Endothia Species as Pathogens of Chestnut and Oak

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ABSTRACT.—Most of the approximately 14 woody plant-inhabiting *Endothia* species have not been documented as *bona fide* pathogens. Many have been simply reported as weak parasites or as apparent saprobes occurring on moribund or dead tissues without demonstration of proof of pathogenicity. In at least two cases, stresses of the hosts appear to be major predisposing factors to susceptibility. Four species of the genus that appear to be major pathogens are *E. parasitica* (primarily on *Castanea* and *Quercus* spp.), *E. gyrosa* (primarily on *Q. palustris* and *Liquidambar formosana), E. eugeniae* (on *Eugenia aromatica)* and *E. havanensis* (on *Eucalyptus* sp.). In Virginia, *E. parasitica* continues to kill *Castanea dentata* and to canker C. *mollissima* and *Q. virginiana;* the disease on *Q. virginiana* is widespread in Tidewater, Virginia, resulting in the death of a few trees and causing visible debility to heavily cankered individuals. Pin oak blight, caused by *E. gyrosa,* continues to be a major problem in the successful landscape culture of its host in Virginia; stress factors (predisposition) appear to play a significant role in host susceptibility.

The fungal genus *Endothia* embraces about 14 species worldwide, most of which are pathogens or saprophytes of woody plants. Of special importance in Virginia and certain other areas in the eastern United States are *E. parasitica* (Murr.) P. J. & H. W. And. and *E. gyrosa* (Schw.) Fr., the American chestnut *(Castanea dentata* [Marsh.] Borkh.) and pin oak (*Quercus palustris* Muenchh.) blight pathogens, respectively. Both canker-inciting fungi pose a potential threat to the successful culture of tree hosts which they parasitize.

In addition to the near total destruction of the American chestnut and infection of Chinese chestnut *(C. mollissima* Bl.), *E. parasitica* also incites cankers on several species of oak. The most notable of them is Southern live oak (*Quercus virginiana* Mill.), a uniquely beautiful and historic landscape species which thrives from eastern Virginia along the Atlantic and Gulf of Mexico coasts to Texas. The pathogen kills not only individual branches but also entire trees occasionally. Because of the deeply furrowed bark of this species, numerous lesions remain undetected to the untrained eye, especially prior to bark sloughage in the canker region. Preliminary aspects of disease biology, survey and control are under investigation.

Since the first documentation of pin oak blight in 1970, this disease has been found to be more extensive and severe in eastern Virginia than was originally known. Although *E.* gyrosa-incited

cankers have been detected on pin oak in the Piedmont and northeastern areas of Virginia, its apparent blighting of this species in the Lynchburg area is particularly severe. *Endothia gyrosa* attacks several other oak species, such as Q. *phellos* L., and other tree genera. Disease surveys are continuing, and factors associated with disease development and control are being studied at Virginia Polytechnic Institute and State University with the hope that satisfactory disease management systems can be effected.

THE FUNGAL GENUS *ENDOTHIA* AND ITS HOSTS

The genus *Endothia* was established by Fries (1849). It was based in part on collections made at Salem, North Carolina, in 1822, by Schweinitz who placed the fungus in the genus *Sphaeria* under the new epithet *gyrosa. Sphaeria gyrosa* then became *Endothia gyrosa,* the type species of *Endothia.* Muller and von Arx (1962) placed the genus in the family Diaporthaceae, order Diaporthales, of the class Ascomycetes. Partial treatments of the genus are found in the works of Shear *et al. (1917),* Muller and von Arx (1962), Kobayashi (1970), and Roane and Stipes (1976).

Mention of the genus *Endothia* in botanical or phytopathological circles in the United States brings to mind generally only one species, *E. parasitica,* causal agent of the earlier catastrophic American chestnut blight (Merkel, 1906; Anderson and Anderson, 1913) and of cankering of Chinese chestnut and related species (Graves, 1950; Headland *et al.* 1976); Figures 1A and 1B depict these cankers. This fungus was introduced into North America around 1900 (Shear *et al.,* 1917). It, however, is only one of five species currently found in North America. The four remaining indigenous ones are *E. fluens (Sow.)* Shear & Stevens (= *E. radicalis* [Schw.] [Ces. and de Not.], *E. gyrosa, E. viridistroma* Wehmeyer (Wehmeyer, 1936) and *E. singularis* (H. & P. Syd.) Shear and Stevens (Shear *et al.,* 1917). Of these taxa, only *E. parasitica* and *E. gyrosa* are considered aggressive parasites, either killing or seriously maiming certain of their hosts.

An additional five species are found in certain tropics and subtropics on woody dicots such as *Eucalyptus, Coccoloba* and *Eugenia.* These are *E. coccolobii* Vizioli (1923), *E. eugeniae* (Nutman and Roberts) Reid and Booth (1969), *E. havanensis* Bruner (1916), *E. longirostris* Earle (1901) and *E. tropicalis* Shear and Stevens (Shear *et al.,* 1917). Of this group, only *E. eugeniae* (Nutman and Roberts,

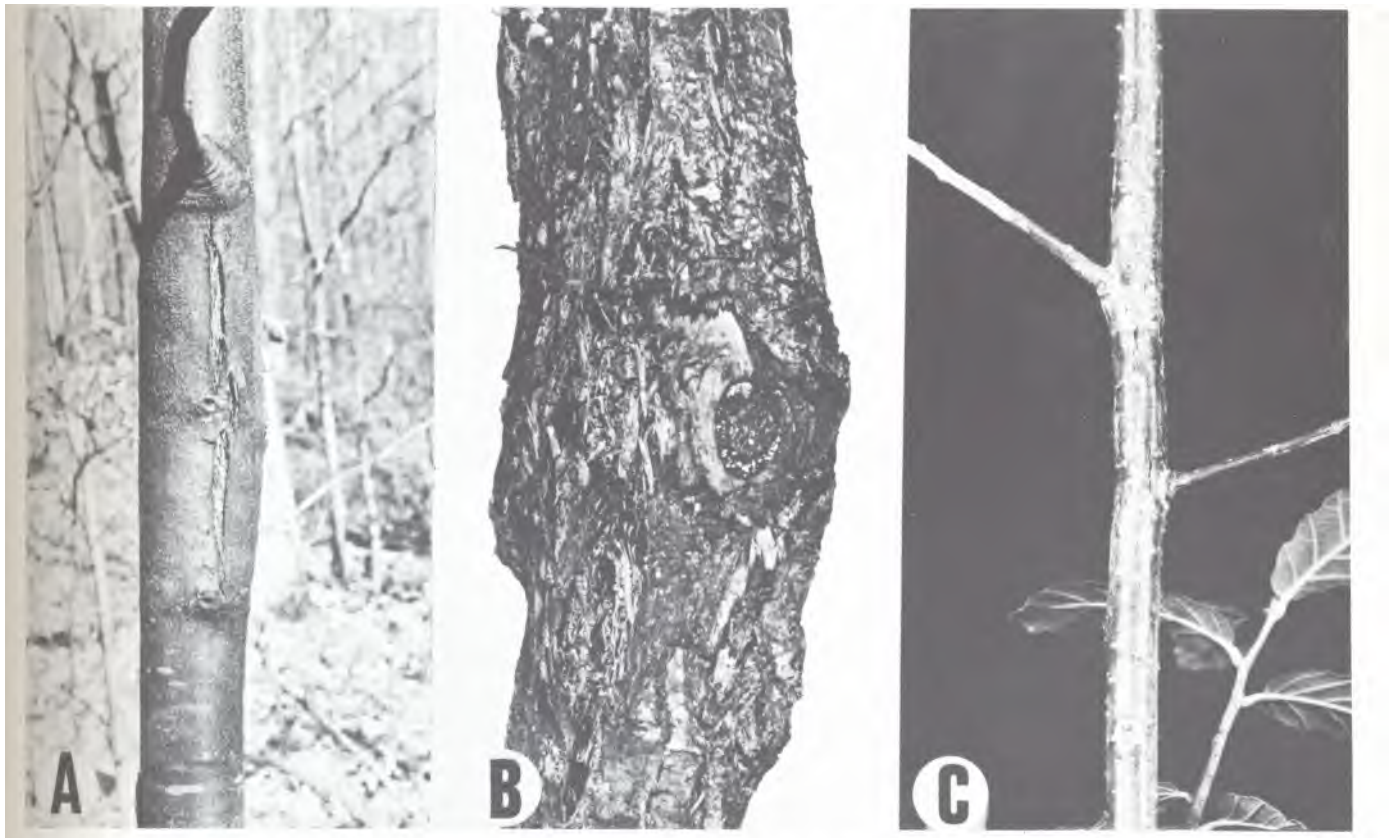

Figure 1. Cankers caused by *Endothia parasitica.* A. American chestnut *(Castanea dentata),* natural infection. B. Chinese chestnut (*Castanea mollissima*), natural infection (Photo courtesy of Dr. G. J. Griffin in Headland *et al.,* 1976). C. Cork oak (*Quercus suber*), artificially inoculated by Dr. Curtis May with isolate obtained from live oak (*Quercus virginiana*) canker at Colonial Williamsburg, Virginia (May and Davidson, 1960).

1952) and *E. havanensis* (Boerboom and Mass, 1970) are aggressive parasites, especially in situations where their hosts are predisposed by unfavorable growing conditions.

The remaining four species are allegedly saprophytes. They are *E. macrospora* Kobayashi and Ito (1956), *E. japonica* Kobayashi and Ito (1956), *E. tetraspora* Kobayashi (1965) and *E. nitschkei* Otth (1868). *Endothia parryi* (Farlow) Cooke (Cooke, 1885) has been removed from the genus *Endothia* and is now designated *Dothidella parryi* (Farl., Theiss. & Syd.) (Theissen and Sydow, 1915). The genetic status of *Endothiella robiniae* Chona and Munjal (1950), *Endothia sordida* Fuckel (1866) and *Endothiella simoniani* Negru and Mozes (1965) is uncertain at this time. In addition, past and present morphologic, chemotaxonomic, physiologic and numerical taxonomic studies on *Endothia* might provide additional insights into biological relationships as well as resolve the problem on a practical level (Emert *et al.*, 1973; Stipes and Ratliff, 1973; Roane *et al.*, 1974; Roane and Stipes, 1974; Roane *et al.*, 1975; Stipes and Roane, 1976; Roane and Stipes, 1976).

Since the biology of chestnut blight has been well covered at this conference, we have chosen to focus our remarks primarily on the cankering of live oak *(Q. virginiana)* by *E. parasitica* in Virginia (Gruenhagen, 1965; May and Davidson, 1960; Stipes and Davis, 1972; Stipes and Phipps, 1971a).

Table 1 lists the various tree hosts on which *E. parasitica* has been reported. Although this pathogen decimated the natural population of C. *dentata,* several large specimens survive either by virtue of resistance or by escape; the latter are known to thrive as disjunct populations outside the Appalachians. *E. parasitica* causes rather severe cankering of Chinese chestnut (Graves 1950, Headland *et al.*, 1976), live oak and less serious cankering of post oak, *Quercus stellata* Wangh. (Clapper *et al.*, 1946). Ham (1967) reported that swollen butt of scarlet oak (*Q. coccinea* Muenchh.) was likely induced by *E. parasitica* (Fig. 2). This type of syndrome on oak, however, also has been attributed to fire damage.

Table 1
Tree hosts of *Endothia parasitica* as recorded in various reports with specifications neither to parasitic nor saprophytic habit.[a/]

Acer palmatum Thunb.	*Quercus montana* Willd.
Acer pensylvanicum L.	*Quercus muhlenbergi* Engelm.
Acer rubrum L.	*Quercus petraea* (Mattuschka) Lieblein
Carpinus caroliniana Walt.	*Quercus prinus* L.
Carya ovata (Mill.) K. Koch	*Quercus pubescens* Willd.
Fagus sylvatica L.	*Quercus robur* Mill.
Liriodendron tulipifera L.	*Quercus rubra* L.
Ostrya virginiana (Mill.) [K. Koch]	*Quercus sessiliflora* Salisb.
Quercus alba L.	*Quercus stellata* Wangh.
Quercus coccinea Muenchh.	*Quercus velutina* Lam.
Quercus falcata Michx.	*Quercus virginiana* Mill.
Quercus ilex L.	*Rhus typhina L.*
Quercus macrocarpa Michx.	

[a]Annotated from Anderson & Rankin (1914), Bazzigher (1953), Biraghi (1950), Clapper *et al.* (1946), Clinton (1913), Darpoux (1948), Darpoux (1949), Fulton (1912), Gravatt (1949), Gravatt (1952), Ham (1967), Heald (1943), May & Davidson (1960), Seymour (1929), Shear *et al.* (1917).

List excludes *Castanea* and *Castanopsis* spp.

LIVE OAK AND INFECTION BY ENDOTHIA PARASITICA

Live oaks as a group are constituted of different species depending upon the section of the country to which one refers (Hepting, 1971). Hence, the necessity of Latin binomials in conjunction with colloquial names becomes obvious. As a group they are

Figure 2. Swollen butt of scarlet oak *(Quercus coccinea)* resulting from infection by *Endothia parasitica.* Photo courtesy of Dr. D. L. Ham (Ham, 1967).

evergreen, have very dense wood, grow to large diameters and although are used now rather exclusively in landscapes, were used in times past in shipbuilding. The group is represented by (1) *Quercus agrifolia* Nee, California live oak or coast live oak of the Far West, (2) *Q. chrysolepis* Liebm., canyon live oak of the West and Mexico, and (3) *Q. virginiana,* the subject of this section of the paper.

Quercus virginiana, variously known as live oak, Eastern live oak, Virginia live oak, scrub live oak, dwarf live oak and Rolfs oak, has a fairly restricted range, extending in a narrow coastal strip from Virginia to Georgia where the range widens to embrace the southern third of Georgia and all of Florida to Key Largo (Fig. 3). It again becomes a coastal strip tree from western Florida to Texas, where its range widens, extending about 483 km (300 mi) inland (Alexander, 1953; Fowells, 1965). Little (1944) lists several cultivars, *macrophylla, virescens, typica, eximea, fusiformis* and *geminata.* Although live oak is sensitive to low temperatures which thereby presumably restrict its range, a nice specimen thrives in the Appalachians at Blacksburg, Virginia (altitude about 640 m = 2,100 ft). Several large specimens thrive also at Richmond, Virginia.

Figure 3. Distribution of live oak, *Quercus virginiana* (Fowells, 1965).

Quercus virginiana, a tree of history and beauty, is relatively slow growing and attains tremendous size with age, having a possible span of 46 m (150 ft), trunks up to 1.8 - 2.1 m (6 - 7 ft) and a height of 15.2 - 22.8 m (50 - 75 ft). It branches near the ground into massive and wide-spreading limbs, and forms a broad, dense, round-topped crown of dark, glossy leaves (Lindgren *et al.,* 1949; Fowells, 1965; May, 1972). Many large and old, therefore historic specimens adorn landscapes in the Tidewater area of Virginia, especially at Hampton Institute and at the United States Army Compound, Fort Monroe, both at Hampton, Virginia (Fig. 4). This species apparently has been relatively resistant to disease and insect attack until the introduction of the chestnut blight organism around 1900 after which time several species of oak including live oak contracted the disease.

Figure 4. The Algernourne Oak *(Quercus virginiana)* at the U. S. Army Compound, Fort Monroe, Virginia. Named for Fort Algernourne, the first fort built at Point Comfort in 1609, the present site of Fort Monroe. Branch spread is 100 ft (30.5 m), circumference is 20 ft (6.1 m) at 2 ft above ground level, and age has been estimated by R. J. Stipes to be between 303 years (minimum, based on age of a major leader) and 437 years (most likely figure, based on age of single, major bole at 2 ft above ground level).

As early as 1933 and 1934, Taubenhaus described a decline of live oak near Austin, Texas, that killed over 200 trees. The possibility of drought injury was excluded and evidence for natural spread was indicated even though the cause was not determined (Taubenhaus, 1933 & 1934; Halliwell, 1964). Dunlap and Harrison (1949) also studied the declining trees for an 8-year period and found that environment had little effect on the disease. The disorder was seen in both landscape and forested sites, on acid and alkaline soils, in sand and heavy clay soils and in wet as well as dry soils. Clinical examinations yielded no clues.

The syndrome as described by Halliwell (1966) which required 3 - 8 years from initiation to death, included (1) a marginal necrosis of leaves that proceeded inward, (2) defoliation on individual branches rather than the entire tree, (3) twig dieback and suckering of the main branch, and (4) discoloration in and acetic odor evolved by the heartwood and vascular system. He consistently isolated a *Cephalosporium* sp. from discolored heartwood and vascular tissue of not only naturally infected live oak but also water oak, Southern red oak *(Q. falcata Michx.)* and post oak. Using various inoculation techniques and inocula, Halliwell reproduced the syndrome in live oak and after fulfilling Koch's Postulates by reisolating the *Cephalosporium* suggested that the disease be designated as "Cephalosporium decline of oak." In a sequel to this work, Van Arsdel and Halliwell (1970) emphasized that live oak decline involved a causal complex of

Cephalosporium sp. (= *Phialophora obscura), Dothiorella quercina, Hypoxylon atropunctatum* and possibly mechanical root disturbance. In a still later paper, Van Arsdel (1972) indicated that the *Cephalosporium* sp. in question was "probably C. *diospyri* Crandall although other spore stages in the life cycle suggest that this name will be superseded."

In contrast to these reports in Texas, the live oak decline situation in Virginia and other states along the Atlantic seaboard and Gulf Coast east of Texas involves a somewhat different syndrome and entirely different associated fungus. Dieback, defoliation and stag-heading (Fig. 5A) are seen in addition to loosening, cracking and exfoliation of bark (Fig. 5B, C), revealing mycelial fans of the associated fungus (Fig. 5D). May and Davidson (1960) identified *E. parasitica* fruiting bodies on bark and *E. parasitica* buff-colored mycelial fans in and under the bark of cankered areas on *Q. virginiana* from Colonial Williamsburg. Although they had not reproduced the disease in live oak, American chestnut trees inoculated with their isolate from live oak developed typical *E. parasitica* induced chestnut blight cankers. Inoculated greenhouse cork oak *(Quercus suber* L.) seedlings also developed cankers having vertical fissures (Fig. 1C). Gruenhagen (1965) examined live oak specimens from declining trees in the Fort Monroe and Newport News areas of Virginia. Although he found no cankers, biopsies from the Fort Monroe specimen yielded a fungus similar to that reported by May and Davidson (1960). *Endothia parasitica* cankers on live oak were reported later in Virginia (Stipes and Phipps, 1971b; Stipes and Davis, 1972). Batson and Wicher (1968) proved pathogenicity of *E. parasitica* on artificially inoculated landscape live oaks at Georgetown, South Carolina. Peacher (1969) reported *E. parasitica* cankers on live oak in Mississippi, and Phelps (1974) reported it for the first time from North Carolina and Florida. Unpublished reports have indicated that *E. parasitica* canker of live oak occurs in Alabama and possibly in other states or areas where live oak grows (Anon. 1964).

In Virginia, it is difficult to find a non-cankered live oak. Although older and larger trees are more heavily cankered than younger ones, those with a dbh of 15.2 cm (6 in) or so can be cankered. Stromata are found commonly on moribund tissues of blighted trees, although they are not produced consistently on calloused folds of all canker lesions (Stipes, unpublished data). The mode of transmission has not been determined, but it is presumed that the same agents that were documented to transmit *E. parasitica* from lesions on American chestnut trees also may be involved in its transmission in the case of live oak canker. Pruning tools also would be suspect when used first on diseased then healthy trees. Because of the relatively large number of hosts and therefore abundance of inoculum of *E. parasitica,* precautions should be taken to avoid unnecessary wounds that serve as infection courts. Figure 5E depicts a healed wound on *Q. virginiana* from which a canker had been excised. Stipes (unpublished data) was able to isolate *E. parasitica* from such calluses on live oak at Colonial Williamsburg (Stipes and Phipps, 1971b).

PIN OAK AND INFECTION BY *ENDOTHIA GYROSA*

According to a recent poll taken by the National Landscaper's Association (Benko & Wimberely, 1970), the pin oak *(Q. palustris)* was ranked as first choice among landscape trees on the basis of 1) hardiness, 2) freedom from disease, 3) good form and color, and 4) stability. It grows rapidly and is easily reproduced from seed.

The obscure scale, *Melanaspis obscura* (Comstock), is undoubtedly the worst insect pest of pin oak (Collingwood and Brush, 1964) in Virginia and possibly elsewhere. The senior author has observed heavy infestations of it on trees stressed by a number of factors including drought, crowded growing space, elevated temperatures and inadequate nutrition. The most common abiotic problem that has been observed on the species, however, is iron deficiency which is expressed as an interveinal chlorosis and marginal and interveinal necrosis (Pirone, 1972; Hepting, 1971).

In 1970, the senior author observed a new blighting of pin oak consistently associated with *E. gyrosa* (Stipes & Phipps, 1971a; Stipes *et al.,* 1971). Additional details on the syndrome have been reported in a previous paper (Stipes *et* a/., 1978). An hypothesis on moisture stress as a key predisposing factor for disease development was formulated; this has been confirmed in part at least, and other research contributions in the overall biology of the disease have been and are being made by Stipes and associates (Hunter, 1977; Appel-unpublished data).

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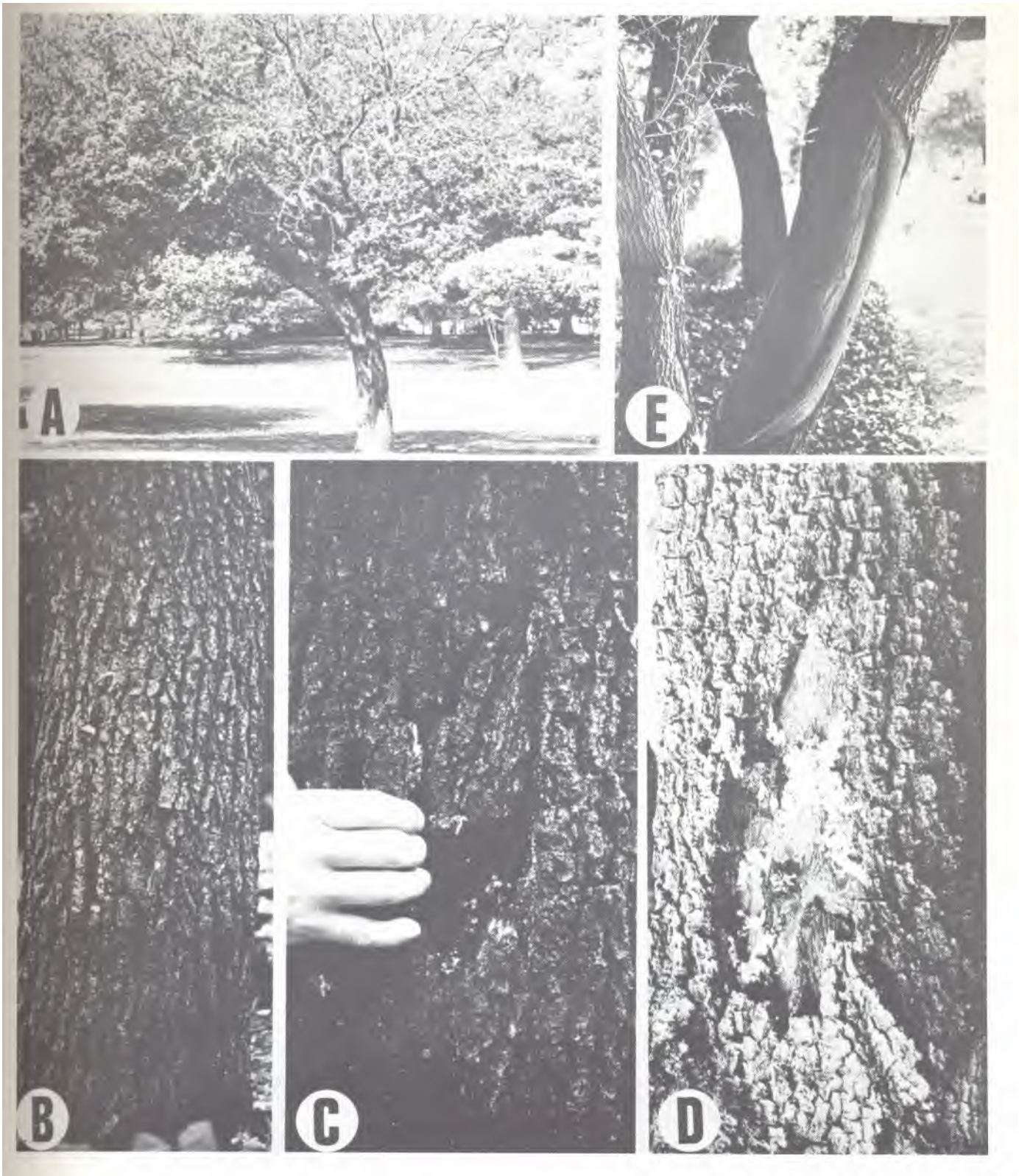

Figure 5. *Endothia parasitica* canker and blight of live oak *(Quercus virginiana).* A. Dieback and defoliation of tree at Colonial Williamsburg, Virginia. B. Usual initial visible symptom is loosening and cracking of bark. C. Bark is easily removed by hand. D. Exposed wood revealing typical mycelial fans. Cankers are bordered by calloused "lip." E. A large calloused border has developed following surgical removal of canker (Colonial Williamsburg).

LITERATURE CITED

Alexander, T. R.
1963. PLANT SUCCESSION ON KEY LARGO, FLORIDA, INVOLVING *PINUS CARIBAEA* AND *QUERCUS VIRGINIANA*. Quart. Jour. Fla. Acad. Sci. 16:133-138.

Anderson, P. J. and H. W. Anderson.
1913. THE CHESTNUT BLIGHT FUNGUS AND A RELATED SAPROPHYTE. Penna. Chestnut Tree Blight Comm. Bull. 4:1-26.

Anderson, P. J. and W. H. Rankin.
1914. ENDOTHIA CANKER OF CHESTNUT. N. Y. (Cornell) Agr. Exp. Sta. Bull. 347. p. 531-618.

Anon.
1964. WORK CONFERENCE REPORT ON CANKER OF LIVE OAK. Unpublished report of work conference of federal and state plant pathologists held at Atlanta, GA, May 18, 1964. 48p.

Appel, D. N.
1977. BIOLOGY AND PHYSIOLOGY OF PIN OAK BLIGHT CAUSED BY *ENDOTHIA GYROSA*. Ph.D. Dissertation Research, Unpublished.

Batson, W. E. and W. Witcher.
1968. LIVE OAK CANKERS CAUSED BY *ENDOTHIA PARASITICA*. Phytopathology 58:1473-1475.

Bazzigher, G.
1953. BEITRAG ZUR KENNTNIS DER *ENDOTHIA PARASITICA* (MURR.) AND., DEM ERREGER DES KASTANIENSTERBENS. Phytopath. Z. 21:105-132.

Benko, M. and J. Wimberley.
1970. LANDSCAPE GROUP MEETS IN ILLINOIS. Amer. Nurseryman 131:9, 114, 115.

Biraghi, A.
1950. NUOVI OSPITI DI *ENDOTHIA PARASITICA*. Ann. Sper. Agr. N.S. 4:109-118.

Boerboom, J. H. A. and P. W. Th. Maas.
1970. CANKER OF *EUCALYPTUS GRANDIS* AND *E. SALIGNA* IN SURINAM CAUSED BY *ENDOTHIA HAVANENSIS*. Turrialba 20:94-99.

Bruner, S. C.
1916. A NEW SPECIES *OFENDOTHIA*. Mycologia 8:239-242.

Chona, B. L. and R. L. Munjal.
1950. NOTES ON MISCELLANEOUS INDIAN FUNGI. I. Indian Phytopathology 3:105-116.

Clapper, R. B., G. F. Gravatt, and D. C. Stout.
1946. *ENDOTHIA* CANKER ON POST OAK. Plant Dis. Rep. 30: 381.

Clinton, G. P.
1913. CHESTNUT BARK DISEASE, *ENDOTHIA GYROSA* VAR. *PARASITICA* (MURR.) CLINT. *In* Conn. Agr. Exp. Sta. Ann. Rpt. 1911/12. p. 359-453.

Collingwood, G. H. and W. D. Brush.
1964. KNOWING YOUR TREES. American Forestry Assoc., Washington, D. C. 349 p.

Cooke, M. C.
1885. SYNOPSIS PYRENOMYCETEN. Grevillea (London) 13:100-109.

Darpoux, H.
1948. CHESTNUT CANKER CAUSED BY *ENDOTHIA PARASITICA*. Rev. Tech. Prot. Veg. I, 4, p. 307-330.

Darpoux, H.
1949. LE CHANCRE DU CHATAIGNER CAUSE PAR *ENDOTHIA PARASITICA*. Institut national de la recherche agronomique. Document phytosanitaire 7.

Dunlap, A. A. and A. L. Harrison.
1949. DYING OF LIVE OAKS IN TEXAS. Phytopathology 39:715-717.

Earle, F. S.
1901. SOME FUNGI FROM PUERTO RICO. Muehlenbergia 1:10-23.

Emert, G. H., R. J. Stipes, R. D. Brown, Jr., and J. E. Talmadge.
1973. DIFFERENTIATION OF *ENDOTHIA GYROSA* AND *E. PARASITICA* BY DISC GEL ELECTROPHORESIS. Phytopathology 63:801. (Abstr.)

Fowells, H. A.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. USDA Forest Service Agric. Hdbk. 271. 762 p.

Fries, D. M.
1849. SUMMA VEGETABILIUM. Scandivaviae sect. 2. p. 385. Upsaliae.

Fuckel, L.
1865. EXSICCATI RHENANI HEDWIGIA 5:28.

Fulton, H. R.
1912. RECENT NOTES ON THE CHESTNUT BARK DISEASE. *In* Penna. Chestnut Blight Conf. Rpt. 1912. p. 48-56.

Gravatt, G. F.
1949. THE CHESTNUT BLIGHT IN ASIA AND NORTH AMERICA. Unasylva 3:2-7.

Gravatt, G. F.
1952. BLIGHT ON CHESTNUT AND OAKS IN EUROPE IN 1951. Plant Dis. Rep. 36:111-115.

Graves, A. H.
1950. RELATIVE BLIGHT RESISTANCE IN SPECIES AND HYBRIDS OF *CASTANEA*. Phytopathology 40:1125-1131.

Gruenhagen, R. H.
1965. LIVE OAK DECLINE IN VIRGINIA. Plant Dis. Rep. 49:269.

Halliwell, R. S.
1964. LIVE OAK DECLINE. Proc. 40th Intl. Shade Tree Conf., Houston, Texas. p. 178-180.

Halliwell, R. S.
1966. ASSOCIATION OF *CEPHALOSPORIUM* WITH A DECLINE OF OAK IN TEXAS. Plant Dis. Rep. 50: 75-78.

Ham, D. L.
1967. THE ETIOLOGY OF *ENDOTHIA PARASITICA* ON SCARLET OAK. M. S. Thesis, Duke University, Durham, N.C. 25p.

Headland, J. K., G. J. Griffin, R. J. Stipes, and J. R. Elkins.
1976. SEVERITY OF NATURAL *ENDOTHIA PARASITICA* INFECTION OF CHINESE CHESTNUT. Plant Dis. Rep. 60: 426-429.

Heald, F. D.
1943. INTRODUCTION TO PLANT PATHOLOGY, 2ND ED. McGraw-Hill Book Company, New York. 603 p.

Hepting, G. H.
1971. DISEASES OF FOREST AND SHADE TREES OF THE UNITED STATES. USDA Forest Service Agric. Hdbk. No. 386. 658 p.

Hunter, P. P.
1977. THE BLIGHT AND CANKER OF PIN OAK (*QUERCUS PALUSTRIS* MUENCHH.) INCITED BY *ENDOTHIA GYROSA* (SCHW.) FR.: SOME FACTORS AFFECTING DISEASE DEVELOPMENT. Ph. D. Dissertation, Va. Polytech. Inst. & State Univ. Library, Blacksburg. 113 p.

Kobayashi, T.
1965. NOTES ON THE GENUS *ENDOTHIA* IN JAPAN. II. A NEW SPECIES HAVING FOUR-SPORED ASCI. Trans. Mycol. Soc. Japan 6:97-100.

Kobayashi, T.
1970. TAXONOMIC STUDIES OF JAPANESE DIAPORTHACEAE WITH SPECIAL REFERENCE TO THEIR LIFE HISTORIES. Bull. Govt. Forest Expt. Sta. 226. 242 p. Tokyo, Japan.

Kobayashi, T. and K. Ito.
1956. TWO NEW SPECIES OF *ENDOTHIA*. Ann. Phytopath**ii** Soc. Japan 21:151-152.

Lindgren, R. M., R. P. True, and E. R. Toole.
1949. SHADE TREES FOR THE SOUTHEAST. *In* Trees, Yearbook of Agriculture, 1949. U. S. Dept. of Agric., Washington, D. C. 944 p.

Little, E. L., Jr.
1944. CHECK LIST OF THE NATIVE AND NATURALIZED TREES OF THE UNITED STATES INCLUDING ALASKA. USDA Forest Service, Washington, D. C. 325 p.

May, C. and R. W. Davidson.
1960. *ENDOTHIA PARASITICA* ASSOCIATED WITH A CANKER OF LIVE OAK. Plant Dis. Rep. 44: 754.

May, C.
1972. SHADE TREES FOR THE HOME. USDA Agric. Hdbk. No. 425.48 p.

Merkel, H. W.
1906. A DEADLY FUNGUS ON THE AMERICAN CHESTNUT. *In* 10th Ann. Rept. N. Y. Zool. Soc. 1905. p. 97-103.

Muller, E. and J. A. von Arx.
1962. DIE GATTUNGEN DER DIDYMOSPOREN PYRENOMYCETEN. Beitr. zur. Kryptogamenfl. Schweiz. Band 11, Heft 2.922 p.

Negru, A. and S. Mozes.
1965. NEW AND RARE FUNGI FOUND ON PEAT BOGS "MOHOS" IN THE PEOPLE'S REPUBLIC RUMANIA. Akad. Nauk. Armianskoi SSR Verevan. Isvestiia. Biologicheskia Nauki Gerevan 18:57-63.

Nutman, F. J. and F. M. Roberts.
1952. ACUTE DIE-BACK OF CLOVE TREES IN THE ZANZIBAR PROTECTORATE. Ann. Appl. Biol. 39:599-608.

Otth, G.
1868. SECHSTER NACHTRAG ZU DEM IN NR 15-23 DER MITTHEILUNGEN ENTHALTENEN VERZEICHNISSE SCHWEIZERISCHER PILZE. Naturforschende Gesellschaft, Bern. Mitteilungen. p. 37-70.

Peacher, P. H.
1969. LIVE OAK IN MISSISSIPPI INFECTED BY *ENDOTHIA PARASITICA*. Plant Dis. Rep. 53:304.

Phelps, W. R.
1974. LIVE OAK IN NORTH CAROLINA AND FLORIDA INFECTED BY *ENDOTHIA PARASITICA*. Plant Dis. Rep. 58:596-598.

Pirone, P. P.
1972. TREE MAINTENANCE. 4th ed. Oxford Univ. Press, N. Y. 574p.

Reid, J. and C. Booth.
1969. SOME SPECIES SEGREGATED FROM THE GENERA *CRYPTOSPORA, CRYPTOSPORELLA* AND *SILLIA*. Can. J. Bot. 47:1055-1060.

Roane, M. K., R. J. Stipes, P. M. Phipps, and 0. K. Miller, Jr.
1974. *ENDOTHIA GYROSA*, CAUSAL PATHOGEN OF PIN OAK BLIGHT. Mycologia 66:1042-1047.

Roane, M. K. and R. J. Stipes.
1974. THE GENUS *ENDOTHIA:* A REAPPRAISAL. Va. J. Sci. 25: 74 (Abstr.).

Roane, M. K., R. J. Stipes, and J. R. Elkins.
1975. PIGMENT ANALYSIS OF FRUITING STRUCTURES AND MYCELIUM IN THE GENUS *ENDOTHIA*. Va. J. Sci. 26:65 (Abstr.).

Roane, M. K. and R. J. Stipes.
1976. THE FUNGAL GENUS *ENDOTHIA* IN THE SOUTHERN APPALACHIANS. *In* Distributional History of the Biota of the Southern Appalachians, Part IV: Algae and Fungi. Univ. Press of Va., Charlottesville. p. 227-242.

Seymour, A. B.
1929. HOST INDEX OF THE FUNGI OF NORTH AMERICA. Harvard Univ. Press, Cambridge, Mass. 732 p.

Shear, C. L., N. E. Stevens, and R. J. Tiller.
1917. *ENDOTHIA PARASITICA* AND RELATED SPECIES. U. S. Dept. Agr. Bull. 380. 82 p.

Snow, G. A., J. S. Beland, and F. J. Czabator.
1974. FORMOSAN SWEETGUM SUSCEPTIBLE TO NORTH AMERICAN *ENDOTHIA GYROSA*. Phytopathology 64: 602-605.

Stipes, R. J. and T. C. Davis.
1972. DISEASES OF LANDSCAPE TREES OBSERVED IN VIRGINIA. Plant Dis. Rep. 56:108-111.

Stipes, R. J., P. P. Hunter, J. R. Elkins, and M. K. Roane.
1978. ENDOTHIA CANKERS OF OAKS. *In* Proc. First Metropolitan Tree Improvement Alliance Conference, Lanham, MD., July, 1976. (USDA Forest Service, Broomall, PA, In Press(.

Stipes, R. J. and P. M. Phipps.
1971a. A SPECIES OF *ENDOTHIA* ASSOCIATED WITH A CANKER DISEASE OF PIN OAK *(QUERCUS PALUSTRIS)* IN VIRGINIA. Plant Dis. Rep. 55:467-469.

Stipes, R. J. and P. M. Phipps.
1971b. CURRENT STATUS OF *ENDOTHIA* CANKER OF LIVE OAK IN VIRGINIA. Plant Dis. Rep. 55:201.

Stipes, R. J., P.M. Phipps, and 0. K. Miller, Jr.
1971. A PIN OAK BLIGHT ASSOCIATED WITH A SPECIES OF *ENDOTHIA*. Va. J. Sci. 22:86 (Abstr.).

Stipes, R. J. and J. L. Ratliff.
1973. EFFECT OF TEMPERATURE ON LINEAR GROWTH *OFENDOTHIA GYROSA*. Va. J. Sci. 24:136 (Abstr.).

Stipes, R. J. and M. K. Roane.
1976. EFFECTS OF pH AND TEMPERATURE ON THE GROWTH OF TEN *ENDOTHIA* SPECIES. Va. J. Sci. 27:60 (Abstr.).

Taubenhaus, J. J.
1933. LIVE OAK DISEASE IN AUSTIN. 47th Ann. Rep., Texas Agr. Exp. Sta.

Taubenhaus, J. J.
1934. LIVE OAK DISEASE IN AUSTIN. 48th Ann. Rept., Texas Agr. Exp. Sta.

Theissen, R. and H. Sydow.
1915. DIE DOTHIDEALES. Annales Mycologici 13:149-746.

Van Arsdel, E. P.
1972. SOME CANKERS ON OAKS IN TEXAS. Plant Dis. Rep. 56:300-304.

Van Arsdel, E. P. and R. S. Halliwell.
1970. PROGRESS IN RESEARCH ON LIVE OAK DECLINE. Plant Dis. Rep. 54:669-672.

Vizioli, J.
1923. SOME PYRENOMYCETES OF BERMUDA. Mycologia 15:107-119.

Wehmeyer, L. E.
1936. CULTURAL STUDIES OF THREE NEW PYRENOMYCETES. Mycologia 28:35-46.