease in relation to stand improvement. Div. Forest Path., U. S. Bur. Plant Indus. Mimeo. February 16, 1935.

Anon. Information on Strumella canker disease in relation to stand improvement. Div. Forest Path., U. S. Bur. Plant Indus. Mimeo. February 18, 1935.

Bidwell, C. B. and Bramble, W. C. The Strumella disease in southern Connecticut. Jour. Forestry, **32**:15-23. 1934.

Boyce, J. S. Forest pathology. 600 pages. McGraw Hill Book Co., Inc., New York. 1938.

Busse, J. Frost-, Ring- und Kernrisse. Forstwiss. Centbl. **32**:74-84, 1910. Rev. in For. Quart. **8**:239-240. 1910.

Cline, A. C. Forest weeding with special reference to young natural stands in central New England. Mass. Forestry Assoc., Boston, Mass. 1929.

Downs, A. A. Glaze damage in the birch-beech-maple-hemlock type of Pennsylvania and New York. Jour. Forestry **36**:63-70. 1938.

Forest disease control in New England. Committee Report, New England Section, Soc. Amer. Foresters. Jour. Forestry, **33**:469-473. 1935.

Grant, T. J. Nectria cankers on Northeastern hardwoods. U. S. Dept. Agr., Bur. Plant Indus. Mimeo. May 11, 1936.

Grant, T. J. Reduction of Nectria canker in hardwood forests of the Northeast. Northeastern Forest Exp. Sta. Occasional paper No. 6. 1937.

Hawes, A. F. The present condition of Connecticut Forests, a neglected resource. pp. 1-78. Published by the State Forester, Hartford, Connecticut. 1933.

Hepting, G. H. Eastern forest tree diseases in relation to stand improvement. Emergency Conservation Work, Forestry Publication **2**:1-28. Revised 1934.

Hough, A. J. Why timber stand improvement? Jour. Forestry **35**:813-822. 1937

Jensen, J. S. Suggestions for weeding in northern hardwoods. Northeastern Forest Exp. Sta. Occasional paper No. 3. Mimeo. 1935.

Limstrom, G. A. and Kuenzel, J. G. Factors affecting the extent of defect in certain upland hardwoods on the Clark Purchase Unit in Missouri. Preliminary report. U. S. Forest Service. Mimeo. March 1937.

Spaulding, Perley. Nectria canker of hardwoods in New England. Tree pest leaflets No. 10. Mass. Forest and Park Assoc. October 1936.

Spaulding' Perley; Grant, T. J. and Ayers, T. T. Investigations of Nectria diseases in hardwoods of New England. Jour. Forestry, **34**:169-179. 1936.

Stickel, R. W. and Marco, H. F. Forest fire damage studies in the northeast. III. Relation between fire injury and fungal infection. Jour. Forestry **34**:420-423. 1936.

Stone, G. E. Frost cracks. Twenty-fourth annual report. Mass. Exp. Sta., 110-114. 1912.

Welch D. S. The range and importance of Nectria canker on hardwoods in the Northeast. Jour. Forestry, **32**:997-1002. 1934.