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A History of Forest Pathology Research in the South and Southeast

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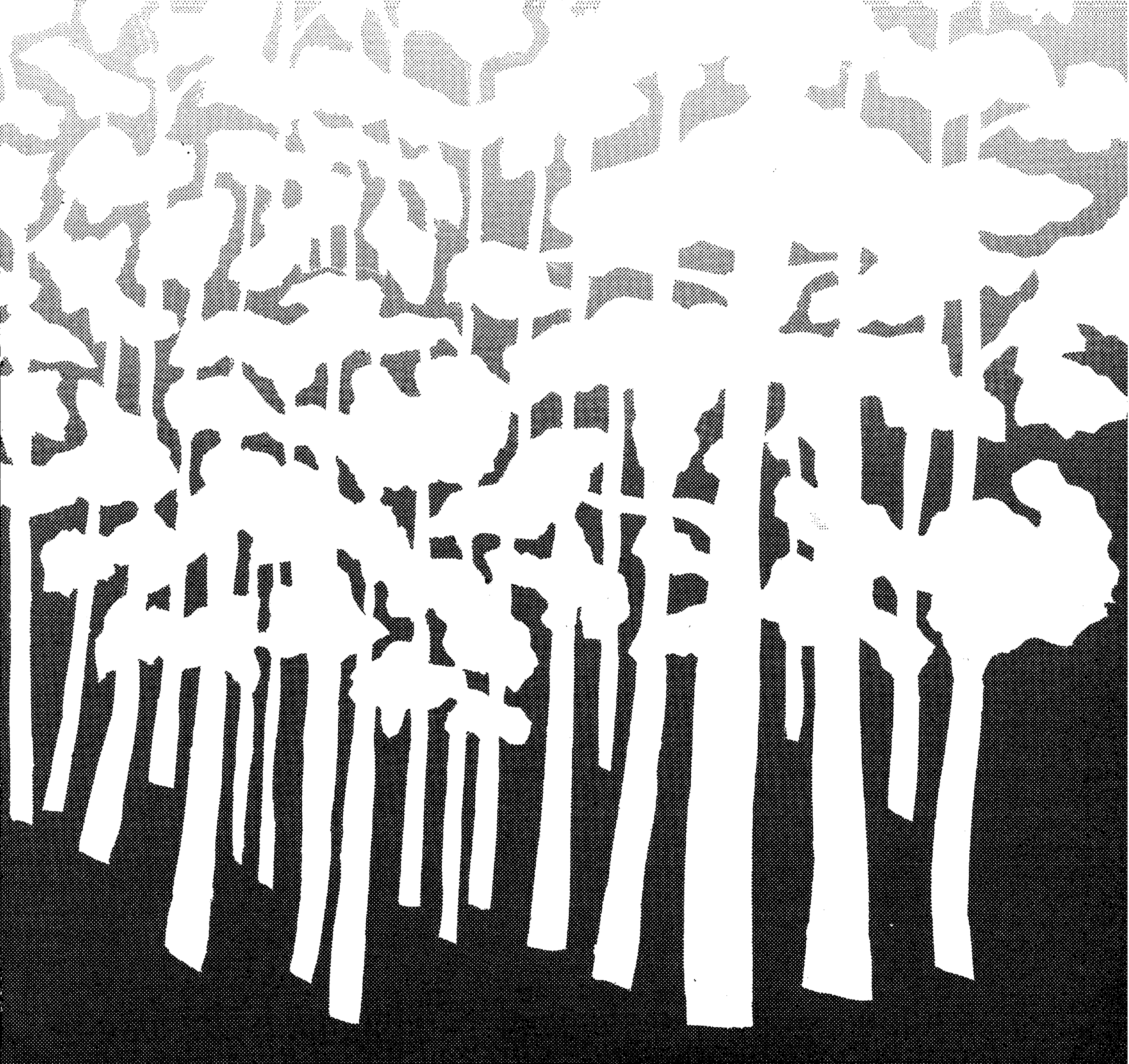

A HISTORY OF FOREST PATHOLOGY RESEARCH
IN THE SOUTH AND SOUTHEAST

by

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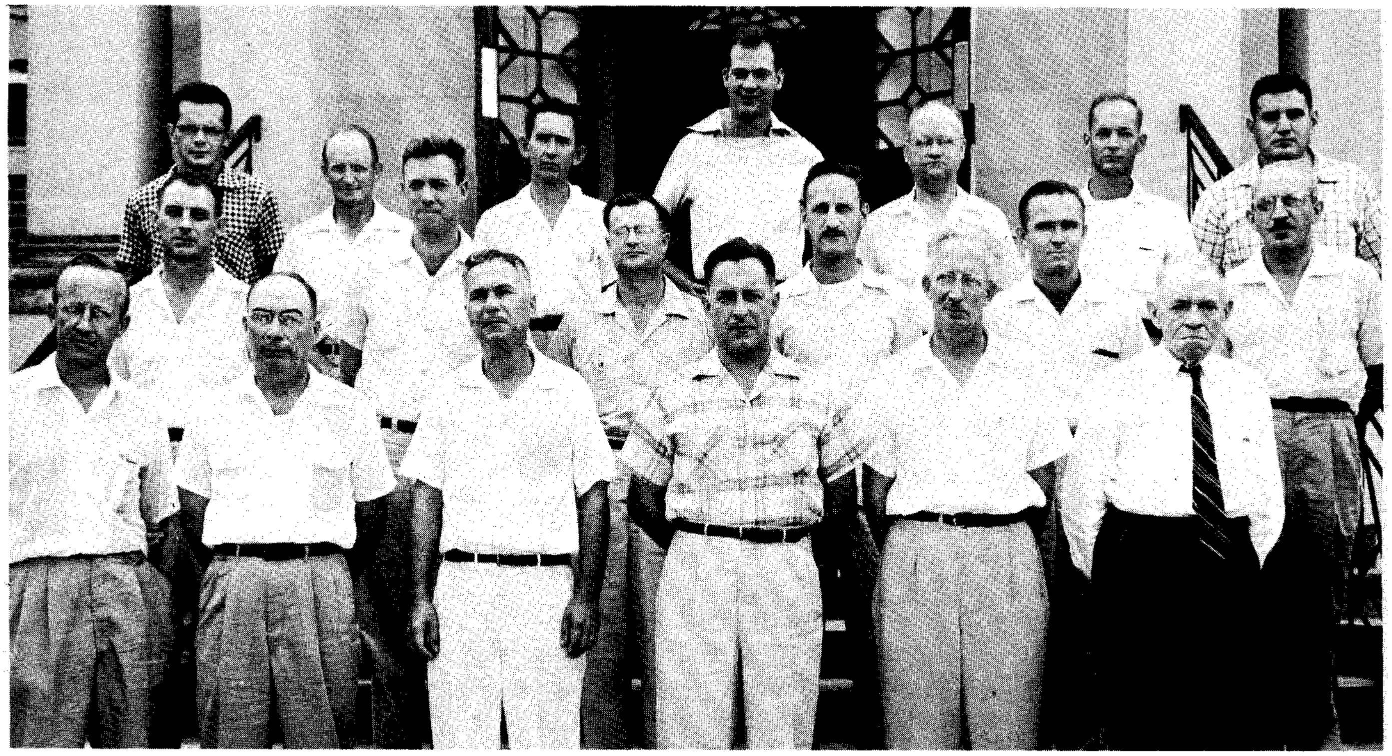

Forest Pathology Work Conference, Athens, Ga. About 1956

Front row left to right--A.A. Foster, A.F. Verrall, G.H. Hepting, B. Henry, W.A. Campbell, Julian Miller.
Back rows--Stegall, Snyder, E.R. Roth, J.S. Boyce, R.G. McAlpine, E.R. Toole, F. Cobb, B. Zak, L.W.R. Jackson, W.C. Bryan, R. Harrison, G. Thompson, M. Reines.

PREFACE

The development of forest disease research in the South and Southeast and what this research accomplished are recorded in many journal and government publications and in many unpublished reports. Also, much detail about the people doing the research and where and under what conditions it was done exist only in the minds of those involved. This history brings together much of this informaton, particularly for the use of pathologists now engaged in research.

In writing this history, I depended partly on my recollections from 45 years' association with forestry in the South and Southeast and partly on the memories of many of the living pathologists who worked in the South and Southeast. Much information was secured from the Forest Experiment Stations' annual reports and published and unpublished reports. George H. Hepting was particularly helpful in furnishing details about the Southeastern Forest Experiment Station. Also, I drew freely from his "Forest pathology in the Southern Appalachians, 1900-1940" (Hepting 1964). P. C. Wakeley's "A biased history of the Southern Station," which is in typed form only, provided much information on the early work in pathology at the Southern Forest Experiment Station.

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THE SOUTHERN FOREST EXPERIMENT STATION

Before the Southern Forest Experiment Station was established in 1921, forest pathology in the South and Southeast consisted mainly of mycological studies by local, State, and itinerant Federal pathologists. These scientists described a number of forest tree diseases such as brown spot needle blight of longleaf pine and pine rusts. One Federal pathologist, W. H. Long (Office of Investigations in Forest Pathology, Bureau of Plant Industry), conducted field trials on rotting of logging slash in the Ozark National Forest during World War I (Long, 1917). These early pathologists also studied the advance of chestnut blight and white pine blister rust into the Southeast. But there was very little information on the disease picture in southern forests, on the impact of disease on yields, or on possible control measures. So, the South was a research pathologist's paradise in the 1920's and 1930's.

When forest management started in the 1920's, even though only a small portion of the total forest land in the South was involved, foresters and lumbermen began calling for practical control measures --particularly for the control of brown spot in longleaf pine nurseries and sapstain in seasoning lumber. Practical field studies were the logical approach to satisfy this demand, and, as a result, the first 2 1/2 decades of forest pathology research at the Southern Station consisted largely of field studies. The makeshift laboratory space available was used mainly for culturing and microscopic examination of diseased material to determine causal organisms. However, a surprising amount of fundamental information came from these field studies and crude laboratory facilities.

In 1951 the products pathology project got a modern culture laboratory at the Harrison Experimental Forest near Saucier, Miss. In 1961, the tree disease projects got up-to-date laboratory space when the Gulfport, Miss., Forest Sciences and the Stoneville, Miss., Research Center facilities were completed. With gas chromatography and other sophisticated procedures provided, more basic research became feasible on the factors influencing infection, disease development, and the biology of pathogens. This information was needed to refine disease prevention and control measures. At the same time, adequate greenhouse space was provided. However, field trials remained an important tool in establishing the practicality of prevention and control measures and in proving the soundness of many basic concepts established in the laboratory or greenhouse.

Before 1953, the pathologists assigned to the Southern Station were in the Division of Forest Pathology of the Bureau of Plant Industry (BPI) with headquarters in Beltsville, Maryland. The

Bureau was reorganized in 1945 to include Soils and Agricultural Engineering, but I will use the shorter name here. Both tree disease and product pathologists were stationed in New Orleans, La., until World War II when they were transferred to Gulfport, Miss. (products), and nearby Harrison Experimental Forest (pine diseases). Pathologists had been stationed temporarily at Bogalusa, La. (brown spot), and the W. W. Ashe Nursery, Brooklyn, Miss. (nursery diseases). Pathologists of the bottomland hardwood project have all been stationed at Stoneville, Miss., since the project was established in 1952.

Under the Bureau of Plant Industry, the three projects (hardwood diseases, pine diseases, and products pathology) each reported directly to the Beltsville office.

The Beltsville pathologists were familiar with each study of each project; they gave continuous, overall technical supervision, and edited all manuscripts for technical accuracy. This relieved field personnel of almost all administrative duties and resulted in a high research output for each pathologist and a cohesive Nationwide forest disease organization. The only variation in this structure at the Southern Station was from 1947 to 1950 when R. M. Lindgren was transferred from Beltsville to New Orleans where he acted essentially as a division chief, and from 1950 to 1953 when George Hepting supervised the program from Asheville. But direct contacts between the projects and the Beltsville office continued.

After forest pathology was transferred from the Bureau of Plant Industry to the Forest Service in 1953, the Southern Station pathologists were placed in the Division of Forest Management until 1956 when the Division of Forest Disease Research was established with A. F. Verrall as Division Chief. He remained Chief until the Assistant Directorships were established in 1964. As long as Berch Henry was Assistant Director for Diseases, Insects, and Genetics, the three pathology projects received technical coordination from a qualified forest pathologist, but after the Assistant Directorships were assigned on a geographical rather than functional basis, close, continuous technical supervision stopped at the Project Leader. The two pathology projects are now under different Assistant Directors.

When work on brown spot dominated the tree disease research program, the Southern Station's territory included Georgia and Florida as well as Alabama and the other states westward into eastern Texas and eastern Oklahoma. In 1964 Georgia and Florida were transferred to the Southeastern Station and Tennessee to the Southern Station. The Products Pathology Project, however, never was restricted by Station boundaries because, by Washington Office directive, the Southern Station handled most field studies in the southern and southeastern States while the Forest Products Laboratory, Madison, Wis., handled studies for the rest of the country. Often the two units had joint studies covering the entire country and even extending into Central America and the Pacific Islands.

Pine Diseases

Personnel

Paul V. Siggers (Associate Pathologist, BPI) started the pine disease research project in 1928 and remained in charge until his retirement in 1952. The only break was in 1935 when he took 6 months educational leave to complete his doctorate at the University of Minnesota. Siggers was a congenial, quiet man of few words, but a dedicated scientist and a keen observer. He had several temporary field assistants, including F. G. Liming, W. C. Bramble, L. D. Glenn, C. M. Christensen, and A. F. Verrall.

Howard Lamb (Junior Pathologist on Civilian Conservation Corps (CCC) funds) joined Siggers in June 1934. He spent the first few years mainly on hardwood tree problems, but after 1937, helped on the fusiform rust study until his transfer to Columbus, Ohio, in March 1940.

Bailey Sleeth (Assistant Pathologist on CCC funds) helped with the fusiform rust problem from May 1938 to August 1941. Sleeth later joined the Texas Agricultural Experiment Station in the Rio Grande Valley.

R. M. Lindgren (see also Products Pathology) was in New Orleans from 1928 to 1931 and returned in 1947 to work mainly on products studies, but he also helped with the fusiform rust and black root rot studies. He transferred to the Forest Products Laboratory in 1950.

Berch W. Henry (Plant Pathologist) was assigned to the black root rot study at the W. W. Ashe Nursery (Brooklyn, Miss.) in 1948. On Siggers' retirement, Henry assumed leadership of the pine disease project at the Harrison Experimental Forest until 1954 when he became Officer-In-Charge of the Southern Forest Genetics Institute and, in 1964, Assistant Director for Insects, Diseases, and Genetics until his retirement in 1973.

R. P. True (Plant Pathologist) transferred from Morristown, New Jersey, to the Olustee, Florida, Naval Stores Station of the Bureau of Agricultural and Industrial Chemistry in July 1942 to assist the Southern Station with its naval stores project. In January 1949, he went to West Virginia University as Professor of Forest Pathology. His stay at Olustee straddled the transfer of the naval stores project from the Southern to the Southeastern Station.

Paul C. Lightle (Plant Pathologist) directed the pine disease project from 1956 to 1959, after which he transferred to the Rocky Mountain Forest Experiment Station at Albuquerque, New Mexico.

Felix J. Czabator (Plant Pathologist) transferred from the Division of Forest Management Research to Forest Disease Research in 1958 and remained until his retirement in 1977. From August 1960 to February 1961 he was in Yugoslavia under contract with the International Cooperative Administration of the State Department, serving as an advisor on nursery problems. At Gulfport his work was mainly on nursery and rust problems. He was in charge of the pine disease research from 1961 to 1969.

Frederick F. Jewell (Plant Pathologist) was assigned to the Genetics Institute in 1955 and helped with the pathology phases of resistance of pines to rust. In 1966 he resigned to accept a professorship in forest pathology at Louisiana Tech University but continues to cooperate with the Genetics Institute.

Glenn A. Snow (Plant Pathologist) arrived in 1957 and has worked on both brown spot and fusiform rust. He became Project Leader in 1970. His present research is mainly on fusiform rust.

Ronald C. Froelich (Plant Pathologist) joined the project in 1961. He worked mainly on annosus root rot at first but later on fusiform rust.

Albert G. Kais (Plant Pathologist) was assigned to the Project in 1962 and has worked on brown spot and fusiform rust. He is currently working on the brown spot disease.

Charles H. Walkinshaw (Plant Pathologist) worked with the pine disease project from 1962 to 1965, studying tissue culture of *Cronartium fusiforme* and the chemistry of spore germination. For the next few years he was Assistant Professor of Microbiology at the University of Mississippi Medical School but continued to cooperate with the Gulfport group. He returned to the Southern Station in 1968 and was assigned to NASA's Lunar Receiving Laboratory in Texas where he continued some work on fusiform rust. He returned to Gulfport in 1973.

Snow, Froelich, Kais, and Walkinshaw currently are assigned to the pine disease project.

Brown Spot Research Before 1928

Brown spot was described in the 1870's but was not recognized as a major problem until forest fire control became general in the South. Prescribed grass fires remained a common field control method; and before about 1915, intentional or accidental fires annually burned much of the longleaf pine area and presumably kept brown spot within bounds. The first observational research of practical value was by H. H. Chapman (1926), a professor at Yale, who suggested that woods fires controlled brown spot.

In 1928, P. C. Wakeley (Silviculturist at the Southern Station), to check Chapman's contention, established a series of plots near Bogalusa, La., on a severe burn that covered a square mile. In a short time the brown spot fungus was reestablished over the entire burn. But seedlings on the burned area started height growth 3 years earlier than those on adjacent unburned areas--Chapman was right.

Carl Hartley (Division of Forest Pathology Research, Washington Office) advised Wakeley to establish more unburned control plots and to try fungicidal control with Bordeaux mixture and lime sulfur. Wakeley had the Great Southern Lumber Company, Bogalusa, La,, spray a series of plots. These studies on brown spot started formal forest disease research in the South and resulted in the assignment of Paul V. Siggers to the Southern Station to start a tree disease research project.

Brown Spot Research, 1928-1952

Siggers took over Wakeley's spraying studies and expanded them to include not only seedlngs in nurseries, but also natural regeneration and plantations. Bordeaux mixture controlled brown spot so well that Bordeaux spraying soon became a standard practice in longleaf pine nurseries.

Most of Siggers' work on brown spot was done by himself or with the aid of temporary field assistants who seldom stayed more than 6 months. The only field assistant who published any results was A. F. Verrall, His two papers on brown spot showed that local disease intensification was mainly by spore dissemination by rain splash, and that temperatures sufficient to kill needles also kill the fungus in them (Verrall 1936) and that resistance of saplings and certain seedlings of longleaf pine is associated with high levels of resin production (Verrall 1934). These studies, of course, reflected Siggers' expert advise.

Research during this period included extensive surveys from South Carolina to Texas that established the hosts, geographic distribution, and economic importance of brown spot in the South. Other field and laboratory research included: resolving the taxonomy of the imperfect stage of the causal fungus and the discovery and naming of the perfect stage (Scirrhia acicola (Dearn.) Siggers); the effect of defoliation on seedlings; and the effect of soil fertilization on diseased seedlings. Economic controls were developed, including fungicidal spray schedules for nurseries and plantations and prescribed burning for natural regeneration.

These findings were made available to foresters in journal reports and Station publications. A complete summary was presented in a technical bulletin (Siggers 1944).

Siggers (1950) noted in cultures of S. acicola, germtube fusions, hyphal fusions, and the breakup of multicellular conidia at septa. He postulated that these might lead to genetic variations.

Brown Spot Research, 1953-1959

Little research on brown spot was done during this period. However, more commercial interest was being shown in longleaf regeneration, and the Alexandria Research Center had developed better planting techniques. So in 1959, 26 fungicidal spray schedules were tried in plantations and natural regeneration in Louisiana and Alabama. Bordeaux mixture proved more effective than ferbam for field use because of its greater persistence. One spray a year proved insufficient; two a year.(Spring and Fall as recommended by Siggers) were adequate; more frequent spraying was most effective but did not justify the added expense. These results were not published.

In constrast to Sigger's report, Berch Henry (1954) found both conidia and ascospores of _S. acicola_ were produced every month of the year.

Brown Spot Research Since 1959

Early in this period, aerial and mist-blower applications of cycloheximide derivatives and of Bordeaux mixture were tested in the field in Louisiana and South Carolina. Again, Bordeaux proved more effective because of its longer residual effect. Both aerial and mistblower applications proved satisfactory and practical. No results were published.

Kais (1964) found that cycloheximide semicarbazone in liquid cultures inhibited spore germination of S. acicola. The fungus revived, however, when transferred to a chemical-free medium. The cycloheximide derivatives gave adequate temporary control of brown spot but had little residual effect (Snow et al. 1964).

Kais (1971) confirmed Henry's report that both conidia and ascospores of S. acicola are discharged every month of the year. Spores were more numerous from May through August. Later Kais (1975a) used four new chemical sprays as well as Bordeaux on longleaf pine seedlings in the field. He recommended Chlorothalonil as an alternative to Bordeaux mixture.

Currently Kais' main research is on brown spot in relation to the breeding of resistant longleaf pines. He is studying the environmental and nutritional requirements of S. acicola needed to produce adequate amounts of spores for artificial inoculations (Kais 1975) and he also is studying methods for inoculation and incubation of seedlings (see Snow 1961). The latter is of particular importance in a program of screening longleaf for resistance because of the inconsistent results of previous workers.

Snow (1961) found that isolates of S. acicola varied widely in culture, but that these differences could not be correlated with pathogenicity, type of symptom, or time of symptom expression. Cultural characteristics also changed with repeated transfers of the fungus on agar. These findings may be explained by Siggers' observations (Siggers 1950).

Longleaf Pine Strains Resistant to Brown Spot

Siggers, Wakeley, and others familiar with longleaf pine regeneration noted that certain individual seedlings apparently were resistant to brown spot, because they remained healthy when close to severely infected seedlings.

In 1928, Wakeley rated 15 of 540 seedlings used in planting as brown-spot resistant, but little use was made of any resistant individuals for three decades; i.e., until Derr and Snyder started their studies of genetic resistance.

In 1937, Siggers found an essentially disease-free 2-year-old longleaf pine seedling in an abandoned nursery. This seedling (called Abe) was transplanted to the Palustris Experimental Forest near Alexandria, La. Harold J. Derr, Silviculturist at the Alexandria Research Center, found that Abe's progeny from wind- and artificial-pollination have a considerable degree of resistance to brown spot, indicating that the resistance is genetically controlled.

E. Bayne Snyder, Geneticist at the Gulfport Genetics Institute, cooperated with Derr and assumed full responsibility for resistance studies when Derr retired in 1976.

Abe and resistant individuals found by Wakeley in 1928 and by others since, gave the geneticists brown-spot resistant parents from Louisiana, Mississippi, Alabama, Georgia, and Florida. Open-pollinated resistant parents yield progeny with adequate resistance, and intercrosses between resistant parents yield highly resistant progeny. So, brown-spot resistant material is easily available with sufficient genetic variability to avoid the dangers inherent in monotypic populations.

Henry and Wells (1967) and others (see Snyder, et al. 1972) found that longleaf pine seed source influences susceptibility to S. acicola. In general, sources from the western part of the range of the longleaf are more susceptible than those from other areas where susceptibility is more variable.

Resistance studies were summarized by Snyder and Derr (1972).

Kais is now working with the geneticists on resistance studies. He is the first pathologist assigned to brown-spot resistance studies.

Wakeley kept very detailed notes on diseases in plantation management studies. He reported (Wakeley 1970) that at age 30 longleaf pine trees classed as lightly infected with brown spot at age 4 produced 1.7 to 2.4 times as much pulpwood as an equal number classed as moderately to heavily infected.

Fusiform Rust

Fusiform rust is one of the most destructive diseases of slash and loblolly pines, particularly on former longleaf pine sites. As long as the resistant longleaf pine predominated on these sites, fusiform rust was not important in forest management. But, with the clearcutting of longleaf stands, two factors made fusiform rust a serious threat: (1) Natural invasion and extensive planting of slash and loblolly pines replaced longleaf over much of its former range, and (2) general fire protection greatly increased the amount of the alternate host--oak--in southern pine forests. As a result, by 1937, fusiform rust was sufficiently prominent that Siggers changed his major research effort from brown spot to fusiform rust.

Fusiform Rust During the Siggers Period

To better evaluate the impact of fusiform rust on different pine species in different parts of the southern pine belt, Siggers, Lamb, and Sleeth extensively surveyed natural stands, plantations, and nurseries.

Nursery spray trials showed that Bordeaux mixture controlled rust in nurseries and observations indicated that pruning infected branches might decrease the number of destructive stem infections. In 1938 nurserymen were advised by mimeographed instructions and personal visits how to recognize infected seedlings so they could be culled during grading and how to spray to prevent infections. CCC camps were visited to acquaint crews with rust symptoms so that worthless infected trees could be removed in sanitation operations and that saplings with only branch infections could be saved by pruning.

Siggers and his assistants also started a comprehensive research program. Lindgren helped after 1947. Studies established:

1. The relative susceptibility of oak species.

2. That infected nursery stock seldom survived in outplantings.

3. Fungicidal spray schedules for nurseries.

4. Temperature requirements for germination of the 4 spore forms and that aeciospores and urediospores remain viable after several months storage at 10°C and for longer periods at 1 to 4°C.

5. The relationship of weather to infection.

6. From tests of slash pine strains from seed collected across the South and from western Cuba, that strains vary in susceptibility, but that geographic source by itself will not yield practical resistance.

7. That a single prescribed burn selectively kills stem-cankered trees and reduces the number of viable branch infections but makes stands more susceptible to future infections.

8. The effect of growth rhythm on the amount of infection. Pines that break dormancy early are most susceptible. Factors promoting early breaking of dormancy were found to be cultivation, soil fertilization, heavy pruning, and seed source.

9. From tests of seedlings whose parents had 0, 1, and 2+ infections and from seed source studies, that genetic resistance does occur but that freedom from rust in nature is a poor indication of resistance, apparently because disease escape complicates the picture.

10. From trials of the dithiocarbamates which became available by 1947, that the ferric form was superior to Bordeaux mixture for rust control in nurseries.

11. That density of planting importantly influences the number of stem infections because close planting promotes early natural pruning before many branch infections reach the stem.

12. That a pulpwood thinning, by opening the stand, greatly increases the number of future infections.

13. That mycelium extends no more than 1/2 inch from visible swellings on seedlings.

Siggers organized Hedgcock's (Beltsville Office) copious notes on the taxonomy, characteristics, hosts, and geographic ranges of the pine oak rusts (Hedgcock and Siggers 1949).

The research findings of Siggers, Lamb, Sleeth, and Lindgren were summarized by Siggers (1955). These findings certainly laid the groundwork for the research that followed.

Fusiform Rust, The Disease Resistance Period

Shortly after Siggers' retirement in 1952, the rust research turned strongly toward studies of genetic resistance for which the pine disease project and the Genetics Institute combined forces. Siggers' studies of geographic seed source and progeny of trees with 0, 1, and 2+ infections clearly showed that variation in susceptibility to fusiform rust exists within the species *Pinus elliotii* and *P. taeda* but the only evidence of practical resistance was in southern Florida slash pine (var. *densa*), which does not have the form and hardiness for commercial use in the longleaf pine belt. A massive screening program would be needed to find suitable rust-resistant strains of the southern pines.

Wakeley's geographic seed source studies indicated that with loblolly pine (unlike slash pine), susceptibility decreases from east to west. Wells (Physiologist, Southern Station) and Switzer (Professor of Forestry, Mississippi State University) found that loblolly from the Florida Parishes of Louisiana exhibits a practical degree of resistance to fusiform rust (Wells and Switzer 1971). The authors speculate that this resistance may exist because loblolly acquired shortleaf pine genes. This possibility is supported by Wakeley's report (Wakeley 1968) that longleaf pines at age 30 in his plantations, showing juvenile resistance to brown spot or showing early height growth, were significantly more susceptible to fusiform rust. Again, this suggests admixtures of genes from the rust-susceptible pine species.

Jewell and coworkers (1964) also showed that resistance is genetically controlled and that some nursery-infected seedlings formed reaction parenchyma and recovered (Jewell and Snow 1972), a process that might also be used in resistance studies.

One of the first needs in a screening program for resistance to fusiform rust was the development of inoculation techniques. Jewell (1960) described a simple system using telia-bearing oak leaves in a humidified tent. Snow and Kais (1972) perfected a system by which regulated amounts of inoculum could be blown onto specific parts of seedlings. This is the precise method needed for the finer research in genetic resistance. Later (see section on the Southeastern Station) a less precise method was developed for mass inoculation of large numbers of seedlings.

Eleuterius (Biological Technician, Gulfport, Miss.) studied the penetration, development, and sporulation of *Cronartium fusiforme* on water oak *Quercus nigra* (Eleuterius 1968). In some cases a hypersensitive reaction occurred so that no uredia and telia formed--only yellow spots on the leaves. So variation in susceptibility among water oaks evidently occurs.

Snow and his coworkers conducted research on the production and dispersal of sporidia of C. fusiforme and on weather and other factors determining infection rate. Their results were published in 1968 as four articles in Phytopathology Volume 58. These findings greatly increased our knowledge of the epidemiology of fusiform rust.

Extensive screening tests for fusiform rust resistance have been made by both the Southern and Southeastern Stations and also by pathologists and geneticists at several southern state universities. The early work, however, was done at the Southern Station. The first evidence was that resistance could be secured by crossing slash or loblolly pines with the essentially immune shortleaf pine. Henry and Bercaw (Gaylord Container Corp.) reported that shortleaf-loblolly hybrids remained rust-free after 5 years exposure in an area of appreciable rust (Henry and Bercaw 1956). Later tests.with artificial inoculations showed that the hybrids, although highly resistant, are not immune.

Strains of loblolly and slash pines have been found that have appreciable resistance to fusiform rust, but further work is needed to establish how practical such resistance is.

Strains of a pathogen, varying in pathogenicity, complicate the control of many plant rusts. The first evidence of such specialization in Cronartium fusiforme was the report by Kais and

Walkinshaw in 1964 of an albino strain of the fungus which is persistent (Kais 1966). Snow and coworkers first reported pathogenic races of *C. fusiforme* in 1969 (Kais and Snow 1972, Snow *et al*. 1975). Such variation is further shown by the finding of greater virulence of inoculum from resistant than from susceptible pines (Snow *et al*. 1976). This finding of physiologic races of *C. fusiforme* greatly complicates developing resistant pine strains, because now they must be tested against many races of the rust. Experience with the cerial rusts raises a further serious question: Do new races of fusiform rust continually develop? The best we can say now is that developing pines resistant to C. *fusiforme* is still far from being solved.

Fusiform Rust, Other Studies

Not all studies after 1952 were on resistance. Researchers also:

1. Produced a guide to thinning. Measurements on rust-killed pines showed that trees with 50 percent or more of the stem cankered probably would not survive until the next thinning and should be removed.

2. Found from field observations that loblolly pine is more susceptible to infection than is slash, but has a lower percentage of infections reaching the stem.

3. Found that in nurseries, basal branching without a swelling is not sufficient evidence of infection to warrant culling.

4. Showed that up to one third of the seedlings in a heavily infected nursery bed can have latent infections that are not detectable at lifting time but will develop on outplanting. This is further evidence of the need for an effective spray program.

5. Devised a rapid differential stain technique for detecting rust mycelium in woody tissue (see Jewell et al. 1962).

6. Determined the rate of spread of branch infections (Jewell 1958, Verrall 1961).

7. Found that six non-native pine species are susceptible to fusiform rust (Jewell 1960a).

8. Found from 55 trials of cycloheximide and several of its derivatives showed that these systemics may reduce aecial

fruiting, but are generally ineffective against fusiform rust when applied by dipping roots of infected seedlings before outplanting, spraying nursery seedlings before and after inoculation, spraying the lower boles of infected trees, or spraying wounds where branches were pruned after fungus had just reached the stem. In other tests, three systemics (benomyl, oxycarboxin, and C4-524) used as a soil drench gave only partial control. Recently, another systemic (Benodanil) has shown much more promise in controlling fusiform rust on seedlings (Hare and Snow 1976).

9. Studied tissue changes in rust-infected slash pine seedlings (Jewell *et al.* 1962).

10. Found that telia and uredia can develop on stems of *Q. nigra*. They also can develop on both upper and lower sides of leaves (see Eleuterius and Snow 1964).

11. Found 5-10 percent of nursery infected seedlings alive after 2.5 years with no evidence of living galls (Snow *et al.* 1963).

12. Found that _C. fusiforme_ can be kept alive at least 5 months in cultures of gall tissue from seedlings. Walkinshaw did much of this tissue culture work under contract with the Washington Office while he was at the Medical School and continued it at NASA after his return to the Forest Service.

13. Also studied the physiology of the germination of _C. fusiforme_ spores (Walkinshaw 1965). One study strongly suggested that endoginous reserves may become depleted in stored aeciospores.

14. Wrote a critical review of the literature on fusiform rust--the disease, pathogen, host relationships, and control (Czabator 1971).

Nursery Diseases

Lamb's early work and recent research on hardwood nursery diseases is discussed later under "Hardwood Tree Diseases" and the research on the control of brown spot and fusiform rust in nurseries has been included in the sections under those headings.

Black Root Rot

An undescribed root deterioration of pine seedlings was found in the W. W. Ashe Nursery near Brooklyn, Miss., soon after the nursery was established in 1936. In 1937 Lamb found nematodes associated with the root rot, later named black root rot. Shortly thereafter Lamb and Sleeth isolated *Fusarium* spp., *Torula marginata*, and *Sclerotium bataticola* from diseased roots, and Sleeth showed that the rot was infectious. (None of this information was published).

By 1947, black root rot was causing sufficient reduction in yields at the Ashe Nursery that control became imperative. So, Siggers and Lindgren started soil fumigation trials. The following year Berch W. Henry joined the Southern Station and was assigned full-time to a study of black root rot. During the next 4 years, six fumigants were tried at different concentrations in fall and spring applications. Several fumigants gave adequate disease control but ethylene dibromide and methyl bromide proved best. The carryover effect of fumigation and the survival of diseased seedlings on outplanting also were studied.

Henry failed to produce typical symptoms of black root rot with artificial inoculations with nematodes and fungi isolated from diseased seedlings or with various combinations of the organisms.

An explanation of the etiology of black root rot had to wait further research at the Southeastern Forest Experiment Station. Henry (1953) summarized the Southern Station findings on black root rot.

Although black root rot is primarily a nursery disease, Smalley and Scheer (Research Foresters, Southern Station) reported it in slash pine plantations in the Florida sand hills (Smalley and Sheer 1963).

Miscellaneous Nursery Research

In 1952 Henry tried four seed and seven soil treatments for the control of seed decay and damping-off of longleaf and loblolly pine seedlings. A preplant soil treatment with formaldehyde proved most effective. (No results were published).

In 1964 the Southern Station cooperated with Louisiana State University in a test of soil fumigation at the Southwest Louisiana Nursery near Oberlin. The test was conducted in an area where root diseases and weeds seriously curtailed production and reduced quality of seedlings. Of the four fumigants tried, methyl bromide gave best control of nematodes, weeds, and fungi but could be justified on a basis of cost only where weeds were a major problem (Shoulders et al. 1965).

Nursery Extension

Felix Czabator joined the Division of Forest Management at the Southern Station in 1956. Previously, he had been a nurseryman for the State of Alabama and troubleshooter for Mississippi State Nurseries. At the Southern Station he did service work for tree nurseries on Soil Bank Funds. In 1958 he transferred to the Division of Forest Research and continued to advise nurserymen on disease and other problems. Thus, the Station was able to get its expertise on nursery practices to State and Federal nurseries within its territory. This service was -discontinued in 1960 when Czabator went to Yugoslavia as an advisor on nursery problems. Currently service work is the responsibility of State and Private Forestry.

Annosus Root Rot

By 1960, timber managers were becoming alarmed by losses from Fomes annosus. From what we know now, the reason for this upsurge was obvious. Large acreages of plantations of slash and loblolly pines that were -planted on old-field sites in the 1940's had reached the- age for thinning.

Southern Station pathologists made a preliminary survey of plantations in 1960 and started an annotated bibliography of the world literature on *Fomes annosus*. The bibliography was started by J. W. Koenigs who also helped with the original survey. He completed the literature review after his return to New York State College of Forestry (Koenigs 1960).

In 1961 the Southern and Southeastern Stations joined forces to make a detailed survey of southern pine forests from Virginia to Texas to appraise the annosus situation. This survey established the main factors contributing to annosus damage: thinning plantations on old field sites, particularly those on deep light soils and those with dense litter (Powers and Verrall 1962). This information was basic to future research on contributing factors and control.

Most later research on annosus root rot was done by Froelich:

1. Based on the finding that deep litter favored annosus damage, tests of prethinning prescribed burning were started in 1963. Burning materially reduced the amount of attack (Froelich et al. 1978).

2. Dusting sulfur (2000 lb/acre) appeared to check the spread of *F. annosus* by providing a long-term reduction in soil pH (Froelich and Nicholson 1973).

3. Based on an analysis of the soil in 137 plots with severe, light, or no annosus damage, a formula was devised for assessing annosus hazard by soil factors (Froelich *et. al.* 1966).

Other Research

From 1930 to 1934 Siggers tested slash disposal methods in the Ouachita National Forest and found that slash left as it falls rotted fast and was more economical than piling, lopping and scattering, or burning (Siggers 1935).

Dean Weddell (University of Georgia) brought to the attention of pathologists, a new disease of shortleaf pine. Siggers and Doak (1940) described it as "littleleaf disease" of shortleaf pine, but the main research on this disease was done later at the Southeastern Station.

R. P. True, at Olustee, Florida, in addition to his main assignment of histological studies on the effect of acid treating on turpentining, made pathological studies of fungus relationships to turpentining. He reported that some fungi are agents of dry-face (True 1946) and that the pitch-canker fungus prolongs gum flow. This work overlapped the transfer of the Naval Stores Project to the Southeastern Station and is considered more fully in the section on that Station.

Cone rust can damage cone crops of slash and longleaf pines--this is particularly true in open-pollination studies at the Genetics Institute. Jewell (1957) found that bagging pine flowers for controlled pollination prevents cone-rust infections. In 1958-59 the Southern and Southeastern Stations cooperated in ferbam spray trials for cone rust control. Results suggested that a single spray might be adequate, but timing had to be worked out. The Southeastern Station assumed responsibility for future trials.

Normally, heartrot is a minor problem in second growth southern pines because they have little heartwood. However, Lightle and Starr (Miss. State Univ.) found appreciable amounts of Fomes pini and Polyporus schweinitzii in young slow-growing pines on poor sites (Lightle and Starr 1957). The slow-growing trees had a large amount of heartwood.

Phytophthora cinnamomi was found killing Lawson cypress in the Crown Zellerbach arboretum near Bogalusa, Louisiana (Campbell and Verrall 1963). This work was in cooperation with the Southeastern Station.

Froelich and Snow (1965) noted tipburn and killing of slash pines near electric power substations in southern Mississippi which presumably was due to seepage of urea herbicides used in substations for weed control.

W. F. Mann (Officer-in-Charge, Alexandria Research Center) and coworkers found that the hemiparasite *Seymeria cassioides* attacks the roots of slash pine, and weakens or kills seedlings (Mann *et al.* 1971).

Hardwood Tree Disease

Forest pathologists from the U.S. Department of Agriculture's Mississippi Valley Laboratory (St. Louis, MO.), and later the Washington Office of the Division of Forest Pathology, Bureau of Plant Industry, and local State plant pathologists, made excursions into the bottomland and upland hardwood forests 50 years before the establishment of the formal hardwood disease project at the Southern Forest Experiment Station. In 1907 Hermann von Schrenk published

Bureau of Plant Industry Bulletin 114, entitled "Sap-rot and other diseases of sweetgum." In 1917 W. H. Long published USDA Bull. 496 on "Investigations of the rotting of slash in Arkansas". As far as I can determine, Long's tests were the first forest pathology experimentation in the South.

Early Work at the Southern Station

In 1931 L. O. Overholts, Professor at Pennsylvania State University, spent several months at the Southern Station as a Bureau of Plant Industry field assistant collecting and identifying fungi--mainly heart- and saprot-fungi. He was assisted by Frank Kaufert (Field Assistant, Bureau of Plant Industry). At that time, Overholts was the national expert on the Polyporaceae and his collections gave the Southern Station a good herbarium of decay fungi and their associated decays. Cultures of many of the fungi were obtained, but unfortunately, these cultures have been lost. The fruitbodies and decayed wood remain, but in a deteriorated condition.

During the fungus collection period, Kaufert also obtained data on the incidence of fire damage and associated rot. He reported that a high proportion of immature and mature bottomland hardwoods are fire-scarred and that decay associated with these scars is a major cull factor (Kaufert 1933).

In 1932 George H. Hepting (Field Assistant, Bureau of Plant Industry) studied decay following fire in young Mississippi Delta hardwoods. These studies yielded extensive data on the rate of scar healing, the rate of upward spread of decay, and other information on heartrots. Hepting used this material for his doctoral dissertation at Cornell and also published it (Hepting 1935). Kaufert, who assisted Hepting, conducted some disease studies in the Lake States and then became Dean of the College of Forestry at the University of Minnesota.

In 1934, Howard Lamb (Assistant Conservationist on Civilian Conservation Funds) joined Paul Siggers who was in charge of pine disease research. Lamb was assigned to a study of nursery diseases of black locust, mainly at the Soil Conservation Service nursery at Robson, La. and at the Woodworth, La. State Forest Nursery. Many seedlings were being lost from unknown causes. Non-parasitic troubles, such as damage from heat, drought, and insects, caused much of the loss, but some root rot and damping-off occurred. Lamb tried a number of soil and seed treatments when soil fungi were involved. Lamb also examined eight plantings of Asiatic chestnuts in Mississippi in 1935 and 1936. Deterioration of these plantings from fire, cattle damage, etc. prevented useful findings. After 1935 Lamb worked mainly on pine diseases until he transferred to Columbus, Ohio in 1940.

Formal Research Project

The Southern Station's formal hardwood tree disease project started in 1952 when E. Richard Toole transferred from the Southeastern Station and was assigned to the Stoneville (Miss.) Research Center. From the start, the project primarily was concerned with the diseases of bottomland hardwoods in the Mississippi Delta, because it is here that the large volume of hardwood timber and future potential exists. However, the project has extended studies to the bottomland forests along other rivers and, to some extent, upland hardwoods in forests and to shade trees.

In 1971 the pathology and entomology projects at Stoneville were combined. There are administrative advantages to such combined projects, but technical direction is likely to suffer because the Project Leader is proficient in one field only. This is particularly true now that the Assistant Directors are assigned on a geographic basis and do not provide the technical direction obtained with the previous Divison Chiefs.

Personnel

E. Richard Toole, like Paul Siggers, is a auiet, dedicated research scientist who, with little fanfare, personally turned out an enormous amount of information and directed the research of assistants when he was fortunate enough to have them. Toole always had a free hand in selecting and carrying out studies. He remained Project Leader until his retirement in 1969. After retirement, he continued work on decays of wood products at the Forest Products Utilization Laboratory at Mississippi State University.

Theodore H. Filer joined the project in 1963, originally to study mycorrhizae associated with hardwoods. After Toole's retirement in 1969, Filer was in charge of the pathology studies at Stoneville. In 1971 the pathology and entomology projects were combined. In 1974 Filer was appointed Leader of this unit.

F. I. McCracken was assigned to the project in 1967 to continue Toole's work on heartrots. McCracken has worked principally on the biology of decay fungi.

Research Results

Toole's main published contributions were:

1. Decay after fire injury in southern bottomland hardwoods (Toole 1959). This publication includes practical directions for estimating the amount of rot present in different species and its expected rate of spread.

2. Rot entrance through dead branches of southern bottomland hardwoods (Toole 1961). Practical instructions are given for estimating the amount of rot present and rate of spread in different species.

3. Deterioration of logging slash in the South (Toole 1965a). The rate of deterioration as influencing salvage of top wood, and fire hazard for different species logged in different seasons are included.

4. Toole and W. M. Broadfoot (soils expert) showed that sweetgum blight is more severe on poor sites, particularly where high contents of sodium and potassium reduce available water (1959) and that irrigation will alleviate symptoms (1959a).

Some may believe that this list of Toole's major contributions is too restricted. True, he had made important conributions in the Southeast before coming to the Southern Station, and his many studies at Stoneville on cankers, sweetgum lesion, and several other diseases listed later were significant. Certainly, Toole was one of the Station's research leaders, when considering the volume and quality of his research.

Up to 1961, Toole had no real laboratory or greenhouse space, and consequently, his studies were almost entirely field investigations. In 1961, when modern laboratory and greenhouse facilities were completed at Stoneville, studies on the physiology of pathogens and the role of mycorrhizae were possible.

Filer and Toole (1966) found that a number of basidiomycetes and ascomycetes were associated with mycorrhizae of sweetgum and oaks. Filer (1975) reported that yearly winter and spring flooding did not alter the kinds of ecto- and endomycorrhizae of sweetgum and oaks and only temporarily reduced populations of soil fungi. Filer, also studied disease control in nurseries, and developed controls for septoria canker of cottonwood (Filer et al. 1971). A beginning was made in genetic resistance to diseases in hardwoods when Cooper and Filer (1976) found that 10 of 320 cottonwood clones tested were resistant to septoria leaf spot. Many other nursery diseases have been studied. Filer (1973) developed new information on the use of tetracycline systemics to suppress elm phloem necrosis, including time of application, rates, and methods of injection. An inexpensive pressure apparatus was developed to inject chemicals into trees (Filer 1973a).

Toole, Filer, and McCracken have made many other contributions, including new occurrences of disease, describing new diseases, and lesser research findings. Some of these are:

1. Polyporus zonalis on hackberry in Alabama.

2. Clitocybe tabescens decline of elm and water oak.

3. Sycamore anthracnose.

4. Cephalosporium wilt of elm.

5. Wetwood in cottonwood.

6. Pythium sylvaticum root rot of several species.

7. Corticium galactinum root rot of several species.

8. Polyporus lucidus root rot.

9. Fusarium solani stem canker of oak, tupelo, cottonwood, and yellow-poplar.

10. Colletotrichum gleosporioides on leaves and twigs of dogwood.

11. Botryosphaeria ribis lesions on sweetgum (Toole 1963).

12. Decay following increment borings (Toole and Gammage 1959).

13. Rate of decay in relation to height in the tree based on inoculation tests (Toole 1964).

14. Decay hazard after thinning sweetgum sprout clumps (Toole 1965).

15. Effect of methyl bromide on hardwood mycorrhizae (Filer and Toole 1968).

Surveys

In 1950, B. W. Henry (Pine Disease Project) and T. W. Bretz (University of Missouri), in cooperation with the Arkansas Resources and Development Commission, made a survey of oak wilt in Arkansas and found wilt in six northern counties. In 1958 and 1959, Toole, Verrall (Chief, Division of Forest Disease Research), and P. C. Lightle (Pine Disease Project Leader) made aerial and ground surveys of Arkansas and eastern Oklahoma for oak wilt. Three trees were found in Oklahoma--the first wilt reported there--and a few trees in Arkansas in areas previously known to have oak wilt. No buildup had occurred since the first report in Arkansas in 1951 (Verrall et al. 1959). The main oak wilt surveys in the South were, of course, made by the Southeastern Station, and included surveys in the Southern Station's territory.

From casual surveys in Arkansas, Louisiana, Mississippi, Alabama, and Texas, Toole and Lightle (1960) reported that persimmon wilt was not a major problem because it occurred only in open stands of little value except as food for game and had not been reported on timber-producing sites.

Observations on sweetgum blight were made in the Southern Station's territory from 1952 to 1957, mainly by Toole. He perfected his surveys by establishing 41 plots in 6 locations for periodic observations on 2,239 trees. These surveys and research findings clearly showed that sweetgum blight was a response to moisture shortages.

A survey of 26 sycamore plantations in Louisiana, Mississippi, Arkansas, and Tennessee determined the incidence of such diseases as canker, leaf scorch, and dieback (Filer *et al.* 1975).

Products Pathology

By 1918 the southern lumber industry was well aware of severe losses from stain, mold, and decay during the air-seasoning process. This resulted in some early studies of stain control by the Forest Products Laboratory, but no effective fungicides were developed. R. L. Pettigrew and H. M. Knowlton (Forest Products

Laboratory), from 1914 to 1917, tested several chemical dips for stain control at the Great Southern Lumber Company,,Bogalusa, La. Nothing better than soda was found. In 1922, Ernest E. Hubert (Assistant Plant Pathologist, Forest Products Lab.) made a survey of stain conditions in Louisiana; and, in 1928, tested different piling methods for air seasoning in Texas, Louisiana, Mississippi, and Arkansas to determine if piling design influenced stain occurrence. None of this early work was published, but it did emphasize the need for solving the sapstain problem.

In 1917, C. J. Humphrey (Bureau of Plant Industry's Office of Investigations in Forest Pathology) described decay conditions in lumber stored at wholesale and retail yards in the East and South. This was an observational study and the recommended controls were based on reasoning rather than research.

In the early 1920's, a number of severe outbreaks of Poria incrassata "dry rot" in southern buildings resulted in a spurt of observational studies of this fungus. C. W. Edgerton (1924) described several cases. C. J. Humphrey (1923) also described a number of Poria cases, and; additional cases were also cited by Humphrey and L. E. Miles (1925). However no real research was involved, and sound economical controls had to wait until research was conducted on this rot problem. In the late 1920's and early

1930's, C. Audrey Richards (Bureau of Plant Industry at the Forest Products Lab.) examined several cases of Poria rot in Florida. She recommended the same controls as given by Humphrey, Miles, and Edgerton--controls so drastic that rebuilding was sometimes preferable.

The start of the formal products pathology research project at the Southern Station was in 1928 when Ralph M. Lindgren (Assistant Pathologist, Bureau of Plant Industry) was assigned to the Southern Station to investigate sapstain control in green lumber and other wood products. The project continued until July 1979 when Amburgey resigned. There are no plans to hire another products pathologist at the Southern Station, thus essentially closing one of the most fruitful projects at that Station.

Shortly after the Products Pathology Project was established at the Southern Station in 1928, the Wood Preservation Section of the Forest Products Laboratory, Madison, Wis., started a field exposure site at the Harrison Experimental Forest, Saucier, Miss. Thousands of treated and untreated stakes and posts have been exposed there to determine average service life. Starting in 1960, T. C. Scheffer (Pathologist at the Forest Products Lab.) also established some exposure tests at the Harrison Forest. None of these studies are discussed in this report--only those Forest Products Laboratory studies jointly conducted with the Southern Station. Considering the Forest Products Laboratory and the Southern Station exposures, there is little doubt that the Harrison Experimental Forest has been one of the world's most extensive field exposure sites ,for wood products protection.

Personnel

Ralph M. Lindgren directed the products pathology studies from their inception in 1928 until September 1931, when he left New Orleans for further graduate study. After an assignment in tree diseases, a couple of years as Vice President of the Chapman Chemical Company, and a war-time assignment on *Cryptostegia*, he was assigned to the Beltsville Office of the Division of Forest Pathology, Bureau of Plant Industry. He returned to New Orleans in 1947 to direct all the forest pathology projects. In 1950 he transferred to the Forest Products Laboratory, Madison, Wisconsin as a Division Chief. He retired in 1962. Lindgren was one of those unusual researchers who, in addition to plenty of brain power, had the ability to get widespread cooperation from many sources. He had a high degree of dedication and persistence and could take basic approaches to problems without losing sight of the practical side. He was one of the most important forest pathologists of all times, both for his research and for his effect on other workers when he was an administrator.

In 1929 A. Dale Chapman (Agent, Bureau of Plant Industry, Forest Products Laboratory) came south to assist Lindgren. After Lindgren left in 1931, Chapman directed the sapstain studies until early 1933 when he returned north for a few months before resigning to establish the Chapman Chemical Company, one of the most important purveyors of wood-treating chemicals.

Theodore C. Scheffer (Field Assistant, Bureau of Plant Industry) joined the project in January 1930. Except for the 1931-1932 school year, when he was at the University of Wisconsin, he stayed in New Orleans until the fall of 1934 when he went to Johns Hopkins (1934-1935 school year). In 1935 he was assigned to the Forest Products Laboratory from where he cooperated with the Southern Station in many studies and publications. Since retirement in the early 1970's he has been conducting products pathology research at Oregon State. University but is still cooperating with the Forest Service with publications. Scheffer is one of the outstanding products pathologists and has contributed many important papers on the practical and basic phases of wood protection.

Ira Hatfield (Field Assistant, Bureau of Plant Industry) joined the sapstain project in September 1934, but resigned in June 1936 to accept a position with a chemical company handling stain-control chemicals.

Arthur F. Verrall (Assistant Pathologist, Bureau of Plant Industry) transferred to New Orleans from the Dutch Elm Disease Laboratory, Morristown, N. J., in 1936. He directed, the products pathology studies and in 1956 became Chief, Division of Forest Disease Research but still maintained leadership of the products pathology studies. In 1964, when the Assistant Directors replaced the Division Chiefs, he remained as Project Leader under Washington technical supervision. Verrall retired in 1965 to accept the forest pathology professorship at Stephen F. Austin State University. He continued to cooperate with the Southern Station by completing the Navy studies and writing several papers.

Paul V. Mook (assistant Pathologist, BPI) assisted Verrall from 1942 to 1948, except for the period May to September 1946 when he helped the University of Pennsylvania with its Navy contract to study mold deterioration of many products in the tropics (Panama Canal Zone). He proved invaluable in the sapstain research because of his inventiveness. He devised and constructed or had constructed several pieces of equipment that made tests easier or, in some cases, feasible.

George M. Harvey assisted Lindgren on pulpwood deterioration studies from February 1950 to December 1953 when he transferred to the Pacific Northwest Forest Experiment Station.

William H. Scheld joined the project in 1962 to study protection of pulpwood by continuous water sprays. He left in 1967 on educational leave and, although he never returned, he helped DeGroot to interpret and publish the water-spray data.

Rodney C. DeGroot (Principal Pathologist) joined the project in 1968 as Project Leader. In 1976 he transferred to the Forest Products Laboratory, Madison, Wis.

Terry L. Amburgey joined the project in 1959. When DeGroot left in 1976 Amburgey was transferred to an entomology project but continued to work on products pathology until he resigned in 1979 to accept a professorship at Mississippi State University.

Sapstain

The sapstain project required Federal financing and extensive financial support from the lumber associations; the use of several million board feet of lumber furnished by a number of lumber companies; donation of chemicals by the chemical industry, particularly Dow and DuPont chemical companies; and the donation of many hours of labor by lumber mills. Particular credit is due Roger Simmons, Executive Secretary of the American Pitch Pine Export

Company, for securing financial support. Grover Harrison, Manager of the Louisiana Central Lumber Company, also was very influential in getting support for the project.

Lindgren, Chapman, and Scheffer tested a large number of fungicides in small-scale tests to determine their effectiveness in controlling stain, mold, and decay in green lumber during air seasoning. The most promising were tried in mill-scale tests on full-sized lumber in regular seasoning piles at a number of southern mills. Three chemicals proved so effective that, by 1933, they were on the market under trade names and in general use:

1. Ethyl mercuric chloride for use on all wood species.

2. Sodium tetrachlorophenate for use on hardwoods.

3. Sodium 2-chloro-orthophenyl phenolate which, in mixture with sodium tetrachlorophenate, for use on all species.

In addition to control tests, Lindgren, Chapman, and Scheffer also determined: (1) the fungi causing stain of green lumber; (2) the rate of radial, tangential, and longitudinal spread of stain fungi in wood; (3) the effect of stain on the rate of water loss and water gain; (4) the relative decay resistance of stained and unstained sapgum; and (5) the effect of stain on the strength of wood. In trying to protect logs with sapstain chemicals, they found that bark beetles carried the fungi below the treated surface during the warm months. The same chemicals also gave only marginal protection to seasoning poles and posts prior to pressure treatment. Lindgren and his colleagues also studied methods of applying chemicals at large and small mills, and the handling practices during manufacture and air seasoning that influence the effectiveness of dips. Included were tests of bulk piling treated green lumber, loss of chemicals by rain wash, and delaying dipping after sawing.

Ira Hatfield investigated the dissemination of stain fungi, and found both wind and insects were important disseminators. He also made some chemical dipping trials with ethyl mercuric phosphate, which soon replaced the less effective chloride, and with sodium pentachlorophenate, which was soon marketed by two companies. Hatfield also made further observations on mill practices that influence stain control.

Verrall, after he was transferred from Morristown, N. J., to the Southern Station in 1936, made a few stain-control tests with the help of T. C. Scheffer from the Forest Products Laboratory. No new chemicals were found in these early trials.

All the information on stain, mold, and decay of green lumber, logs, and other green products made through the 1930's was summarized in a technical bulletin by Scheffer and Lindgren (1940). This bulletin remains the "bible" of sapstain and its.control except for recent changes in fungicides used.

Further studies by Verrall showed that treated green lumber can be bulk piled safely for at least 2 weeks and still be air-seasoned essentially stain-free. He also secured more extensive information on: (1) the relative importance and seasonal prevalence of stain fungi (Verrall 1939); (2) the fungi associated with treated green lumber (Verrall 1941a); and (3) the dissemination of stain fungi (Verrall 1941). He made a cultural and staining ability comparison of *Diplodia natalensis* from stained wood and diseased cotton, orange, etc. (Verrall 1942), and described new species of stain fungi cultivated by ambrosia beetles attacking green southern woods (Verrall 1943).

In 1940, the war effort threatened supplies of stain-control chemicals and therefore, the sapstain control work was reopened in 1942.

A series of small-scale and mill-scale tests showed that the use of critical chemicals could be cut in half and effectiveness increased by using mixtures:

1. l/Z-strengths of either mercury or phenate plus borax.

2. 1/4-strengths each of mercury and phenate plus borax.

Tests also showed that the mercurials were differentially adsorbed by wood so that treating solutions tend to weaken with use. These problems were controlled by maintaining high solution levels in vats. Leaching of chemicals by rain was more fully explored and found most troublesome soon after the lumber was dipped and that phenates were more resistant to washing than the mercurials. One test showed that green hickory, ash, oak, dogwood, and sapgum could be adequately protected by sapstain dips for several months during handling and shipment to England. Verrall (1949) found that a number of molds on wood were favored by certain toxicants. These emergency period stain studies were summarized in a Technical Bulletin by Verrall and Mook (1951).

Building Decays

Observations, mainly in Florida, in the early 1930's by C. Audrey Richards (Pathologist, Forest Products Lab.) and L. V. Teesdale (Forest Products Lab.) showed that many unsolved building decay problems existed in the South. As a result, Verrall initiated a study of building decay in 1939. In 1941 he made a survey of defense housing in Texas, Louisiana, and Mississippi to determine the minimum foundation ventilation needed to protect substructure wood. Soil moisture was found more influential than ventilation. These studies, including the effects of ventilation, soil moisture, and soil covers, were continued for several years with observations by the Southern Station from South Carolina to Texas, and similar studies in other parts of the country by pathologists at the Forest Products Laboratory and Beltsville, Maryland. The results were published by the Forest Products Laboratory and Beltsville offices, and were the basis of specifications for ventilation and soil covers in the Minimun Property Standards of the Federal Housing Administration.

On-the-job Preservative Treatments

Early in the building decay studies it became evident that on-the-job applications of preservatives should be useful in protecting wood exposed off the ground but subject to rain seepage. Because little was known of such applications and the Forest Products Laboratory was not inclined to secure the needed information, the Southern Station investigated this problem. In 1944 Verrall started an extensive series of "joint" tests, i.e., wood dipped in or brush-treated with preservatives, was exposed above ground and subject to rain seepage at joints, simulating those in buildings. Several thousand units were exposed over a lo-year period and some were kept under observation for over 15 years. Test variables included: type of preservative, length of immersion, the effect of added water repellents, and the effect of painting treated wood. One test unit, a joint simulating a step rail attached to the side of a newel, has become a standard test unit. In addition to field exposure tests, the factors influencing penetration and absorption of oil-carried preservatives were determined. These studies were summarized in a Technical Bulletin (Verrall 1965).

Decay Associated with Rain Seepage in Buildings

In 1946, Verrall installed tests to determine the factors influencing the decay of wood siding. These studies were made possible by a grant from the Federal Housing Administration. Later, in 1958, under a contract with the Navy's Bureau of Yards and Docks (to be discussed later), further exposures increased the number of experimental siding panels to more than 40, including such variables as: amount of roof overhang, type of sheathing paper, effect of wood sheathing, type of joint of siding to trim, type of siding, effect of preservative dips with and without water repellents, end painting, and effect of eave gutters. This study also included examination of 1,500 buildings in 8 states and the in-place preservative treating of deteriorating siding on actual buildings.

A number of different types of joints and designs used in step and porch rails, in steps, and in porch flooring also were tested. Additional studies included: determining the fungi associated with decay following rain seepage, the physics of water entry into joints, the association of decay and mold fungi, and determining temperatures on the surface and interiors of exposed woodwork. The information on decay associated with rain seepage was published in a Technical Bulletin (Verrall 1966).

Water-Conducting Fungi

Shortly after Verrall came to New Orleans in 1936, C. Audrey Richards (Pathologist, Forest Products Lab.) accompanied him on a trip through Florida to point out the buildings where she had found the water-conducting decay fungus Poria incrassata. At that time the recommended control consisted of removal of decayed wood and all sound wood within 2 feet of visible decay because of a belief that the fungus can survive and grow with no water source except the water of metabolism. This drastic treatment was extremely costly. Over the next 25 years, Verrall observed many cases of Poria decay. In each case, he recommended controls, revisited the building after controls were completed to determine if they had been carried out, and made a final inspection at least a year later to determine if control was effective. Information from these cases plus some laboratory and field tests were summarized in a Technical Bulletin (Verrall 1968). The effective simplified control consisted of removing the source of water (usually soil moisture conducted through rhizomorphs) and removing only wood too rotten to support its load. In every case, conducted water was vital and after this source was removed, the fungus died.

Navy Yards and Docks Contract

The contract with the Bureau of Yards and Docks was handled primarily by the Forest Products Laboratory, but about half of the work was done by the Southern Station. In addition to the experiments with siding already discussed, Verrall visited Navy buildings, docks, and other wood structures in Southeastern United States, Panama, Oahu, and Guam. The Navy was furnished a report on conditions at each installation, and many special reports on such subjects as decay hazard in cold-storage and shower rooms, and the covering of defective wood siding with asbestos-cement shingles. Inspections and tests covered a period of about 10 years. Scheffer and Verrall furnished the Navy a detailed manuscript on the protection of wood structures from attacks by fungi and other deteriorating agents, which the Navy used as a basis for a manual on "Wood Preservation." Later, Scheffer and Verrall (1973) published their report in a reduced form.

Included in the Navy studies were some preservative tests with step-rail units and 2- X 2-foot porch flooring units of several wood species exposed in Mississippi, Wisconsin, and Oregon. These were conducted by Verrall, Scheffer, and Harvey, respectively (Scheffer et al. 1963). The results of these regional exposures were used by Scheffer as part of the basis for his Climate Index of decay hazard (See Scheffer and Verrall 1973).

Condensation In Air-cooled Buildings

The Navy inspections in addition to previous surveys and experimental studies gave the first evidence of condensation problems associated with air-conditioning by refrigeration (Verrall 1962). It was some time before architects and engineers accepted these findings, but now a condensation hazard is recognized as a result of poor air-conditioning practices.

Ammunition Box Protection

In 1942, Verrall started tests financed by Frankford Arsenal, Army Ordinance. Scheffer (at the Forest Products Lab.) and Leonard Teitell (Chief, Biochemistry Division, Frankford Arsenal) cooperated. Twenty-five hundred M-22 ammunition boxes were exposed in Mississippi, Wisconsin, and the Panama Canal Zone. Test factors included: 16 chemical dips, 4 pressure treatments, effect of water repellents on preservative effectiveness, effect of painting treated wood, effect of uncovered and tarpaulin-covered piles, and effect of soil treatments for termite protection. In addition, at Gulfport, a test of wire-bound hardwood veneer boxes was included and a large number of simulated boxes were used to study miscellaneous factors. The results of these tests were published in three Frankford Arsenal Reports and were summarized by Verrall and Scheffer (1969). A water-repellent preservative dip of ammunition shipping boxes is now standard procedure.

Pulpwood Deterioration

In 1948, Lindgren started an extensive study of the deterioration of pulpwood in the South. He also included in these studies a few tests with poles, posts, and logs. He was assisted by George M. Harvey from February 1950 through December 1953, after which Harvey transferred to the Pacific Northwest Forest Experiment Station. Harvey continued the pulpwood studies after Lindgren left but Lindgren directed the work from the Forest Products Laboratory.

The pulpwood studies were made in cooperation with the Forest Products Laboratory and several pulp companies. The factors studied were: season of cutting, peeled versus rough bolts, the effect of bolt diameter and length, fungicidal sprays, end coatings, and hardwood and pine. Actual pulping tests of some of the stored material were made at the Forest Products Laboratory to determine the effect of deterioration on pulp quality and yield.

Some of the important results (Lindgren 1951, 1953) were: (1) for short storage periods, close piles of long, large diameter, rough bolts during winter deteriorated slowest, (2) for longer storage periods, small peeled bolts in open piles were best, and (3) a spray of pentachlorophenol plus benzene hexachloride in oil protected rough bolts for at least 6 months. Most pine pulpwood and log decay during the first few months of storage was found to be caused by _Peniophora gigantea,_ but later _Lenzites saepiaria_ was dominant.

One of the most important findings of the pulpwood and post studies was that fluorides (as ammonium bifluoride) applied as a water spray, stimulte the mold _Trichoderma_ which inhibits early decay by _Peniophora_ and greatly increases permeability of the sapwood (Lindgren and Harvey 1952). The latter can have beneficial effects in treating with wood preservatives and in certain pulping processes. Later, Verrall (1966) showed that the same mold is commonly associated with _Lenzites saepiaria_ in nature and frequently increases its decay rate.

The pulpwood studies also showed that stain fungi enter through most live branch scars, but only 20 percent of dead branch scars. Stain fungi also enter through ax nicks and bruised areas and, in small-sized pulpwood, stain and decay fungi apparently can penetrate uninjured bark.

Some water-spray trials on rough round pulpwood and sawlog sizes were made by Carpenter and Toole (1963) at the Stoneville Research Center. They found that continuous and intermittant water spray kept hardwood logs free of stain and decay except for stain in hackberry, presumably of chemical origin. Scheld and DeGroot (1971) and DeGroot and Scheld (1973) found that water sprays kept pine bolts stain and decay free but permitted the growth of bacteria and a number of nonstaining fungi that reduced toughness and increased permeability.

Other Research

1. Samples of southern oaks were collected in 1942 for tests of decay resistance as boat wood at the Forest Products Laboratory. Boats were inspected for decay occurrence--a project directed by Carl Hartley at the Beltsville, Md., office.

2. In 1942 and 1943, Verrall helped George Hepting (Southeastern Station) in a survey of possible decay hazard in Army Air Corps wooden training planes. He also made some observations on possible condensation within'wooden plane stabilizers at the New Orleans laboratory. This material was published by Hepting (1944) who was in charge of the plane study.

3. DeGroot (1971) reported that *Streptomyces* inhibits *Lenzites saepiaria* in agar culture but increases decay rate in soil block tests.

4. DeGroot made a survey in the Mobile, Ala., area to determine the incidence and location of decay in buildings. The findings were essentially the same as reported by Verrall (1966).

Amburgey, in his work:

1. Wrote a series of papers to get the wood protection findings to the using public. Included is a detailed manual on building decay under a contract with Housing and Urban Development (Verrall and Amburgey 1979). This publication

is an expanded version of the manuscript that Scheffer and Verrall were unable to publish. It is the only complete publication on the subject.

2. With DeGroot, established a study of the deterioration of window units subject to rain seepage. A pentachlorophenol water-repellent dip gave good protection; dethiaminizing did not.

3. With the entomologists studied the interaction of decay and termites. The results were reported in four articles in volume 1 of Sociobiology.

4. Compared the relative effectiveness as a wood preservative, of the old type pentachlorophenol and the same material with the dioxines removed (Amburgey 1977).

5. Studied the discoloration of asphalt shingles by an alga and its control with a hypochlorite (Amburgey 1974).

6. Tested techniques in an attempt to improve the current laboratory standard decay tests (Amburgey 1976).

Dissemination of Research Results

Getting research results to the practical users is an important part of research. Because the Products Pathology Project offered unique opportunities along this line, a separate section on dissemination is included here.

Sapstain. By the mid-19301s southern lumbermen were experts in the art of air drying lumber without fungus degrade because: many had first-hand knowledge of protection methods from the mill-scale studies, and Lindgren, Chapman, Scheffer, and Hatfield, by articles in trade journals and lectures at association meetings, kept the industry abreast of new findings.

Building Decay. With periodic reports of practical findings, Verrall informed builders and architects of decay-control methods. He maintained contact with the pest-control industry by publications in their trade journals, by addressing pest-control operators at State meetings, and by giving a course in building decay at their national short course at Purdue University. Lindgren chaired and Verrall was a member of the Building Research Advisory Board's committee to review the Federal Housing Administration's Minimum Property Standards in the 1950's. Thus, they were able to get better decay protection into these national standards. DeGroot chaired and Scheffer and Verrall were members of a similar committee in the 1970's to bring the standards up to date. Amburgey, with his contacts with Housing and Urban Development, prepared or had prepared, a manual on building decay, a slide series on decay, and guides for inspecting buildings for decay.

The Military. The Army Ordinance and Navy contracts permitted Scheffer and Verrall to get better decay-preventive measures into the military use of wood. Contacts were sufficiently high to get at least some of their recommendations into application directives.

SOUTHEASTERN FOREST EXPERIMENT STATION

The Southeastern Forest Experiment Station originally was organized as the Appalachian Forest Experiment Station, but when Georgia and Florida were transferred to that Station from the Southern Station, and West Virginia transferred to the Northeastern Station in 1964, it became the Southeastern Forest Experiment Station.

Forest pathology research at the Southeastern Station has been indelibly stamped by George H. Hepting, who, except for research done as a graduate student with the Northeastern and Southern Stations, spent his entire professional career at the Southeastern Station. During his tenure there, 1933 to 1971, he conducted, directed, or influenced all pathology research in the Southeast and for 3 years in the early 1950's also supervised the projects at the Southern Station. During the last 8 years before retirement in 1971, he was attached to the Washington Office but stationed in Asheville. During these last years, he authored several important publications: (1) The monumental compendium of the diseases of forest and shade trees (Hepting 1971), the most important single book for American forest pathologists; (2) the relationship of climate and climatic changes to forest diseases (Hepting 1971a); and (3) the effect of air pollution on trees (Hepting 1971b). These are more than literature reviews because they reflect Hepting's long research and research directing efforts. Another important activity during this period was his initiation of and perfection of electronic storage and retrieval of the literature on forest tree diseases (Hepting 1967).

Of course, a Hepting never retires--since his official retirement, he has done extensive writing and counseling, reviewed manuscripts for journals and applications for National Research Council grants. Hepting is one of the all-time greats in forest pathology. His dynamic personality has been felt far beyond his official territory, as I can personally attest from my contacts with him over the years. His standing among pathologists and foresters is further shown by the many calls made on him for consultation, not only in the continental United States, but also in such places as New Zealand (1951) and Puerto Rico, Haiti, and St. Croix (1953). He also was adjunct professor at North Carolina State University (1967-1975) and was the first professional forester elected to the National Academy of Sciences.

Early Work

Even more than in the Deep South, the Appalachian Region was frequented by forest pathologists from the North. R. G. Atkinson and Hermann von Schrenk published on fungi and tree diseases of the area before 1900. More detailed surveys were made between 1908 and 1913 by Perley Spaulding, A. H. Graves (1913, 1914), G. G. Hedgcock, W. H. Long (1913), and others. During the next decade (1913-1923), Hedgcock collected extensive data on the rusts inhabiting the leaves, stems, and cones of conifers, with emphasis on untangling their taxonomic complexities. The parts on the pine-oak rusts were later assembled and published with Siggers' aid (Hedgcock and Siggers 1949). Hedgcock also made some collections and observations on heart rots.

In 1924 and 1925, Gravatt and E. P. Marshall (Washington and New Haven offices, Division of Forest Pathology) made a survey of chestnut blight to establish its rate of spread and behavior (Gravatt and Marshall 1926) and Hedgcock, Gravatt, and Marshall (1925) studied Polyporus schweinitzii and Fomes annosus in coniferous plantations on the Biltmore Estate in North Carolina. Hedgcock, in the late 1920's and early 1930's, made an extensive study of cull in Appalachian hardwoods from New Jersey and Pennsylvania to North Carolina and Tennessee. He was aided, at various times, by temporary assistants (Frank H. Kaufert, A. Dale Chapman, and J. J. McDermott). This study included data on the amount of cull for the principal hardwood species and its variation with tree diameter and age. It established that fire wounds are the major infection courts for butt rot.

Establishing a Forest Pathology Research Program at Asheville

A concerted study of Southern Appalachian tree diseases was started in 1925 with the Appalachian Forest Research Council instrumental in securing the necessary appropriation. C. J. Humphrey (Division of Forest Pathology, Bureau of Plant Industry) was assigned to cooperate with the Appalachian Station in Asheville, N.C., in 1925. He was the first forest pathologist headquartered in the area. Humphrey started a study of the effect of decay on the tannin content of blight-killed chestnut. However, he remained in Asheville less than a year, resigning to accept a position in the Philippines.

From March 1927 until August 1931, Ralph M. Nelson headed the Asheville office of the Division of Forest Pathology. Aided by temporary assistants (Lake S. Gill, Ralph M. Lindgren, E. J. Eliason, and Dow V. Baxter), Nelson completed the chestnut blight studies, particularly the rate of deterioration (Baxter and Gill 1931) and the tannin content of blight-killed chestnuts (Nelson and Gravatt 1929).

Nelson's major effort was on the relationship of blue stain and pine bark beetles. He demonstrated that blue stain fungi can kill pines quickly and contended that beetles were largely vectors only

(Nelson 1934). Nelson (1931) also made one of the first formal studies of decay in southern pines, finding that little occurred under age 90 and that redheart was more prevalent than butt rot. He also studied Nectria canker on yellow-poplar and Asiatic chestnut (Nelson 1940); started a collection of cultures from sporophores of wood rotters to be used in identifying cultures from decayed wood; and made large-scale plantings of Asiatic and hybrid chestnuts.

In August 1931, because of reduced appropriations and Nelson's transfer to the Forest Service, the Asheville Office of the Division of Forest Pathology was closed.

The Civilian Conservation Corps (CCC) Period, 1933-1940

The Asheville Office was reestablished in 1933 with the appointment of George H. Hepting to give advice on tree diseases to State and National CCC Camps in the Southern Appalachians. These camps were established to employ youths to build roads, camps, lookout towers, etc., and to engage in timber stand improvement. It was the disease phases of timber stand improvement that concerned forest pathologists. Much of the funding for this pathology work was provided through the Forest Service.

Personnel

During the CCC period, pathology personnel at the Southeastern Station usually consisted of two pathologists with a third present for short periods.

George H. Hepting was in charge and actively engaged in both the service and research phases.

Franklin D. Liming helped Hepting with the research phases from September 1933 to August 1934 when he left to accept a position at Ohio State University.

Elmer R. Roth joined the program in April 1934 and for many years was one of Hepting's chief assistants. We will meet Roth again later.

M. L. Lohman arrived in 1935 and spent a few years at Asheville working on Atropellis twig canker of pines.

Luther Shaw assisted Lohman during the summer of 1934 on twig canker and then moved to the Southwest to study a somewhat similar canker of western pines.

Between 1938-1940, Bailey Sleeth (Alleghany Forest Experiment Station), Kenneth H. Garren, Locke Craige, and Paul Warlick each spent about a year at Asheville on heartrot studies.

The CCC Program

Starting in May 1933, Hepting visited CCC camps in the Southern Appalachians to advise CCC personnel on handling disease problems in timber stand improvement work. Starting the following year Hepting and Roth visited more than 100 camps and prepared reports and recommendations for camp directors. Hepting wrote a bulletin on tree diseases in relation to stand improvement (Hepting 1946a) which went through several editions and finally was incorporated in a general publication (Jemison and Hepting 1949).

Early in the program it became obvious that there was little practical information on handling diseases in timber stand improvement and that service work must be supplemented by a research program. So, in conjunction with the service work, Hepting initiated an extensive research program. The main research findings of this period are:

1. Fruiting of Nectria and Strumella on cankered trees (Hepting 1941a). Nectria was found to fruit for several years on felled stems, so that cut trees would have to be burned to reduce inoculum. Strumella does not fruit on down logs but will fruit on girdled, standing dead trees.

2. In thinning oak sprout clumps, the rate of healing and danger of decay varies with the size of the removed sprout, method of cutting, and type of crotch (Roth and Hepting 1943).

3. Sprouts arising lowest on oak stumps are least likely to develop rot, but sprouts arising high on stumps tend to become dominant. Therefore, early attention is needed to insure that low-origin sprouts make up a stand (Roth and Hepting 1943a).

During the first few years at Asheville, Hepting also was busy organizing Hedgcock's data on decay in hardwood, adding new material, and preparing it for publication. It was first released in 1935 as three Appalachian Station Technical Notes (No. 13, 14, and 16). Later, it was published as a Technical Bulletin (Hepting and Hedgcock 1937). Included are the relationships of decay to basal and other wounds, tree diameter, age, and stump sprouts; and the rate of healing of basal wounds.

Hepting also reported several other studies:

1. With R. W. Davidson (Beltsville Office) described some leaf and twig diseases of hemlock in North Carolina (Hepting and Davidson 1935).

2. Described and determined the cause of mimosa wilt (Hepting 1939).

3. Published his doctoral dissertation on decay following fire in Mississippi River Delta hardwoods (Hepting 1935). This included the first report of compartmentalization of decay in tree stems, a point later greatly expanded by Shigo at the Northeastern Forest Experiment Station.

4. Organized and published A. D. Chapman's data on decay losses in shortleaf and loblolly pines (Hepting and Chapman 1938).

5. With D. J. Blaisdell reported a protective zone in sweetgum fire wounds (Hepting and Blaisdell 1936).

6. With R. W. Davidson described a new species of Rosellinia causing a leaf and twig disease of hemlock (Hepting and Davidson 1937).

7. With K. H. Garren and P. W. Warlick correlated oak top rot with external factors (Hepting *et al.* 1940).

Lohman proved that *Atropellis tingens*, associated with twig canker of pines, is pathogenic and made a comparison of it with similar fungi from other regions (Lohman *et al.* 1942). Experience, however, has shown that *A. tingens* is not of economic importance on southern pines.

Elmer Roth (1943) found that invisible incipient decay infections in seasoned and unseasoned oak ties and posts increased decay rate in service even though the decay in service was by fungi other than those originally in the oak tree. He also described top rot in hardwoods following snow damage (Roth 1941).

The Littleleaf Period, 1940-1943

The littleleaf disease, first described in 1932, was causing extensive decline of shortleaf pine in the Piedmont Plateau from Alabama to the Carolinas. Because of its distribution, research on it was assigned to the Southeastern Station and, by 1940, littleleaf research became a major effort of that Station.

Satellite Centers and Personnel

During the littleleaf research period, the Asheville staff consisted of Hepting, supervising the pathologists stationwide; Elmer Roth, who continued working mainly on various heartrot and canker problems; John S. Boyce, Jr., and before transferring to Athens, E. R. Toole. Josiah Lowe, on sabbatical leave from Syracuse, spent part of the 1949-50 school year identifying the wood-destroying fungi in the Asheville herbarium (Lowe 1961). Also, in the 1940's William C. Snyder, on sabbatical leave from the University of California, made a taxonomic study of Fusaria causing wilts of mimosa, staghorn sumac, and pitch canker of pines.

Before 1940, pathologists worked out of Asheville but in the 1940's satellite centers were started to place pathologists near the diseases assigned to them. The first satellite was at Athens, Ga. At first the pathologists were housed in the School of Forestry building, but in 1963, a well-equipped building was completed on the campus of the University of Georgia for all the Southeastern Station projects at Athens. This location permitted ready interchange of ideas with the university faculties in plant pathology, forestry, botany, and horticulture. This created a cultural atmosphere conducive to research--in contrast to such relatively isolated centers as Lake City and Gulfport, where cultural atmosphere must come largely from within.

Lyle W. R. Jackson and Thomas S. Buchanan were the first pathologists stationed at Athens, working mainly on littleleaf. Buchanan remained until 1944 when he joined the marines and Jackson resigned in 1946 to accept a professorship in the School of Forestry, University of Georgia.

In 1946 William A. Campbell reported to Athens and was in charge of the littleleaf studies. After 1954, he became the Director's representative for all the Forest Service projects at the Athens-Macon Center. Campbell was primarily a mycologist but also was involved in much of the pathology research. Starting in 1941, he spent two years at the Research Triangle Park as Project Leader for soilborne organisms, which project was moved to Athens in 1963. Campbell retired in 1971 and accepted a professorship at the University of Georgia.

Bratislav Zak reported to Athens in 1947 and was involved in research on littleleaf, cone rust, and mycorrhizae.

E. Richard Toole worked on the control of hemlock twig rust as a summer assistant in 1938. At Hepting's suggestion he selected the biology of the recently-found pathogen of mimosa wilt for his doctoral dissertation at Duke University. In 1941, he returned to the Southeastern Station on a permanent basis to work on the wilts of mimosa, sumac, and oak, and on the littleleaf disease of shortleaf pine. After a short stay at Athens, Toole moved to Alabama Polytechnic Institute, Auburn, Alabama, to establish another satellite center in proximity to serious littleleaf depredations. For a few years, Toole worked there on some of the soil aspects of littleleaf with the help of W. R. Boggess and Professor Ware of Auburn. The fact that both Athens and Auburn were in the Southern Station territory at that time was a minor point, since the Asheville office had assumed full responsibility for littleleaf research, and pathology was in the Bureau of Plant Industry, not the Forest Service. Toole transferred to the Southern Station in 1952.

Early in the littleleaf research, the soils aspects became so obvious that Hepting got permission from Washington to hire a soils expert and, as a result, Otis L. Copeland, Jr. became the first avowedly non-pathologist professional in the Division of Forest Pathology. From 1948 to 1953, Copeland was stationed on the Calhoun Experimental Forest, Union, S.C. where littleleaf was so severe that shortleaf pine seldom grew beyond pulpwood size. With the aid of Robert C. McAlpine, a geology major who later became an Assistant Director of the Southeastern Station, Copeland worked out the major relationships of soils to littleleaf. Similar to Lake City, Union was a temporary specialized location and no pathologists have been located there since 1953.

When Georgia and Florida were transferred to the Southeastern Station in 1946, the research program was broadened to include more southern pine diseases. Included in the transfer was the Lake City, Florida, Research Center where R. P. True was working on the fungal and physiologic disturbances associated with the naval stores industry. True continued these studies until January 1949 when he became professor of forest pathology at the University of West Virginia. Russell B. Clapper completed True's studies (1948-1953) at Lake City and also finished his earlier work on chestnuts resistant to blight. Clapper retired in 1953.

Not all research during the period 1940 to 1953 was on littleleaf. In addition to the naval stores work already mentioned, research included: Sapstreak of sugar maple; a blight of white pine later shown to be an air-pollution problem; the first appearances of Fomes annosus as a major pest; oak wilt; needle cast; nursery diseases; a new Cronartium stem rust of Virginia pine; and many diseases of minor importance.

During World War II, Hepting investigated discolorations of yellow-poplar aircraft woods and moisture problems in wood airplanes, and Roth investigated wood decay in boats. Roth, an excellent field pathologist, also continued his studies on various phases of heartrots and cankers until 1958 when he transferred to State and Private Forestry in Atlanta.

Near the end of this period George Hepting was assigned by the Bureau of Plant Industry, at the request of the Forest Service, to compile the forest disease section of the Timber Resources Review. tie was responsible for assembling all information on disease losses from the Forest Survey cull data from each Region along with data from such special surveys as those for oak wilt, pole blight, littleleaf, and sweetgum blight. These loss figures are valuable not only in setting research needs but also in estimating how much expected timber deficits could be offset by better disease control.

Walter Dwyer worked on Fomes annosus in 1948 and 1949.

In addition to Hepting's pathologist, two others spent considerable time in the Southeast. Bowen S. Crandall, who was under Washington supervision, had been working in Tennessee on the newly epidemic persimmon wilt and on a root problem of redcedar seedlings which later was shown to be caused by the seed-corn maggot. About 1940, Crandall moved to Athens, Georgia, still under Washington supervision, in connection with chestnut blight and persimmon wilt, and occupied space with L. W. R. Jackson and Thomas S. Buchanan, the latter two under Asheville supervision, working on littleleaf. A couple of years later, Crandall returned to Washington and William A. Campbell was added to the staff and put in charge at Athens. In addition to Bowan Crandall, another Washington pathologist spent considerable time in the Southeast. During the 1930's, 1940's and 1950's, Jesse D. Diller roamed through the southeastern and southern states establishing plots and making observations on Atropellis canker of pines, planting large numbers of oriental and hybrid chestnuts, and studying crawlspace moisture problems in buildings.

Research Since 1953

When the Division of Forest Pathology (Bureau of Plant Industry) was transferred to the Forest Service in 1953, Hepting became Chief of the Division of Forest Disease Research and maintained a unified control on all pathology research stationwide. However, he no longer reported to a pathologist in Washington, but to the Station Director. With Hepting's assignment to the Washington office staff in 1962, but still headquartered in Asheville, Harry R. Powers, Jr. became the division chief. When the assistant directorships replaced the divisions in 1964, Thomas S. Buchanan returned to the Southeast as Assistant Director for Fire, Insects, and Disease, remaining until his retirement in 1972. This still permitted at least some semblance of unified supervision of disease research. After Buchanan retired, the assistant directors were assigned geographic areas rather than subject matters. Thereafter, effective technical supervision dropped to the project leader level.

Personnel

In 1954, the pathology staff consisted of:

At Asheville:

George H. Hepting, Chief of the Division of Forest Disease Research.

Elmer R. Roth, Hepting's main assistant. In 1958, Roth transferred to State and Private Forestry in Atlanta.

John S. Boyce, Jr., working on needle cast, annosus root rot, and oak wilt. About 1961, Boyce resigned to accept a position at the University of Georgia.

W. A. Stegall, a former blister rust aide, reported in 1954 as a subprofessional and worked in the surveys of oak wilt, sweetgum blight, air pollution damage, and white pine blister rust. He died in 1968.

At Athens-Macon:

William A. Campbell remained as Project Leader and Director's Representative until he retired in 1971.

Bratislav Zak remained until 1962 when he transferred to the Pacific Northwest Forest and Range Experiment Station.

A. Alfred Foster, working out of Lake City, had such spectacular results in nursery disease control, saving two Georgia State Nurseries from abandonment because of root rot, that the Georgia State Forester offered to finance much of Foster's expenses and salary if he were moved to Georgia. As a result, Foster went to Athens for a short time then to Macon, Georgia, where the Georgia Forestry Commission was headauartered and near one of the largest tree nurseries. Foster spent the next few years (1953-1961) making a name for himself by cleaning up nursery disease problems by soil fumigation. Production at the Georgia nurseries was dramatically increased and weeding costs decreased by fumigation. Foster resigned in 1961 to accept a position with the Tennessee Valley Authority.

B. E. Hopper, about 1956, spent a year at Athens studying nematodes in nurseries before joining the faculty at Auburn University.

Many of the early pathologists had left by 1954: R. P. True was professor of forest pathology at the University of West Virginia, E. R. Toole transferred to the Southern Station in 1952; R. B. Clapper retired in 1953, Otis L. Copeland left in 1954; T. S. Buchanan enlisted in the marines in 1945 and after working in industry and Liberia joined the Washington staff before returning to Asheville in 1964 as an assistant director; and L. W. R. Jackson joined the School of Forestry at the University of Georgia in 1946.

Starting in 1955, considerable new young blood was added to the pathology staff:

W. Craig Bryan after completing a major study of defects in Piedmont hardwoods, joined the littleleaf staff at Athens in 1955 and later helped Zak with mycorrhizae research. Currently, he is working on endotrophic mycorrhizae in the Institute of Mycorrhizae at Athens.

Charles R. Berry came to Asheville in 1957 to study air-pollution, but also spent time on rehabilitation of littleleaf sites. Since 1971 he has been in the Institute of Mycorrhizae.

Charles S. Hodges, Jr. started working on nursery diseases under Foster in 1958. After getting his doctorate at the University of Georgia he went to Raleigh, N. C. on Soil Bank funds to help the states of North and South Carolina improve their tree nurseries by increasing production and reducing weeding costs through soil fumigation. Later he was transferred to the Research Triangle Park on annosus root rot. Hodges resigned in 1973 but returned after a foreign assignment and currently is at the Institute of Pacific Islands Forestry in Honolulu.

Frederick R. Matthews, previously a summer assistant on oak wilt in the early 1950's, developed controls for cone rust in seed orchards during 1958 to 1961 at Lake City. He is now at Athens on fusiform rust.

Samuel Rowan reported to Macon in 1958 on nursery diseases. In 1962, he returned to school at the University of Georgia and since 1968 has been at Athens on fusiform rust and root rot in nurseries.

Harry R. Powers, Jr., Hepting's chief assistant in Asheville from 1960 to 1962, became Chief of the Division of Forest Disease Research. After the Assistant Directorships were established, Powers transferred to Athens to develop methods for mass testing of pine seedlings for resistance to fusiform rust. Later, he became Project Leader for Diseases of Plantations and Seed Orchards, which currently includes all disease reseach at the Southeastern Station.

Elmer G. Kuhlman joined the Asheville staff in 1961. He is now at Research Triangle studying annosus root rot, fusiform rust, and more recently pitch canker and chestnut blight.

John L. Ruehle reported to Athens in 1961 and was assigned to the Soil-borne Disease project to study nematodes associated with tree roots. Recently, he has been working on mycorrhizae in the Institute of Mycorrhizae.

Donald H. Marx, while working on his master's degree in 1961, was an assistant to Zak on mycorrhizal studies at Athens. He moved to the Research Triangle in 1963 while completing his doctorate at North Carolina State. He returned to Athens in 1966 as a member of the Soil-borne Organisms project under Campbell. On Campbell's retirement in 1971, Marx became Project Leader until 1976 when the project was reorganized as the Institute of Mycorrhizae with Marx as Director.

Guy V. Gooding, Jr., joined the Research Triangle staff in 1962 to work on serology, viruses, and fusiform rust. In 1965, he joined the faculty of North Carolina State University.

F. F. Hendrix spent 1962 to 1964 in Asheville on annosus root rot. Since then he has been in Plant Pathology at the University of Georgia.

Ronald W. Roncadori was on the rusts, nursery, and hardwood disease project at Macon and Athens from 1963 to 1966, and then went to Plant Pathology at the University of Georgia.

Thomas Miller started in 1964 at Macon and worked on site effects of fusiform rust. Then, after two years at the Research Triangle on his doctoral program, he transferred to Athens were he is currently on seed disease problems under Powers.

Eldon W. Ross spent 1965 to 1971 at Athens on annosus root rot after which he went to Washington as Assistant in the Division of Forest Insect and Disease Research. He was Assistant Director at the Northeastern Forest Experiment Station for Continuing Research Programs in Ohio and Pennsylvania, until returning to Asheville in March 1979 as Station Director.

Jerome W. Koenigs was at the Research Triangle from 1966 to 1977 on basic research on the biochemistry of wood decay and the physiology of decay fungi. He also worked on annosus root rot and other problems. He resigned in 1977, and accepted a position with the International Paper Company.

L. David Dwinell reported to Athens in 1966 and worked on fusiform rust. From 1968 to 1972 he took over responsibility for INTREDIS from Hepting and currently is under Powers on fusiform rust and pitch canker.

Otis C. Maloy, Fields Cobb, Arthur Rhoads, and W. A. Costonis also spent short periods at the Southeastern Station during this period.

Research Problems

Littleleaf, heartrot, black root rot, and some other diseases given concentrated attention in the past remained important factors in forest management but did not require further intensive research. By 1950, a host of new problems appeared that required immediate research effort by pathologists. Oak wilt threatened to devastate the oak forests; sweetgum blight became common throughout the host range; cone rust impeded seed production in seed orchards; white pines were dying from what later was shown to be air-pollution damage; annosus root rot increased in importance as more southern pine plantations reached the thinning stage; and fusiform rust had become a formidable factor.

Some of these, as oak wilt and sweetgum blight, have ceased to be major problems; cone rust and black root rot remain important but are kept in bounds by economical controls; others, as fusiform rust and littleleaf, remain vexing problems requiring intensive research, and some, as pitch canker and annosus root rot, remain important problems locally. Currently, fusiform rust is the major research subject at both the Southern and Southeastern Stations. Originally, research on this rust was assigned to the Southern Station but in the 1960's, forestry interests in the Southeast requested that research be expanded to include the Southeastern Station also and, as a result, the two stations have teamed up for a concerted attack on this No. 1 disease of southern pines.

The pathology satellite centers at Auburn, Union, and Macon were closed by 1953 or soon thereafter. Lake City was inactive after Clapper's retirement in 1953 until Frederick R. Matthews was stationed there (1958-1961) to develop controls for cone rust. Since his transfer to Athens in 1961, no pathologists have been stationed at Lake City. This center, the logical choice for the naval stores studies, is too isolated for most long-time pathology research.

A new satellite was established near Raleigh, N. C., in 1962, in the Research Triangle Park, with a primary function to study soil-borne organisms. Prior to 1962, pathologists on this project had been temporarily located at Chapel Hill and Raleigh, N.C. The Research Triangle was intended to be the main research center for forest disease research in the Southeast, but circumstances dictated that the Athens Center assume this responsibility. In 1963, the main soil-borne organisms project was transferred to Athens and the

Research Triangle concentrated on annosus root rot, although other studies included pitch canker, basic research on wood decay, and recently, chestnut blight. The pathology staff at the Research Triangle was reduced to one pathologist in 1977 under the supervision of Powers at Athens. Thus, forest disease research currently is concentrated at the Athens Research Center.

Research Results

Research findings during the early and CCC periods already have been considered under those sections. Also, no attempt is made to include all findings of the many minor researches or any findings after 1975. Thus, the evaluation of such studies as the recent ones on the effect of mycorrhizal fungi on growth of plantation trees is left to future historians. The most significant reports during the first 40 years of pathology research, as seen by George Hepting, are included in the following lists he gave me. These lists are, with some editing:

The Most Exciting Research Results

1. Putting together the jigsaw of hundreds of matings that established the sex and compatability makeup of the oak-wilt pathogen.

2. Proving that actidione and phytoactin are ineffective in blister rust control and convincing the Forest Service and wide commercial and governmental interests of this.

3. Proving that most butt rot in sprout oaks comes from the parent stump, not from dying appended sprouts.

4. Showing a clear association between stack gas from soft-coal-fired power plants and the killing of pines in Tennessee and Pennsylvania.

5. On a first long-chance gambit, discovering and propagating wilt-resistant mimosa trees.

6. Finding the cause of failure in wood training aircraft (WW-II), that grounded all PT-19's and PT-10's until the cockpit wash-water practice was stopped.

7. Developing fumigation of nursery beds, saving southern nurseries and revitilizing southern nursery practices.

8. Perfecting the first electronic literature storage and retrieval system in forestry.

The Most Valuable Research Results

1. Showing the relation of butt rot to wound age and size in oaks.

2. First enunciating the theory of compartmentalization of heart rot in trees in 1935.

3. Relating changes in climate to oak decline, sweetgum blight, pole blight, maple decline, ash dieback, et al.

4. Establishing the techniques used in the current testing of southern pine seedlings for resistance to fusiform rust.

5. Proving that ozone, in addition to soft coal stack gases, is a major air pollutant affecting conifers.

6. Producing the compendium on American tree diseases.

7. Discovering the causes of, and naming the pathogens of several new diseases: pitch canker, two hemlock blights, stem rust of Virginia pine, mimosa wilt, sumac wilt, and nectria canker of yellow-poplar.

Cankers

Nectria and Strumella, the most important canker fungi on Southern Appalachian hardwoods, were important factors in the CCC timber improvement operations, even though little was known about handling them. Among the researches started in the CCC period was a longtime field study on the effects of eradicating cankered trees on subsequent cankering. Eighteen years' observations showed that eradication was unnecessary with Nectria and ineffective against Strumella (Roth and Hepting 1954). They concluded that the best handling consisted of selecting canker-free trees for crops trees and utilizing cankered trees in thinning operations.

Pine Pitch Canker. In 1946, Hepting and Roth reported a new canker on Virginia pine, in which the causal fungus rapidly kills or seriously deforms leaders, branches, and sometimes the main stem. The causal Fusarium later was named F. lateritium f. pini (Snyder et al. 1949). Innoculations proved the susceptibility of all major southern pines except loblolly (Hepting and Roth 1953). South Florida slash pine also has been seriously affected (Bethune and Hepting 1963).

Chestnut blight never was a high priority on the research program at the Southeastern Station. As already mentioned, Humphrey and Nelson did some work on the rate of deterioration and tannin content of blight-killed chestnuts. Also Nelson and Diller planted several thousand exotic and hybrid chestnuts, and later, under Hepting the best six lines of our many Chinese chestnut imports were planted under more controlled conditions. In recent years, a search was being made for living American chestnuts that might be resistant. When Clapper joined the Lake City staff in 1948, he continued his interest in possible resistance in American and Asiatic chestnuts and various hybrids. He had been active in the field for almost 25 years, working with R. Kent Beattie and Diller. Nothing very promising in terms of forest trees came of this research (Diller and Clapper 1965).

During World War II, the Southeastern Station pathologists submitted a detailed investigative report, requested by The War Production Board, on the amount of chestnut wood available for tanning leather, and how long the supply would last. The rate of deterioration of blight killed chestnut was redetermined. Rot progressed at the rate of 1.5% per year while loss of tannin content was 3.5% per year but more as decay increased (1951. Southeastern Sta. Ann. Report).

Kuhlman recently has reactivated chestnut-blight work at the Research Triangle, checking on European claims of natural abatement of the blight there through changes in the causal fungus.

Heartrots

As already pointed out, heartrot was a major field of investigation at the Southeastern Station during the early and CCC periods. However, several important studies were reported during the 1940's and 1950's:

1. Decay, discoloration, and cankering follow increment boring of hardwoods and to a much less extent pines (Hepting *et al.*, 1949).

2. Fruiting of decay fungi on felled trees (Hepting and Roth 1950). Some fruiting, particularly *Fomes*, occurs up to 5 years after felling but, never-the-less, felling conky trees is a good sanitation measure.

3. Decay following thinning of sprout oak clumps (Roth 1956), as influenced by sprout diameter and crotch type.

4. Healing and defects following oak pruning (Roth 1948) as influenced by season and wound width. Earlier, Roth and Hepting (1943b) reported on the rate of healing when large companion sprouts are removed and on the chances of decay in the remaining sprout.

5. Origin and development of oak stump sprouts as affecting their decay hazard (Roth and Hepting 1943).

6. Developing a formula to correlate the rate of butt rot development in oak with the age and size of fire wounds (Hepting 1941). This publication is one of the most significant heartrot reports.

7. A number of taxonomic reports of decay fungi by Campbell with Davidson and others.

Littleleaf Disease of Shortleaf Pine

In 1940, after Siggers (see Southern Station Pine Disease Project} made the original survey, described the disease, named it littleleaf, and recognized it as a root disturbance, research on littleleaf was assigned to the Southeastern Station. Hepting initiated a major, multifaceted research attack on this serious and complex disease. During the 1940's and early 1950's, most of the pathologists at the Southeastern Station did at least some work on littleleaf but only the key people will be mentioned here. Hepting directed the program and worked on the management of littleleaf stands and on the nutritional phases; Campbell concentrated on the fungus features; Copeland studied the relationship of soils to the disease; Zak, and later Bryan, studied the possibility of resistance to littleleaf in shortleaf pine. These researches, based on surveys, permanent plots, and laboratory and greenhouse studies, resulted in a wealth of basic and practical information reported in many publications. In the nutritional studies (Roth, Toole, and Hepting 1948), nitrogen was the only soil amendment that helped relieve symptoms and was the only element found to be largely deficient in littleleaf trees.

Campbell and Copeland (1954) summarized the knowledge of littleaf disease in USDA Circular 940. In essence, the symptoms of littleaf are an expression of nitrogen starvation as a result of the death of feeder roots by attacks of Phytophthora cinnamomi, favored by heavy, poor soils with low internal drainage and aeration. Also included in the circular are discussions of symptoms, distribution, the handling of diseased stands, breeding for resistance, and soil rehabilitation.

About 1950, George A. Zentmyer, on sabbatical from the University of California, helped Campbell in identifying Phytophthora species associated with littleleaf disease and forest soils.

The management of littleleaf stands (Campbell, Copeland, anu Hepting 1953) includes predicting hazard by soil series and condition, and proposes that cutting cycles be based on severity of attack if a maximum of wood is to be salvaged. Long-time solution may be soil rehabilitation by favoring soil building hardwoods to create more favorable soil organic content and micro-flora populations (Hepting and Jemison 1950) and possibly the development of resistant strains of shortleaf pine (Bryan 1965).

Wilts

Oak wilt. In the early 1950's oak wilt attracted considerable attention, leading to research programs by several States, notably Arkansas, West Virginia, Missouri, and Wisconsin. In the South and Southeast, Federal research was concentrated at the Southeastern Station. They conducted the early surveys from Virginia to Arkansas in 1951 and 1952. Later the States assumed responsibility for surveys and control programs. Most of the Southeastern Station's survey from 1953 to 1957 primarily were to check the effectiveness of control programs and to determine spread in specific areas.

Research, including that based on surveys, included:

1. Sexuality of the causal organism (Hepting, Toole, and Boyce 1952; Boyce and Garren 1953), including information on the distribution of sexual forms A and B within trees and infection centers. These findings partially explain slow overland spread and were valuable in interpreting field results.

2. Felling diseased trees, spraying the logs and large branches with a mixture of pentachlorophenol and BHC in fuel oil and treating the stumps with ammate greatly reduced insect dissemination (Boyce 1959).

3. Summer-felled trees form no fruiting mats the following spring when most insect activity occurs (Boyce 1954).

4. Longevity of the fungus in oak lumber cut from diseased trees (Englerth, _et_ al. 1956). Steaming, kiln drying, and air seasoning to 20 percent moisture or less killed the fungus, but it can live for several months in logs and lumber before the wood is dried or otherwise treated.

5. Hepting summarized research on and the status of oak wilt in the United States (Hepting 1955).

During the past two decades, oak wilt has subsided, followed by corresponding reduction in research effort. However, mysteries remain. Is the pathogen a widely distributed, native organism, with a weak means of dissemination that flared up because of an unknown temporary environmental factor? This gains some credence by the fact that oak wilt appeared first, and was most severe in the transition zone from forest to prairie where it previously had been without causing appreciable damage. Whatever the answer, the oak-wilt fungus can be highly virulent, and given a more efficient disseminating agent and favorable environmental conditions, could devastate our oak forests.

Mimosa wilt first described by Hepting in 1936, soon threatened to and almost did wipe out mimosa in much of the Southeast and South. Research by Toole, Hepting, and Snyder included the taxonomy of the causal *Fusarium* (Snyder *et. al.* 1949), the life history of the pathogen, variability in culture and in virulence, pathogenicity in various tree species (Toole 1941), and the development of resistant strains of mimosa (Toole and Hepting 1949). The development of virtually immune clones of mimosa is important because it is the first demonstrated instance of very high resistance to a fungus pathogen within a tree species. The resistant strains have stood up remarkably well in widespread ornamental use for 30 years.

Staghorn Sumac Wilt. The causal Fusarium was found in 1948, and named as a new form of Fusarium oxysporium f. rhois (Snyder et al. 1949). The history, symptoms, and etiology of this wilt was summarized by Toole (1949).

Nursery Diseases

When Foster reported for nursery disease work, pine nurseries in Georgia were in such a precarious condition that abandonment of some was being considered. Black root rot was the main culprit. Foster established some practical soil fumigation trials and later studied such practices as irrigation, fertilization, and seed bed density as affecting disease and yield. Being essentially an extension pathologist, Foster implemented his findings and soon the Georgia nurseries were in a healthy, viable condition. The published reports of Foster's findings are meager in comparison to their importance. However, he did report: (1) Soil fumigation to control black root rot (Foster 1961); (2) Reducing the number of ferbam sprays to control fusiform rust by timing sprays with weather suitable for infection (Foster and Krueger 1961); and (3) Fungicidal spray control of Phomopsis blight of Arizona cypress (Foster and Harrison 1957). Foster also prepared the original version of Forest Pest Leaflet No. 32 on nursery disease of southern pines.

Hodges, who started his nursery studies under Foster, solved many disease problems in nurseries in North and South Carolina much as Foster had done in Georgia. Later he reported on a number of research findings: (1) The effect of nursery infection with *Phomopsis juniperovora* on the survival of junipers on outplanting (Hodges and Green 1961); (2) Subjecting pine seedlings to prolonged periods of subfreezing temperatures during transit and storage, greatly reduces survival on outplanting (Hodges 1961); (3) Fungi isolated from nursery soils over a 5-year period (Hodges 1962); and (4) Proof that *Sclerotium bataticola* and *Fusarium oxysporum* cause black root rot (Hodges 1962). Hodges also published several purely mycological papers.

Nematodes

At both the Southern and Southeastern Stations, pathologists studying nursery diseases knew that nematodes commonly were associated with tree seedlings. A survey of nurseries in 1956 and 1957 showed that a number of genera of nematodes were potentially parasitic on pine roots, but obvious damage was associated only with *Meloidodera* and *Tylenchorhynchus* (Hopper 1958). Hodges (1958) reported that soil fumigation eliminates parasitic nematodes for a year while non-parasitic ones repopulate the soil rapidly. At Lake City pine seedlings were found to be undamaged by a hot water treatment that kills cyst nematodes.

However, it wasn't until John L. Ruehle, nematologist, joined the pathology group at Athens in 1961, that the real role of nematodes began to emerge. From surveys of nurseries, plantations, and natural stands, made from 1961 to 1963, and from the literature, Ruehle cataloged the nematodes associated with southern pines and with other conifers and southern hardwoods. Greenhouse tests showed that some nematodes can damage seedlings: (1) Several genera on southern pines; (2) A sting nematode on sycamore; and (3) A dagger nematode on sweetgum. This work was summarized by Ruehle (1973).

Ruehle and Marx found that a lance nematode parasitizes the ectomycorrhizae of pines. In relationship to littleleaf disease, Burham, Marx, and Ruehle (1974) showed that nematodes, by breaking the fungal mantle, create points of entry for Phytophthora cinnamomi. Ruehle has summarized the information on the association of nematodes and forest trees (Ruehle 1973). He concludes that nematodes can interfere with normal mycorrhizal formation by damaging the root cortex, by suppressing the mycorrhizal fungus, and that parasitic nematodes may directly or indirectly cause pathological symptoms commonly attributed to such factors as poor soil, drought, soil erosion, and compaction.

Mycorrhizae

Mycorrhizal studies started in the late 1940's when Jackson (1947) devised a differential stain for mycorrhizal roots, but it wasn't until the 1960's that intensive mycorrhizal research started in the Southeast. A number of mycorrhizal fungi were isolated from southern pines, and Bryan and Zak (1961) synthesized mycorrhizae in culture flasks. Methods were developed to isolate mycorrhizal fungi from roots (Zak and Bryan, 1963; Zak and Marx 1964). Marx, Zak, Bryan, and Davey (the latter of the University of Georgia) determined the effect of pH (Marx and Zak 1965) and of temperature (Marx *et al*. 1970) on mycorrhizal formation.

Marx and Bryan (1969) devised a growth chamber in the greenhouse where air-filtering, fumigating, and air-conditioning made it possible to study mycorrhizal phenomenon under more controlled conditions. The same year, Marx and Davey published in volume 59 of Phytopathology a series of papers on the influence of ectotrophic mycorrhizae on the resistance of pine roots to infection by pathogenic fungi. One fungal symbiont produced an antibiotic which at 2 ppm totally inhibited the littleleaf fungus and at higher concentrations was lethal. In a second paper he showed that several mycorrhizal symbionts in agar plates inhibited the growth of about half of 48 root pathogens tested. In the third and fourth papers

Marx and Davey showed that roots with mature mycorrhizae are resistant to _Phytophthora_ but those with incipient mantles become infected. Since _P. cinnamomi_ is a common soil fungus, and all mycorrhizae start with incipient mantles, the effect of mycorrhizal fungi on infection seems minimal. Later, Ross and Marx (1972) reported that mycorrhizal roots of sand pine also are resistant to _P. cinnamomi_. As already mentioned, Ruehle and Marx reported that lance nematodes parasitize mycorrhizal mantles and permit infection by the littleleaf fungus.

Most of the mycorrhizal studies at Athens were under the Soil-borne Organisms project, but recently the mycorrhizal phases have been separated in the Institute of Mycorrhizae, a Research and Development project with country-wide studies aimed at improving planting survival and growth by ensuring that seedlings have a suitable mycorrhizal fungus present when planted. Marx is Director.

Sweetgum Blight

The Southeastern Station, in 1954, sponsored, with the cooperation of Southern and Northeastern Stations, a survey of sweetgum stands from Maryland to Louisiana (Hepting 1955a). Severe dieback commonly was found throughout the range of sweetgum. Studies by F. H. Berry (Bureau of Plant Industry) had eliminated fungi, viruses, nematodes, and nutrients as the probable cause. Toole and Broadfoot (see Southern Station hardwood project) showed that blight was a response to moisture shortages, particularly on certain soil types. Decline stopped with the return of normal rainfall, and what threatened to be a major problem in 1954, essentially disappeared a few years later.

Air-Pollution Damage

A new disease of eastern white pine--characterized by browning of new needles from the tips, reduced growth, and sometimes death--began to cause concern in the Southeast about 1945 (Toole 1949a). Later it was found that at least two troubles were involved (Hepting and Berry 1961). Emergence Tip Burn, resulted from ozone damage during periods of high atmospheric oxident content (Berry and Ripperton 1963) and Post-Emergence Chronic Tipburn (PECT). PECT is due to air-pollution. In cooperation with TVA, University of Tennessee, and the Tennessee Division of Forestry, a study was undertaken in 1957 to ascertain the cause of PECT. Pruning, fertilization, transplanting, isolating from roots and stems, foliage analysis, and grafting, eliminated adverse soil conditions, severe climate, or pathogenic organisms as the cause and pointed to stack gasses from TVA's Kingston coalburning power station as the probable cause (Berry and Hepting 1964). Recent observations in the worst damage areas show that most susceptible white pines have been eliminated, but many individuals remain that resist PECT, and these have been reproduced by grafting to comprise a seed orchard. Hepting has summarized the impact of air-pollution on trees (Hepting 1971b).

Products Pathology

Although fungus deterioration of forest products was never a major field at the Southeastern Station, some noteworthy results have come from there. Already mentioned is Roth's report that invisible incipient decay increases the decay rate of oak ties and posts even though the decay in service is by different fungi than those present in the incipient decay (Roth 1943).

Hepting (1945) studied decay and stain in stored peeled and rough southern pine pulpwood as influenced by different storage methods.

Wood planes were the mainstay of the Army Air Corps Pilot Training Program in WW-II. Moisture problems at one time grounded many planes. Hepting (1944) determined that washwater in cockpits was the main source of water leading to decay, but rain and splash from wet runways also were factors. Revised washing procedures corrected the main fault. Keeping grommets open helped drainage, and the use of marine-type grommets reduced the entry of splash water.

Yellow-poplar aircraft veneer was in short supply because grading rules eliminated discolored wood. Hepting, Roth, and Luxford (Forest Products Laboratory) (1942) determined the effect of discolorations on strength and the results increased acceptable wood by 25 percent. Red, yellow, lavender, purple, grey, and green discolorations did not reduce strength; brown and black discolorations or roughened surfaces indicated decay and reduced strength.

After World War II, the Navy stored many wooden boats for possible future use. Decay soon became a problem. Carl Hartley (Beltsville) headed a project to determine if the deterioration could be reduced. Elmer Roth, under Hartley's direction, made observations and conducted tests on stored boats along the South Atlantic coast. Roth and Hartley (1957) reported to the Navy that dynamic dehumidification of hulls protected most interior members above the water line and that fungicides in the bilge water helped protect below water parts but only a rain shelter over the boats would protect exteriors.

Although not engaged in building decay research, the Housing Project (Forest Utilization Service) at Athens reported on studies of moisture conditions within frame walls under more controlled conditions than had been possible in the Southern Station's building decay studies.

Naval Stores

Fungus Stimulation of Gum Flow. Soon after pitch canker was found in 1945, Hepting recognized that the then unidentified *Fusarium* causing the canker, might have value in the naval stores industry. So in June 1945, he inoculated some turpentine wounds with *Fusarium* and found increased gum flow on longleaf, Virginia, and shortleaf pines (Hepting 1947). He took out a public patent on the fungus stimulation of gum flow to prevent private exploitation. Further inoculations made at Lake City by True and Snow, as already discussed in research at the Southern Station, showed similar stimulation of gum flow, particularly on slash pine. After True left in 1949, R. B. Clapper continued the studies. He summarized the researches (Clapper 1954): (1) For a short period Fusarium-inoculated trees yielded more resin than acid-treated faces, but, over a period of a year, the two yielded about the same amount. (2) Among various isolates tested, two mutants stimulated more than the parent isolates and metabolic products of the *Fusarium* caused insignificant stimulation. (3) Pitch soaking of wood back of inoculated faces might be developed to practical use for solvent extraction. He also included a review of previous research.

Dry Face. *Diplodia pinea*, *Gloeotulasnella pinicola*, and *Ceratostomella ips* can cause "dry face" although drought and other non-pathogenic factors are the prime causative agents (True 1947).

Pitch Streak. Stain, pitch soak, dry wood, and rot commonly occur as streaks extending well above turpentine faces, particularly when dry face occurs (True and McCulley 1945). Cobb (1957) found that pitch streak occurs mainly in trees of low vigor on droughty sites, particularly when faces are wood chipped. It is primarily a physiologic disorder and was epidemic during the dry years of the mid-1930's and mid-1950's.

Fomes annosus

Annosus root rot was found in several thinned white pine plantations in North Carolina (Hepting and Downs 1944, Boyce 1962). Sporulation was reported every month of the year. Other reports and surveys included *F. annosus* on *Pinus rigida* (Roth 1952) and on redcedar, particularly on eroded soils where the fungus was fruiting on pine stumps (Dwyer 1951). By 1960, when extensive pulpwood plantings of slash pine had reached the thinning stage, *F. annosus* damage reports began coming from many locations, and it was obvious that annosus root rot would be an important factor in the management of southern pine plantations. To prepare for a comprehensive research program, a southwide survey of southern pine stands was made in 1960-61 with the cooperation of the Southern Station. This survey (Powers and Verrall 1962) furnished much of the practical information available on annosus root rot of southern pines. Root rot was more severe in thinned stands on old field sites with coarse-textured soils, deep A horizons, deep litter, and on slopes. At the same time, a research program on *F. annosus* was initiated which extended into the 1970's. Findings included:

1. Kuhlman and Hendrix (1962) devised a selective medium for isolating F. *annosus*.

2. Studies of the factors affecting colonization of stumps and the development of *Fomes annosus* in stumps and roots were conducted by Kuhlman, Hendrix, Hodges, and Ross. Inoculation with spores was more successful than with mycelial fragments. Loblolly pine stumps were susceptible to infection for 12 days in February. Thereafter, *Peniophora gigantea* increased so rapidly that *F. annosus* was

suppressed. P. gigantea was very active in replacing F. annosus in naturally infected stumps and roots. Other fungi, including Trichoderma viride, and bacteria apparently have no limiting effect on F. annosus. Ross (1973) summarized the information on the relationship of environmental and biotic factors to stump colonization and losses in residual stands.

3. Some stump treatments with creosote and ammonium fluoride were established in 1962 and later with borax (Hodges 1970). Only borax significantly reduced infection. In laboratory tests, borax had very low toxicity to F. annosus. Therefore, some mechanism other than toxicity must explain the effectiveness of borax on stumps (Koenigs 1969).

4. F. annosus can attack and kill 3-year-old slash pine seedlings (Ross and Hodges 1964).

5. Some differences in susceptibility among southern pine species occurs, but the differences are not considered of practical significance (Hodges 1969; Kuhlman 1970).

6. Kuhlman reported on: (a) greenhouse inoculations (1969), (b) the number of spores needed for stump infection (1969), (c) survival of spores in soils (1969a), (d) artificial

inoculations, in which some variation in virulence and host susceptibility was found among isolates from several countries (1970), and (e) successful regeneration of pines on annosus-infested sites (Kuhlman and Ross 1970). In contrast to "d" above, Koenigs (1970) reported no practical differences in infectivity among isolates from six countries.

Even though _F. annosus_ commonly fruits on stumps on low- and high-hazard sites, infection and death of residuals is significantly greater on high-hazard sites (Kuhlman 1973).

7. In laboratory tests with pine bolts, _F. annosus_ was suppressed at 35°C and killed at 40°C, indicating that high temperatures may play a role in survival in stumps (Gooding 1964). In wood chips, _F. annosus_ was killed at 40°C in 2 hours. Because stump surfaces reach 40°C or higher for periods of at least 2 hours on more than 50 percent of the days in May through August in the Southern pine belt, temperature can limit stump infection during summer (Gooding et al. 1966). Later, Ross (1969), after further laboratory trials, suggested that neither conidia nor basidiospores are expected to survive on stump surfaces more than 1 hour at 45°C and 95 percent relative humidity. These studies have led to practical suggestions that summer thinning on high-hazard sites will reduce root rot losses.

8. Hendrix and Kuhlman (1964) reported some direct root infections on slash pine but infections through adjacent stumps are more common.

9. Hodges (1969a) summarized the information on infection and spread of *F. annosus*. The Southeastern and Southern Stations translated the latest research information into practical guides to minimize losses from *F. annosus* (Kuhlman *et al.* 1976 and Froelich *et al.* 1977). These publications describe the determination of site hazard and the use of borax stump treatment, summer thinning, prescribed burning, species substitution, etc., in order to reduce losses.

Rusts

White Pine Blister Rust was first reported in North Carolina in 1945. Yost (Plant Disease Control, BPI) and Hepting cooperated in laying out plots to study rust spread. In the 1950's, pathologists of the Southeastern Station made a survey to assess damage and assisted the State of North Carolina and the North Carolina National Forests with Ribes surveys to establish hazard areas and advise on methods of Ribes eradication. Many areas harboring white pine and Ribes were shown to pose no blister rust hazard because of high summer temperatures, and thus Ribes eradication was not needed.

The Southeastern Station's important contribution on white pine blister rust came later when they proved that the cycloheximide systemics were ineffective in controlling blister rust (Powers and Stegall 1965). After some discussion, this finding was accepted and actidione and phytoactin were removed from control programs; but not before millions of dollars had been spent on their use.

Cone rust, although known for many years, did not assume importance until research on southern pine breeding was started, and when seed orchards became a reality. Then, periodic heavy losses from rust demanded control. The Southern Station attacked it from the research geneticist's point of view, i.e. bagging flowers; the Southeastern Station attacked it in terms of seed orchard protection, i.e., fungicidal control. At the start, fungicidal protection seemed a ticklish operation because rust spores and pollen coexisted on receptive pistillate flowers, requiring a selective fungicide lethal to the spores but harmless to the pine flowers and pollen. Spray trials, started in 1957, showed that ferbam prevented rust infection and not only did not harm pine flowers but actually stimulated pollen germination (Matthews and McLintock 1958). Matthews (1964) summarized the information on cone rust, including research results on daily sporidial counts, the effect of weather on sporidial production, fungicidal spray schedules, and the effect of fungicides on seed set and seed germination.

Fusiform rust. Even though the Southeastern Station did not engage in major research on fusiform rust until the mid-1960's, they earlier discovered that: (1) Aeciospores will not infect pines (1949-50, SE Annu. Rep.); (2) Fusiform rust can be an important obstacle to establishing grafted seed orchards (Campbell et al., 1962); (3) Actidione is ineffective against fusiform rust (1961, SE Annu. Rep.); and (4) Fungicides can control the rust in nurseries (see Nursery-Disease section). Since 1965, fusiform rust has been the subject of major disease research. Serological tests showed that C. fusiform and C. quercuum differ in at least one antigen (Gooding and Powers 1965), but separation on the basis of gall shape is uncertain (Powers 1971). Dwinell (1971) showed that black oak seedlings of known resistance to C. fusiforme, can be used to separate the two species. Powers (1969) inoculated 16 pine species with C. fusiforme and C. quercuum and found Jeffrey, Monterey, and ponderosa pines were susceptible to fusiform rust. Since these pines and the California black oak are susceptible, fusiform rust could be a threat to western pine forests (Dwinell and Powers 1974). Later tests established more fully, the relative susceptibility of six pines native to the Carolinas (Power 1975).

Dwinell rated the susceptibility of 24 species of southern oaks to *C. fusiforme* and *C. quercuum* based on the number of telia produced following aeciospore inoculation (Dwinell 1974). Water and willow oaks were highly susceptible to *C. fusiforme* and 10 species reacted significantly differently to the two rust forms.

Many studies on spores were conducted: (1) Abjection of secondary sporidia (T. Miller and Roncadori 1966); (2) The effect of telial column age on germination and sporidial production (Powers and Roncadori 1966); (3) Storage and germination of aeciospores (Roncadori and Matthews 1966); (4) Secondary and tertiary sporidia can infect pine (Roncadori 1968); (5) Sporidia can remain viable up to 8 weeks at 5°C (T. Miller 1970).

Other Research included:

1. Powers and coworkers also reported on volume loss from fusiform rust in young slash pine plantations (Powers *et al.* 1974).

2. T. Miller (1972) confirmed Siggers' report that intensive site preparation increases rust hazard. Site class, however, had no effect.

3. Powers (1968) found that the distance of cotyledon infection from the stem determined if infection will reach the stem because, if too far out, normal cotyledon death occurs before the rust reaches the stem.

4. Koenigs (1968) reported that under some conditions, telial germination and sporidial discharge can occur faster than previously reported. This finding, plus the rapidity of seedling growth exposing untreated tissue, may explain occasional fungicidal failures.

Southeastern Station's Research and Development Program perfected a technique for large-scale testing to determine resistance of southern pine selections to fusiform rust (Matthews and Rowan 1972, Powers 1974). The R&D personnel prepared a detailed manual covering all phases of the test procedure. The testing program, available to State and industry, as well as Federal Agencies, is being operated at Bent Creek, N.C., by the USDA Forest Service's State and Private Forestry.

Recently, most research effort is on the selection of southern pines resistant to fusiform rust and their establishment in seed orchards. A relatively recent finding affecting such a program was the discovery of physiologic races of *C. fusiforme* differing in pathogenicity. Much of this work is being done jointly with the Southern Station.

Miscellaneous Rusts. The hemlock twig blight, caused by *Melampsora farlowii,* caused heavy losses in nurseries in the mid-1930's. Hepting and Toole (1939) describe symptoms and defined the range, importance, etiology, epidemiology, and fungicidal control. The control measures are now in general use. *Cronartium appalachianurn* on Virginia pine was described as a new species, with *Buckleya distichophylla* as the alternate host (Hepting 1957). In 1967, Powers reported that *Cronartium comandrae* was causing important damage to loblolly pine in eastern Tennessee. Later work evaluates resistance of various southern pines and recommends species for use on high hazard sites (Powers 1972).

Miscellaneous Diseases

Needle Blight. Boyce wrote his doctoral thesis on *Lophodermium pinastri,* finding that it was essentially nonpathogenic on southern pines. He continued his interest in needle blights at Asheville, proving that the brown-spot fungus was responsible for needle blights of loblolly and eastern white pines and that *Hypoderma* lethale caused a similar blight of at least six species of southern pines. Boyce (1958) summarized and gave references to these researches in Forest Pest Leaflet 28.

Defects in Piedmont Hardwoods. W. C. Bryan (1960) extensively studied defects in Piedmont hardwoods from 1955 through 1958 by external examination of many trees and 16 mill-scale studies. The factor most influencing defects was small size of trees, particularly as influencing epicormic and adventitious branching, small knots, and stem distortions. Cankers, rot, bird peck, and insect damage were less important than tree size.

Roth (1950) studied the possible causes of discolorations in living yellow-poplar trees, finding that bacteria, commonly present in discolored heartwood, were not responsible. Discoloration follows wounding, broken branches and tops, fire scars, insect injury, and logging damage. The common stains in yellow-poplar apparently are mineral stains resulting from oxidation phenolic reactions.

Spot Die-Out of Loblolly Pine. Planted stands of loblolly pine, particularly on heavy Piedmont soils, after normal growth, suddenly fade and die. Copeland and McAlpine (1962) ascribe die-out to localized unfavorable soil, i.e. poor aeration and permeability leading to root mortality. Thus, it resembles littleleaf, but apparently without pathogenic involvement.

Sapstreak of maple, which caused epidemic dying of residual maples following logging, was first observed about 1940 on the Pisgah National Forest (Hepting 1944) and later in a number of localities in the Lake States. The causal fungus, Endoconidiophora virescens, is identical to or closely related to the common sapstain fungus on southern hardwood lumber. Roth (1951) found lumber from diseased maples dipped in a sapstain-control fungicide and air seasoned, can be shipped safely to other maple-producing areas.

Literature Storage and Retrieval

Prior to 1940, the number of forest pathologists was small and the literature in the field correspondingly meager. Most pathologists were familiar with the entire domestic and foreign literature on forest pathology. Presently the literature has become so voluminous that a pathologist can keep abreast of only a small specialized segment of it. George Hepting recognized this problem and, in the early 1960's, developed the Internatinal Tree Disease Register (INTREDIS) system of electronic storage and retrieval of the world literature on forest pathology (Hepting 1967). With the help of several pathologists, particularly V. J. Nordin of Canada, the literature abstracted in the Review of Applied Mycology, Forestry Abstracts, Biological Abstracts, and Abstracts of the Air Pollution Control Association was coded, put on cards, and transferred to tape. The code included subject, host, country, pathogen, and abstracting journal. The tapes were stored at Asheville under Hepting's supervision until 1968 when L. D. Dwinell assumed responsibility. In 1972, the storage tapes and responsibility were transferred to the National Agriculture Library in Washington to amalgamate INTREDIS with several other related literature retrieval banks.

UNIVERSITIES

Forest disease research in the South and Southeast was dominated by the U.S. Department of Agriculture (BPISAE and later FS), until the universities began adding forest pathologists to their faculties, either in their departments of plant pathology or forestry schools. Many of these pathologists (including Boyce, Jewell, Van Arsdel, Toole, and Verrall) came after long service with the USDA Forest Service. Since 1960, the universities of the South and Southeast have assumed an important role in forest disease research, including a significant amount of research in cooperation with the USDA Forest Service.

Some universities, however, had forest pathologists prior to 1960. Also, some earlier research on forest tree diseases and fungus deterioration of forest products was conducted by general plant pathologists at the universities. Already mentioned in the Southern Station section are reports by Edgerton and Hollis et al. (LSU) and by Miles (Auburn). However, for this history, emphasis is placed on research by those pathologists spending a major portion of their research effort on forest pathology. Schools without forest pathologists occasionally publish on a forest tree disease but no attempt was made to locate and include all such material.

Much of the information in this section was furnished by the universities. Some schools, however, did not-furnish the needed information and, in these cases, I depended on my personal knowledge and on published reports in the Plant Disease Reporter, Journal of Forestry, Forest Science, and Phytopathology plus papers reviewed in the Review of Applied Mycology.

University of Arkansas, Fayetteville, Ark.

Forest pathology research at the University of Arkansas started in the late 1950's when Charles L. Wilson (Ph. D., West Virginia) joined the faculty of the Department of Plant Pathology.

Wilson's researches included: (1) Chlorosis of loblolly and shortleaf pine seedlings associated with high pH and large amounts of K_2O and Ca (Wilson 1959); (2) Oak wilt: survival in material buried in forest litter (Gilespie and Wilson 1960), the growth of Ceratocystis fagacearum in oak wood as indicated by the use of radioactive S_{35} (Wilson 1961), and the nuclear behavior of C. fagacearum (Aist and Wilson 1967, 1968); (3) Blights of Arizona cypress caused by Cercospora thujina (Wilson 1961a) and Phomopsis juniperovora (McDaniel and Wilson 1962); (4) Persimmon wilt including growth of the pathogen within the xylem (Wilson 1963) and a proposal for the use of persimmon wilt as a silvicide for weed persimmon on range land (Wislon 1965); (5) Growth of _Ceratocytis ulmi_ in elm wood and the response of the host (Wilson 1965a); (6) The nuclear behavior of fungi: The unique asexual division in _C. fagacearum, Fomes annosus,_ and some other fungi and the close association of the centriole with nuclear migration (Aist and Wilson 1967; Griffin and Wilson 1967; Armentrout _et al._ 1968).

About 1970, Wilson left Arkansas to become Research Leader, Shade Tree and Ornamental Plant Laboratory (Agric. Res. Serv.) at Delaware, Ohio. He was replaced by Frank H. Tainter (Ph. D. Minn.), Associate Professor.

Tainter has worked mainly on: Oak wilt: (1) Survey showing that wilt remains static in Arkansas (Tainter _et al._ 1973); (2) Studies showing that the oak-wilt fungus can be used safely to kill unwanted red oaks (Tainter 1972); (3) Isolations from many inoculated oaks showed that survival of _C. fagacearum_ was markedly lower after 8 months, possibly because of high summer temperatures, dying of branches, and sapwood invasion by _Hypoxylon_ (Tainter and Gubler 1973). Further studies suggested that _Hypoxylon_ rapidly reduces carbohydrate reserves and thus starves _C. fagacearum_ preventing it from fruiting (Tainter and Gubler 1974).

Tainter also worked on Comandra rust: (1) A survey established the range in Arkansas (Tainter 1971); (2) The development of the rust in _Comandra_ (Tainter 1973); (3) The germination of aeciospores: temperature and pH optima (Eppstein and Tainter 1976) and the presence of a germination self-inhibitor (Eppstein and Tainter 1976a).

The comandra rust studies are continuing, including work on phenology, host range, cytology in pine, and possible development of resistant pine strains. Tainter also has or is doing some work on mycorrhizae, the effect of bromine emmissions from industry on pine, fungi isolated from discolored asphalt shingles, and the dynamics of microbial populations in pine nurseries.

Auburn University, Auburn, Ala.
(Formerly Alabama Polytechnic Institute)

L. E. Miles, Professor of Plant Pathology from 1922 to 1927, collaborated with C. J. Humphrey (U.S. Bureau of Plant Industry) in one of the earliest reports of _Poria incrassata_ attack in buildings and stored lumber (Humphrey and Miles 1925).

Forest pathology research at Auburn has been conducted separately and jointly in the Department of Botany and Microbiology and in the Forestry Department. The following have been involved:

Terry C. Davis, Jr. (Ph. D. WVA), Assistant Professor of Forestry and Forest Pathology, 1965 to present.

Walter D. Kelley (Ph. D., North Carolina State), Assistant Professor of Forest Pathology, 1966 to present.

Elroy A. Curl (Ph. D. Ill.), Professor of Plant Pathology, 1954 to present.

James F. Goggans (Ph. D. NC State), Professor of Forestry, 1947 to present.

Jack T. May (Ph. D. Michigan State), Associate Forester, 1949 to 1958.

Norton L. Marshall (Ph. D., Maryland), Assistant Professor of Plant Pathology, 1959 to present.

William R. Boggess (MF Duke), Associate Forester, 1939 to 1943.

Bruce E. Hopper, in the 1950's spent some time with the Southeastern Station and as a graduate assistant at Auburn making a survey of nematodes in pine nurseries.

Currently, Davis teaches forest pathology and conducts research while Kelley (in Botany and Microbiology) conducts forest pathology research. The others occasionally collaborate with the forest pathologists.

Research in forest tree diseases and wood products deterioration at Auburn included:

Fomes annosus: (1) Curl, Arnold, and Kelley studied the effect of cultural practices and biotic soil factors on the growth of *Fomes annosus* (Kelley and Curl 1972). Germination of spores was severely inhibited on sterilized soils from infected plots that were clear cut and then burned, or burned, disced, and planted to oats; (2) Few conidiophores of *F. annosus* were found on infected trees but large basidiocarps occurred under duff. More importantly, numerous small basidiocarps occurred in bark crevices above the duff and may be important in spread by air-borne spores (Kelley and Davis 1973).

Fusiform rust: (1) Goggans (1949) found less rust damage on slash pine in mixture with loblolly pine. He suggested using alternate rows of slash and loblolly pines and eventually removing the loblolly; (2) Goggans (1957) also made a study of the incidence of rust in 150 plots by species, age, and density of planting; (3) May and Goggans (1950) published a general description of fusiform rust, the damage it causes, and the treatment of young pine stands to limit damage; (4) Boggess and R. Stahelin (1948) found that cultivating and fertilizing pine stands increased rust infection fourfold; (5) Testing for plus strains of pine (Davis and Goggans 1968).

Soil pathogens: (1) Kelley and R. Rodriguez-Kabana (1970) determined enzymes produced by *Phytophthora cinnamomi* and Kelley (1975) reported significant differences in enzyme production among isolates; (2) The effect of *Trichoderma* on chlamydospore production by *P. cinnamomi* (Kelley and Rodriguez-Kabana 1974); (3) Kelley and Rodriguez-Kabana (1975) made studies over several years on the effects of potassium azide and of sodium azide on soil fungi and nematodes. Methyl bromide was more effective than the azides as a soil fumigant; (4) Hopper and Padgett (1960) made surveys of nematodes in the soil of forest nurseries.

Miscellaneous: (1) A report of a canker on eastern mistletoe caused by *Hymenochaete agglutinans* (Davis 1968); (2) The superiority of plastic over metal tubing for draining wetwood trees; (3) An account of *Curvularia intermedius* associated with seedling blight of Arizona cypress and eastern red cedar. Davis et al. (1974), summarized the information on pests of Arizona cypress seedlings and their fungicidal control; (4) Curl et al. (1959), reported phloem necrosis of elm in Alabama; (5) Davis *et al.* (1976), summarized 25 years of fence post service tests at Auburn; (7) Davis (1966) reported that the use of fungus-stained excelsior in excelsior-cement mixtures shortened the setting time.

Clemson University, Clemson, S. C.

Wesley Witcher (Ph. D. NC State), professor in the Department of Plant Pathology and Physiology, initiated forest pathology research at Clemson in 1960 and directed their research program and taught forest pathology through the 1977-78 academic year, after which forest pathology was transferred to the School of Forestry.

Among Witcher's 35 publications are a number on forest tree diseases, including: (1) *Fomes annosus*: Infection through pruned branches (Witcher and Beach 1962); spread (Witcher 1963); associated soil micro-organisms (Adams *et al.* 1964); (2) Fusarium canker of yellow-poplar (Amett and Witcher 1979); (3) *Endothia parasitica* on live oak (Batson and Witcher 1968); (4) Occurrence reports: Oak wilt, Dutch elm disease, and Monochaetia canker of Arizona cypress and red cedar; (5) Use of benomyl on conifers (Witcher *et al.* 1973); (6) Control of needle cast on Scotch pine (Witcher *et al.* 1975).

Duke Univerisity, Durham, N. C.

Forest pathology at Duke originally was taught by Frederick A. Wolf, Professor in the Botany Department. Wolf had a primary interest in diseases of tobacco but published a number of papers on disease of other plants, including trees. Those on tree diseases were mainly mycological and included: Leaf spots on honey locust, ash, sycamore, red bud, and Chihuahua pine.

Wolf et al. (1938) cataloged the fungi of the Duke Forest and described their relation to tree diseases; published (Wolf and Wolf 1939) a study of Botryosphaeria ribis canker of willow; and published (Wolf and Barbour 1941) an account of brown spot disease of pine.

In September 1961, Willaim J. Stambaugh (Ph. D. Yale) organized a forest pathology program in the School of Forestry (later the School of Forestry and Environmental Studies). Stambaugh, still Professor of Forest Pathology, has spent much of his time in teaching but has managed the following research:

Fomes annosus: (1) Stambaugh, F. W. Cobb, R. A. Schmidt, and F. C. Krieger (1962) reported on the effect of microclimate on spore dispersal and subsequent stump invasion, based on a study made at Penn. State.

(2) The effect of soil moisture content and soil temperature on F. annosus infections. In the greenhouse, root infections of 2-year-old loblolly pine were higher when seedlings were subject to temporary wilting point depletions than when soil was kept near field capacity. Also, infection was higher in soils at 10 to 15°C than in soils subject to fluctuations of 15 to 38°C (Towers and Stambaugh 1968).

(3) J. D. Artman and Stambaugh (1970) found that suspending oidia of Peniophora gigantea in SAE 30 motor oil in a chain saw oil reservoir, was highly successful in establishing P. gigantea in pine stumps during a felling operation and thus restricting infections by F. annosus.

(4) With inoculations of severed roots of dominant red cedar in pure stands and of suppressed cedars under loblolly pines, proximal movement of the fungus was greater in roots of dominant trees and, in both classes, root penetration in the proximal direction exceeded that in the distal direction (Howell and Stambaugh 1972).

Cylindrocladium Root Rot

C. E. Cordell, A. S. Jutter, and Stambaugh (1971) made the first report of Cylindrocladium floridanum on yellow-poplar seedlings, on which it was causing serious mortality.

University of Florida, Gainesville, Fla.

Early Work

As at most universities, forest pathology at the University of Florida remained as stepchild of general plant pathology until the 1960's, with only insignificant research results. Forest pathology was taught by George F. Weber (Ph.D. Wisc.), Professor of Plant Pathology from 1922 to 1964. Weber maintained a primary interest in diseases of subtropical and tropical plants. His non-teaching participation in forest pathology consisted mainly of a few observations: (1) Damage caused in buildings by *Poria incrassata* (Weber 1930); (2) Mimosa wilt in Florida; (3) *Cronartium ouercuum;* (4) *Coleosporium* on pine; (5) Leaf blister on oak; (6) Weber, Davidson, and Cambell (1942) described *Phychogaster cubensis* causing rot in oak and wax myrtle; (7) Reported that the chestnut blight fungus can enter chestnuts through killed twigs (Birchfield and Weber 1957).

Between Weber's retirement and the arrival of Schmidt (see below) Daniel A. Roberts (Ph.D. Cornell), Professor of Plant Pathology, taught forest pathology. In the field of forest pathology he worked on damping-off of pine seedlings in nurseries but apparently the results were never published.

Formal Forest Pathology Project

In September 1967, a forest pathology research program was initiated in the School of Forest Resources and Conservation under the direction of Robert A. Schmidt (Ph.D. Penn. St.), Associate Professor of Forest Pathology. This research program emphasizes the epidemiology of fusiform rust, including disease resistance and is one of the best coordinated and most extensive program in this field at the universities. In addition to Schmidt, the following also have been active in the program:

Charles A. Hollis (Ph. D., NY State), Assistant Professor of Forest Pathology

Ray E. Goddard (Ph. D. TX A&M), Assistant Professor of Forest Genetics

Donald L. Rockwood (Ph. D. NC State), Assistant Professor of Forest Genetics

W. L. Pritchett (Ph. D. IA State), Professor of Forest Soils

James W. Kimbrough (Ph. D. Cornell), Professor of Botany

W. H. Smith (Ph. D. MS State), Professor of Forest Nutrition

Fusiform Rust

Even though the program is relatively new, a number of significant publications on fusiform rust have appeared:

Resistance. (a) Early identification of resistant slash pine families through controlled inoculation (Goddard and Schmidt 1971); (b) Resistance results from field progeny tests (Schmidt and Goddard 1971); (c) Literature review of inoculation techniques (Schmidt 1972); (d) Predicted gains for resistance in slash pine (Rockwood and Goddard 1973); (e) Comparative performance of slash pine for resistance in high-hazard sites (Sohn et al. 1975); (f) Phenotypic selections of slash pine for resistance are most effective in populations exposed to high incidence of rust and significant gains can be realized as early as 3 years after roguing. (Goddard et al. 1975).

Distribution and incidence of rust in slash pine plantations in Florida and Georgia showed that rust was increasing with each year of planting (Schmidt et al. 1974).

Effect of site factors. A study of the relationship of soil and tissue nutrients, soil drainage, fertilization, and tree growth to fusiform rust incidence showed that incidence is (1) least on poorly-drained soils and highest on well-drained sites, and (2) directly correlated with extractable soil and foliar P and inversely with total N (Hollis *et al*. 1975). Greenhouse studies showed that the number of galls is positively correlated with seedling height and total amount of N, P, and K and with increases of P (Schmidt *et al*. 1972).

Other. *C. fusiforme* was kept alive for 6 months on a chemical medium, producing infective aeciospores (Hollis *et al*. 1972).

Other Research

A study of decline of live and laurel oaks used as an overstory in commercial ferneries (Schmidt and C. P. Seymour 1972) showed that decline was due to root pruning and wounding associated with cultivation and followed by root and butt rot.

Pitch canker also has been studied in slash pine plantations. Schmidt and E. M. Underhill (Hudson Pulp and Paper Company) reported that in 16 plots over a 3-year period, the number of cankers increased 7.6 percent per annum with an annual loss of 0.23 cords per acre (Schmidt and Underhill 1974). In 1976, George M. Blakslee (Ph. D. Duke) joined the faculty to teach forest pathology and do research on pitch canker because it had reached epiphytotic proportions in some areas of Florida.

The University of Georgia, Athens, Ga.

Julian H. Miller, Plant Pathologist and Head, Department of Plant Pathology of the University of Georgia, was interested in forest pathology throughout his long tenure, up to his retirement in 1958. He discussed forest seed bed diseases in the Southeast (J. Miller 1935) and published historical sketches of forest tree diseases of Georgia (J. Miller 1950), consisting of short paragraphs on the major and many of the minor diseases. Miller also started a catalog of Georgia fungi, including those on trees: (1) Pyrenomycetes (See J. Miller and Burton 1942); (2) Ascomycetes (J. Miller 1941); and (3) Hypoxylon species of the world (J. Miller 1961). He also described several new fungal species causing leaf spots on honey locust, southern red oak, and magnolia.

John S. Boyce, Jr. (PhD Duke) joined the faculty of the Department of Plant Pathology in 1961, remaining until 1966. His researches include: The rate of Penetration of Fomes annosus in fresh pine stumps and roots (Boyce 1963); (2) A study showing there are fewer fungi in the soil around trees infected with F. annosus (Veech and Boyce 1964); (3) A report that phytoactin is ineffective against fusiform rust (Taylor and Boyce 1965); (4) Finding that Peniophora fruits in all seasons, suggesting that inoculum of Peniophora, as an antagonist of F. annosus, could be increased by felling a few pines several months prior to a thinning operation (Boyce 1966); (5) Proved that Monochaetia is pathogenic on Arizona cypress and red cedar (Boyce and Graves 1966); and (6) Reported Polyporus tomentosus var. circinatus was associated with basal cankers and butt and root rot of slash pine (Boyce 1967).

Currently, the Department of Plant Pathology relies mainly on the Southeastern Station pathologists for most forest tree disease research. Dwinell, Marx, T. Miller, Powers, Rowan, and Ruehle are adjunct professors or research associates. F. F. Hendrix (PhD Calif.) resigned from the Southeastern Station in 1964 to join the faculty of the Department of Plant Pathology. Hendrix teaches forest pathology and retains some interest in the mycology of Pythium and Phytophthora in forest soils, mainly in collaboration with W. A. Campbell (See Hendrix and Campbell 1973).

L. W. R. Jackson resigned from the Southeastern Station in 1946 to join the faculty of the School of Forest Resources. He continued his interest in forest tree diseases and his research publications include: (1) A description of an abiotic needle curl of shortleaf pine on dry sites (Jackson 1948). (2) Reducing damping-off of stratified and unstratified pine seeds by fungicidal dusting (Hamilton and Jackson 1951). (3) Littleleaf drastically reduces seed viability (Jackson 1952). (4) Developed grafting techniques that showed that littleleaf disease is not of viral origin (Jackson and Zak 1949). (5) Described the anatomy of fusiform rust galls (Jackson and Parker 1958). (6) Calculated that the age of a fusiform rust canker in years is about 2/3 its length in inches (Jackson 1968). (7) Both ecto- and endotrophic mycorrhizae occur on several hardwoods (Jackson and Driver 1969).

William A. Campbell (Ph.D. Penn St.), on retirement from the Southeastern Station, became a professor in the School of Forest Resources. He maintained his primary pathology interst in the mycology of soil-borne Phycomycetes. His publications in collaboration with Hendrix are listed above.

Louisiana State University, Baton Rouge, La.

For many years, forest pathology research at Louisiana State was conducted only as a side line by general plant pathologists in the Department of Plant Pathology and Botany. C. W. Edgerton (1924), Professor of Botany and Plant Pathology from 1908 to 1950, published one of the earliest accounts of Poria incrassata attack in buildings and later (Johnson and Edgerton 1936) first reported Fomes geotropus on magnolia.

A. G. Plakidas (Ph.D. Nebr), Professor of Plant Pathology from 1927 to 1960, described a new leaf spot of magnolia caused by Isariopsis magnoliae Plk. (Plakidas 1960) and the perfect stage (Venturia acerina Plk) of Cladosporium humile on maple (Plakidas 1942).

J. P. Hollis (Ph.D. Neb), Professor of Plant Pathology from 1954 to the present, although maintaining a primary interest in rice diseases, conducted studies on soil fumigation in pine tree nurseries. Most of this work was published jointly with T. Handsbrough (Forester) and R. G. Merrifield (Associate Pathologist) of the North Louisiana Hill Farm Experiment Station. One study was in cooperation with the Southern Station (Shoulders et al. 1965) These reports showed that soil fumigation would increase production by controlling root disease but the most effective fumigant, methyl bromide, was economically feasible only if a weed problem existed.

A. A. Antonopoulos (Ph.D. Colo. St.), Assistant Professor from 1969 to 1976, described the morphology of Cronartium fusiforme aeciospores as reveiled under the electronic microscope (Antonopoulos and Chapman 1976).

Currently forest pathology is under John P. Jones (Ph.D. GA), Assistant Professor. Jones joined the faculty in 1977. Jones' primary research interest is in forest pathology, presently nursery diseases including a study of fungicidal control of fusiform rust in cooperation with the U.S. Forest Service.

Louisiana Tech University, Ruston, La.

Forest pathology research at Louisiana Tech started in 1966 when Frederick F. Jewel1 (Ph.D. Wisc) left the Southern Station to become Professor of Forest Protection in the School of Forestry. Jewel1 has maintained a vigorous research program on Cronartium fusiforme and C. quercuum, much of it in cooperation with the Southern Station's Gulfport laboratory. His research since leaving the Southern Station is reported in 17 publications, including: (1) Resistance in pine (Jewel1 and Mallett 1966; Jewel1 and Snow 1972; Jewel1 and Spiers 1976), (2) Histology of rust infection (Jewel1 and Walker 1967; Jewel1 1969; 1972, 1975), and (3) General (Peterson and Jewel1 1968).

Fred Jewel1 is one of the most respected pathologists in the field of resistance to fusiform rust.

Mississippi State University, Mississippi State, Miss.

Forest Diseases

Lee E. Miles spent 1920-1922 at Mississippi State as Plant Pathologist, State Plant Board, before going to Alabama Polytechnic Insititute. He made copious notes on the rusts occurring in Mississippi, including Cronartium comandrae on southern pines. This catalog of rusts was published considerably later (Miles 1934).

About 1960, G. K. Parris of the Department of Botany and Weed Science started some research on tree diseases, but the teaching load was heavy and thus research was limited. He did, however, show that needle browning on roadside loblolly pine can be controlled by a fungicide applied with a mist blower. He also reported observations on an abiotic leaf curl of pine (Parris 1967) and on Polyporus lucidus on honey locust (Parris 1966).

Parris retired in June 1973 and Vernon D. Ammon (Ph.D. MO) replaced him in October 1973. Ammon is State's first forest pathologist in the forest tree disease field. Ammon has started a research program, concentrating on two problems: (1) Sycamore anthracnose: the infection process and the selection of sycamore strains for resistance. (2) Fusiform rust: the resistance mechanism and, in cooperation with the Southern Station, the histology of different reactions when slash, loblolly, and shortleaf pines are inoculated with high and low virulent strains of C. fusiforme.

Forest Products Pathology

The Forest Products Utilization Laboratory at Mississippi State University was established in 1964 and has developed into one of the strongest products research institutions in the United States. In 1969, the laboratory added a forest pathologist, E. Richard Toole (Ph.D. Duke), a retiree from the Southern Station--to study the fungal deterioration of wood and wood products. Included in Toole's researches are: (1) The biodeterioration of particle board (Toole and Barnes 1974). (2) The influence of season on organisms infecting untreated pine stakes (Toole 1971). (3) Variation in decay resistance of southern pine sapwood (Toole 1970). (4) Effect of decay fungi on the micro-structure of red oak heartwood (Toole 1972). (5) A comparison of oxygen utilization and weight loss for evaluating wood preservatives in soil-block tests (Toole 1975). (6) Using crushing strength to evaluate wood preservatives (Toole 1971a). (7) Reduction in crushing strength and weight loss associated with several white and brown rotters (Toole 1971c). (8) A study showing the spores of brown-rot fungi germinate better on pine and those of white-rot fungi on gum (Toole 1971). (9) In cooperation with the Southern Station, the influence of variation in physical and chemical properties of red-oak lumber'on decay (Toole 1970).

Toole retired in 1978 and Amburgey joined the staff in 1979.

North Carolina State University, Raleigh, N. C.

Although R. F. Poole, D. E. Ellis, and others had taught forest pathology for a number of years, it was not until the 1950's when Arthur Kelman (Ph.D. NC St.) became responsible for forest pathology, that an outstanding course and research program was developed. During the 1960's, forest pathology research was expanded until today North Carolina State is one of the leaders in this field. Ellis B. Cowling (Ph.D. Wisc) arrived in 1961 to work with Kelman and, in 1965, replaced him as leader of the forest pathology program.

Personnel

Until 1975, the faculty in forest pathology research and extension in the Department of Plant Pathology and the School of Forest Resources consisted of:

Fred Whitfield, 1950-1976, Extension forest pathology.

Charles S. Hodges, Jr. (Ph.D. GA), 1959-1976, Forest mycology, root and seedling diseases (with USDA).

Arthur Kelman (Ph.D. NC St), 1950-65, Physiology of tree diseases and wood deterioration.

Charles B. Davey (Ph.D. Wisc), 1965-present, Soil microbiology, mycorrhizae, tree nutrition.

Ellis B. Cowling (Ph.D. Wisc), 1965-present, Physiology of tree disease, biochemistry of wood deterioration.

Larry F. Grand (Ph.D. Wash. St.), 1967-present, Forest mycology, mycorrhizae, shade and Christmas-tree disease, soil-borne pathogens.

Michael P. Levi (Ph.D. Leeds), 1971-present, Extension wood products pathology, wood preservation.

Ronald K. Jones (Ph.D. VA Polytech), 1970-present, Extension specialist on diseases of shade trees, woody ornamentals, Christmas trees.

David M. Benson (Ph.D. Colo St), 1974-present, Soil-borne diseases, diseases of woody ornamentals, Christmas trees, shade trees.

Four adjunct professors (with the Southeastern Station) also have been on the faculty:

W. A. Campbell (Ph.D. Penn. St.), 1963-1964.

George Kuhlman (Ph.D. Ore St), 1965-present, Soil-borne pathogens and pine rusts.

Jerome Koenigs (Ph.D. Wash St), 1966-77, Physiology of wood deterioration and tree diseases.

George H. Hepting (Ph.D. Cornell), 1967-1975, Consultant on forest and wood-products pathology, air pollution.

Three visiting professors and seven postdoctoral fellows also have worked in forest pathology at North Carolina State.

Research Program

Through 1975, at least 150 publications on forest and shade tree diseases and on fungus deterioration of forest products have come from the research program. Space precludes more than a mention of the subjects covered and the major findings. Some publications in which an adjunct professor was the senior author, have been included in the section on the Southeastern Station. In addition to research, North Carolina State has an important forest pathology extension program. This program has led to many extension publications and sets of slides, or slides and tapes on pests of forest trees and wood products. None of this extension material is covered. Also, the faculty, particularly Cowling, has been involved, often with other universities, in writing sections or chapters in several recent definitive books on pathology. None of this is reviewed here.

Research Results at North Carolina State

Air pollution: North Carolina State has relied mainly on Hepting (adjunct professor) for work on the effect of air pollution on forest trees (see section on Southestern Station). However, Cowling et al. (1975) summarized the information on increased acidity of rain and snow resulting from industrial activity in North America and Europe and its effect on trees.

Fomes annosus: Research reports include: (1) Mycelial growth in inoculated lateral roots is greater in suppressed than dominant loblolly pines (T. Miller and Kelman 1964). Mycelial growth was inversely related to root carbohydrate reserve. (2) Tissue and monobasidial cultures "from the United States, Canada, Japan, Europe, India, and New Zealand have optimum temperatures for growth on agar of 20 to 28°C, and the variation is not correlated with geographic origin or mean annual temperature of source (Cowling and Kelman 1964). (3) L. Shain (1967) reported that a phenol-enriched resin-soaked reaction zone forms ahead of F. annosus in living roots and that advance is more rapid in dead roots. (4) C. Bassett et al. (1967) found that formannosin, a toxic metabolite of F. annosus, formed in some culture media but is not detected in nature nor is Peniophora or Trichoderma affected by it. (5) J. N. Thompson et al. (1968) reported that F. annosus grew at the same rate through as over split surfaces of fresh pine sapwood bolts. The cambial zone browned in advance of the fungus and water moved from infected to uninfected regions. (6) Cowling and M.. Johansson (1970) summarized the information on the physiology of F. annosus.

Nematodes: Ruehle (1962) described the histopathology of nematode attack on pine roots. (2) Ruehle and J. N. Sasser (1962), from field surveys and greenhouse pathogenicity tests, reported the stunting of southern pines by nematodes. They also reported control of nematodes in outplanting sites by fumigation with the beneficial effects still evident after 5 years (Ruehle and Sasser 1964).

Fusiform rust: (1) Epidemiology. Snow, Froelich, and Popham published their researches in four articles in Phytopathology (Volume 58): Sporidia were liberated mainly during periods of high relative humidity, mainly at night and early morning; determined weather conditions conducive to infection; the effect of temperature oh sporidial production. The time required for infection of pines and the effect of field and laboratory exposure. (2) Resistance: B. Kinloch and Kelman (1965) found little difference in susceptibility among progeny from infected and rust-free loblolly pines. Kinloch and R. Stonecypher (1969) observed genetic variation in susceptibility among progeny of controlled and wind pollinated families of loblolly pine planted in an area of high incidence. Zobel et al. (1971) reported on a cooperative program (23 industries and three state forest services) of expected gains from breeding for resistance, geographic variation in resistance in slash and loblolly pines, and the use of seed orchards. Stonecypher et al. (1973) reported on inheritance patterns. K. von Weissenberg (1973) described the possible use of chemical markers (as long-chain fatty acids) as indicators of resistance. (3) Miscellaneous studies: D. Bramlett and Kelman (1963) reported on the effect of cycloheximides on spore germination. T. Miller (1970) found that sporidia stored at 5°C retain viability for 8 weeks. R. L. Blair and Cowling (1974) found that seedlings are predisposed to infection by soil fertilization and site factors other than soil, but height of exposure above ground and age has little effect. D. Myren and Kelman (1975) listed the insects and fungi associated with galls, and indicated that gall tissue has lowered toughness value which contributes to wind breakage. M. Veal *et al*. (1974) reported that rust reduces yield and quality of pulp.

Miscellaneous tree diseases: (1) Pathogenicity on pines of staining species of *Ceratocystis* (Basham 1970). (2) Kelman and Gooding (1965) proved pathogenicity of *Cylindrocladium* causing root and stem rot of yellow-poplar, eastern white pine, and Fraser fir. (3) Kelman *et al.* (1960). *Exosporium* needle blight of cedar. (4) H. W. Scheld and Kelman (1963). The effect of temperature on growth, spore germination, and infection by *Phomopsis juniperovora*. (5) Mycology: Grand and others have published a number of papers on tree fungi. (6) Mycorrhizae: Marx published several papers (see Southeastern Station section for his contributions). (7) *Phytophthora cinnamomi*: Morphology and physiological characteristics of mating types (Haasis *et al.* 1964). Sporangial formation (Haasis *et al.* 1965).

Fungus deterioration of wood: North Carolina State, particularly under Cowling's direction, has assumed leadership in the field of the chemistry of wood deterioration: (1) The chemistry of lingnin deterioration (Kirk and Kelman 1965). (2) The hydrolysis of cellulose and lignocellulose materials was summarized by Cowling (1975). (3) The relationship of N and other elements in wood to decay rate. A number of studies by Cowling with W. Merrill and/or Levi were summarized by Cowling (1970) and by Basham and Cowling (1975). (4) Even though N content of wood influences decay rate, N fertilization of a forest stand does not influence the decay rate of wood cut from it (Cowling _et al_. 1969). (5) Some work was done on wood preservation. C. K. Chou _et al_. (1974) studied the hyphal uptake, toxic limits, and effect of Cu-Cr-As preservatives on colonizing wood and Levi _et al_ (1974) found that grape plants growing next to treated stakes do not absorb these elements. Levi (1973) reported highly variable retentions of creosote in pressure treated southern pine veneer cores. (6) Some work on the genetics of wood-destroying fungi and natural decay resistance has been reported (Amburgey 1970, 1970a).

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Forest pathology at SFA is in the School of Forestry. The first forest pathologist there was Arthur F. Verrall (Ph.D. Minn), Professor of Forest Pathology from 1965 to 1970. His researches included: (1) A study of increased porocity of pine logs stored under a commercial water spray and the use of a water repellent to overcome this in lumber cut from the logs (Verrall 1970). (2) A report of a possibly new pine-oak rust (Verrall 1968a). (3) With a grant from the Southern Station, a study of some factors affecting the compatibility of decay fungi and molds (unpublished).

Thomas W. McGrath (Ph.D. Wisc) now is teaching forest pathology at SFA.

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Eugene P. Van Arsdel (Ph.D. Wisc) left the North Central Forest Experiment Station in the late 1960's to become Associate Professor of forest pathology in the Plant Sciences Department of Texas A&M. The first major problem facing him in Texas was the decline of live oak, which is an important tree on the fringe of the prairie. R. S. Halliwell (Associate Professor of plant pathology 1966) had reported the association of a Cephalosporium with the decline. Van Arsdel and Halliwell (1970) described decline as a complex of which Cephalosporium is a major component. Cephalosporium wilt can be separated from such damage as that caused by soil fill, excavation, and over fertilization, by the use of infra-red photography

(Van Arsdel and Bush 1970). Van Arsdel and Bush determined the uptake of benomyl solution in sycamore, live oak, and post oak as a possible wilt control (Van Arsdel *et al.* 1972).

Other researches reported by Van Arsdel includes: (1) The life cycle and spread of ash rust (Van Arsdel and Chitzonidis 1970). (2) Poplar rust. Chitzonidis and Van Arsdel (1970) suggest that high summer temperatures kill most of the rust and that it is reintroduced annually from the North as weather cools in the fall. Van Arsdel also is working on some of the epidemiology phases of fusiform rust in East Texas; some of this is in cooperation with the Southern Station. He had studied epidemiology of white pine blister rust in the North.

SOUTHWIDE FOREST DISEASE WORKSHOP

At George Hepting's suggestion, the pathologists at the Southern and Southeastern Stations met in Athens, Ga., in 1953 for an in-service exchange of ideas, and these meetings were continued in alternate years. Occasionally, outside pathologists were invited but primarily the meetings were to coordinate the research programs of the two Stations.

By 1960, industry had greatly expanded forest management in the South and was feeling the serious impact of diseases. As a result, two groups of interested foresters, mostly from industry and schools met in 1960 to discuss what could be done to stimulate financial support for research in the insect and disease fields by Federal and State governments and by industry. These meetings led to the organization of the Southern Forest Disease and Insect Research Council, with strong affiliation with the Southern Pulpwood Association. An interim committee, chaired by T. E. Maki of North Carolina State University, was formed in 1962 to study research needs. One of this committee's suggestions was that as many as possible of the South's forest pathologists meet every few years to coordinate research. As a result, the in-service meetings were expanded in 1962, to include pathologists and interested foresters in industry, state governments, and schools as well as the pathologists of the Southeastern and Southern Stations.

By 1970, as many as 90 people attended these workshops. Meetings, now at 18-month intervals, are proving valuable in exchanging ideas on problems and on research underway or planned. They also are a means of getting research results to practicing forest managers. At Hepting's suggestion, a steering committee system was formed to insure continuity and integrity of the workshops.

With the expanded attendance, the workshop has lost much of its original purpose as a coordinating forum for the two Stations. Such coordination, however, is being accomplished by frequent exchanges between the project leaders of the two Stations, by joint studies where problems overlap Station boundaries, and by personal contacts among Federal, State, and industry personnel. This has done much to increase mutual trust and understanding and to increase cooperative efforts.

SUMMARY:

AN EVALUATION OF FOREST PATHOLOGY RESEARCH IN THE SOUTH AND SOUTHEAST[1]

[1] This is discussed more fully country wide by George Hepting (1970) and by Hepting and Cowling (1977).

The forest pathologists at the Southern and Southeastern Forest Experiment Stations can be proud of their research because of beneficial effect on forest management and the use of forest products. The first half century of this research consisted largely of practical field research directed at solving the economically important disease problems facing forest managers and wood users. For several decades this left little time for the small number of pathologists involved to delve into more basic research. Some of the beneficial effects of this research on southern forestry and wood utilization are:

Estimating Losses

Forest pathologists prepared the disease loss figures in the Timber Resources Review of 1958. The disease loss figures helped: (a) To estimate how much our future timber requirement deficiencies might be made up by better disease control, and (b) to determine research needs.

Reducing Losses

Some outstanding examples of research that has had an important financial impact are: (a) The determination of the rate of southward spread of chestnut blight, the rate of deterioration of blight-killed trees, and the rate of reduction of tannin content of such trees gave commercial interests the data needed to determine rate of use or salvage and to develop substitutes for chestnut products. (b) The rate of decay in southern and Appalachian hardwoods following fire injury; that entering through branch stubs; and that of logging slash furnishes the information needed to set harvesting and salvaging schedules that minimize loss from decay. (c) The finding and propogating of lines of eastern white pine resistant to the emissions from soft-coal burning power plants permits growing white pine in areas where air-pollution had threatened to eliminate this species. (d) Soil fumigation and fungicidal sprays developed to control root rot, brown spot, and fusiform rust in nurseries greatly increases yields and quality of seedlings and, in some cases, prevented abandonment of nurseries where root rot was critical. (e) Controls for cone rust greatly increase seed yields in orchards and genetic research. (f) A soil rating scale permits easy determination of sites where shortleaf pine can be grown without important losses from little leaf disease. (g) A site classification for southern pines, the effect of season of cutting, and stump treatments lessen losses from Fomes annosus.

In the field of products pathology, research developed: (a) Mechanically-applied chemical dips to protect air-seasoning lumber from stain, mold, and decay. (b) Simple preservative treatments to protect wood ammunition boses from decay during open storage. (c) Minor changes in building designs and simple preservative treatments that prevent decay associated with rain seepage, condensation, and water-conducting fungi.

Although I cannot assign definite monetary saving to southern forestry and wood utilization resulting from forest pathology research conducted at the Southern and Southeastern Stations, there is no doubt that it is more than the total expenditures for forest pathology research at the two stations up to 1960. The results certainly point to the value of research and the need for a continuing vigorous research program in the fields of forest tree diseases and wood products protection.

The above evaluation is based on research at the two Federal Forest Experiment Stations. Recently, the southern universities also are making important contributions to forest pathology research so there is every reason to believe that ongoing research by Federal, State, and private agencies will provide economical controls for the future disease problems of southern forest managers and wood users.

Status of Forest Pathologists

Despite the contributions they have made, forest pathologists for a long time were in the unenviable position of being "outsiders", foresters called us plant pathologists and plant pathologists called us foresters. At the 1961 annual meeting of the American Phytopathological Society (APS) in Biloxi, Miss., George Hepting gave a talk on forest pathologists and their work, urging using the APS as their major forum. Two years later, the APS established a forest pathology subject matter committee and, since then, a section on forest diseases has been included in the APS annual meetings, resulting in a many-fold increase in the number of forest disease papers at the annual meetings. The stature of forest pathologists also was increased by forest pathologists participating in the meetings of the International Congress of Plant Pathologists. These recognitions of the professional standing of forest pathologists are a result of their contributions to the forest and wood-using industries and to the science of phytopathology.

LITERATURE CITED

Adams, J.T., Jr., W. Witcher, and C.L. Lane.
1964. Microorganisms in soil from Fomes annosus infected pine stands. Plant Dis. Rep. 48:114-118.

Aist, J.R. and C.L. Wilson.
1967. Nuclear behavior in the vegetative hyphae of Ceratocystis fagacearum. Amer. J. Bot. 54:89-104.

Aist, J.R. and C.L. Wilson.
1968. Interpretation of nuclear division figures in vegetative hyphae of fungi. Phytopathology 58:876-877.

Amburgey, T.L.
1970. Genetic control of basidiospore formation by isolates of Lenzites trabea. Phytopathology 60:951-954.

Amburgey, T.L.
1970a. Relationship of capacity to cause decay to other physiological traits in isolates of Lenzites trabea. Phytopathology 60:955-960.

Amburgey, T.L.
1974. Organisms causing discoloration and deterioration of asphalt roofing shingles. For. Prod. J. 24(6):52-54.

Amburgey, T.L.
1976. Observations on the soil-block and agar-block methods of evaluating wood decay. Mat. und Organ. 11:273-277.

Amburgey, T.L.
1977. Fungitoxicity of pentachlorophenol having reduced impurities. For. Prod. J. 27(11):18-19.

Amburgey, T.L., F.A. Carter, and D.R. Roberts.
1978. Resistance of wood from paraquat-treated trees to termites and the fungus Gloeophyllum trabeum. Wood Sci. 10:187-192.

Amburgey, T.L. and B.R. Johnson.
1978. Effect of ammonium hydroxide on thiamine and available micronutrients in ponderosa pine sapwood. Phytopathology 68:951-954.

Amett, J.D. and W. Witcher.
1974. Histochemical studies of yellow poplar infected with Fusarium solani. Phytopathology 64:414-418.

Antonopoulos, A.A. and R.L. Chapman.
1976. Morphology of Cronartium fusiforme aeciospores: A light and scanning electron microscopic study. Bot. Gaz. 137:285-289.

Armentrout, V.N., G.G. Smith, and C.L. Wilson.
1968. Spherosomes and mitochondria in the living fungal cell. Amer. J. Bot. 55:1062-1067.

Artman, J.D. and W.J. Stambaugh.
1970. A practical approach to the application of Peniophora gigantea for control of Fomes annosus. Plant Dis. Rep. 54:799-802.

Barham, R.O., D.H. Marx, and J.L. Ruehle.
1974. Infection of ectomycorrhizae and nonmycorrhizal roots of shortleaf pine by nematodes and Phytophthora cinnamomi. Phytopathology 64:1260-1264.

Basham, H.G.
1970. Pathogenicity and development of wilt in loblolly pine inoculated with some blue-stain fungi in the genus Ceratocystis. Phytopathology 60:750-754.

Basham, H.G. and E.B. Cowling.
1975. Distribution of essential elements in forest trees and their role in wood deterioration. Mat. und Organ. 3:155-165.

Bassett, C., R.T. Sherwood, J.A. Kepler, and P.B. Hamilton.
1967. Production and biological activity of fomannosin, a toxic sesquiterpene metabolite of the fungus Fomes annosus. Phytopathology 57:1046-1052.

Batson, W.E., Jr. and W. Witcher.
1968. Live oak canker caused by Endothia parasitica. Phytopathology 58:1473-1475.

Baxter, D.V. and L.S. Gill.
1931. Deterioration of chestnut in the Southern Appalachians. U.S. Dep. Agric. Tech. Bull. 257,22p.

Berry, C.R. and G.H. Hepting.
1964. Injury to eastern white pine by unidentified atmospheric constituents. For. Sci. 10:2-13.

Berry, C.R. and L.A. Ripperton.
1963. Ozone, a possible cause of white pine emergence tipburn. Phytopathology 53:552-557.

Bethune, J.E. and G.H. Hepting.
1963. Pitch canker damage to south Florida slash pine. J. For. 61:517-519, 522.

Birchfield, W. and G.F. Weber.
1957. Blight fungus invades chestnut from killed twigs. Plant Dis. Rep. 41:359-361.

Blair, R.L. and E.B. Cowling.
1974. Effects of fertilization, site, and vertical position on the susceptibility of loblolly pine seedlings to fusiform rust. Phytopathology 64:761-762.

Boggess, W.R. and R. Stahelin.
1948. The incidence of fusiform rust in slash pine plantations receiving cultural treatments. J. For. 46:683-685.

Boyce, J.S., Jr.
1954. Mat formation by the oak wilt fungus on felled versus standing trees. Plant Dis. Rep. 38:676-677.

Boyce, J.S., Jr.
1958. Needle cast of southern pines. U.S. Dept. Agric. For. Serv. For. Pest Leaflet 28,4p.

Boyce, J.S., Jr.
1959. Oak wilt spread in control-treated and untreated counties in the southern Appalachians. J. For. 57:660-661.

Boyce, J.S., Jr.
1962. Fomes annosus in white pine in North Carolina. J. For. 60:553-557.

Boyce, J.S., Jr.
1963. Growth of Fomes annosus into slash pine stumps after top inoculation. Plant Dis. Rep. 47:218-221.

Boyce, J.S., Jr.
1966. Sporulation of Peniophora gigantea with reference to control of annosus root rot. For. Sci. 12:2-7.

Boyce, J.S., Jr.
1967. Red root and butt rot in planted slash pines. J. For. 65:493-494.

Boyce, J.S., Jr. and K.H. Garren.
1953. Compatibility types of the oak wilt fungus in 23 Appalachian trees. Phytopathology 43:644-645.

Boyce, J.S., Jr. and A.A. Graves.
1966. Monochaetia canker on Arizona cypress in Georgia and South Carolina. Plant Dis. Rep. 50:482-483.

Bramlett, D.L. and A. Kelman.
1963. The influence of cycloheximide on germination of spores of Cronartium fusiforme. Plant Dis. Rep. 47:1024-1028.

Bryan, W.C.
1960. Losses from defect in Piedmont hardwoods. U.S. Dep. Agric. For. Serv. Southeast. For. Exp. Sta. Paper 109,31p.

Bryan, W.C.
1965. Testing shortleaf pine seedlings for resistance to infection by Phytophthora cinnamomi. U.S. Dept. Agric. For. Serv. Res. Notes SE-50, 4p.

Bryan, W.C. and B. Zak.
1961. Synthetic culture of mycorrhizae of southern pines. For. Sci. 7:123-129.

Bushaber, J.A., C.L. Wilson, and J.R. Aist.
1967. Asexual nuclear behavior of some plant-pathogenic fungi. Phytopathology 57:43-46.

Campbell, W.A., O.L. Copeland, and G.H. Hepting.
1953. Managing shortleaf pine in littleleaf disease areas. U.S. Dep. Agric. For. Serv. SE Sta. Pap. 25.

Campbell, W.A. and O.L. Copeland.
1954. Littleleaf disease of shortleaf and loblolly pines. U.S. Dep. Agric. Circ. 940,41p.

Campbell, W.A., S.P. Darby, and J.C. Barber.
1962. Fusiform rust, an obstacle to the establishment of grafted slash and loblolly pine seed orchards. Ga. For. Res. Pap. 11,5p.

Campbell, W.A. and A.F. Verrall.
1963. Phytophthora cinnamomi associated with Lawson cypress mortality in Louisiana. U.S. Dep. Agric. Plant Dis. Rep. 47:808.

Carpenter, B.E., Jr. and E.R. Toole.
1963. Sprinkling with water protects hardwood logs in storage. South. Lumberman 207 (2576):25-26.

Chapman, H.H.
1926. Factors determining natural reproduction of longleaf pine on cut-over lands in LaSalle Parish, La. Yale Univ. School For. Bull. 16,44p.

Chitzonidis, A. and E.P. Van Arsdel.
1970. Autumn introduction and winter survival of poplar rust on the Texas coastal plain. Phytopathology 60:502.

Chow, C.K., R.D. Preston, and M.P. Levi.
1974. Fungitoxic action of a copper-chromium-arsenate wood preservative. Phytopathology 64:335-341.

Clapper, R.B.
1954. Stimulation of pine oleoresin flow by fungus inoculation. Econ. Bot. 8:269-284.

Cobb, F.W.
1957. Pitch streak-a disease of turpentined slash pine. Naval Stores Rev. 67(9):4,5.

Cooper, D.T. and T.H. Filer, Jr.
1976. Resistance to septoria leaf spot in eastern cottonwood. Plant Dis. Rep. 60:812-814.

Copeland, O.L., Jr. and R.G. McAlpine.
1962. Soil characteristics associated with spot die-out in loblolly pine plantations. For. Sci. 8:12-15.

Cordell, C.E., A.S. Jutter, and W.J. Stambaugh.
1971. Cylindrocladium floridanum causes severe mortality of seedling yellow-poplar in a North Carolina nursery. Plant Dis. Rep. 55:700-702.

Cowling, E.B.
1970. Nitrogen in forest trees and its role in wood deterioration. Acta Universitatis Upsalienses 164:1-19.

Cowling, E.B.
1975. Physical and chemical constraints in the hydrolysis of cellulose and lignocelluloseic materials. Biotechnology and Bioengineering Symp. 5:163-181.

owling, E.B., B. Dillner, and S. Rydholm.
1969. Comparative decay susceptibility of sapwood in nitrogen-fertilized and nonfertilized stands of Norway spruce and Scots pine. Phytopathology 50:1022.

Cowling, E.B., A.S. Heagle, W.W. Heck.
1975. The changing acidity of precipitation. Phytopathology News 9(10):5.

Cowling, E.B. and M. Johansson.
1970. Physiology of Fomes annosus. Proc. 3rd Internal. Conf. on Fomes annosus. p192-205.

Cowling, E.B. and A. Kelman.
1964. Influence of temperature on growth of Fomes annosus isolates. Phytopathology 54:373-378.

Curl, E.A. and M.M. Arnold
1964. Influence of substrate and microbial interactions on growth of Fomes annosus. Phytopathology 54:1486-1487.

Curl, E.A., L.L. Hyche, and N.L. Marshall.
1959. An outbreak of phloem-necrosis in Alabama. Plant Dis. Rep. 43:1245-1246.

Czabator, F.J.
1971. Fusiform rust of southern pines--A critical review. U.S. Dep. Agric. For. Serv. Res. Pap. SO-65, 39p.

Czabator, F.J. and H. Enghardt.
1959. Nursery-infected seedlings develop fusiform rust cankers after outplanting. Tree Planters' Notes 37:23-25.

Davidson, R.W., W.A. Campbell, and G.F. Weber.
1942. Ptychogaster cubensis, a wood-decaying fungus of southern oaks and waxmyrtle. Mycologia 34:142-149.

Davis, T.C.
1966. Effect of blue stain on setting of excelsior-cement mixtures. For. Prod. J. 16(6):49-50.

David, T.C.
1968. Hymenochaete agglutinans on Phorodendron flavescens. Plant Dis. Rep. 52:496-499.

Davis, T.C., H.D. Beals, K.W. Livingston, and T.R. McIntyre.
1976. Fence post service tests at Auburn University-A twenty-five year report. Ala. Agric. Exp. Sta./Auburn Univ. For. Dep. Series No. 8,8p.

Davis, T.C., Jr. and J.F. Goggans.
1968. Testing plus pines for fusiform rust resistance. Auburn Univ. Agric. Exp. Sta. Highlights of Agric. Res. 15(3):10.

David, T.C., J.F. Goggans, and R.J. Meier.
1974. Pest control problems encountered in seedling production of Arizona cypress. Tree Planters' Notes 25(2):7-10.

DeGroot, R.C. and H.W. Scheld.
1971. Biodegradation of sapwood from southern pine logs stored under a continuous water spray. For. Prod. J. 21(10):53-55.

DeGroot, R.C.
1971a. Interaction between wood decay fungi and Streptomyces species. Bull. Torrey Bot. Club 98:336-339.

DeGroot, R.C. and H.W. Scheld.
1973. Permeability of sapwood in longleaf pine logs stored under continuous water spray. For. Prod. J. 23(4):43-46.

Diller, J.D. and R.B. Clapper.
1965. A progress report on attempts to bring back the chestnut tree in Eastern United States. J. For. 63:186-188.

Dwinell, L.D.
1971. Interaction of Cronartium fusiforme and Cronartium quercuum with Quercus velutina. Phytopathology 61:1055-1058.

Dwinell, L.D.
1974. Susceptibility of southern oaks to Cronartium fusiforme and Cronartium quercuum. Phytopathology 64:400-403.

Dwyer, W.W., Jr.
1951. Fomes annosus on eastern redcedar in two Piedmont forests. J. For. 49:259-262.

Edgerton, C.W.
1924. "Dry rot" in buildings and building material. Louisiana State Univ. Louisiana Bull. 190,12p.

Eleuterius, L.N.
1968. Morphology of Cronartium fusiforme in Quercus nigra. Phytopathology 58:1487-1492.

Eleuterius, L.N. and G.A. Snow.
1964. Caulicolous telia and uredia of Cronartium fusiforme. Plant Dis. Rep. 48:366.

Englerth, G.H., J.S. Boyce, Jr., and E.R. Roth.
1956. Longevity of the oak wilt fungus in red oak lumber. For. Sci. 2:2-6.

Eppstein, D.A. and F.H. Tainter.
1976. Temperature and pH optima for germination of Arkansas collections of comandra blister rust aeciospores. Can. J. For. Res. 6:459-461.

Eppstein, D.A. and F.H. Tainter.
1976a. Germination self-inhibitor from Cronartium comandrae aeciospores. Phytopathology 66:1395-1397.

Filer, T.H., Jr.
1973. Supression of elm phloem necrosis symptoms with tetracycline antibiotics. Plant Dis. Rep. 57:341-343.

Filer, T.H., Jr.
1973a. Pressure apparatus for injecting chemicals into trees. Plant Dis. Rep. 57:338-341.

Filer, T.H., Jr.
1975. Mycorrhizae and soil microflora in a green-tree reservoir. For. Sci. 21:36-39.

Filer, T.H., Jr., D.T. Cooper, R.J. Collins, and R. Wolfe.
1975. Survey of sycamore plantations for canker, leaf scorch, and dieback. Plant Dis. Rep. 59:152-153.

Filer, T.H., F.I. McCracken, C.A. Mohn, and W.K. Randall.
1971. Septoria canker on nursery stock of Populus deltoides. Plant Dis. Rep. 55:460-463.

Filer, T.H. and E.R. Toole.
1966. Sweetgum, mycorrhizae and some associated fungi. For. Sci. 12:432-437.

Filer, T.H., Jr. and E.R. Toole.
1968. Effect of methyl bromide on mycorrhizae and growth of sweetgum seedlings. Plant Dis. Rep. 52:483-485.

Foster, A.A.
1961. Control of black root rot of pine seedlings by soil fumigation in the nursery. Ga. For. Res. Council Rep. 8,5p.

Foster, A.A. and R.P. Harrison.
1957. Seedling losses in Arizona cypress. Tree Planters' Notes 29:20-21.

Foster, A.A. and D.W. Krueger.
1961. Protection of pine seed orchards and nurseries from fusiform rust by timing ferbam sprays to coincide with infection periods. Ga. For. Res. Pap. 1,4p.

Froelich, R.C., T.R. Dell, and C.H. Walkinshaw.
1965. Factors associated with occurrence of Fomes annosus in pine plantations. Phytopathology 55:1058-1059.

Froelich, R.C., T.R. Dell, and C.H. Walkinshaw.
1966. Soil factors associated with Fomes annosus in the Gulf States. For. Sci. 12:356-361.

Froelich, R.C., C.S. Hodges, Jr., and S.S. Sackett.
1978. Prescribed burning reduces severity of annosus root rot in the South. For. Sci. 24:93-100.

Froelich, R.C., E.G. Kuhlman, C.S. Hodges, M.J. Weiss, and J.D. Nichols.
1977. Fomes annosus root rot in the South. Guidelines for prevention U.S. Dept. Agric. For. Serv. South. For. Exp. Sta., Southeast. For. Exp. Sta., State and Private For. unnumbered bulletin 17p.

Froelich, R.C. and J.D. Nicholson.
1973. Spread of Fomes annosus reduced by heavy application of sulfur. For. Sci. 19:75-76.

Froelich, R.C. and G.A. Snow.
1965. Pine trees near power substations demaged by urea herbicides. Plant Dis. Rep. 49:970-971.

Gilespie, W.H. and C.L. Wilson.
1960. Limited saprophytic survival of the oak wilt fungus Ceratocystis fagacearum (Bretz) Hunt. Plant Dis. Rep. 44:687-689.

Goddard, R.E. and R.A. Schmidt.
1971. Early identification of fusiform rust resistant slash pine families through controlled inoculation. Proc. Eleventh Conf. South. For. Tree Improve. p.31-36.

Goddard, R.E., R.A. Schmidt, and F.V. Linde.
1975. Effect of differential selection pressure on fusiform rust resistance in phenotypic selections of slash pine. Phytopathology 65:336-638.

Goggans, J.F.
1949. Cronartium fusiforme on slash and loblolly pine in the Piedmont Region of Alabama. J. For. 47:978-980.

Goggans, J.F.
1957. Southern fusiform rust. Ala. Polytech Inst. Agric. Exp. Sta. Bul. 304,19p.

Gooding, G.V., Jr.
1964. Effect of temperature on growth and survival of Fomes annosus in freshly cut pine bolts. Phytopathology 54:893-894 (abst.)

Gooding, G.V., Jr., C.S. Hodges, and E.R. Ross.
1966. Effect of temperature on growth and survival of Fomes annosus. For. Sci. 12:325-333.

Gooding, G.V., Jr. and H.R. Powers, Jr.
1965. Serological comparison of Cronartium fusiforme, C. quercuum, and C. Ribicola by immunodlffusion tests. Phytopathology 55:670-674.

Gravatt, G.F. and R.P. Marshall.
1926. Chestnut blight in the southern Appalachians. U.S. Dep. Agric. irc. 370, llp.

Graves, A.H.
1913. Notes on diseases of trees in the southern Appalachians. Phytopathology 3:129-139.

Graves, A.H.
1914. Notes on diseases of trees in the southern Appalachians. Phytopathology 4:63-72.

Griffin, B.R. and C.L. Wilson.
1967. Asexual nuclear behavior and formation of conidia in Fomes annosus. Phytopathology 57:1176-1177.

Haasis, F.A., R.R. Nelson, and D.H. Marx.
1964. Morphological and physiological characteristics of mating types of Phytophthora cinnamomi. Phytopathology 54:1146-1151.

Haasis, F.A., R.R. Nelson, and D.H. Marx.
1965. Occurrence of mating types in Phytophthora cambivora. J. Elisha Mitchell Sci. Soc. 75:76.

Halliwell, R.S.
1966. Association of Cephalosporium with a decline of oak in Texas. Plant Dis. Rep. 50:75-78.

Hamilton, J.R. and L.W.R. Jackson.
1951. Treatment of shortleaf pine and loblolly pine seed. Plant Dis. Rep. 35:274-276.

Hare, R.C. and G.A. Snow.
1976. Two systemic fungicides show promise for control of fusiform rust. Plant Dis. Rep. 60-530-531.

Hedgcock, G.G., G.F. Gravatt, and R.P. Marshall.
1925. Polyporus schweinitzii Fr. on Douglas-fir in the eastern United States. Phytopathology 15:568-569.

Hedgcock, G.G. and Siggers, P.V.
1949. A comparison of the pine-oak rusts. U.S. Dep. Agric. Tech. Bull. 978.30p.

Hendrix, F.F. and W.A. Campbell.
1973. Pythiums as plant pathogens. Ann. Rev. Phytopath. 11:77-98.

Hendrix, F.F., Jr. and E.G. Kuhlman.
1964. Root infection of Pinus elliottii by Fomes annosus. Nature 201(4914):55-56.

Henry, B.W.
1953. A root rot of southern pine nursery seedlings and its control by soil fumigation. Phytopathology 43:81-88.

Henry, B.W.
1954. Sporulation by the brown spot fungus on longleaf pine needles. Phytopathology 44:385-386.

Henry, B.W. and T.E. Bercaw.
1956. Shortleaf-loblolly hybrid pines free of fusiform rust after 5 years' exposure. J. For. 54:779.

Henry, B.W. and 0.0. Wells.
1967. Variation in brown-spot infection of longleaf pine from several geographic sources. U.S. Dep. Agric. For. Serv. Res. Note SO-52,4p.

Hepting, G.H.
1935. Decay following fire in young Mississippi delta hardwoods. U.S. Dep. Agric. Tech. Bull. 494,32p.

Hepting, G.H.
1939. A vascular wilt of the mimosa tree. U.S. Dep. Agric. Circ. 535,11p.

Hepting, G.H.
1941. Prediction of cull following fire in Appalachian oaks. J. Agric. Res. 62:109-120.

Hepting, G.H.
1941a. Eastern forest tree diseases in relation to stand improvement. Civ. Cons. Corps For. Publ. 2,26p.

Hepting, G.H.
1944. Preventing decay in wood aircraft. Aero Digest 44(4):126-128.

Hepting, G.H.
1944a. Sapstreak, a new killing disease of sugar maple. Phytopathology 34:1069-1076.

Hepting, G.H.
1945. Decay and staining of southern pine pulpwood. Paper Ind. 27:379-382.

Hepting, G.H.
1947. Stimulation of oleoresin flow in pines by a fungus. Science 105:209.

Hepting, G.H.
1955. The current status of oak wilt in the United States. For. Sci. 1(2):95-103.

Hepting, G.H.
1955a. A southwide survey for sweetgum blight. Plant Dis. Rep. 39:261-265.

Hepting, G.H.
1957. A rust on Virginia pine and Buckleya. Mycologia 49:896-899.

Hepting, G.H.
1964. Forest pathology in the southern Appalachians, 1900-1940. For. Hist. 8.11-13.

Hepting, G.H.
1967. The INTREDIS register for literature retrieval in forest pathology. Proc. XIV IUFRO Congress. Section 24:385-387.

Hepting, G.H.
1970. The case for forest pathology. J. For. 68:78-81.

Hepting, G.H.
1971. Diseases of forest and shade trees of the United States. U.S. Dep. Agric. For. Serv. Agric. Handb. 386, 658p.

Hepting, G.H.
1971a. Climate and forest diseases. In: Man's impact on terrestrial and oceanic ecosystems, pp203-226. Eds. W.H. Mathews, F.E. Smith, and E.D. Goldberg. MIT Press.

Hepting, G.H.
1971b. Air pollution and trees. In: Man's impact on terrestrial and oceanic ecosystems, pp116-129. (See Hepting 1971a for citation)

Hepting, G.H. and C.R. Berry.
1961. Differentiating needle blights of white pine in the interpretation of fume damage. Int. J. Air and Water Pollution 4:101-105.

Hepting, G.H. and D.J. Blaisdell.
1936. A protective zone in red gum fire scars. Phytopathology 26:62-67.

Hepting, G.H. and A.D. Chapman.
1938. Losses from heartrot in two shortleaf and loblolly pine stands. J. For. 36:1193-1201.

Hepting, G.H. and E.B. Cowling.
1977. Forest pathology: Unique features and prospects. Ann. Rev. Phytopathol. 12:431-450.

Hepting, G.H. and R.W. Davidson.
1935. Some leaf and twig diseases of hemlock in North Carolina. Plant Dis. Rep. 19:308-309.

Hepting, G.H. and R.W. Davidson.
1937. A leaf and twig disease of hemlock caused by a new species of Rosellinia. Phytopathology 27:305-310.

Hepting, G.H. and A.A. Downs.
1944. Root and Butt rot in planted white pine at Biltmore, North Carolina. J. For. 42:119-123.

Hepting, G.H., K.H. Garren, and P.W. Warlick.
1940. External features correlated with top rot in Appalachian oaks. J. For. 38:873-876.

Hepting, G.H. and G.G. Hedgcock.
1937. Decay in merchantable oak, yellow poplar, and basswood in the Appalachian region. U.S. Dep. Agric. Tech. Bull. 570, 30p.

Hepting, G.H. and G.M. Jemison.
1950. A cure for littleleaf disease. Amer. For. 56(11):20-22.

Hepting, G.H. and E.R. Roth.
1950. The fruiting of heartrot fungi on felled trees. J. For. 48:332-333.

Hepting, G.H. and E.R. Roth.
1953. Host relations and spread of the pine pitch canker disease. Phytopathology 43:475 (abst.).

Hepting, G.H., E.R. Roth, and R.F. Luxford.
1942. The significance of the discolorations in aircraft veneers: yellow-poplar. U.S. Dep. Agric. Bur. Plant Ind., Soils, and Agric. Eng. For. Path. Special Release 1375, 8p.

Hepting, G.H., E.R. Roth, and B. Sleeth.
1949. Discolorations and decay from increment borings. J. For. 47:366-370.

Hepting, G.H. and E.R. Toole.
1939. The hemlock rust caused by Melampsora farlowii, Phytopathology 29:463-473.

Hepting, G.H., E.R. Toole, and J.S. Boyce, Jr.
1952. Sexuality in the oak wilt fungus. Phytopathology 42:438-442.

Hodges, C.S.
1958. The effect of fumigation on the relative abundance of soil microorganisms. Assoc. South Agric. Workers Proc. 1958:222-223.

Hodges, C.S.
1961. Freezing lowers survival of three species of southern pines. Tree Planters' Notes 47:23-24.

Hodges, C.S.
1962. Fungi isolated from southeastern forest tree nursery soils. Mycologia 54:221-229.

Hodges, C.S.
1962a. Black root rot of pine seedlings. Phytopathology 52:210-219.

Hodges, C.S.
1969. Relative susceptibility of loblolly, longleaf, and slash pine roots to infection by Fomes annosus. Phytopathology 59:1031 (abst.)

Hodges, C.S.
1969a. Modes of infection and spread of Fomes annosus. Ann. Rev. Phytopath. 7:247-266.

Hodges, C.S.
1970. Evaluation of stump treatment chemicals for control of Fomes annosus. Proc. Third Internat. Conf. on Fomes annosus p43-53.

Hodges, C.S. and H.J. Green.
1961. Survival in the plantation of eastern redcedar seedlings infected with Phomopsis blight in the nursery. Plant Dis. Rep. 45:134-136.

Hollis, C.A., R.A. Schmidt, and J.W. Kimbrough.
1972. Axenic culture of Cronartium fusiforme. Phytopathology 62:1417-1419.

Hollis, C.A., W.H. Smith, R.A. Schmidt, and W.L. Pritchett.
1975. Soil and tissue nutrients, soil drainage, fertilization, and tree growth as related to fusiform rust incidence in slash pine. For. Sci. 21:141-148.

Hopper, B.E.
1958. Plant-parasitic nematodes in the soils of Southern forest nurseries. Plant Dis. Rep. 42:308-314.

Hopper, B.E. and W.H. Padgett.
1960. Relationship of nemas (nematodes) with root rot of pine seedlings at the E.A. Hauss State Forest Nursery, Atmore, Alabama. Plant Dis. Rep. 44:258-259.

Howell, F.C. and W.J. Stambaugh.
1972. Rates of pathogenic and saprophytic development of Fomes annosus in roots of dominant and suppressed eastern redcedar. Plant Dis. Rep. 56:987-990.

Humphrey, C.J.
1923. Decay of lumber and building timbers due to Poria incrassata (B. and C.) Burt. Mycologia 15:258-277.

Humphrey, C.J. and L.E. Miles.
1925. Dry-rot in buildings and stored materials and how to combat it. Ala. Polytech. Inst. Circ. 78,28p.

Jackson, L.W.R.
1947. Method for differential staining of mycorrhizal roots. Science 105:291-292.

Jackson, L.W.R.
1948. "Needle curl" of shortleaf pine seedlings. Phytopathology 30:1028-1029.

Jackson, L.W.R.
1952. Influence of littleleaf on quality of shortleaf pine seed. Phytopathology 42:57.

Jackson, L.W.R.
1968. Growth of fusiform branch cankers on loblolly and slash pine. Naval Stores Rev. 78(4):6-7.

Jackson, L.W.R. and C.H. Driver.
1969. Morphology of mycorrhizae on deciduous forest tree species. Castanea 34:230-235.

Jackson, L.W.R. and J.N. Parker.
1958. Anatomy of fusiform rust galls on loblolly pine. Phytopathology 48:637-640.

Jackson, L.W.R. and B. Zak.
1949. Grafting methods used in studies of the littleleaf disease of shortleaf pine. J. For. 47:904-908.

Jemison, G.M. and G.H. Hepting.
1949. Timber stand improvement in the Southern Appalachian region. U.S. Dept. Agric. For. Serv. Misc. Publ. 693, 80p.

Jewell, F.F.
1957. Preventing cone rust on slash pine by pollination techniques used in breeding programs. Phytopathology 47:241-242.

Jewell, F.F.
1958. Cronartium fusiforme extent below slash pine branch cankers. Phytopathology 48:394 (abst.)

Jewell, F.F.
1960. Inoculation of slash pine seedlings with Cronartium fusiforme. Phytopathology 50:48-51.

Jewell, F.F.
1960a. New pine hosts for southern fusiform rust. Plant Dis. Rep. 44:673.

Jewell, F.F.
1969. Evidence of hyphal growth of Cronartium quercuum in the pine host cambium. Plant Dis. Rep. 53:793-794.

Jewell, F.F.
1972. A comparison of Cronartium fusiforme and C. quercuum in pine. Phytopathology 62:767.

Jewell, F.F.
1975. Characteristics of Cronartium fusiforme in slash pine cotyledons. Plant Dis. Rep. 59:407-410.

Jewell, F.F. and S.L. Mallett.
1964. Resistance to fusiform rust in slash pine as shown by artificial inoculation. Phytopathology 54:1294.

Jewell, F.F. and S.L. Mallett.
1966. Testing slash pine for rust resistance. For. Sci. 13:413-418.

Jewell, F.F. and G.A. Snow.
1972. Anatomical resistance to gall-rust infection in slash pine. Plant Dis. Rep. 56:531-534.

Jewell, F.F. and D.C. Speirs.
1976. Histopathology of one- and two-year-old resisted infections by Cronartium fusiforme in slash pine. Phytopathology 66:741-748.

Jewell, F.F., R.P. True, and S.L. Mallett.
1962. Histology of Cronartium fusiforme in slash pine seedlings. Phytopathology 52:850-858.

Jewell, F.F. and N.M. Walker.
1967. Histology of Cronartium quercuum on shortleaf pine. Phytopathology 57:545-550.

Johnson, H.W. and C.W. Edgerton.
1936. A heart rot of magnolia caused by Fomes geotropus. Mycologia 28:292-295.

Kais, A.G.
1964. Germination and growth of Scirrhia acicola in liquid culture inhibited by cycloheximide semicarbazone. Plant Dis. Rep. 48:553-556.

Kais, A.G.
1966. Persistance of albinism in Cronartium fusiforme. Plant Dis. Rep. 50:842.

Kais, A.G.
1971. Dispersal of Scirrhia acicola spores in southern Mississippi. Plant Dis. Rep. 55:309-311.

Kais, A.G.
1975. Environmental factors affecting brown-spot infections on longleaf pine. Phytopathology 65:1389-1392.

Kais, A.G.
1975a. Fungicidal control of Scirrhia acicola on longleaf pine seedlings. Plant Dis. Rep. 59:686-688.

Kais, A.G. and G.A. Snow.
1972. Host response of pines to various isolates of Cronartium quercuum and Cronartium fusiforme. U.S. Dep. Agric. Misc. Publ. 1221:495-503.

Kaufert, F.H.
1933. Fire and decay injury in the southern bottomland hardwoods. J. For. 31:64-67.

Kelley, W.D.
1975. Physiological differences among isolates of Phytophthora cinnamomi. Can. J. Microbiol. 21:1548-1552.

Kelley, W.D. and E.A. Curl.
1972. Effect of cultural practices and biotic soil factors on Fomes annosus. Phytopathology 62:422-427.

Kelley, W.D. and T.C. Davis, Jr.
1973. Conidiophores and basidiocarps of Fomes annosus in east central Alabama. Phytopathology 63:1424.

Kelley, W.D. and R. Rodriguez-Kabana.
1970. Enzymatic activity of Phytophthora cinnamomi in sterilized soil. Phytopathology 60:584.

Kelley, W.D. and R. Rodriguez-Kabana.
1975. Sodium azide as a soil fumigant in forest tree nurseries. Proc. Amer. Phytopath. Soc. 2:47.

Kelley, W.D. and R. Rodriguez-Kabana.
1976. Competition between Phytophthora cinnamomi and Trichoderma spp. in autoclaved soil. Can. J. Microbiol. 28:1120-1127.

Kelman, A. and G.V. Gooding, Jr.
1965. A root and stem rot of yellow-poplar caused by Cylindrocladium scoparium. Plant Dis. Rep. 49:797-801.

Kelman, A., C.S. Hodges, Jr., and H.R. Garriss.
1960. Needle blight of redcedar, Juniperus virginiana. Plant Dis. Rep. 44:527-531.

Kinloch, B.B., Jr. and A. Kelman.
1965. Relative susceptibility to fusiform rust of progeny lines from rust-infected and non-infected loblolly pine. Plant Dis. Rep. 49:872-874.

Kinloch, B.B., Jr., and R.W. Stonecypher.
1969. Genetic variation in susceptibility to fusiform rust in seedlings from a wild population of loblolly pine. Phytopathology 59:1246-1255.

Kirk, T.K. and A. Kelman.
1965. Lignin degradation as related to the phenoloxidases of selected wood-decaying Basidiomycetes. Phytopathology 55:739-745.

Koenigs, J.W.
1960. Fomes annosus: a bibliography with subject index. U.S. Dep. Agric. For. Serv. So. For. Exp. Sta. Occas. Pap. 181,35p.

Koenigs, J.W.
1968. Control of fusiform rust on southern pines in nurseries. Plant Dis. Rep. 52:597-599.

Koenigs, J.W.
1969. Growth and survival of Fomes annosus at high concentrations of borax. Phytopathology 59:1717-1721.

Koenigs, J.W.
1970. Inoculation of southern pine seedlings under aseptic conditions. For. Sci. 16:280-286.

Kuhlman, E.G.
1969. Number of conidia necessary for stump root infection by Fomes annosus. Phytopathology 59:1168-1169.

Kuhlman, E.G.
1969a. Survival of Fomes annosus spores in soil. Phytopathology 59:198-201

Kuhlman, E.G.
1969b. Inoculation of loblolly pine seedlings with Fomes annosus in the greenhouse. Can. J. Bot. 47:2079-2082.

Kuhlman, E.G.
1970. Seedling inoculations with Fomes annosus show variation in virulence and in host susceptibility. Phytopathology 60:1743-1746.

Kuhlman, E.G.
1973. Variation in infection of loblolly pine roots on high and low hazard sites in the southeastern United States. Proc. Fourth Internal. Conf. on Fomes annosus, p 179-183.

Kuhlman, E.G. and F.F. Hendrix, Jr.
1962. A selective medium for the isolation of Fomes annosus. Phytopathology 52:1310-1312.

Kuhlman, E.G., C.S. Hodges, Jr., and R.C. Froelich.
1976. Minimizing losses to Fomes annosus in the southern United States. U.S. Dept. Agric. For. Serv. Res. Pap. SE-151, 16p.

Kuhlman, E.G. and E.W. Ross.
1970. Regeneration of pine on Fomes annosus-infected sites in the southeastern United States. Proc. Third Internat. Conf. on Fomes annosus, p71-76.

Levi, M.P.
1973. The durability and treatability of southern pine veneer cores-a preliminary study. Amer. Wood Preservers Assoc. Proc. 69:224-229.

Levi, M.P., D. Huisingh, and W.B. Nesbitt.
1974. Plant uptake of wood preservatives from treated posts not detected. For. Prod. J. 24(9):97-98.

Lightle, P.C. and J.W. Starr.
1957. Heartrot in southern pines. U.S. Dep. Agric. For. Serv. So. For. Notes #108.

Lindgren, R.M.
1951. Deterioration of southern pine pulpwood during storage. Proc. For. Prod. Res. Soc. 5:169-180.

Lindgren, R.M.
1953. Deterioration losses in stored southern pine pulpwood. Tappi 36:260-263.

Lindgren, R.M. and G.M. Harvey.
1952. Decay control and increased permeability in southern pine sprayed with fluoride solutions. J. For. Prod. Res. Soc. 2(5):250-256.

Lohman, M.L., E.K. Cash, and R.W. Davidson.
1942. An unidentified Atropellis on cankered Pinus virginiana. J. Wash. Acad. Sci. 32:296-298.

Long, W.H.
1913. A preliminary note on Polyporus dryadeus as a root parasite on the oak. Phytopathology 3:285-287.

Long, W.H.
1917. Investigations of the rotting of slash in Arkansas. U.S. Dep. Agric. Bull. 496,15p.

Lowe, J.L.
1961. Synopsis of the Polyporaceae of the Southeastern United States. J. Elisha Mitchell Sci. Soc. 77:43-61.

Mann, W.F., Jr., B.C. Williamson, and J.M. McGilvray.
1971. Parasitic weed--A new problem. For. Farmer 30(6):6-8.

Marx, D.H. and W.C. Bryan.
1969. Studies on ectomycorrhizae of pine in an electronically air-filtered airconditioned, plant-growth room. Can. J. Bot. 47:1903-1909.

Marx, D.H., W.C. Bryan, and C.B. Davey.
1970. Influence of temperature on aseptic syntheses of ectomycorrhizae by Thelephora terrestris and Pisolithus tinctorius on loblolly pine. For. Sci. 16:424-431.

Marx, D.H. and B. Zak.
1965. Effect of pH on mycorrhizal formation of slash pine in aseptic culture. For. Sci. 11:66-75.

Mathews, F.R.
1964. Some aspects of the biology and the control of southern cone rust. J. For. 62:881-884.

Mathews, F.R. and S.J. Rowan.
1972. An improved method for large-scale inoculation of pine and oak with Cronartium fusiforme. Plant Dis. Rep. 56:931-934.

May, J.T. and J.F. Goggans.
1950. Southern fusiform rust of slash and loblolly pine in the Alabama Piedmont. Ala. Polytech Inst. Agric. Exp. Sta. Leaflet 30,6p.

McCracken, F.I.
1972. Sporulation of Pleurotus ostreatus. Can. J. Bot. 50:2111-2115.

McDaniel, A.T. and C.L. Wilson.
1962. A study of symptoms and control of Phomopsis juniperovora on Arizona cypress. Plant Dis. Rep. 46:364-365.

Miles, L.E.
1934. The rusts of Mississippi. Plant Dis. Rep. 18:54-73.

Miller, J.H.
1935. Forest seed bed diseases in Georgia and South Carolina. Plant Dis. Rep. 19:259.

Miller, J.H.
1941. The Ascomycetes of Georgia. Plant Dis. Rep. Suppl. 131:31-93.

Miller, J.H.
1950. A historical sketch of diseases of forest trees in Georgia. Plant Dis. Rep. Suppl. 191:98-101.

Miller, J.H.
1961. A monograph of the world species of Hypoxylon, 158p. U. of Georgia Press.

Miller, J.H. and G. Burton.
1942. Georgia Pyrenomycetes III. Mycologia 34:1-7.

Miller, T.
1970. Inoculation of slash pine seedlings with stored basidiospores of Cronartium fusiforme. Phytopathology 60:1773-1774.

Miller, T.
1972. Fusiform rust in planted slash pines: Influence of site preparation and spacing. For. Sci. 18:70-75.

Miller, T. and A. Kelman.
1966. Growth of Fomes annosus on roots of suppressed and dominant loblolly pines. For. Sci. 12:225-233.

Miller, T. and R.W. Roncardori.
1966. Abjection of secondary sporidia of Cronartium fusiforme. Phytopathology 56:1326-1327.

Myren, D.T. and A. Kelman.
1975. Fungi inhabiting fusiform rust galls and some properties of rust-infected tissue. Plant Dis. Rep. 59:148-151.

Nelson, R.M.
1931. Decay in loblolly pine on the Atlantic Coastal Plain. In: Selective logging in the loblolly pine-hardwood forests of the Middle Atlantic Coastal Plain with special reference to Virginia. Va. For. Serv. Publl. 43:58-59.

Nelson, R.M.
1934. Effect of bluestain fungi on southern pines attacked by bark beetles. Phytopatholog. Zeitschrift 7:327-353.

Nelson, R.M.
1940. Vigorous young yellow-poplar trees can recover from injury by nectria cankers. J. For. 38:587-588.

Nelson, R.M. and G.F. Gravatt.
1929. Tannin content of dead chestnut trees. J. Amer. Leather Chemists Assoc. 24:479-499.

Parris, G.K.
1966. Death of honeylocust in Mississippi associated with Polyporus lucidus. Plant Dis. Rep. 50:243-244.

Parris, G.K.
1967. "Needle curl" of loblolly pine. Plant Dis. Rep. 51:805-806.

Peterson, R.S. and F.F. Jewell.
1968. Status of American stem rusts of pine. Ann. Rev. Phytopath. 6:23-40.

Plakidas, A.G.
1942. Venturia acerina, the perfect stage of Cladosporium humile. Mycologia 24:27-37.

Plakidas, A.G.
1960. Angular leaf spot of magnolia. Mycologia 52:255-259.

Powers, H.R., Jr.
1968. Distance of needle infection from stem affects likelihood of gall development on slash pine by Cronartium fusiforme. Phytopathology 58:1147-1149.

Powers, H.R., Jr.
1969. Testing of pathogenic variability within Cronartium fusiforme and C. qwercuum. Proc. UFRO Advanced Study Institute. August 1969 pp. 505-509.

Powers, H.R., Jr.
1971. Variation in shape of rust galls on loblolly pine. Plant Dis. Rep. 55:623-625.

Powers, H.R., Jr.
1972. Comandra rust on southern pines. J. For. 70:18-20.

Powers, H.R., Jr.
1975. Relative susceptibility of five southern pines to Cronartium fusiforme. Plant Dis. Rep. 59:312-314.

Powers, H.R., Jr., J.P. McClure, H.A. Knight, and G.F. Dutrow.
1974. Incidence and financial impact of fusiform rust in the South. J. For. 72:398-401.

Powers, H.R., Jr. and R.W. Roncadori.
1966. Teliospore germination and sporidial production by Cronartium fusiforme. Plant Dis. Rep. 50:432-434.

Powers, H.R., Jr. and W.A. Stegall, Jr.
1965. An evaluation of cycloheximide (Acti-Dione) for control of white pine blister rust in the southeast. Plant Dis. Rep. 49:342-346.

Powers, H.R., Jr. and A.F. Verrall.
1962. A closer look at Fomes annosus. For. Farmer 21(13) 8-9, 16-17.

Rockwood, D.L. and R.E. Goddard.
1973. Predicting gains for fusiform rust resistance in slash pine. Proc. 12th South. For. Tree Improve. Conf. p31-37.

Roncadori, R.W.
1968. The pathogenicity of secondary and tertiary basidiospores of Cronartium fusiforme. Phytopathology 58:712-713.

Roncadori, R.W. and F.R. Mathews.
1966. Storage and germination of aeciospores of Cronartium fusiforme. Phytopathology 56:1328-1329.

Ross, E.R.
1969. Thermal inactivation of conidia and basidiospores of Fomes annosus. Phytopathology 59:1798-1801.

Ross, E.W.
1973. Fomes annosus in the southeastern United States: Relation of environmental and biotic factors to stump colonization and losses in the residual stand. U.S. Dep. Agric. Tech. Bull. 1459,26p.

Ross, E.W. and C.S. Hodges.
1964. Fomes annosus infections in young slash pine plantations. Phytopathology 54:904 (abst.).

Ross, E.W. and D. H. Marx.
1972. Susceptibility of sand pine to Phytophthora cinnamomi. Phytopathology 62:1197-1200.

Roth, E.R.
1941. Top rot in snow damaged yellow poplar and basswood. J. For. 39:60-62.

Roth, E.R.
1943. Effect of invisible decay on deterioration of untreated oak ties and posts. J. For. 41:117-121.

Roth, E.R.
1948. Healing and defects following oak pruning. J. For. 46:500-504.

Roth, E.R.
1950. Discolorations in living yellow-poplar trees. J. For. 48:184-185.

Roth, E.R.
1951. The viability of spores and mycelium of Endoconidiophora virescens on sugar maple lumber. Plant Dis. Rep. 35:379-381.

Roth, E.R.
1952. Roots of living Pinus rigida decayed by Fomes annosus. Plant Dis. Rep. 36:330.

Roth, E.R.
1956. Decay following thinning of sprout oak clumps. J. For. 54:26-30.

Roth, E.R. and C. Hartley.
1957. Decay prevention in wooden boats during storage. U.S. Dep. Agric. For. Serv. Report SR-12401, 46p.

Roth, E.R. and G.H. Hepting.
1943. Wounds and decay caused by removing large companion sprouts of oak. J. For. 41:190-195.

Roth, E.R. and G.H. Hepting.
1943a. Origin and development of oak stump sprouts as affecting their likelihood to decay. J. For. 41:27-36.

Roth, E.R. and G.H. Hepting.
1943b. Wounds and decay caused by removing companion sprouts of oak. J. For. 41:190-195.

Roth, E.R. and G.H. Hepting.
1946. Pitch canker, a new disease of some southern pines, J. For. 44:742-744.

Roth, E.R. and G.H. Hepting.
1954. Eradication and thinning tests for Nectria and Strumella canker control in Maryland. J. For. 52:253-256.

Roth, E.R., E.R. Toole, and G.H. Hepting.
1948. Nutritional aspects of the littleleaf disease of pine. J. For. 46:578-587.

Ruehle, J.L.
1962. Histopathological studies of pine roots infected with lance and pine cystoid nematodes. Phytopathology 52:68-71.

Ruehle, J.L.
1964. Plant-parasitic nematodes associated with pine species in southern forests. Plant Dis. Rep. 48:60-61.

Ruehle, J.L.
1973. Nematodes and forest trees-types of damage to tree roots. Ann. Rev. Phytopath. 11:99-118.

Ruehle, J.L. and J.N. Sasser.
1962. The role of plant-parasitic nematodes in stunting of pine in southern plantations. Phytopathology 52:56-68.

Ruehle, J.L. and J.N. Sasser.
1964. Additional data on results of nematicidal fumigation in pine plots in North Carolina. Plant Disease Rep. 48:534-536.

Scheffer, T.C. and R.M. Lindgren.
1940. Stains of sapwood and sapwood products and their control. U.S. Dep. Agric. Tech. Bull. 714,124~.

Scheffer, T.C., A.F. Verrall, and G.M. Harvey.
1963. On-site preservative treatments: Their effectiveness for exterior millwork of different species used in various climates. For. Prod. J. 13(1):7-13.

Scheffer, T.C., A.F. Verrall, and G. Harvey.
1971. Fifteen-year appraisal of dip treating for protecting exterior woodwork: Effectiveness on different wood species and in various climates. Material und Organismen 6:27-44.

Scheffer, T.C. and A.F. Verrall.
1973. Principles for protecting wood buildings from decay. U.S. Dep. Agric. For Serv. Res. Pap. FPL-190,55p.

Scheld, H.W. and R.C. DeGroot.
1971. Toughness of sapwood in water-sprayed longleaf pine logs. For. Prod. J. 21(4):33-34.

Scheld, H.W., Jr., and A. Kelman.
1963. Influence of environmental factors on Phomopsis juniperovora. Plant Dis. Rep. 47:932-935.

Schmidt, R.A.
1972. A literature review of inoculation techniques used in studies of fusiform rust. NATO-IUFRO Advanced Study Institute. U.S. Dep. Agric. For. Serv. Misc. Pub. 1221, p341-356.

Schmidt, R.A. and R.E. Goddard.
1971. Preliminary results of fusiform rust resistance from field progeny tests of selected slash pine. Proc. Eleventh Conf. South. For. Tree Improve. p.37-44.

Schmidt, R.A., R.E. Goddard, and C.A. Hollis.
1974. Incidence and distribution of fusiform rust in slash pine plantations in Florida and Georgia. Univ. Fla. IFAS Agric. Exp. Sta. Bull. 763,21p.

Schmidt, R.A., M.J. Foxe, C.A. Hollis, and W.H. Smith.
1972. Effect of N,P, and K on the incidence of fusiform rust galls on greenhouse-grown seedlings of slash pine. Phytopathology 62:788 (abst.)

Schmidt, R.A. and C.P. Seymour.
1972. Etiology of oak decline in Florida ferneries. Plant Dis. Rep. 56:811-814.

Schmidt, R.A. and E.M. Underhill.
1974. Incidence and impact of pitch canker in slash pine plantations in Florida. Plant Dis. Rep. 58:451-454.

Shain, L.
1967. Resistance of sapwood in stems of loblolly pine to infection by Fomes annosus. Phytopathology 57:1034-1045.

Shoulders, E., J.P. Hollis, R.G. Merrifield, E.E. Turner, and A.F. Verrall
1965. Test of soil fumigants in Louisiana. Tree Planters Notes No. 73(Oct):14-21.

Siggers, P.V.
1935. Slash-disposal methods in logging shortleaf pine. U.S. Dep. Agric. For. Serv. So. Sta. Occasional Pap. 42,5p.

Siggers, P.V.
1944. The brown spot needle blight of pine seedlings. U.S. Dep. Agric. Tech. Bull. 870,36p.

Siggers, P.V.
1950. Possible mechanism of variation in the imperfect stage of Scirrhia acicola. Phytopathology 40:726-728.

Siggers, P.V.
1955. Control of the fusiform rust of southern pines. J. For. 53:442-446.

Siggers, P.V. and K.D. Doak.
1940. The littleleaf disease of shortleaf pine. U.S. Dep. Agric. For. Serv. So. For. Exp. Sta. Occas. Pap. 95,5p.

Smalley, G.W. and R.L. Sheer.
1963. Blackroot rot in Florida sand hills. Plant Dis. Rep. 47:669-671.

Snow, G.A.
1961. Artificial inoculation of longleaf pine with Scirrhia acicola. Phytopathology 51:186-188.

Snow, G.A., F.J. Czabator, and S.S. Sorrels.
1964. Cycloheximide derivatives for controlling brown spot on longleaf pine. Plant Dis. Rep. 48:551-556.

Snow, G.A., R.J. Dinus, and A.G. Kais.
1975. Variation in pathogenicity of diverse sources of Cronartium fusiforme on selected pine families. Phytopathology 65:170-175.

Snow, G.A., R.J. Dinus, and C.H. Walkinshaw.
1976. Increase in virulence of Cronartium fusiforme on resistant slash pine. Phytopathology 66:511-513.

Snow, G.A., F.F. Jewell, and L.N. Eleuterius.
1963. Apparent recovery of slash and loblolly pine seedlings from fusiform rust infection. Plant Dis. Rep. 47:318-319.

Snow. G.A. and A.G. Kais.
1972. Technique for inoculating pine seedlings with Cronartium fusiforme. In Biology of rust resistance in forest trees. U.S. Dept. Agric. For. Serv. Misc. Publ. 1221 pp325-326.

Snyder, E.B. and H.J. Derr.
1972. Breeding longleaf pines for resistance to brown spot needle blight. Phytopathology 62:325-327.

Snyder, W.C., E.R. Toole, and G.H. Hepting.
1949. Fusaria associated with mimosa wilt, sumac wilt, and pine pitch canker. J. Agric. Res. 78:365-382.

Sohn, S.T., R.E. Goddard, and R.A. Schmidt.
1975. Comparative performances of slash pine for fusiform rust resistance in high rust hazard locations. Proc. 13th South. For. Tree Improve. Conf. p.204.

Stambaugh, W.J., F.W. Cobb, R.A. Schmidt, and F.C. Krieger.
1962. Seasonal inoculum dispersal and white pine stump invasion by Fomes annosus. Plant Dis. Rep. 46:194-198.

Stonecypher, R.W., B.J. Zobel, and R.L. Blair.
1973. Inheritance patterns of loblolly pines from a non-selected natural population. N.C. Agric. Exp. Sta. Bull. 220,60p.

Tainter, F.H.
1971. Rust disease threatens Arkansas forests. Ark. Farm Res. 20(2):9.

Tainter, F.H.
1972. Oak wilt, a selective silvicide in Arkansas? Ark. Farm Res. 21(6):8.

Tainter, F.H.
1973. Development of Cronartium camandrae in Comandra umbellata. Can. J. Bot. 51:1369-1372.

Tainter, F.H. and W.D. Gubler.
1973. Natural biological control of oak wilt in Arkansas. Phytopathology 63:1027-1034.

Tainter, F.H. and W.D. Gubler.
1974. Effect of Hypoxylon and other microorganisms on carbohydrate reserves of oak-wilted trees. For. Sci. 20:337-342.

Tainter, F.H., M. Tucker, B. Washburn, and J. Tiner.
1974. Oak wilt remains static in Arkansas. Plant Dis. Rep. 58:622-624.

Taylor, W.K. and J.S. Boyce, Jr.
1965. Effect of phytoactin on the fusiform rust fungus, Cronartium fusiforme. Plant Dis. Rep. 49:698-701.

Thompson, J.N., E.B. Cowling, and E.W. Ross.
1962. Changes in moisture content and color of the cambial zone of bolts of pine sapwood during colonization by Fomes annosus. Can. J. Bot. 46:1533-1537.

Toole, E.R.
1941. Fusarium wilt of the mimosa tree (Albizzia julibrissin). Phytopathology 31:599-616.

Toole, E.R.
1949. Fusarium wilt of staghorn sumac. Phytopathology 39:754-759.

Toole, E.R.
1949a. White pine blight in the Southeast. J. For. 47:378-382.

Toole, E.R.
1959. Decay after fire injury to southern bottomland hardwoods. U.S. Dept. Agric. Tech. Bull. 1189,25p.

Toole, E.R.
1961. Rot entrance through dead branches in southern hardwoods. For. Sci. 7:218-226.

Toole, E.R.
1963. Sweetgum lesion caused by Botryosphaeria ribis. Plant Dis. Rep. 47:229-231.

Toole, E.R.
1964. Progress of oak heartrot varies with height in tree. Plant Dis. Rep. 48:585.

Toole, E.R.
1965. Decay 10 years after thinning of sweetgum sprout clumps. Plant Dis. Rep. 49:986.

Toole, E.R.
1965a. Deterioration of hardwood logging slash in the South. U.S. Dep. Agric. Tech. Bull. 1328,27p.

Toole, E.R.
1970. Variation in decay resistance of southern pine sapwood. For. Prod. J. 20(5):49-50.

Toole, E.R.
1971. Influence of season on organisms infecting untreated southern pine stakes. Phytopathology 61:1013-1014.

Toole, E.R.
1971a. Evaluation of wood preservatives using crushing strength. Phytopathology 61:182-183.

Toole, E.R.
1971b. Germination of spores of wood decay fungi on wood. Phytopathology 61:88-90.

Toole, E.R.
1971c. Reduction in crushing strength and weight associated with decay by rot fungi. Wood Sci. 3(3):172-178.

Toole, E.R.
1972. Effect of decay fungi on the microstructure of red oak heartwood. Wood Sci. 5:34-37.

Toole, E.R.
1975. Oxygen utilization by decay fungi for the evaluation of wood preservatives. For. Prod. J. 25(7):46-48.

Toole, E.R. and M.M. Barnes.
1974. Biodeterioration of particle board. For. Prod. J. 24(10):55-57.

Toole, E.R. and W.M. Broadfoot.
1959. Sweetgum blight as related to alluvial soils of the Mississippi River flood plain. For. Sci. 5:2-9.

Toole, E.R. and W.M. Broadfoot.
1959a. Irrigation lessens sweetgum blight. U.S. Dept. Agric. For. Serv. South For. Notes 120.

Toole, E.R. and W.N. Darwin.
1970. Influence of variation in physical and chemical properties of red oak lumber on decay resistance. Miss. Sta. Univ. For. Prod. Util. Lab. Res. Rep. 10,8p.

Toole, E.R. and J.L. Gammage.
1959. Damage from increment borings in bottomland hardwoods. J. For. 57:909-916.

Toole, E.R. and G.H. Hepting.
1949. Selection and propagation of Albizzia for resistance to Fusarium wilt. Phytopathology 39:63-70.

Toole, E.R. and P.C. Lightle.
1960. Status of persimmon wilt. Plant Dis. Rep. 44:45.

Towers, B. and W.J. Stambaugh.
1968. The influence of induced soil moisture stress upon Fomes annosus root rot of loblolly pine. Phytopathology 58:269-272.

True, R.P.
1946. Some fungi are agents of dry-face. AT-FA J. 8(8):11-14,20.

True, R.P. and R.D. McCulley.
1945. Defects above naval stores faces. South. Lumberman 171(2153):200, 202, 204.

True, R.P. and M.M. Smucker.
1947. Symptoms induced at standard wounds by fungi isolated from dry turpentine faces. Phytopathology 37:437 (abst.).

Van Arsdel, E.P. and D.L. Bush.
1970. The remote sensing of oak-decline symptoms. Phytopathology 60:589 (abst.).

Van Arsdel, E.P. and A. Chitzonidis.
1970. Life cycle and spread of ash rust in Texas. Phytopathology 60:1317 (abst.).

Van Arsdel, E.P. and R.S. Halliwell.
1970. Progress in research on live oak decline. Plant Dis. Rep. 54:669-674.

Van Arsdel, E.P., S.D. Lyda, and T.W. Jares.
1972. Treatment of Cephalosporium wilt disease with a benomyl fungicide. Phytopathology 62:807 (abst.).

Veal, M.A., R.L. Blair, J.B. Jett, W.T. McKean, and E.B. Cowling.
1974. Impact of fusiform rust on pulping properties of young loblolly pine. Proc. 1974 Ann. Meet. Amer. Phytopath. Soc. Abst. 185.

Veech, J.A. and J.S. Boyce, Jr.
1964. Soil microorganisms in two Georgia slash pine plantations with annosus root rot. Plant Dis. Rep. 48:873-874.

Verrall, A.F.
1934. The resistance of saplings and certain seedlings of Pinus palustris to Septoria acicola. Phytopathology 24:1262-1264.

Verrall, A.F.
1936. The dissemination of Septoria acicola and the effect of grass fires on it in pine needles. Phytopathology 26:1021-1024.

Verrall, A.F.
1939'. Relative importance and seasonal prevalence of wood-staining fungi in the southern states. Phytopathology 29:1031-1051.

Verrall, A.F.
1941. Dissemination of fungi that stain logs and lumber. J. Agric. Rec. 63:549-558.

Verrall, A.F.
1941a. Fungi associated with stain in chemically treated green lumber. Phytopathology 31:270-274.

Verrall, A.F.
1942. A comparison of Diplodia natalensis from stained wood and other sources. Phytopathology 32:879-884.

Verrall, A.F.
1943. Fungi associated with certain ambrosia beetles. J. Agric. Res. 66:135-144.

Verrall, A.F.
1949. Some molds on wood favored by certain toxicants. J. Agric. Res. 78:695-703.

Verrall, A.F.
1961. Spread of *Cronartium fusiforme* branch infections. Phytopathology 51:646 (abst.).

Verrall, A.F.
1962. Condensation in air-cooled buildings. For. Prod. J. 12:531-536.

Verrall, A.F.
1965. Preserving wood by brush, dip, and short-soak methods. U.S. Dep. Agric. Tech. Bull. 1334,50p.

Verrall, A.F.
1966. Building decay associated with rain seepage. U.S. Dep. Agric. Tech. Bull. 1366,58p.

Verrall, A.F.
1968. *Poria incrassata* rot: Prevention and control in buildings. U.S. Dep. Agric. Tech. Bull. 1385,27p.

Verrall, A.F.
1968a. A possibly new pine-oak rust. Plant Dis. Rep. 52:248.

Verrall, A.F.
1970. Log storage under water spray makes lumber more porous. Stephen F. Austin Sta. Univ. Texas Forestry Paper 1,4p.

Verrall, A.F. and T.L. Amburgey.
1979. Prevention and control of decay in homes. Unnumbered, undated bulletin of U.S. Govt. Printing Office, 148p.

Verrall, A.F. and P.V. Mook.
1951. Research on chemical control of fungi in green lumber, 1940-1951. U.S. Dep. Agric. Tech. Bull. 1046,60p.

Verrall, A.F. and T.C. Scheffer.
1959. Preservative treatments for protecting wood boxes. U.S. Dep. Agric. For. Serv. Res. Pap. FPL-106,57p.

Verrall, A.F., E.R. Toole, and P.C. Lightle.
1959. Oak wilt in Oklahoma and Arkansas. Plant Dis. Rep. 43:1288.

Von Weissenberg, K.
1973. Indirect selection for resistance to fusiform rust. Acta Forestalia Finnica 134:1-46.

Wakeley, P.C.
1968. Rust susceptibility in longleaf pine associated with brown-spot resistance and early commencement of height growth. For. Sci. 14:323-324.

Wakeley, P.C.
1970. Thirty-year effects of uncontrolled brown spot on planted longleaf pine. For. Sci. 16:197-202.

Walkinshaw, C.H.
1965. Chemical inhibition in germination of Cronartium fusiforme aeciospores. Phytopathology 55:996-999.

Weber, G.F.
1930. Dry rot of lumber in storage and in buildings. Fla. Agric. Exp. Sta. Press Bull. 424,2p.

Wells, 0.0. and G.L. Switzer.
1971. Variation in rust resistance in Mississippi loblolly pine. Proc. 11th. Conference on Southern Forest Tree Improvement:25-30.

Wilson, C.L.
1959. Chlorosis of loblolly and shortleaf pine seedlings related to calcium content of nursery soil. Plant Disease Rep. 43:964-965.

Wilson, C.L.
1961. Study of the growth of Ceratocystis fagacearum in oak wood with the use of autoradiograms. Phytopathology 51:210-215.

Wilson, C.L.
1961a. An undescribed blight of Arizona cypress. Plant Dis. Rep. 45:96-98.

Wilson, C.L.
1963. Wilting of persimmon caused by Cephalosporium diospyri. Phytopathology 53:1402-1406.

Wilson, C.L.
1965. Consideration of the use of persimmon wilt as a silvicide for weed persimmon. Plant Dis. Rep. 49:789-791.

Wilson, C.L.
1965a. Ceratocystis ulmi in elm wood. Phytopathology 55:477.

Witcher, W.
1963. Spread of Fomes annosus in a certain pine stand. S.C. Acad. Sci. 25:23.

Witcher, W., J.D. Amett, L.W. Baxter, and M.L. Cocke.
1975. Control of needle cast of Scotch pine in South Carolina. Plant Dis. Rep. 59:881-883.

Witcher, W., L.W. Baxter, and S.A. Marbut.
1973. Benomyl promising chemical for leaf and stem diseases of redcedar and Arizona cypress. Plant Dis. Rep. 57:315-317.

Witcher, W. and R.E. Beach.
1962. Fomes annosus infection through pruned branches of slash pine. Plant Dis. Rep. 46:64.

Wolf, F.A. and J. Barbour.
1941. Brown-spot needle disease of pines. Phytopathology 31:61-74.

Wolf, F.A., K.H. Garren, and J.K. Miller.
1938. Fungi of the Duke Forest. Duke Univ. School For. Bull. 2,122p.

Wolf, F.A. and F.T. Wolf.
1939. A study of Botryosphaeria ribis on willow. Mycologia 31:217-227.

Zak, B. and W.C. Bryan.
1963. Isolation of fungal symbionts from pine mycorrhizae. For. Sci. 9:270-278.

Zak, B. and D.H. Marx.
1964. Isolation of mycorrhizal fungi from roots of individual slash pines. For. Sci. 10:214-222.

Zobel, B.J., R.L. Blair, and M. Zoerb.
1971. Using research data--Disease resistance. J. For. 69:486-489.

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VERRALL, ARTHUR F.

7982. A history of forest pathology in the South and Southeast, U.S. Dep. Agric. For. Serv. Gen. Tech. Rep, SO-36,200 p. South. For. Exp. Stn. New Orleans, La.

This history brings together the literature and the lives of those connected with forest disease research in the South and the Southeast. The author presents the "why" aspects along with the "what" of such research.