The Great Trinity Forest Management Plan

Volume 25

Insects and Disease

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Guide to Insect Borers in North American Broadleaf Trees and Shrubs Continued

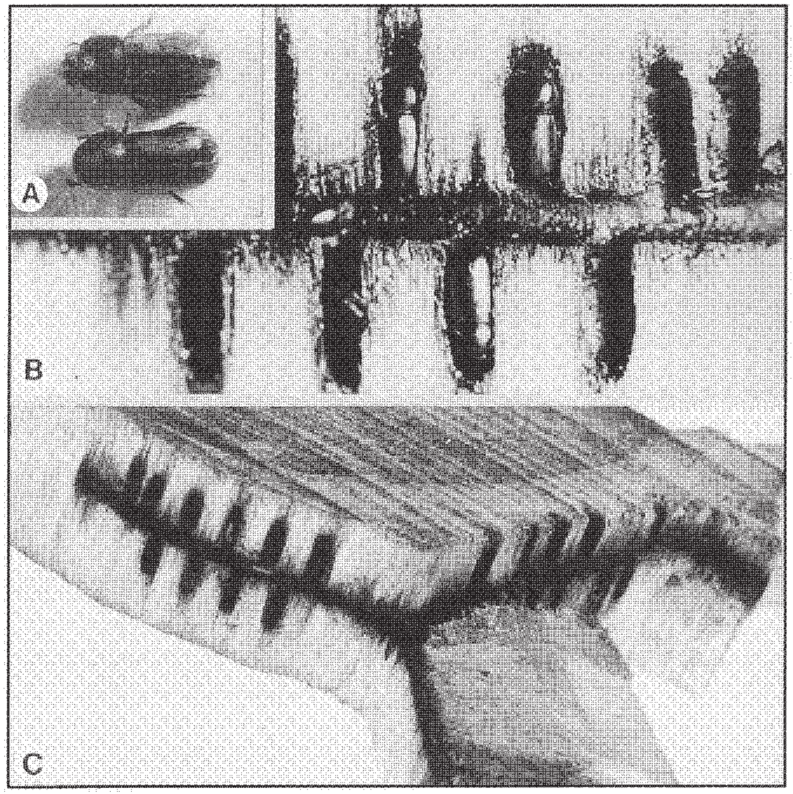

Figure 219—Trypodendron betulae, *[birch timber beetle]: A, adult; B, part of gallery with cradles containing teneral adults; C, gallery system showing entrance tunnel, branched galleries with numerous cradles (courtesy L. Abrahamson).*

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water, and pignut hickories, but undoubtedly attacks other hickory species (Gagne and Kearby 1979, Wood 1982).

Range. Vermont south to Florida and west to Texas and Kansas (Bright 1968, Wood 1982); probably occurs throughout the natural range of hickories (Beal and Massey 1945, Blackman 1922).

Description. ***Adult.*** Reddish brown, cylindrical ambrosia beetle with head directed downward and hidden from above by pronotum (figure 220A) (Beal and Massey 1945, Bright 1968, Wood 1982). One of the largest species of *Xyleborus* in North America; females 3.9 to 4.5 mm long, males 2.3 to 2.6 mm long and somewhat lighter colored. Pronotum slightly longer than wide, broadly rounded in front, roughened on anterior, and shiny and sparsely punctured on posterior. Elytra slightly wider than pronotum with sides parallel. Elytral declivity drops off abruptly and steeply and bears four large acute teeth and several acute granules. ***Egg.*** Oval, smooth, white, 0.9 mm long by 0.4 mm wide (Gagne and Kearby 1979). ***Larva.*** White with amber head and mandibles, legless, C-shaped body, 2.5 to 4.7 mm long. ***Pupa.*** Exarate, white.

Biology. This beetle overwinters in adult stage in galleries of host trees. Hibernating adults emerge and are attracted to new susceptible host trees by their odors during March and April (Beal and Massey 1945, Chamberlin 1939, Gagne and Kearby 1979). Most attacks are in the lower trunk. Male beetles are rare in most populations. Females bore through the bark and straight into the wood. They often make cavelike excavations at the end of the straight entrance tunnel from which unbranched galleries radiate outward. This species does not deposit eggs in niches or cradles as do many scolytids, but lays them in groups of 1 to 16, mostly toward the ends of open galleries about 1.5 cm long. Eggs hatch in about 7 days. Larvae move freely in the gallery system and feed on the ambrosial fungi that grow on gallery walls; the fungus is transmitted from host to host by adult females. Larvae have three instars and develop from eggs to adults in about 35 days. New adults either emerge and seek new hosts or remain and extend the existing gallery system. The second generation of adults commences in early July, but most attacks are in late July and early August. There are two generations per year; second generation adults do not emerge and seek new hosts but overwinter in the galleries.

Injury and damage. Weakened and dying trees are most susceptible, but this pest occasionally attacks fresh-cut logs and stumps (Beal and Massey 1945, Blackman 1922, Gagne and Kearby 1979). Trees under attack by *Scolytus quadrispinosus* are particularly susceptible to infestation. Attacks are common on the basal portion of the trunk within 1.5 m of the ground and in buttress roots. Large trees generally sustain a higher rate of infestation per unit area than small trees. White frass in bark crevices usually is the first sign of beetle attack (figure 220B). Dissection reveals palmate or simple, branched gallery system (figure 220C and D). Entrance tunnels extend straight into the bole 1 to 3 cm then branch up to

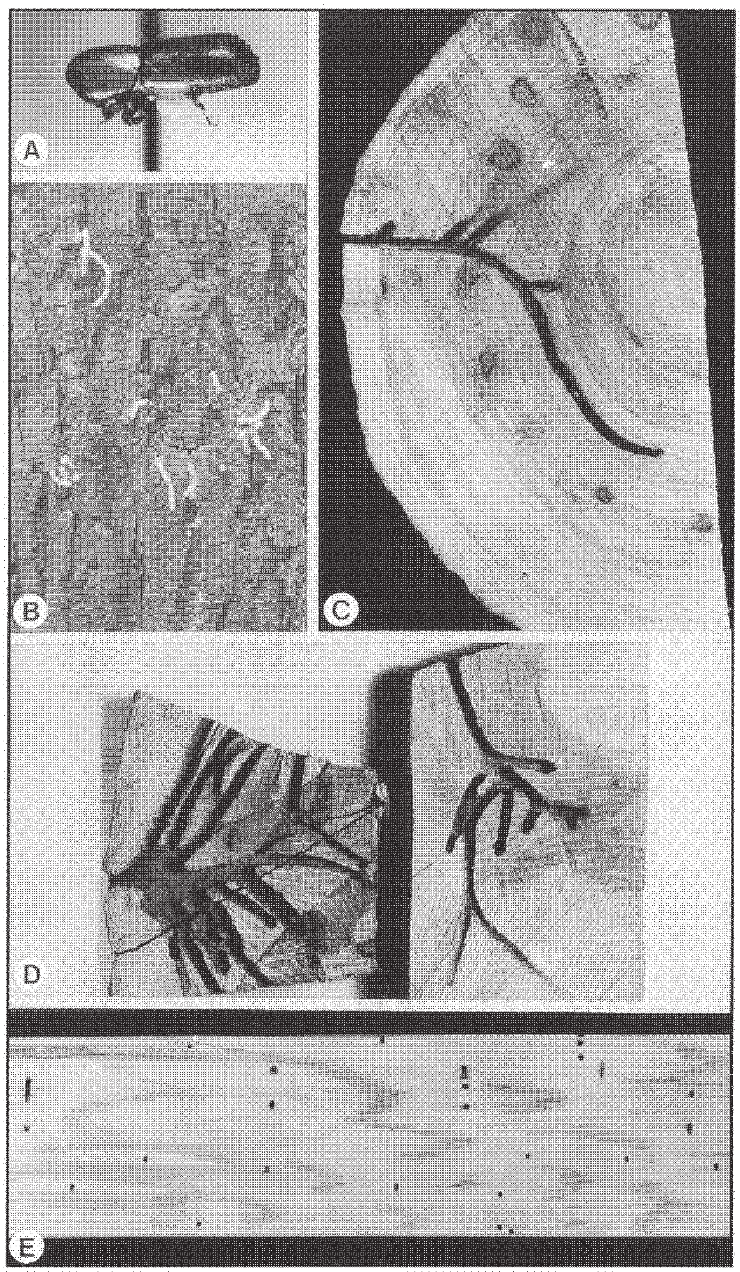

Figure 220—Xyleborus celsus, *[hickory timber beetle]: A, adult; B, white frass on bark; C, simple branched gallery; D, entrance tunnels, cavelike chamber, and palmate branching; E, stained holes in lumber (A, specimen courtesy M. Roling).*

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six times. At the end of the entrance tunnel, beetles often make a cavelike excavation from which unbranched galleries radiate in a fanlike pattern in a single plane. Branch galleries are usually simple, but some have secondary branches and a few even anastomose or rejoin. Galleries may extend to depths of 6 cm or more. Those extended by second-generation beetles are longer and more complex. This insect causes rapid deterioration of dying hickories. The black-stained galleries degrade wood products sawn from infested logs (figure 220E).

Control. Practices that keep trees healthy and prevent *S. quadrispinosus* attacks will largely eliminate problems with *X. celsus*. Prompt harvesting and milling of weakened trees and those infested by *S. quadrispinosus* will minimize losses from degrade by *X. celsus* (Beal and Massey 1945).

Xyleborus affinis Eichhoff

[oak-hickory ambrosia beetle]

Hosts. Oak, hickory, pecan, chestnut, sweetgum, persimmon, locust, hackberry, birch, mimosa, black cherry, cedar, baldcypress. More than 250 species of trees, including hardwoods, palms, and a few conifers. Oak, hickory, pecan, and sweetgum favored in the United States (Beal and Massey 1945, Bright 1968, Wood 1982).

Range. Worldwide. Throughout the eastern United States from Massachusetts south to Florida and west to Michigan and Texas (Bright 1968, Wood 1982). Also in all of Mexico and Central and South America; also found in Hawaii, Malaysia, India, and tropical Africa.

Description. ***Adult.*** Yellowish to reddish brown, 2.6 to 2.9 times longer than wide, cylindrical ambrosia beetle with its head directed downward under pronotum (Beal and Massey 1945, Bright 1968, Wood 1982). Females, 2.3 to 2.8 mm long, larger and darker than males, 1.7 to 2.0 mm long. Front of head shiny with large punctures; antennal club as long as wide. Pronotum of female broadly rounded in front and roughened, smooth, shiny, and finely punctured. Pronotum of male with anterior area shallowly concave and anterior margin with blunt tubercle. Elytra as broad as pronotum and rounded behind. Elytral declivity broadly convex, sloping, surface dull, opaque. ***Egg.*** Off white, shiny, oblong, 0.62 to 1.05 mm long (Roeper and others 1980). ***Larva.*** White, slightly curved to C-shaped, legless. ***Pupa.*** White initially, then pigmented to light brown, 1.9 to 2.2 mm long.

Biology. In the eastern United States, females emerge from hibernation in spring and fly to susceptible hosts. One female initiates the gallery; in time, 15 to 20 progeny females and only 1 or 2 males may be present (Hubbard 1897, Roeper and others 1980, Wood 1982). Eggs are deposited in groups of two to six in the galleries; larvae feed and develop on the ambrosial fungus that grows on the gallery walls and eventually pupate freely in the same galleries. New progeny females either emerge and seek new hosts or attack the same hosts in which they developed; some even extend old parent galleries. However, new adults emerge and usually seek new hosts with a high wood-moisture content more suitable for the ambrosia fungus culture and brood development. Life cycle requires approximately 1 month. Beetles reared on a synthetic diet produce broods with a sex ratio of 8.5 females to 1.0 male; fertilized females deposit only one unfertilized male egg per brood. The male beetle always matures and emerges before its sibling females and is ready to inseminate each as she emerges. Because males are flightless, mating must occur before the females leave the tree in which they developed. An unmated female produces two to three haploid males with whom she mates to produce female progeny. There are two or more generations a year.

Injury and damage. This beetle occasionally attacks weakened and dying trees but prefers cut, souring (fermenting) logs, green-sawn lumber, and stumps (Beal and Massey 1945, Roeper and others 1980, Wood 1982). Numerous pin-sized holes in bark indicate attack. Sawdust-like frass pushed from holes indicate that the beetles are constructing galleries in the wood. The gallery system is more complex than that of most other ambrosia beetles. Removal of the bark and dissection of the wood can expose the gallery system. The main entrance penetrates the bark and often turns longitudinally (less commonly horizontally), etching the surface of the sapwood. Surface galleries may branch and rebranch but eventually turn radially into the sapwood and frequently extend into the heartwood. The transverse galleries in the wood often branch and rebranch in more than one horizontal plane or level. Galleries are often more extensive and usually more heavily stained than those made by many other scolytid species. Thus, damage can be extensive in logs intended for lumber and other wood products. This beetle is one of the most destructive sawmill species in the tropical lumber industry. It sometimes bores wine and beer casks, causing leakage.

Control. Nothing is known of the natural enemies. In areas with a history of damage, fresh-cut logs can be safely stored under continuous water spray. Green lumber can be protected by an insecticidal dip.

Xyleborus ferrugineus **(Fabricius)**

[cosmopolitan ambrosia beetle]

Hosts. Oak, hickory, birch, ash, maple, beech, walnut, water tupelo, sweetgum, chestnut, baldcypress, pine. More than 180 host species recorded worldwide (Bright 1968, USDA FS 1985, Wood 1982). Sweetgum, oak, and hickory favored in the southern United States.

Range. One of the most widely distributed and economically important ambrosia beetles in the world, especially in the Tropics (Bright 1968, Wood 1982). Occurs from Massachusetts south to Florida and west to Michigan and southern California. Found in Mexico, Central and South America, tropical Africa, Hawaii to Micronesia, Australia, and southern Asia.

Description. ***Adult.*** Reddish brown, elongate, cylindrical ambrosia beetle; female 2.0 to 3.3 mm long and male about 1.8 mm long, 2.8 times longer than wide (Blackman 1922, Blatchley and Leng 1916, Wood 1982). Head tucked under pronotum and not visible from above. Pronotum of female slightly longer than wide, broadly rounded in front, roughened with rasplike ridges in front; posterior portion shining with sparse, moderately coarse punctures. Pronotum of male drastically different—front margin drawn into an acute point, anterior slope distinctly concave and much smoother. Elytral declivity rather steep, flat to slightly convex, sloping, two large teeth near middle and several small granules. ***Larva.*** White except for brown head, curved, legless.

Biology. Habits are similar to those of other members of the genus *Xyleborus* (Beal and Massey 1945, Blackman 1922, Doane and others 1936, Wood 1982). Adults overwinter in brood chambers. In spring, some females remain in the host, extend the galleries, and continue to produce offspring; other females emerge and fly, usually at night, to new host trees. Females mate before leaving the brood tree because males do not fly. Single females begin the new entrance galleries and are often joined by additional females. In some cases, apparently depending on the moisture content of the host, they make galleries on the surface of the sapwood, then penetrate all the sapwood, whether it is 2 or 30 cm deep. Heartwood is less commonly tunneled. Eggs are deposited near the ends of galleries but not in niches. Eggs hatch in 6 to 10 days, and the larvae feed freely within the galleries on ambrosia fungi cultured on the gallery walls by the adults. Galleries are constantly being extended to accommodate the enlarging family. Females leave the brood colony from time to time to start new colonies, but the original colony continues to work in the same tree as long as the moisture content of the wood is favorable for ambrosia fungus growth. Adults have been taken in flight monthly from April through September in Georgia (Turnbow and Franklin 1980b).

Injury and damage. Beetles favor unthrifty, cut, and broken trees, especially logs and stumps over 10 cm in diameter in a fermenting condition (Beal and Massey 1945, Blackman 1922, Wood 1982). Occasionally attacks slightly weakened trees, hastening or causing mortality. Lower tree trunks and sour logs on the ground are especially attractive. White frass may be seen on the bark. Dissection reveals the complex gallery system. Entrance galleries penetrate the bark, then extend longitudinally over the surface of the sapwood, etching both the inner bark and wood. Transverse or diagonal galleries branch off the longitudinal galleries and then rebranch. At different heights, tunnels lead radially from the surface galleries into the sapwood; these, in turn, branch and rebranch. The same gallery system is often extended by new brood females, sometimes into heartwood, in time producing an elaborate system of galleries. Most economically damaging losses occur in the Tropics to cut logs in the forest, in temporary storage, or on loading docks, where tunnels may render the sapwood worthless within a few weeks. This borer is the principal vector of wilt disease of cacao.

Control. Nothing is known of natural enemies. Prompt salvage and use of infested trees and logs, along with destruction of infested debris and slabs, can help to minimize losses.

Xyleborus xylographus (Say)

[oak timber beetle]

Hosts. Oak, hickory, walnut, chestnut, maple, beech, birch, apple, pine, spruce, hemlock, larch. Prefers oaks, but attacks many other hardwoods (Beal and Massey 1945, Blatchley and Leng 1916, Doane and others 1936, Hopkins 1898, Wood 1982).

Range. Quebec, Ontario, and New Hampshire south to Florida and west to Texas, Kansas, and Minnesota (Bright 1968, Wood 1982). Also recorded from Cuba.

Description. ***Adult.*** Reddish brown to yellowish, or red, elongate, cylindrical ambrosia beetle; female 2.5 to 2.8 mm long, and male 2.2 to 2.4 mm long, 2.8 times as long as wide (Blatchley and Leng 1916, Bright 1968, Hopkins 1898, Wood 1982). Head directed downward under pronotum, not visible from above; ends of antennae club shaped. Pronotum has parallel sides; anterior margin broadly rounded with asperities; posterior portion smooth, shiny, and finely punctured. Elytra shiny with parallel sides. Elytral declivity steep, flattened, somewhat convex; interiors of large, strial punctures reticulate. ***Egg.*** Ovate, yellow to pearly white, 0.52 to 0.55 mm long and 0.24 to 0.26 mm wide. ***Larva.*** Yellowish white to yellow, with pale brown head; prothorax with conical hump larger than head and abdomen and sparsely clothed with fine hairs, 2.8 to 3.0 mm long.

Biology. Because of identification errors, much of the older literature refers to *X. saxeseni* (Ratzeburg). Females emerge in April and May from galleries in brood trees where they overwinter as adults (Beal and Massey 1945, Doane and others 1936, Hopkins 1898). Males have no flight wings, so they must mate before females emerge to find new hosts; females outnumber males about 20 to 1. Females construct entrance galleries that penetrate the bark and enter the sapwood, then branch. Females deposit as many as 10 eggs loosely against gallery walls. Periodically, females enlarge or extend the walls of the brood chamber and deposit additional eggs; consequently, all development stages are present in brood chambers during summer and early fall. More than one brood may be produced in a gallery system, but new progeny females often emerge and attack new hosts.

Injury and damage. Beetles favor lower portions of declining and dying trees, logs, stumps, exposed roots, and green slash (Beal and Massey 1945, Doane and others 1936, Hopkins 1898). Attack sites are common around the edges of wounds, in deep bark crevices, and in roughened areas of bark. Favorite entrance sites are in and adjacent to bark openings made by sapsuckers and large insect borers. White frass occurs at entrance holes. In cross sections, there is an entrance gallery that penetrates the bark and enters straight or obliquely into the sapwood for 25 mm or more, then branches and rebranches more or less following the annual growth rings. Fungus-blackened galleries in the sapwood and heartwood are defects that degrade wood products sawn from infested logs.

Control. Unidentified predaceous insects and disease cause some mortality (Hopkins 1898). Maintenance of tree health and prevention of bark injuries will help lessen the likelihood of attack. Prompt use of infested material can help to minimize losses from wood degrade.

Xyleborus dispar (Fabricius)

[pear blight beetle]

Hosts. Alder, ash, beech, birch, chestnut, elm, maple, oak, poplar, sycamore, yellow-poplar, willow, apple, apricot, cherry, grape, hawthorn, peach, pear, plum, pomegranate, quince, walnut, nectarine, hazel, acacia, pine, hemlock, cedar. Fruit trees, particularly pear, preferred. Attacks many broadleaf species and a few conifers (Essig 1958, Mathers 1940, Wilson 1913, Wood 1982).

Range. Apparently introduced from Europe, this beetle was first reported from Massachusetts in 1816 (Essig 1958, Wilson 1913, Wood 1982). Eastern North America, from Nova Scotia and Maine south to North Carolina and west to Ontario and Michigan; in the West from British Columbia south through Washington, Idaho, Oregon, Utah, and California.

Description. ***Adult.*** Dark brown to black ambrosia beetle, elongate, cylindrical, elytra strongly punctured with fine yellowish hairs arising from punctures (Wilson 1913, Wood 1982). Females 2.8 to 3.5 mm long, 2.2 times as long as wide; males lighter colored and much more compressed, about 1.7 mm long. Head almost globular; frons broadly convex. Pronotum armed with six to eight serrations on anterior margin. Elytra with sides parallel anteriorly and narrowly rounded behind. Elytral declivity moderately steep, not serrate or armed with denticles. ***Egg.*** Pearly white, oblong, 0.1 mm long and 0.6 mm wide. ***Larva.*** Pure white except for dark alimentary canal visible through cuticle and brownish mandibles; legless, curved shape, nearly cylindrical except slight tapering toward posterior end; about 5 mm long. ***Pupa.*** White, sparsely hairy and roughened with large thick tubercles.

Biology. Beetles overwinter in galleries in host trees. Adults emerge in late March and April (Mathers 1940, Slingerland and Crosby 1919, Wilson 1913, Wood 1982). Females fly to susceptible host trees to produce new broods. Males do not fly but they mate before females move to new hosts. Females bore through the bark and into the sapwood, then construct vertical galleries from the main galleries. When the first vertical branch gallery is completed, a female deposits a cluster of one to seven eggs, then plugs the branch gallery with frass. Females can produce one or more vertical galleries and lay additional eggs. From 6 to 45 eggs have been observed in a gallery system. Oviposition is complete by mid-June. Eggs hatch in 2 to 3 weeks. Larvae apparently consume little or no wood but feed almost entirely on ambrosial fungus that grows on the gallery walls. Pupation occurs freely in the galleries and lasts about 4 weeks. Beetles, if cultured on artificial diets, develop from eggs to adults in 42 days, but require 80 to 84 days in the field. New adults complete development by late summer or autumn, but they remain in their galleries during winter; adults often line up in overwintering galleries. There is one generation a year.

Injury and damage. Unthrifty, injured, and dying trees, including limbs and boles 5 to 20 cm in diameter, are most often attacked (Essig 1958, Gossard 1913, Slingerland and Crosby 1919, Wilson 1913, Wood 1982). Fruit trees, particularly pear, seem especially susceptible. They sometimes girdle and kill young trees growing in nurseries. Dying and flagging branch tips of pear and apple are often mistaken for blight disease. Frass can be seen around the entrance holes, which are most often located just below bud scars on the bark. In small main stems and branches, the main gallery penetrates the sapwood, then turns and spirals or circles the small stems, girdling and killing them. In larger stems and branches, the entrance gallery penetrates straight into the sapwood for 1 to 5 cm, then branches into two transverse galleries. Vertical galleries, both above and below the transverse galleries, may be present. This beetle is troublesome in commercial pear, apple, nectarine, and apricot orchards. It may be a vector of fire blight disease.

Control. Cultural practices that keep trees healthy and vigorous and prompt disposal of prunings and broken branches prevent most attacks (Essig 1958, Gossard 1913, Slingerland and Crosby 1919).

Xyleborus sayi **(Hopkins)**

[eastern twig ambrosia beetle]

Hosts. Maple, birch, hickory, walnut, ash, basswood, sassafras, northern red oak, American hornbeam, chestnut, dogwood, tupelo, mountain-laurel, spicebush. Favors maples, especially red and sugar maples, in northern range; sassafras favored in southern range (Beal and Massey 1945, Bright 1968, Hazen and Roeper 1980, Wood 1982).

Range. Eastern species recorded from Ontario, Quebec, and Maine southward to northern Georgia and west to Missouri, Illinois, and Michigan (Bright 1968, Wood 1982).

Description. ***Adult.*** Dark brown to black, stout, elliptical ambrosia beetle, 2.2 times as long as wide (Beal and Massey 1945, Bright 1968, Wood 1982). Females 2.3 to 2.7 mm long; males 1.2 to 1.6 mm long with nonfunctional wings. Head hidden from above by prothorax; antennal club obliquely truncate. Pronotum broadly rounded and feebly punctured with two small teeth at apex. Elytra shiny, pubescent, punctures shallow. Elytral declivity convex, nearly smooth except striae coarsely punctured, without marginal teeth. ***Egg.*** Whitish, translucent, oblong, 0.70 mm long by 0.36 mm wide (Hazen and Roeper 1980). ***Larva.*** White with brownish mandibles, legless, slightly curved.

Biology. Adults overwinter within galleries. In Michigan, adults emerge and attack in late April and cease in early July (Hazen and Roeper 1980). In northeast Georgia, emergence and flight begin in March, peak in April, and continue until early September

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(Turnbow and Franklin 1980b). Females fly to susceptible trees, bore through the bark and into the xylem, and inoculate the galleries with ambrosia fungus that is carried in an intersegmental pouchlike mycetangium on the thorax. Eggs are laid in small groups near the ends of lateral galleries from mid-May to late July in Michigan. Larvae feed freely throughout the gallery system on whitish ambrosia fungus growing from the gallery walls, pass through two larval instars, and are present from early June to mid-August. Pupae are found free in the galleries from mid-July to early September. Progeny adults per gallery system range from 14 to 25; females outnumber males 3.6 to 1.0 and are first observed in late July. Females mate with flightless, sibling males in the parent galleries. New progeny adults remain in brood galleries to overwinter. This beetle has one generation a year in Michigan and possibly more in its southern range.

Injury and damage. This ambrosia beetle attacks weakened and windthrown trees and fresh-cut logs but prefers twigs, small-diameter stems, and branches, especially small subcanopy maples of low vitality (Hazen and Roeper 1980, Wood 1982). Wilted and yellowed foliage on branches and young trees is evidence of infestation. Entrance holes are usually found at lenticels on smooth bark of young maples and are generally spaced regularly over the bark surface, averaging one hole per square decimeter. Fine frass is ejected from the entrances, but only small amounts accumulate on the bark. Entrance galleries are perpendicular to the bark surface and penetrate the wood 7 to 10 mm. This pest constructs a lateral tunnel 13 to 22 mm long perpendicular to the entrance gallery on the same plane; usually, the tunnel follows the annual growth rings. Often, another branch tunnel originates at the deepest point of the entrance tunnel and runs opposite the first branch tunnel. Tertiary galleries occasionally extend from the secondary branches. Damage to sugar maple regeneration is generally minor; no more than 2% of understory maple saplings have been infested in a given year.

Control. Nothing is known of natural enemies, and direct controls have not been needed.

Xyleborinus saxeseni (Ratzeburg)

[lesser shothole borer] (figure 221)

Hosts. Hickory, pecan, oak, walnut, sweetgum, yellow-poplar, dogwood, persimmon, holly, maple, honeylocust, beech, yellow birch, hackberry, mimosa, madrone, hemlock, baldcypress, cedar. Wide host range of forest, ornamental, and fruit trees including both broadleaf and coniferous species. Prefers hickory, pecan, peach, oak, beech, and maple (Beal and Massey 1945, Blatchley and Leng 1916, Kovach and Gorsuch 1985).

Range. Introduced from Europe. Southern Canada from Ontario to British Columbia; in the United States from Maine south to Florida and west to California; and in Baja California and Hidalgo, Mexico (Wood 1982). Common in southeastern United States (Kovach and Gorsuch 1985, Turnbow

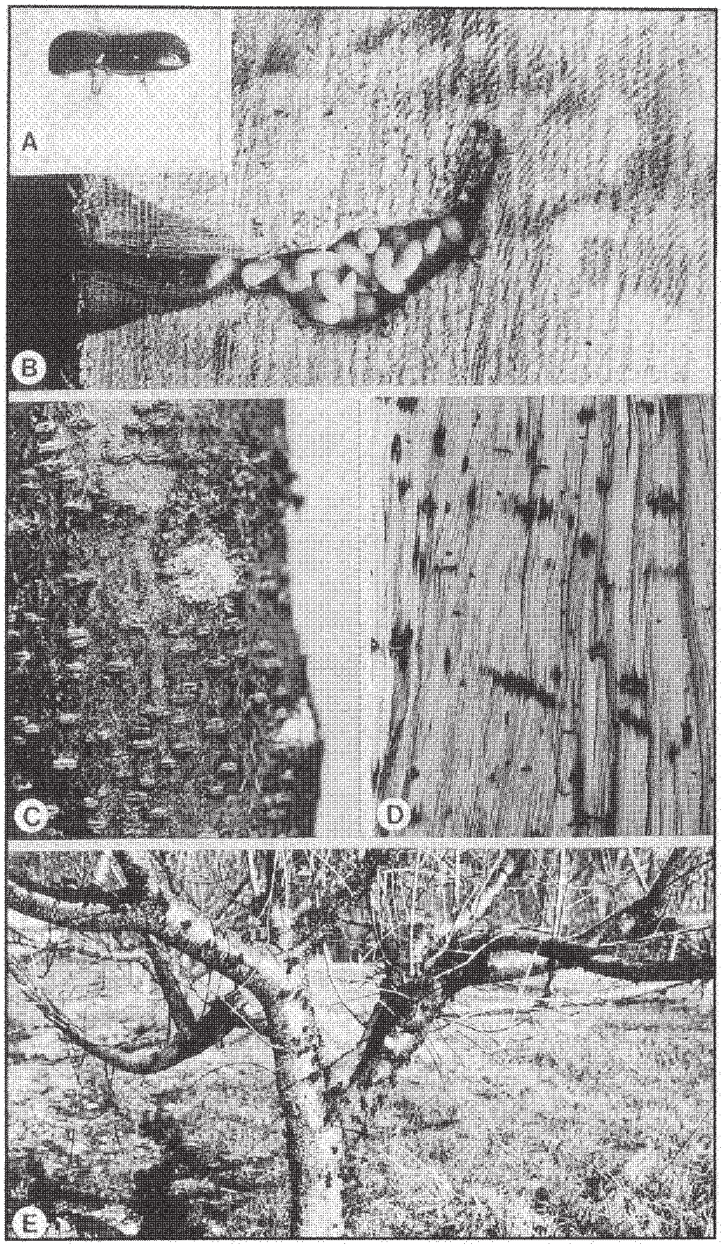

Figure 221—Xyleborinus saxeseni, *[lesser shothole borer]: A, adult; B, mass of nearly mature larvae in cavelike brood chambers; C, white frass on bark; D, black-stained galleries in wood; E, globular masses of gum at entrance holes (A, courtesy M. Roling; C & E, courtesy C. Gorsuch).*

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and Franklin 1980b). Occurs in Europe, Asia, Australia, and South America.

Description. ***Adult.*** Dark brown, elongate, cylindrical ambrosia beetle, female 1.9 to 2.4 mm long, male slightly smaller, three times as long as wide (figure 221A) (Blackman 1922, Blatchley and Leng 1916, Wood 1982). Front of head convex with coarse shallow punctures. Anterior part of pronotum broadly rounded and roughened; posterior portion smooth, minutely punctured. Distinguished from the *Xyleborus* species by its conical scutellum. Elytra shiny with coarse shallow punctures. Elytral declivity convex with steep slope and armed with rows of acute granules. ***Egg.*** Whitish, translucent, and oblong. ***Larva.*** White with light brown head, curved to C-shaped, 1.9 to 2.8 mm long (figure 221B).

Biology. In northeast Georgia, adults emerge from hibernation in mid-February when temperatures reach 18 °C; flights increase sharply during March, peak in April, then decline until November (Turnbow and Franklin 1980b). Females fly to susceptible trees, bore into the sapwood, and make enlarged chambers in the galleries that they inoculate with an ambrosia fungus (Blackman 1922, Kovach and Gorsuch 1985, Wood 1982). Eggs are deposited in the chambers. Larvae and adults work to extend and enlarge the brood chambers. The larvae feed on a combination of ambrosial fungus growing on the chamber walls and on wood produced by enlarging the burrows. At times, the chambers are filled with a mass of larvae. There are no individual cradles, and pupation occurs freely in the large chambers. All stages are sometimes found together in the same chamber. An average of 21 beetles develop and emerge from each brood chamber. Females outnumber males by ratios of 7:1 to 37:1; mating occurs either before the females leave the parent trees or unmated females produce two to three males with whom they mate before they can produce female progeny. A generation is completed in less than 2 months; four to five generations a year may be produced in the southern United States.

Injury and damage. Weakened, injured, and dying trees and fresh-cut logs are prone to infestation (Beal and Massey 1945, Blackman 1922, Wood 1982). Trunks 5 to 50 cm in diameter are most apt to be attacked, but branches down to about 2.5 cm in diameter are also susceptible. White frass can be seen on the bark below the tiny round entrance holes (figure 221C). Dissection of infested stems reveals a radial entrance tunnel about 1 mm in diameter extending through the bark and 1 to 7 cm into the wood. The innermost portion of the gallery (about half the gallery length) is widened and enlarged mostly in a vertical direction parallel with the wood grain (figure 221B). The enlarged portion of the gallery is sometimes referred to as a "tabular cave" or a leaf-type chamber. The walls of the galleries, and sometimes the wood immediately surrounding the galleries, is stained black (figure 221D). Logs and lumber with stained pinhole defect are downgraded for use in fine furniture and other select uses. This pest also attacks wine casks. In *Prunus* species, especially peach, globular masses of gum exude and accumulate on the bark of living trees that have been attacked (figure 221E). This beetle is the most common scolytid, representing 95% of about a dozen species found in South Carolina peach orchards.

Control. Two species of predaceous beetles—*Colydium lineola* Say and *Enoclerus sphegeus* (Fabricius)—have been found in galleries (Essig 1958). Infested timber should be harvested and milled promptly. Along the Gulf Coast, logs cut during the warm seasons should be removed and used within 1 to 2 weeks (Blackman 1922).

Xylosandrus compactus (Eichhoff)

black twig borer (figure 222)

Hosts. Avocado, magnolia, common fig, dogwood, golden-shower, Jerusalem-thorn, live oak, laurel oak, red maple, Florida maple, pecan, hickory, redbud, sweetgum, French mulberry, sugarberry, camphor-tree, mango, eastern hophornbeam, redbay, sycamore, southern elder, sweetleaf, eucalyptus. Host range along the southern parts of the United States undoubtedly will grow, because the species is known to have at least 200 host species belonging to 62 families worldwide (Chellman 1978, Nelson and Davis 1972, Ngoan and others 1976, Oliver 1978).

Range. Native of Southeast Asia, widely distributed in tropical and subtropical regions from West Africa to Hawaii, southern Japan, and Brazil (Ngoan and others 1976, Wood 1982). First collected in Florida in 1941 but reported several years later. Has since spread northward into Georgia and westward into Alabama, Mississippi, Louisiana, and eastern Texas.

Description. ***Adult.*** Tiny, dark brown to black, shiny, stout, cylindrical ambrosia beetle (figure 222A) (Bright 1968, Ngoan and others 1976, Wood 1982). Females 1.4 to 1.8 mm long, 2.1 times as long as wide; males 0.8 to 1.1 mm long, reddish brown. Head concealed from above. Pronotum subcircular, anterior margin with six to eight serrations. Elytra have parallel sides and are broadly rounded behind. Elytral declivity evenly arched, finely granulate. ***Egg.*** White, translucent, ovoid, without sculpture, 0.55 by 0.33 mm (figure 222B). ***Larva.*** White except for pale brown head, legless, curved to C-shaped, abdomen pointed posteriorly in young larva but rounded in mature larva (figure 222C). ***Pupa.*** White, yellow, finally black, soft bodied, exarate (figure 222D).

Biology. In north Florida, female beetles emerge from hibernation and attack new twigs from late February to mid-March about the time dogwood trees bloom (Ngoan and others 1976, Wood 1982). Females bore into twigs and branches of host trees and produce brood chambers in the stem pith. They deposit eggs in loose clusters in the brood chambers and not in individual cradles as do some ambrosia beetles. The eggs hatch in 4 to 6 days, and the larvae feed on ambrosia fungus growing from the walls of the brood chambers. The fungus *Fusarium solani* (Mart.) Sacc. is carried by the females into the brood chambers for

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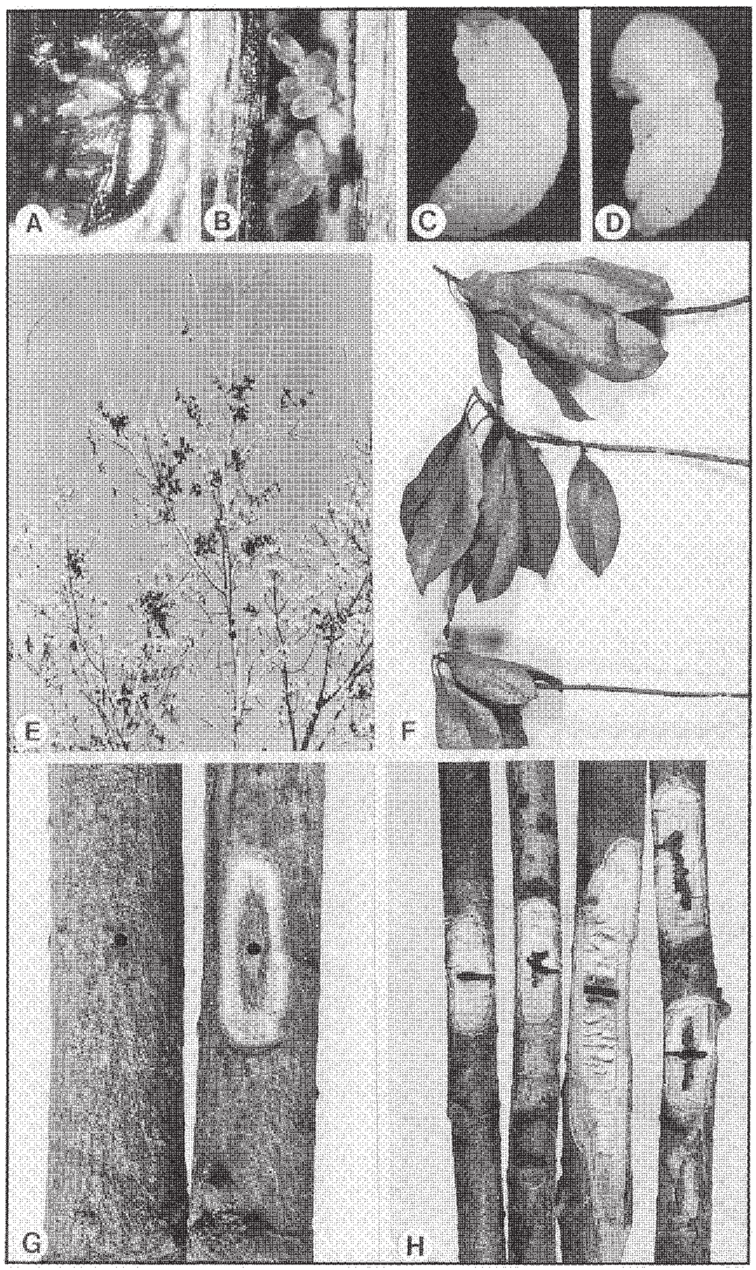

Figure 222—Xylosandrus compactus, *[black twig borer]: A, adult; B, eggs; C, larva; D, pupa; E, twigs dying from beetle attack; F, twigs killed by beetles; G, entrance hole in bark and wood; H, brood chambers in pith of twigs (A-E, courtesy R. Wilkinson).*

inoculation. Larvae mature in 7 to 8 days and pupate freely in the brood chambers. Pupae develop in 8 to 9 days. From 1 to 40 beetles develop in a brood chamber. Adults mature in 8 to 9 days. New beetles emerge during the afternoon and attack the same or different host usually within 30 minutes. Populations are highest from June to September, when all stages may be present. Females outnumber males by about 10 to 1. Beetles have been captured in sticky traps from February through September, making it difficult to evaluate numbers of generations a year. Average life cycle is 28 days. Thus, it is possible to complete five to six generations a year. Adults remain in the brood chambers to overwinter.

Injury and damage. This beetle attacks healthy, vigorous twigs of living dicotyledonous trees and shrubs. The first signs of infestation are terminals, twigs, and small branches with fading, wilting, yellowing, and browning foliage scattered through the tree crown (figure 222E and F) (Chellman 1978, Nelson and Davis 1972, Ngoan and others 1976, Oliver 1978, Wood 1982). As many as 50 affected branchlets have been observed on 1 large infested magnolia in Louisiana. Inspection of a flagging branchlet reveals a small pin-sized hole, usually on the underside of the stem (figure 222G). Small quantities of frass may be present at the entrance. The entrance hole is slightly oval, ranging from 0.76 to 0.89 mm by 0.71 to 0.81 mm. The entrance hole extends directly through the bark and xylem at a right angle to the stem axis. The hole extends to the stem pith, where small cavities or brood chambers 2 to 57 mm long are excavated along the stem axis, usually in both directions from the entrance (figure 222H). Dissecting affected twigs may reveal all stages of the insect in the brood chambers and dark stain in the xylem adjacent to the chambers. Small, infested twigs 1 to 8 mm in diameter typically contain one entrance, and they usually succumb. Larger twigs 8 to 22 mm in diameter usually have several entrance holes (up to 20 per twig). These twigs also die, or cankerlike swellings form along them. Cankers range from 10 to 210 mm long, with up to 13 entrance holes. Injuries result in dieback, canker formation, unsightly dead leaves on attacked twigs, and, less commonly, tree mortality (Mangold and others 1977). Economic losses have been sustained by avocado growers in Florida, and the beetle has become increasingly destructive to ornamental trees and shrubs (Ngoan and others 1976). It causes extensive mortality among large forest trees and understory shrubs in Hawaii (Nelson and Davis 1972).

Control. Flagging twigs and branches should be pruned out and destroyed while the brood is present (Oliver 1978). Fertilization and irrigation that keep trees healthy and vigorous can help to lessen dieback and injury (Chellman 1978). Insecticides applied with a hydraulic sprayer have controlled infestations in flowering dogwood in Florida (Mangold and others 1977).

Coleoptera

Xylosandrus germanus **(Blandford)**

[black stem borer] (figure 223)

Hosts. Elm, oak, red maple, beech, hickory, pecan, sumac, willow, birch, sweetgum, tupelo, dogwood, ash, black cherry, redbud, buckeye, linden, sassafras, black walnut, butternut, bayberry, yellow-poplar, hornbeam, pear, apple, rhododendron, grape, poison ivy, pine, cedar, hemlock. Worldwide, over 200 species in 52 families recorded as hosts; favors broadleaf trees and shrubs but also attacks some conifers (Hoffman 1941, Weber and McPherson 1983a).

Range. The Far East, Central Europe. In the eastern United States, it has been found in 17 states, from Connecticut and New York south to Georgia and west to eastern Texas, Missouri, and Michigan (Weber and McPherson 1982). Introduced apparently from Japan; first reported in 1932 on greenhouse-grown grape vines in Long Island, New York (Hoffman 1941).

Description. ***Adult.*** Dark brown to black, shiny, stout, almost cylindrical ambrosia beetle, rounded in front and rear (figure 223A) (Hoffman 1941, Wood 1982). Females 2.2 to 2.4 mm long, 2.3 times as long as wide; males 1.5 to 1.7 mm long, lighter in color. Head finely and scantily punctured, hidden under prominent pronotum; eyes deeply emarginate. Pronotum about as long as wide, anterior margin in female with 8 to 10 low, blunt asperites, and posterior smooth and faintly punctured; anterior margin of male pronotum smooth and anterior slope with numerous low asperites. Elytral declivity begins slightly behind middle; steep, broadly convex, more oblique than abrupt, suture slightly raised. ***Egg.*** Elliptical, soft, white, translucent, shiny, 0.67 by 0.38 mm (figure 223B). ***Larva.*** White, with light brown head, elongate and rather flat when newly hatched, but becoming robust, slightly curved (figure 223C). ***Pupa.*** White, exarate, 1.8 to 2.5 mm long.

Biology. Beetles emerge from hibernation in late March in North Carolina and in mid-May in Illinois and New Jersey (Hoffman 1941, Schneider and Farrier 1969, Weber and McPherson 1983b). Adult flights to suitable hosts peak from late April to early June. Females bore through the bark into the sapwood, construct a brood chamber and one or more branch galleries, and inoculate the gallery walls with an ambrosia fungus—*Ambrosiella hartigii* Batra. Egg laying does not begin until the brood chambers have been formed and the white ambrosia fungus begins to grow—about 5 days after the galleries were excavated. Females deposit from 2 to 50 eggs loosely in small clusters in the brood chamber. Oviposition period averages about 26 days, and females deposit an average of 1 egg per day, but a few females deposit up to 140 eggs. After oviposition in the brood chambers, the females construct the branch galleries. Eggs hatch in 4 to 6 days, and the young larvae feed on the ambrosia fungus mats in both the brood chamber and branch galleries. The larvae pass through three larval instars and pupate freely in the galleries in about 12 days. Pupation lasts 7 to 8 days. New adults assume normal color 5 to 6 days

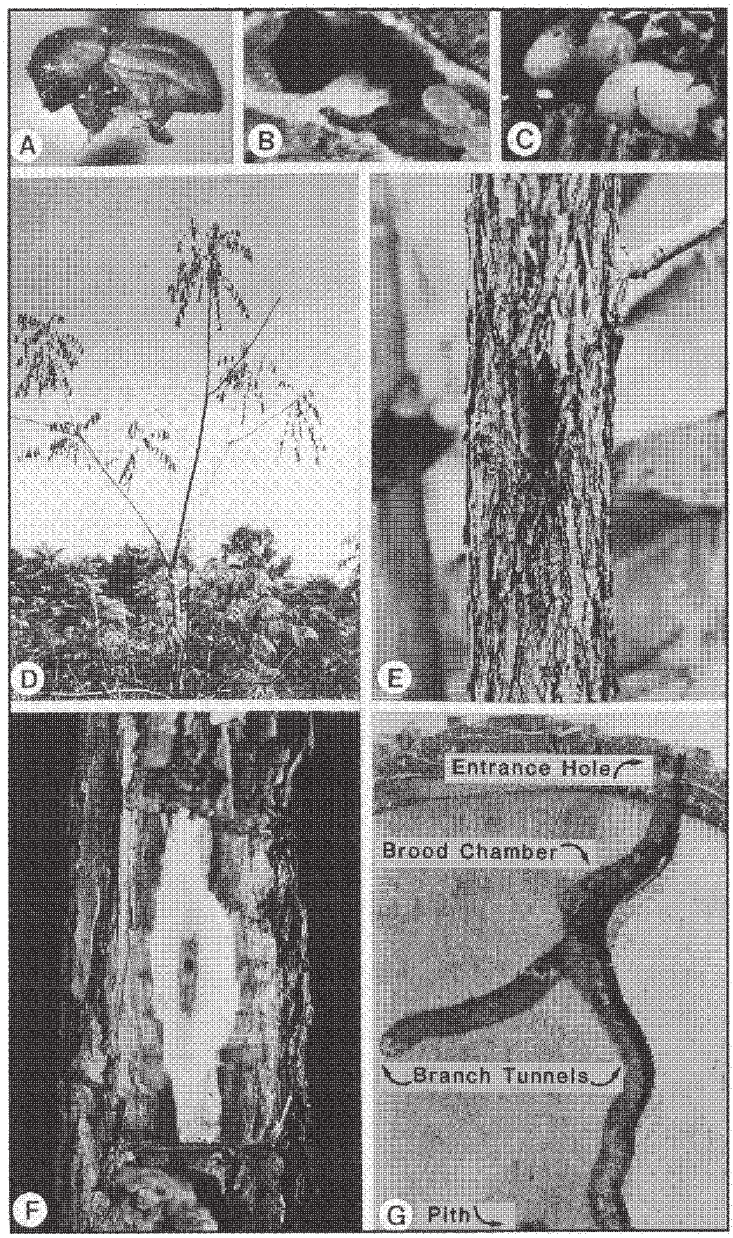

Figure 223—Xylosandrus germanus, *[black stem borer]: A, adult; B, cluster of eggs in gallery with white ambrosia fungus; C, larvae; D, black walnut sapling dying from beetle attack; E, sap-stained bark at beetle entrance; F, entrance hole in sapwood; G, gallery entrance, brood chamber, and branch tunnels (courtesy B. Weber and J. Van Sambeek).*

Coleoptera

Coleoptera

after emergence. Development from egg to adult averages about 26 days. Diploid females are produced from fertilized eggs, whereas haploid males arise from unfertilized eggs; females outnumber males by about 10 to 1. Males cannot fly, so females must either mate before leaving the brood trees or first produce two to three males parthenogenetically with whom they mate. The beetles overwinter in the brood chambers where they develop; sometimes, as many as 200 beetles may be found hibernating in 1 gallery system. The beetle has two generations a year, and possibly three, in the southern parts of its range.

Injury and damage. Unlike most ambrosia beetles, this insect attacks vigorous trees as well as diseased, dying, and recently dead ones and fresh-cut trees and stumps (Anderson and Hoffard 1978, Schneider and Farrier 1969, Weber 1981, Weber and McPherson 1983b, Wood 1982). On black walnut in young plantations and elm and maple growing as understory plants, attack sites are most common on the lower trunks of saplings 0.9 to 6.4 cm (occasionally up to 10 cm) in diameter and less common in the lower branches within 2 m of the ground. Cut oak and beech stumps up to 50 cm in diameter are sometimes attacked. Wilting, yellowing, and dying foliage on the aboveground portion of the tree are initial symptoms of attack and are found most frequently during May and June (figure 223D). Sometimes the only symptoms of attack are pinholes, but they are small (about 1 mm diameter) and difficult to detect. Sap may ooze from the pinholes and stain the bark (figure 223E and F). Fine dustlike frass is often present in bark crevices around the pinholes. Under moist conditions, cylindrical rods or coiled strands of compacted frass up to 5 cm long are extruded from the entrance holes. *Fusarium* cankers of varying sizes are often associated with pinholes and dieback. These cankers appear as sunken necrotic areas under the bark; later, the bark cracks and callus tissue may be visible around the canker. Although the tops of attacked trees may die, the roots are usually still alive and send out sprouts. About 75% of infested trees suffer top dieback, but most of these produce basal sprouts, which are good indicators of injury. Dissection reveals a gallery entrance about 1 mm in diameter and a horizontal entrance tunnel 2 to 3 mm long extending into the sapwood. This tunnel is then enlarged into an elongate (7 to 12 mm), irregular, vertically oriented, cavelike gallery (figure 223G). One to three branch tunnels 1 to 25 mm long may extend more or less radially from the cavelike brood chamber. In some young black walnut plantations, 30 to 40% of the trees have suffered dieback from beetle/*Fusarium* canker attacks. Also, high rates of dieback, resprouting, and deformity from the beetle/*Fusarium* attacks have occurred in yellow-poplar plantations in Ohio. The beetle has also been implicated in the transmission of Dutch elm disease.

Control. Some predation by an unidentified immature hemipteran has been observed; no parasites have been reported (Weber and McPherson 1983b). Good management and silvicultural practices including establishing plantations on good sites, planting trees to permit thinning of injured ones, and providing adequate weed control are best for minimizing losses (Weber 1981). Fresh hardwood stumps within a radius of 500 m of young plantations in problem areas should be chemically treated to prevent population buildup. Also, cankered, dying, and dead treetops and branches should be removed and burned promptly to destroy developing beetles. Differences among geographic seed sources in susceptibility to beetle attack in research trials offer future control alternatives.

Xylosandrus crassiusculus (Motschulsky)

[granulate ambrosia beetle] (figure 224)

Hosts. Sweetgum, peach, cherry, plum, pecan, willow oak, water hickory, honeylocust, cottonwood, black willow, American elm, sugarberry, persimmon, magnolia, grape. Attacks over 200 broadleaf trees, shrubs, and vines worldwide in 41 plant families (Anderson 1974, Wood 1982). In the 20 years since this beetle's introduction into North America, it has been found in 13 broadleaf species but shows some preference for sweetgum.

Range. Widely distributed in Africa, southern Asia, Indonesia, Australia, and the islands of the Pacific, including the Hawaiian Islands (Wood 1960). Apparently migrated from Indonesia or southern Asia by way of Hawaii to the mainland United States. It was first reported in 1974 in North America from Summerville (Dorchester County), South Carolina (Anderson 1974). The insect has spread rapidly. Besides South Carolina, published records now include Florida, North Carolina, Louisiana, and east Texas (Atkinson and others 1988, Chapin and Oliver 1986). Additional unpublished records in the United States National Museum collection reveal specimens collected in Georgia and Mississippi.

Description. ***Adult.*** Reddish brown, stout, cylindrical ambrosia beetle, rounded in front and rear, with head largely hidden under prominent pronotum (figure 224A) (Atkinson and others 1988, Kovach and Gorsuch 1985, Wood 1982). Front of head strongly and uniformly reticulate. Pronotum as long as wide, anterior margin in female with several blunt asperites; pronotal asperites absent in male. Females 2.1 to 2.9 mm long, 2.1 times as long as wide; males remotely resemble females but are very small, with radically reduced thorax and hunchbacked appearance. Elytra are slightly longer than wide, and somewhat larger than pronotum, with small punctures. Elytral declivity steep, convex, dull, densely covered with small granules. ***Larva.*** White with well-developed, light brown head and legless, curved body (figure 224B).

Biology. Adult beetles are found from May through August (Atkinson and others 1988, Wood 1982). Overwintering probably occurs in the adult stage as in other *Xylosandrus* spp. Males are rare, small, flightless, and presumably haploid. Females mate with sibling males before emerging to attack new hosts. Females fly to suitable hosts in spring to initiate new attacks. They bore

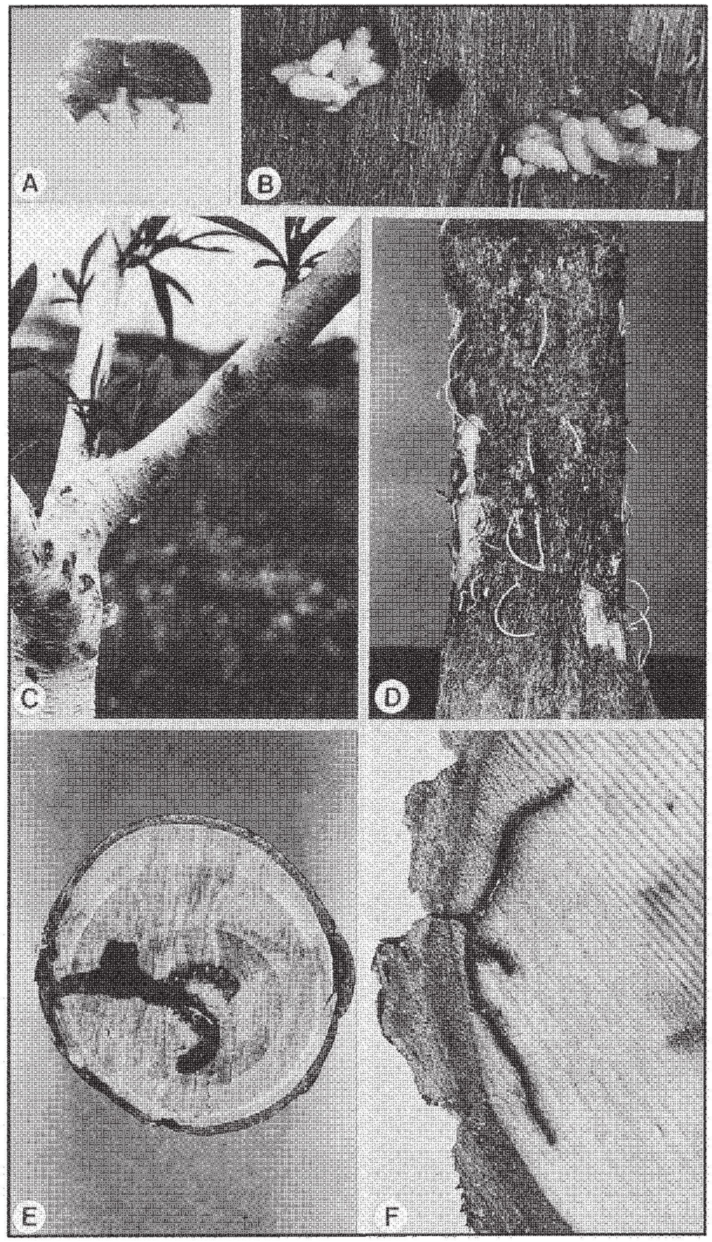

Figure 224—Xylosandrus crassiusculus, *[granulate ambrosia beetle]: A, adult; B, larvae and pupae; C, gummy exudate at entrances on peach bark; D, strands of compacted frass; E, gallery with entrance, brood chamber, and branch galleries; F, gallery system in large cottonwood (C & E, courtesy C. Gorsuch).*

tunnels that usually contain a brood chamber and branch one or more times in the sapwood. Females deposit eggs in the brood chamber, and the larvae feed on the ambrosia fungus cultured on the gallery walls. Masses of larvae and pupae can sometimes be found together in the brood chamber. No individual egg niches, larval tunnels, or pupal chambers are made. In Malaysia, the life cycle reportedly is 5 to 7 weeks. The number of progeny varies from 23 to more than 100 per gallery. Several generations occur per year.

Injury and damage. Healthy and stressed trees as well as freshly cut material from 1.5 cm in diameter to large logs are attacked (Wood 1982). This beetle prefers stems smaller than 7.5 cm in diameter but sometimes infests material larger than 20 cm in diameter. It commonly attacks newly transplanted seedlings near the root collar. Round 2-mm diameter entrance holes usually at lenticels may be found in the bark (Kovach and Gorsuch 1985). Masses of gummy exudate usually accumulate at entrance sites on *Prunus* spp. such as peach trees (figure 224C). Long strands of compacted frass sometimes curl out of the galleries (figure 224D). Dissection reveals a gallery system that reportedly resembles that of *Xyleborus dispar* (Wood 1982), but actually the galleries seem to vary with host species, stem diameter, and possibly wood moisture content. In small-diameter stems, galleries penetrate the bark and sapwood for 4 to 8 mm, then open into an enlarged cavelike brood chamber that contains one or two short branch galleries (figure 224E). In large diameter stems, the brood chambers are usually smaller and more elongate, and the branch galleries are usually longer and more numerous (figure 224F). Apparently healthy peach trees have been attacked in South Carolina; growers are concerned because of the beetles' aggressive behavior toward both healthy and stressed trees (Kovach and Gorsuch 1985). Nursery-grown oaks and elms have suffered from attacks in Florida (Atkinson and others 1988). In south Mississippi, young 8- to 9-year-old pecan plantations have been heavily infested and some trees have died.

Control. Cultural practices that eliminate breeding sites help minimize populations and losses (Atkinson and others 1988, Kovach and Gorsuch 1985). Prunings should be burned or destroyed with a flail mower. Dying trees, brush piles, and other debris should be burned by late winter before the adults emerge and reinfest crop trees. Growers should emphasize practices that promote tree vigor. Chemical controls may be needed to protect valuable trees.

Coleoptera

Family Platypodidae — Ambrosia Beetles

The platypodids are almost all tropical and subtropical beetles; only two species are covered in this manual. They are distinguished from other ambrosia beetles by their large size; longer, more slender body; wide, prominent head flattened in front, not covered by the pronotum; and long, slender tarsus, with the basal joint longer than the others combined (Arnett 1968, USDA FS 1985). Larvae are elongate, fleshy, straight to only slightly curved, and subcylindrical, with only scattered short setae. They bore into the wood and cultivate an ambrosial fungus upon which both adults and larvae feed. When abundant, they are more destructive than other ambrosia beetles because their burrows are more extensive and penetrate deeper into the sapwood and heartwood. Weakened, dying, and recently felled trees are preferred; however, vigorous, healthy trees are also attacked, especially when wounds and dead areas are present. Their burrows and associated wood stains often ruin the value of hardwood timber.

Genus and Species

Platypus compositus (Say)

[hardwood platypus] (figure 225)

Hosts. Oak, hickory, pecan, chestnut, poplar, birch, beech, elm, basswood, sweetgum, magnolia, persimmon, willow, maple, cherry, tupelo, baldcypress. Prefers oak, hickory, maple, and beech, but other hosts are also commonly attacked (Beal and Massey 1945, Chamberlin 1939).

Range. Primarily a tropical and subtropical species, extending through Central and South America and Mexico into Texas east to Florida and northward from southern Missouri to southern New York (Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Most common and widely distributed *Platypus* sp. in the United States; most common in the South, particularly along the Gulf Coast.

Description. ***Adult.*** Large, very elongate, cylindrical, reddish brown ambrosia beetle, 4.3 to 5.0 mm long, about four times as long as wide (figure 225A) (Arnett 1968, Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Head visible from above, as wide as pronotum, noticeably broad and flattened in front. Pronotum finely, shallowly, and sparsely punctured, longer than wide, with two tiny margined pits just behind the middle of both sexes. Elytra elongate with punctate striae. Elytral declivity in males prolonged into heavy process that bears three teeth on their tips; truncate and unarmed (toothless) in females. ***Egg.*** Elongate to oval, pearly white, clear to opaque, 0.72 to 0.89 mm long, 0.41 to 0.48 mm wide (figure 225B). ***Larva.*** Elongate, fleshy, subcylindrical, nearly straight to slightly curved, white to creamy white, with prominent chitinous ridges dorsally on prothorax, 4.8 to 6.4 mm long (figure 225C).

Biology. Adults are active throughout the growing season from spring to October

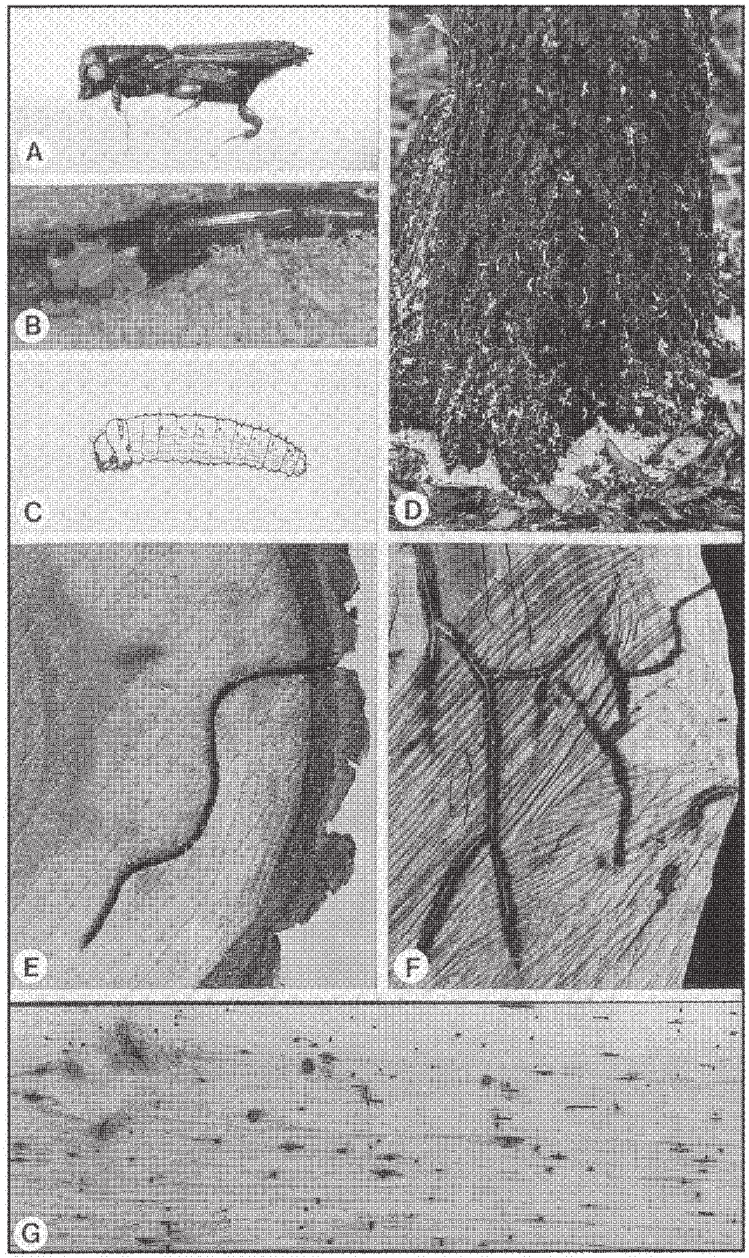

Figure 225—Platypus compositus, *[hardwood platypus]: A, adult; B, egg cluster; C, larva; D, white frass on bark and piled around base of tree; E, unbranched gallery in cottonwood; F, multibranched gallery in pecan; G, black-stained holes in oak lumber.*

or November (Blackman 1922, Chamberlin 1939, Doane and others 1936, Hubbard 1897). Adults are attracted to declining host trees, particularly those with fermenting sap. Males initiate the galleries; each male is soon joined by one female. The males are aggressive fighters and frequently battle over females. The beetles produce deep galleries in the sapwood and heartwood. Females deposit 100 to 200 eggs in loose clusters of 10 to 12 in the galleries. Larvae feed entirely on ambrosia fungus (brought to new sites by parent beetles) that grows prolifically on moist gallery walls. Larvae wander freely in the tunnels as they feed and grow. They can move rapidly within the tunnels, but they do not damage or destroy eggs and small larvae along the galleries. Larvae require 5 to 6 weeks to develop. When nearly mature, the larvae help to extend the galleries, but they do not consume the wood. To pupate, mature larvae construct deep cradles above and below the feeding galleries; pupation occurs in these cradles, and newly transformed adults emerge from the host through entrance holes made by the parent beetles. There are three to four generations per year in the Gulf Coast region.

Injury and damage. This pest seldom attacks healthy, vigorous trees but rather limits its attacks on living trees to those weakened from drought, disease, old age, insect defoliation, wounding, and other factors that produce serious stress (Chamberlin 1939, Craighead 1950, Hubbard 1897). It prefers severely weakened and dying trees, fresh-felled trees, and logs full of moisture. Larger trees in the pole- and sawtimber size classes are favored over smaller trees. Whitish, fibrous boring dust is often present in bark crevices around the entrance holes. During periods of plentiful moisture and high humidity, the borings may stick together as they are pushed out to form compacted, stringlike strands; the white borings sometimes accumulate in loose piles around the base of infested trees (figure 225D). Dissection reveals a simple but extensive gallery system that often penetrates deep into the sapwood and sometimes into the heartwood (figure 225E). In some trees and logs where the moisture level remains favorable, the galleries may branch and rebranch several times, and sometimes follow the growth rings (figure 225F). Numerous short, vertical pupation cells or cradles may be present above or below the galleries. Galleries and cradles are stained black by fungi growing on the gallery walls. Beetles do not kill trees but may hasten the death of severely weakened ones. The most serious damage caused by this insect is the extensive black, fungus-stained galleries that penetrate the sapwood and heartwood. This insect, one of the most destructive ambrosia beetle species in the logging and lumbering industry, can, in a few weeks, render wood worthless for lumber (figure 225G).

Control. Preventive measures, such as keeping trees vigorous and preventing wounds, are the best means of minimizing damage to living timber. In the Deep South, trees felled between April and October should be removed from the woods and processed within 2 to 3 weeks (Craighead 1950). If green logs cannot be milled promptly, they should be either stored under water, sprayed continuously with water, or sprayed with a protective insecticide. Trap trees with girdling and destruction properly timed have been used with some success in high-risk areas (Blackman 1922).

Platypus quadridentatus (Olivier)

[oak platypus] (figure 226)

Hosts. Oak, chestnut, horse chestnut, magnolia, hemlock. Oaks, particularly red oaks, are favored (Beal and Massey 1945, Chamberlin 1939).

Range. Mexico and northward from east Texas and southern Missouri east to southern Pennsylvania and Florida (Atkinson 1989, Beal and Massey 1945, Blackman 1922, USDA FS 1985).

Description. ***Adult.*** Elongate, slender, cylindrical, dark brown to reddish brown ambrosia beetle, 4.2 to 4.6 mm long, 3.8 times as long as wide (figure 226A) (Arnett 1968, Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Head visible from above, noticeably flattened in front, shallowly and densely punctured, sparsely clothed with moderately long hairs. Pronotum longer than broad, slightly constricted along sides at middle, bears two very large pores just behind middle in female; pits very small to absent in male. Elytra elongate, serrate, third and fifth interstriae elevated, forming blunt processes in female; male with large acuminate process arising from interstria 9 and a spinose process arising from interstria 3 of declivity. ***Egg.*** Elongate to oval (slightly shorter and thicker than that of *P. compositus*), pearly white to clear or opaque (figure 226B). ***Larva.*** Elongate, fleshy, subcylindrical, white with light brown head, 4.5 to 6 mm long (figure 226C).

Biology. Adults, present from spring to fall, are attracted to weakened trees (Beal and Massey 1945, Doane and others 1936, Hubbard 1897, USDA FS 1985). The male initiates the gallery. After mating, females bore deeply into both the sapwood and heartwood. Females attract several males but choose only one. Beetles inoculate the galleries with ambrosia fungus and deposit up to 200 eggs loosely in small clusters along the galleries. Larvae wander or roam freely throughout the extensive gallery system and feed on ambrosia fungus growing from the gallery walls; they mature in 5 to 6 weeks. Mature larvae bore short cradles at right angles to the main galleries and parallel to the wood grain to pupate. Pupation takes place in the cradles, which commonly occur in groups up to 10 or 12. One generation is produced in a given host. Three or more generation occur each year in the South.

Injury and damage. Weakened, windthrown, and dying trees, recently cut logs, and unseasoned green lumber may be attacked (Chamberlin 1939, Doane and others 1936, Hubbard 1897, USDA FS 1985). The lower boles of standing sawtimber-sized trees are particularly susceptible. Large amounts of white, fluffy, shredded, fibrous frass are often present on the bark and on the ground at the base of the tree or log (figure 226D). Entrance holes in the bark are 0.9 to 1.3 mm in diameter. The

Coleoptera

Coleoptera

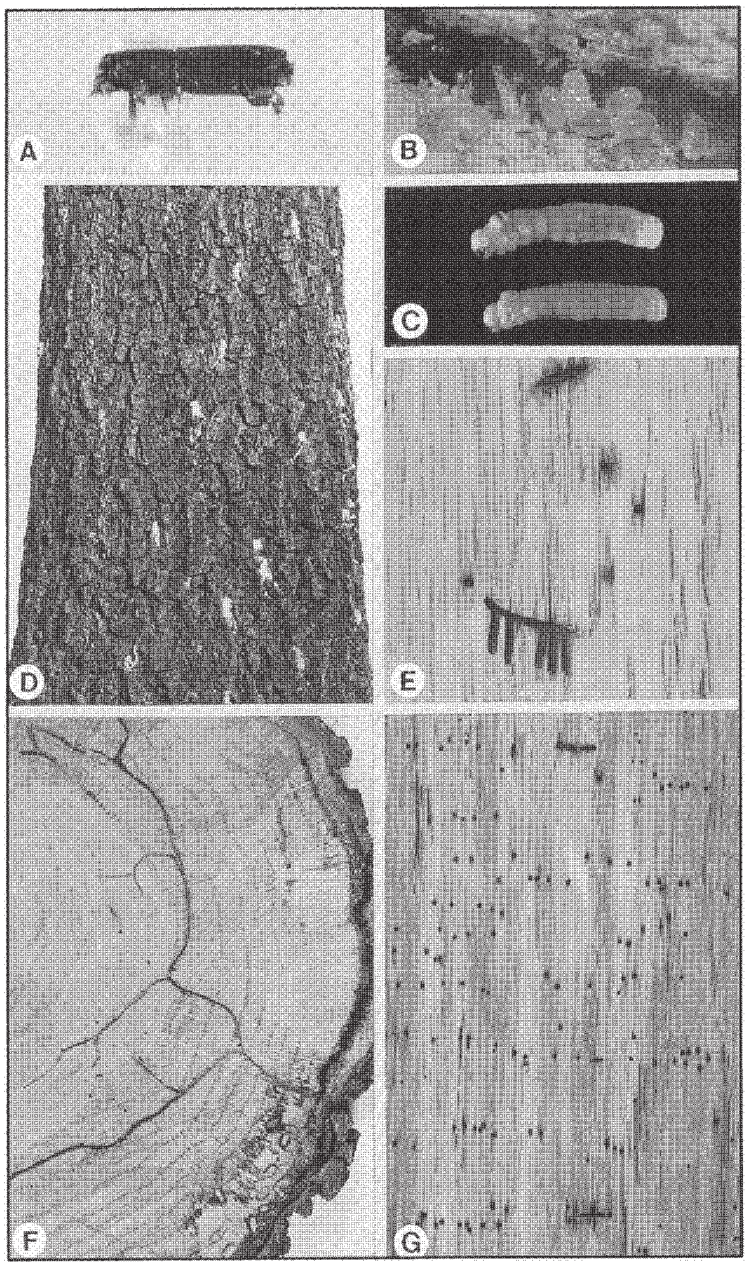

Figure 226—Platypus quadridentatus, *[oak platypus]: A, adult; B, egg cluster; C, larvae; D, white piles of frass on bark; E, closeup of galleries with cradles; F, complete gallery with branching in red oak; G, numerous black holes in oak lumber.*

gallery system is simple but very extensive, penetrating deeply into the sapwood and heartwood, sometimes to depths of 25 to 30 cm, and often branching and rebranching many times (figure 226E and F). Short pupal cells or cradles occur vertically either above or below the galleries (figure 226E). Although less common and less populous than *P. compositus*, it is still one of the most destructive ambrosia beetles. Its black-stained holes degrade the wood and lower the monetary value of affected logs and lumber (figure 226G). In the past, magnolia seedlings grown in nurseries have been seriously damaged by this beetle in Florida.

Control. Maintenance of tree health and vigor can prevent injury (USDA FS 1985). Individual trees and timber stands stressed from drought, unseasonal flooding from beaver dams, wildfire, or storm damage, should be surveyed frequently for infestation. Prompt salvage may be dictated when stressed timber becomes infested. During the warm season in the Deep South, logs should be milled within 2 to 3 weeks to avoid damage (Craighead 1950, Hubbard 1897). Green logs can be protected by submerging in water, storing under continuous water spray, or spraying with an insecticide. Insecticides may be needed occasionally to protect seedlings in nurseries.

Coleoptera

Order Hymenoptera—Sawflies And Horntails

Hymenoptera, one of the largest orders of insects, is divided into two suborders. Members of Apocrita, the larger suborder, are largely beneficial, either as parasites or predators of pests or as pollinators of commercial crops. Members of the suborder Symphyta are mostly phytophagous and include the sawfly and horntail borers covered here (Borror and others 1981, USDA FS 1985). Adults are characterized as having four membranous wings; the fore pair is larger and more completely veined than the hind pair. Members of Symphyta are distinguished by having an abdomen that is broadly joined to the thorax (not threadlike as in Apocrita). Also, the adult females have a well-developed ovipositor, either sawlike or hornlike, fitted for making incisions and inserting eggs in plant tissue. Larvae are slightly curved to S-shaped, with three pairs of small thoracic legs and abdominal prolegs often reduced or absent. Members of this group feed in tender shoots, petioles, galls, or solid wood. They seldom cause widespread economically damaging losses, but sometimes are troublesome and cause moderate damage locally to nurseries, young plantations, ornamentals, and weakened timber stands.

Family

Family Tenthredinidae—Gall Sawflies

Members of this family are mostly leaf feeders, but some burrow internally in buds, petioles, twigs, or stems, usually producing galls (Smith 1968b, Smith 1979, USDA FS 1985). Twenty-nine species of *Euura* are listed as forming galls on petioles, twigs, and stems of willow (Smith 1979), but little is known about most species. Therefore, only four species of *Euura* are covered in this manual. Adults are small sawflies with clear wings and short sawlike ovipositors. Larvae vary from white to yellowish, greenish, and purplish, usually slightly curved, have three pairs of legs, and most have abdominal prolegs. Although troublesome on ornamentals, they are of minor importance.

Genus and Species

Caulocampus acericaulis (MacGillivray)

maple petiole borer (figure 227)

Hosts. Maple. Sugar maple is preferred (Britton 1906). Norway maple and planetree maple have also been recorded; other species of maple probably serve as occasional hosts (Johnson and Lyon 1988, Solomon 1982).

Hymenoptera

Hymenoptera

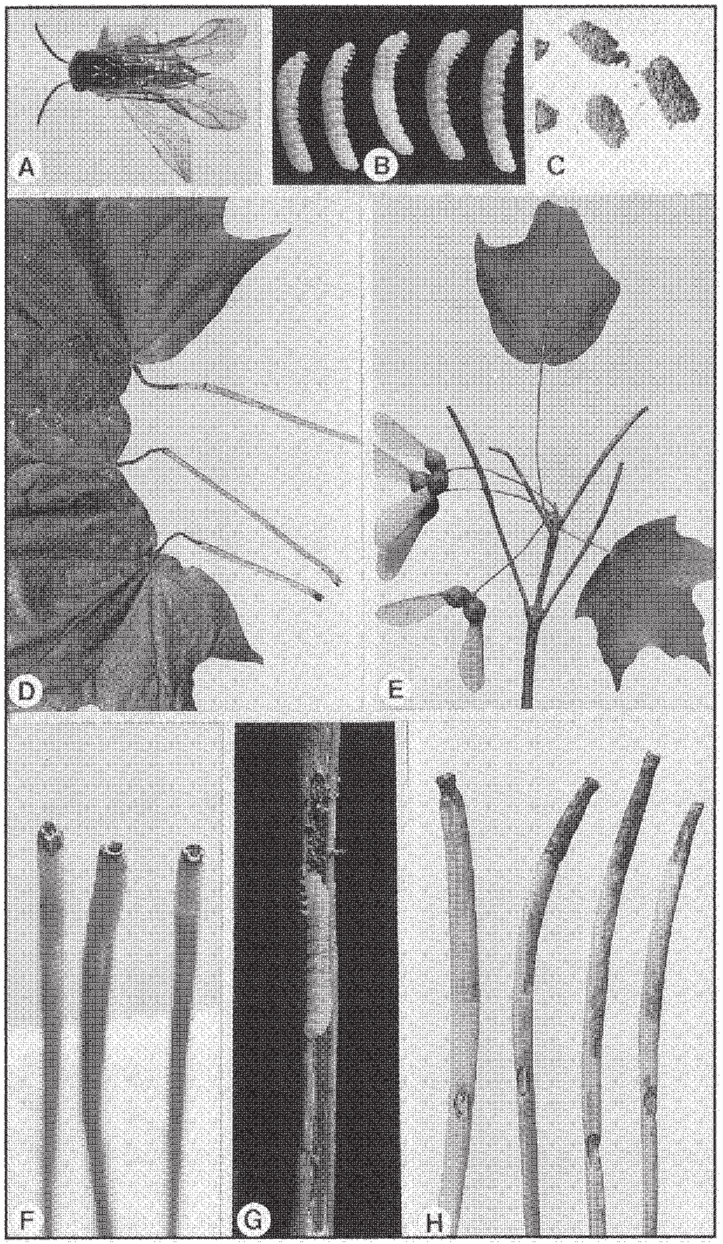

Figure 227—Caulocampus acericaulis, *maple petiole borer: A, adult; B, larvae; C, earthen pupal cells; D, infested petioles limp and darkened; E, petioles with leaf blades detached; F, swollen petioles severed; G, hollowed petiole with larva; H, oval exit holes in petioles (B-H, specimens courtesy C. Pless).*

Range. First reported in 1899 from Danbury, Connecticut (Britton 1906, Johnson and Lyon 1988). Now known from southeastern Canada, Vermont, and New York south through Tennessee and Alabama and west to Kansas, Indiana, and Wisconsin (Solomon 1982, USDA FS 1985).

Description. ***Adult.*** Very small, black and yellow, wasplike sawfly, about 4 mm long, with four transparent wings with wingspan of 10 mm (figure 227A) (Britton 1906, 1912a; Herrick 1935; Smith 1968a). Head and thorax shiny black, except yellowish on underside of thorax; antennae black with first two segments yellowish, and about 2 mm long. Abdomen and legs honey yellow, except tip of abdomen black. ***Egg.*** Colorless, very long, slender, noticeably curved or falcate, nearly uniform in thickness except slightly thicker at one end, 0.98 by 0.19 mm. ***Larva.*** Uniformly buff or straw yellow, head dark yellow to light brown with dark brown to black mandibles, three pair small thoracic prolegs (figure 227B). Full-grown larvae about 8.0 mm long and 1.5 mm in diameter, slightly curved resembling weevil larvae. ***Pupa.*** Pupal case round-to-oval earthen cell, about 5 mm in diameter (figure 227C).

Biology. Adults emerge from pupation cells in the soil in late April and May (Britton 1906, 1912a; Craighead 1950; Herrick 1935). The adults fly to host trees and oviposit mostly during early May. Females deposit eggs singly, primarily in the distal end of the petiole or in the base of the leaf blade where the major veins branch from the petiole. As many as 19 eggs have been found in the abdomen of a female. After a short incubation, the eggs hatch, and the larvae begin feeding and tunneling in the petiole. In about 3 weeks, the leaf blades are severed or break and fall to the ground. The larvae continue to feed inside the portion of petiole still attached to the tree. In 7 to 14 days, the bare petioles containing the larvae abscise and fall to the ground. The larvae vacate their petiole galleries and burrow into the soil 5 to 8 cm. Here, they form tiny earthen cells around themselves where they overwinter as prepupae. Pupation occurs in spring, and adults soon emerge to complete the life cycle. There is one generation a year.

Injury and damage. The first symptoms of wilting, yellowing, and browning leaves appear about mid-May. Injured leaves begin to fall to the ground in late May and early June (Britton 1906, 1912a; Craighead 1950; Johnson and Lyon 1988; USDA FS 1985). Close examination of the affected leaves will reveal that about 6 to 12 mm of the petiole extending from the leaf blade is limp, partially hollowed, and darkening (figure 227D). Inspection of the foliage will show the remainder of the infested petioles to be slightly swollen and still attached to the tree (figure 227E). The severed ends of the petioles appear neatly girdled (figure 227F). Slicing the petiole reveals the hollowed interior, the larva, and loose granular frass (figure 227G). The bare petioles drop to the ground from early to late June. Larvae leave a tiny, irregularly oval hole in each petiole as they enter the soil (figure 227H). The ground under heavily infested sugar maples may be littered, almost covered with fallen leaves and bare petioles during June and early July. Leaf drop and defoliation of 5 to 20% is common in Ohio, and up to one-third of the leaves are lost on infested trees in Connecticut (Britton 1912a, Solomon 1982). However, leaf drop is seldom serious enough to substantially weaken or threaten the tree. Conversely, early season leaf drop is unsightly and disturbs owners of shade and ornamental maples and sometimes creates unseasonal cleanup problems.

Control. Two hymenopterous parasites—*Bracon montowesi* (Viereck) and an unidentified chalcid—have been reported (Britton 1906, Marsh 1979). Picking and destroying the infested petioles on small trees as soon as they are noticed may help to reduce sawfly populations (Craighead 1950). Raking and burning the infested fallen petioles promptly and daily before the larvae vacate their galleries is recommended (Britton 1906, Herrick 1935). Chemical treatment has been suggested and may provide some protection in problem areas (Britton 1906, Craighead 1950).

Euura atra (Jurine)

[smaller willow shoot sawfly] (figure 228)

Hosts. Willow. Acute leaf, golden leaf, laurel leaf, weeping, crack, and European yellow willows have been recorded as hosts (Ives and Wong 1988, Wong and others 1976). Introduced European willows, especially acute leaf willow, are preferred in Alberta. European aspen and several other willow species have been recorded as hosts in Europe.

Range. An introduced palearctic species first recorded in North America in 1888 in Quebec. It has since been reported from the Maritime Provinces and New Brunswick westward to Alberta (Ives and Wong 1988, MacCall and others 1972, Smith 1979, Wong and others 1976). It seems to be most troublesome across the Canadian prairies.

Description. ***Adult.*** Small, slender, dark black sawfly, shiny, 5 to 8 mm long, with short sheath and saw on abdomen of female (figure 228A). Two pair of clear wings; forewings reach slightly beyond abdomen. Antennae threadlike and slightly less than half body length. ***Egg.*** Pale, whitish, elongate, markedly tapered at one end, about 0.26 by 0.83 mm (figure 228B) (Ives and Wong 1988, Wong and others 1976). ***Larva.*** Pale black head with dark gray shading, greenish white body, three pairs of well-developed thoracic prolegs with claws, caudal abdominal segments usually held in slightly curled position, about 8 mm long when mature (figure 228C) (Ives and Wong 1988, Rose and Lindquist 1982, Wong and others 1976).

Biology. Adults emerge during late May and early June (Ives and Wong 1988, MacCall and others 1972, Rose and Lindquist 1982, Wong and others 1976). After mating, females make a saw-puncture opening in tender succulent shoots, usually near the base of the shoot, and deposit eggs singly next to the shoot pith. Most oviposition occurs during mid-June, and eggs hatch from mid- to late June. Larvae tunnel in or near the pith and undergo five to seven instars. Young larvae produce reddish frass,

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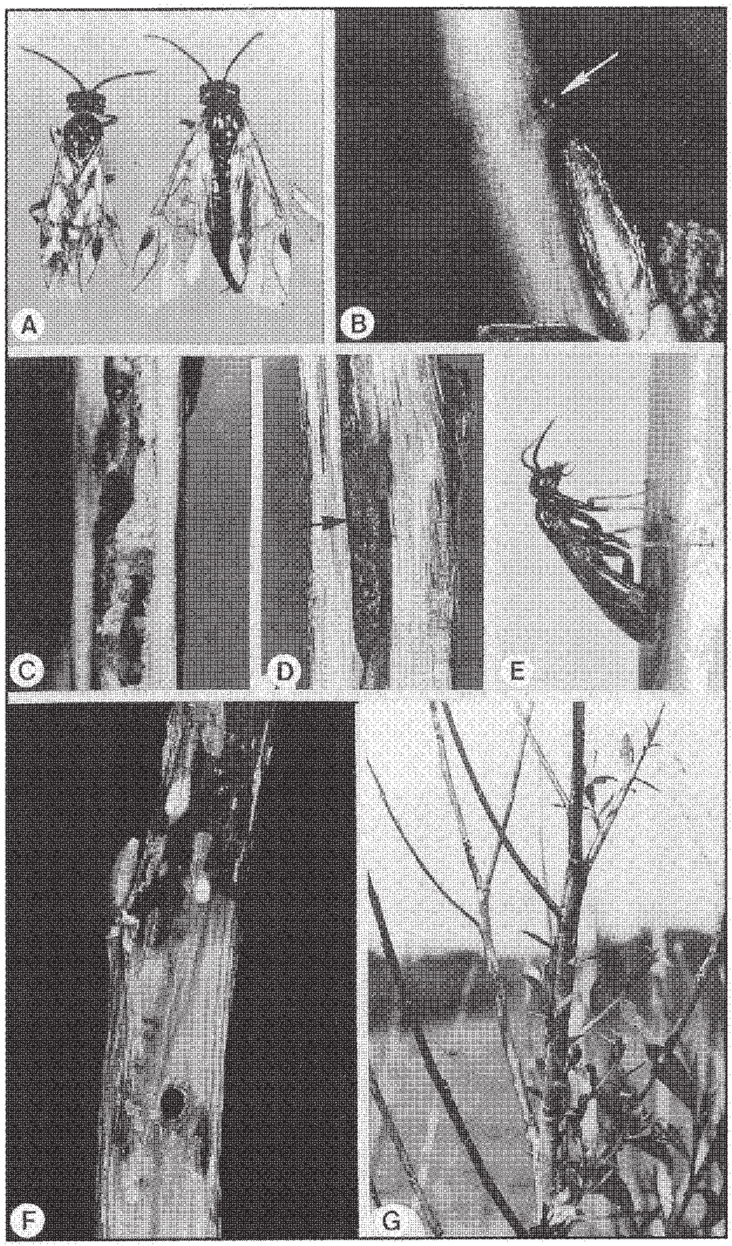

Figure 228—Euura atra, *[smaller willow shoot sawfly]: A, adults; B, egg niche site just above bud; C, larval burrow with frass and larva; D, cocoon within gallery; E, adult emerging from hole in shoot; F, exit hole; G, infested willow shoots failing to leaf out in spring (courtesy H. Wong).*

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and older larvae produce whitish frass, which is generally pushed to one end of the tunnel. Stems may contain more than one larva, but each larva has a separate gallery; if not, cannibalism occurs. Larvae may tunnel toward the shoot tip or toward the base of the shoot. When feeding is complete by late September or early October, the larvae gnaw exit holes through the bark at one end of the gallery, then plug them with frass, bits of pith, and silk. The larvae then retreat to the other end of their galleries in late October and early November and spin brownish transparent cocoons in which they overwinter in the larval stage or as prepupae. A few larvae overwinter in the galleries without constructing cocoons. This sawfly has one generation a year.

Injury and damage. New tender shoots 3 to 18 mm in diameter are most susceptible to attack (Ives and Wong 1988, MacCall and others 1972, Rose and Lindquist 1982, Wong and others 1976). Few symptoms are noticeable during the early stages of attack. The trained eye may see the tiny egg scars that occur in succulent shoots near their base (figure 228B). In some cases, infested stems may swell slightly. Tunneling usually kills the infested shoots, but dieback does not occur until late in the growing season or more likely the following spring. The leaves on infested shoots turn yellow and brown, and the stem becomes brown. Dying shoots are commonly infected by a *Cytospora* fungus. Dissection of infested shoots in summer reveals the larvae along with one to three galleries about 12 mm long (ranging from 8 to 21 mm) in the pith. The frass typically is pushed to one end of the gallery (figure 228C). Dissection during winter and spring reveals a brown cocoon containing a prepupa or a pupa in the gallery (figure 228D). Adults emerge from tiny round exit holes usually indicated externally by a slightly depressed, round, discolored area on the shoot (figure 228E and F). This sawfly attacks terminals and branch ends; as many as 30 larvae have been observed in a 2-m-long whip of acute leaf willow. When the trees leaf out in spring, dead shoots are most noticeable (figure 228G). This insect sometimes causes severe damage to willow in nursery stooling beds and occasionally in shelterbelts. Cuttings have to be checked carefully before distribution to avoid dissemination of infested stock. Thus, infestations have the double effect of reducing the number of cuttings produced and increasing production costs because of the extra checking required.

Control. Several insect parasites have been reared from infested shoots including two *Eurytoma* spp., two *Tetrasticus* spp., and an unidentified species in the family Trichogrammatidae (MacCall and others 1972). The downy woodpecker has been observed digging the larvae from their tunnels (Wong and others 1976). In problem areas, growers should select the least susceptible species of willow, such as peach leaf willow, for planting. Pruning and destroying wilted blackened shoots as they appear in fall and spring before adults emerge may help to reduce infestations (Rose and Lindquist 1982). Soil-applied systemic insecticides have given up to 93% control in nurseries (Wong and others 1976).

Euura exiguae Smith

[sandbar willow gall sawfly] (figure 229)

Host. Willow. Sandbar willow, commonly known as coyote willow, and its subspecies are only known hosts (Smith 1968b).

Range. A western species occurring from the Rocky Mountains to the Pacific Coast and the Columbia River in Oregon to southern California (Price 1989, Smith 1968b). It is the most common willow sawfly below about 2,000 m elevation.

Description. ***Adult.*** Black sawfly with orange to dull yellow markings on legs, ventral edges of tergites, distal edges of sternites of abdomen, and frontal crest and orbits of head (figure 229A) (Smith 1968b, 1970). Abdomen of female equipped with an ovipositor consisting of saw, sheath, and guide; saw averages 1.29 mm long and 0.11 mm wide; sheath from above tapers evenly to a point, not inflated. Front of head glossy or finely striate-punctate. Cerci subcylindrical or slightly clubbed apically. Females 3.6 to 7.0 mm long; males 3.0 to 5.5 mm long. ***Larva.*** Earliest instars pale green from ingested plant material; mid-instars become waxy, cream color; last instar dull, purplish gray, 8 to 10 mm long (figure 229B). Head light brown with pigmented spots on interocular area; antennae plate type and unsegmented; mandibles robust and toothed. Three pairs of thoracic prolegs and six pairs of prominent functional abdominal prolegs. ***Pupa.*** Creamy white, becoming yellowish and finally dark brown to black (figure 229C).

Biology. Adults begin emerging in early March, about the time the first sandbar willow blooms, peaking by late March and ceasing in late April (Smith 1968b, 1970). Adults drink water eagerly upon emerging from the gall and in cages consume small amounts of honey and sugar water. In nature, they are commonly observed on both male and female aments of their hosts eating pollen and drinking nectar; sometimes, they consume whole stamens and parts of capsules. Soon after emerging, mating, and feeding, the females begin ovipositing. Adults are relatively fragile and live only 1 to 2 weeks. Oviposition is accomplished as much through rapid vibration of the abdominal saw as by the more obvious sawing motion. When the oviposition punctures reach the proper depth, the egg and colleterial fluid from the accessory gland are injected through the ovipositor into the meristematic tissue of the tender shoot. Although the eggs are deposited singly, one to four eggs may be deposited in a shoot. The colleterial fluid immediately causes a gall—the expanding gall may become obvious within 48 hours. The galls expand rapidly and generally attain their maximum size before larval eclosion or by the end of the first larval stage. Larvae each make a separate burrow to feed on tissue within the gall. Mature larvae typically cut exit holes in the side of the gall, then plug them with frass, silk, and sawdust before retreating down the mine and entering the prepupal stage. They feed until reaching the prepupal

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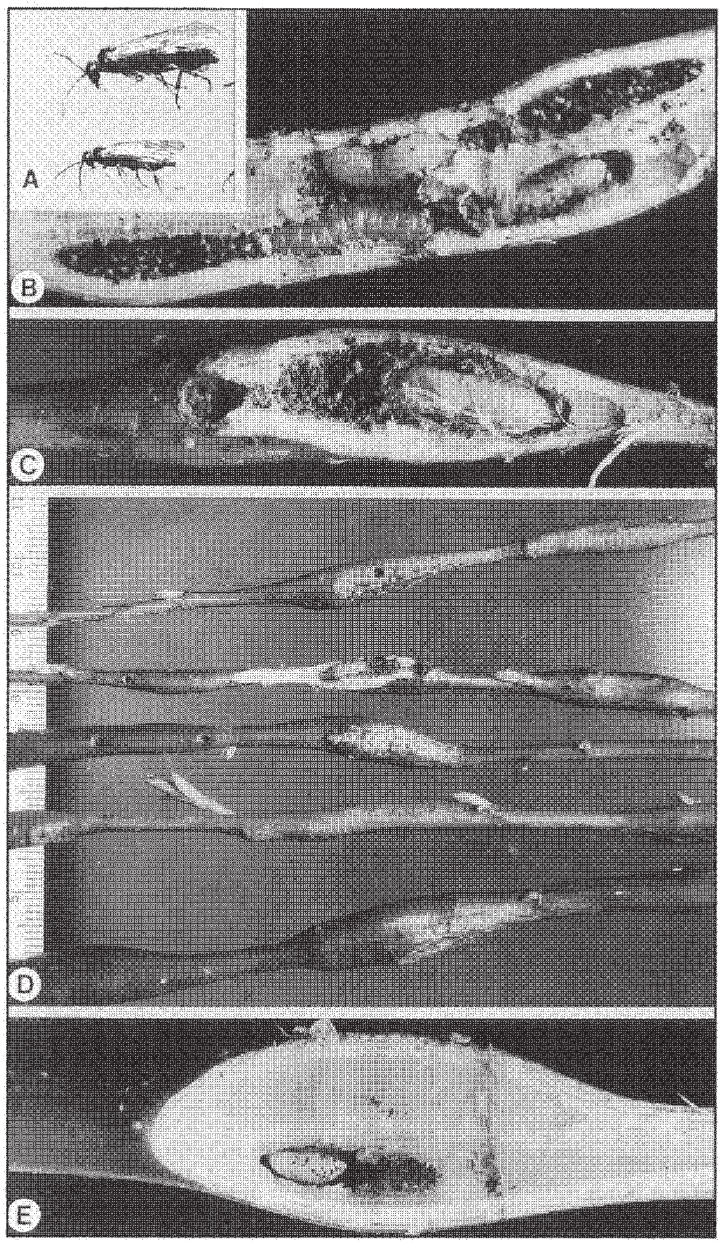

Figure 229—Euura exiguae, *[sandbar willow gall sawfly]: A, adults; B, larvae in gall galleries; C, pupa within gall; D, galls and exit holes on willow shoots; E,* Eurytoma *inquiline kills many sawfly larvae within gall (courtesy E. Smith).*

stage by late September. They overwinter in the prepupal stage within the gall (figure 229C). Pupation occurs during early spring, and the new adults emerge through precut exit holes. There is one generation a year.

Injury and damage. This pest favors sandbar willows growing in sheltered areas overhanging water or humid swales or thickets, with most galls often confined to the lee side of the plants (Price 1989; Smith 1968b, 1970). It is the most common gall sawfly of willow in lowland California and Oregon. Females prefer the most vigorous shoots such as sucker growth or sprouts. Oviposition scars are tiny puncture marks and difficult to detect; however, the galls form quickly and are very noticeable. The galls are thin walled, tapering at both ends, sinuate or linear in outline, and 20 to 70 mm long by 5 to 15 mm wide, with smooth, pubescent, or glabrous surfaces, but never glaucous (figure 229D). Young galls are green when first formed but become uniform brown to russet when mature. Exit holes 1.5 to 2.0 mm are left in the side of the galls. The largest and healthiest galls are characteristically those where the egg never hatched or the larva died early. Galls rarely adversely affect the host other than by distorting the stem. However, they can weaken the branches, causing some breakage. Heavily infested plants may exhibit multiple branching.

Control. Birds prey upon all stages of the insect (Smith 1970). Twelve species of braconid, ichneumonid, and pteromalid parasites kill large numbers of larvae. Also, several inquilines occupy, feed, and develop in the galls and destroy numerous sawfly larvae—a curculionid, *Anthonomus hematopus* (Boheman); three eurytomids, *Eurytoma fossae* Bugbee plus two *Eurytoma* spp.; and a cosmopterygid, *Batrachedra salicipomonella* (Clemens) (figure 229E). Although it is uncommon, some galls are flooded internally by sap, and the larvae drown. Also, excessive heat, caused when galls are exposed for extended periods to direct sunlight, kills some immature larvae.

Euura lasiolepis Smith

[arroyo willow gall sawfly] (figure 230)

Host. Willow. The insect is host species specific, attacking only arroyo willow and its varieties (Price and Clancy 1986, Smith 1968b); considerable variation exists in susceptibility among clones of arroyo willow.

Range. West of the Rocky Mountains to Pacific Coast and from northern California south to Arizona (Price and Craig 1984, Smith 1968b). A different color phase of the insect occurs in the Central Valley of California and in northern Arizona.

Description. ***Adult.*** Small wasplike sawfly, 3 to 8 mm long, with sheath and saw averaging 1.68 mm long and 0.10 mm wide (figure 230A) (Smith 1968b, 1970). Two geographic color phases—a dark, coastal phase that is black with small amber markings and an orange and black Central Valley phase that is slightly larger, translucent, and waxy orange except for brownish black markings. All intergrades occur in interior California. Front of head not polished as in

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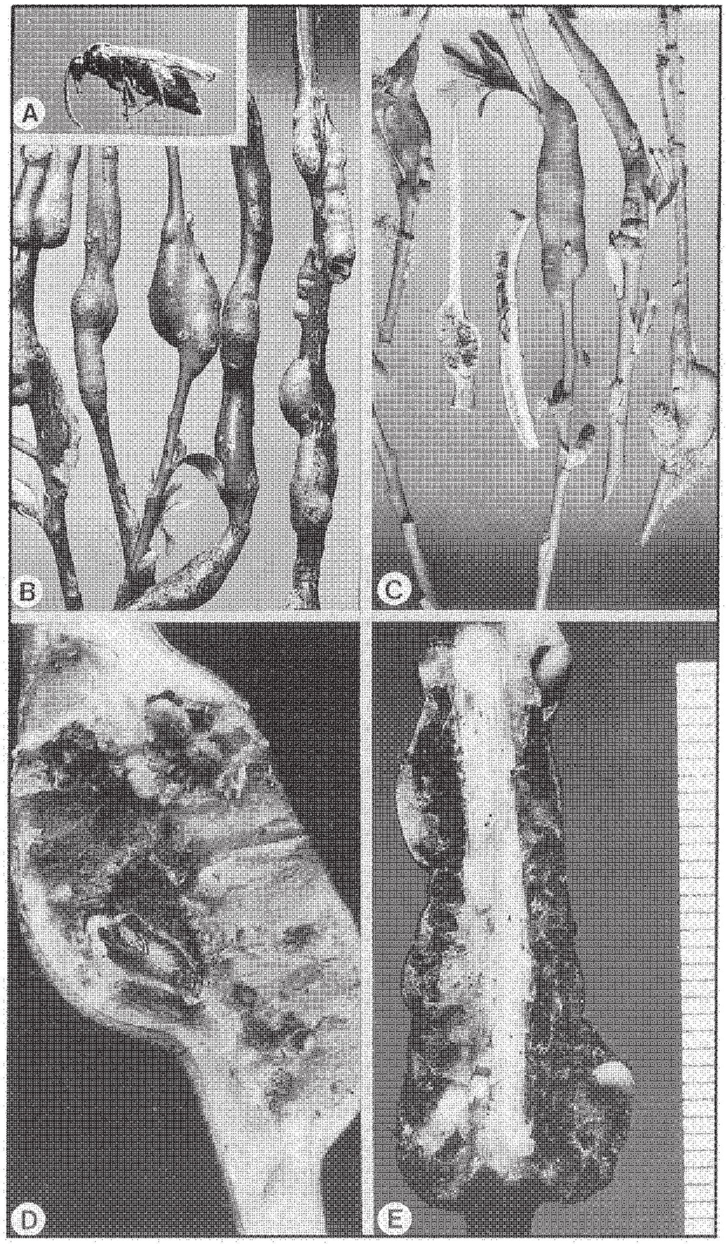

Figure 230—Euura lasiolepis, *[arroyo willow gall sawfly]: A, adult; B, typical galls on willow shoots; C, parasite exit holes and bird excavations in galls; D,* Ichneutes *parasite pupa in gall cell; E,* Dorytomus *inquiline larvae displaced sawfly larvae in gall (courtesy E. Smith).*

E. exiguae. Cerci tapering, distally acuminate, and keeled. ***Egg.*** Newly laid egg is sausage shaped, clear to transparent; anterior end slightly larger than posterior end, 0.55 to 0.60 mm long and 0.20 to 0.25 mm in diameter (Price and Craig 1984). Eggs swell rapidly during embryonic development, becoming more globose and measuring 0.50 to 0.55 mm long and 0.29 to 0.33 mm in diameter. ***Larva.*** Young larva pale green, becoming cream colored and shiny, and finally dull, bluish gray; 8 to 10 mm long (Smith 1970). There are three pairs of thoracic legs and six pairs of prominent abdominal prolegs.

Biology. In California, adult sawflies emerge from late February to early June, with peak emergence during early March (Smith 1968b). In Nevada and at higher elevations in Arizona, adults emerge mostly in May and June (Price and Craig 1984). Emergence generally occurs in the morning, and adults feed on host flowers (Smith 1970). Females lay trails of sex pheromone across the foliage to attract males. After mating, females begin ovipositing within a few minutes, usually on the same plant from which they emerged and then mated on. Females make many short flights between shoots. To oviposit, females search the terminal four or five nodes of shoots, then face down the short petiole toward the shoot and insert their long sawlike ovipositors down the petioles and into the young, succulent stems, laying individual eggs just below the axial bud primordium of each young stem. Two (or rarely 3) eggs, deposited by the same or different females, are in a stem or gall; up to 10 oviposition scars have been found on a shoot. At the time of oviposition, females inject colleterial fluid into the growing tissues, thus immediately inciting gall formation. Larvae feed on the parenchyma cells of galls, tunneling downward toward its base; males pass through five instars, and females pass through six instars. Final instars in October and November do not seem to feed but rasp away at the gall tissue to prevent being crushed by it. Full-grown larvae spin cocoons by matting frass and rasped gall tissues together with silk. Mature larvae overwinter within cocoons inside the galls. Pupation occurs from February through June; the pupal period lasts about 15 days. There is one generation a year.

Injury and damage. This sawfly favors vigorous clonal growths of arroyo willows with many tender shoots that grow in marshy areas along foothill streams, drainage ditches, borrow pits, and around springs and cattle tanks (Price and Clancy 1986; Price and Craig 1984; Smith 1968b, 1970). Oviposition leaves a small scar near the base of the petiole where the ovipositor was inserted; these scars become more noticeable with age as the margins separate and the damaged tissue browns slightly. Growth of galls is rapid through June, then decelerates during July and August; galls reach their greatest diameter by the end of August. The galls are thick walled and tortuous, with smooth, shiny, or corrugated surfaces; yellowish green except purple to red in bright sun; 20 to 70 mm long by 3 to 21 mm in diameter (figure 230B). The larvae do not make exit holes in the galls for adults as occurs with *E. atra* and *E. exiguae*; instead, the new adults chew their own round exit holes in spring. Galled stems sometimes break, but overall damage to plants is slight.

Control. Natural controls often kill a high proportion of sawfly broods (Price and Craig 1984; Smith 1968b, 1970). Egg mortality caused by galls that fail to develop, or by rapid growth of gall tissue that crushes the eggs, accounts for about 39% of the brood and is the most important mortality factor in Arizona populations. In Arizona, 10% of the brood is killed by the ichneumonid parasite *Lathrostizus euurae* (Ashmead) and another 2% is parasitized by a pteromalid, *Pteromalus* sp. The inquiline *Batrachedra striolata* Zeller sometimes bores into galls, feeds on the gall tissue, and kills the sawfly larvae, but it kills only about 1% of the larvae. Birds, particularly mountain chickadees, peck into the galls and capture about 4% of the larvae from cocoons (figure 230B and C). Ants and grasshoppers destroy a few sawflies. In California, several species of parasites, especially *Ichneutes* sp. (figure 230D) and inquilines, particularly the weevil *Dorytomus luridus* (Mannerheim) (figure 230E), are important natural controls, but losses have not been assessed.

Euura salicis-nodus Walsh

[willow spindle gall sawfly]

Host. Willow. Sandbar willow is only recorded host; both very hairy and less hairy varieties attacked (Judd 1954, Rohwer 1909).

Range. Best known in northeastern North America but widely distributed west to the Rocky Mountains and from Ontario south to Mexico (Rohwer 1909, Smith 1979).

Description. ***Adult.*** Small, wasplike sawfly, black except for reddish brown spot enclosing ocelli on head, 4.1 to 4.6 mm long (Rohwer 1909). Head narrowed toward top; front of head strongly rugose. Wings hyaline, highly iridescent, with pale brown venation. Sheath broad, in lateral view, straight on upper margin, roundly truncate at apex. Cerci not extending beyond sheath. ***Larva.*** Body cylindrical, without setae, white or cream colored to pale; head greenish white, yellowish with dark eye spots and mandibles; body 4 to 9 mm long (Peterson 1962, Rohwer 1909).

Biology. Adult sawflies emerge during April and May, usually peaking in mid-April (Judd 1954). After feeding and mating, females begin ovipositing in tender shoots. One to three eggs are usually deposited in a shoot by the same or different females. The females inject colleterial fluid into the growing shoots during oviposition; galls develop rapidly whether or not eggs were actually deposited. Larvae feed on the gall tissue and usually develop in separate chambers within the galls. Galls become partially filled with frass. Full-grown larvae typically chew a round exit opening in the side, usually near one end of the gall, but some larvae leave a thin membrane covering the exit burrow. Mature larvae spin a flimsy cocoon surrounded by brown frass within the gall during fall and overwinter with their heads toward the gall openings. They pupate in spring. There is one generation per year.

Injury and damage. Shrubby growths of willow growing along the edges of fields, roadsides, and streams are likely targets for infestation (Judd 1954, Peterson 1962, Rohwer 1909). Spindle-shaped galls on twigs and branches are the most noticeable signs of infestation. Galls begin as gradual enlargements that eventually become spindle shaped, 19 to 38 mm long, and two or three times the stem diameter. Each gall may be perforated by one to three circular openings about 1 mm or more in diameter at either end. Dissection reveals one or two elongated chambers in the gall. Most galls are separate from one another, forming individual swellings along the twig. One or a few galls per stem commonly occur, but up to eight may occur per 30 cm of branch. Damage is generally negligible despite possible breakage or pruning at galled sites.

Control. Three species of hymenopterous parasites—*Habrocytus thyridopterigis* Howard, *Hoptocryptus* sp., and *Ichneutes* sp.—have been recorded, but little is known of their effectiveness (Judd 1954). *Eurytoma* sp., apparently an inquiline in the galls, destroys some sawfly larvae.

Family Siricidae—Horntails

The siricids are commonly known as horntails because of their hornlike projection on the last abdominal segment in adults. Only one species important to hardwoods is covered in this manual. The adults are medium to large, thick-waisted, cylindrical insects with long threadlike antennae and well-developed wings (Furniss and Carolin 1977, USDA FS 1985). Larvae are yellowish white and cylindrical with vestigial thoracic legs and lacking prolegs. Horntails occasionally attack healthy trees, but prefer trees that have been damaged or killed by fire, wind, insects, or diseases. Economic damage to hardwood trees is minor.

Genus and Species

Tremex columba (Linnaeus)

pigeon tremex (figure 231)

Hosts. Beech, elm, hickory, maple, oak, poplar, apple, pear, sycamore, hackberry. Prefers maple and beech, but readily attacks hickory, elm, and oak (Blackman and Ellis 1916, Stillwell 1967). Attacks other species less frequently.

Range. Throughout the United States and southern Canada west to the Rocky Mountains with a few records from Utah, Arizona, and southern California (Doane and others 1936, Ives and Wong 1988, USDA FS 1985). Three geographic races, with race 1 common in southeastern Canada and the northeastern United States, race 2 common in the southeastern United States north to Pennsylvania and west to Utah, and

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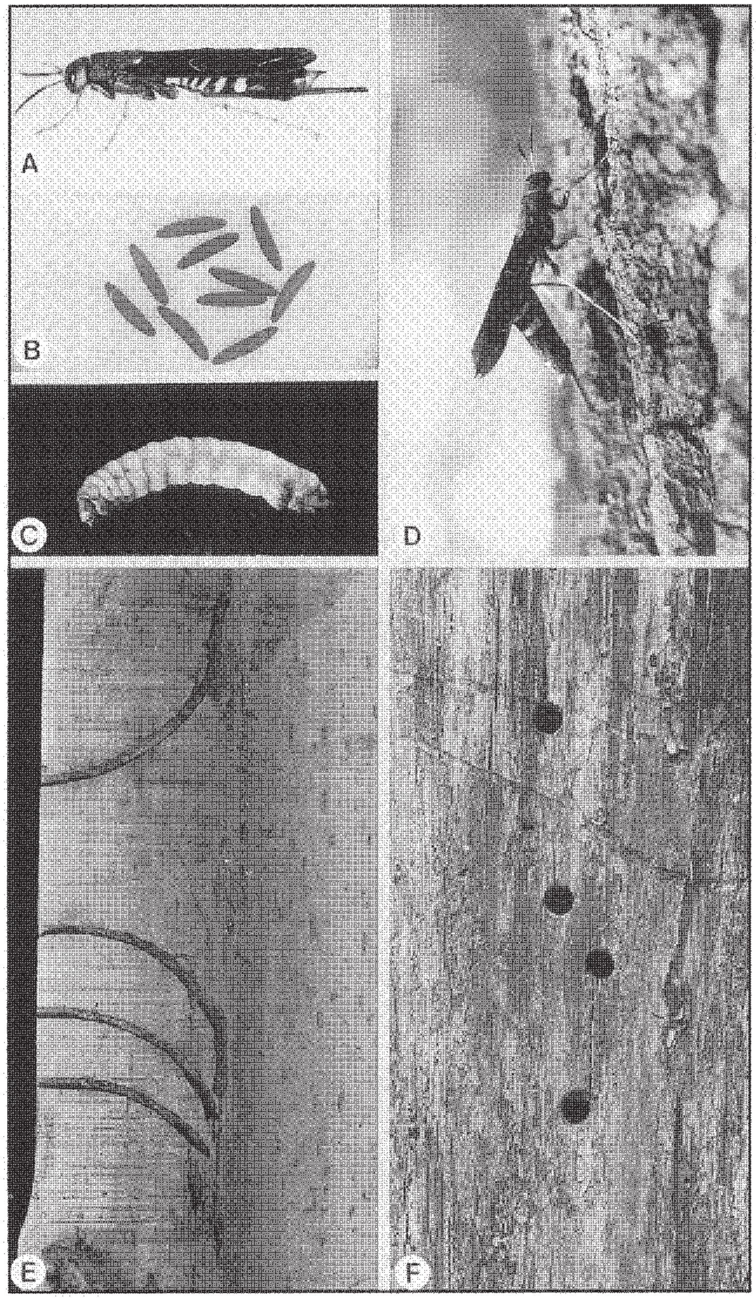

Figure 231—Tremex columba, *pigeon tremex: A, adult; B, eggs; C, larva; D, female ovipositing in tree; E, galleries with curving exits; F, round exit holes.*

race 3 in the Rocky Mountains. Some overlap in range among the three races.

Description. ***Adult.*** Large, cylindrical, heavily bodied, thick-waisted, wasplike horntail with abdomen ending in hornlike projection (figure 231A) (Beal and others 1952, Doane and others 1936, USDA FS 1985). Horny projection of abdomen long and spearlike; encasing ovipositor in females but short and triangular in males. Head large, widened behind eyes. Two pairs of wings transparent to smoky brown. Females 37 to 50 mm long; males 18 to 37 mm long. The three geographic races differ in color: race 1, abdomen black with brownish yellow bands and spots, head and thorax brown; race 2, abdomen yellow with sides of eighth and ninth segments black, head and thorax yellowish brown; race 3, brownish yellow throughout. ***Egg.*** Dark brown to blackish, elongate, slender, straight to slightly curved, narrow at ends, 1.0 to 1.5 mm long and about 0.2 mm in diameter (figure 231B) (Stillwell 1967). ***Larva.*** Cylindrical, straight to lightly curved or slightly S-shaped, white except for amber head, brownish mandibles; 14 to 50 mm long when mature (figure 231C) (Beal and others 1952, McDaniel 1936, Stillwell 1967). Head overhung by prothoracic segment, dome shaped, smooth, and shining. Three pairs small thoracic legs, nonsegmented, clawless. Abdomen ends in brown sclerotized prong.

Biology. In southern range, emergence of adults begins in early June, but in New Brunswick, emergence begins in mid-August, peaks in early September, and continues until early October (Blackman and Ellis 1916, McDaniel 1936, Stillwell 1967, USDA FS 1985). Over most of the range, adults are present from early summer to early fall. When ready to oviposit, females select suitable sites on the bark and drill holes with sawlike movements of the ovipositor (figure 231D). Oviposition channels are 2 to 20 mm deep in the wood and usually at right angles to the bark surface. From two to seven eggs are deposited at intervals, sometimes end to end in the oviposition channel as the ovipositor is withdrawn. Eggs usually hatch in 3 to 4 weeks, but in New Brunswick, some do not hatch until the following May or June. At oviposition, a wood-rotting fungus—*Daedalea unicolor* Buller ex Fries—carried in paired intersegmental sacs near the base of the ovipositor, is deposited in the wood. Larvae feed on the fungus-softened wood and construct long, round galleries that loop and meander through the sapwood and heartwood. Without the fungus, eggs hatch, but larvae cannot develop beyond the first instar. Larvae pack the frass tightly within the gallery and tunnel for 15 cm to 2 m, and occasionally up to 3 m. Female larvae also carry the wood-rotting fungus in a hypopleural fold between the first and second abdominal segments. Pupation occurs in the galleries in the sapwood and lasts 3 to 6 weeks. The new adults tunnel their way to the surface and emerge. In Michigan and New Brunswick, a generation requires 2 years, but in the southern range apparently only 1 year.

Injury and damage. This pest usually attacks trees weakened or dying from disease, other insects, fire, flooding, or other causes; it occasionally attacks healthy trees, especially injured ones (Beal and others 1952, Blackman and Ellis 1916, Stillwell 1967). In the early stages, infestations present little or no evidence of entrance holes and ejected frass. However, it is common in the summer and fall to observe adult females ovipositing on susceptible tree trunks (figure 231A). Dead females with their ovipositors firmly wedged in the wood can sometimes be found, especially on living trees that have green or sappy wood. Dissecting infested stems can reveal frass-packed, meandering, larval galleries and the empty adult exit tunnels that curve in a sweep to the surface (figure 231E). From the exterior, the exit holes are circular and 7 to 8 mm in diameter (figure 231F). Exit holes are typically clustered in localized parts of stems. Because the insect prefers weakened trees, it is not an important pest. However, it can cause economically damaging losses in dying timber and salvage operations.

Control. Four species of hymenopterous parasites—*Ibalia maculipennis* Haldeman, *Megarhyssa atrata* (Fabricius), *M. greeni* Viereck, and *M. macrurus* (Linneaus)—destroy up to 40% of the larvae and pupae (Burks 1979, Carlson 1979, Stillwell 1967). Woodpeckers, especially the pileated woodpecker and hairy woodpecker, are effective predators, but unfortunately they destroy many of the parasites as well. Infestations can be avoided by keeping trees healthy and vigorous. Tree injuries should be promptly dressed and filled to discourage oviposition.

Family Xiphydriidae—Wood Wasps

Members of this family resemble the siricids in having threadlike antennae, well-developed wings, and a cylindrical body but are distinguished by smaller size and shorter ovipositor sheath (Borror and others 1981, USDA FS 1985). Larvae are smaller than but similar to the siricids. Only one species is covered here. It commonly attacks dying and dead branches of host trees; damage is usually minor.

Genus and Species

Xiphydria maculata Say

[maple wood wasp] (figure 232)

Host. Maple. Silver maple and red maple recorded most frequently, but occasionally reported from sugar maple (Deyrup 1984, Knight 1968). Basswood and apple mentioned as hosts, but their status seems questionable (Smith 1976).

Range. Common in southeastern Canada from New Brunswick to Ontario and in the northeastern United States from Maine to Indiana; isolated records from as far west as Manitoba, Kansas, and eastern Texas; one dubious record from California (Deyrup 1984, Smith 1976, USDA FS 1985).

Description. ***Adult.*** Medium-sized, blackish wasp with yellow and white markings; female 11 to 20 mm long, male 7 to 11 mm long (figure 232A) (Harrington 1884, Rohwer 1918, Smith 1976). Head black with yellow stripes dorsally and laterally; antennae white with two basal segments

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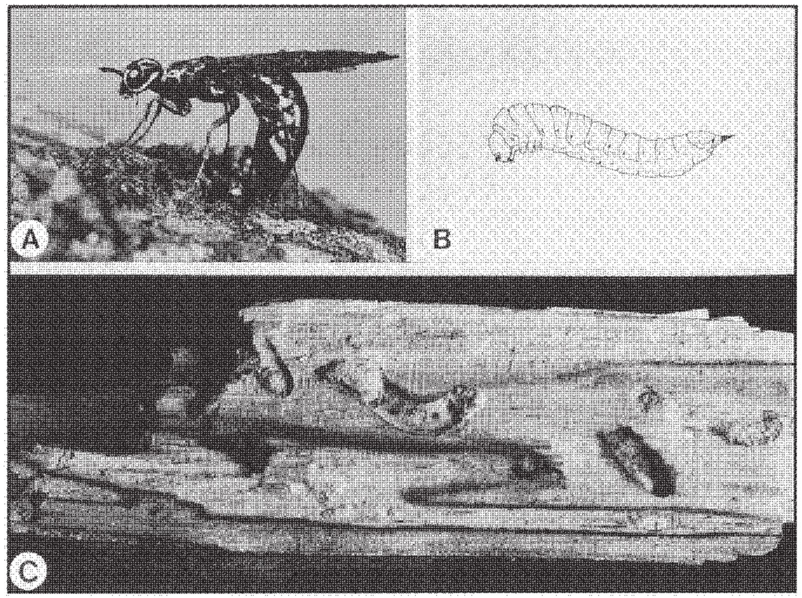

Figure 232—Xiphydria maculata, *[maple wood wasp]: A, adult ovipositing in maple branch; B, larva; C, larval galleries in wood (A, courtesy D. Funk; C, specimen courtesy D. Smith).*

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black in female and brownish black throughout in male. Thorax black with broad, yellow band and two yellow spots. Legs orange to red. Abdomen black with yellow to white lateral spots on segments 2 or 3 to 8. Ovipositor contained in sheath projecting slightly beyond tip of abdomen. Wings grayish brown with black veins. ***Larva.*** Yellowish white, cylindrical, except thorax and terminal segments slightly enlarged (figure 232B) (Furniss and Carolin 1977, Smith 1976, USDA FS 1985). Body straight to slightly S-shaped; abdomen ending in a brown, concave, hornlike projection; 18 to 20 mm long. Thoracic legs rudimentary teatlike structures.

Biology. In Ontario, adults emerge from mid-June to late July; in Indiana, adults begin to emerge in late May and finish by early July (Deyrup 1984, Harrington 1884). Adults emerge onto the bark and mate after a brief tapping ritual by both sexes. Females select a suitable host trunk or branch of recently dead or weakened tree and drill through the bark with their ovipositors, depositing one or more eggs at the interface between the bark and wood (figure 232A). Females deposit propagules of symbiotic fungus during oviposition. Upon hatching, the larvae bore immediately into the wood and tunnel mostly longitudinally, packing their galleries tightly with frass. Before pupation, larvae sometimes make bends or loops in the galleries and approach the surface. They overwinter in the larval stage and pupate in spring. New adults chew their way to the surface and emerge. There is one generation a year.

Injury and damage. Wasps attack weakened, dying, and recently dead trees and, less commonly, living trees over a range of sizes (Deyrup 1984, Harrington 1884, Knight 1968, Smith 1976). They mostly attack stems 2.5 to 9.0 cm in diameter, somewhat preferring saplings and branches 4 to 5 cm in diameter. Because the larvae do not eject frass, infestations are difficult to detect until the adults exit. Fallen branches under maple trees sometimes indicate attack; infestations can be confirmed by examining broken ends of branches for frass-filled galleries that weakened them. Dissection of infested stems reveals several galleries densely packed with whitish frass (figure 232C). Recently transplanted young trees with thin bark and branches of shade and ornamental trees have been riddled with galleries in Ontario.

Control. Seven insect parasites—*Aulacus burquei* (Provancher), *A. digitalis* Townes, *Coeloides rossicus betulae* Mason, *Orussus* sp., *Rhyssella nitida* (Cresson), *Spathius elegans* Matthews, and *Xiphydriophagus meyerinckii* (Ratzeburg)—have been recorded (Deyrup 1976, Rohwer 1918). The insect is generally of little economic importance, but in problem areas, wrapping or spraying the trunks of newly transplanted trees during May and June provides protection.

Family Cephidae—Stem Sawflies

The cephids are borers in tender shoots of trees and shrubs. Adults are small- to medium-sized sawflies with slender, compressed bodies and filiform antennae (Borror and others 1981, Craighead 1950). Most are dark colored; some are marked with yellow or red. Larvae are usually yellowish white and most are S-shaped. Their feeding typically causes shoot mortality and dieback. Damage is occasionally serious in localized infestations, but injury is seldom widespread.

Genus and Species

Hartigia cressoni (Kirby)

[raspberry horntail] (figure 233)

Hosts. Raspberry, blackberry, boysenberry, rose. Raspberry appears to be major host; both wild and cultivated varieties are attacked (Middlekauff 1969, Ries 1937).

Range. Western species common in California, with isolated collections from Oregon, Nevada, Montana, and Colorado (Smith 1986).

Description. ***Adult.*** Slender, black or dark brown and yellow, wasplike sawfly (figure 233A) (Essig 1912, Smith 1986). In females, head and eyes black with yellow markings. Antennae black with middle segments yellow orange to amber. Thorax black with small to large yellow spots mostly on sides. Legs black basally and mostly yellowish distally. Abdominal segments 1 and 5 entirely black, segments 6 and 9 entirely yellow, other segments partially yellow. Abdomen laterally compressed and equipped with a sheath; lancet broad and rounded dorsally. Wings hyaline, amber to orange tinged with brownish veins. Females 11 to 17 mm long; males 11 to 15 mm long and mostly black. Females easily distinguished from other members of genus by extensive yellow on abdomen and yellow markings on antennae. ***Egg.*** Glossy, pearly white, oval, somewhat flattened, curved, and sharp pointed at one end, about 1.5 mm long and two-thirds as wide (Essig 1912, Middlekauff 1969, Ries 1937). ***Larva.*** Yellowish green at first, becoming mostly white; cylindrical, somewhat S-shaped, with thoracic region somewhat enlarged dorsally and laterally; 22 to 25 mm long when mature (figure 233B) (Essig 1912, Middlekauff 1969, Middleton 1917). Head pale yellow to light brown with darkened mouthparts. Thorax with three pairs of vestigial, fleshy, teatlike legs without tarsal claws; abdominal prolegs absent. Abdomen ends in short tubular prong.

Biology. Adults begin emerging in early March; populations peak in April, May, and June, decline during July, and are gone by early August (Essig 1912, Middlekauff 1969, Ries 1937, Smith 1986). The adults are

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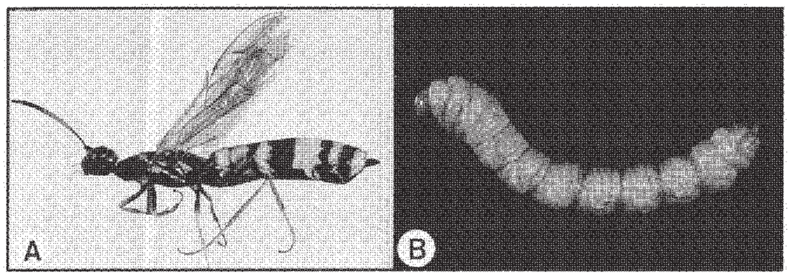

Figure 233—Hartigia cressoni, *[raspberry horntail]: A, adult; B, larva (specimens courtesy D. Smith).*

most active during midday (when temperatures are highest), feeding on nectar. Females oviposit by making a slit in tender shoots usually near the second or third leaf axil of new canes. They force single eggs slightly downward 1.5 to 6.0 mm from the opening and just beneath the epidermis. Areas surrounding the oviposition punctures become discolored and easily visible. Eggs hatch in a few days, and the young larvae feed on surrounding tissues, remaining near the points of hatching until they are about 6 mm long. Then, they begin to travel downward, burrowing in spirals encircling the shoot one to three times in the cambium for 25 to 30 mm. Next, they work into the pith and upward toward the tip of the young shoot, which soon withers and dies. As soon as the shoot tip dies, the larvae turn downward, working through the center of the pith to within 30 to 60 cm of the ground and sometimes into the roots. Larvae mature after about 4 to 6 months, usually in October. Mature larvae overwinter within the burrows. Pupation occurs during spring in a silken cocoon. New adults chew an opening in the cane to exit. There is apparently one generation per year (Middlekauff 1969), although there is some evidence of two (Essig 1912, Ries 1937).

Injury and damage. The earliest indications of infestation are oviposition niches just before and during the early flower stage. The oviposition sites discolor, usually becoming whitish to yellowish brown and slightly swollen (Essig 1912, Middlekauff 1969, Ries 1937, Smith 1986). Soon after young larvae girdle the stems, shoots wilt, droop, wither, and turn brown and black. Dying shoots promptly call attention to the infestations. Infested shoots may die back 15 to 50 cm. Two or more new shoots may issue from canes just below the girdle. Dissection of injured canes reveals the tight spiral galleries and long tunnels in the center of the stems. Some canes may be killed back to the ground. In California, the insect has been economically important in reducing fruit production, particularly at higher altitudes in the central and northern foothill counties of the Sierra Nevada. Shoot mortality rates of 90% or more have been recorded in commercial raspberry plantings in Placer County.

Control. Several unidentified parasites have been reared from the pupae (Essig 1958). In the past, a recommended control practice was to locate egg sites on shoots by the swollen, discolored areas and mash the stem between the thumb and forefinger to crush the eggs (Essig 1912). Some growers cut the infested shoots just below the girdle in spring, whereas others prune out the infested canes during winter. Insecticides may be needed in commercial plantings.

Hartigia trimaculata (Say)

[rose shoot sawfly] (figure 234)

Hosts. Rose, blackberry. Reared from rose and blackberry, and adults collected on raspberry and boysenberry; other *Rubus* species probably serve as hosts (Champlain 1924, Ries 1937, Smith 1986).

Range. Distributed across southern Canada from New Brunswick west; throughout the United States from Vermont south to

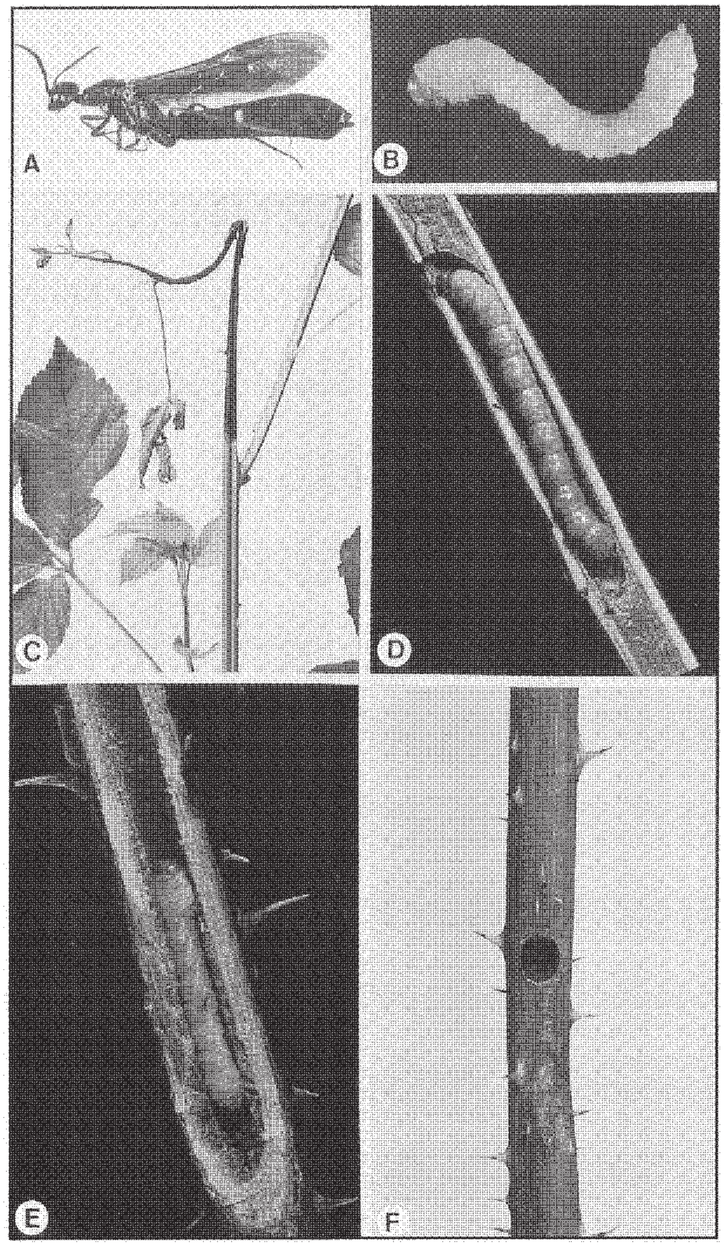

Figure 234—Hartigia trimaculata, *[rose shoot sawfly]: A, adult; B, S-shaped larva; C, infested blackberry shoot dying back; D, gallery with feeding larva in blackberry; E, gallery with frass and larva in rose; F, exit hole in cane (A, specimen courtesy D. Smith).*

Florida and Louisiana and west to the Great Plains; and in a small area in the West around Caldwell and Boise, Idaho (Smith 1986). Appears to be most common along Atlantic Coast and north central United States.

Description. ***Adult.*** Elongate, slender, mostly black, wasplike sawfly (figure 234A) (Ries 1937, Smith 1986). Head black with small, yellow spots around eye, mandible, and molar areas. Mandibles bidentate, translucent, yellowish with black tips and brown palpi. Antennae black and swollen beyond fourth segment. Legs black and lightly marked with yellow on inner surface of foretibia. Wings uniformly dark black infuscated with black veins. Thorax black. Abdomen compressed, elongate, widened dorso-ventrally toward apex, black with large, yellow spot laterally on fourth segment, and occasionally a smaller spot on third or sixth segment. Saw sheath reaches only slightly beyond tip of abdomen. Sheath narrow, not rounded dorsally. Saw not distinctly widened at base. Females range from 12 to 14 mm long; males 10 to 17 mm long. ***Larva.*** Pinkish white, cylindrical, somewhat S-shaped, with slightly enlarged thorax, and abdomen terminating in short, horny projection or prong (figure 234B) (Middleton 1917, Smith 1986). Head pale with mandibles and other mouthparts darkened. Thorax with three pairs of small teatlike, fleshy legs. Full-grown larvae are about 21 mm long.

Biology. Adults begin emerging in late April; numbers peak in May, June, and July, and are all dead by early to mid-August (Champlain 1924, Middlekauff 1969, Ries 1937, Smith 1986). Occasionally, the adult sawflies can be observed flying and alighting on terminals and new shoots. Females crawl downward from terminal tips along the shoot, stopping repeatedly to insert their ovipositors into succulent tender tissue. The punctures are made at short intervals along the stem. Several dozen punctures are often clustered within a small area. To oviposit, females insert the eggs singly deep in the shoot tissue. It seems likely that only one egg is laid in most terminals. When two or more eggs are placed in a shoot, the one that hatches first is the only one to survive. The larvae begin feeding in the succulent terminals, which soon wilt and die; then they feed in the pith, packing frass behind in their tunnels as they move down the stems. At frequent intervals, the larvae girdle the insides of the stems apically to their burrows, often causing the stems to break at that point. Fully grown larvae make a partial opening in the stem to the outside in the fall, then spin cocoons at the basal ends of burrows and overwinter within. Pupation takes place during spring inside the cocoons. This sawfly has one generation a year.

Injury and damage. Although the blackish adults may be seen flying and crawling about the succulent new growth of host plants, the earliest indications of injury are wilting and drooping of tender terminals (Champlain 1924, Middlekauff 1969, Ries 1937, Smith 1986). Close examination reveals ovipositor puncture marks along the shoots. Affected shoots promptly turn brown and black and sometimes break (figure 234C).

When infested shoots fail to break early from the punctures, they frequently break at girdled sites along the stem. Infested shoots may continue to die back as the larvae burrow further downward, repeatedly girdling the stem. Dissection reveals a frass-packed gallery and slightly S-shaped larva (figure 234D and E). Emerging adults leave circular exit holes in the stems (figure 234F). In the past, this borer has been an economically important pest in Pennsylvania. Infested rosebushes produce fewer flowers, and the loss of blackberry canes reduces fruit production.

Control. The infested terminal and shoot tips should be pruned and destroyed as soon as wilting and dying are noticed (Champlain 1924). When pruning is delayed, shoots must be cut lower to ensure that tunneling larvae are removed. Chemical control occasionally may be needed locally when high populations exist.

Janus abbreviatus (Say)

willow shoot sawfly (figure 235)

Hosts. Willow, poplar. Prefers black willow; two clones of the interspecific hybrid *Salix babylonica* x *S. alba* have been mentioned specifically as hosts; poplars, including eastern cottonwood, quaking aspen, bigtooth aspen, and balsam poplar have been recorded (Osgood 1962, Riley 1888, Solomon and Randall 1978).

Range. Southern Canada from New Brunswick west to Alberta and in the eastern and central United States from Maine west to Minnesota and south to Virginia, Arkansas, and Mississippi, and in Oregon (Smith and Solomon 1989, Solomon and Randall 1978).

Description. ***Adult.*** Delicate, brown, wasplike sawfly 7 to 10 mm long, with wingspan of 12 to 16 mm in females and 10 to 12 mm in males (figure 235A and B) (Ries 1937, Smith and Solomon 1989, Solomon and Randall 1978). Head and thorax shiny black with tiny, white to yellow markings. Abdomen black with segments 2 and 3 (and sometimes part of 4) red to reddish brown in females; only venter red in males. Abdomen of females compressed, much deeper than wide; sharp sawlike ovipositor. Abdomen not compressed in males. Wings hyaline, without violaceous reflections; base of radial vein atrophied near base. ***Egg.*** Translucent to whitish, oval to elongate, 0.8 to 1.0 mm long and 0.3 to 0.5 mm in diameter (Solomon and Randall 1978). ***Larva.*** Cylindrical with thorax slightly enlarged dorsally and laterally; typically S-shaped; 8 to 11 mm long at maturity; white, except for pale yellow head, brownish mandibles, and brownish, short, tubular prong at tip of abdomen (figure 235C) (Middleton 1917, Solomon and Randall 1978). Thoracic legs short, fleshy, and without claws; abdominal prolegs absent. ***Pupa.*** White, 8 to 10 mm long, enclosed in partially transparent cocoon (figure 235D).

Biology. Adults from the overwintering brood emerge mid-April to mid-May in Mississippi and May to July in Michigan (Middlekauff 1969, Osgood 1962, Reighard 1985, Ries 1937, Solomon and Randall 1978). Adults are cautious and take flight

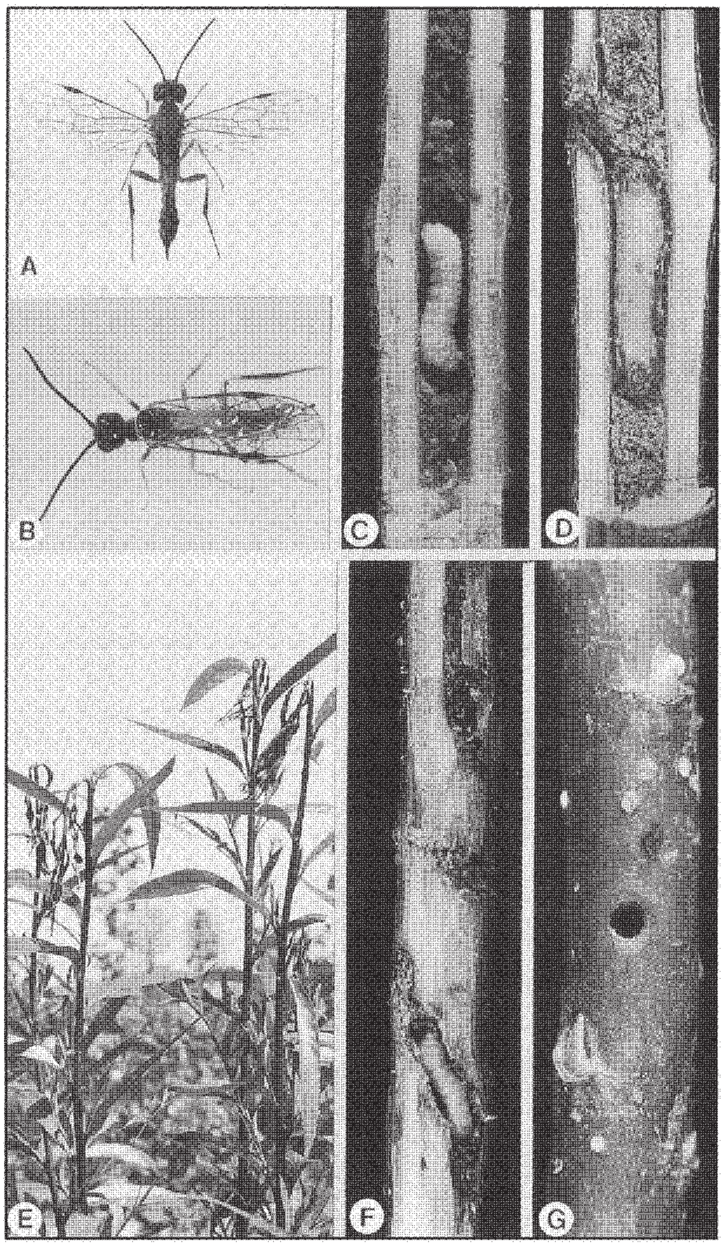

Figure 235—Janus abbreviatus, *willow shoot sawfly: A, adult with wings spread; B, adult with wings folded; C, S-shaped larva in gallery; D, cocoon in gallery; E, wilting and drooping shoots in black willow nursery bed; F, spiral girdling of stem; G, round exit hole in shoot.*

after slight disturbances. Females use their ovipositors to girdle succulent shoots by making a series of punctures encircling the stem and are selective about shoot diameter and distance from stem tip. They girdle willow shoots at an average of 44 mm from the tip; shoot diameter at the point of girdle averages 2.4 mm. Girdle sites on cottonwood average 50.1 mm from the tip and 3.2 mm in diameter. To girdle a shoot, females insert their ovipositors, withdraw them, move slightly around the stem, and puncture again, making 4 to 5 punctures in each of 1 to 3 trips around the stem for a total of 5 to 16 punctures per girdle. Shoot tips begin to wilt in 30 to 60 minutes after punctures are made. Females oviposit in the tender shoots 7 to 26 mm below the girdled site. Single eggs (rarely two) are deposited per shoot and typically are inserted at oblique angles into the pith. Eggs hatch in 7 to 12 days. Initially, young larvae tunnel toward the shoot apex near the girdled site, then turn and tunnel downward for 15 to 36 cm. In nursery stool beds, the entire length of the shoot is often tunneled, and occasionally the side of the rootstock. Larvae pack brownish frass in the gallery as they tunnel; they eject frass from the shoot only at breaks and girdled points along the stem. Before pupation, mature larvae cut a hole almost through the bark surface to permit emergence of the adult. Then they prepare a thin, somewhat transparent, membranous, cocoonlike structure in which to pupate. In its northern range, the insect reportedly requires 1 year to complete a generation; in Mississippi it has three generations per year, with first-generation adults emerging from mid-April to mid-May, second generation adults appearing from mid-June to mid-July, and third generation adults emerging from early August through September. Larvae of the last generation overwinter in cocoons, transforming to pupae and adults the following spring.

Injury and damage. The earliest evidence of injury is wilting and drooping terminals and branch ends (figure 235E) (Solomon and Randall 1978). Injured shoot tips wither and turn brown or black. Infested shoots gradually die back 30 to 60 cm; young shoots sometimes die back to the rootstocks. Peeling the bark off infested shoots reveals numerous spiral girdles made by the tunneling larva (figure 235F). Slicing through the center of infested shoots with a sharp knife reveals galleries filled with brown frass (figure 235C and D). Injured plants often produce many new branches just below the injured part, giving them a bushy appearance. The emerging adults leave behind round exit holes 1.5 to 2.5 mm in diameter (figure 235G). This insect is a major factor in the suppression and mortality of sucker shoots in cutover aspen stands in the Lake States, killing up to 9% of the dominant sucker shoots annually (Osgood 1962). In Mississippi, injury to cottonwood is usually minimal because most attacks occur on lateral branches. However, the pest severely damages nursery-grown willow; 90% of the shoots are sometimes killed by the first-generation sawflies (Solomon and Randall 1978). Damage to willow plantations in Maryland has been so severe that the trees appeared to have been damaged by frost or fire. Repeated attacks in young plantations sometimes adversely affect tree form.

Control. In Mississippi, two hymenopterous parasites—*Bracon jani* Muesebeck and *Eupelmus* sp.—commonly kill 1 to 12% of the sawfly larvae in willow shoots (Solomon and Randall 1978). In the Lake States, up to 22% of the larvae in aspen shoots are parasitized by five species of hymenopterous parasites—*Bracon* sp., *Eurytoma* sp., *Scambus granulosus* Walley, *S. pterphori* (Ashmead), and *Tetrastichus productus* Riley (Osgood 1962). Three species of hymenopterous parasites—*Eurytoma* sp., *Microbracon* sp., and *Tetrastichus* sp.—have been reared in New Jersey (Middleton 1917). Up to 9% of the sawfly larvae in Mississippi have been killed by an unidentified fungus (Solomon and Randall 1978). Overwintering mortality of larvae in Mississippi has been estimated at 56%; mortality is most prevalent in the smallest, least vigorous shoots (Solomon and Randall 1978). Infestations can be reduced in nurseries by pruning and destroying infested shoots (Riley 1888). In Michigan's poplar nurseries and plantations, planting small blocks of willow (which the insect prefers over poplar) nearby as a trap crop, then annually coppicing the willow to destroy overwintering larvae and create a crop of succulent sprouts for next year's sawflies, has been recommended for control (Reighard 1985). Insecticides have reduced girdled shoots by 75 to 90%, but repeated applications are necessary (Reighard 1985).

Janus bimaculatus (Norton)

[viburnum stem sawfly] (figure 236)

Host. Viburnum. Blackhaw and nannyberry mentioned specifically as hosts, and other viburnum species are undoubtedly susceptible (Middlekauff 1969, Solomon 1982).

Range. Eastern North America from Quebec and Ontario south through Maine and New York to Maryland and Virginia and west to Illinois and Minnesota (Middlekauff 1969, Ries 1937, Smith and Solomon 1989).

Description. ***Adult.*** Small, mostly black, wasplike sawfly, 6 to 10 mm long (Ries 1937, Smith and Solomon 1989) (figure 236A). Head and pronotum black except lateral margin of pronotum translucent and whitish. Abdomen of females noticeably compressed, much deeper than wide; basal segments, venter, and legs reddish yellow to orange; ends in short, stout, amber-colored, sawtoothed ovipositor. Wings mostly hyaline and iridescent except for two, round, black, fuscous apical spots on each forewing. Males slightly smaller than females and radial vein of forewing atrophied at base. ***Larva.*** White with light amber head and mandibles, cylindrical, S-shaped, 7 to 10 mm long (figure 236B).

Biology. Adults are observed as early as May 9 in Illinois and as late as July 10 in Maine (Ries 1937). Adult activity seems greatest during early June across its range, when females are busy girdling and ovipositing in young viburnum stems. Females deposit eggs in tender shoots 15 to 40 mm from the apices. Larvae tunnel basally within

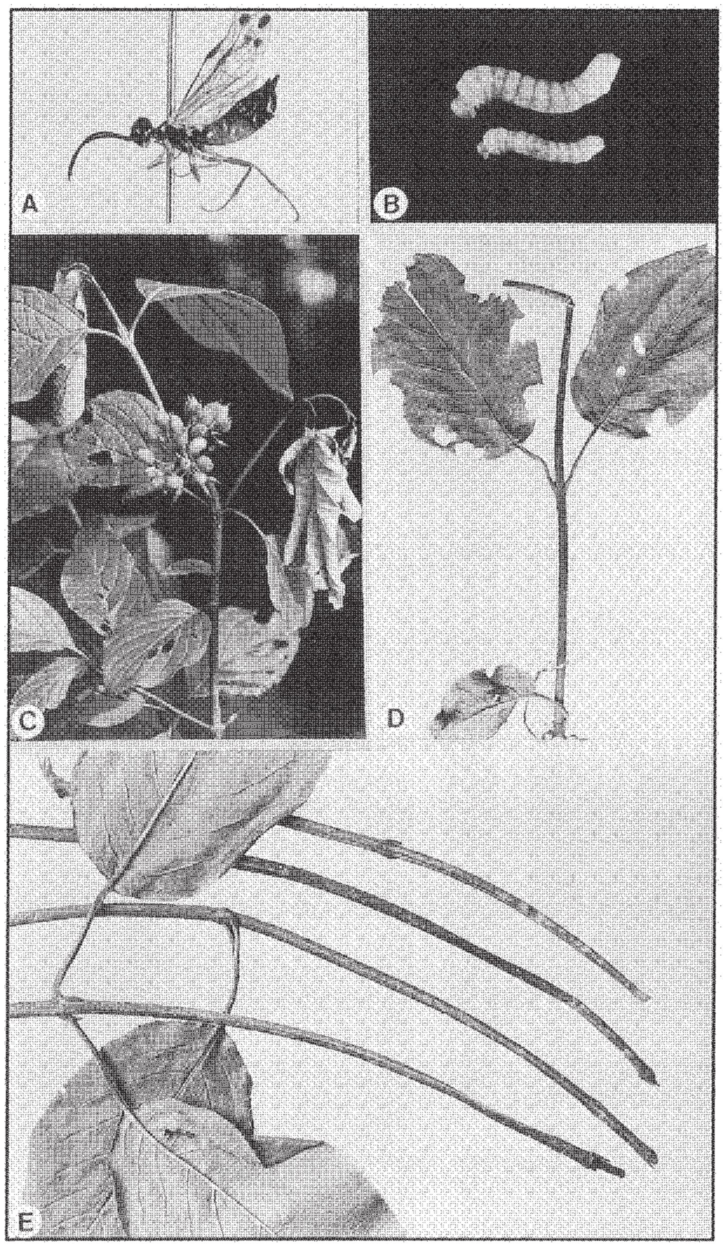

Figure 236—Janus bimaculatus, *[viburnum stem sawfly]: A, adult; B, larvae; C, wilting and drooping viburnum shoots; D, terminal leaves and shoot tip breaking away; E, dead, blackened, leafless shoots typical of infestation (A, specimen courtesy D. Smith).*

the shoots. Mature larvae prepare thin cocoons in the galleries where they overwinter. This stem sawfly has one generation a year.

Injury and damage. Wilting and drooping tender terminals and branch ends are the earliest evidence of infestation (figure 236C). Closely examining affected shoots reveals the girdle, the sawfly punctures, and the oviposition site. Leaves and shoot ends turn brown, then black, and soon begin breaking away (figure 236D). Dissection of infested shoots exposes hollowed stems with brown frass and sometimes the white, S-shaped larvae. Shoots gradually turn brown and black and die back 3 to 9 cm. Leaves die and shed along the affected stems as they die further back, typically leaving darkened, dead, leafless shoots projecting from infested plants (figure 236E). The insect has been reported as a nursery pest in Ohio and has killed up to 6% of the twig growth of blackhaw in Pennsylvania (Solomon 1982).

Control. Birds have been reported as predators in Wisconsin (Solomon 1982). Nothing else is known of natural controls, and direct controls have not been needed.

Janus integer **(Norton)**

currant stem girdler (figure 237)

Host. Currant. Both wild and cultivated currants are attacked; however, wild currant is the original host and appears to be favored over cultivated varieties (Marlatt 1895).

Range. Canada from Newfoundland and Quebec to British Columbia, across the northern United States from New Hampshire and New York west to Washington and Oregon and south to Virginia and Iowa (Middlekauff 1969, Smith and Solomon 1989). Seems most prevalent in the Northeast.

Description. ***Adult.*** Delicate, shiny, black and reddish, wasplike sawfly; female averages about 12 mm long with wingspan of 20 mm; male averages about 9 mm long with wingspan of 12 mm (figure 237A) (Ries 1937, Slingerland 1897, Smith and Solomon 1989). Head and pronotum black with yellowish mandibles and similar markings at base of wings on thorax. Abdomen noticeably compressed, being deeper than wide, and equipped with a stout, sharp, sawtoothed ovipositor at apex in females; basal three to four segments red to reddish orange with remaining segments black. Abdomen of male brownish yellow and not compressed. Legs brownish yellow in both sexes. Wings hyaline, without violaceous reflections, with one fuscous black spot below stigma on forewing. ***Egg.*** Elongate to oval, rounded at both ends; white to yellowish white when first laid, becoming transparent before hatching; delicate structure without surface sculpturing; 1.0 to 1.1 mm long (Marlatt 1895, Slingerland 1897). ***Larva.*** Cylindrical, slightly S-shaped with somewhat enlarged thorax; white to creamy white with pale yellow, rounded head, brown mandibles; short tubular prong at tip of abdomen; three pairs fleshy, unjointed, teatlike legs on thorax; abdominal prolegs absent; 10.0 to 12.7 mm long when mature (figure 237B) (Marlatt 1894, 1895; Middleton 1917).

Biology. The adults emerge during May and June and begin ovipositing soon after

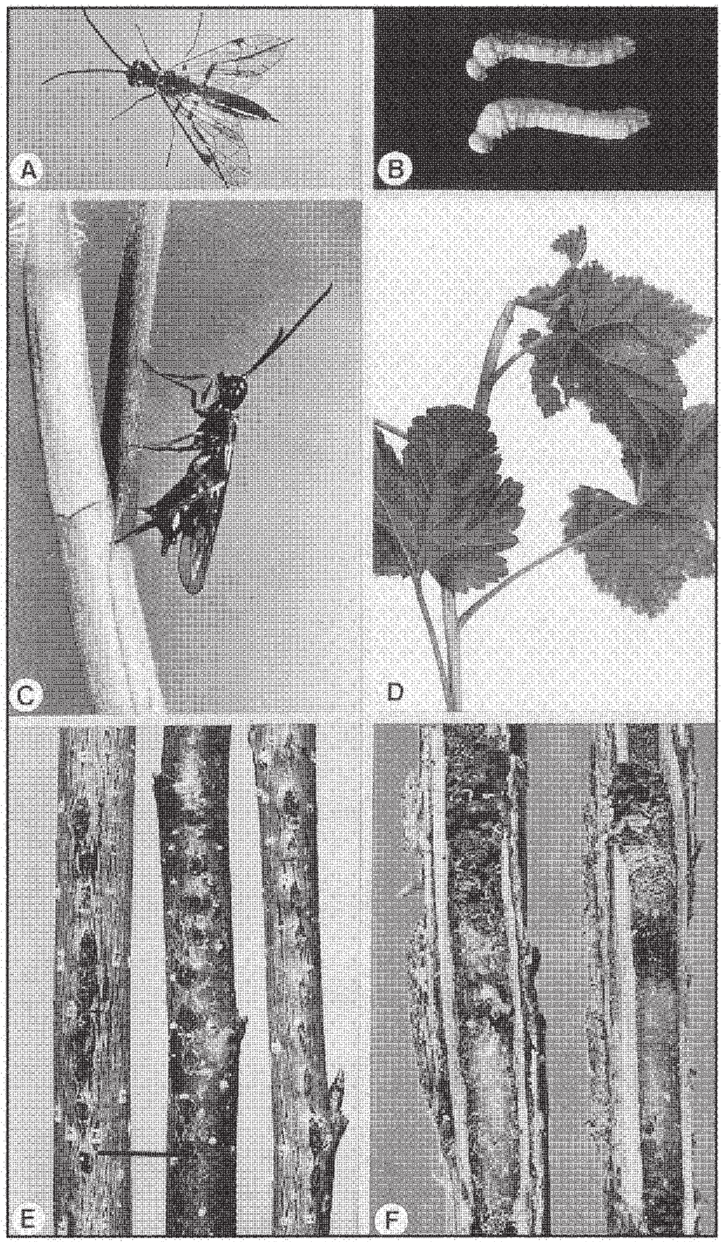

Figure 237—Janus integer, *currant stem girdler: A, adult; B, larvae; C, female ovipositing in shoot; D, currant shoot broken at girdled site; E, scars from probing punctures by female ovipositor; F, cocoons in frass-packed galleries (courtesy NY Agricultural Experiment Station).*

(Marlatt 1894, Slingerland 1897). Females may visit several plants before selecting terminals for oviposition and may begin depositing eggs within 2 hours of emergence. To oviposit, the females take a position with heads upward a few centimeters below the shoot tips (figure 237C). They quickly push the full length of their ovipositors into the tender shoots and deposit single eggs in the pith. They quickly withdraw their ovipositors, accomplishing the whole operation of laying an egg in about 1 minute. The slits cut by their ovipositor saws are so small that they can scarcely be found even with a hand lens until a few days later, when the sides of the shoots swell slightly. Immediately after ovipositing, females move up the shoots for 3 to 25 mm and girdle them by forcing their ovipositors in the shoots and withdrawing them in a twisting or sawing motion. They move around the stems and repeat the puncture-sawing action four to six times or until girdles are nearly complete, which takes about 4 minutes. Female can lay up to 30 eggs and girdle the same number of shoots. Eggs hatch in about 11 days. The young larvae feed and tunnel downward mostly in the pith, leaving enough of the woody stem to hold it upright. Larvae continue to feed for 75 to 150 mm, packing the dark brown frass behind them in the galleries. During fall, larvae prepare cells for overwintering and eventually pupate at the lower ends of the galleries. They chew round passageways nearly through the stem for later exit, then spin thin, glistening, silken cocoons around themselves to overwinter. Beginning in April, larvae pupate within the silken cocoons and emerge as adults after about 2 weeks. There is one generation a year (Middlekauff 1969, Ries 1937).

Injury and damage. The earliest symptoms of damage are sudden wilting and drooping of terminal shoots during spring and early summer after new growth is several centimeters long (Marlatt 1894, 1895; Middlekauff 1969; Slingerland 1897). Wilted shoots typically wither rapidly and die. Some shoots are so thoroughly girdled that, instead of wilting and drooping, they drop over immediately and hang suspended or fall to the ground (figure 237D). Careful examination of the wilted or broken terminals reveals that they were deftly girdled with several sharp, somewhat curved cuts encircling the stem and extending through or nearly through 5 to 10 cm below the tip. Sometimes when the terminal is quite large, the puncture cuts do not extend deep enough to sever the stem. Partially girdled terminals are slow to wilt and may or may not die and break off later. The girdled or severed terminals are the principal kind of injury, but another 15 mm of the infested shoot may die back from tunneling by the larva. Also, stems may have scars resulting from probing punctures made by the female (figure 237E). Dissecting infested stems reveals galleries densely packed with brown frass, except for the bottom portion, which is occupied by the larva or cocoon (figure 237F). Injuries stop the growth and disfigure or stunt the plant for the rest of the season. The insect has been particularly troublesome to currant growers in New

York and is especially objectionable in nursery cuttings.

Control. Six species of insect parasites have been recorded; up to a third of the sawfly larvae have been destroyed by parasites, largely by a braconid parasite—*Bracon apicatus* Provancher (Marsh 1979, Slingerland 1897). The greatest natural mortality rates (up to 85%) occur when eggs fail to hatch and newly hatched larvae die. Populations can be reduced by pruning and destroying the flagged (infested) shoots. Early pruning in May and June requires removal of only the top 5 to 8 cm of the shoot; late pruning from July to April requires removing the top 20 cm of the shoot to ensure getting all the larvae. Insecticides applied during the oviposition period should be effective against adults.

Janus quercusae Smith

[oak shoot sawfly] (figure 238)

Host. Oak. Found only in two species, Nuttall oak and water oak, which are in the red oak group (Smith and Solomon 1989). However, because this pest also occurs outside the range of Nuttall and water oaks, it likely infests other species in the red oak group.

Range. Newly discovered species known only from Mississippi, Maryland, and Virginia (Smith and Solomon 1989). It undoubtedly occurs elsewhere in the East, particularly between Mississippi and Maryland.

Description. ***Adult.*** Female delicate, black and red, wasplike sawfly, 6.5 to 8.0 mm long, with wingspan of 11 to 13 mm; male unknown (figure 238A) (Smith and Solomon 1989). Head, antennae, and thorax black with yellow mandibles, palpi, and indistinct markings on pronotum. Abdomen compressed, noticeably deeper than wide; black with at least segments 3 to 6 red; ends with a sharp, sawlike ovipositor. Forelegs and midlegs yellow; hindlegs black, yellow, and orange. Wings hyaline with indistinct, ochre markings and brownish veins; radial vein complete in forewing. ***Larva.*** Nearly cylindrical, thorax somewhat enlarged, slightly S-shaped with head and thorax most noticeably curved downward; white with yellowish head and light brown mandibles (figure 238B).

Biology. Adults emerge from mid-April in Mississippi to mid-May in Virginia (Smith and Solomon 1989). Females lay eggs in the tender terminals and branch ends during spring when shoots elongate. The shoots are girdled by a series of ovipositor punctures apically to the oviposition sites and 3 to 8 cm from the shoot tips. Larvae tunnel basally in the stem pith for 4 to 10 cm, eventually hollowing the shoots and packing frass behind them within the galleries (figure 238C). The larvae girdle the shoots from within one or more times in their travel down the shoots. Larvae are fully grown by mid- to late June and construct thin, white to light brown, partially transparent, cellophane-like cocoons around themselves near the basal ends of the galleries (figure 238D). They spend the rest of the summer, fall, and winter in the cocoons, and pupate in early spring. Adults emerge through round holes in the sides of the shoots. The oak shoot sawfly has one generation a year.

Injury and damage. Flagging shoots

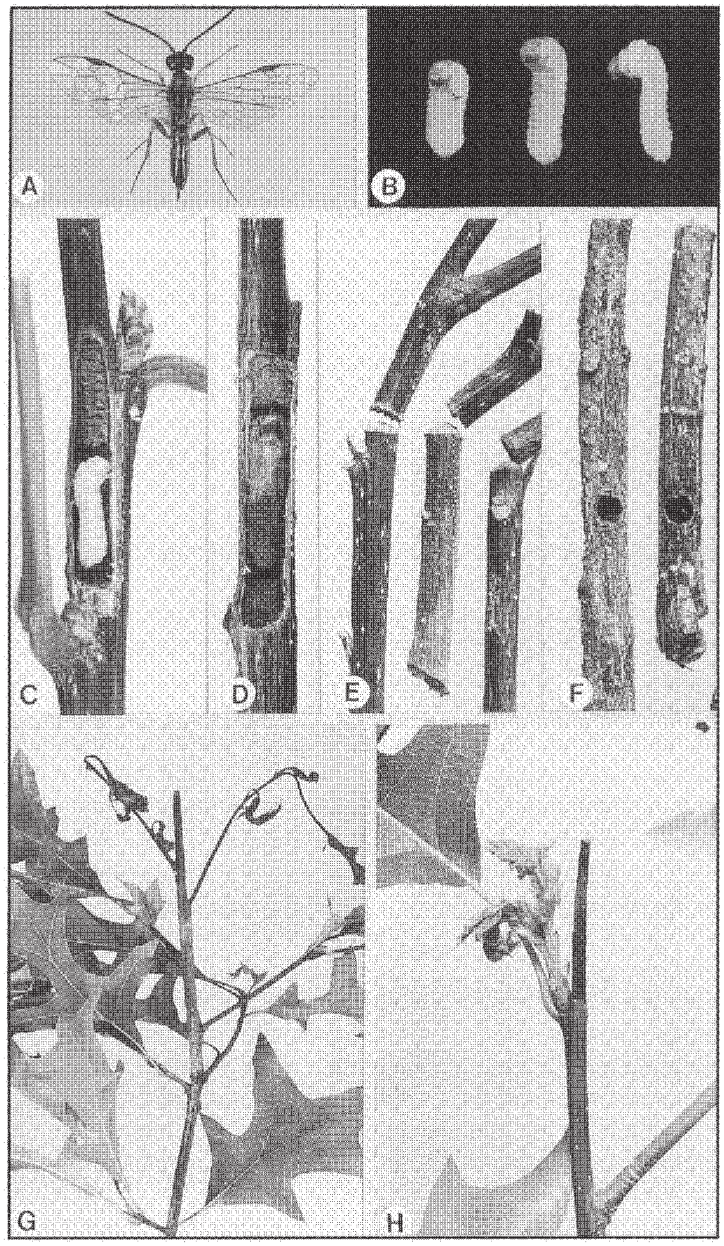

Figure 238—Janus quercusae, *[oak shoot sawfly]: A, adult; B, larvae; C, frass-packed gallery with S-shaped larva; D, cocoon in gallery; E, shoots with dome-shaped breaks at girdled sites; F, exit holes in shoots; G, flagging dying shoot; H, infested shoot with tip detached and new lateral shoot emerging.*

Hymenoptera

Hymenoptera

from mid-April to mid-July provide the earliest evidence of attack (figure 238G). New expanding leaves and succulent new growth of terminals and branch ends begin wilting and drooping soon after attack. Affected shoots turn yellowish brown then black, flagging the injured shoots. Most shoots break at girdled sites 3 to 8 cm from the apices and drop to the ground, leaving only blunt stubs (figure 238G and H). As the larvae tunnel down the stems, the shoot stubs gradually turn dark brown or black, and any succulent side shoots also wither, droop, and darken (figure 238G). By midsummer, new lateral shoots often issue from bud sites just below the blackened stubs (figure 238H). The tunneled portion of the shoot is easily broken at one or more sites that are girdled from the inside by the larva (figure 238E). The girdled site is always nearly perfectly round, with the tightly packed frass protruding from the branch stub in a dome shape; the site is concave in the end of the detached portion. The emerging adults leave round exit holes 1.2 to 1.6 mm in diameter in infested shoots (figure 238F).

Control. Parasitic larvae in sawfly cocoons and very small exit holes in the bark directly over sawfly cocoons have been observed, but no adult parasites have been obtained, and none have been identified. Direct controls will probably be needed for ornamental trees, but none have been investigated.

Janus rufiventris (Cresson)

[white oak shoot sawfly] (figure 239)

Host. Oak. Oregon white oak is only known host, but this pest probably attacks other oaks in the white oak group within its range (Hanson 1986).

Range. A western species known only from California and Oregon (Hanson 1986, Middlekauff 1969, Ries 1937).

Description. ***Adult.*** Small, delicate, black and red, wasplike sawfly, 7 to 8 mm long (figure 239A) (Ries 1937, Smith and Solomon 1989). Head and thorax shiny black with yellowish mandibles and whitish thoracic membranes laterally. Abdomen compressed, being deeper than wide, uniform brick red with brownish yellow cerci and amber saw and terminating with short, sawlike ovipositor. Legs blackish brown. Wings hyaline, slightly infuscated along margins and veins. Distinguished by only one preapical spur on hind tibia, entirely red abdomen, and wings infuscated toward tips and along veins. ***Larva.*** Cylindrical with slightly enlarged thorax, slightly S-shaped, head and thorax curved somewhat downward, whitish with slightly darker head and mandibles (figure 239B).

Biology. In California, adult emergence has been recorded from mid-March to early June (Middlekauff 1969, Ries 1937), whereas in Oregon emergence occurs from mid-April to mid-May (Hanson 1986). Females select current year's growth for oviposition (figure 239C), preferring succulent, vigorous shoots. They oviposit from late April to early June in the Willamette Valley of Oregon. Females insert one egg into the outer pith. Immediately after oviposition, the females girdle the stems with their ovipositors by making a series of deep punctures around the circumference 4 to

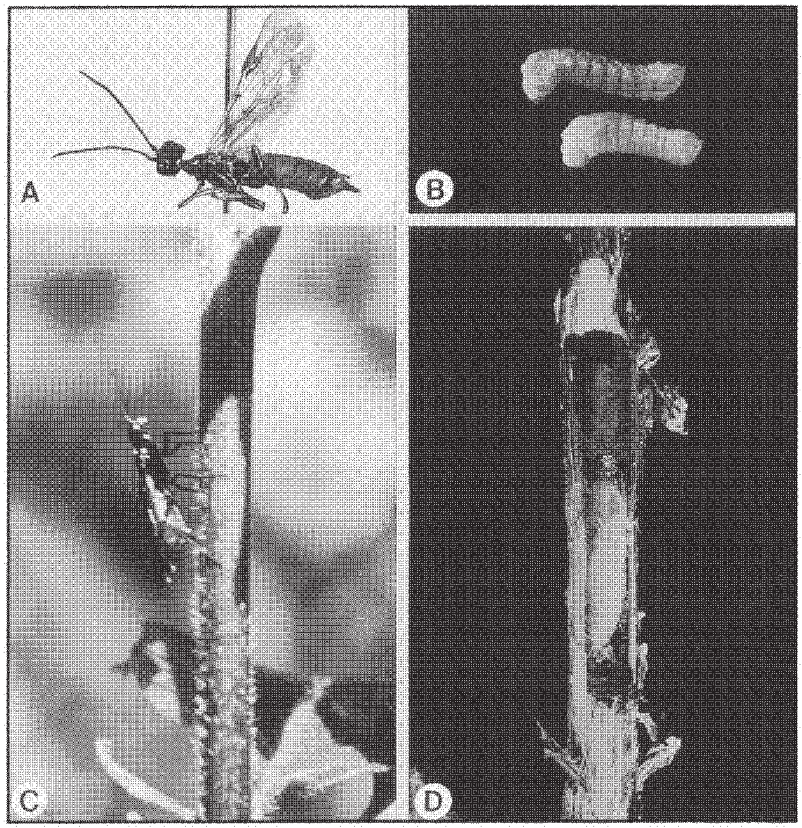

Figure 239—Janus rufiventris, *[white oak shoot sawfly]: A, adult; B, larvae; C, female ovipositing in Oregon white oak shoot; D, infested shoot with gallery containing cocoon (A, specimen courtesy D. Smith; B-D specimens courtesy P. Hanson).*

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10 mm distal to the eggs. Girdling requires 4 to 7 minutes. These cuts almost totally sever the stem. Upon hatching, the larvae initially tunnel toward the apex (point of girdling); in subsequent instars, they turn and burrow toward the base of the stem. Feeding larvae consume almost all the interior of the shoot, packing the frass tightly in the vacated gallery. In late July and early August, fully grown larvae begin lining a chamber near the base of the shoot with silk, which is spread flat rather than spun into threads, resulting in a translucent, parchment-like cocoon (figure 239D). This insect overwinters as a postfeeding, last-instar larva or as a pharate pupa. Adults emerge in spring. There is one generation a year.

Injury and damage. Wilting and drooping shoots of terminals and branch ends during spring and early summer mark the beginning of injury (Hanson 1986). Most affected shoots, nearly severed by a ring of deep punctures 6 to 17 cm from the apex, quickly darken and usually detach within 1 week. Buds, leaves, and the shoot tissue die sequentially as larval tunneling and girdling proceed basally. Dissection of infested shoots reveals galleries tightly packed with brown frass, extending 4 to 9 cm, and containing one larva or a thin glazed cocoon with the mature larva or pupa inside. New adults cut emergence holes directly over the pupation chambers to exit. Tender, thick, stem shoots on vigorously growing young trees and especially stump sprouts are most susceptible to infestation. Damage has been negligible to date.

Control. Natural controls cause larval mortality rates estimated at about 34%, a third of which is by two hymenopterous parasites—*Eurytoma* sp. and *Pteromalus* sp. (Hanson 1986). Some mortality occurs in the egg and first-instar stages associated with cracking of the stem near the girdle, causing desiccation. Infested stems with irregular holes and peeled edges suggest some bird predation. Direct controls have not been needed.

Order Diptera—Flies

Members of the order Diptera constitute a large and diverse group with widely varied forms and habits. Many species are destructive crop pests; bloodsucking forms are injurious to humans and animals, and some are important vectors of serious diseases; some are parasites and predators of other insect pests and are beneficial; others are merely scavengers (Borror and others 1981, USDA FS 1985). Only a few species are destructive to trees and shrubs. The flies are readily recognized by their one pair of functional wings, the hindwings being reduced to mere knobs called halteres. Larvae, known as maggots, are legless and vary greatly in form from slender and elongate to stout and cylindrical.

Family

Family Agromyzidae—Cambium Miners

The cambium miners are small, mostly black flies, with short antennae and hyaline wings, that are covered with bristly setae (Frick 1959, Furniss and Carolin 1977, USDA FS 1985). Larvae are soft, white, legless, and headless, with paired, hooklike mouthparts. The larvae pass through three larval instars; puparia are formed by shrinkage and hardening of the last larval skin. Larvae mine for long distances in the cambium region of host trees. Cambium miner defects detract from the appearance of clear wood and sometimes reduce its value. Fifteen species of *Phytobia* have been recognized in North America, but only the five species with known hosts and biologies are covered in this manual (Spencer and Steyskal 1986, Teskey 1976).

Genus and Species

Phytobia setosa (Loew)

[maple cambium miner] (figure 240)

Host. Maple. Sugar maple favored, but red maple recorded (Greene 1917, Hanson and Benjamin 1967, Ward and Marden 1964). Other maple species probably serve to a lesser extent.

Range. Recorded from Quebec and nine states from Massachusetts and New York south to Virginia and west to Wisconsin and Iowa (Frick 1959, Hanson and Benjamin 1967, Spencer and Steyskal 1986). Probably occurs throughout the natural range of sugar maple and possibly red maple, but distribution records, particularly in the South, are lacking.

Description. ***Adult.*** Small, mostly black fly with indistinct, yellowish to red markings, large eyes, and 4.0 to 4.5 mm long (figure 240A) (Greene 1917, Spencer and Steyskal 1986). Head sooty black, often suffused with red around lunule; ocelli and first segment of antennae pale yellow; third segment of antennae reddish brown. Dorsum of thorax black, slightly shiny, and thickly covered with bristly setae. Halteres

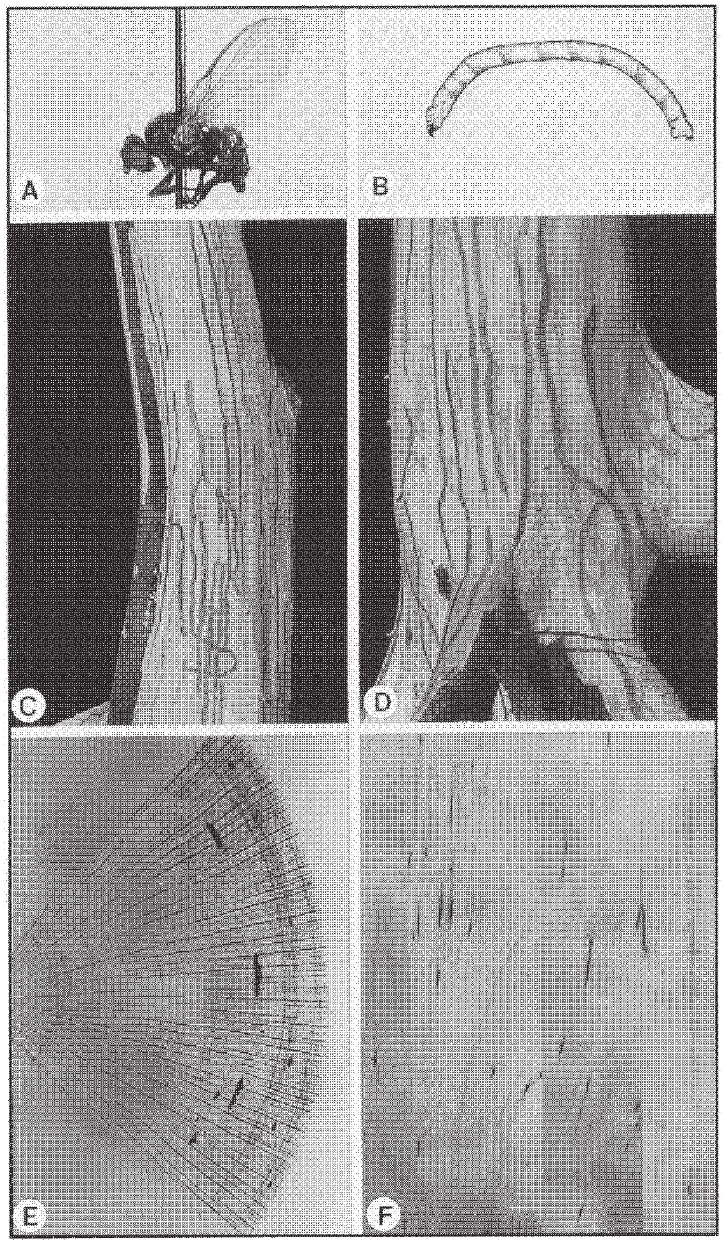

Figure 240—Phytobia setosa, *[maple cambium miner]: A, adult; B, larva; C, bark removed exposing larval mines on sapwood; D, mines extending into roots; E, cross section of stem with pith flecks; F, brown streak defects in maple veneer (A, specimen courtesy R. Peterson; E, specimen courtesy W. Wallner).*

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with yellowish brown stems and whitish knobs. Abdomen concolorous and covered with numerous setae. Legs black with yellowish knees. Wings hyaline with yellowish brown to dark brown veins. ***Larva.*** Narrowly elongate, cylindrical to slightly flattened in cross section, tapered slightly at each end, legless, opaque white, 15 to 22 mm long, and 0.7 to 1.0 mm in diameter (figure 240B) (Greene 1917, Hanson and Benjamin 1967, Teskey 1976). Mouthparts small; mandibles with two black, clawlike hooklets, one much larger than the other. Thoracic (and usually all) abdominal segments, have bands of minute spinules that are better developed laterally than dorsally or ventrally; spinules in four or five rows on last abdominal segment and in three rows on next-to-last abdominal segment. ***Puparium.*** Coarctate, cylindrical, tapered slightly at both ends, 3.6 to 5.4 mm long, and l.5 to 2.2 mm wide. Black, chitinized mouthparts visible at anterior end. Anal area marked by circular depression with black center. All body segments, except head, clearly defined by transverse grooves.

Biology. Adults emerge late April to early May, about the time that sugar maple buds begin to swell (Greene 1917, Hanson and Benjamin 1967). Eggs are deposited singly near lenticels on 1-year-old twigs, 2 to 8 cm below current year's growth. Newly hatched larvae bore through the bark and mine toward the new growth and then reverse direction and mine toward the main stem and down the bole toward the roots. Previously thought to mine in the cambium; they actually mine narrow areas of newly differentiating xylem just below the cambial zone. These narrow zones are the paths of least resistance for larval mining and are metabolic sinks rich in carbohydrates (Gregory and Wallner 1979). First-instar larvae mine 1.8 to 2.1 m by early June. Second-instar larvae mine downward another 3.6 m by mid-June to early July. Final- (or third-) instar larvae mine an average of 2.4 m by late June to mid-July. If larvae reach the base of the tree before the time to pupate, they usually reverse directions and mine upward. Some may reverse directions two or more times, causing a zigzag pattern of mines. Mature larvae mine along roots for about 22 cm, then bore out through a slit in the bark. Larvae exit the roots from early July to late August. Some larvae exit through the bark of the bole instead of the roots. Most larvae form puparia in the litter or mineral soil near the root, but some move 5 to 7.6 cm away from the root to pupate. The puparia overwinter in the soil. This cambium miner has one generation a year.

Injury and damage. It is almost impossible to detect cambium miner infestations in standing trees without some destructive sampling. Peeling bark from the trunk or roots exposes the elongate, serpentine larval mines on the white surface of the sapwood and inner phloem (figure 240C) (Gregory and Wallner 1979, Hanson and Benjamin 1967, Wallner and Gregory 1980, Ward and Marden 1964). Mines made by first-instar larvae in the branches and upper bole are very narrow and threadlike, making them difficult to discern, but those made by larger larvae further down the trunk are larger and easier to detect. The largest, most prominent mines occur near the root collar (figure 240D) and at 8 to 12 m on the bole. Larval mining produces parenchyma flecks, also known as pith flecks. The serpentine mines appear as brown streaks in lathe-turned veneer and as light-colored, oblong to flattened blemishes on log ends (figure 240E). Pith flecks on log ends generally decrease the value of veneer products. Parenchyma flecks mar the natural color and pattern of the wood grain. Numerous pith flecks (more than 1/ft^2) or flecks that cross the grain make wood unsuitable for face-grade veneer (figure 240F), downgrading it to core stock. Up to 89% of sugar maples sampled in Wisconsin show some flecking, which causes as much as 40% degrade in face veneer and furniture wood and results in losses of 1 to 14% in monetary value. Pith flecks affect wood quality but not sap-sugar concentrations for maple syrup.

Control. A hymenopterous parasite—*Symphyta agromyzae* Rohwer—has been reared from this miner, but it apparently has little effect on populations (Hanson and Benjamin 1967). Three systemic insecticides have given 71 to 100% control of the larvae in experimental trials, but further tests are needed to refine these controls (Hanson and others 1965).

Phytobia betulivora **Spencer**

[birch cambium miner] (figure 241)

Host. Birch. River birch is possibly the only host (Greene 1914, Spencer and Steyskal 1986). Sweet birch, red maple, and wild cherry have been mentioned, but references are not clear on *Phytobia* species (Frick 1959, MacAloney and Ewan 1964, USDA FS 1985).

Range. Canada and New York south to the District of Columbia and west to Illinois and Kansas (Spencer and Steyskal 1986). Probably throughout the range of river birch. Identical injury in river birch has been found in North Carolina, Mississippi, Arkansas, and the Great Lakes region, but the miner species has not been confirmed as *P. betulivora* (Beal and others 1952, MacAloney and Ewan 1964).

Description. ***Adult.*** Small, blackish fly with large compound eyes that occupy most of head; measures 3 to 4 mm long (figure 241A) (Greene 1914, Spencer and Steyskal 1986). Females slightly larger and more robust with a shiny, black, slightly flattened ovipositor that extends about 0.5 mm beyond end of abdomen and slightly wider at apex than at base. Head blackish gray with reddish orange frons and five or six long bristles. All antennal segments reddish orange; arista slightly swollen at base. Legs blackish brown with pale orange "knees." Wings hyaline with dark veins. ***Larva.*** Opaque white, elongate, filiform to cylindrical, 20 to 30 mm long, and 1 mm wide when mature (figure 241B). Anterior and posterior ends of body taper slightly. Head small; mouthparts consist of a large, shiny, black, chitinized, hooklet with two smaller toothlike processes, one on each side and slightly back of the large hooklet (Greene 1914). Two slightly raised padlike surfaces covered with brown hooklike setae on the

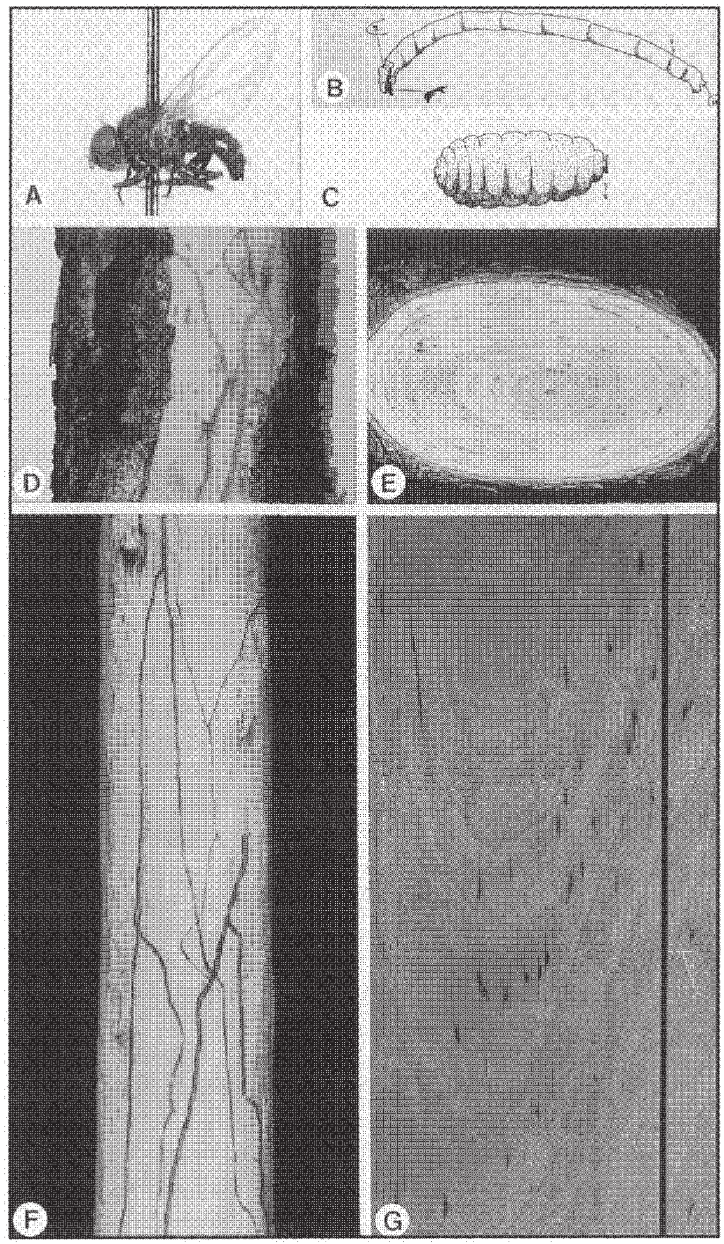

Figure 241—Phytobia betulivora, *[birch cambium miner]: A, adult; B, larva; C, puparium; D, bark removed to expose larval mines; E, cross section with many pith flecks; F, long, narrow mines on bole; G, brown streak defects in lumber (A, specimen courtesy R. Peterson; B & C, after Greene [1914]).*

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last two abdominal segments. ***Puparium.*** Barrel shaped, 4 to 5 mm long, and 2 mm in diameter (figure 241C). Posterior spiracles have three bulbs each but are slightly less prominent than the anterior pair.

Biology. Adults emerge from mid-April to mid-May (Beal and others 1952, Brown and others 1949, Greene 1914, Snyder 1954). Oviposition apparently occurs most commonly in branch forks in the upper portion of tree crowns. To oviposit, females perforate the periderm of young branches with the ovipositor and deposit an egg in the living tissue beneath. Newly hatched larvae burrow directly into the cambial area between the phloem and xylem where they feed throughout their development. As they grow, larvae mine from the branches down the bole to the basal part of the trunk and finally into the roots. When larvae reach the root collar, many turn and mine upward for 1 to 2 m or more before turning again and mining into the roots. Larvae mine along the roots, sometimes encircling them, and move as far as 60 cm from the root collar. When maturing, larvae burrow through the bark to exit, sometimes on the top or side, but usually on the underside of the root. Puparia are formed in the soil from 12 to 25 mm from the exit sites on the roots. Pupation occurs during August, and puparia overwinter in the soil. Although 3 years are reportedly required for development, a 1- or 2-year life cycle seems likely.

Injury and damage. There are no external symptoms of miner infestations on standing trees; larval mines can only be detected by peeling bark (figure 241D) (Beal and others 1952, Brown and others 1949, Greene 1914, MacAloney and Ewan 1964). Mines begin in branches as tiny, hairline burrows, pale and difficult to detect. Mines become larger and darker as larvae progress down the bole (figure 241F) and may be more than 12 m long and 2.2 to 3.2 mm in diameter at the base of the tree. Mining larvae reverse directions in the basal part of the trunk, damaging the butt log, which is typically the most valuable part of the tree. In cross section, mines are small semicircular or lunate pith flecks orientated so that the long diameter is directed tangentially (figure 241E). Damage is visible in sawn wood products as brown to yellowish brown flecks, marks, and streaks (figure 241G) (known in the lumber industry as "pith ray flecks") that degrade the product and reduce its value. Logs with numerous pith fleck defects are unsuitable for veneer. The defects do not affect the strength of the wood but detract from its beauty.

Control. One hymenopterous parasite—*Sympha agromyzae* Rohwer—is the only recorded natural enemy of this miner (Greene 1914). No direct controls have been developed.

Phytobia pruni (Grossenbacher)

[cherry cambium miner] (figure 242)

Hosts. Cherry, plum, hawthorn. Mahaleb cherry, sour cherry, black cherry, chokecherry, mazzard, garden plum, and several species of hawthorn listed (Grossenbacher 1910, 1915; Hough 1963; Spencer and Steyskal 1986). Black cherry with cambium miner injury receives most notice

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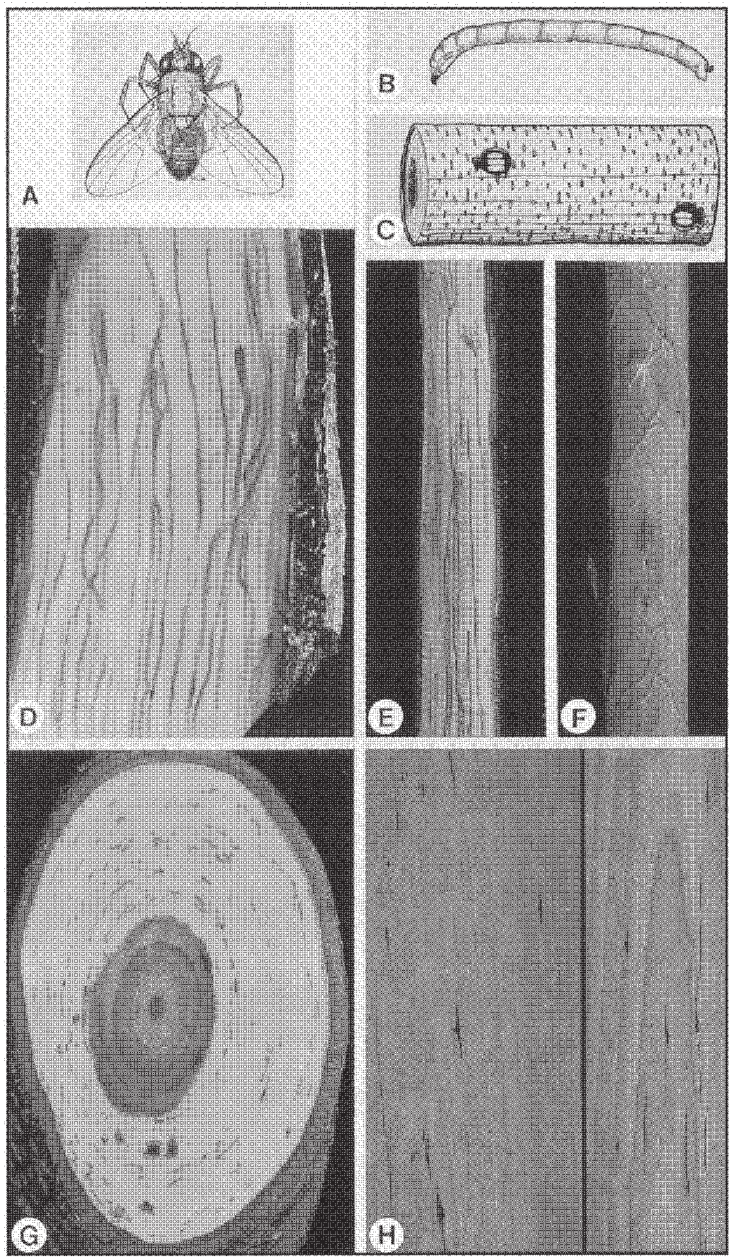

Figure 242—Phytobia pruni, *[cherry cambium miner]: A, adult; B, larva; C, eggs; D, wide larval mines near tree base; E, threadlike mines in upper bole; F, crisscrossing mines beginning to heal in midbole; G, cross section with pith-fleck defects; H, pith fleck and gum spots in cherry lumber (A-C, after Grossenbacher [1915]).*

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(Hough 1963; Kulman 1964; Rexrode and Baumgras 1980, 1984).

Range. Eastern species occurring in New York, Pennsylvania, West Virginia, and Maryland; mentioned in the Northeast and mid-Atlantic regions (Grossenbacher 1910, Hough 1963, Kulman 1964, Rexrode and Baumgras 1984); and recently discovered by the author in North Carolina, Arkansas, and Mississippi. It is probably found throughout much of eastern and central North America.

Description. ***Adult.*** Small black fly, about 4 mm long; frons blackish to blackish brown, wider than eyes, but not projecting above the eyes as in *P. setosa* and *P. betulivora* (figure 242A) (Frick 1959; Grossenbacher 1910, 1915; Hough 1963; Spencer and Steyskal 1986). ***Larva.*** Whitish, long, narrow, cylindrical to filiform, wormlike maggot (figure 242B). Body devoid of setae, anterior four segments each have one irregular, platelike girdle; other segments each have two to nine incomplete girdles of tiny rectangular plates. Pair of prominent, large, black hooklets as mouthparts. Thorax slightly larger diameter than abdomen. Newly hatched larva 2.0 to 2.5 mm long and 20 mm or more when grown.

Biology. Adults emerge during May and June and as late as July in the Finger Lakes region of New York (Grossenbacher 1910, 1915; Hough 1963). Females mate and begin laying eggs within 2 to 3 days in lenticels in the bark of young, mostly 2- to 3-year old twigs in the upper tree crown (figure 242C). Females insert eggs in groups of one to three downward or upward in lenticels mostly on the underside of twigs. Eggs hatch within 2 to 3 days, and young larvae feed on the cortex just beneath the periderm before penetrating the cambial area. Larvae burrow apically or basally in the cambium, depending on the orientation of egg depositions. Larvae from eggs inserted upward in the lenticels mine apically for short distances, then turn and mine basally. After reaching the main stem from major branches, most larvae continue to mine downward, but a few mine upward for a time before turning and mining basally. Larvae generally follow nearly straight courses, especially in rapidly growing trees, whereas a few meander or zigzag, particularly in trees of poor vigor. They reportedly overwinter as partially grown larvae within mines in the tree, then resume feeding in spring. Larvae reach the base of the tree, turn and move upward for varying distances, then back downward. In late spring or early summer, mature larvae bore outward, usually exiting at a bark fissure between thick plates. Pupation occurs in the soil and lasts about 3 weeks. There is one generation a year.

Injury and damage. There is no visible bark injury on living trees. Removing bark exposes larval mines (figure 242D, E, and F) (Grossenbacher 1910; Hough 1963; Kulman 1964; Rexrode and Baumgras 1980, 1984). Long, narrow mines are almost hairline in the branches and upper bole but gradually widen and darken as they progress down the trunk. Most mines are nearly straight, and several parallel each other down the stem with little crisscrossing

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(figure 242E), but few mines meander and crisscross (figure 242F). Mines are widest (1 to 3 mm) and darkest near the stump and about twice as wide at points where larvae reverse direction (figure 242D). In cross section, the crescent mines are called "pith-ray flecks," or "parenchyma flecks," and are about 2.0 to 3.0 mm long and 0.5 mm wide, extending across several rays in the spring wood (figure 242G). Yellow to brown amorphous material (mostly ray parenchyma cells, damaged cells, and insect excrement) is present in the pith fleck, but many flecks are blackened by gum. When gummosis occurs, pith flecks filled with gum are called "gum spots." Gum spots in valuable wood are far more serious defects than pith flecks (figure 242H). Studies in New York and Pennsylvania indicate that *P. pruni* is the major cause of solid wood defects in black cherry (Hough 1963). Recent studies in West Virginia indicate that *P. pruni* is less important than bark beetles in causing gum spot defects in the lower bole, the most valuable part of the tree (Kulman 1964; Rexrode and Baumgras 1980, 1984). Recent prices paid for gum-free black cherry veneer logs in the Northeast range up to $2,000 per thousand board feet. Veneer log buyers inspect each log end carefully for evidence of gum-spot defects. Logs rejected for veneer stock because of gum spots lose 50 to 70% of their value. In Pennsylvania, up to 90% of logs are rejected for veneer because of gum spots. Such defects are so common in some areas that buyers will not bid at timber sales.

Control. Heaviest cambium miner populations have been associated with fast-growing trees of sprout origin and those with large, branchy, dominant crowns (Rexrode and Smith 1990). Thus, in stand management operations, favoring seedlings and removing superdominants are recommended practices (Hough 1963). With fewer spreading "wolf" trees and better natural pruning for crop tree uniformity, there will be fewer entry points for miner attacks. Nothing is known of natural enemies, and direct controls have not been investigated.

***Phytobia amelanchieris* (Greene)**

[serviceberry cambium miner] (figure 243)

Host. Serviceberry. Downy serviceberry and western serviceberry recorded as hosts; other species of serviceberry will probably prove to be hosts as more is learned about the insect (Brown 1913, Spencer and Steyskal 1986).

Range. Massachusetts, North Carolina, Tennessee, West Virginia, Washington, and Canada (Frick 1959, Spencer and Steyskal 1986). Very common in downy serviceberry in Arkansas. Probably occurs over much of the range of serviceberry species in North America.

Description. ***Adult.*** Small, mostly black fly closely resembling *P. setosa* but smaller; 3.0 to 3.5 mm long (figure 243A) (Greene 1917, Spencer and Steyskal 1986). Head black with narrow red and pale yellow markings and ocellar triangle with long, black setae. Antennae with segments 1 and 2 dark reddish brown, third segment rounded and dull black, arista black. Dor-

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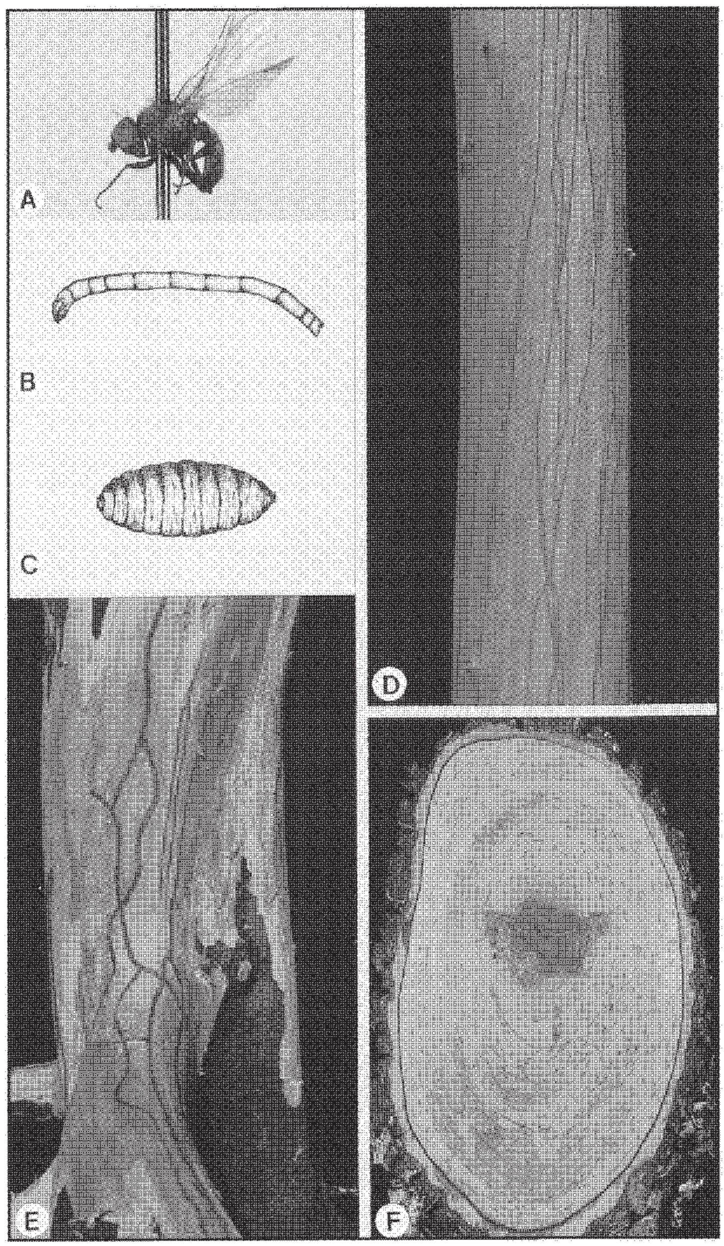

Figure 243—Phytobia amelanchieris, *[serviceberry cambium miner]: A, adult; B, larva; C, puparium; D, narrow, straight larval mines in upper bole; E, broad, meandering mines at base of tree; F, cross section with many pith flecks (A, specimen courtesy R. Peterson; B & C, after Greene [1917]).*

sum of thorax opaque. Abdomen blacker and shinier than thorax with black legs, except femora reddish distally. Wings 3.0 to 4.3 mm long, hyaline; veins nearly black. ***Larva.*** Opaque white, slender, cylindrical or tubelike, tapering very slightly at extreme anterior and posterior ends; 20 to 25 mm long and 0.65 to 0.85 mm diameter (figure 243B). Mouthparts small; mandible consists of two black hooklets, one considerably larger than the other. ***Puparium.*** Barrel shaped, pale yellow, and clearly segmented with the anterior and posterior segments much narrower than others (figure 243C).

Biology. Adults emerge from April 13 to 17. Adults can be collected from branches and buds in West Virginia on April 18 (Greene 1917, Spencer and Steyskal 1986). Eggs are apparently deposited at lenticel sites on twigs and small branches in the upper portion of hosts. Larvae make pale, red, threadlike mines in the cambium and progress toward the base of the plant and into the roots. Larvae develop rapidly; nearly full-grown larvae have been observed from mid-June to mid-July. To pupate, larvae burrow out through the bark of roots and form puparia in the soil. Although the time of pupation is unknown, based on larval collections and sizes, it apparently occurs during fall. Puparia overwinter in the soil. This cambium miner has one generation a year.

Injury and damage. Infestations and injury are detectable only by destructive sampling. Removing bark reveals larval mines or tracks. In the upper and midstems, the miner tracks are very narrow, threadlike, reddish (figure 243D) (Spencer and Steyskal 1986). Tracks exposed beneath the bark may number 1 to 20 on a 6 to 8 cm diameter stem and usually parallel each other, crisscrossing down the stem. Those made by nearly mature larvae at the base of the tree and in the roots are larger in diameter and meander considerably (figure 243E). In stem cross section, the ends of mines appear as small "pith ray flecks" and may number 250 or more per 8-cm-diameter stem (figure 243F). The damage is of little consequence because serviceberry is not a commercial species for lumber and veneer, and the injury does not kill or affect tree growth.

Control. Nothing is known of natural enemies or controls.

Phytobia sp.

[ash cambium miner] (figure 244)

Host. Ash. White ash preferred in the North, green ash in the South (Skelly and Kearby 1969, 1970). Other ash species are probably attacked to a lesser extent.

Range. Previously reported in only eight counties in south central Pennsylvania (Skelly and Kearby 1970), but the author has found it commonly in Arkansas, Louisiana, and Mississippi. Probably occurs over much of the eastern United States.

Description. ***Adult.*** No adults have been reared for description. ***Larva.*** Narrow, elongate, cylindrical, slightly flattened, tapered slightly toward the anterior and posterior ends (figure 244A) (Skelly and Kearby 1970). Anterior end small, not retractile, curved. Mandible has two notice-

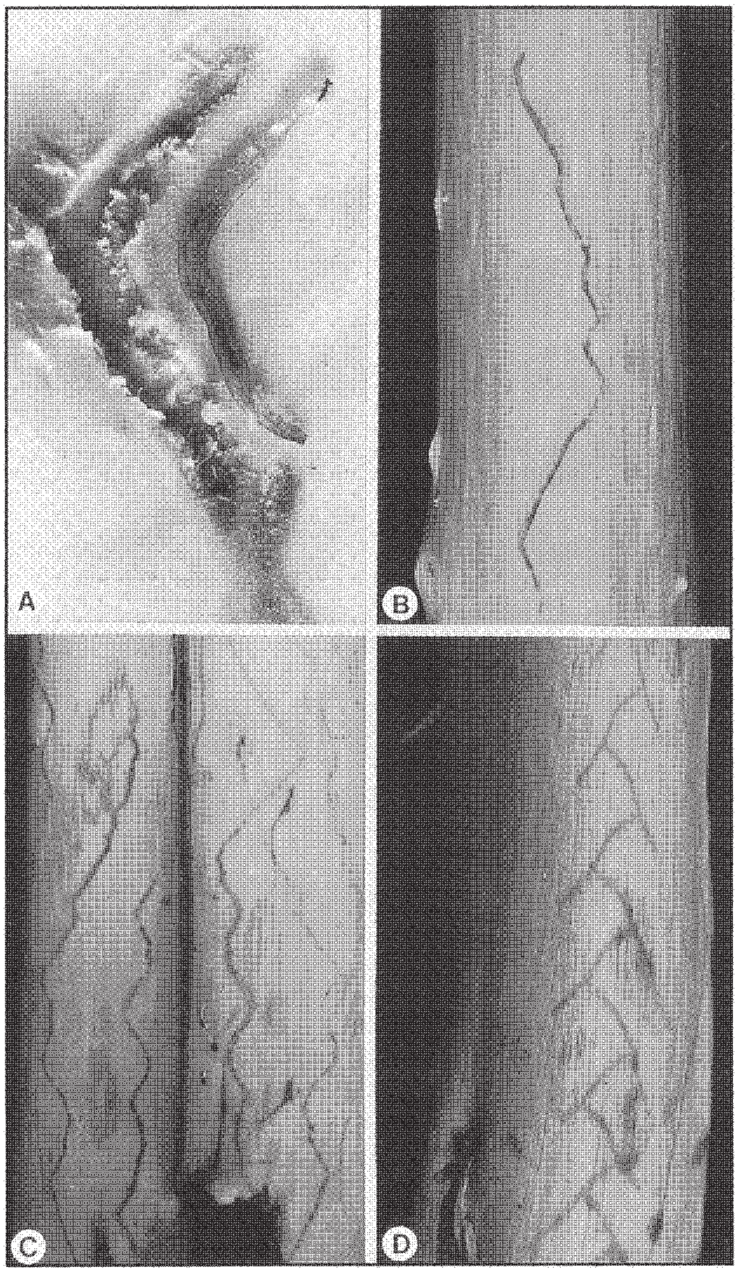

Figure 244—Phytobia *sp., [ash cambium miner]: A, larva beside its burrow in cambium and phloem; B, sinuate mine on surface of green ash sapwood; C, multiple zigzag mines on underside of bark; D, bipectinate larval mine in ash root.*

able, black, clawlike teeth or hooklets. Larvae distinguished from those of *P. setosa* by small, oblique tooth on the left side that is bidentate and other teeth that are similar in size. Body opaque white, segments almost indistinct without magnification, posterior spiracles consist of three short bulbs. Mature larvae 20 to 25 mm long and 1.1 to 1.25 mm diameter.

Biology. Adults apparently emerge during late spring and summer and presumably oviposit in small twigs and branches (Skelly and Kearby 1969, 1970). Young larvae mine rapidly downward in the cambium of the branches and bole, eventually reaching the roots. They spend about 10 months in the lower trunk and roots. Larval burrowing habits differ from other *Phytobia* cambium miners. Although young larvae burrow in long, narrow paths and meander little, they eventually mine in serpentine paths and finally in distinct zigzags. Once in the roots, many larvae make pectinate or bipectinate mines, a habit not reported for other *Phytobia* species. Moreover, larvae feed at times in layers of the phloem, as indicated by the disappearance of mines from the cambium and reappearance several centimeters away. In contrast, detailed studies of *P. setosa* show that larvae mine in narrow zones of newly differentiating xylem just below the cambium (Gregory and Wallner 1979). Although larvae have been found in roots to 7.6 m from the root collar, most of their root burrowing is in the nearest 1.5 m of roots. Second-stage larvae overwinter within the mines in the roots. Larvae are somewhat active during winter, as indicated by fresh, white or slightly tan frass deposits in the mines. Feeding is resumed in spring, with larvae reversing directions in the roots and lower trunk. In Pennsylvania, mature larvae cut holes in the bark or roots and enter the soil to pupate in May and June. In Mississippi, the larvae appear to exit the bark much earlier, and many mine upward from the roots to the root collar or above to cut holes and exit the bark. This miner has one generation a year.

Injury and damage. In standing trees, injury is virtually undetectable (Hardwood Research Council 1987; Skelly and Kearby 1969, 1970). When bark is removed, tan to brown mines on both the white, inner phloem and surface of the xylem become visible. In the branches and upper bole, the mines are mostly narrow, threadlike, and straight to serpentine. In the middle and lower bole, many mines become more sinuate and some distinctly zigzag (figure 244B and C). In the roots, in addition to these patterns, pectinate and bipectinate-shaped mines may be present (figure 244D). As mines fill and heal over, the wood grain covering the mines becomes distorted and slightly bulging or swollen. Moreover, much of the brown deposit in most mines fades or bleaches, becoming nearly colorless. Consequently, the pith flecks in cross sections and log ends of ash are hardly noticeable in contrast to those caused by *Phytobia* species in maple and other trees. The reason may be that ashes are ring porous, whereas all other hosts attacked by cambium miners are diffuse porous. In sawn lumber and sliced veneer of ash, most mines do not show up as brown streaks and marks as in other host species. Instead, they are most noticeable as zigzag tracks varying from slightly lighter to slightly darker than the natural wood. However, the distorted wood grain gives it a characteristic "gothic arch" grain pattern. Such tracks viewed from one direction may be almost indistinct, but when the board is tilted or the angle of light changed, the tracks become distinct. Grain distortions interfere with the milling and fine finishing process of infested wood and is objectionable in international markets. These mines are referred to in the lumber industry as "worm tracks, "pith flecks," "pith ray flecks," "medullary spots," and sometimes as "glassworm" or "glass tracks," especially in Europe. Although not recognized as grading defects in lumber, in face veneers, they are considered defects by the Fine Hardwood Veneer Association.

Control. Dead larvae have been found in their mines following unusually cold winters. No other natural controls are known, and direct controls have not been investigated.

Glossary

Acuminate—gradually tapering to a sharp point.
Ambrosia—mycelium cultured in galleries as food by 17 species in the families Scolytidae and Platypodidae.
Ampulla, **ampullae**—a blisterlike structure on abdominal segments of larvae of some members of Cerambycidae.
Antenna, **antennae**—a segmented sensory appendage borne one on each side of the head.
Arcuate—arched or bowlike.
Arista—a large dorsal bristle on the apical antennal segment of members of Diptera.
Asperate—roughened; surface roughenings of tiny dotlike elevations are termed **asperites**.
Attenuate—gradually tapering apically.
Bark scar—a healed-over injury in the bark.
Biordinal crochets—crochets on the proleg of a uniserial circle of two lengths, alternating.
Bipectinate—having comblike teeth on the side of the antennal segments.
Biramous—having two branches.
Bispinose—armed with two spines.
Bole—a tree trunk once it has grown to large poletimber or sawtimber size.
Bristle—a stiff hair, usually short and blunt.
Brood—all individuals that hatch from eggs of one parent or series of parents and normally mature about the same time.
Cambium—a thin layer of meristematic cells between the bark and wood that gives rise to new phloem and xylem cells.
Canker—a localized necrotic lesion of the bark and cambium and sometimes the wood.
Carina, **carinae**—an elevated ridge or keel.
Caudal—pertaining to the rear end of the insect body.
Cell—(1) the closed area bounded by veins in an insect wing. (2) a nest, chamber, or compartment.
Cephalad—toward or in direction of the head.
Cercus, **cerci**—an appendage (generally paired) of the tenth abdominal segment, usually slender and segmented.
Cervical shield—a hardened plate on the prothorax of caterpillars just behind the head.
Chaetotaxy—arrangement and nomenclature of the setae on the insect.
Chlorosis—an abnormal yellowing of foliage.
Chorion—the outer shell or covering of an insect egg.
Ciliate—fringed with a row of parallel hairs.
Clavate—clubbed, usually toward the tip.
Coarctate—a pupa having all appendages and body parts concealed by a thickened, usually cylindrical case.
Cocoon—a covering composed of silk, other viscid fiber, and debris constructed by larva for protection of pupa.
Colleterial—a viscid secretion during oviposition by an accessory gland connected to the oviduct.
Concentric—circles or spheres, one within another.
Coppice—reproduction from sprouts arising from stools, rootstocks, or stumps.
Costa, **costae—**the thickened anterior vein or margin of an insect's wing.
Coxa, **coxae**—the basal segment of the insect's leg.
Cradle—a small chamber or niche along the gallery where the immature stages of some members of Scolytidae and Platypodidae develop.
Cremaster—the apex of the last abdominal segment, often with spined hooks.
Crenulate—evenly rounded and rather deeply curved.
Crochets—the curved spines or hooks on the prolegs of caterpillars and on the cremaster of pupae.
Cuprous—coppery; metallic copper red.
Diameter at breast height—diameter of a tree at 1.37 m above ground.
Deciduous—having leaves that fall at the end of a growing season.
Declivity—the sloping rear end of the elytra of members of Coleoptera, especially in the Scolytidae family.
Decumbent—bending downward.

Defect—a blemish or imperfection in wood such as a hole, a bark pocket, decay, or stain.
Deflexed—abruptly bent downward.
Degrade—a reduction in quality and grade caused by defects in the wood.
Dentate—toothed.
Denticulate—set with little teeth (denticles) or notches.
Depressed—flattened down as if pressed.
Dieback—progressive dying from the extremity of part of the plant.
Discal—a large median cell in the wing extending from the base to the center.
Distal—toward the free end of any appendage.
Dorsum—the upper surface of the insect body; referring to the dorsal surface.
Eclosion—emergence of the adult from the pupa or the act of the larva hatching from the egg.
Ellipsoidal—oblong-oval, ends equally rounded.
Elytron, **elytra—**hard or leathery forewings of beetles that usually meet in a straight line down the middle of the dorsum.
Emarginate—notched.
Entomogenous—growing in or on an insect.
Excrement—waste products eliminated by an insect mainly from digestion.
Exudation—a discharge of sap, gum, and fine frass from minute openings.
Exarate—a type of pupa in which the legs and wings are free from the body.
Exuvium, **exuviae**—the cast skin of larvae at metamorphosis.
Falcate—convexly curved.
Fascia—a transverse band, usually crossing forewings.
Femur, **femora**—the upper part or thigh of the insect leg.
Fibrous—consisting of or including long, narrow pieces or fibers of wood.
Filiform—threadlike.
Flagging—conspicuous dead twigs and branches with the foliage still present and discolored.
Forceps—hook- or pincerlike processes terminating the abdomen.
Frass—wood fragments mixed with excrement produced by insect larvae.
Frons—the upper anterior portion of the head.
Funicle—the slender stalk portion of the antenna.
Fuscous—a mixture of black and red.
Gall—an abnormal growth or swelling of plant tissue caused by insects or other external stimuli.
Gallery—a long narrow passage, chewed in the bark, cambium, and/or wood by a tunneling larva.
Gena, **genae**—part of the head below the eyes.
Generation—the time required to complete the life cycle of an insect.
Genitalia—sexual organs and associated structures.
Girdle—a cut in the living phloem or xylem or both, which encircles a stem, branch, or root.
Glabrous—smooth, without hairs.
Globose—nearly spherical; globular.
Granular—small chips or grains of wood, as in insect frass with a grainy texture.
Gregarious—living close together, but not social.
Grub—an insect larva; usually the larva of Coleoptera and some members of Hymenoptera.
Gummosis—formation of gummy exudates, often in masses.
Haltere—small filament on each side of the thorax representing the hindwings in Diptera.
Heartwood—the nonliving inner core of wood, usually darker than sapwood.
Hibernaculum, **hibernacula**—silken-trash shelter in which a larva hibernates.
Hibernation—a period of inactivity occurring during seasonal low temperatures.
Hooklet—minute, black, hook-shaped mouthpart in larvae of the order Diptera.
Hyaline—transparent or nearly so.
Incubation—the hatching period of an egg.
Infection—the establishment of a parasite in a host plant.

Infestation—borer attacks usually occuring in numbers.
Inquiline—an insect living habitually as a guest in the nest of another insect.
Instar—the period or stage between molts in a larva, usually numbered.
Larva, **larvae**—a young insect that hatches from the egg and differs fundamentally in form from the adult.
Lenticel—a lens-shaped cortical pore on the stem; serves for the exchange of gases.
Life cycle—the time between fertilization of an insect egg and the death of the individual adult that proceeds from that egg.
Lunule—a crescent-shaped mark around the eye.
Maggot—a legless larva of the order Diptera.
Mandibles—the first pair of jaws of insects, usually stout and toothlike.
Marginate—having an elevated margin with a flat border.
Mesothorax—middle segment of the thorax.
Midrib—the central vein of a leaf.
Mimic—the resemblance of one animal to another that is not closely related.
Molt—to shed the outer skin to accommodate growth of the body.
Monogamous—a union where a female is fertilized by one male only.
Mycelium—the threadlike vegetative part of fungi.
Mycetangia—pouchlike structures on insect bodies for storing fungi as in members of Scolytidae and Platypodidae.
Nuptial chamber—a cavelike opening made by bark beetles in the inner bark beneath the entrance hole and from which the egg tunnels originate.
Ocellus, **ocelli**—lateral simple eyes of insects.
Ochreous—yellowish with a slight tinge of brown.
Opaque—without surface luster; not transparent.
Ornamental—a plant grown for its esthetic qualities.
Ovipositor—a tubular structure at the rear end of a female insect, used to deposit eggs on or in a suitable material.
Palpus, **palpi**—a jointed sensory appendage of the mouth.
Parasite—an organism living in or on, and nourished by, another living organism, which is injured or killed.
Pathogen—an organism that causes a disease.
Pectinate—comblike; even processes on the antennae like the teeth of a comb.
Pheromone—an insect-produced chemical that stimulates a specific reaction by the receiving individuals; i.e., sex attractants.
Phloem—inner bark; tissue concerned with translocation of foodstuffs.
Pinaculum, **pinacula**—an enlarged seta-bearing papilla forming a flat plate.
Pith fleck—a small discolored spot, mark, or streak of mineral, gummy, or pithlike tissue embedded in the xylem.
Plumose—feathery.
Pole—a young tree 10.2 cm in diameter at breast height (dbh) and up to 20.3 or 30.5 cm in dbh.
Polygamy—the condition of a single male having three or more female mates.
Predator—any animal that preys on (kills and eats) other animals.
Proboscis—any extended mouth structure in members of Diptera and Lepidoptera.
Proleg—an appendage that serves the purpose of a leg, as with the abdominal legs of caterpillars and sawflies.
Pronotum—the upper surface of the prothorax.
Prosternum—the forebreast between the forelegs.
Prothoracic shield—a hardened darkened plate extending transversely across the first thoracic segment.
Prothorax—the first thoracic segment; it bears the first pair of legs but no wings.
Pubescence—short, fine, soft hairs.
Punctate—set with small puncture-like impressions.

Pupa, **pupae—**the resting stage of an insect intermediate between the larva and adult stages.
Puparium, **puparia—**the thickened, hardened, barrel-like larval skin within which the pupa is formed in Diptera.
Recumbent—lying down; reclining.
Resistance—qualities possessed by a plant that function to minimize damage by insects.
Rachis, **rachises—**extension of the petiole bearing the leaflets in compound leaves.
Reticulate—covered with a network of raised lines.
Rufous—brilliant reddish yellow.
Rugose—wrinkled.
Sapling—a young tree less than 10.2 cm in diameter at breast height.
Sapwood—living outer layers of wood, usually light in color.
Saw—a median pair of flattened plates of the ovipositor.
Sawlog—a log of suitable size (generally 30.5 cm in diameter at the small end) and quality for sawing into lumber.
Sawtimber—trees of size and quality to yield sawlogs.
Scale—flattened and modified hairs, as on wings of members of Lepidoptera.
Seedling—a young tree grown from seed, up to the sapling stage.
Serpentine—winding or turning one way then the other.
Serrate—notched like the teeth of a saw.
Serrulate—finely serrated; with minute teeth or notches.
Seta, **setae**—bristlelike hair.
Sheath—a structure enclosing the saw in sawflies.
Shelterbelt—a strip of trees or shrubs maintained to provide shelter from wind.
Shoot—any young, tender, succulent, current-year, aerial outgrowth from a plant.
Silviculture—the art and science of growing and tending forest tree crops.
Sinuate—wavy.
Spine—a large seta or thornlike process.
Spinule—a minute pointed spine.
Spiracles—breathing pores located along sides of the insect body.
Stemma, **stemmata**—simple eyes of larvae.
Sternite—the ventral part of a body segment.
Stool—a living stump (usually willow or poplar) maintained in nuserybeds to produce cuttings.
Striae—parallel, fine, longitudinal, impressed lines as on the elytra of members of Coleoptera.
Sulcate—deeply grooved.
Symbiosis—the coexistence of different species without disadvantage to either and often with mutual benefit.
Tarsus, **tarsi**—the insect foot; the outermost jointed division of the leg.
Teneral—newly transformed adult not entirely hardened or fully colored.
Tergite—the dorsal part of a segment.
Termen—the outer margin of a wing.
Tibia, **tibiae**—a single-segmented division of the insect leg between the femur and the tarsus.
Tridente—three-toothed.
Truncate—cut off squarely at the tip.
Tubercle—a small rounded projection from the surface sometimes bearing setae.
Uniordinal crochets—crochets on the proleg that are uniform in length and in a single series circle.
Vector—a carrier of a disease-producing organism.
Venter—the undersurface of the abdomen.
Vertex—the top of the head.
Vestiture—the surface covering of insects such as hairs or scales.
Windthrow—uprooting of trees by the wind.
Xylem—the principal strengthening and water-conducting tissue of branches, stems, and roots.

Diagnostic Host Index

This index should enable foresters and others not trained in entomology to identify many of the borers that cause injury to broadleaf trees and shrubs. The index serves in lieu of keys to borers and their damage and provides a means of narrowing the search for the identity of a borer observed on a particular host. **Using this index involves the following steps:**

1. Identifying the host tree or shrub,
2. Determining the part or parts that are injured,
3. Consulting the habit groups to see which one most closely describes the insect,
4. Referring to the text pages on which insects in the selected habit group are discussed and illustrated to decide which description best fits the insect and/or its injury.

Plant parts on shrubs are designated like those of trees, with trunk indicating the main stem, and the difference between twigs and small branches versus large branches based on relative size. The habit group refers to the characteristics of the larvae or adults, the type of injury caused, or the particular habits exhibited by various borer groups.

The following 16 habit groups are described and used:

Beetle, ambrosia—adult small, compact, cylindrical, with head largely hidden beneath thorax; larva white, legless, usually C-shaped, in frass-free gallery in xylem.

Beetle, bark—adult small, compact, cylindrical, with head largely hidden beneath thorax; larva white, legless, C- shaped, in frass-packed gallery in cambium region.

Beetle, false powderpost—adult elongate, cylindrical, with head largely hidden beneath thorax, with rasplike pronotum; larva white, C-shaped, with thoracic legs, in gallery filled with powderlike frass in xylem.

Beetle, timber—adult elongate, subcylindrical, with deflexed narrow head; larva elongate, cylindrical, with taillike structure, in mostly frass-free gallery deep in xylem.

Borer, clearwing—larva white, pink, or brown, elliptical spiracles, with thoracic legs and abdominal prolegs, in frass-free galley in phloem and/or sapwood.

Borer, flatheaded—larva white, elongate, slender, legless, with or without thoracic segments enlarged and flattened, in long, narrow, winding gallery in phloem and/or xylem.

Borer, roundheaded—larva white, fleshy, cylindrical, with or without thoracic legs and abdominal ampullae, in large frass-free or frass-packed gallery in phloem and xylem.

Carpenterworm—larva pink to white, with thoracic legs and abdominal prolegs, strong mandibles, disagreeable goatlike odor, in large, mostly frass-free gallery in phloem and xylem.

Caterpillar—larva variable in color and size, cylindrical, 13 body segments, with thoracic legs and fleshy abdominal prolegs, usually in frass-free gallery in shoots or phloem and/or xylem of roots and stems.

Gallformer—larva white to brown, size and form variable, gallery with or without frass, in galls.

Girdler/pruner, flatheaded—larva white, thoracic segments enlarged and flattened, narrow frass-packed gallery, xylem of stem severed leaving phloem intact, which usually breaks.

Girdler/pruner, roundheaded—larva white, fleshy, cylindrical, frass-free or frass-packed gallery, xylem of stem severed leaving phloem intact, which usually breaks; in a few species, the adult girdles the stem from the outside.

Horntail—larva white, cylindrical, slightly S-shaped, abdomen ending in hornlike projection, in frass-packed gallery in xylem.

Miner, cambium—larva white, long, slender, legless, headless, with hooklike mouthparts, in long, narrow, frass-packed mine in cambium region.

Sawfly—larva yellowish white to purplish green, curved to S- shaped, cylindrical, with small thoracic legs, in frass- packed gallery, usually in tender shoots and stems.

Weevil—larva white, subcylindrical, fleshy, C-shaped, legless, in gallery containing some dark frass in shoots, stems, or under bark.

(For additional details on habit groups, see the introductory text at the beginning of each order and family).

Insect Index

This is an alphabetical listing of the insect species by both scientific and common names.

Common and Scientific Names of Host Plants

acacia	*Acacia* spp.
ailanthus	*Ailanthus altissimia* (Mill.) Swingle
alder	*Alnus* spp.
black	*Alnus glutinosa* (L.) Gaertn.
Italian	*Alnus cordata* Desf.
mountain	*Alnus tenuifolia* Nutt.
Oregon	*Alnus* sp.
speckled	*Alnus rugosa* (Du Roi) Spreng.
white	*Alnus incana* Moench.
alkali blite	*Suaeda fruticosa* (L.) Forsk.
almond	*Prunus dulcis* (Miller) D.A. Webb
American cranberrybush	*Viburnum trilobum* Marsh.
antelope brush	*Purshia* sp.
apple	*Malus domestica* Borkh.
apricot	*Prunus armeniaca* L.
Arizonia cypress	*Cupressus arizonica* Greene
arrowwood	*Viburnum dentatum* L.
ash	*Fraxinus* spp.
black	*Fraxinus nigra* Marsh.
Carolina	*Fraxinus caroliniana* Mill.
European	*Fraxinus excelsior* L.
green	*Fraxinus pennsylvanica* Marsh.
Oregon	*Fraxinus latifolia* Benth.
white	*Fraxinus americana* L.
aspen	*Populus* spp.
bigtooth	*Populus grandidentata* Michx.
European	*Populus tremula* L.
quaking	*Populus tremuloides* Michx.
(see also poplar)	
(see also cottonwood)	
Australian pine	*Casuarina equesitifolia* L.
avocado	*Persea americana* Mill.
azalea	*Rhododendron* spp.
baccharis	*Baccharis* spp.
eastern	*Baccharis halimifolia* L.
seepwillow (mulefat)	*Baccharis glutinosa* Pers.
baldcypress	*Taxodium distichum* (L.) Rich.
basswood	*Tilia* spp.
American	*Tilia americana* (L.)
(see also linden)	
bayberry	*Myrica pensylvanica* Lois.
beech	*Fagus* sp.
American	*Fagus grandifolia* Ehrh.
birch	*Betula* spp.
gray	*Betula populifolia* Marsh.

paper	*Betula papyrifera* Marsh.
river	*Betula nigra* L.
sweet	*Betula lenta* L.
western paper	*Betula papyrifera* var. *commutata* (Regel) Fern.
white	*Betula* sp.
yellow	*Betula alleghaniensis* Britton
blackbead	*Pithecellobium* spp.
blackberry	*Rubus* sp.
blackgum (see also black tupelo)	*Nyssa sylvatica* Marsh.
blackhaw	*Viburnum prunifolium* L.
blueberry	*Vaccinium* spp.
blue paloverde	*Cercidium floridum* Benth. ex Gray
Boston ivy, Japanese ivy	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon
boxelder	*Acer negundo* L.
box-thorn	*Lycium* sp.
boysenberry (loganberry)	*Rubus loganobaccus* L.H. Bailey
buckeye	*Aesculus* spp.
California	*Aesculus californica* (Spach.) Nutt.
Ohio	*Aesculus glabra* Willd.
burdock	*Arctium* spp.
bursera	*Bursera* spp.
butternut	*Juglans cinerea* L.
buttonbush	*Cephalanthus occidentalis* L.
California boxelder	*Acer negundo* ssp. *californicum* (Torr. & Gray) Wesmael
camphor-tree	*Cinnamomum camphora* (L.) J.S. Presl
catalpa	*Catalpa* spp.
catclaw	*Acacia greggii* Gray
ceanothus	*Ceanothus* spp.
blueblossom	*Ceanothus thyrsiflorus* Eschsch.
cedar	
eastern redcedar	*Juniperus virginiana* L.
Spanish	*Cedrela odorata* L.
cherry	*Prunus* spp.
black	*Prunus serotina* Ehrh.
mahaleb	*Prunus mahaleb* L.
sour	*Prunus cerasus* L.
wild	*Prunus* spp.
chestnut	*Castanea* spp.
American	*Castanea dentata* (Marsh.) Borkh.
chokecherry	*Prunus virginiana* L.
coralbean	*Erythrina fusca* Lour.

corn	*Zea mays* L.
cotoneaster	*Pyracantha coccinea Roem.*
cottonwood	*Populus* spp.
black	*Populus trichocarpa* Torr. & Gray
eastern	*Populus deltoides* Bartr. ex Marsh.
Fremont	*Populus fremontii* Wats.
lanceleaf	*Populus acuminata* Rydb.
narrowleaf	*Populus angustifolia* James
plains	*Populus deltoides* var. *occidentalis* Rydb.
swamp	*Populus heterophylla* L.
(see also: poplar and aspen)	
coyote brush	*Baccharis pilularis* DC.
crabapple	*Malus sylvestris* (L.) Mill.
currant	*Ribes* spp.
dewberry	*Rubus* spp.
dogwood	*Cornus* spp.
red-osier	*Cornus stolonifera* Michx.
ebony	*Pithecellobium* spp.
blackbead	*Pithecellobium flexicaule* (Benth.) Coult.
elder	*Sambucus* spp.
American	*Sambucus canadensis* L.
blackbead	*Sambucus* sp.
blue	*Sambucus cerulea* Raf.
European	*Sambucus nigra* L.
Pacific red	*Sambucus callicarpa* Greene
elm	*Ulmus* spp.
American	*Ulmus americana* L.
cedar	*Ulmus crassifolia* Nutt.
English	*Ulmus procera* Salisb.
slippery	*Ulmus rubra* Muhl.
eucalyptus	*Eucalyptus* spp.
Blakely's red gum	*Eucalyptus blakelyi* Maiden
Blue gum	*Eucalyptus globulus* Labill.
manna gum	*Eucalyptus viminalis* Benth.
sugar gum	*Eucalyptus cladocalyx* F. Muell.
fig	*Ficus* spp.
fringetree	*Chionanthus virginicus* L.
giant ragweed	*Ambrosia trifida* L.
gingko	*Gingko biloba* L.

goldenrod	*Solidago* spp.
golden-shower	*Cassia fistula* L.
gooseberry	*Ribes* spp.
grape	*Vitis* spp.
greasewood	*Sarcobatus* sp.
black	*Sarcobatus vermiculatus* (Hook.) Torrey
great leucaena	*Leucaena pulverulenta* (Schlecht.) Benth.
guajillo	*Acacia berlandieri* Benth.
gumbo-limbo	*Bursera simaruba* (L.) Sarg.
hackberry	*Celtis* spp.
netleaf	*Celtis reticulata* Torr.
hawthorn	*Crataegus* spp.
cockspur	*Crataegus crus-galli* L.
pear	*Crataegus calpodendron* (Ehrh.) Medic.
hazel (hazelnut)	*Corylus* spp.
hemlock	*Tsuga* spp.
hickory	*Carya* spp.
bitternut	*Carya cordiformis* (Wangenh.) Koch
mockernut	*Carya tomentosa* (Poir.) Nutt.
pignut	*Carya glabra* (Mill.) Sweet
shagbark	*Carya ovata* (Mill.) Koch
water	*Carya aquatica* (Michx.) Nutt.
(see also pecan)	
holly	*Ilex* spp.
American	*Ilex opaca* Ait.
honeylocust	*Gleditsia triacanthos* L.
hop	*Humulus lupulus* L.
hophornbeam	*Ostrya* spp.
eastern	*Ostrya virginiana* (Mill.) Koch
hornbeam	*Carpinus* sp.
American	*Carpinus caroliniana* Walt.
horsebean	*Parkinsonia aculeata* L.
horsechestnut	*Aesculus* spp.
(see buckeye)	
huisache	*Acacia farnesiana* (L.) Willd.
indigobush	
(see smokethorn)	
Jerusalem-thorn	*Parkinsonia aculeata* L.
kapok	*Ceiba pentandra* (L.) Gaertner
larch	*Larix* spp.

laurel (mountain-laurel)	*Kalmia* spp.
laurelcherry	*Prunus* spp.
Carolina	*Prunus caroliniana* (Mill.) Ait.
leadplant	*Amorpha canescens* Pursh.
lilac	*Syringa vulgaris* L.
linden	*Tilia* spp.
European	*Tilia cordata* Mill.
(see also basswood)	
lindheimer mimosa	*Mimosa lindheimeri* Gray
locust	*Robinia* spp.
black	*Robinia pseudoacacia* L.
New Mexico	*Robinia neomexicana* Gray
loquat	*Eriobotrya japonica* (Thunb.) Lindley
lupine	*Lupinus* spp.
madrone	*Arbutus* spp.
magnolia	*Magnolia* spp.
southern	*Magnolia grandiflora* L.
mahogany	*Swietenia* spp.
mango	*Mangifera indica* L.
mangrove	*Rhizophora mangle* L.
manzanita	*Manzanita* spp.
maple	*Acer* spp.
bigleaf	*Acer macrophyllum* Pursh.
black	*Acer nigrum* Michx.
Florida	*Acer barbatum* Michx.
mountain	*Acer spicatum* Lam.
Norway	*Acer platanoides* L.
planetree	*Acer pseudoplatanus* L.
red	*Acer rubrum* L.
Rocky Mountain	*Acer glabrum* Torr.
silver	*Acer saccharinum* L.
southern sugar	*Acer barbatum* Michx.
(see Florida maple)	
striped	*Acer pensylvanicum* L.
sugar	*Acer saccharum* Marsh.
mazzard (sweet cherry)	*Prunus avium* (L.)
mesquite	*Prosopis* spp.
honey	*Prosopis glandulosa* Torr.
western honey	*Prosopis glandulosa* var. *torreyana* (L. Benson) M.C. Johnst.
mimosa	*Albizia julibrissin* Durazzini
mistletoe	*Phoradendron* spp.
mountain-ash, American	*Sorbus americana* Marsh.
mountain-laurel	*Kalmia latifolia* L.
mountain-mahogany	*Cercocarpus* spp.

mulberry	*Morus* spp.
red	*Morus rubra* L.
Russian (see white)	
white	*Morus alba* L.
nannyberry	*Viburnum lentago* L.
nectarine	*Prunus persica* var. *nuciperscia* (Suckow) C. Schneider
ninebark	*Physocarpus opulifolius* (L.) Maxim.
oak	*Quercus* spp.
Arizona white	*Quercus arizonica* Sarg.
bear	*Quercus ilicifolia* Wangenh.
black	*Quercus velutina* Lam.
blackjack	*Quercus marilandica* Muenchh.
bur	*Quercus macrocarpa* Michx.
California black	*Quercus kelloggii* Newb.
California scrub	*Quercus dumosa* Nutt.
canyon live	*Quercus chrysolepis* Liebm.
cherrybark	*Quercus falcata* var. *pagodifolia* Ell.
chestnut	*Quercus prinus* L.
chinkapin	*Quercus muehlenbergii* Engelm.
coast live	*Quercus agrifolia* Nee
Dunn	*Quercus dunnii* Kellogg
Emory	*Quercus emoryi* Torr.
Engelmann	*Quercus engelmannii* Greene
Gambel	*Quercus gambelii* Nutt.
interior live	*Quercus wislizeni* A. DC.
laurel	*Quercus laurifolia* Michx.
live	*Quercus virginiana* Mill.
Mexican blue	*Quercus oblongifolia* Torr.
northern red	*Quercus rubra* L.
Nuttall	*Quercus nuttallii* Palmer
Oregon white	*Quercus garryana* Dougl. ex Hook.
overcup	*Quercus lyrata* Walt.
pin	*Quercus palustris* Muenchh.
post	*Quercus stellata* Wangenh.
scarlet	*Quercus coccinea* Michx.
scrub	*Quercus* sp.
Shumard	*Quercus shumardii* Buckl.
silverleaf	*Quercus hypoleucoides* A. Camus
southern red	*Quercus falcata* Michx.
swamp chestnut	*Quercus michauxii* Nutt.
swamp white	*Quercus bicolor* Willd.
turkey	*Quercus laevis* Walt.
water	*Quercus nigra* L.

white	*Quercus alba* L.
willow	*Quercus phellos* L.
olive	*Olea europaea* L.
orange (sweet)	*Citrus sinensis* (L.) Osbeck
Osage-orange	*Maclura pomifera* (Raf.) Schneid.
paperbark-tree (bottlebrush or cajeput-tree)	*Melaleuca quinquenervia* (Cav.) S.T. Blake
paulownia	*Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud.
peach	*Prunus persica* Batsch.
peanut	*Arachis hypogaea* L.
pear	*Pyrus communis* L.
pecan (see also hickory)	*Carya illinoensis* (Wangenh.) K. Koch
pentstemon	*Pentstemon* spp.
peppertree (California)	*Schinus molle* L.
persimmon	*Diospyros* spp.
common	*Diospyros virginiana* L.
Japanese	*Diospyros kaki* L.
photinia	*Heteromeles* spp.
pigeon plum	*Coccoloba diversifolia* Jacq.
pine	*Pinus* spp.
plum	*Prunus* spp.
beach	*Prunus maritima* Marshall
Chickasaw	*Prunus angustifolia* Marshall
Chinese	*Prunus* sp.
garden	*Prunus domestica* L.
wild	*Prunus* sp.
poison ivy	*Toxicodendron radicans* (L.) Kuntze
poison oak	*Toxicodendron diversilobum* (Torrey & A. Gray) E. Greene
pomegranate	*Punica granatum* L.
poplar	*Populus* spp.
balsam	*Populus balsamifera* L.
Lombardy	*Populus nigra* var. *italica* Muenchh.
white (silver) (see also aspen and cottonwood	*Populus alba* L.
privet	*Ligustrum* spp.
pyracantha	*Pyracantha* spp.
quince	*Cydonia oblonga* Miller
raspberry	*Rubus* spp.

redbay	*Persea borbonia* (L.) Spreng.
redbud	*Cercis* spp.
eastern	*Cercis canadensis* L.
rhododendron	*Rhododendron* spp.
rose	*Rosa* spp.
rush bebbia	*Bebbia juncea* (P.H. Timberlake)
Saltbush	*Atriplex* sp.
fourwing	*Atriplex canescens* (Pursh.) Nutt.
Gardner	*Atriplex gardneri* (Moq.) D. Dietr.
Parry	*Atriplex parryi* Wats.
shadscale	*Atriplex confertifolia* (Torr. & Frem.)
sassafras	*Sassafras albidum* (Nutt.) Nees
seagrape	*Coccoloba uvifera* (L.) L.
serviceberry	*Amelanchier* spp.
downy	*Amelanchier arborea* (Michx.) Fern.
western	*Amelanchier alnifolia* (Nutt.) Nutt.
smokethorn	*Dalea spinosa* Gray
sneezeweed	*Helenium* sp.
sourwood	*Oxydendrum arboreum* (L.) DC.
Spanish cedar	*Cedrela odorata* L.
spicebush	*Lindera benzoin* (L.) Blume
spruce	*Picea* spp.
sugarberry (see also hackberry)	*Celtis laevigata* Willd.
sumac	*Rhus* spp.
smooth (common)	*Rhus glabra* L.
poison-sumac	*Rhus vernix* L.
sweetfern	*Comptonia* peregrina (L.) J.M. Coulter
sweetgum	*Liquidambar styraciflua* L.
sweetleaf	*Symplocos tinctoria* (L.) L'Her.
sycamore	*Platanus occidentalis* L.
Arizona	*Platanus wrightii* Wats.
California	*Platanus racemosa* Nutt.
thistle	*Carduus* spp.
tupelo	*Nyssa* spp.
water	*Nyssa aquatica* L.
black (see also blackgum)	*Nyssa sylvatica* Marsh.
viburnum	*Viburnum* spp.
Virginia creeper	*Parthenocissus quinquefolia* L. Planch.

walnut	*Juglans* spp.
black	*Juglans nigra* L.
English	*Juglans regia* L.
Japanese	*Juglans siebolidiana* Maxim.
willow	*Salix* spp.
acute leaf	*Salix* sp.
arroyo	*Salix lasiolepis* Benth.
black	*Salix nigra* Marsh.
Bonpland	*Salix bonplandiana* H.B.K.
crack	*Salix fragilis* L.
European yellow	*Salix* sp.
golden leaf	*Salix* sp.
laurel leaf	*Salix pentandra* Lorbeerweide
meadow	*Salix petiolaris* J.E. Sm.
Pacific	*Salix lasiandra* Benth.
sandbar (coyote)	*Salix exigua* (Nutt.)
Scouler	*Salix scoulerana* Barrett ex Hook.
weeping	*Salix babylonia* L.
wisteria	*Wisteria* spp.
witch-hazel	*Hamamelis virginiana* L.
yellow-poplar	*Liriodendron tulipifera* L.
Zelkova	*Zelkova* sp.
Japanese	*Zelkova serrata* (Thunb.) Makino

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OAK PESTS

A Guide to Major Insects, Diseases, Air Pollution and Chemical Injury

United States
Department of
Agriculture

Forest Service
Southern Region

Southern Research Station

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OAK PESTS: A Guide to Major Insects, Diseases, Air Pollution and Chemical Injury

By

J. D. Solomon,*
F. I. McCracken,*
R. L. Anderson, †
R. Lewis, Jr., ‡
F. L. Oliveria, †
T. H. Filer,*
P. J. Barry †

* Retired, Southern Research Station, USDA Forest Service, Stoneville, MS.

† Southern Region, USDA Forest Service. Anderson is in Atlanta, GA; Oliveria is in Pineville, LA; Barry is in Asheville, NC.

‡ Washington Office, USDA Forest Service, Washington, DC.

CONTENTS

INTRODUCTION TO 1997 REVISION

This publication has been revised because additional research and evaluations have been conducted, providing new data. The oak wilt and decline section has been changed; Texas live oak decline has been replaced with oak decline, and the oak wilt section has been updated and expanded. Corticium and Texas root rots have been deleted, and dryadeus root rot has been added. Figure 28c in the root damage by *Prionus* sp. section has been replaced. Pesticide information has been revised to conform with current recommendations.

The most current taxonomic classifications of pathogenic fungi and disease names are not always indicated in the text of individual disease descriptions. To keep the reader current on the presently accepted scientific and disease names, a list of new names that are synonyms of the old ones is provided on page 64.

Special thanks to: A.D. Wilson for preparing the list of revised names for diseases and fungal taxa; Wilson and Starkey for preparing the oak wilt section; Leininger for preparing the dryadeus root rot section; J.W. Taylor for revising the pesticide section; C.A. Lowe for editing the revisions and offering quality suggestions; and H.D. Brown for revising, editing, and coordinating the project. Wilson and Leininger are with the Southern Research Station, USDA Forest Service, Stoneville, Mississippi; Starkey, Taylor, Lowe, and Brown are with the Southern Region, USDA Forest Service; Starkey is in Pineville, Louisiana; Taylor, Lowe, and Brown are in Atlanta, Georgia.

INTRODUCTION

The oaks (*Quercus* spp.) are among our most valuable hardwood resources, amounting to one-third of the hardwood sawtimber volume in the United States. Over half the annual cut of oak lumber is produced in the 13 Southern States. Oaks are best known for their timber production and resulting fine furniture, beautiful flooring, and other products. Yet, aesthetics, watershed management, recreation, and wildlife are goals now given equal or greater priority by many. The oaks are valued for shade and ornamental purposes — a single tree sometimes adds thousands of dollars to real estate values.

Insects, diseases, and pollutants present a continuing threat to oaks. A major portion of the acorn crop is destroyed during some years — hampering regeneration efforts. Seedling mortality and dieback add to this problem. Terminal and top injury adversely affect tree form. Repeated defoliations cause growth loss and mortality. Borers and decay cause defect and degrade amounting to an annual loss of millions of dollars. Indirect losses occur through disruption of sustained forestry practices, regulation of forest types, and altered wildlife habitat. Homeowners may incur the expense of chemical control and possibly the cost of tree removal if mortality occurs. Nuisances created by numerous insects decrease tourist use and revenue.

It is far better to prevent attack by insects and disease than it is to remedy them after they occur. Be aware of, and use, cultural practices that maintain and promote tree vigor. Match tree species to the proper site. Assure sufficient water, nutrients, space, and sunlight. Avoid accidental injuries such as cuts, bruises, and broken limbs. Use practices that favor natural controls such as birds and other predators, parasites, and insect pathogens. Practices such as "pick-up and destroy" and "prune-out and destroy" can help reduce hibernating forms and inoculum reservoirs. When all else fails, chemical controls may become necessary.

This booklet will help nurserymen, forest woodland managers, pest control operators, and homeowners to identify and control pest problems on oaks. The major insect and disease pests of oaks in the South are emphasized. Descriptions and illustrations of the pests and their damage are provided to aid in identification. Brief notes are given on biology and control to aid in predicting damage and making control decisions. A list of chemical controls is provided. Chemical controls are subject to change as certain compounds are banned and new materials approved. Thus, the chemical control section can be removed (tear sheet) and discarded when outdated. For further information on pesticides, contact your State Forester, county agent, or the nearest office of State and Private Forestry, USDA Forest Service.

INSECTS

INSECT DEFOLIATORS

ELM SPANWORM, *Ennomos subsignarius* (Hübner)

Importance. — Elm spanworms attack red and white oaks, and other species especially *Carya,* (hickory, pecan and related trees) throughout the East. This is a destructive forest pest, particularly in the southern Appalachians where widespread, severe outbreaks have occurred. Repeated defoliation can cause growth loss, dieback, reduction in mast crops, and mortality.

Identifying the Insect (figure 1a). — Larvae are slate grey to brownish-black with yellowish body markings (yellow or green at low population densities) and 1.6 to 2 inches (40 to 50 mm) long. The adults are snow-white moths. The olive green eggs are laid in masses on the underside of small branches (figure 1b).

Identifying the Injury (figure 1c). — Young larvae feed on the edge and undersides of leaves, causing a shot hole appearance. Later, they consume the entire leaf except the main veins, leaving a feathered appearance to the tree.

Biology. — Overwintering eggs hatch in early spring when the buds break, usually April in the South. The larvae feed for 4 to 6 weeks, and then pupate in net-like cocoons on the host tree or understory. Six to 10 days later, in late June to mid-July, the moths emerge and deposit their eggs. There is one generation per year.

Control. — Insect parasites attack the eggs of the elm spanworm. Other natural enemies also are important in keeping infestations in check. Chemical controls are often needed to protect high-value trees.

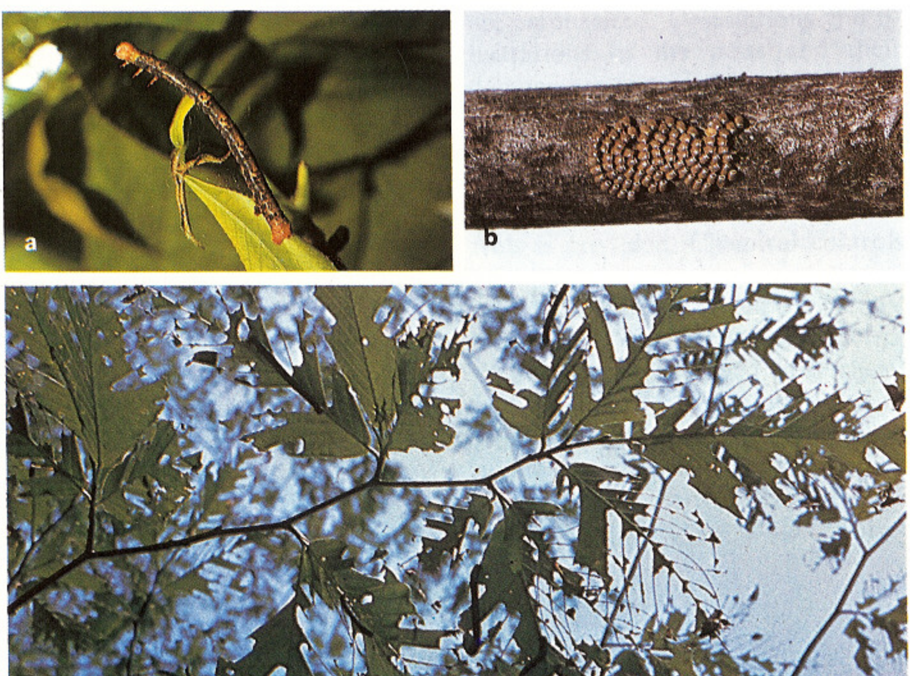


Figure 1. — (a) Elm spanworm larva; (b) elm spanworm egg mass on branch; (c) defoliation by elm spanworm.

FALL CANKERWORM, *Alsophila pometaria* (Harris)

Importance. — The fall cankerworm is one of the most common and injurious species of loopers in eastern forests. Repeated defoliation causes growth loss, reduction in mast, can eventually kill trees and causes a nuisance in high-use areas.

Identifying the Insect (figure 2a). — Larva color varies with population density from light green with yellow stripes, to green with a dark dorsal stripe, to black with whitish lines. The mature larva is .8 to 1-inch (19 to 25 mm) long. The adult female is wingless and ash gray; males have wings. Eggs are laid in masses of more than 100 on small twigs (figure 2b).

Identifying the Injury (figure 2c). — Early signs are small holes in leaves or complete skeletonization of the leaves. Larger larvae consume all except the midrib and major veins. Feeding is complete in 5 to 6 weeks.

Biology. — Overwintering eggs hatch in late April or early May. The larvae feed on young leaves at branch tips. Mature larvae enter the soil to pupate. Adults emerge, mate, and deposit eggs in November and December. There is one generation per year.

Control. — The eggs and larvae of the fall cankerworm are attacked by insect parasites. Other natural enemies also help control this pest. Sticky bands placed on trunks of high-value trees can snare the wingless females before they lay their eggs. Chemical controls may be needed.

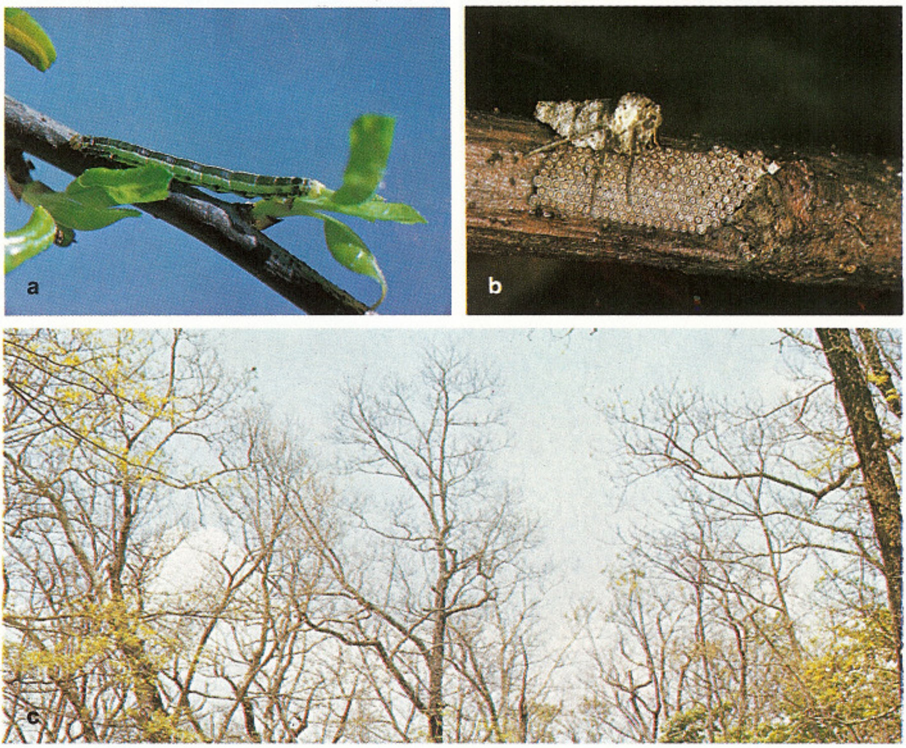


Figure 2. — (a) Fall cankerworm larva; (b) fall cankerworm female moth and egg mass on branch; (c) oak stand defoliated by fall cankerworm.

ORANGESTRIPED OAKWORM, *Anisota senatoria* (J. E. Smith)

Importance. — This defoliator occurs over much of the East. It defoliates trees in parks, campgrounds, picnic areas, and along city streets. However, forest stands of red and white oaks on upland sites suffer most when outbreaks occur.

Identifying the Insect (figure 3a). — The larva is black with eight narrow yellow stripes; it is about 2 inches (50 mm) long. There is a pair of long, curved "horns" on the second thoracic segment. The adult moth is yellowish-red; forewings are orange-purple and each has an oblique band and white spot.

Identifying the Injury (figure 3b). — Young larvae feed in groups, skeletonizing the leaf. Later, they consume all but the main veins. Older larvae are less gregarious and can be found crawling on lawns and sides of houses.

Biology. — Adults appear in June and July, and deposit clusters of several hundred eggs on the underside of leaves. The eggs hatch within a few days and the caterpillars feed during July to September for 5 to 6 weeks. In the fall, mature larvae pupate in the soil, where they overwinter. There is generally one generation per year.

Control. — Natural enemies generally prevent widespread defoliation, but chemical control may be needed for high-value trees.

Figure 3. — (a) Orangestriped oakworm larva; (b) tree defoliated by orangestriped oakworm.

VARIABLE OAKLEAF CATERPILLAR, *Heterocampa manteo* (Doubleday)

Importance. — This defoliator is common throughout eastern North America. It feeds on all species of oaks, but prefers the white oaks. Some infestations have covered millions of acres — retarding growth and tree vigor. Outbreaks usually subside after 2 to 3 years, before serious tree mortality occurs.

Identifying the Insect (figure 4a). — Caterpillar color is variable, but is generally yellowish green with a narrow white stripe down the center of the back, bordered dorsally with reddish-brown, and one or two yellowish stripes on the sides. Mature larvae may reach 1.5 inches (37 mm) long. The adult moth is ashy grey with three dark wavy lines across the forewings.

Identifying the Injury (figure 4b). — Young larvae skeletonize the leaf while older larvae devour the entire leaf except the leaf stalks and main veins. There are two periods of defoliation — one in June to July and another in August to October.

Biology. — There are two generations in the South and one generation in the North. In the South, the larvae feed from early May until late June, and pupate in the soil. Second-generation larvae feed from mid-August until late September, then move to the ground to spin cocoons and overwinter as prepupae. Larvae of the single generation in the North are present during June to mid-August.

Control. — Insect parasites and predators eat the eggs and larvae of this pest. Winter mortality also helps keep most infestations in check. Chemical control is occasionally needed to protect high-value trees.

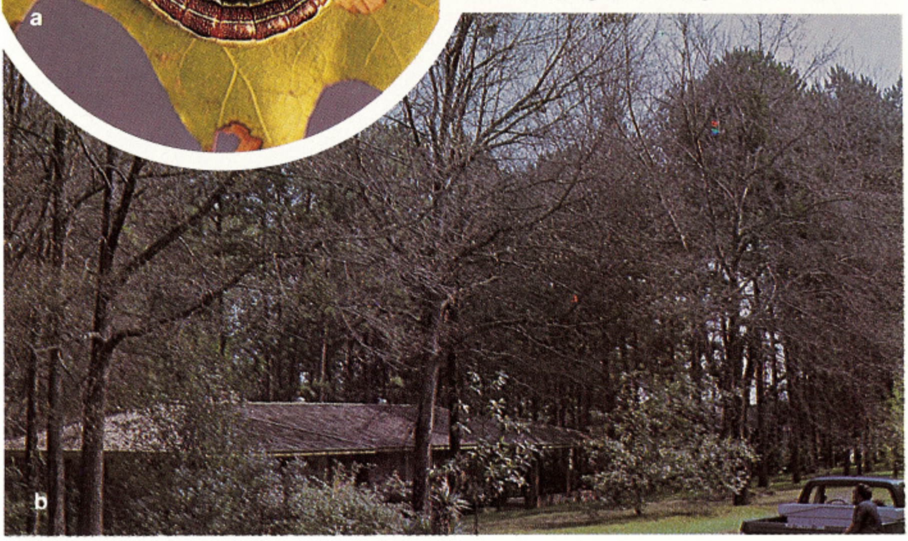



Figure 4. — (a) variable oakleaf caterpillar larva; (b) defoliation by variable oakleaf caterpillar in residential area.

YELLOWNECKED CATERPILLAR, *Datana ministra* (Drury)

Importance. — This caterpillar is a defoliator of oaks and a few other hardwoods throughout the United States. Infestations have been most common in the Appalachian and Ozark Mountains and foothills. Damage is more severe to shade and ornamental trees than to forest stands.

Identifying the Insect (figure 5). — The larva is yellowish and black striped, and moderately covered with fine, white hairs. The head is jet black; the segment behind the head is bright orange-yellow — hence its name, yellownecked caterpillar. Full grown larvae are about 2 inches (50 mm) long. When disturbed, the larvae lift their head and tail in a distinctive "U" shape.

Identifying the Injury. — Newly hatched larvae skeletonize the leaf; older larvae devour all except the leaf stalk. Individual trees, or even stands, may be defoliated during summer and early fall.

Biology. — Moths appear during June and July and deposit white eggs in masses of 50 to 100 on the undersides of the leaves. Larvae feed in groups, maturing in August and September. Mature larvae drop to the soil and pupate at depths of 2 to 4 inches (5 to 10 cm) where they spend the winter. There is one generation per year.

Control. — Natural enemies generally keep infestations in check. Chemical controls are occasionally needed.

Figure 5. — Yellownecked caterpillar larvae.

FOREST TENT CATERPILLAR, *Malacosoma disstria* (Hubner)

Importance. — Outbreaks occur periodically on oaks and other hardwoods over wide areas of the eastern half of North America. Growth loss and dieback occur, but trees are seldom killed unless they sustain 3 or more successive years of defoliation.

Identifying the Insect (figure 6a). — Caterpillars have pale bluish lines along the sides of a brownish body; a row of keyhole-shaped white spots down the middle of the black back; sparsely covered with whitish hairs; and reach 2 inches (50 mm) at maturity. Adult moths are buff-brown with darker, oblique bands. Egg masses of 100 to 350 eggs encircle the twigs and are covered with frothy, dark brown cement.

Identifying the Injury (figure 6b). — The first noticeable signs of attack are sparse crowns and falling frass. Caterpillars often cluster on the lower trunks of infested trees. Trees or even stands may be completely defoliated during spring.

Biology. — Eggs hatch in early spring. Caterpillars feed for 4 to 6 weeks on the opening buds, foliage, and flowers. Despite its name, this species does not form tents. Pupation occurs in yellowish cocoons and lasts 10 to 14 days. Moths emerge from late May to July and deposit their eggs, which overwinter. There is one generation per year.

Control. — Natural controls include insect parasites of the pest's eggs, larvae, and pupae. Predators, virus and fungus diseases as well as high and low temperatures also kill forest tent caterpillars. Several chemicals and a microbial insecticide are registered for control.

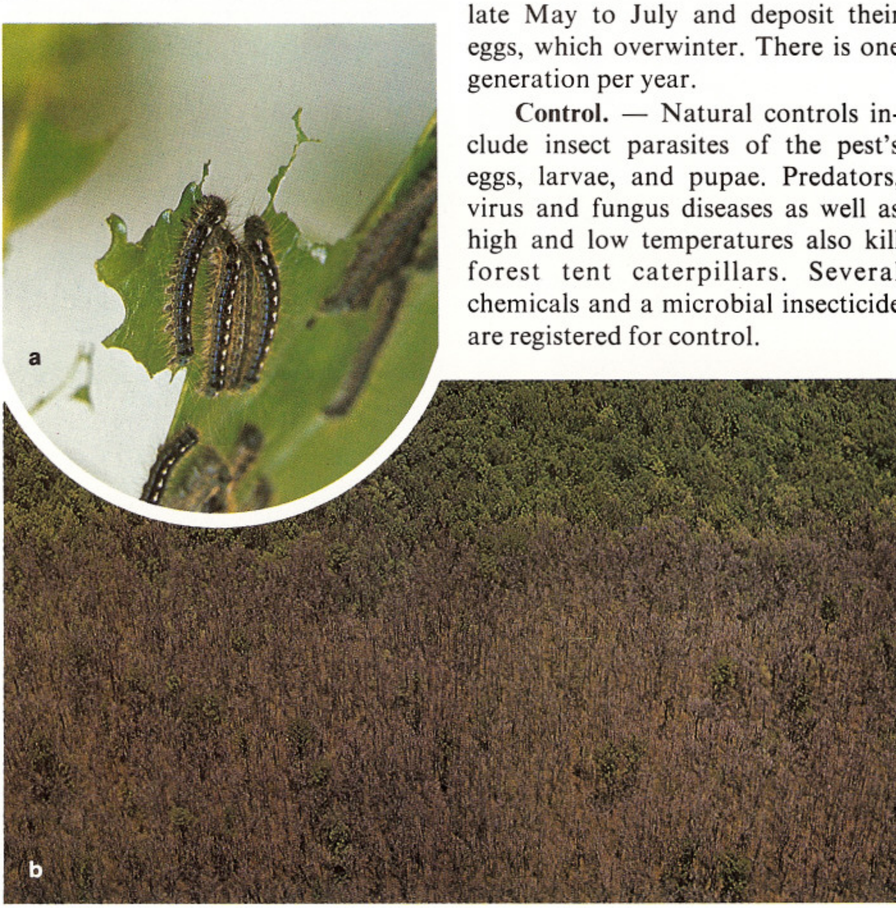


Figure 6. — (a) Forest tent caterpillar larvae; (b) defoliation by forest tent caterpillar.

GYPSY MOTH, *Lymantria dispar* (Linnaeus)

Importance. — The gypsy moth, which came from France, has long been considered one of the most important pests of red and white oaks in the Northeast. It has spread southward to Virginia and appears to be moving in on southern hardwoods. It causes widespread defoliation resulting in reduced growth, loss of vigor, mortality, and reduces aesthetic, recreational and wildlife values.

Identifying the Insect (figure 7a). — Larvae are brownish gray with tufts of hair on each segment and a double row of five pairs of blue spots, followed by six pairs of red spots, on the dorsum. Larvae are about 1.6 to 2.4 inches (40 to 60 mm) long. Adult females are whitish and males are dark brown.

Identifying the Injury (figure 7b). — Young larvae chew small holes in leaves. Older larvae feed on leaf edges, consuming entire leaves except for the larger veins and the midrib. The entire tree may be defoliated.

Biology. — Larvae emerge in May from overwintering eggs and feed until mid-June or early July. Pupation occurs in sheltered places and lasts 2 weeks. Adults emerge in July and August. Females deposit masses of 100 to 800 eggs covered with buff-colored hairs on trunks and other sites.

Control. — Natural controls including introduced insect parasites and predators, virus disease, and adverse weather conditions help control the gypsy moth. Chemical and microbial insecticides have been used extensively.

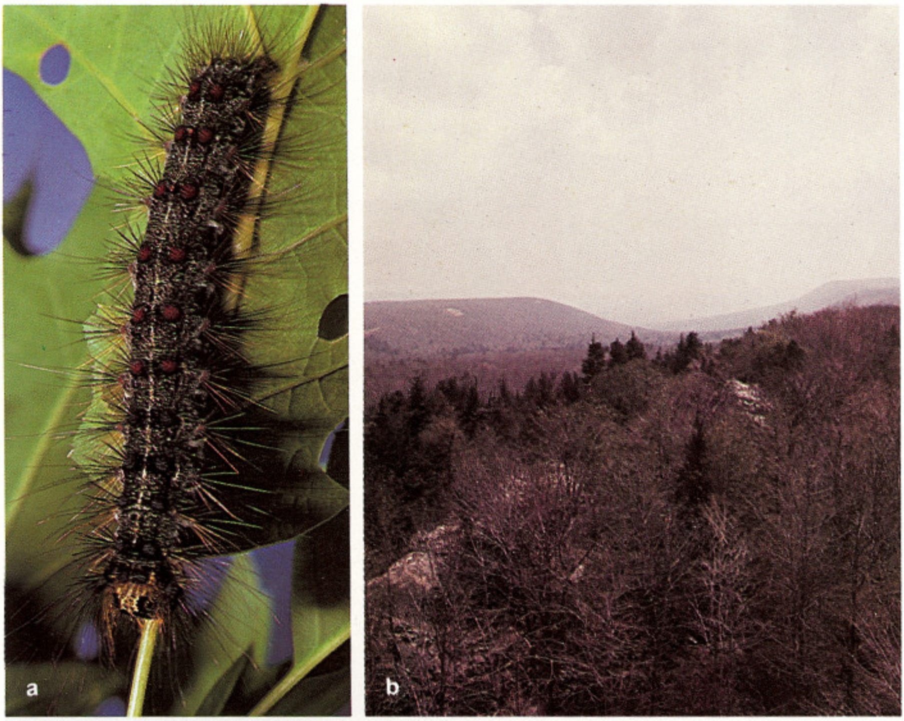


Figure 7. — (a) Gypsy moth larva; (b) defoliation by gypsy moth.

SLUG OAK SAWFLY, *Caliroa quercuscoccineae* (Dyar)

Importance. — This pest is usually endemic on the oaks; however, during 1974-1976, it was epidemic in Kentucky, Virginia and Tennessee. Repeated defoliations retard growth, vigor, and mast crops, and kill some trees.

Identifying the Insect (figure 8a). — Larvae are slug-like, yellowish-green and shiny with a black head and thoracic legs, and .5 inch (12 mm) long. Larvae feed in groups. The adult is a typical sawfly, about .25 inch (6-8 mm) long, and light brown.

Identifying the Injury (figure 8b). — Leaves may be skeletonized. Larvae consume the epidermis, making the leaf transparent. The leaf is left with a fine network of veins. Defoliation starts in the upper crown in early summer and progresses downward. By late summer, heavily infested trees may be completely defoliated.

Biology. — Larvae in cocoons survive the winter. Larvae pupate in the spring. Adults and larvae are present throughout the summer. Eggs are deposited in single rows of slits on the lower leaf surface along main veins. There are two to three generations per year.

Control. — Microbial diseases and other natural enemies generally keep the slug oak sawfly in check. Insecticides may be needed on high-value trees.

Figure 8. — (a) Slug oak sawfly larvae; (b) feeding injury by slug oak sawfly.

WALKINGSTICK, *Diapheromera femorata* (Say)

Importance. — The walkingstick attacks oaks and other species throughout the East. Branches are killed or die back in heavily defoliated stands. Continued defoliation for several years can kill the trees. The insects create a nuisance in high-use areas such as parks and recreation areas.

Identifying the Insect (figure 9a). — Nymphs and adults are slender and have long thin legs and antennae. While motionless, they closely resemble twigs of their host. Adults are about 2.5 to 3 inches (62-76 mm) long. Body color varies.

Identifying the Injury (figure 9b). — The entire leaf blade, except the base of stout veins, is consumed. During heavy outbreaks, large stands are often completely denuded. Trees may be defoliated twice during the same season.

Biology. — Overwintering occurs in the egg stage, in leaf litter. Eggs hatch in May and June. Nymphs reach adulthood during summer and fall. Females deposit up to 150 eggs which are dropped randomly to the forest floor. There is one generation per year in the South; 2 years are required farther North.

Control. — Natural controls are often effective. Chemical control is occasionally needed in high-use areas.

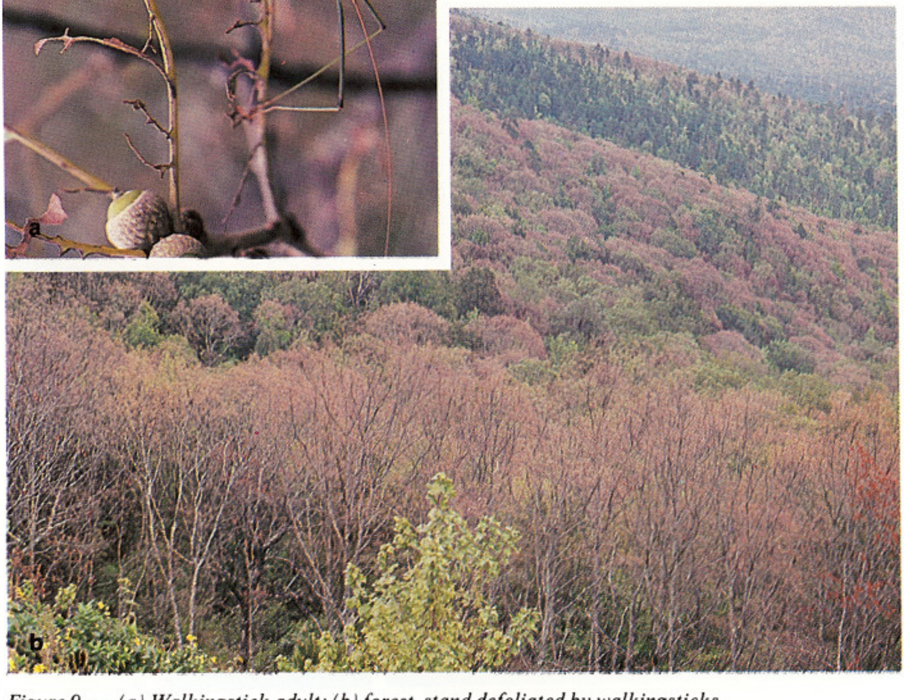


Figure 9. — (a) Walkingstick adult; (b) forest stand defoliated by walkingsticks.

OAK LEAFROLLER, *Archips semiferanus* (Walker)

Importance. — This insect sometimes defoliates many red and white oaks throughout the East. Defoliation has been most severe along ridge tops where white and chestnut oak frequently occur. Forest areas are often defoliated for several consecutive years, killing many trees.

Identifying the Insect (figure 10). — Larvae are various shades of green about 1.2 inch (29 mm) long, and have black heads. At rest, the wings of the adult appear bell-shaped and are creamy brown and gray with a darker cross band.

Identifying the Injury. — The larvae either fold or roll individual leaves together, forming an enclosure for protection and rest, when not feeding. Extensive stands of trees may be completely defoliated, including the understory.

Biology. — Overwintering eggs hatch in April and the young larvae begin rolling the leaves and feeding. Feeding is complete by mid-June and pupation occurs in cocoons within the rolled leaf or in bark crevices. Moths emerge in late June or early July and deposit eggs in masses on the trunk and branches.

Control. — Natural enemies are usually effective. Chemical controls may be needed to protect high-value trees.

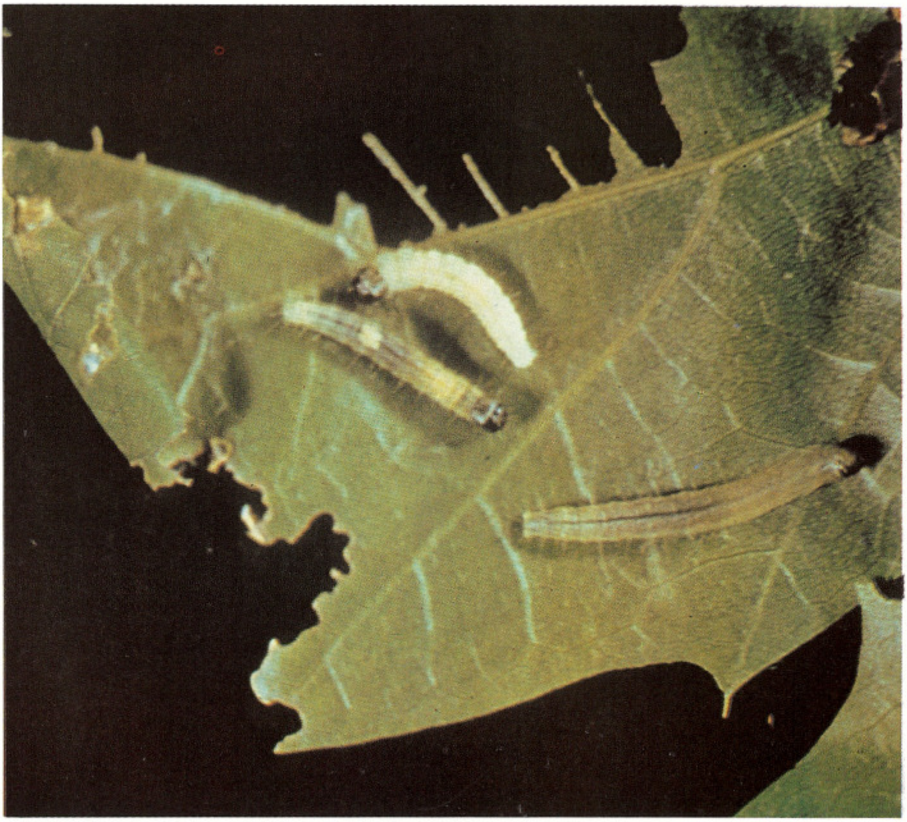


Figure 10. — Oak leafroller larvae.

SOLITARY OAK LEAFMINER, *Cameraria hamadryadella* (Clemens)

GREGARIOUS OAK LEAFMINER, *Cameraria Cincinnatiella* (Chambers)

Importance. — These leafminers occur over much of the East. They attack various oaks, but prefer the white oak group. Heavy infestations cause browning and premature dropping of foliage — sometimes over large areas.

Identifying the Insect. — Adults and larvae of both species are similar. Young larvae are flat and taper toward the rear, and are about .25 inch (6 mm) long at maturity. Adults are pale and silvery with bronze patches on the wings.

Identifying the Injury. — Larvae of the solitary oak leafminer feed singly, forming irregular, blotch-like mines just below the upper leaf surface; a single leaf may contain several contiguous mines (figure 11). Larvae of the gregarious oak leafminer feed together, forming large mines.

Biology. — The winter is spent in the larval stage in leaves on the ground. Adult moths emerge during the spring and females lay eggs on the leaves. There are two to several generations per year.

Control. — Rake fallen leaves promptly and burn them to destroy pupae in cocoons. Natural enemies are helpful. Chemical control is occasionally needed.

Figure 11. — Leafmines caused by the solitary oak leafminer.

OAK SKELETONIZER, *Bucculatrix ainsliella* (Murteldt)

Importance. — This insect is common on the oaks, particularly the red oaks, in the East. Trees that sustain repeated attacks are weakened and suffer crown thinning and die-back. Ornamental trees appear especially vulnerable.

Identifying the Insect (figure 12a). — Larvae are slender, yellowish-green, and .2 inch (5 mm) long. They often spin down on silken threads when disturbed. Adults are small, blackish and marked with paler areas.

Identifying the Injury. — Caterpillars eat the fleshy green part of the lower surface, entirely or in part, which gives the leaves a brownish, skeletonized appearance (figure 12b). As heavily infested trees are defoliated, the skeletonized leaves drop off and cover the ground.

Biology. — Winter is spent in the pupal stage in white cocoons, about .1 inch (3 mm) long and ridged longitudinally on leaves and trunks. Adults emerge during the spring and deposit eggs on the undersides of fully grown leaves. The youngest (first-instar) larvae enter the leaves to feed, forming tiny mines. Older larvae feed externally. There are two or more generations per year.

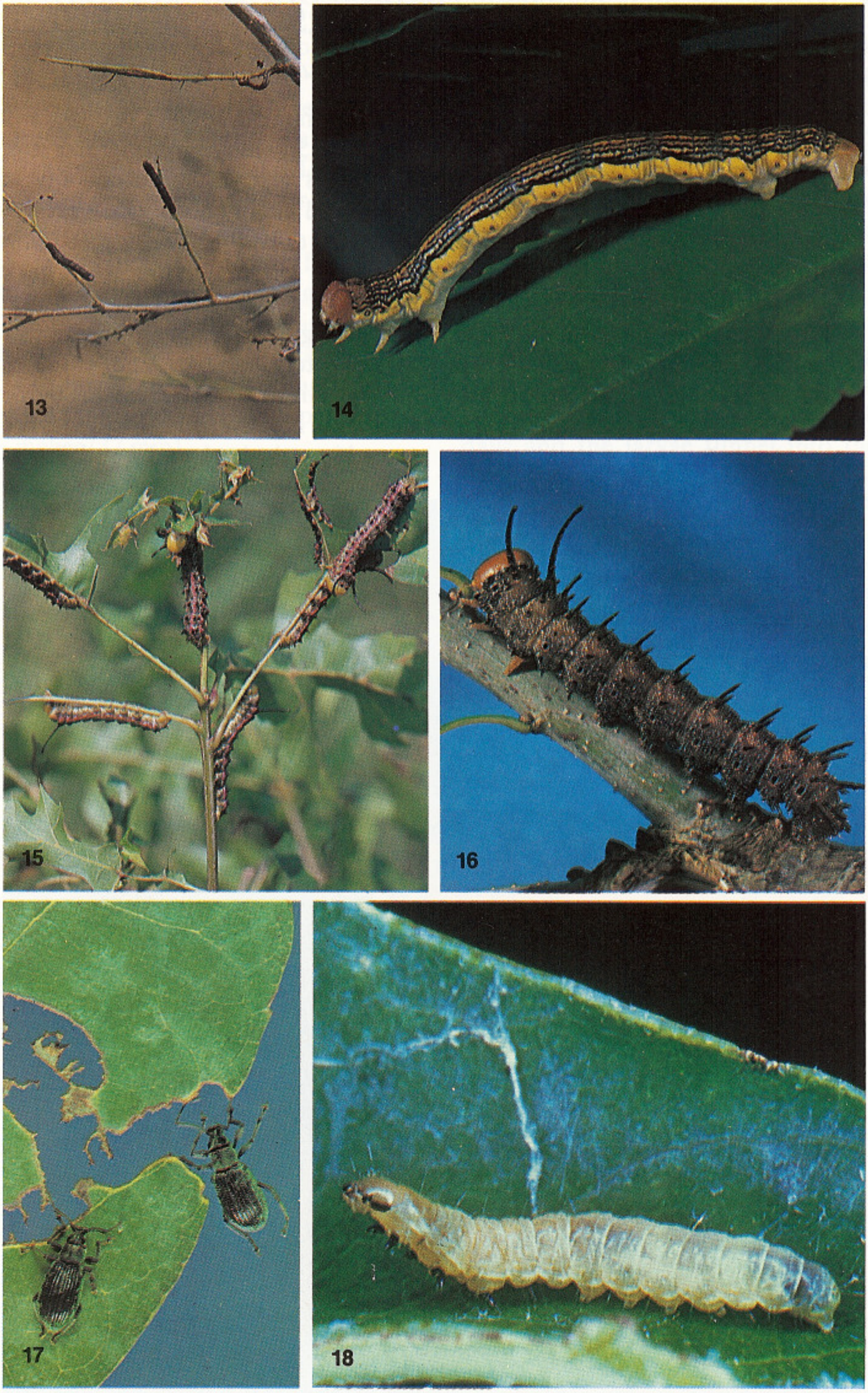
Control. — Rake fallen leaves promptly and burn them to destroy cocoons. Insecticides may be necessary on high-value trees.

Figure 12.—(a) Larvae and cocoons of oak skeletonizer on undersurface of leaf; (b) leaf skeletonized by oak skeletonizer.

MINOR DEFOLIATORS

Insect	Injury	Control*
Spring cankerworm, *Paleacrita vernata* (Peck); the larva (figure 13) is a typical looper, yellowish-brown to greenish-black with two yellowish stripes, about 1.2 inch (30 mm) long; the female moth is wingless, gray with black dorsal line; one generation per year.	Many hosts, heavy on live oak in Texas; skeletonizes leaves at branch tips; may devour all but midribs and large veins; outbreaks can occur on shade trees and forested areas; reduces tree vigor and growth.	1 2 11 12
Linden looper, *Erannis tiliaria* (Harris); the larva (figure 14) is a looper-type, yellow with brown head and 10 wavy black lines on dorsum,1.5 inches (37 mm) long; female moth is wingless, yellowish-gray with two rows of black spots; one generation per year.	Many hosts, heavy on white oaks in South; partial feeding on individual leaves (ragging) is typical, complete defoliation occurs during outbreaks; outbreaks less common in South than in North; reduces tree vigor and growth.	1 2 11
Pinkstriped oakworm, *Anisota virginiensis* (Drury); the larva (figure 15) is greenish-brown with four pink stripes, a pair of long, curved "horns" is on the second thoracic segment, 2 inches (50 mm) long; the adult is a brownish-red moth, white spot on forewings; two generations per year.	Red and white oaks; leaves eaten except leaf stalks and midribs; stripped branches and trees common, entire stands less common; defoliation in summer and fall; less common than orangestriped oakworm, except in bottomland forests; causes growth loss and crown decline.	1 11
Spiny oakworm, *Anisota stigma* (Fabricius); the larva (figure 16) is tawny and pinkish with white specks, 2 inches (50 mm) long, two long curved "horns" are on the second thoracic segment, and short spines on all other segments; one or two generations per year.	Red and white oaks; larvae feed on leaves, July to September, consuming all but leaf stalk and main veins; partial defoliation common; heavy widespread defoliation uncommon.	1 11
Asiatic oak weevil, *Cyrtepistomus castaneus* (Roelofs); adults (figure 17) are greenish-brown to black weevils, .25 inch (6 mm) long, with short snouts; one generation per year.	Wide host range, including red and white oaks; adults emerge in spring and feed on leaves by chewing in from the margins toward the midribs and devour all but the larger veins; during fall they create nuisances by invading houses in large numbers.	1 11
Oak leaftier, *Croesia semipurpurana* (Kearfott); the larva (figure 18) is dirty white to light green, .5 inch (12 mm) long, pale head, brownish thoracic legs; adults are yellow with brown markings; one generation per year.	Foliage of red oak group; young larvae feed on buds in early spring; older larvae fold or tie together sections of leaves with webbing and feed inside the folds until late May; severe outbreaks have occurred in upland oaks, killing some trees, with decline of others.	1 11

*See CONTROLS, page 66.



Figures 13-18.— (13) Spring cankerworm larvae on defoliated branch; (14) linden looper larva; (15) pinkstriped oakworm larvae; (16) spiny oakworm larva; (17) asiatic oak weevil and feeding injury; (18) oak leaftier larva.

CARPENTERWORM, *Prionoxystus robiniae* (Peck)

Importance. — Carpenterworms are serious borers throughout the United States. Wormholes cause degrade estimated at 15 percent of the value of rough sawn lumber and unsightly scars on ornamental trees.

Identifying the Insect (figure 19a). — Newly hatched larvae are .25 inch (6 mm) long and reddish pink. Larvae gradually become greenish white and are 2 to 3 inches (50 to 75 mm) long at maturity. Brown pupal skins protruding from entrance holes are common in early summer. Adults are grayish, stout-bodied moths; the hindwing in the male has an orange spot (figure 19b).

Identifying the Injury (figure 19c). — Earliest signs of attack are sap spots on the trunk. Later, frass (wood chips and pellets) is ejected from entrance holes. Burrows 2 inches (50 mm) in diameter under the bark, and galleries .5 inch (12 mm) in diameter and 5 to 8 inches (12 to 22 cm) long in the wood are typical. Galleries are open or only loosely plugged with frass. Holes in lumber are dark stained.

Biology. — Adult moths appear in April to June and deposit 400 to 800 eggs in bark crevices. Eggs hatch in 10 to 12 days and young larvae tunnel into the bark and wood. Pupation occurs within the gallery during spring and lasts 3 weeks. A life cycle requires 1 to 2 years in the South, and 2 to 4 years in the North.

Control. — Maintain high tree vigor. Remove brood trees. Prevent bark injuries. Natural enemies help. Control with trunk spray or gallery fumigation.

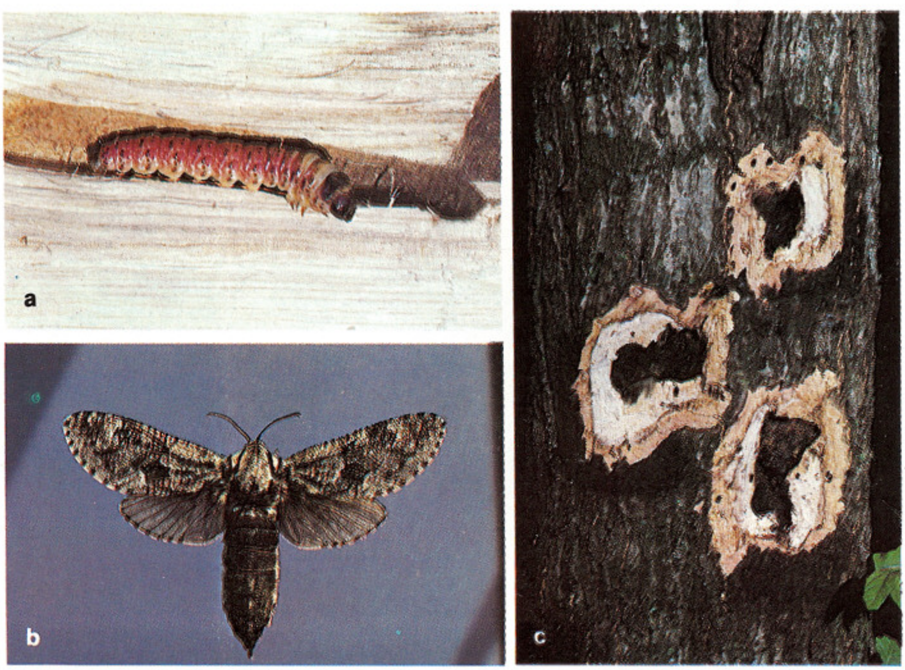


Figure 19. — (a) carpenterworm larva in gallery; (b) carpenterworm female moth; (c) tree trunk with carpenterworm attacks.

OAK CLEARWING BORER, *Paranthrene simulans* (Grote)

Importance. — This borer attacks the lower trunk of red and white oaks throughout the East. In the South, attacks are most common between root flanges of large red oaks. Damage includes degrade, entries for decay and nursery cull.

Identifying the Insect (figure 20a). — The larva is purplish gray, black head, brown thoracic shield, and 1 inch (25 mm) long. Adults are colorful, black and orange banded, beelike moths with a wing expanse of 1.5 inches (37 mm).

Identifying the Injury (figure 20b). — Sap spots and fine frass first appear. Later, granular frass is ejected in clumps from .3 to .6 inch (9 to 15 mm) entrance holes. There is little mining under the bark. Galleries are .3 inch (9 mm) in diameter, 4 inches (10 cm) long in the wood, and shaped much like those made by carpenterworms (figure 20c).

Biology. — Moths emerge during June and July and deposit eggs in bark crevices. Eggs hatch in 15 to 18 days and the larvae tunnel into the bark and wood of host trees. Pupation occurs within the gallery. A generation requires 2 years.

Control. — Open-grown trees are most susceptible, thus maintain a well stocked stand. Identify and remove brood trees. Prevent or minimize injuries. Larvae can be "wormed-out" with a knife and wire. Insecticides will protect valuable trees. Individual borers can be killed by gallery fumigation.

Figure 20. — (a) Male moth of oak clearwing borer; (b) oak clearwing borer entrance holes in bark; (c) gallery made by oak clearwing borer.

RED OAK BORER, *Enaphalodes rufulus* (Haldeman)

Importance. — Many of the large oaks in the East have been attacked by this borer, resulting in defects and serious degrade in the timber. Valuable shade trees in parks and cities are sometimes injured.

Identifying the Insect (figure 21a). — Adult borers, are light brown, robust beetles with long antennae and about 1 inch (25 mm) long. The shiny white, robust larvae have tiny legs on the thorax.

Identifying the Injury. — Initially, tiny pin-holes with fine, extruded frass are present. Later, entrance holes become larger and sap-stained, followed by ejection of granular frass (figure 21b). A few excelsior-like fibers are present in frass just before pupation. Tunnels are about .5 inch (12 mm) in diameter and 6 to 10 inches (15 to 25 cm) long (figure 21c).

Biology. — The pest has a 2-year life cycle. Eggs are laid in July and August on the bark. The larva mines under the bark during the first year, tunneling into the wood the second year. Pupation occurs and the adult exits through the bark near the entrance.

Control. — Maintain high tree vigor. Remove brood trees. "Worm-out" with knife or wire. Control in high-value trees with trunk spray or gallery fumigation.

Figure 21. — (a) Adult beetle of red oak borer; (b) sapstained bark and entrances typical of the red oak borer; (c) cross-section of oak trunk with red oak borer holes.

WHITE OAK BORER, *Goes tigrinus* (DeGeer)

Importance. — This borer is found in the East wherever its host species grow. Young trees 2 to 8 inches (5 to 20 cm) in diameter, in the white oak group are attacked. Some degrade occurs.

Identifying the Insect (figure 22a). — The larva is moderately robust and cylindrical; 1 to 1.5 inches (25 to 37 mm) long; yellowish-white; head strongly depressed with dark brown mandibles; and legless. The adult beetle has a spine on each side of the thorax; about .8 to 1 inch (20 to 28 mm) long; white and brown mottled; and antennae about as long as the body.

Identifying the Injury (figure 22b). — Egg niches .25 inch (6 mm) in diameter cut singly in the bark are followed by sap ooze and fine, moist frass. Later, the insects eject yellowish, ribbon-like pieces of frass containing pulverized wood and fibrous shreds. Galleries are about .5 inch (12 mm) in diameter and 6 inches (15 cm) long. Each borer leaves a small, elongate entrance hole and a circular .3 inch (8 mm) exit hole.

Biology. — Adult beetles emerge during May to June and deposit eggs. Eggs hatch in about 3 weeks and the larvae tunnel directly into the wood. Pupation occurs within the gallery and lasts 2 to 3 weeks. A life cycle requires 3 to 5 years.

Control. — Woodpeckers and sap-ooze are the most important natural controls. Remove brood trees. Follow practices that promote stand vigor. Direct controls are occasionally needed.

Figure 22. — (a) White oak borer larva in gallery; (b) brood-tree of white oak borer with numerous attacks and frass around the base of the tree.

TWOLINED CHESTNUT BORER, *Agrilus bilineatus* (Weber)

Importance. — This borer attacks red and white oaks throughout the East. Trees weakened by drought, defoliation, or other factors are most susceptible. Larvae destroy the cambium and girdle the tree. Mortality has been extensive in weakened stands.

Identifying the Insect. — Adult beetles are about .2 to .5 inch (6 to 12 mm) long, slender, and black with a light yellowish stripe on each wing cover. Larvae are white, slender, flattened, about 1 inch (25 mm) long, and have two spines at the rear end.

Identifying the Injury (figure 23). — Larvae excavate winding mines in the inner bark and outer sapwood of the main trunk and large branches, frequently girdling the tree. Attacks usually begin in the tree tops and extend downward as the trees continue to weaken. D-shaped emergence holes are evidence of infestation.

Biology. — Adults emerge during spring and early summer and deposit eggs in bark crevices. Eggs hatch in 10 to 14 days and the larvae burrow through the bark and cambium. They overwinter in cells in the bark and pupate the following spring. There is one generation per year.

Control. — Control is mainly a matter of preventing attacks through cultural practices that promote tree vigor. Spraying to protect foliage from defoliators is recommended in some areas. Trunk sprays offer some promise.

Figure 23. — Twolined chestnut borer larvae and mines in inner bark.

OAK TIMBERWORM, *Arrhenodes minutus* (Drury)

Importance. — The oak timberworm is a major cause of defect and degrade in the red and white oaks in the East. Attacks are most commonly associated with wounds on mature trees.

Identifying the Insect (figure 24a). — Adults are brownish black, brentid weevils about 1 to 1.4 inches (25 to 35 mm) long. The female has a narrow snout, while the male's mouth-parts are broad and flattened. The larvae are white, elongate, cylindrical, and curved (figure 24b).

Identifying the Injury. — Attacks usually occur at blazes, around other borer entrances, and other wounds that expose the sapwood. White, powdery frass at egg sites on exposed wood is good evidence of infestation. Winding tunnels .1 inch or smaller (0.2 to 3 mm) in diameter, characterize damage in lumber.

Biology. — During spring and early summer, females chew cylindrical holes into the sapwood and lay single eggs. Eggs hatch in a few days and the larvae bore almost through the tree then "U-turn" back across the grain to the point of origin. Pupation occurs in the gallery, and adults emerge through circular holes near the egg site. The life cycle requires 2 to 3 years.

Control. — Avoid wounds and injuries, including other borer attacks to largely prevent infestation by the oak timberworm.

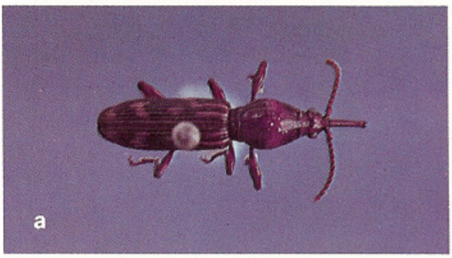


Figure 24. — (a) Oak timberworm adult female; (b) oak timberworm larvae and galleries in wood.

COLUMBIAN TIMBER BEETLE, *Corthylus columbianus* (Hopkins)

Importance. — This beetle occurs over much of the East and attacks the white oaks and, to a lesser extent, the red oaks. It attacks the trunks of live trees of all sizes. Damaged wood is degraded for such uses as veneer, cooperage, and furniture.

Identifying the Insect (figure 25a). — Adults are black to reddish-brown, cylindrical beetles about .2 inch (4 mm) long. The larvae are white, legless and C-shaped.

Identifying the Injury (figure 25b). — Holes less than .1 inch (1 to 2 mm) in diameter, are bored straight into the sapwood until the tunnel nears the heartwood, then it turns right or left. Damage is conspicuous in log ends. Streaks of stain originating from the tunnels are known as flagworm defects.

Biology. — Adult beetles construct galleries. Eggs are laid in chambers along the main tunnel where the larvae live and develop. Larval food is a white fungus that grows on the gallery walls. There are two to three generations per year.

Control. — There is no apparent relationship between tree vigor and susceptibility. No natural enemies have been found. Protection of veneer-quality trees with insecticides seems possible.

Figure 25. — (a) Columbian timber beetle adult in brood cell; (b) columbian timber beetle galleries and "flag" stains in white oak.

PIN-HOLE BORERS, *Platypus* spp. and *Xyleborus* spp.

Importance. — These ambrosia beetles are best known for their damage to fresh-cut logs and unseasoned lumber. They also readily attack weakened, stressed, and dying trees and healthy trees with bark injuries. Damage is largely in the form of degrade.

Identifying the Insect. — Adult beetles are black to brown; .1 to .2 inch (3 to 6 mm); elongate and cylindrical with a wide head in *Platypus* and cylindrically compact in *Xyleborus* species. Larvae are white, slightly curved to curculiform, legless, and .1 to .2 inch (3 to 6 mm) long.

Identifying the Injury (figure 26a). — White to light brown boring dust in small piles in bark crevices is good evidence of attack. Numerous round holes about .1 inch or less (1.5 to 3 mm) in diameter, branched or unbranched, stained black, extend into the wood. The lower trunk may sustain hundreds of attacks (figure 26b).

Biology. — The beetles are attracted to wood with a moisture content above 48 percent. They do not feed on the wood, but instead feed upon ambrosia fungi which they culture within the galleries. In the Gulf States, beetles are active most of the year. There are two or more generations per year.

Control. — Maintain tree vigor. Salvage infested timber immediately. Promptly use logs during summer months. Store logs under water or water spray. Green lumber is often kiln dried or chemically dipped to prevent attack.

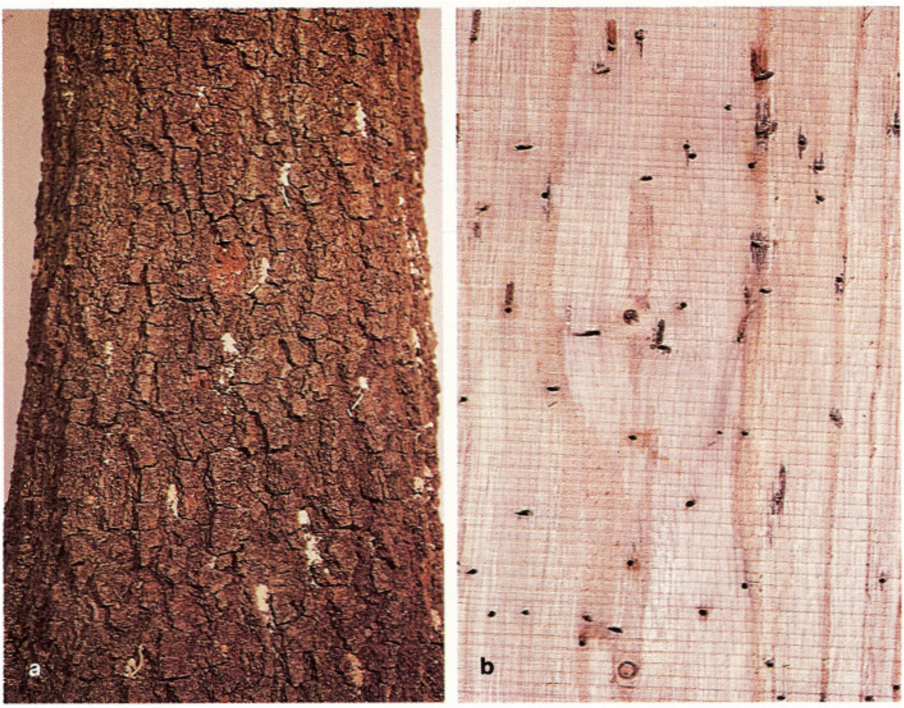


Figure 26. — (a) Pin-hole borer attacks indicated by frass on bark; (b) numerous holes made in wood by pin-hole borers.

TWIG PRUNER, *Elaphidionoides villosus* (Fabricius)

Importance. — The twig pruner occurs throughout the East. It prefers the oaks but also attacks other deciduous species. Larvae bore into the stems and cut off or prune twigs, terminals, and branches about .25 to 1 inch (6 to 25 mm) in diameter. Severe pruning adversely affects tree form and the aesthetic quality of ornamental plantings, and creates clean-up problems.

Identifying the Insect (figure 27a). — Larvae are cylindrical, white, and measure about .5 to .8 inch (12 to 21 mm) long at maturity. Adult beetles are gray mottled.

Identifying the Injury (figure 27b). — During the summer, fall, and winter, pruned twigs (with leaves attached) 12 to 40 inches (30 to 100 cm) long litter the ground under infested trees. The end of the severed twig presents a smoothly cut surface. Split the pruned twigs to reveal the larva.

Biology. — Adults emerge during spring and deposit eggs in small twigs. The larva burrows down the center of the stem and severs the twig, which falls to the ground, in late summer or fall. Pupation and adult emergence occur the following spring. There is one generation per year.

Control. — Collect and burn severed twigs during the fall and winter. Natural enemies help control the twig pruner. Insecticides are rarely needed.

Figure 27. — (a) Ends of girdled twigs, tunnel, and larva of twig pruner; (b) young tree with top recently severed by twig pruner.

TILEHORNED PRIONUS, *Prionus imbricornis* (Linnaeus)
BROADNECKED ROOT BORER, *Prionus laticollis* (Drury)

Importance. — These root borers occur throughout the East. Roots are often hollowed or severed. Open-grown trees and those weakened by disease are most susceptible. Young, vigorous trees are occasionally cut off at the ground.

Identifying the Insect (figure 28a). — Larvae of both species are fleshy, creamy white with three pairs of small legs. They have cylindrical bodies and attain lengths of up to 3 inches (75 mm). The adult beetles are robust, broad, dark brown, somewhat flattened, and up to 1.5 inches (37 mm) long (figure 28b).

Identifying the Injury. — Because injury occurs to the roots below ground, correct diagnosis is difficult. The above-ground symptoms are gradual decline of the tree, characteristic of severe, prolonged stress, i.e., leaves sparse, small, and yellowish. Examination of roots reveal the burrowing larvae and root damage (figure 28c).

Biology. — Adult beetles emerge from the soil in early summer and deposit 300 to 500 eggs in the soil. Young larvae burrow through the soil to the roots and begin feeding. The feeding period lasts 3 to 5 years.

Control. — Disease, drought, mechanical injury, and poor soil conditions increase tree susceptibility. Therefore, follow cultural practices that will keep trees thrifty and vigorous. Insecticides are seldom needed.

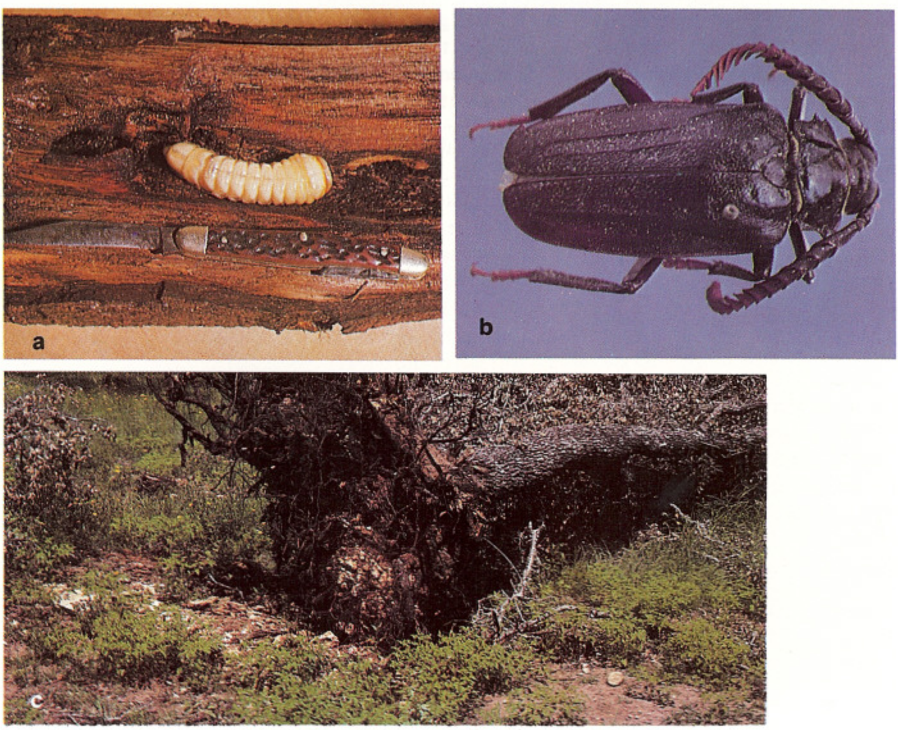
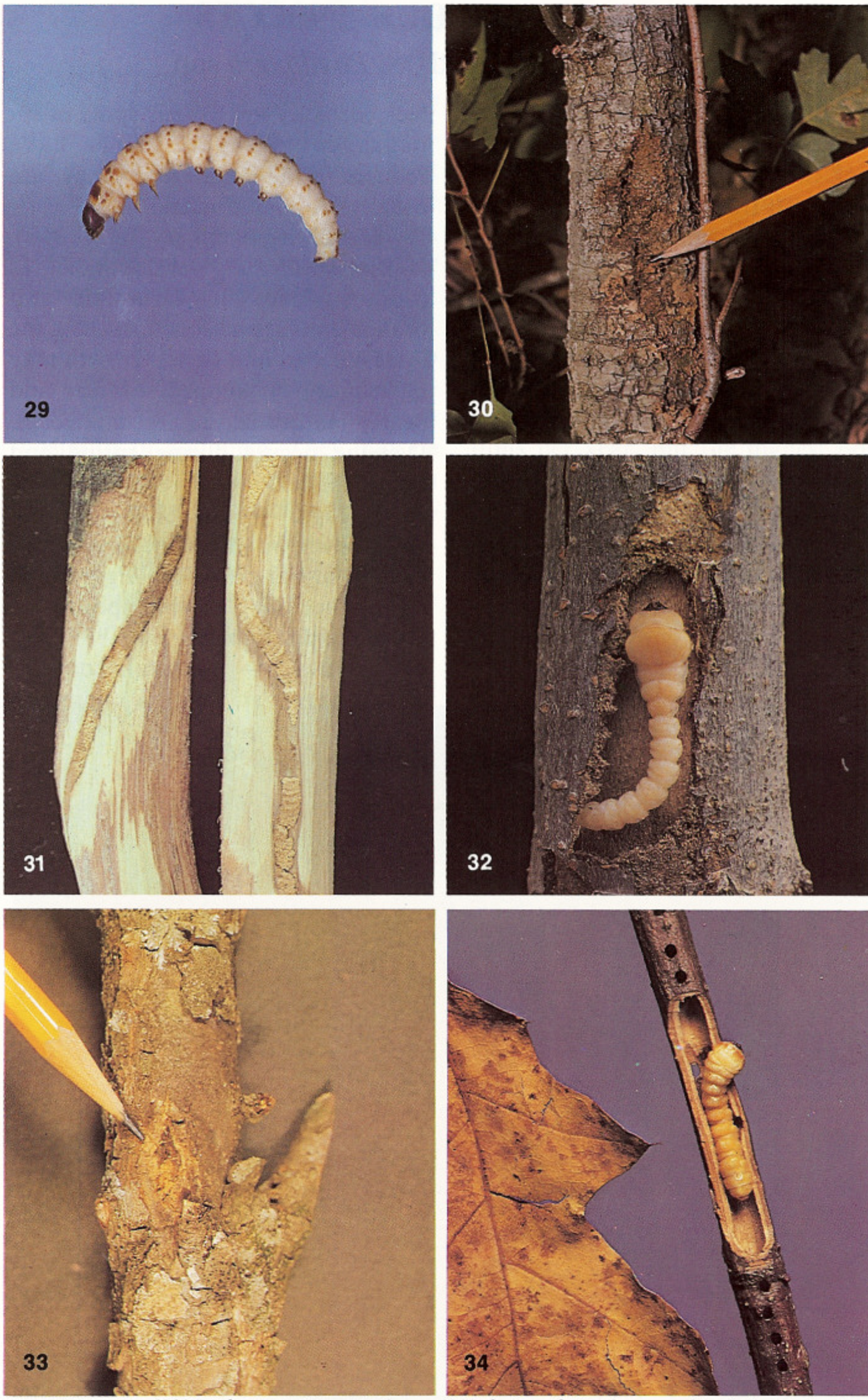


Figure 28. — (a) Larva of Prionus *species tunneling in root; (b) adult beetle of* Prionus *sp.; (c) root damage by* Prionus *sp.*

MINOR BORERS

Insect	Injury	Control*
Little carpenterworm, *Prionoxystus macmurtrei* (Guerin); larva (figure 29) pink to white, dark head and thoracic shield, 2.25 inches (57mm); adult gray-mottled moth; life cycle 2 to 3 years.	Trunks and branches of sawtimber and shade trees; prefers red oaks; mine under bark, and gallery in wood .4 x 6 inches (1 x 15 cm); frass of wood chips and excrement pellets; causes lumber degrade, disfigures ornamental trees.	5 7 8 9 11 13
Beech borer, *Goes pulverulentus* (Haldeman); roundheaded larva, white, legless, cylindrical, about 1.5 inches (37 mm); adult brownish-gray longhorned beetle; life cycle 3 to 5 years.	Trunks of saplings and poles of red oaks; attacks are clustered (figure 30); galleries are about .4 x 8 inches (0.9 x 20 cm); grayish frass with fibrous shreds extruded in ribbons; degrade, entries for decay, stem breakage.	1 5 6 7 11
Spotworm borer, *Agrilus acutipennis* (Mannerheim); larva is slender, flattened, white, about 1.3 inches (32 mm) long; adult beetle is narrow, dark metallic blue, about .5 inches (12 mm) long; a generation requires 2 years.	Trunks over .5 inch (12 mm) in diameter in white oak group, particularly heavy on overcup oak in river bottoms; larvae tunnel spirally in outermost growth ring (figure 31); spot stains and frass-packed tunnels are defects that degrade lumber.	5
Flatheaded appletree borer, *Chrysobothris femorata* (Olivier); larva (figure 32) is flatheaded, white, about 1 inch (25 mm) long; adult beetle is oval, flattened, greenish bronze, about .6 inch (16 mm) long; one generation per year.	Trunks and branches of red and white oaks of all sizes; larvae bore into phloem and outer sapwood; mines girdle and kill small trees; newly transplanted trees and those weakened or stressed are most susceptible.	5 8 9 10 11
Oak branch borer, *Goes debilis* (LeConte); roundheaded larva, legless, yellowish-white, about .6 inch (15 mm); adult longhorned beetle, mottled reddish-brown and gray; life cycle 3 to 4 years.	Small branches and terminals about .3 to 1.5 inches (9 to 37 mm) in diameter, mainly white oaks; attacks (figure 33) near crooks and branch crotches; galleries about .2 x 3 inches (6x75 mm); yellowish frass protrudes from elongate entrance hole; infested stems become swollen, and often break or die back.	1 3 5 6
Oak-stem borer, *Aneflormorpha subpubescens* (LeConte); roundheaded larva, slender, about .7 inch (18 mm) long; adult narrow, light brown, spine on the third and fourth segments of antennae. One generation per year.	Seedlings and sprouts about .5 to 1 inch (12 to 25 mm) diameter; red and white oaks; larva bores down center of stem, cutting off sections, burrows to stem base or roots to overwinter; frass is ejected through row of small holes in bark (figure 34), kills large numbers of seedlings and sprouts in Southeast.	1 11

*See CONTROLS page 66.



Figures 29-34. — *(29) Little carpenterworm larva; (30) cluster of attacks on sapling by beech borer; (31) bark removed to expose larval mines of spotworm borer; (32) flatheaded appletree borer larva in mine under bark; (33) oak branch borer entrance, with yellow frass; (34) oak-stem borer larva in gallery of stem with row of small holes.*

MISCELLANEOUS INSECTS

OAK PHYLLOXERIDS, *Phylloxera* spp.

Importance — Phylloxerids are very small, aphid-like insects that attack the foliage and buds of red and white oak trees of all sizes. Heavy infestations stunt and weaken the trees. The distorted foliage mars the beauty of ornamentals.

Identifying the Insect (figure 35a). — Phylloxerids are small .01 to .02 inch (0.3 to 0.6 mm) long, aphid-like, lack cornicles and usually spiny in appearance. Winged forms have reduced wing veination. They are usually found in clusters.

Identifying the Injury (figure 35b). — Buds and young developing leaves (undersurface) on terminals and branch ends are attacked, causing the leaves to curl and twist. Growth may be reduced or stopped. Mature and nearly mature leaves are unaffected. Damage occurs during spring and early summer.

Biology. — The biology is not well known, but overwintering occurs as eggs in bark crevices. Eggs hatch during the spring. There appear to be several generations per year.

Control. — Natural controls usually keep damage to a minimum. Ornamentals may require chemical control.

Figure 35. — (a) Close-up of oak phylloxerid feeding along leaf midrib; (b) left, leaves curled and deformed by phylloxerids; right, healthy leaves.

OAK LEAF APHIDS, *Myzocallis* spp.

Importance. — These aphids infest the undersides of leaves, leaf stalks, and tender twigs of trees in the red and white oak groups throughout the East. Heavy infestations distort the foliage and weaken the plants. Honeydew and sooty molds further mar the beauty of ornamentals.

Identifying the Insect (figure 36). — The aphids are .04 to .06 inch (1 to 1.5 mm) long, soft-bodied, pear-shaped, with a pair of cornicles at posterior of abdomen. They may be yellow, green, pink, or brown, with darker pigmented blotches on the abdomen, and dusky bands on wings. Winged and wingless forms occur.

Identifying the Injury. — Clusters of aphids feed largely on the underside of the leaves. Feeding injury curls and folds the leaves. Every leaf on a tree may be curled and distorted during heavy attacks. Leaf surfaces become sticky with honeydew followed by growth of black, sooty fungus.

Biology. — Overwintering occurs as eggs deposited in bark crevices of host plants. The eggs hatch in the spring and nymphs begin feeding on the leaves. There are several generations per year, but the highest populations have been observed during the spring.

Control. — Natural enemies usually keep infestations in check. Insecticides are sometimes needed on ornamentals and other high-value trees.

Figure 36. — Oak leaf aphids.

OAK LACE BUG, *Corythucha arcuata* (Say)

Importance. — Adults and nymphs feed on white oaks from Alabama and the Carolinas to southern Canada. By the end of August, the leaves may be discolored and perform little photosynthesis.

Identifying the Insect (figure 37). — Nymphs are black and covered with spines. Adults have broad, transparent, lacelike wing covers; flattened; and about .25 inch (6 mm) long.

Identifying the Injury. — Infested leaves have chlorotic flecks on the upper side of the leaf. Heavily infested trees may be partly defoliated, especially during dry weather.

Biology. — Adults overwinter in bark crevices and similar protected areas of their host. They arouse from hibernation during spring and attach eggs to the underside of leaves. Upon hatching, nymphs begin feeding on the underside of the leaf. A complete cycle from egg to adult may develop in 30 to 45 days; several generations occur each year. In late summer, all active stages may feed together.

Control. — Natural enemies are usually effective. Chemical controls may be needed on shade and ornamental trees.

Figure 37. — Adults and nymphs of oak lace bug.

PERIODICAL CICADA, *Magicicada septendecim* (Linnaeus)

Importance. — Cicadas (locusts) attack oaks as well as other species and are widely distributed in the East. Egg-laying punctures by the adults often severely damage young, transplanted trees and branches of large trees.

Identifying the Insect (figure 38a). — Adults are heavy bodied, and 1.6 inches (40 mm) long. Their wings are transparent with prominent veins. The female is completely black on top, while the male has four or five orange-brown abdominal segments.

Identifying the Injury (figure 38b). — Females puncture the twig in straight rows to lay eggs and often damage twigs so severely that their terminal portions die. Large numbers of molted skins of the nymphs may be found attached to trees trunks.

Biology. — The adult female cuts the bark of twigs and lays 24 to 28 eggs. Newly hatched nymphs drop to the ground, burrow into the soil, and feed on the roots for 13 to 17 years.

Control. — Protect small trees with netting. Properly timed insecticides may be necessary.

Figure 38. — (a) Periodical cicada; (b) branches with egg-laying puncture injuries by periodical cicada.

LECANIUM SCALES, *Lecanium* spp.

Importance. — The lecanium scales are distributed throughout the United States. High scale populations severely reduce vitality, weaken the tree, and cause branch or crown dieback. They have been of greatest concern to shade and ornamental red and white oaks.

Identifying the Insect (figure 39). — The body of the adult female is circular to ovoid, strongly convex or tortoise-shaped, and about .2 to .3 inch (4 to 7 mm) in diameter. Young females may be tan or mottled with black, but older females are reddish or dark brown. After their eggs hatch, the female body shells remain loosely attached to the bark. Scales commonly overlap and encircle portions of infested twigs.

Identifying the Injury. — Trees of poor vigor or with branch and crown dieback should be examined closely for scale insects. Lecanium scales are most prominent on twigs during the spring and early summer.

Biology. — Eggs are produced underneath the female in late spring. Eggs hatch in early summer and the immature insects seek feeding sites on the underside of leaves. In late summer, they migrate to twigs where they overwinter. They complete their development in the spring. There is usually one generation per year.

Control. — Parasites and predators are effective in controlling infestations. However, insecticides are often used and are most effective against immature scales.

Figure 39. — (a) Lecanium scale insects on a branch.

GOUTY OAK GALL, *Callirhytis punctata* (Osten Sacken)

Importance. — This gall is among over 600 gall insects that attack the oaks in the United States. Gouty oak gall is most common on scarlet, red, pin, water, and black oaks. In heavy infestations, twigs, large branches, and occasionally entire trees may be killed.

Identifying the Insect. — Adults are small, black, cynip wasps with an oval, shiny, and slightly compressed abdomen. The larvae are white and globe-shaped.

Identifying the Injury (figure 40a). — Galls are irregular, globose, woody, 1.5 inches (38 mm) in diameter, and encircle the twigs and small branches. They sometimes occur so close together that they form nearly continuous masses (figure 40b).

Biology. — This species has alternate generations. The first produces small blisterlike galls on leaves in the spring. The second produces gouty galls during the summer.

Control. — Natural controls are generally adequate. Prune galls from small trees and destroy. Chemical control is possible, but poorly defined.

Figure 40. — (a) Close-up of single gall showing gall insect emergence holes; (b) trees heavily infested by gouty oak galls.

OAK-APPLE GALL, *Amphibolips confluenta* (Harris)

Importance. — This is one of many leaf galls that affect oaks. These galls usually damage the tree less than do twig galls. However, heavy infestations of this and other leaf galls can cause premature leaf fall and are unsightly on ornamental trees.

Identifying the Insect. — Adults are very small and dark with an oval, compressed abdomen. The larvae are small and globe-shaped.

Identifying the Injury (figure 41). — Galls are about .5 to 2 inches (12 to 50 mm) in diameter, and are filled with a fibrous mass. Each contains a single larva inside a hard center capsule. The galls are produced on the midrib or stem of leaves. Galls formed during spring are green, but become light brown on drying with a thin, papery shell. Oak-apple galls occur principally on red, black, and scarlet oaks.

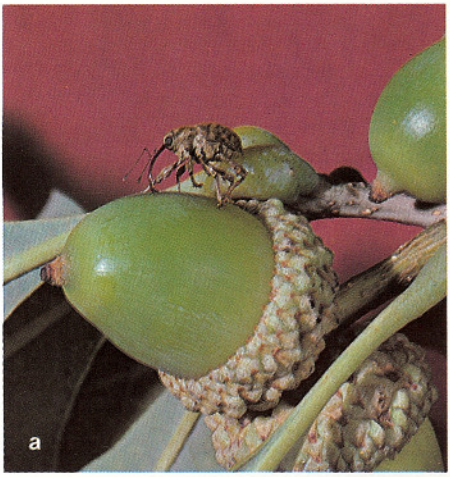
Biology. — Oak-apple galls usually start during spring when the young leaf is being formed, sometimes appropriating the entire leaf for its own purpose. The biology is poorly known, but it probably has alternate generations on different host parts.

Control. — Natural enemies are usually sufficient. Galls can be picked or pruned off small ornamental trees. Direct controls are seldom necessary.

Figure 41. — Cluster of oak-apple galls.

ACORN WEEVILS, *Curculio* spp.

Importance. — These weevils attack both red and white oaks and are found wherever the hosts grow. Also, weevils in the genus *Conotrachelus* and moths in the genus *Melissopus* account for some losses. A major portion of the crop may be destroyed.



Identifying the Insect (figure 42a). — Acorn weevils are robust and brown. The beak is long and slender, sometimes longer than the body, in the female. The larvae are legless, robust, dirty-white, and C-shaped.

Identifying the Injury (figure 42b). — There may be one or more holes in the acorn. Dissecting the acorn will reveal signs of feeding and one or more C-shaped larvae.

Biology. — Female weevils drill one or more holes into the acorn and deposit a single egg in each hole. Larvae feed until full grown, then cut exit holes in the shell. Full-grown larvae enter the soil where they spend 1 to 2 years before pupating and emerging as adults.

Control. — Natural controls help to minimize losses. Chemical control may be needed in seed orchards.

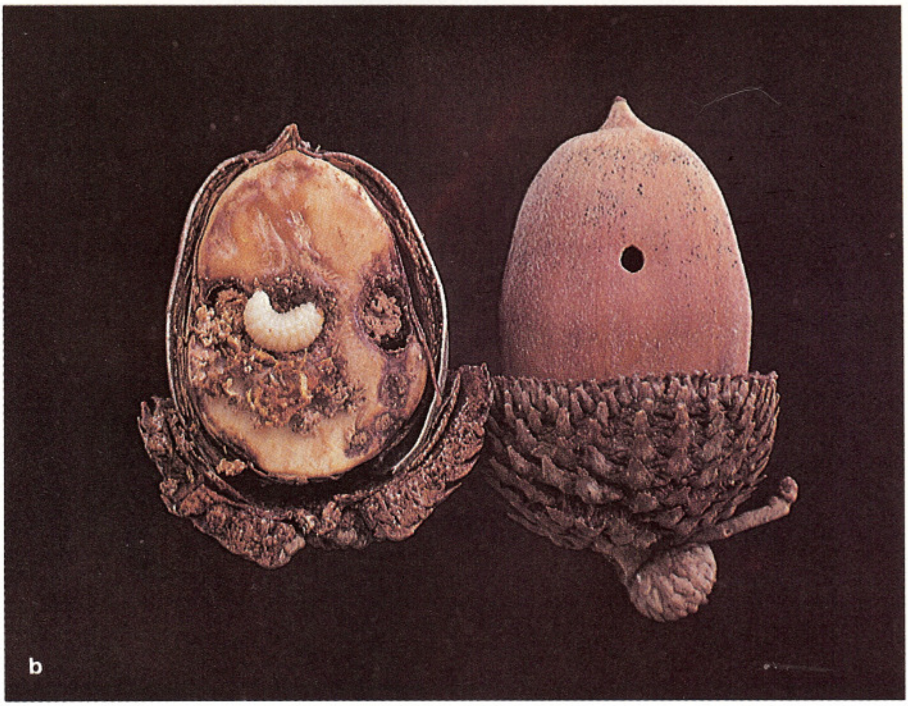


Figure 42. — (a) Adult acorn weevil on acorn; (b) larva, feeding injury, and exit hole of acorn weevil.

MINOR MISCELLANEOUS INSECTS

Insect	Injury	Control*
Giant bark aphid, *Longistigma caryae* (Harris); (figure 43) with relation to other aphids, this species is very large, .25 inch (6 mm) long, long slender legs, and is covered with a bluish-white "bloom": several generations per year.	Terminals, twigs, and branches of red and white oaks; aphids feed by sucking the plant sap; heavily infested stems badly weakened or killed; honeydew and sooty molds mar beauty of ornamentals.	1 11
Pit scales, *Asterolecanium* spp.; adult females are circular and enclosed in yellowish, waxy, translucent covering, .04 to .08 inch (1 to 2 mm) in diameter; one generation per year.	Found on twigs, branches, and trunks of red and white oaks; prefers white oaks; maturing females produce ring-like swellings or pits on the bark (figure 44) causing a rough appearance; branches and trees may be killed.	1 11
Kermes scales, *Kermes* spp.; adult females are globular or gall-like, yellow-brown-black, solid or mottled, about .1 to .3 inch (3 to 7 mm) in diameter.	Scales (figure 45) occur on twigs, branches, near buds, near wounds, on leaf midribs, and petioles of red and white oaks; dieback or "flagging" of newly formed terminals, branch ends, and new leaves; early leaf drop; mar beauty of shade trees.	1 11
Obscure scale, *Melanaspis obscura* (Comstock); adult female cover (figure 46) circular, grayish to black — resembling bark in color .08 to .1 inch (2 to 3 mm) in diameter; two generations per year.	Trunks and branches of red and white oaks; infestations are often heavy and layered, killing branches, or resulting in general weakening, and sometimes death of tree.	1 11
Spider mites, *Oligonychus* spp. and *Eotetranychus* spp.; .02 inch (0.5 mm) long, spider-like, eight legs, sucking mouthparts; large numbers often present; many generations per year.	Foliage and buds of red and white oaks; scattered chlorotic stippling on leaves (figure 47) later yellowing or bronzing, then browning and dying of foliage; mats of webbing often present; weakens tree and mars beauty.	1 11
White grubs, *Phyllophaga* spp.; larva (figure 48) is milky white, C-shaped, about 1 inch (25 mm) long, brown head; adult beetle is robust, oval, brown, about .5 to 1 inch (12 to 25 mm) long.	Wide host range, including oak seedlings and young trees; larval feeding prunes and girdles roots; nurseries and young plantations often damaged; adults may defoliate trees.	1 11

*See CONTROLS page 66.

Figures 43-48. — *(43) Nymphs and adults of giant bark aphid; (44) pit scale on oak branch; (45) kermes scale on oak twigs; (46) obscure scale on oak branch; (47) left, healthy leaves; right, chlorotic stipling caused by spider mites; (48) left, white grubs and root injury; right, healthy roots.*

DISEASES

DECAY FUNGI – CANKER ROTS

HISPIDUS CANKER, *Polyporus hispidus* (Bull.) Fr.

Importance — Hispidus canker, caused by *P. hispidus,* appears on willow oak, Nuttall oak, white oak, and hickory. Incidence of infestation varies by area and species, but may be as high as 13 percent. Cankers lengthen about 6 inches (15 cm) yearly. The decay column length exceeds the canker length. Diseased trees are quickly converted to culls.

Identifying the Fungus (figure 49a).— Hispidus conks are about 2 to 12 inches (5 to 30 cm) wide, spongy, stalkless, yellowish-brown to red, with pores on the lower surface. Conks are produced during the summer or fall. They dry to a black mass, fall, and can usually be found around the base of infected trees.

Identifying the Injury (figure 49b). — Hispidus cankers are large, elongate, sunken in the center and bordered by callus folds. Infected stems become spindle-shaped. A small branch stub may be found near the center where the infection started.

Biology. — Microscopic spores are released from conks for a few weeks. They are spread by the wind, but most travel no more than 140 yards (128 m). Spores reaching dead branches on healthy trees start new infections. Conks will form after deadening or felling diseased trees.

Control — Cut hispidus-diseased trees as soon as possible for salvage and to reduce disease spread by limiting spore dissemination to healthy trees. No suitable treatment is known for high-value trees in urban areas.

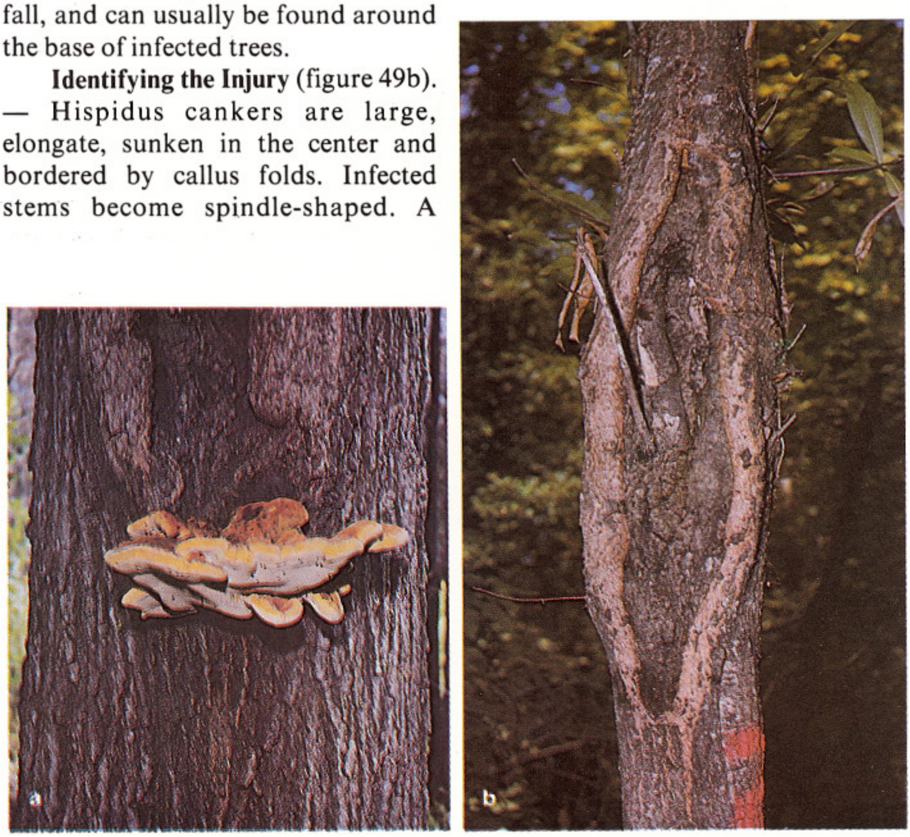


Figure 49. — (a) Polyporus hispidus *conk; (b) Hispidus canker.*

SPICULOSA CANKER, *Poria spiculosa* Campb. & Davids

Importance. — Spiculosa cankers, caused by *P. spiculosa,* may occur on up to 10 percent of the bottom-land red oaks in some areas. The decay column increases about 10 inches (25 cm) in length, yearly.

Identifying the Fungus. — Conks of *P. spiculosa* develop flat under the bark and the brown fruiting surface becomes exposed with maturity following tree death. Doubtful infections can be identified by chopping into the canker center. The brown fungus material will be exposed if the infection is well established.

Identifying the Injury (figure 50). — Cankers appear as rough, circular swellings with depressed centers. Remains of a branch stub can usually be found in the center of the canker.

Biology. — Spores are released from the conks and carried by the wind to branch stubs on healthy trees where infection occurs. Trees respond to invasion of the cambium by developing callous tissue.

Control. — Cut diseased trees or deaden them to allow room for healthy growing stock. No suitable treatment is known for high-value trees in urban areas.

Figure 50. — Spiculosa canker, including cross section.

IRPEX CANKER, *Irpex mollis* Leys ex Fr.

Importance. — Irpex canker, caused by *I. mollis,* occurs most frequently on red oaks. Incidence of this disease varies greatly in different areas. It is the least common of the canker rots, affecting only a small percentage of the trees. However, the decay under Irpex cankers extends above and below the canker face as much as 8 feet (2.4 m). The rate of decay is unknown.

Identifying the Fungus (figure 51). — The conks of *I. mollis* are 1 to 5 inches (2.5 to 12 cm) wide and creamy white, yellowing with age. They have short, jagged "teeth" on the lower surface. Conks usually occur during late summer and fall.

Identifying the Injury. — Infections are associated with dead branch stubs. Irregular cankers up to 2 feet (0.6 m) long may develop. There is white rot in the heartwood behind these cankers. The canker face will have a number of sunken areas with swollen margins resulting from callous tissue formation.

Biology. — Reproduction is by means of microscopic spores, produced and released by the conks each fall. The spores are spread by the wind to branch stubs on susceptible trees where infection occurs. The wood is decayed and the cambium killed, causing progressively larger cankers.

Control. — Control measures are similar to those described for hispidus cankers.

Figure 51. — Irpex mollis *conks on canker surface, including cross section.*

BUTT ROTS

Importance. — Butt rot, the decay at the base of living trees, is the result of the invasion of one of a number of decay fungi (*Polyporus* spp., *Hericium* sp., and *Pleurotus* sp.) which enter the trees through wounds. Fire wounds are the most typical type. Data indicate that butt rot affects 29 percent of the white oaks and 39 percent of the red oaks on loess and alluvial sites in the Midsouth. It is the most serious cause of cull.

Identifying the Fungi. — Numerous fungi can cause butt rot; however, five are responsible for about one-half of the identified cases. The following description will help to identify the most common fungi.

Hedgehog Fungus Rot. — *Hericium erinaceus* (Bull.) Pers conks are 4 to 10 inches (10 to 25 cm), globular, and occur singly or in clusters. They are white, but yellow with age, and have tooth-like projections pointing downward. This fungus is found mostly during the fall in butt hollows or where other openings in the tree have developed (figure 52).

Polyporus Fungus Rot. — *Polyporus fissilis* Berk & Curt., produces shelf-like, white, succulent conks 3 to 8 inches (7.6 to 20.3 cm) wide, that yellow with age (figure 53). The lower surface is made up of small pores. They usually appear during the fall or winter.

Figure 52. — Hericium erinaceus *conk.*

Figure 53. — Polyporus fissilis *conk.*

Varnish Fungus Rot. — *Polyporus lucidus* Leys ex. Fr. produces conks 3 to 10 inches (7.6 to 25.4 cm) in size which usually appear yearly during the summer near the soil line (figure 54). The conks have a shiny, reddish, hard upper surface; a short, stout stalk; and pores on the lower surface. The consistency is tough and woody.

Sulfur Fungus Rot. — *Polyporus sulphureus* Bull. ex Fries has conks 2 to 12 inches (5 to 30 cm) wide. They are soft, fleshy, moist, bright orange-red on the upper surface and red-yellow on the lower pore surface. The conks become hard, brittle, and white with age. They appear singularly or in clusters, usually during the fall (figure 55).

Oyster Fungus Rot. — *Pleurotus sapidus* Kalchr. forms shelf-like conks which are white to light grey. They are soft and fleshy and may have a short stalk. Gill structures radiate from the point of attachment on the lower surface (figure 56). Conks appear on living trees and slash during most of the year except dry periods.

Identifying the Injury (figure 57). — Conks, old wounds, hollows, abnormal swellings or butt bulge indicate butt rot. Decayed wood may be soft or brittle, and brown to white. The decay core may be small or include the entire heartwood. The core extends vertically from less than an inch to several feet. Affected trees are weak and subject to breakage.

Figure 54. — Polyporus lucidus *conk.*

Figure 55. — Polyporus sulphureus *conk.*

Biology. — Following tree wounding, bacteria and non-decay fungi flourish on the exposed woody tissues, creating conditions for establishment of decay fungi. Windborne microscopic spores released for a few days to several weeks from conks on infected trees germinate on wounds and penetrate the tree. The decaying stage of the rot fungi follows and conks will be produced. The rate of decay varies with the tree species, fungus, and wound size. Decay is most extensive when wounds are large; decay usually does not develop in wounds less than 2 inches (5 cm) wide. Regardless of wound size, wood volume loss is minimal when wounds are less than 4 years old.

Control. — Because all infections occur through bark wounds, injury prevention is the primary approach to control. Severely decayed trees of no value should be deadened. Consider early salvage for infected trees that have value because the lower, most valuable portion of the log is being decayed, with an increased susceptibility to insect attack, windthrow and degrade from stain. Repair valuable urban trees by removing the decay, treating the cavity with a fungicide and filling it with a suitable material.

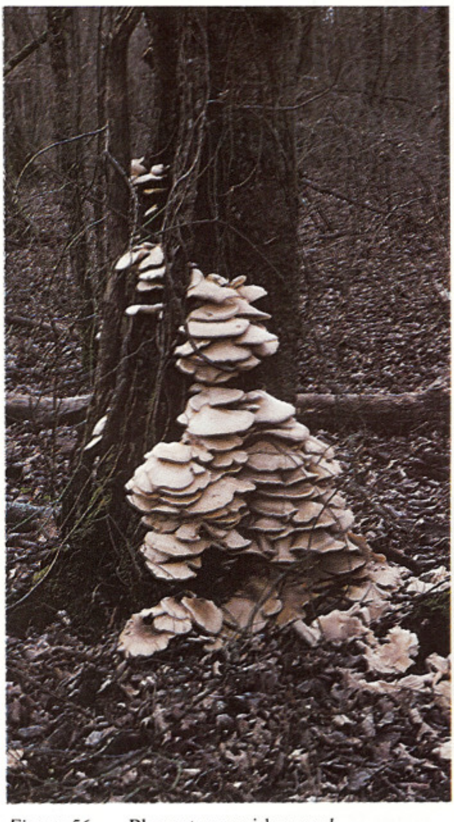


Figure 56. — Pleurotus sapidus *conk.*

Figure 57. — Butt bulge indicates decay.

TOP ROTS

Importance.— Top rot results from the invasion of the heartwood by many of the same fungi *(Sterium spp. and Poria* sp.) which cause butt rot. The incidence of infection is similar to butt rot, but typically less. However, the associated volume losses are much less since this disease occurs in that part of the tree which is not usually used for timber. Top rot results in limb breakage and thus becomes important as a safety hazard in high use and urban areas.

Identifying the Fungi. — Three common top rot fungi, *S. gausapatum* Fr., *P. andersoni* (E11 & Ev) Neuman and *S. subpileatum* Berk. & Curt. must usually be identified by cultural characteristics because conks rarely are seen on dead branches. Others, such as *Hericium erinaceus, Polyporus fissilis, Pleurotus sapidus* and *Polyporus sulphureus* were described previously with butt rot fungi.

Identifying the Injury.— The presence of broken limbs often indicates decay (figure 58). Examination of the broken surface will confirm its existence. Presence of branch scars alone indicates top rot. The incidence and amount of decay rise sharply with increased size and/or age of scars. The decay can be estimated by judging the scar size and age in broad classes (table 1).

Table 1. Expected length of decay in the main stem behind branch scars of oaks.

Age	Diameter of branch scar inches (cm) 1-3 (2.5-7.5)	4-6 (10.2-15.2)	7-10 (18-25)
less than 15 years	1.2 (3.0)	4.8 (12.1)	30 (76.2)
more than 15 years	2.4 (6.0)	12 (30.4)	68.4 (173.7)

Biology. — The life cycle of heart rot fungi, as top rots, is about the same as was discussed for butt rots. The environment differs, thus some different fungi are involved. Those butt rot fungi which invade the roots are not encountered and others, such as *Stereum* sp., become more prevalent.

Control. — There are no measures for direct control of top rots. Recognizing top decay and early harvesting of infected trees is the most useful control method. Prevention of injuries inflicted during logging could help reduce top rot in growing stock. In urban or high-use areas, early detection and appropriate removal of hazardous limbs should be carried out.

Figure 58. — Fungus conk indicates top rot.

ROOT ROTS

SHOESTRING ROOT ROT

Clitocybe tabescens (Scop. ex Fr.) Bres,
Armillaria mellea Vahl ex Fr.

Importance. — Root rot organisms, *C. tabescens* and *A. mellea,* cause major losses throughout the United States. Windthrow of infected trees in urban and high-use areas contribute to the importance of root diseases. Additional losses occur from loss of vigor.

Identifying the Fungi (figure 61). — In the fall, clumps of yellow mushrooms grow on the ground near the tree and occasionally on the bole several feet above the ground. Thin black strands of mycelia (rhizomorphs) are produced on the root surface which resemble black shoe laces. *C. tabescens* is a southern form of *A. mellea.* The mushroom has decurrent gills and produces white spores.

Identifying the Injury. — Infected trees may have low vigor. Roots may show various degrees of decay and have rhizomorphs on the surface. Frequently, root rot is evident only on wind-thrown trees. The rate of spread in the soil is about 1 foot (0.35 m) per year.

Biology. — The fungus can live in dead roots and stumps for many years. Rhizomorphs spread through the soil on infected roots near healthy roots that become infected. Mushrooms produce abundant spores, but they are not important in infection of living trees. The fungus is most pathogenic on slow-growing trees.

Controls. — Spread can be controlled by removing the infected tree. Sterilize the soil before replanting. Any cultural practices that reduce stress and increase tree vigor will prolong tree life.

Figure 59. — Clitocybe tabescens *mushrooms on oak.*

DRYADEUS ROOT ROT, *Inonotus dryadeus* (Pers.:Fr.) Murrill

Importance. — This fungus is distributed widely on oak, elm, and maple species in the East. It is common at the bases of older, living oaks in yards, parks, and along streets. While its ability to kill trees is questionable, it will decrease tree health over time.

Identifying the Fungus. — Fruiting bodies are tan-to-buff colored conks or irregular cushions, 4 to 24 inches by 3 to 10 inches, on roots or at bases of trees. Young conks may grow around green leaves or show leaf imprints on top from where leaves lay on the growing conks. A yellowish liquid may exude from young conks, and old conks look like burned wood on top (figure 60).

Identifying the Injury. — Thinning crowns may result from long-term infections that degrade root systems. The slow crown deterioration weakens the tree and may lead to a more serious butt rot.

Biology. — Microscopic spores enter the tree through dead or scarred roots or through fire or logging scars at tree bases. Once extensive decay has occurred, conks are produced.

Control. — The best control is to prevent injury (e.g., from lawn mowers and tire traffic) because the fungus enters through wounds in the bark of roots or tree bases. As with all root and butt rotters, bole and crown conditions should be monitored regularly for signs of weakening and possible breakage.

Figure 60. — Young (tan) and old (black) Inonotus dryadeus *conks on water oak.*

DECLINES AND WILTS

OAK DECLINE

Various abiotic stresses, insects, and pathogens

Importance. — Oak decline affects a few to many oaks, mainly red oaks, over broad forest areas of the eastern United States. Damage varies by region, site condition, forest type, and year. Hickory species may be affected in association with oaks.

Identifying the Agents. — Environmental, stand, and site factors usually are involved at first. Various insects and pathogens are involved in later stages.

Identifying the Injury. — Oak decline usually affects mature overstory trees and is typified by a gradual but progressive dieback of the crown (figure 61), reduced growth, and tree death after several years.

Biology. — Oak decline involves complex interactions between environmental and biological stresses and subsequent attacks by secondary pests. Predisposing factors, such as genetic potential, climatic factors, or old age, can set the stage for damage by some other injury. Drought, insect defoliation, unseasonable freezes, root damage, or extended flooding can incite active decline. Contributing factors, such as pathogens (e.g., Armillaria root rot, page 47), insects (e.g., two-lined chestnut borer, page 20), or both, (figure 62) can kill trees.

Control. — Harvest oak stands before they become over mature. Promote advanced reproduction in young and middle-aged stands to ensure regeneration at harvest. Removing dead and declining oaks utilizes trees before they degrade but will not correct conditions leading to decline.

Figure 61. — Red oak crowns in various stages of decline. From left to right: crowns are fairly healthy, actively declining, and recently killed.

Figure 62. — Mycelial fans (white patches) of Armillaria root rot and horizontal galleries (white lines) of two-lined chestnut borer at base of red oak in the last stage of decline.

OAK WILT, *Ceratocystis fagacearum* (T.W. Bretz) J. Hunt

Importance. — Oak wilt is one of the most destructive diseases of oaks in the Eastern United States. Red and live oaks (in Texas) are more severely affected than white oaks. Susceptible trees may be killed within a few months after infection. The disease generally progresses more rapidly in the homogeneous stands of semievergreen live oaks in the shallow soils of central Texas than in the mixed-hardwood stands of deciduous oaks in deeper soils of northern and eastern States.

Identifying the Fungus. — The fungus is recognized by the presence of grayish fungal mats beneath cracks in the bark of infected red oaks (figure 63a). Fungal mats do not form on white or live oaks. The imperfect stage (*Chalara quercina*) may be identified microscopically in pure culture.

Identifying the Injury. — Symptoms range from leaf bronzing, marginal and veinal leaf necrosis, and twig dieback in early stages of the disease to defoliation, branch dieback, and eventual death of the tree (figure 63b-e).

Biology. — The fungus spreads short distances by root transmission through root grafts and common root systems (live oaks) shared between infected and healthy trees. Sapwood beetles (Nitidulidae) are well-established vectors in northern States and are responsible for long-distance transmission by carrying spores from fungal mats to wounds in healthy trees. Vector transmission is not well defined in Texas.

Control. — Controls used in northern and eastern States include the use of silvicides to kill infected red oaks to reduce fungal mat formation and insect transmission, and the avoidance of tree wounding during periods of insect activity. Trenching (figure 63f) to sever root grafts helps control root tranmission of the fungus from infected to uninfected roots. Firewood should be covered with plastic and used within a year after cutting to reduce vector activity. The triazole fungicide (propiconazole) is useful in preventing infections in healthy, threatened trees with high economic value.

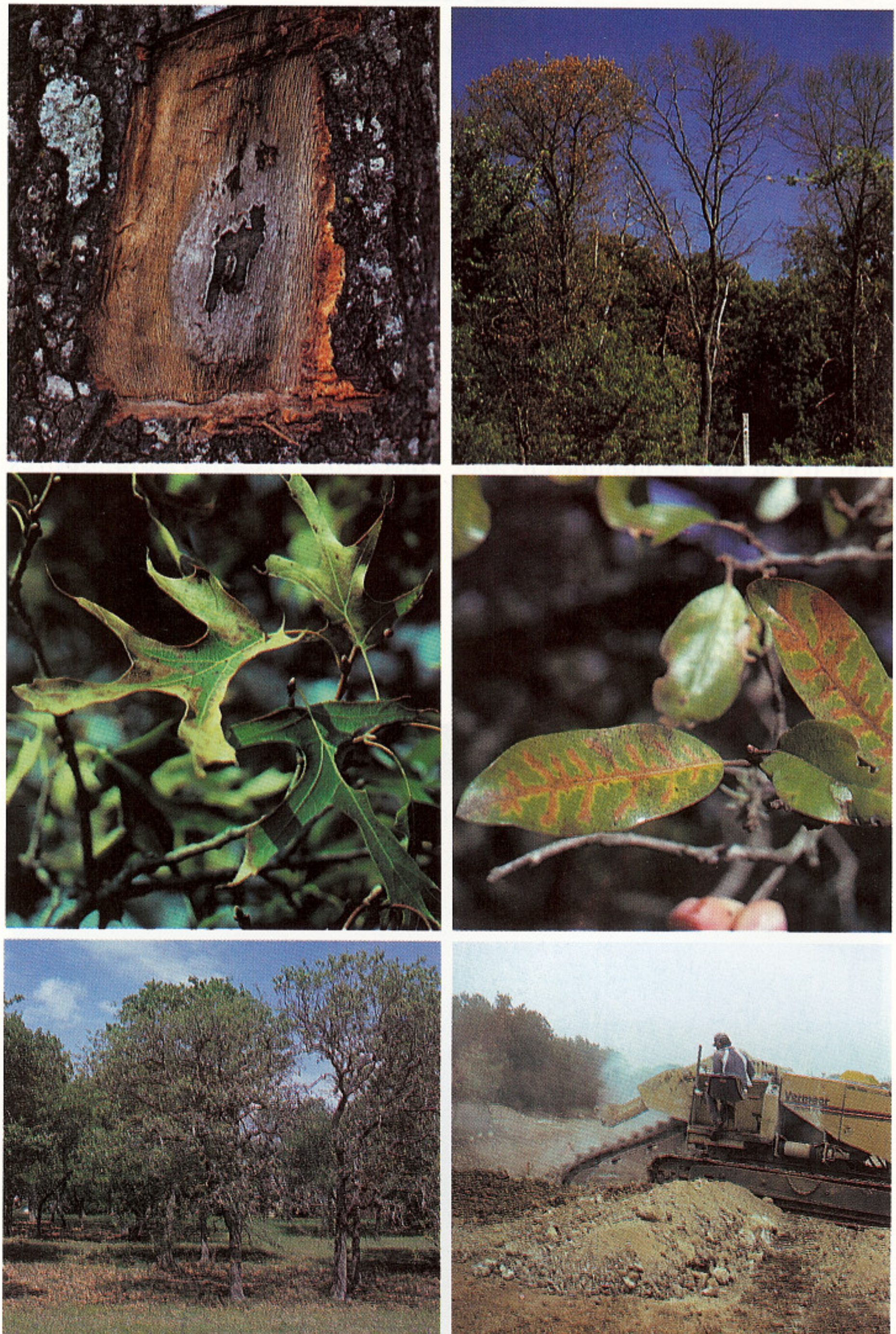


Figure 63. — (a) Fungal mat on red oak; (b) declining crowns of red oaks (c) marginal leaf necrosis of red oak; (d) veinal necrosis of live oak; (e) defoliation of live oak; (f) trenching to prevent root transmission.

CANKERS

NECTRIA CANKER, *Nectria galligena* Bres.

Importance. — Nectria cankers, caused by *N. galligena*, are frequently found on some oak species. These cankers are most important in trees less than 20 years old. The canker can girdle and kill young trees or make them weak and subject to wind breakage.

Identifying the Fungus. — The fungus can be identified by the creamy-white fruiting structures that appear on cankers soon after infection. It can also be identified by the small, red, lemon-shaped perithecia near canker margins after 1 year.

Identifying the Injury (figure 64). — Well-defined localized areas of bark, cambium, and underlying wood are killed by the invading fungus. A concentric callus ridge develops around the expanding canker annually and bark sloughs off the older parts of the canker. After several years, the annual concentric callus ridges on the cankers resemble a target.

Biology. — The fungus overwinters as a saprophyte in cankers and produces spores for new infections during the spring. Windblown and water-splashed spores infect tree wounds and branch stubs. Secondary infections result from spores produced on new spring cankers.

Control. — Cankers may be minimized in high-value areas by not pruning during wet weather, avoiding wounds, pruning out branch cankers, and sterilizing pruning tools before moving to an uninfected tree.

Figure 64. — Nectria canker.

BOTRYODIPLODIA CANKER, *Botryodiplodia theobromae* Pat.

Importance. — *B. theobromae,* can cause cankers and dieback in oak species over a wide geographical area. It is a potentially destructive pathogen under certain adverse environmental conditions, especially if trees are somewhat stressed.

Identifying the Fungus. — Black, stromatic fruiting structures of the fungus develop on bark over the cankers. However, microscopic examination of spores is necessary for correct identification. Mature spores are dark, two-celled, and elongate.

Identifying the Injury. — It is difficult to identify the canker by symptoms alone. Therefore, the fungus must be isolated and identified. Active cankers on trees with rough bark can be detected only after removing bark to expose dead cambium. Old or inactive cankers appear sunken and are surrounded by callus tissues. Dieback is frequently caused by *B. theobromae,* but can be confused with injury resulting from other diseases or stress conditions (figure 65).

Biology. — The biology of Botryodiplodia cankers in oaks is poorly known. However, the cankers are favored by high temperatures. Cankers and dieback can develop rapidly in stressed trees. Fungal spores are spread by the wind and insects.

Control. — Cankers can be minimized by preventing wounds, pruning out cankered and dead limbs to reduce inoculum, and maintaining tree vigor when possible.

Figure 65. — Botryodiplodia canker, including cross section.

HYPOXYLON CANKERS, *Hypoxylon* spp.

Importance. — Hypoxylon cankers affect most oak species in North America. Both *H. atropunctatum* and *H. mediterranium* have been reported in oaks. They affect mainly trees that have been stressed by wilt, drought, construction damage, or other injuries. Limbs and boles weakened by *Hypoxylon* spp. can be a safety hazard in high-use areas.

Identifying the Fungus (figure 66). — *Hypoxylon* spp. can be identified by the light-to-dark-colored crusty fungus tissue (stromata) over the cankered area. Numerous small black fruiting structures are embedded in the stromata.

Identifying the Injury. — Bark sloughing and decay are associated with Hypoxylon cankers. Affected trees are subject to wind breakage.

Biology. — The fungus infects stressed trees through wounds and either produces a canker or quickly kills the tree by colonizing the sapwood. Fruiting structures develop on the cankers and ascospores are discharged into the air and spread to new infection sites. Hypoxylon cankers are generally secondary to some other disease or stressing condition in trees.

Control. — Remove cankered limbs before they fall on someone, and to reduce the amount of inoculum for new infections. Maintain tree vigor and avoid wounding and stubbing of branches to minimize conditions favoring cankers.

Figure 66. — Hypoxylon canker, including close-up view.

LEAF DISEASES

ANTHRACNOSE, *Gnomonia quercina* Kleb = *Gloeosporium quercinum* West

Importance. — Severely affected oaks may be defoliated by midsummer, which reduces growth, predisposes trees to other diseases and makes the trees unsightly. White oaks are most severely affected. Anthracnose does not result in major losses in forests.

Identifying the Fungus. — Black, dot-size, cushion-like, fruiting bodies form on necrotic tissue where spores are produced. A beaked, flask-shaped, fruiting structure can be found on overwinter leaves.

Identifying the Injury (figure 67). — Round to irregular, light-brown to black areas appear on the leaf, most frequently along veins. Affected leaves often appear scorched, and may curl or twist and drop from the tree. Infrequently, cankers and dieback can occur on small twigs.

Biology. — The fungus overwinters in dead leaves. Spores (ascospores) are windblown to the new, expanding leaves and shoots. Another spore type (conidia), which reinfects other leaves or shoots, is then produced.

Control. — Collect and dispose of fallen leaves and twigs. Remove unneeded branches to increase air movement. Fertilize to increase vigor and use fungicide sprays.

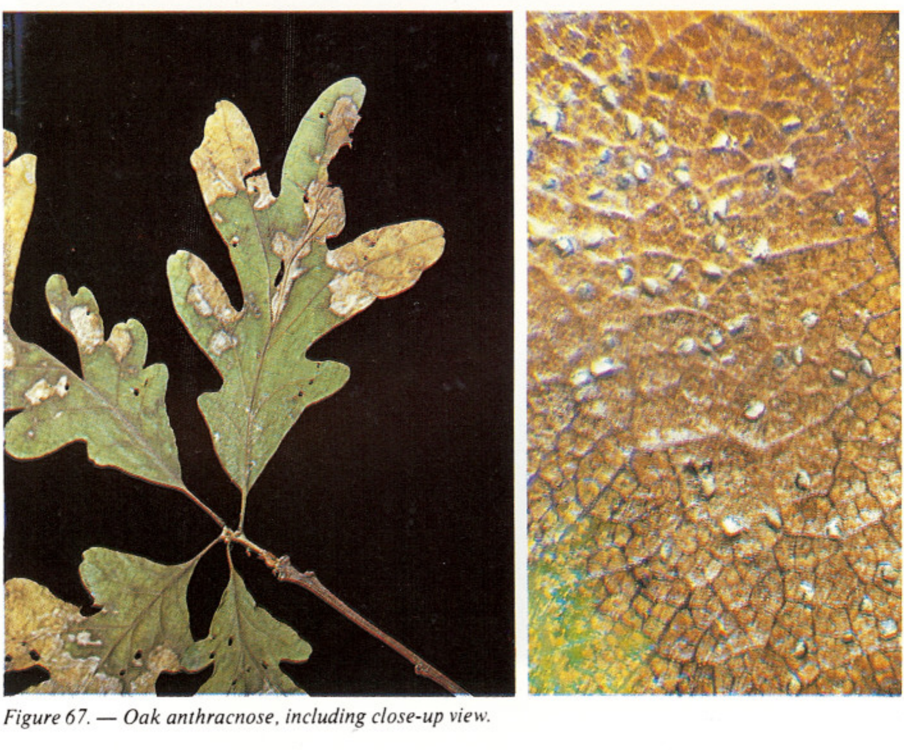


Figure 67. — Oak anthracnose, including close-up view.

LEAF BLISTER, *Taphrina caerulescens* Tul.

Importance. — Because most of the affected leaves remain on the tree, oak leaf blisters do not cause losses under forest conditions. Affected trees may appear unsightly, but there is little damage.

Identifying the Fungus. — The mycelium occurs intercellularly in the leaf tissue. Dome-shaped, microscopic, fungus cells are formed beneath the cuticle, usually on the upper leaf surface. The distal cell becomes the sac (ascus) in which eight ascospores are formed.

Identifying the Injury (figure 68). — Affected leaves develop many blisters on the upper surface. The blisters are round, raised, wrinkled and vary in color from yellow to purple. The leaf is depressed on the corresponding lower surface.

Biology. — Spores (ascospores) of the fungus are produced on the surface of the blisters. The spores are carried by the wind to bud scales where they remain over winter. In the spring when the buds are expanding, the fungus enters the leaf through the natural leaf openings (stomata) and the cycle is complete.

Control. — Collect and dispose of leaves. Plant or manage for resistant oak such as pin and Shumard. Properly timed fungicide sprays can control this fungus.

Figure 68. — Oak leaf blister.

ACTINOPELTE LEAF SPOT, *Actinopelte dryina* (Sacc.) Hoehn.

Importance. — Actinopelte leaf spot can reach epidemic proportions and cause major loss of foliage. Growth losses, increased stress on the tree and unsightly conditions result. Overall, the disease normally remains endemic and causes foliage loss only in the fall, with no subsequent effect.

Identifying the Fungus. — Small, brown, dot-like fruiting bodies are formed on the necrotic tissue. Spores are elliptic and clear or colorless and can be microscopically observed by crushing a fruiting body.

Identifying the Injury (figure 69). — Round to irregular, red-brown spots develop along the leaf veins. The spots are normally surrounded by light brown areas and may merge to kill large areas of the leaf in late summer. Small twig cankers may be formed.

Biology. — The fungus overwinters in the affected twigs and foliage. Spores of the fungus are spread by wind and rain-splash the next growing season.

Control. — Collect and dispose of fallen leaves. Remove unneeded branches to increase air movement. Fertilize to increase vigor and use fungicide sprays.

Figure 69. — Actinopelte leaf spots, including close-up view.

LEAF RUST: FUSIFORM RUST and EASTERN GALL RUST,
Cronartium fusiforme quercuum (Berk) Miyabe
Hedge & Long and *C.*

Importance. — In forest stands these diseases are of minor importance on oak (alternate host). However, they affect the aesthetic value of shade trees and ornamentals. Fusiform rust on pine (primary host) is the most important disease of pine in the Southeast.

Identifying the Fungi (figure 70). — Both fungi develop brown, bristly spine-like structures on the underside of the oak leaf.

Identifying the Injury. — Small yellow spots develop on the leaf surfaces in spring. Some defoliation may occur. Red, water and willow oaks are primarily affected. White oaks are seldom affected.

Biology. — Leaf rusts require two hosts to complete their life cycle. Fungus spores (aeciospores) produced on pine galls are windblown and infect young oak leaves. Spores (urediospores) are produced on the oak leaf which re-infect oak. Spiny-like hairs (telial columns) on the lower oak leaf surface release teliospores which produce another spore stage (basidiospore) that infects pine. This infection results in a gall with aeciospores, and the cycle is completed.

Control. — No control needed.

Figure 70. — Rust telial columns on oak leaf, including close-up view.

SEEDLING DISEASES

DAMPING-OFF, *Cylindrocladium* spp.

Importance. — Soil-inhabiting fungi such as *Fusarium, Cylindrocladium, Rhizoctonia, Pythium* and *Phytophthora* species cause heavy losses (25 to 50 percent) in pre- and post-emergence seedlings. Fungi attack the young developing radicles killing seedlings 30 to 45 days after the seedlings emerge.

Identifying the Fungus. — The pathogens involved are minute and can be identified only by the use of a microscope. Tentative identification can be made by cultural characteristics. *Cylindrocladium* spp. are the most important pathogens in hardwood nurseries.

Identifying the Injury (figure 71). — The first symptom is failure of seedling emergence. The seed may rot or seeds may have a dead or damaged radicle (pre-emergence damping-off). Seedlings may remain stunted (post-emergence damping-off).

Biology. — The fungi are mostly soilborne and remain inactive in the absence of a host as chlamydospores or sclerotia. The presence of host roots stimulates the fungus, which grows over roots and penetrates the epidermis and cortex. *Cylindrocladium* spp. also produce airborne conidia which may cause leaf spots and defoliation.

Control. — Grass cover crops will reduce the inoculum potential; however, clover and other leguminous cover crops increase the pathogen. Do not apply nitrogen fertilizer until 45 days after the seedlings emerge.

Figure 71. — Damping-off of oak seedlings.

PHANEROGAMS

MISTLETOE, *Phoradendron* spp.

Importance. — Branches beyond the mistletoe infection may be stunted and even die. Trees usually are not killed. However, in heavy infections on water oak, trees may decline and be killed. This true mistletoe is used for Christmas greens.

Identifying the Causal Organism (figure 72). — Leafy, evergreen tufts of perennial shoots with dark green, leathery leaves occur as bunches on branches of oaks. The plant is opposite-leaved and the stems are rounded and jointed. The flowers are inconspicous. White to red berries are produced in the fall.

Identifying the Injury. — The most conspicuous sign of the disease is the presence of the parasite. The affected branch may be slightly enlarged and multiple infections may result in tree decline. Excess shading of tree leaves by large mistletoe plants produces dieback and decline.

Biology. — The sticky seeds are spread by birds and animals. The seeds lodge on young branches, germinate, grow into the young branch and produce a mistletoe plant.

Control. — Control is normally not needed but mistletoe can be controlled by removing it and cutting branches at least 1 foot below the infection point.

Figure 72. — Mistletoe infection, including close-up view.

CHEMICAL DAMAGE, AIR POLLUTION, PESTICIDES AND OTHER CHEMICALS

Importance. — The total impact of chemical damage is unknown. Large losses have occurred in very localized areas. The losses normally can be traced to a point source such as a chemical spill or industrial waste. Not as easily recognized but perhaps more damaging are the non-point source pollutants such as those associated with a large city. Many oak species decline, dieback and succumb over a period of years. On the other hand, some oak species are relatively resistant to many pollutants and are not affected.

Identifying the Causal Agent. — Chemicals can arrive at the tree in a variety of forms through the air or soil. Several conditions must occur to cause damage. There must be a susceptible host in a receptive condition, and the chemical must arrive in a quantity and form that will affect the host. Some chemicals damage on contact, others interact with tree processes.

Identifying the Injury (figure 73). — Most chemicals have certain characteristic symptoms. *Ozone* causes small bleached or pigmented spots on the upper leaf surface. *Sulfur dioxide* kills some areas between the leaf veins. *Fluoride* kills tissue on the leaf margin or between the veins. *Ammonia* causes faded leaf margins and dead or dying tissue with green islands mostly near veins. *Herbicides* cause blotchy dead areas on the surface of mature leaves; expanding leaves curl and become distorted.

Because of great variation of susceptibility among trees and the combination of chemical and climatic factors, diagnosis is complex. Thus, proper diagnosis may require a person with extensive training and experience.

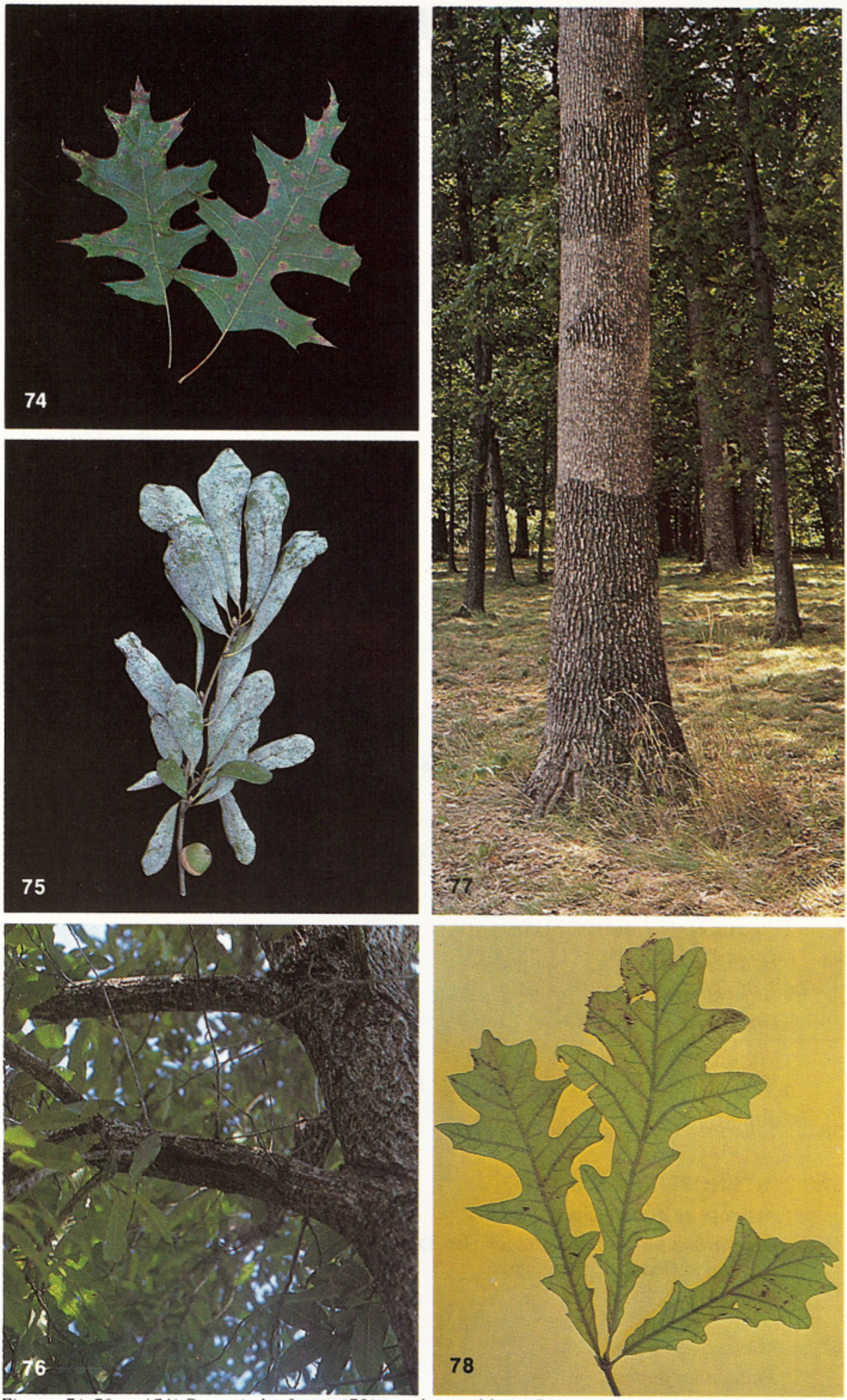
Control. — Protect from chemicals or plant resistant trees.

Figure 73. — Chemical damage — due to ammonia.

MINOR DISEASES

Disease Agent	Injury	Control*
Leaf spot, *Septoria* spp. The fungus overwinters on dead leaves; spores are wind disseminated to young leaves in the spring.	Small round spots with straw-colored centers may be numerous; (figure 74); red oaks are preferred; defoliation may result in growth loss, but no mortality.	4 5 14 15
Powdery mildew, *Microsphaera alni* and *Phllactinia guttata.* These fungi overwinter on dead leaves and their spores are spread by the wind to healthy leaves.	White, powdery mold patches on leaves and buds (figure 75); leaves may be distorted, stunted and dropped prematurely.	5 15
Twig canker, *Dothiorella quercina.* The fungi overwinter on dead tissues; in the spring, spores are wind disseminated to wounds and twigs.	Small sunken branch cankers and twig dieback (figure 76).	8 14 15
Spot anthracnose, *Elsinoe, quercus – falcatae.* The southern red oak is preferred host; spreads by wind disseminated spores.	Very small spots on leaf upper surface starting about mid-summer.	5 15
Smooth patch, *Aleurodiscus oakesii* (figure 77).The fungus survives on the bark surface and releases spores which continues its spread.	Often regarded as a threat to stand by owner, but it is of minor importance; control rarely needed.	
Iron-deficiency chlorosis (figure 78); iron deficiency may be a common problem with pin and willow oaks in some of the less acid soils.	Yellow-green discoloration between veins; leaves may curl, turn brown along margins and between veins.	16

*See CONTROLS page 66.



Figures 74-78.— (74) Septoria leaf spot; (75) powdery mildew; (76) twig canker; (77) smooth patch; (78) iron-deficiency chlorosis.

REVISIONS OF NAMES FOR DISEASES AND FUNGAL TAXA

Page	Names Previously Used	Names Currently Accepted
40	*Polyporus hispidus* (Bull.) Fr.	*Inonotus hispidus* (Bull.:Fr.) Karst.
41	*Poria spiculosa* Campb. & Davids	*Phellinus spiculosus* (Campbell & Davidson) Niem.
42	IRPEX CANKER	SPONGIPELLIS CANKER
	Irpex mollis Leys ex Fr.	*Spongipellis pachyodon* (Pers.) Kotl. & Pouz.
43	*Hericium erinaceus* (Bull.) Pers	*Hericium erinaceus* (Bull.:Fr.) Pers.
	Polyporus fungus rot	Tyromyces fungus rot
	Polyporus fissilis Berk & Curt.	*Tyromyces fissilis* (Berk. & Curt.) Donk
44	*Polyporus lucidus* Leys ex. Fr.	*Ganoderma lucidum* (W. Curt.:Fr.) Karst.
	Polyporus sulphureus Bull. ex Fries	*Laetiporus sulphureus* (Bull.:Fr.) Murr.
44, 45	*Pleurotus sapidus* Kalchr.	*Pleurotus ostreatus* (Jacq.:Fr.) P. Kumm.
46	*Sterium* spp.	*Stereum* spp. (spelling correction)
	Poria sp.	*Inonotus* spp.
	S. gausapatum Fr.	*Stereum gausapatum* (Fr.:Fr.) Fr.
	P. andersoni (Ell & Ev) Neuman	*Inonotus andersonii* (Ell. & Everh.) Cerny.
	S. subpileatum Berk. & Curt.	*Xylobolus subpileatus* (Berk. & Curt.) Boidin
	Polyporus fissilis	*Tyromyces fissilis*
	Pleurotus sapidus	*Pleurotus ostreatus*
	Polyporus sulphureus	*Laetiporus sulphureus*
47	*Clitocybe tabescens* (Scop. ex Fr.) Bres	*Armillaria tabescens* (Scop.) Dennis, Orton & Hora
	Armillaria mellea Vahl ex Fr.	*Armillaria mellea* (Vahl:Fr.) P. Kumm.
52	*Nectria galligena* Bres.	*Nectria galligena* Bres. in Strass.
53	BOTRYODIPLODIA CANKER	LASIODIPLODIA CANKER
	Botryodiplodia theobromae Pat.	*Lasiodiplodia theobromae* (Pat.) Griffon & Maubl.
54	*H. atropunctatum*	*H. atropunctatum* (Schwein.:Fr.) Cooke
	H. mediterranium	*H. mediterraneum* (De Not.) J.H. Miller
55	*Gnomonia quercina* Kleb	*Apiognomonia errabunda* (Roberge) Höhn.
	Gloeosporium quercinum West	*Discula umbrinella* (Berk. & Broome) Sutton
56	*Taphrina caerulescens* Tul.	*Taphrina caerulescens* (Desmaz. & Mont.) Tul.
57	ACTINOPELTE LEAF SPOT	TUBAKIA LEAF SPOT
	Actinopelte dryina (Sacc.) Hoehn.	*Tubakia dryina* (Sacc.) Sutton
58	*Cronartium fusiforme quercuum* (Berk) Miyabe Hedge & Long and C.	*Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Hedgc. & N. Hunt) Burdsall & G. Snow
62	*Microsphaera alni*	*Microsphaera penicillata* (Wallr.:Fr.) Lév.
	Phllactinia guttata	*Phyllactinia guttata* (Wallr.:Fr.) Lév.
	Dothiorella quercina	*Botryodiplodia gallae* (Schwein.) Petr. & Syd.

PESTICIDES

EPA-registered chemicals for control of insects and diseases that attack oaks. (See labels for dosages and application methods.)

INSECT	INSECTICIDE
Elm spanworm	*Bacillus thuringiensis* Carbaryl
Fall cankerworm Spring cankerworm	*Bacillus thuringiensis* Carbaryl Acephate
Linden looper	Methoxychlor Naled
Orangestriped oakworm Pinkstriped oakworm Spiny oakworm	Carbaryl Chlorpyrifos Methoxychlor
Yellownecked caterpillar	Chlorpyrifos
Forest tent caterpillar	Carbaryl Acephate Dylox Chlorpyrifos
Gypsy moth	*Bacillus thuringiensis* Carbaryl Methoxychlor Acephate
Variable oakleaf caterpillar	Carbaryl Malathion
Caterpillars	Pyrethrin Imidacloprid Permethrin

INSECT	INSECTICIDE
Slug oak sawfly	Carbaryl Pyrethrin
Oak leafroller	Carbaryl Diazinon
Oak leaftier, Solitary oak leafminer Gregarious oak leafminer	Carbaryl Malathion Diazinon
Oak skeletonizer	Carbaryl
Insect borers	Lindane
Oak leaf aphids Giant bark aphids	Carbaryl Diazinon Malathion Acephate
Oak lacebug	Carbaryl Malathion and mixtures Lindane Methoxychlor
Periodical cicada	Carbaryl
Lecanium scales Pit scales Kermes scales Obscure scale	Carbaryl Diazinon Malathion Methoxychlor
Spider mites	Dicofol Diazinon Malathion

PESTICIDES, (continued)

EPA-registered chemicals for control of insects and diseases that attack oaks. (See labels for dosages and application methods.)

FUNGI	FUNGICIDE
Powdery mildew	Chlorothalonil Benomyl Lime sulphur
Septoria leaf spot Actinopeltes *Dothiorella quercina*	Ferbam Captan Benomyl
Elsinoe falcatae Anthracnose	Zineb Copper (metallic) Benomyl
Leaf blister	Captan Ferbam
Damping-off Clitocybe root rot Armillaria root rot	Captan Dexon

FUNGI	FUNGICIDE
Phymatotrichum Corticum root rot *Polyporus lucidus*	
Stereum Irpex canker Poria canker Nectria canker	Lime sulphur
Botryodiplodia	Copper (metallic) plus methoxychlor
Fusiform rust *Eastern gall rust*	Captan Ferbam Oil plus lime sulphur

CONTROLS

Controls for insects and diseases presented in table form

1. Natural controls often adequate.
2. Place sticky bands around trunk.
3. Prune infected twigs and destroy.
4. Rake fallen infected leaves and destroy.
5. Maintain high tree vigor with cultural practices.
6. Open-grown trees most susceptible; maintain good stocking.
7. Identify and remove brood trees.
8. Prevent or minimize injuries.
9. Mechanically "worm-out" with knife and wire.
10. Wrap trunk of newly transplanted trees.
11. Control with chemical insecticide
12. Control with biological insecticide.
13. Control with gallery fumigation.
14. Remove and burn diseased materials from the tree and area.
15. Control with chemical fungicide.
16. Control with iron chelate.

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INDEX

INSECTS

DISEASES

INDEX, (continued)

CAUTION

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed them. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Environmental Protection Agency, consult your State forestry agency, county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

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U.S. DEPARTMENT OF AGRICULTURE

United States
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Agriculture

Forest Service

**Southern Forest
Experiment Station**

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Louisiana

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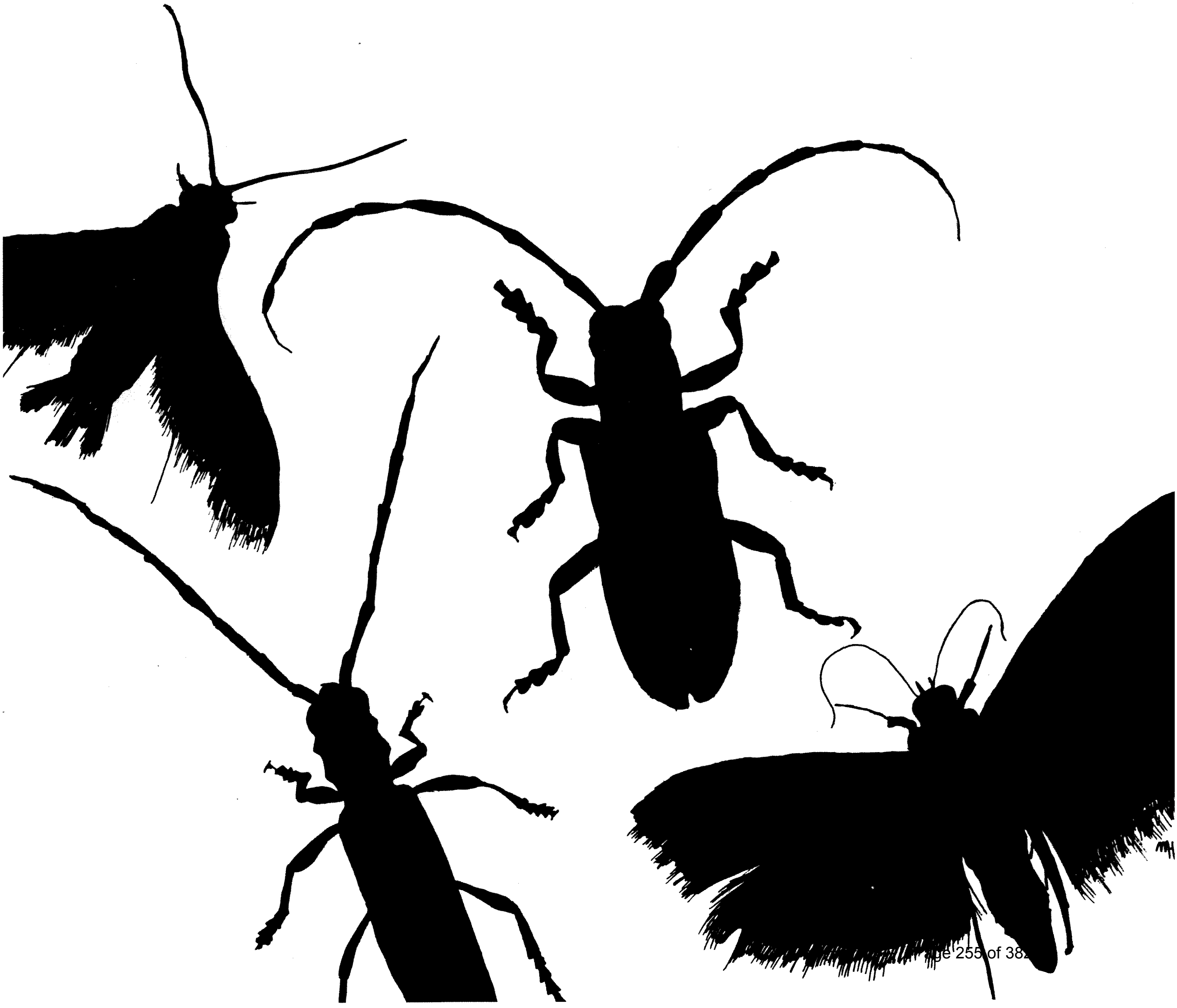
A Guide to the Insect Borers, Pruners, and Girdlers of Pecan and Hickory

J. D. Solomon and J. A. Payne



SUMMARY

Many insect borers, pruners, and girdlers attack, damage, and kill pecan and hickory trees. By using the information contained in this publication, resource managers, landowners, and other interested people should be better able to identify and manage these pests. Yellow-bellied sapsuckers are also discussed because damage caused by these birds is often confused with that of insect borers. Class, order, and family names of these pests are listed in the Appendix as additional information for the reader.

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A Guide to the Insect Borers, Pruners, and Girdlers of Pecan and Hickory

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INTRODUCTION

Pecan, *Carya illinoensis* (Wangenh.) K. Koch, and at least 10 species of hickory, *Carya* spp., are native to the Eastern United States. Eight of these are economically important when grown for timber production, commercial nut production, ornamental purposes, and wildlife food. Pecan is best known for its nutritious nuts, which are produced in quantities that make them a major economic commodity, but is also a prized species for use in fine furniture and paneling (Kennedy and others 1981). During recent years, it has been commonly called the "black walnut of the South," and interest in commercial plantings is growing because of its high stumpage value (Adams and Thielges 1976-77). The hickories have long been known for their use in the manufacture of handle stock, sporting goods, and some furniture.

Insect borers, pruners, and girdlers are injurious pests of pecan and hickory. Although most of these pests have a wide distribution, they seldom threaten trees over large areas. Damaging populations typically occur on a local basis, such as a nursery, individual nut-producing grove, forest stand, young timber plantation, or ornamental trees in a neighborhood or small geographic locality. Much has been written on the insect pests affecting the nuts and foliage of pecan, but little has been published on the insect borers affecting the tree itself. The cryptic habits of the insect borers have hampered efforts to document this group of pests. Known information is widely scattered and found in older literature, much of which is not generally available to those who need to use it.

The terminals, branches, trunks, and roots of trees of all sizes are vulnerable to borers. Natural regeneration is sometimes heavily infested by girdlers and pruners. Nurseries and young plantings located close to heavily infested stands or woodlots are most likely to be damaged. Loss of terminals and main stems in young timber plantations adversely affects tree form. Pruners and girdlers can drastically reduce the number of nut-bearing branches and subsequent nut crop of nut-producing trees. Girdled branches can create cleanup problems on residential properties. Young transplanted trees are particularly susceptible to borers and often need protection. Borer holes and associated stain and decay cause defects in the wood that reduce its value for lumber, veneer, handle stock, and other products. Wormholes and bark scars also adversely affect the aesthetic beauty of shade and ornamental trees. Borers sometimes invade the cambium and callus around new grafts and prevent union of scion and stock; recently top-worked trees have suffered serious damage in the past. Stressed trees are particularly susceptible to bark beetles and pin-hole borers. Bark beetles have caused widespread mortality of hickory during extended periods of drought. Yellow-bellied sapsuckers are included in this guide because the holes they peck in the bark are often confused with those caused by insect borers.

Impact from pests can be minimized through good management. Cultural practices that maintain and promote tree vigor are of utmost importance. New plantings should be on good sites, preferably away from heavily infested stands, woodlots, or old, deteriorating orchards. Adequate space, water, and nutrients should be provided. Efforts should be made to keep injuries such as cuts, bruises, and broken limbs resulting from cultivation, mowing, thinning, and harvesting equipment to a minimum. Injuries that do occur should be promptly treated to speed the healing process. Practices such a "pick-up and destroy" and "prune-out and destroy" can help to reduce damage by girdlers and pruners, especially when practiced on an area or neighborhood basis. When possible, practices should be adopted that favor natural controls such as predators, parasites, and insect pathogens. Chemical control may occasionally be needed.

J. D. Solomon is research entomologist at the Southern Hardwoods Laboratory, maintained at Stoneville, MS, by the Southern Forest Experiment Station, Forest Service—USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group. J. A. Payne is research entomologist at the Southeastern Fruit and Nut Research Laboratory, Agricultural Research Service, USDA—Byron, GA.

This publication should aid forest managers of timber resources, farm managers of nut producing groves, extension and pest control personnel, and homeowners to identify, manage, and control the major insect borer, pruner, and girdler pests of pecan and hickory. Descriptions and illustrations of the pests and their damage—including galleries, frass, size and portion of tree infested, and tree condition—are presented to aid in identification. Information on biology and control are given to help in predicting damage, managing populations, and making control decisions. Specific chemical controls are not given in this publication. For the latest information on pesticides contact your State Forester, Extension Agent, or the nearest office of State and Private Forestry, USDA Forest Service.

PECAN CARPENTERWORM
Cossula magnifica (Strecker)

Importance.—The pecan carpenterworm, *Cossula magnifica* (Strecker), is primarily a pest of pecan, but is also found in the hickories and reportedly some oaks throughout the Southern United States and Mexico (Baker 1972, Matz 1918, Moznette and others 1931). It attacks the branches and trunks of trees of all sizes, but shows a preference for trees 8 to 31 cm d.b.h. Small branches may break or dieback at the tunneled sites. Although very few trees break or die from carpenterworm attack, heavy repeated attacks may structurally weaken the tree, reduce its vigor, and provide entryways for decay fungi and other pathogens. The value of sawlogs and lumber from infested trees is markedly reduced because wormholes will cause the wood to be degraded. Although populations may be heavy locally, widely scattered infestations and sporadic appearance minimize the overall economic impact of the pecan carpenterworm.

Description.—The adult is a grayish moth mottled with brown and black blotches (fig. 1A) (Moznette and others 1931, Baker 1972, Gill 1924). The forewings are mottled with small brown patches, and each has a large brownish area at the distal end; the hindwings are uniformly darker without distinct markings. The wingspan ranges from 37 to 44 mm. The larva is pinkish in color and naked or only sparsely covered with short fine hairs that arise from the numerous tubercles (fig. 1B). The head, cervical shield, and anal plate are shiny dark brown. The full-grown larva may reach 37 mm in length. The pupa is brown and has a sharp projection on its head that is used to help force its way through the pupal cell and along the larval burrow to the exit hole.

Evidence of Infestation.—The earliest signs of attack are entrance holes, sap-stained bark, and small quantities of moist frass on the small branches during summer and early fall (fig. 2A). Dissecting the infested branch will reveal the larval tunnel (fig. 2B). However, these signs are often overlooked because the infested branches may be high above the ground, and the frass becomes scattered as it falls to the ground. It becomes easier to recognize the attacks when the larvae later bore into the trunk during the autumn (Moznette and others 1931, Turner and others 1918). Although attacks may occur at any point on the trunk, they are usually concentrated around the basal part of the trunk from groundline up to about 1.2 m. Attacks in the trunk are characterized by a small circular entrance hole about 6 mm in diameter with sap-stained bark below the entrance and a few excrement pellets and fine frass in bark crevices (fig. 2C). Pellet-like frass often accumulates in piles on the ground around the base of infested trees. Entrance holes are enlarged to about 9 mm just prior to pupation. Brown pupal skins may be found protruding from entrance holes during emergence in May and June. Entrances to galleries heal over leaving uniformly round or oval bark scars for several years as evidence of previous attacks.

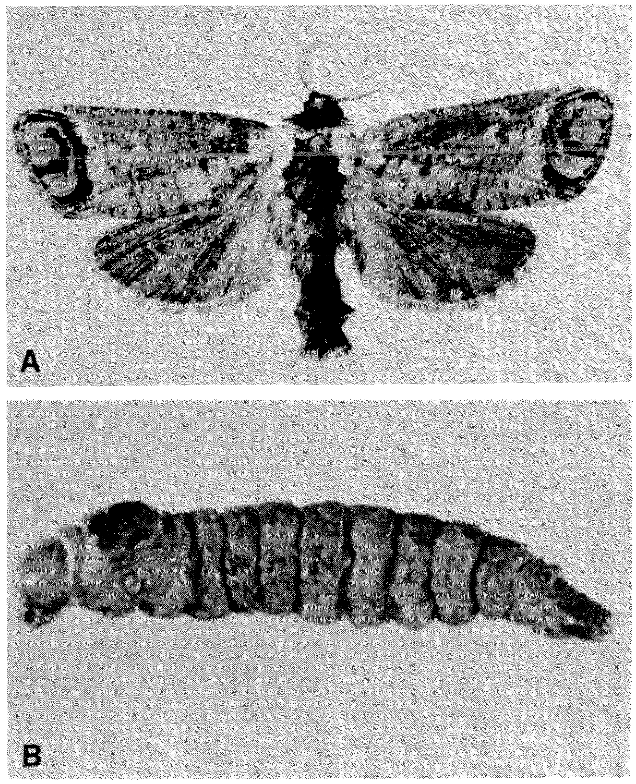

Figure 1.—*Life stages of* Cossula magnifica: *(A) adult moth; (B) mature larva.*

Biology.—Eggs are deposited on the bark of small branches in the tops of trees after emergence and mating of the adult moths from late April through June (Baker 1972, Moznette and others 1931, Gill 1924). The newly hatched larvae first attack small twigs and

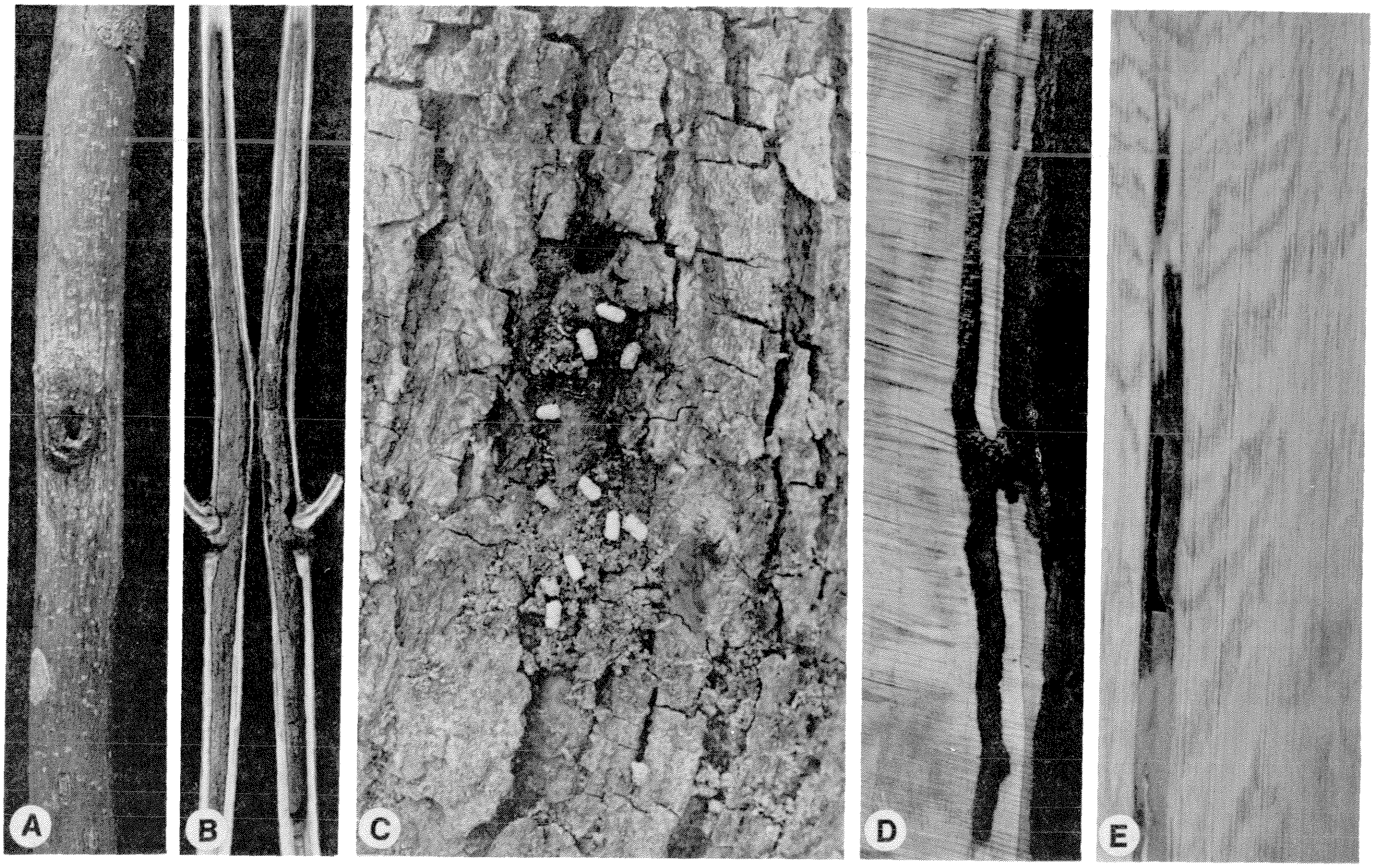

Figure 2.—*Injury by larvae of* Cossula magnifica *in pecan: (A) entrance hole with sap-stained bark in small branch; (B) small branch dissected to expose gallery; (C) entrance hole, frass, and stained bark in large trunk; (D) completed gallery in wood of large trunk; (E) wormhole and stain defects in lumber.*

branches and tunnel out the pithy center (fig. 2B). When the larva becomes too large for the small twig, it crawls out and enters a large branch. Entrances in twigs and small branches are usually made adjacent to buds, leaf petioles, or small secondary branches. The larva may tunnel up to 10 cm in both directions from the entrance hole, leaving only shells of small branches 10 to 13 mm in diameter. By early fall the larvae vacate their branch galleries, crawl downward on the bark, and bore into the trunk and large branches. Larvae attacking the trunk usually initiate galleries in bark crevices and tunnel horizontally or obliquely upward for 13 to 32 mm, then vertically for another 6 to 13 cm (fig. 2D). Many larvae also tunnel downward from the point of entrance another 5 to 10 cm. The cross-section of the vertical portion of the gallery is usually round, and about 6 mm in diameter. The wormholes and associated stain and decay show up as defects in the lumber (fig. 2E). The insect over-winters as a larva within the gallery. The following April or May the mature larva enlarges the entrance hole and then encloses itself and pupates in the upper end of the gallery behind a very peculiar but characteristic barrier or network of threadlike material. The sharp projection on the head end of the pupa enables the pupa to move through the barrier and down the tunnel to the entrance hole for emergence. Entrances to vacated galleries heal over, leaving uniformly round or oval bark scars in the bark (fig. 3). Although little is known about the life history, there appears to be one generation per year.

Control.—Although reported to occur throughout the South from North Carolina to Florida and west to Texas, infestations are generally widely scattered (Boethel and others 1980). Trees planted as ornamentals or in orchards, groves, or other open-grown situations are generally more heavily infested than those growing in well-stocked forest stands. Care should be exercised so that new plantings are not established adjacent to old orchards or stands heavily infested with carpenterworms. Keeping the trees in vigorous condition and free of disease cankers and mechanical injuries will help to prevent infestation. Two tachinid parasites, *Phorocera comstocki* Williston (Leiby 1925) and *P. signata* Aldrich and Webber have been reared, but little is known of their effect on carpenterworm populations. Small numbers of borers can be controlled by injecting a fumigant into the gallery and then using clay or putty to plug the entrance hole. Insecticides used periodically in groves to control nut

Figure 3.—*Round, oval scars in bark provide evidence of previous attack by* Cossula magnifica.

and foliar insects provide some, but not complete, control of carpenterworms. Chemical control specifically for pecan carpenterworm is seldom justified (Boethel and others 1980).

DOGWOOD BORER

Synanthedon scitula (Harris)

Importance.—Although the dogwood borer, *Synanthedon scitula* (Harris), is perhaps best known for its economic damage to the flowering dogwood for which it is named, it sometimes causes serious damage to pecan (Herrick 1904, Moznette and others 1931). It has also been found attacking hickory, oak, and many other species. It is known from southeastern Canada southward over the Eastern United States west to Texas. Damage results from the larvae feeding just beneath the outer bark in the phloem and cambium. Individual branches and even young trees may be completely girdled and killed, but most often the stem is only partially girdled or patches of bark killed. Attacks may occur at any point on the trunk and branches of trees of all sizes. Trees that are wounded, diseased, or in poor vigor are most susceptible to attack. It often attacks grafted and budded trees, destroying much of the cambium and callus tissue and preventing the union of scion and stock. Topworked trees have suffered serious damage in the past.

Description—The adult is a delicate bluish-black clearwing moth with yellow markings on the thorax, yellow-banded legs, and yellow stripes on segments two and four of the abdomen (fig. 4A) (Herrick 1904, Pless and Stanley 1967). Wings are transparent with bluish-black margins and have a wingspan of 14 to 20 mm. Eggs are pale yellow to brown, elliptical in shape, and about 0.5 mm long and 0.4 mm in diameter. Larvae are off-white to cream colored with reddish-brown heads, and range in size from less than 1 mm when newly hatched to 14 mm when mature (fig. 4B). The prothoracic shield has two dorsal yellowish-brown spots. The pupa is brown and remains inside a cocoon until time for adult emergence.

Evidence of Infestation.—The most easily recognized early sign of attack is the presence of fine frass that has been extruded from the tunnels through small openings in bark crevices (Herrick 1904, Underhill 1935). By cutting away the outer bark, larval tunnels and feeding larvae can be exposed (fig. 4B). When inspecting trees for damage, it is important to examine the lower trunk of young trees, especially around and just above the groundline. Trees wounded,

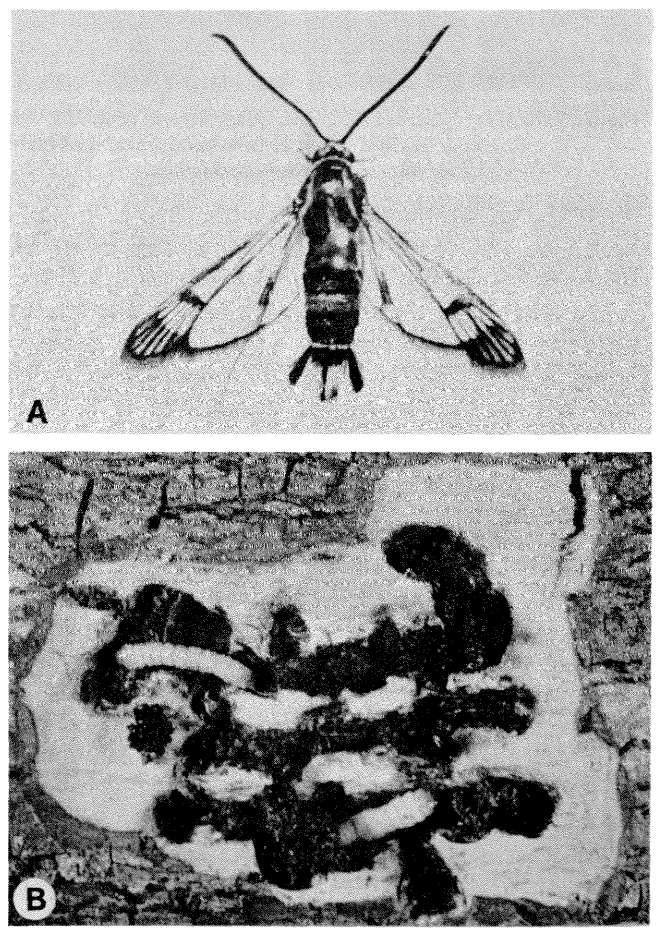

Figure 4.—*Life stages and tunnels of* Synanthedon scitula *in pecan: (A) adult clearwing moth; (B) bark removed exposing the larvae and burrows.*

diseased, or in poor vigor are most susceptible to attack and should be inspected frequently. After trees have been infested for a year or so, the dead bark over the borer tunnels begins to loosen and break away, sometimes exposing the wood beneath (fig. 5A). Trees that are badly infested may have an unhealthy appearance, exhibit dieback of branches in parts of the crown, and send out sprouts from near the groundline. Mortality occurs if trees are completely girdled. Graft failures should be inspected closely for evidence of infestation. Frass around fresh wounds and points of grafting and budding can mean the beginning of an infestation. Small brown pupal skins may be found protruding from the bark from April through October (fig. 5B). Exposure of infested sites by prying the bark loose frequently reveals one to a dozen or more larvae of various sizes feeding close together in localized tunnels.

Biology—Adults emerge from April to October with the greatest number appearing in the early part of the year (Pierce and Nickels 1941, Pless and Stanley 1967). Eggs may be deposited on the bark anywhere along the trunk or branches, although most are placed close to wounds, on or adjacent to frass, near openings produced by other borers, and around grafts or buds.

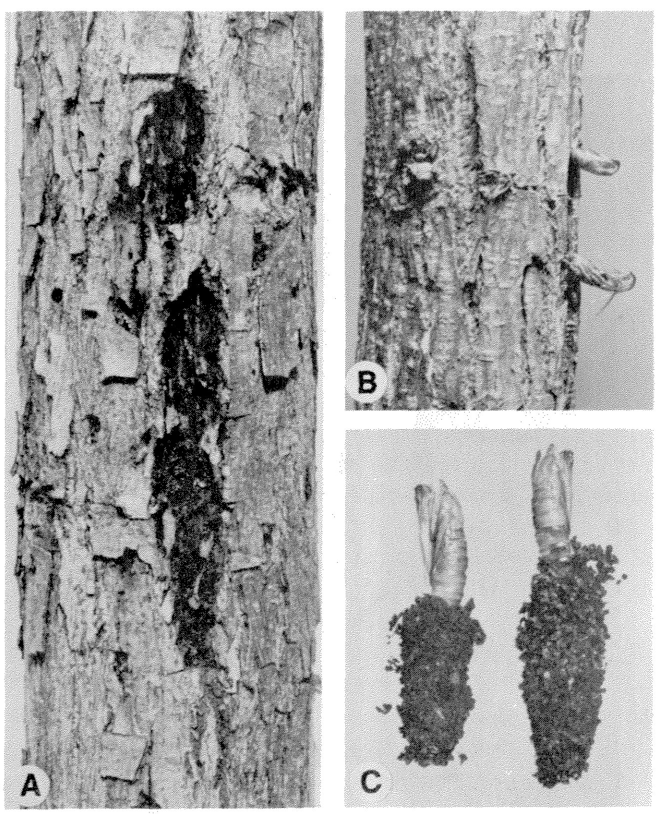

Figure 5.—*Evidence of attack by* Synanthedon scitula *in pecan: (A) active attack on trunk of young tree; (B) pupal skins in bark are positive signs of infestation; (C) dark-brown frass-covered cocoons just under the bark with protruding pupal skins.*

The eggs hatch in 8 to 9 days. Newly hatched larvae are small, fragile, and very sensitive to humidity; many die from dessication before locating a suitable niche to begin boring. The newly hatched larvae are able to move short distances and usually seek wounds, fresh grafts, and tunnels of other borers to become established, although a few are able to successfully establish burrows at uninjured sites. Larvae make irregularly shaped tunnels or burrows that spiral upward in the bark and cambium. Although the sapwood may be etched, no burrows are made into the sapwood. Larvae of various sizes overwinter in their burrows and are able to withstand a wide range of temperatures. The following spring the immature larvae continue feeding, while the mature ones pupate. The mature larva usually prepares a cocoon of frass and silken threads in the burrow beneath the outer bark for pupation (fig. 5C). Pupae within cocoons are rarely found in the leaves and trash around the base of the tree. The pupal stage lasts 8 to 12 days. There is one generation per year, with some evidence of a second generation in its southern range.

Control.—Except under conditions favorable for the borers, natural enemies usually keep infestations in check (Pless and Stanley 1967, Underhill 1935). Parasites that have been recovered are four braconids, *Apanteles sesiae* Viereck, *Agathis buttricki* Viereck, *Microbracon sanninoidae* Gahan, *M. mellitor* Say, two ichneumonids, *Phaeogenes ater* Cress., *Scambus (Itoplectis) conquisitor* Say, and one eulophid, *Hyssopus sanninoidae* Gir. In some cases, up to 50 percent of the larvae are parasitized. A disease caused by the fungus *Cordyceps* sp. has been found but is not prevalent. Woodpeckers excavate a small number of larvae. Adhering to recommended cultural practices for keeping trees vigorous and free of bark injuries is important in preventing serious damage due to dogwood borers. Direct control is seldom needed in natural stands but is sometimes needed in groves, nurseries, and ornamental trees (Pierce and Nickels 1941).

AMERICAN PLUM BORER

Euzophera semifuneralis (Walker)

Importance.—The American plum borer, *Euzophera semifuneralis* (Walker), a pest of pecan and hickory, has a wide host range, being especially troublesome to fruit trees (Blakeslee 1915, Pierce and Nickels 1941). It is widely distributed throughout the United States and is also found in Canada, Mexico, and Columbia, South America (Heinrich 1956, Forbes 1890). It is primarily a pest of trees in poor vigor, usually attacking trees that have been mechanically wounded or infected by canker-type fungous diseases. The larvae rarely succeed in establishing themselves on healthy, uninjured trees. Damage results from the larvae feeding in the cambial area, sometimes girdling and killing small trees. It may also be found feeding on the callus tissue of recently grafted or budded trees. Graft failures are sometimes attributed to this borer.

Description.—The adult has a light-gray body with grayish-brown forewings that have a broad, wavy band of black and brown markings (fig. 6A) (Blakeslee 1915, Heinrich 1956, Forbes 1890). The hindwings are smokey gray with a distinct black margin. The wingspan ranges from 17 to 25 mm. Eggs vary from dull white when deposited to pink or brown as incubation progresses. Each egg is oval and measures about 0.6 mm long and 0.4 mm in diameter. The larva is white when newly hatched but the color varies from dull white to pinkish or reddish brown as it develops (fig. 6B). The head is dark brown and the cervical shield is pale yellow with black markings on the sides. Full-grown larvae range from 16 to 28 mm and average about 25 mm in length. The pupa is brownish black and is found inside a white silken cocoon.

Evidence of Infestation.—The most obvious sign of infestation is an accumulation of dark-brown or black frass adhering to the bark at the site of attack (Blakeslee 1915, Pierce and Nickels 1941). The frass typically is made up almost entirely of excrement pellets stuck or adhering loosely together by sap exudate and silken threads. Attacks are limited almost entirely to trees with mechanical wounds, frost damage, sun scalds, disease cankers, pruning wounds, and recent grafts and buds (fig. 7A). Patches of dead or diseased cambium or partially girdled stems are favored sites for invasion. Larvae, larval burrows that extend into the living tissue, and accumulations of frass can be exposed by lifting pieces of dead bark. The presence of one or more loosely woven cocoons of white silken threads under the bark is very characteristic of the American plum borer (fig. 7B). The white silken cocoons distinguish this borer from the dogwood borer, which has dark-brown or black cocoons usually entirely covered with frass. Attacks may be found on trees and branches of all sizes, but they are most commonly found on the lower trunk just above the groundline.

Biology.—The insect overwinters as a larva in a white silken cocoon under loose bark near the entrance to its feeding burrows (Blakeslee 1915, Pierce and Nickels 1941). Pupation occurs within the cocoon during March and early April and lasts 20 to 30 days. Adults emerge during April and May. The females mate and begin ovipositing 1 to 3 days after emer-

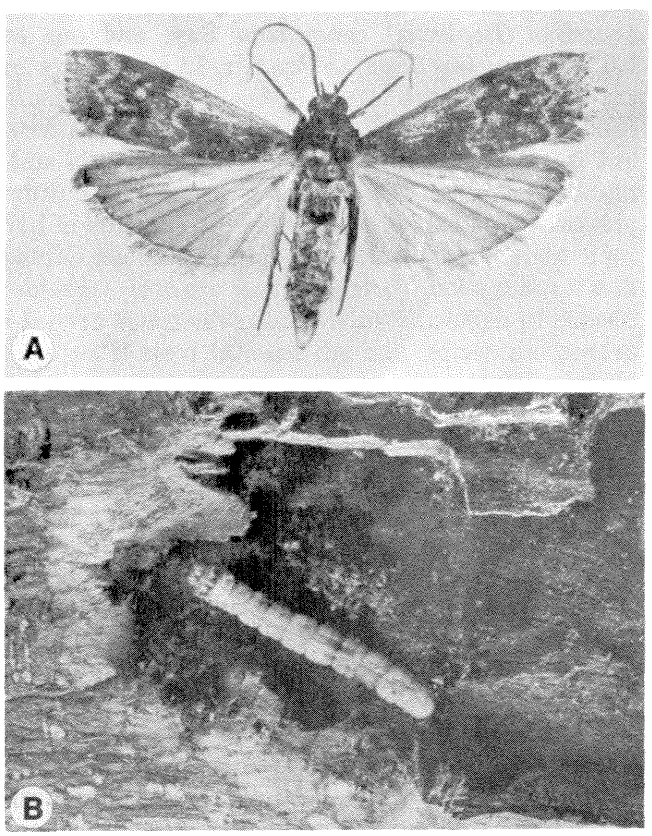

Figure 6.—*Life stages of* Euzophera semifuneralis: *(A) adult moth; (B) nearly grown larva.*

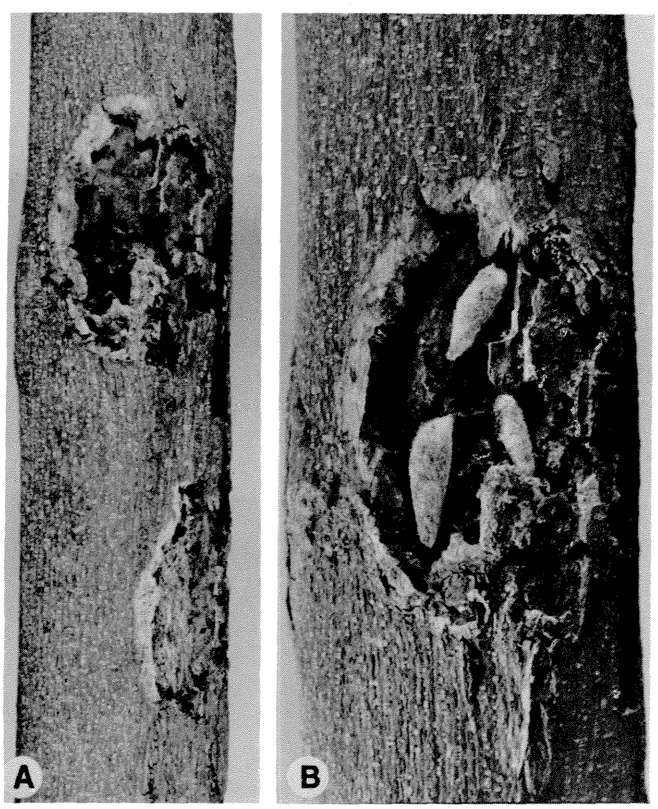

Figure 7.—*Evidence of infestation by* Euzophera semifuneralis *in pecan: (A) bark removed to expose tunneling injury; (B) closeup of white silken cocoons in mined cavity.*

gence and deposit eggs for 1 to 4 days. Females deposit from 12 to 74 eggs singly on twigs or in small groups in cracks and crevices of the bark of suitable host trees. The eggs hatch in 8 to 14 days and the young larvae seek wounds, cankers, and other suitable sites to begin feeding. The larval development period is 4 to 6 weeks. The mature larvae construct loosely woven cocoons of white silken threads under the bark for pupation. The pupation period for summer broods lasts 10 to 18 days, about half the time required for spring pupation. There are two or more generations per year. Larvae may be found almost continuously, indicating considerable overlapping of broods.

Control.—Because the insect is largely incapable of establishing itself in healthy, vigorous, uninjured trees, damage is unlikely except when trees suffer from frost injury, sun scald, mechanical wounds, or canker-type fungous diseases (Blakeslee 1915, Kelsey and Stearnes 1960, Pierce and Nickels 1941). Therefore, good cultural practices that prevent such injuries help to minimize damage from the American plum borer. Five ichneumonid parasites, *Mesostenus thoracicus* (Cress.), *M. gracilis* Cress., *Itoplectis marginatus* (Prov.), *Pimpla* sp., and *Idechthis* sp., help to suppress infestations. An unidentified threadworm parasite has also been reared. Predators include larvae of the ostomid, *Tenebrioides corlicalis* Melsheimer, ants, and woodpeckers. Chemical control is possible but seldom needed.

ACROBASIS SHOOT BORERS
Acrobasis spp.

Importance.—The acrobasis shoot borers are pests of pecan and hickory as well as black walnut and butternut from Ontario and Quebec in southeastern Canada southward to Florida and west to Texas in the United States (Baker 1972, Neunzig 1972). Some of the more important species include *Acrobasis nuxvorella* Neunzig, *A. juglandis* (LeBaron), *A. caryivorella* Ragonot, and *A. demotella* Grote. The acrobasis shoot borers are perhaps best known for their damage to foliage and nuts, although they often act as shoot borers during spring when growth begins (Payne and others 1979, Neunzig 1972). Boring and tunneling by the shoot borers cause many new tender shoots to become stunted, distorted, or die. Seedlings in nurseries can suffer serious damage. Mortality to the terminals of young trees intended for timber production is perhaps the most damaging type of injury (Kearby 1978). The destruction of terminals causes reduced growth and dichotomous branching, which results in forks, crooks, and abnormal branching. Repeated terminal injury during early growth can adversely affect the tree form that is so important when the goal is production of saw logs for lumber, veneer, and other products.

Description.—The adults are grayish to brownish moths with reddish, black, or white markings on the forewings and a wingspan of 12 to 20 mm (fig. 8A) (Payne and others 1979, Gill 1925, Neunzig 1972). The eggs are oval to elliptical, convex above and flattened below, with a reticular micropattern on the outer surface of the chorion. When first deposited, the eggs are greenish white, but they gradually assume a whitish and then reddish tinge as development progresses. Eggs vary from 0.5 to 0.8 mm in length and 0.25 to 0.36 mm in width. Newly hatched larvae are pale reddish brown and about 0.8 mm long. Mature larvae (fig. 8B) are cylindrical, taper slightly toward each end, and 10 to 19 mm in length. Head and mouthparts are dark yellowish brown; the prothoracic shield is pale brown; and the body is olive green to jade green, usually darker dorsally than ventrally. The newly formed pupa is olive green but gradually changes to light brown.

Evidence of Infestation.—Shoot damage occurs almost entirely during the spring (Martinat and Wilson 1978, Neunzig 1972, Payne and others 1979). The earliest evidence of injury may be holes in the swelling and unfolding buds. The majority of attacks to the shoot occurs after the buds have opened, but before there is much elongating or unfolding of the leaflets. Entrance holes are usually made into the basal part of the shoot just above the terminal leaf scar of the previous season's growth. However, some larvae make entrance holes some distance out on the shoot, usually where the inner base of a petiole joins the shoot (fig. 9A). Small amounts of frass are extruded from the gallery entrance and silked together to make a short loose tube, often forming an extension of the tunnel in all except *A. demotella,* whose larvae do not form a frass tube. The frass tube often becomes prominant as loosening bud scales and additional frass are silked together. Tunnels excavated in the tender shoots by the larvae range from 6 to 45 mm long (fig. 9B). The injury usually causes the terminal parts of the tender shoot to wilt, turn yellow and then brown, and die (fig. 9C). Tunneled shoots sometimes become enlarged, swollen, or gall-like. Injured shoots that survive often become stunted and deformed and lose apical domi-

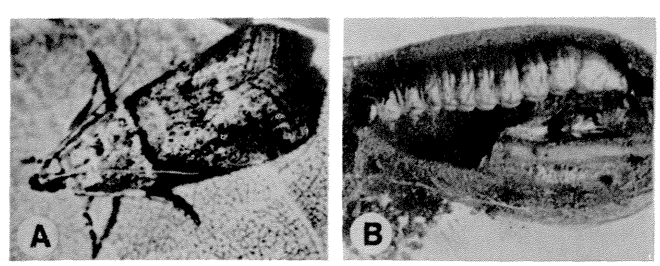

Figure 8.—*Life stages of* Acrobasis *spp.: (A) adult moth; (B) larva in burrow.*

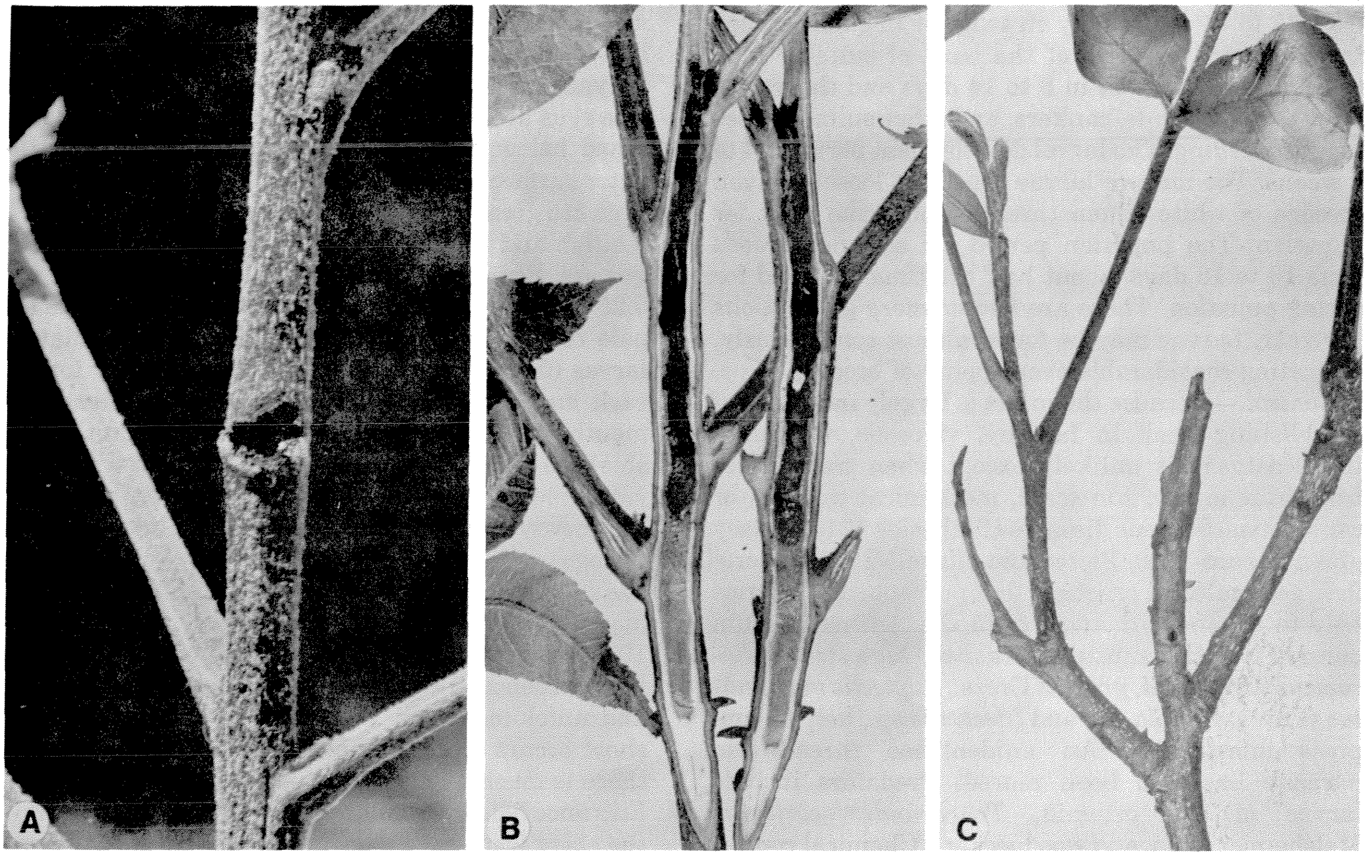

Figure 9.—*Signs of infestation by* Acrobasis *spp. in pecan: (A) entrance hole in terminal shoot; (B) young shoot dissected to expose gallery; (C) shoot terminal killed by larval tunneling.*

nance to a lateral shoot. The different species of *Acrobasis* can be partially separated by habits in attacking buds and shoots, site of entrance into the shoot, amount of tunneling, and characteristics of the frass tube and/or silking together of adjacent leaves, petioles, and shoots (Neunzig 1972).

Biology.—The shoot borers overwinter as partially grown larvae in tightly woven cocoons called hibernacula, typically found where a bud joins the stem (Neunzig 1972, Martinat and Wallner 1980, Payne and others 1979). The larvae emerge from the hibernacula in early spring and tunnel into the swelling buds and tender new shoots. When mature, a few larvae pupate within the galleries, but most vacate the tunnels and pupate under barkplates or drop to the ground and burrow into the litter or soil and pupate. The pupal stage lasts 11 to 18 days. Moths emerge and deposit eggs singly or in small groups, usually on nuts near the base of calyx lobes, on or near buds, and on the underside of leaflets. The eggs hatch in about 7 to 10 days. There may be one to four generations per year depending on species and north-south location. In the fall, third instar larvae construct and overwinter in hibernacula on or adjacent to a bud. Only during the spring do the larvae attack the shoots; later broods feed on the nuts and foliage (Payne and others 1979).

Control.—Natural enemies help in keeping the acrobasis shoot borers in check. Parasites are probably the most important group of natural controls; many species of parasites have been reported (Neunzig 1972, Martinat and Wallner 1980, Gill 1925). When new plantings are established, they should be located away from existing areas containing *Carya* and *Juglans* spp. Corrective pruning during early growth may be the best alternative to control, especially when plantings are intended for timber purposes (McKeague and Simmons 1978). Pruning should be done in May or early June, soon after the current season's shoot damage ceases. The pruning technique should retain the strongest newly developing shoot as the new terminal. Corrective pruning aims to reestablish apical dominance by one shoot in order to correct forks that may have resulted from terminal bud injury, thus improving tree form. Insecticides may be necessary when infestations are heavy (Payne and others 1979).

HICKORY SHOOT CURCULIO

Conotrachelus aratus (Germar)

Importance.—The hickory shoot curculio, *Conotrachelus aratus* (Germar), attacks pecan and hickory throughout the Eastern United States from Massachusetts south to Florida and west to Texas and Kansas (Phillips 1964, Schoof 1942, Brooks 1922). Injury results from both adult and larval feeding. Injury from larvae tunneling within the new shoots and leaf stems is most damaging, resulting in premature foliage loss and weakening or death of nut-producing shoots. Loss of terminals in young trees intended for timber production can result in forks and abnormal trunk development. Heavy damage has occurred in twigs and shoots on young budded trees in nurseries. Severe infestations are found most often on unmanaged trees or in groves adjacent to woodlands containing native pecan and hickory trees (Payne and others 1979). Fifty percent or more of the shoots can become infested. Two other curculio shoot borers, *C. elegans* (Say) and *C. tibialis* Brooks, cause injuries similar to *C. aratus* but are less prevalent.

Description.—The adult is a weevil-type beetle with a short, stout snout that is slightly curved and about one-third the length of the body, or about as long as the head and thorax combined, and has the sternum grooved for reception of the beak (fig. 10A) (Brooks 1922, Payne and others 1979, Schoof 1942). The color is dull grayish to reddish brown with an indistinct broad band of yellowish pubescence behind the middle of the elytra and a narrow line of the same color on each side of the thorax. Adults average about 5 mm long and 2 mm wide. The egg is oval to oblong, creamy white, semitransparent, and averages 1.1 mm long and 0.7 mm in diameter. The larva is yellowish white with a brown head and black jaws and has a scattering of short but noticeable setae (fig. 10B). The larva is legless, slightly curved or crescent shaped, and averages about 6.0 mm long and 1.5 mm in diameter. The pupa is delicate and white but gradually darkens.

Evidence of Infestation.—Soon after growth begins in the spring, feeding and oviposition puncture marks made by adult curculios can be found on tender shoot tips and leaf petioles (Brooks 1922, Phillips 1965, Payne and others 1979). Egg punctures are characterized by dark triangular V-shaped marks or spots 3 mm long on the green bark. These dark puncture marks occur singly just above each leaf axil, but there may be 3 to 10 punctures per shoot. The favorite feeding place of the larva is in the bulblike swelling at the base of the leaf petiole, but it also mines in the pith of new shoots and leaf stems (fig. 11A). An active larval gallery usually has a small amount of dark frass at the entrance (fig. 11B). Dissection will reveal the crescent-shaped larvae. The burrows or galleries may range from 25 to 51 mm long (fig. 11C). The affected shoot tips and leaves usually become yellowish or brown and wither on the tree or drop away. Shoots that are heavily tunneled often break and drop without turning yellow and withering. Late summer and fall feeding by the newly emerging adults cause feeding puncture wounds along the shoot and leaf petioles, but late season damage is negligible.

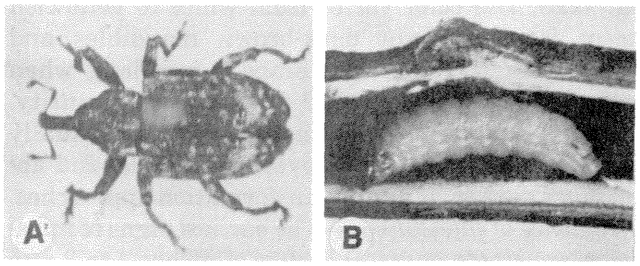

Figure 10.—*Life stages of* Conotrachelus aratus: *(A) adult weevil; (B) mature larva.*

Biology.—The hickory shoot curculio overwinters in the adult stage in litter, trash, or debris on the ground near host trees (Brooks 1922, Payne and others 1979, Schoof 1942). Adults emerge from hibernation and become active in early spring as buds begin unfolding and shoot growth begins. Feeding begins in late March and April in the south and 2 to 4 weeks later in the northern range. After feeding for a short time, females deposit eggs singly in puncture niches in the tender shoot tips and leaf petioles just above the enlarged petiole base. Eggs hatch in about a week and the larvae begin feeding and tunneling within the tender new growth where they complete their larval development. When fully grown by midsummer, the mature larvae vacate their galleries, drop to the ground beneath the tree, and burrow into the soil to a depth of 12 to 51 mm where they form unlined, earthen cells for pupation. The pupal period lasts for 2 to 3 weeks. The adult curculios emerge from the ground mostly during August and September. Emerging adults are comparatively inactive and feed very little before entering hibernation in the autumn. There is one generation per year.

Control.—Fifty percent or more of the larval population may be destroyed by parasites (Brooks 1922). The three species of parasites identified from the larvae are two tachnids, *Myiophasia globosa* (Townsend) and *Cholomyiae inaequipes* Bigot, and one chloropid, *Chaetochlorops inquilinus* (Coquillett). New plantings should be established, when possible, away from heavily infested woodlots. Sanitation and cultural practices such as clipping, collecting, and destroying infested shoots can reduce populations when only a single or few high-value trees isolated from surrounding host trees are involved. Elimination of trash and debris can also help to eliminate hibernation sites. Chemical control is usually not necessary but occasionally may be needed when many adults are present or when there is a history of damage (Payne and others 1979, Phillips 1965, Brooks 1922). Up to three spray applications, beginning in early spring when unfolding buds have 6 to 25 mm of new growth, may be necessary to control the adults before they lay their eggs.

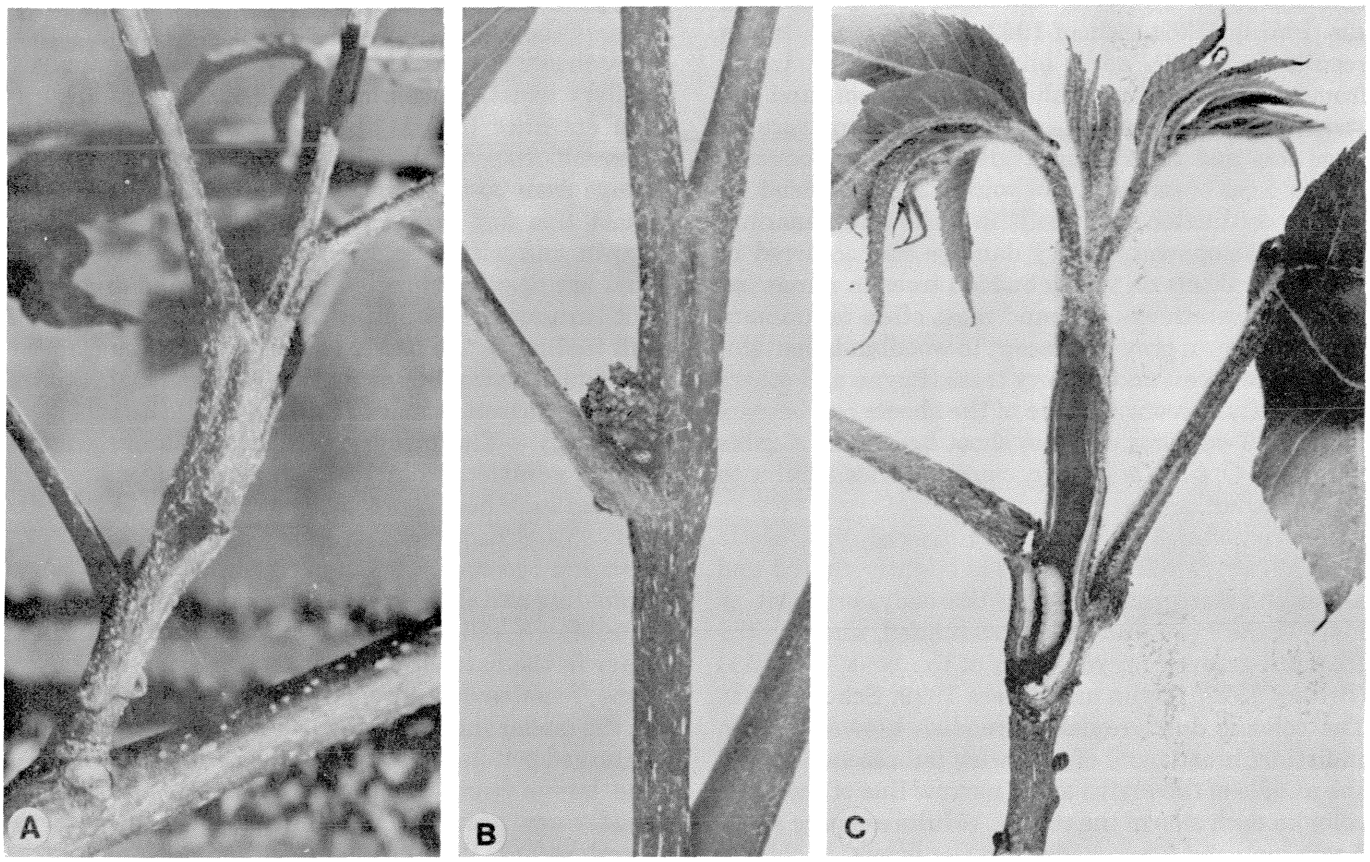

Figure 11.—*Young hickory shoots infested by* Conotrachelus aratus: *(A) swollen shoot with larval entrance hole; (B) dark frass being ejected from gallery entrance; (C) terminal dissected to expose gallery and young larva.*

HICKORY BORER

Goes pulcher (Haldeman)

Importance.—The hickory borer, *Goes pulcher* (Haldeman), is found from southern Canada throughout the Eastern United States, and although primarily a pest of the hickories, will occasionally attack pecan (Baker 1972, Beal and others 1952, Solomon 1974). The larvae tunnel in the sapwood and heartwood of young trees 2 to 14 cm in diameter, mostly from groundline up to about 5 m. Attacks in large trees are infrequent and usually restricted to the branches. Borer injuries in vigorously growing trees usually heal within a few months after the borers emerge, but in trees of poor vigor, up to 3 years are reguired. Galleries that heal slowly are frequently occupied by ants for nesting sites and sometimes kept open indefinitely, thus permitting the establishment of stain and decay fungi. Trunks weakened by tunnels, woodpecker excavations, and decay occasionally break during windstorms. The holes, together with the associated stain and decay, degrade the wood for any commercial use.

Description.—The adult is a typical long-horned beetle with a prominent lateral spine on each side of the pronotum (Solomon 1974). The beetle is light brown with dark elytral bands at the base and just beyond the middle of the wing covers (fig. 12A). They are moderately robust, elongate, and range from 17 to 25 mm long and 5 to 8 mm wide. Females are slightly larger than males and have heavier abdomens but slightly shorter antennae. The eggs are yellowish white, elongate, and average 4 mm long and 1 mm in diameter with a parchment-like surface texture. The larva is slightly robust, fleshy, and generally cylindrical but very slightly flattened dorsally and ventrally; the thoracic segments are slightly broader anteriorly (fig. 12B). The color varies from white to yellowish except for prominant dark-brown mandibles and amber spiracles. Larvae average 4 mm long when newly hatched and reach 18 to 28 mm at maturity. The pupa is white to greenish initially, but gradually becomes yellowish, and its eyes, mandibles, and appendages darken as adult transformation approaches.

Evidence of Infestation.—The earliest signs of infestation are single or small groups of niches 4 to 8 mm in diameter chewed in the bark exposing the

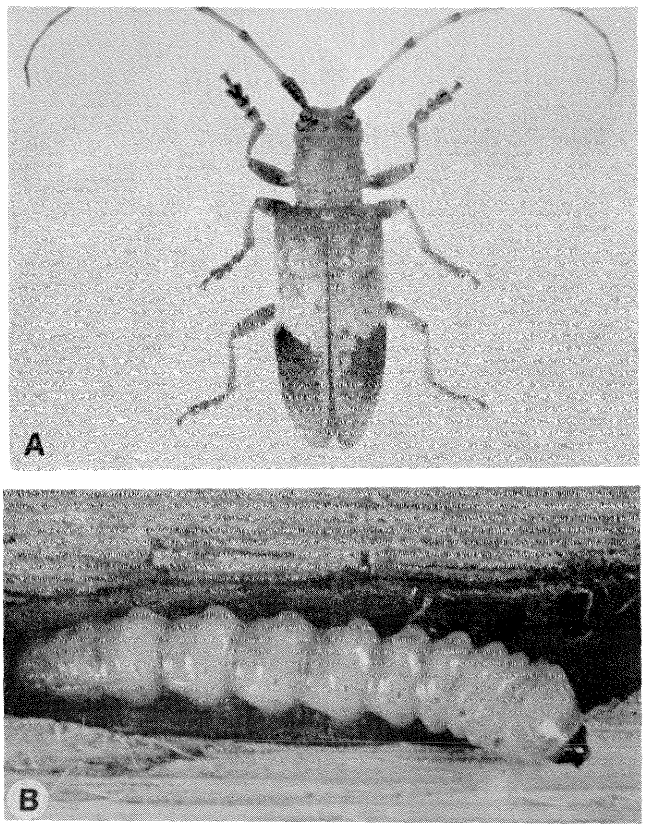

Figure 12.—*Life stages of* Goes pulcher: *(A) adult beetle; (B) mature larva.*

yellowish-brown phloem beneath (fig. 13A) (Beal and Massey 1942, Solomon 1974). However, the most obvious evidence is the sap-stained bark and yellowish frass protruding from the elongate entrance hole (fig. 13B). Sap oozing from the point of attack initially darkens the bark, but in succeeding years the stain becomes bleached or yellowish brown. The frass extrudes from the entrance in curved shapes or ribbon-like pieces that accumulate on the ground below. Numerous excelsior-like wood fibers 8 to 12 mm long in the frass signal larval maturity and approaching pupation. Each borer leaves two holes, an elongate entrance hole and a 7-mm round exit hole (fig. 13C). As these wounds heal, the bark scar at the entrance site appears slightly sunken, with a small bulge around the periphery. The exit hole heals in much the same way that a branch stub is overgrown. The bark scars remain in evidence for several years. Wormholes 10 to 13 mm in diameter in sawn lumber provide good evidence of hickory borer infestation (fig. 13D).

Biology.—The adults emerge during May and June (Solomon 1974). After feeding on tender twigs, leaf petioles, and leaf midribs and then mating, the female begins ovipositing. She chews an oval niche in the bark, then forces her ovipositor through the opening and downward between the bark and sapwood to lay a single egg. One female will deposit up to 14 eggs under experimental conditions on caged trees but would probably deposit many more under natural conditions. Adults live from 11 to 32 days. Females usually deposit their eggs singly, although clusters of two or three egg niches are sometimes found. Open-grown trees and those growing near openings are most frequently selected for oviposition, with a preference shown for branch crotches. The larvae produce small mines 1 to 2 cm in diameter under the bark and then bore directly into the sapwood. The galleries extend horizontally or obliquely upward in the sapwood and heartwood for 2 to 5 cm, rise vertically for another 6 to 12 cm, then turn horizontally back to the surface (fig. 13E). By the time the larva pupates, galleries range from 9 to 16 cm long and 10 to 13 mm in diameter. The life cycle is 3 to 5 years. During late fall and early spring of the final year of the life cycle, the mature larva prepares a pupation chamber at the uppermost portion of the gallery by plugging the gallery tightly with long excelsior-like fibers. Pupation lasts for 15 days. The new adult chews a round exit hole at the upper end of the pupal chamber to emerge.

Control.—Woodpeckers, one of the most important natural enemies, may capture up to one-third of the larvae (Solomon 1974). Some natural mortality is found in vigorous trees that produce heavy sap that oozes from the oviposition sites. Direct controls have not been investigated, but borers in individual trees can be controlled by injecting a fumigant into the galleries, then plugging the entrance holes with clay or putty. Where problems exist in plantings near or adjacent to forests, removal of brood trees in the adjacent woodland is advised.

BROADNECKED ROOT BORER
Prionus laticollis (L.)

TILEHORNED PRIONUS
Prionus imbricornis (Drury)

Importance.—The broadnecked root borer, *Prionus laticollis* (L.), and the tilehorned prionus, *P. imbricornis* (Drury), are pests of pecan and hickory as well as many other trees from southern Canada throughout the Eastern United States and extending west to the Plains States (Payne and others 1976, Linsley 1962). Injury occurs from the larvae feeding on and destroying the roots. The larvae feed first on the root bark, but they soon enter the wood, completely hollowing large roots and often severing them. The larvae move from root to root through the soil, feeding on the surfaces of smaller roots as they go, causing many injuries and wounds. Open-grown mature trees and those weakened by disease, drought,

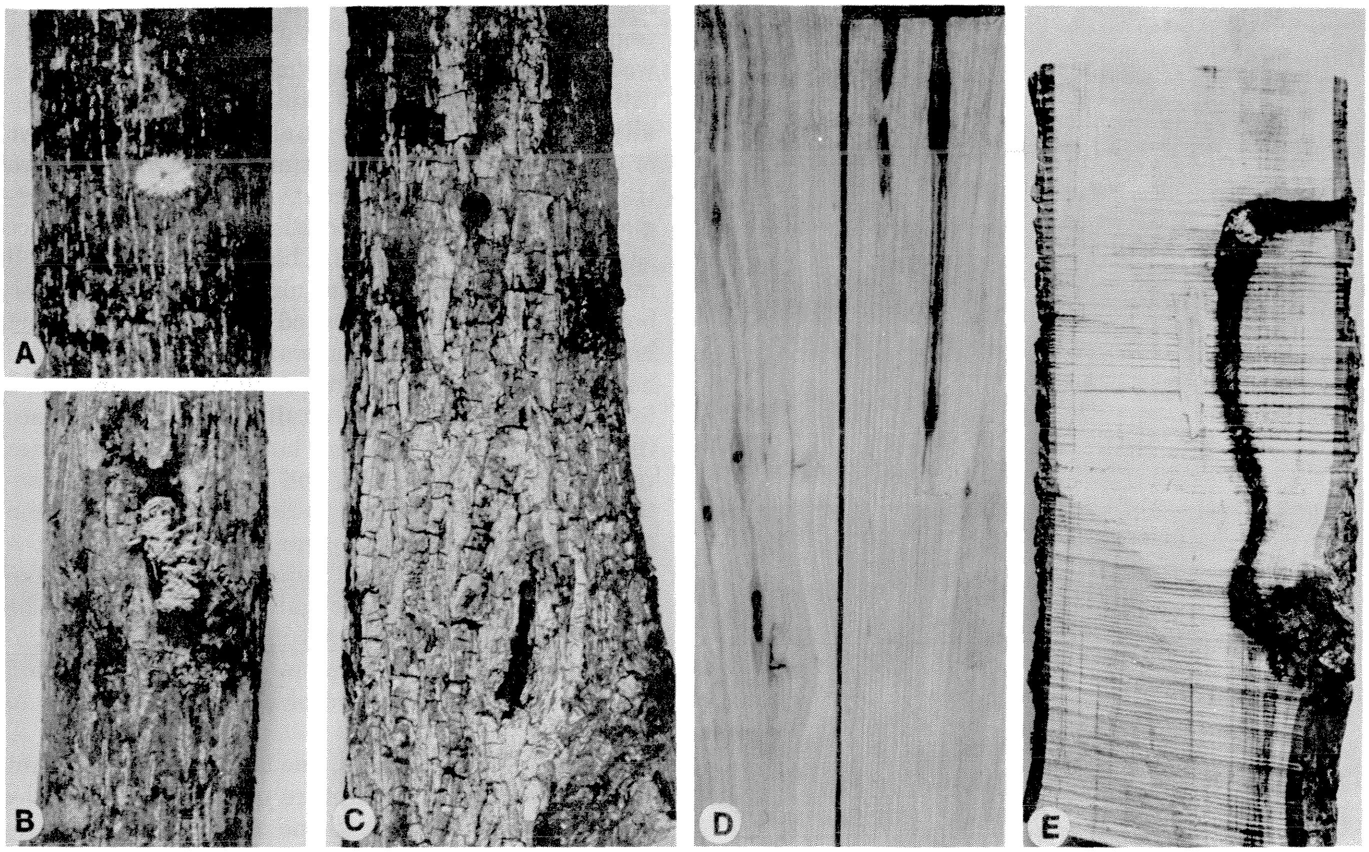

Figure 13.—*Habits and signs of infestation by* Goes pulcher *in hickory: (A) egg niche cut in bark by female beetle; (B) ribbon of frass being extruded from gallery entrance indicating active attack; (C) elongate entrance hole made by larva below and round exit hole made by adult above; (D) defects in sawn lumber; (E) sectioned stem showing typical larval gallery.*

mechanical damage, or soil conditions are most susceptible to attack, but young, vigorous trees can also be attacked and are occasionally cut off at the groundline. Severe root damage results in reduced growth, a poor nut crop, and eventual death of the tree. In southwest Georgia, pecan growers estimated that 3 to 10 percent of the trees showed signs of attack (Payne and others 1970).

Description.—The adults are robust, broad, somewhat flattened, and blackish brown to reddish brown (fig. 14A) (Linsley 1962). They have antennae about half as long as the body, and there are broad spines on each side of the prothorax. Adults of *P. laticollis* measure up to 45 mm long and adults of *P. imbricornis* measure up to 37 mm long. The eggs are irregularly punctate and glossy yellow, but later darken and lose their glossiness (Farrar and Kerr 1968). One end of the egg is slightly larger than the other. Eggs average 3.5 mm long and 1.4 mm wide. The large root-boring larvae are fleshy, elongate-cylindrical, and creamy white to yellowish; they have three pairs of small legs and small heads armed with strong mandibles adapted for boring in wood (fig. 14B) (Payne and others 1970). Mature larvae attain lengths of 9 cm or more and weigh up to 15 g. Pupation takes place inside earthen cells, and pupae are white initially, but their eyes, mandibles, and appendages darken as adult transformation approaches.

Evidence of Infestation.—Since injury to the roots occurs below ground level, correct diagnosis is often difficult (fig. 14C) (Payne and others 1970). Only by excavating the tree and examining the roots can one confirm the infestation (fig. 15A, 15B). The aboveground syndrome is a gradual decline, characteristic of any tree under severe, prolonged stress (fig. 16). Symptoms often resemble a nutrient deficiency—leaves may be sparse, reduced in size, and have a light-green to yellowish tinge. Nut yields from infested trees may be three to seven times less than from healthy trees. As an infestation progresses over a period of several years, 70 to 90 percent of the root system may be destroyed, resulting in a limb-by-limb death of the tree (Sparks and others 1974).

Biology—Adults emerge from the soil in late spring and early summer (Baker 1972, Benham and Farrar 1976). The beetles are normally nocturnal or crepuscular in habit and during the day remain hidden beneath debris or loose bark at the base of the tree. The females are short-lived—about 1 week—but deposit 300 to 500 eggs either singly or in groups in the soil

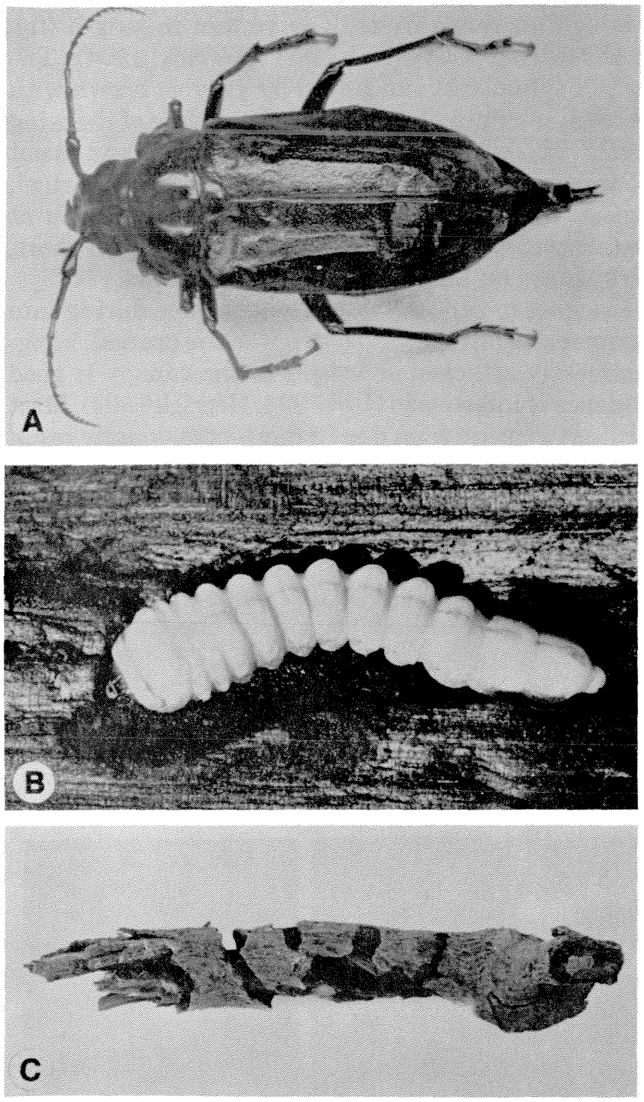

Figure 14.—*Life stages of and injury from* Prionus *spp: (A) adult beetle; (B) mature larva; (C) pecan root girdled and hollowed by larvae.*

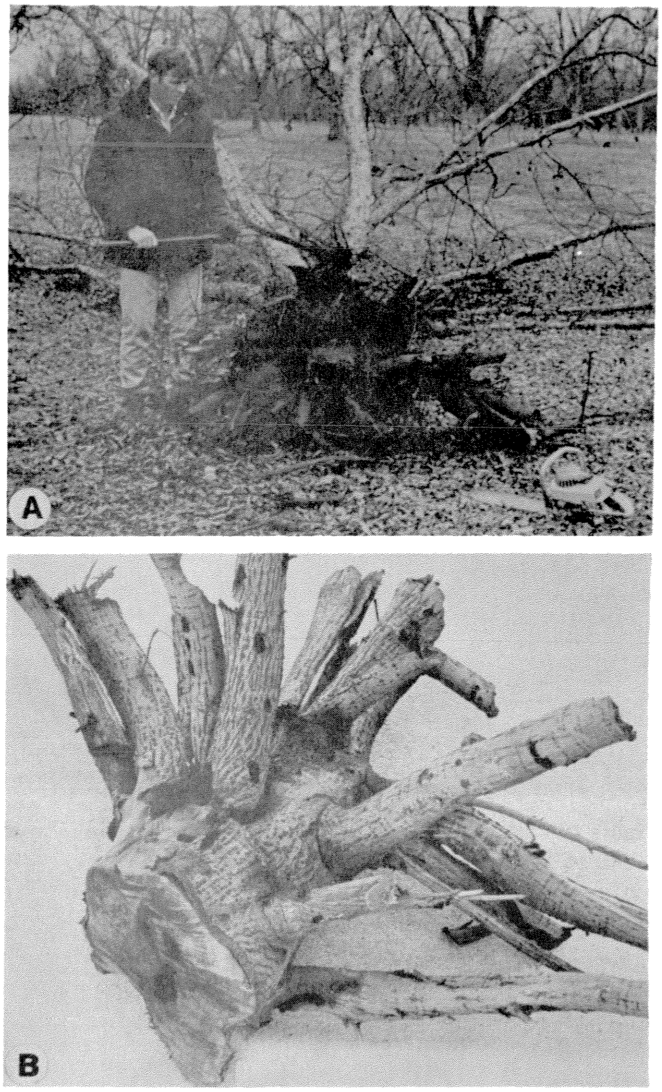

Figure 15.—*Diagnosing for* Prionus *spp. in pecan: (A) excavating roots to confirm* Prionus *infestation; (B) closeup of root system showing holes and girdling—most of smaller roots have been consumed by the larvae.*

near the base of host trees. When the eggs hatch in 2 to 3 weeks, the young larvae dig down to the roots and begin feeding on the bark. They move from root to root through the soil feeding on the surfaces of smaller roots as they go and causing many injuries and wounds. They enter the wood of larger roots and hollow, girdle, or sever them. In the summer, the larvae feed on roots in the upper 15 to 45 cm of the soil, but in winter they are often found at depths down to 80 cm. The feeding period lasts 3 to 5 years. In early spring, mature larvae come to within 6 to 12 cm of the soil surface and prepare large, oval earthen cells in which they pupate and transform to the adult stage.

Control.—Root borers usually attack trees weakened by other factors such as disease, drought, mechanical damage, or soil conditions (Sparks and others 1974). Therefore, cultural practices should be followed to keep trees thrifty and vigorous. Since these root borers are also pests of other tree species, it is advisable to establish new plantings some distance away from orchards and tracts of woodland that are already infested. Although little is known about natural enemies, they undoubtedly play a role in regulating root borer populations. A tachnid parasite (near *Dexilla)* has been reared from *P. laticollis* (Benham and Farrar 1976), and several bacteria and fungi have been isolated from dead larvae and pupae of *P. laticollis*. It may be necessary to use insecticides occasionally if root borer populations threaten high-value trees (Payne and others 1976).

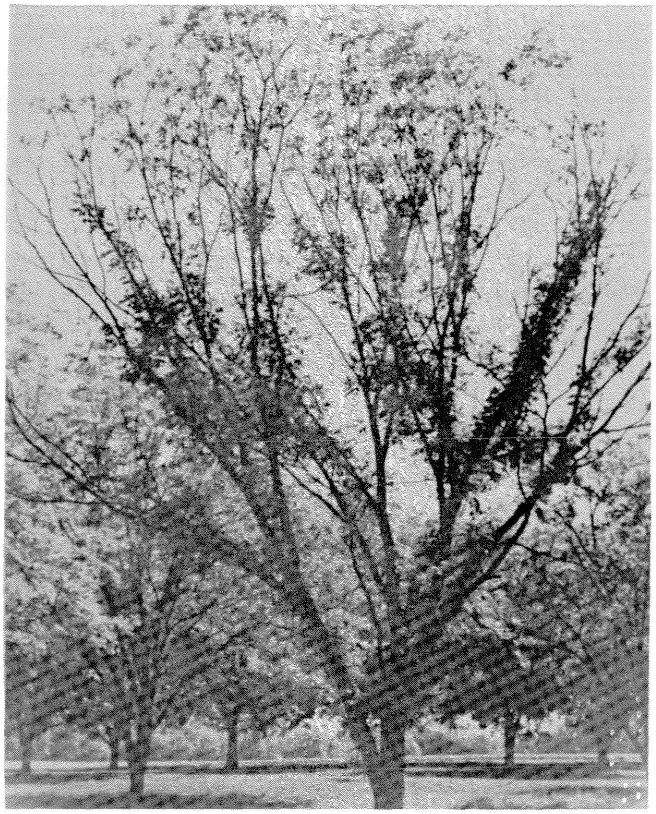

Figure 16.— *Pecan tree in declining condition—symptoms of root injury by* Prionus *spp.*

TWIG GIRDLER

Oncideres cingulata (Say)

Importance.—The twig girdler, *Oncideres cingulata* (Say), a pest of pecan and hickory, and to a lesser extent several other hardwood species, is found most commonly in the Southern States but is known as far north as New England and westward to Arizona (Gill 1924, Herrick 1904, Beal and Massey 1942). The adult beetles girdle twigs and small branches causing the injured portions to break away or hang loosely on the tree. It is not uncommon to see the ground under infested trees almost covered with twigs that have been cut off. This affects the beauty and aesthetic quality of ornamental plantings. The fruiting area of heavily infested trees is often greatly reduced, resulting in low nut yields the following year and sometimes longer. This type of injury causes the development of many offshoots that adversely affect the symmetry of the tree. Pecan nurseries located close to heavily infested woodlots occasionally suffer considerable loss from girdled seedlings. Repeated girdling of terminals causes forks, crooks, and other stem deformities in young timber plantations as well as in natural reproduction (Kennedy and others 1981).

Description.—The adults are typical long-horned beetles that range from 12 to 16 mm in length (fig. 17A) (Bilsing 1916, Gill 1924, Herrick 1904). The body is cylindrical and generally grayish brown with a broad, ashy-gray band across the middle of the wing covers. The eggs are white, elongate oval, and about 2.5 mm in length. The larvae are whitish, cylindrical, legless grubs that reach 16 to 25 mm in length at maturity (fig. 17B). The pupae are white with short, dark spines on the dorsal sides of segments.

Evidence of Infestation.—The presence during late summer and fall of severed twigs on the ground, hanging loosely attached or lodged in the canopy is good evidence of infestation (Gill 1924, Herrick 1904). Most girdled twigs are from 6 to 12 mm—occasionally ranging up to 18 mm—in diameter, and 30 to 60 cm in length. The nature of the girdle itself distinguishes the twig girdler from other branch pruners. The cut by the twig girdler is the only one made from the outside by the adult beetle and has been described as a uniform V-shaped cut (fig. 17A). The cut is seldom

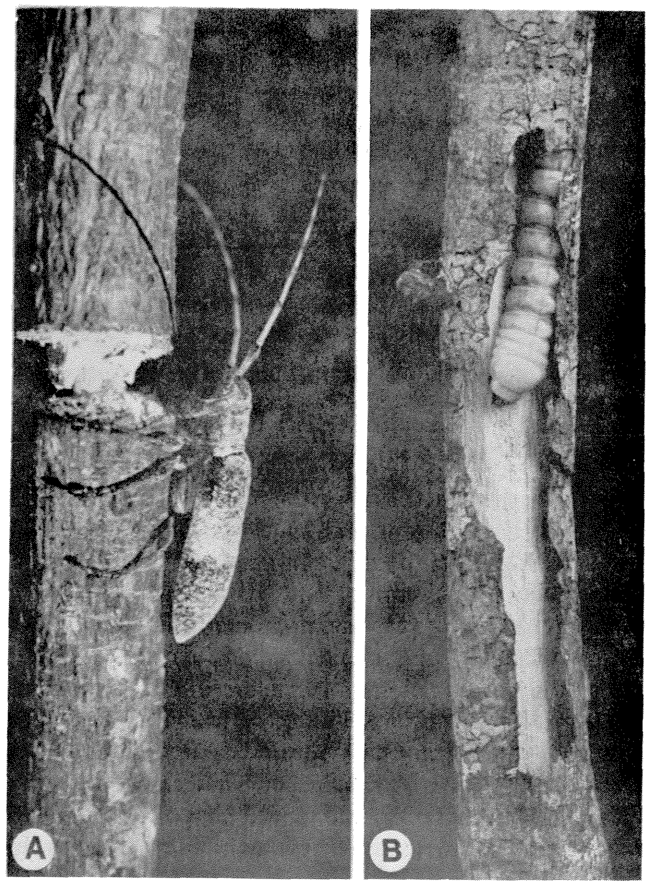

Figure 17.—*Life stages of* Oncideres cingulata: *(A) adult beetle girdling pecan stem; (B) mature larva in gallery.*

complete, leaving a small center with a jagged surface caused by the break. Since the twigs are girdled while the leaves are present, the severed twigs retain the brown leaves for some time (fig. 18). Severed twigs lodged in the tree canopy or on the ground often retain leaves even after the tree sheds its leaves in the autumn. Close inspection of the severed twigs will reveal tiny egg niches and many mandible marks or grooves made in the bark by the female beetles. Large trees usually sustain the most girdling, but young plantation trees are sometimes heavily damaged (fig. 19).

Biology—The adults emerge from late August to early October (Bilsing 1916, Gill 1924, Herrick 1904). They feed on the tender bark near branch ends and mate before ovipositing and girdling the twigs. The branches are apparently girdled by the female so that congenial conditions will be provided for the development of the larvae, which are unable to survive in living twigs. The girdling extends through the bark and well into the wood in a complete circle around the stem and leaves only a thin column of the center wood attached, which breaks easily (fig. 17A). Eggs are laid during or after the cutting process, but never before the beetle makes part of the cut. They are inserted singly beneath the bark or slightly into the wood, usually near a bud scar or adjacent to a side shoot. The number of eggs per twig varies from 3 to 8 but may range up to 40. Adults live 6 to 10 weeks. Females deposit 50 to 200 eggs each, which hatch in about 3 weeks. After overwintering, the larvae grow rapidly in the spring and tunnel toward the severed end of the twig by feeding only on the woody portion and leaving the bark intact. A few small circular holes are made in the bark to eject pellets of frass and excrement. The mature larvae close off the gallery with shredded fibers to form a pupation chamber. Pupation occurs during August and September and lasts 12 to 14 days. The adult chews a circular hole in the bark to emerge. There is one generation per year.

Control.—In orchards, nurseries, and ornamental plantings, the severed twigs on the ground as well as those lodged in the trees should be gathered and burned during the fall, winter, and spring when the eggs and grubs are in the twigs (Gill 1924, Moznette and others 1931). The same practice should be followed in nearby woodlots when plantings in the vicinity have a history of serious damage from this insect pest. Insecticides may be necessary to prevent damage from heavy infestations, although they are probably

Figure 18.—*Main stem of young tree girdled by* Oncideres cingulata.

Figure 19.—*Young plantation tree with terminal and most of branches girdled by* Oncideres cingulata.

unnecessary in natural forest stands. Natural controls are important in keeping twig girdler populations low; desiccation of the eggs is apparently the greatest single decimating factor. Three parasites: an eurytomid, *Eurytoma magdalidis* Ashm., one ichneumonid, *Iphiaulax agrili* (Ashm.), and one eulophid, *Horismenus* sp., help to reduce the girdler population (Beal and Massey 1942). A clerid predator, *Cymatodera undulata* Say, has also been reared.

TWIG PRUNER
Elaphidionoides villosus (F.)

OAK TWIG PRUNER
Elaphidionoides parallelus Newman

Importance.—The twig pruner, *Elaphidionoides villosus* (F.) and oak twig pruner, *E. parallelus* Newman, are found throughout the Eastern United States northward to Canada and westward to Texas, reaching greatest importance in their northern range (Chittenden 1910, Linsley 1963, Moznette and others 1931). They attack pecan and hickory as well as other forest, shade, and fruit trees but show a marked preference for the oaks. The larvae, boring in the stems, cut off or prune twigs and small branches. Pruned twigs drop to the ground or hang loosely from partially severed branches. The ground under heavily infested trees may be littered with fallen twigs and branches. Such pruning and littering adversely affect the aesthetic quality of ornamental plantings and cause clean up problems; heavy twig losses reduce the fruiting area and, in turn, the nut crop; and young trees may be deformed. Injuries to trees in natural stands are seldom serious.

Description.—The adult beetles are elongate, slender, and parallel-sided (fig. 20A) (Chittenden 1910, Linsley 1963). The bodies are light to dark brown and clothed with irregular patches of fine gray hairs giving them a mottled appearance. There are spines on the first few joints of the antennae and the tips of the wing covers are notched and bispinose. They range from 12 to 18 mm in length. *Elaphidionoides villosus* resembles *E. parallelus* very closely, but *E. parallelus* is usually slightly smaller and somewhat more slender. The larvae are elongate, cylindrical, and creamy white; they have short rudimentary thoracic prolegs and measure about 14 to 22 mm in length at maturity (fig. 20B).

Evidence of Infestation.—During the summer, fall, and winter pruned twigs from 8 to 20 mm in diameter and from 20 to 90 cm in length litter the ground under infested trees (Gill 1924, Moznette and others 1931). Pruned twigs may also hang from the crown. The nature of the girdle itself distinguishes the twig pruners from the twig girdler and branch pruner. The cut by twig pruners is made from inside by the larva, which gnaws a circular groove in the wood, leaving only the bark intact. The severed end of the twig presents a smoothly cut surface, near the center of which is an oval 2-mm gallery opening often plugged lightly with frass (fig. 21). A smaller side-twig is usually hollowed out and may be broken in its fall to the ground. There are no egg niches or mandible marks on the bark surface as seen with the twig girdler. Moreover, splitting the freshly pruned twig reveals the nearly grown twig pruner larva inside, while the twig girdler either has not hatched or the larva is too small to be noticed until the following spring and summer.

Biology.—The adults emerge from early spring to early summer (Chittenden 1910, Gosling 1978). The female deposits her eggs in slits in the bark at leaf axils near the tips of very small green twigs that arise from a larger twig 8 to 20 mm in diameter. The young larva burrows down the center of the twig toward its base, hollowing it out more or less completely. When the larva reaches the larger limb, it bores into the branch and burrows a short distance down the center of the stem. In late summer or fall the larva severs the branch by making concentric circular cuts from the

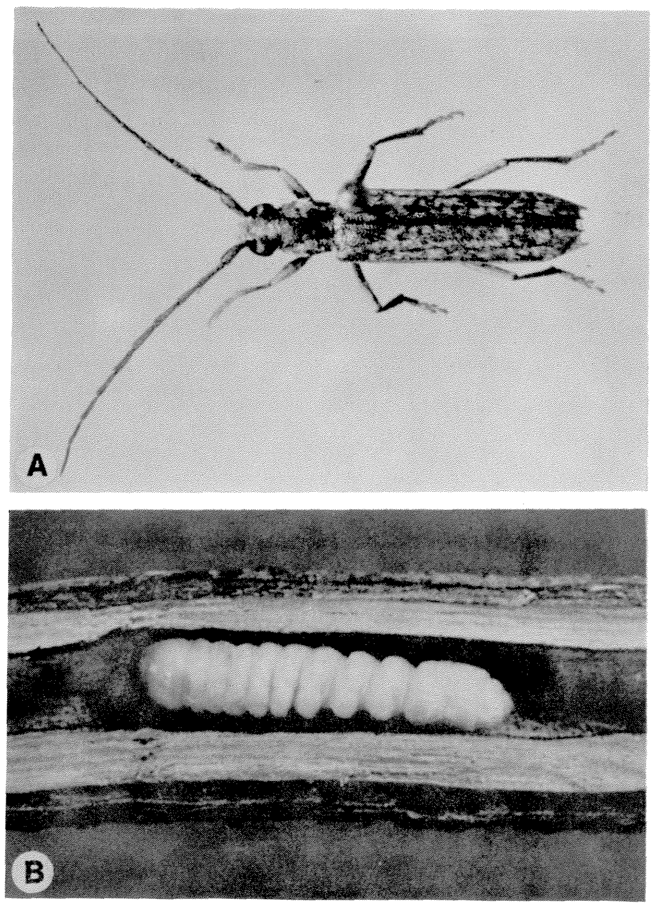

Figure 20.—*Life stages of* Elaphidionoides *sp: (A) adult beetle; (B) mature larva.*

center outward to, but not including, the thin bark. Severed branches later break and fall to the ground with the larvae in them. The larva retreats back into its burrow and plugs the oval gallery at the severed end with small fibrous frass and pupates within the burrow the following spring. There is usually one generation per year, but a 2-year generation life cycle has been reported for *E. parallelus* in its northern range (Gosling 1978).

Control.—Control of twig pruners in orchards, nurseries, and ornamental plantings is similar to that for the twig girdler (Chittenden 1910, Gill 1924). That is, all severed twigs on the ground or lodged in the tree should be collected during fall and winter and destroyed while the grubs are still in the twigs. To be most effective, the severed twigs should be collected over the entire orchard, woodlot, or neighborhood. Insecticides are rarely needed; natural controls help to keep infestations in check. Two braconid parasites, *Bracon eurygaster* Brulle and *Odontobracon elaphivorus* Rohwer, have been recovered from the twig pruner (Linsley 1963), while two braconids, *Meteorus tibialis* Muesebeck and *Iphiaulax eurygaster* Brulle, one ichneumonid, *Agonocryptus discoidaloides* Viereck, and one tachinid, *Minthozelia ruficauda* Reinhard, were reared from the oak twig pruner (Gosling 1978). The downy woodpecker, *Dryobates pubescens* L., blue jay, *Cyanocitta cristata* L., and black-capped chickadee, *Parus atricapillus* L., have been reported to destroy large numbers of the twig pruner (Chittenden 1910). A spider, *Theridium tepidariorum* C. Koch, has also been observed preying upon the twig pruner. Rodents, such as squirrels, have destroyed up to 31 percent of the oak twig pruner population in Michigan studies (Gosling 1978).

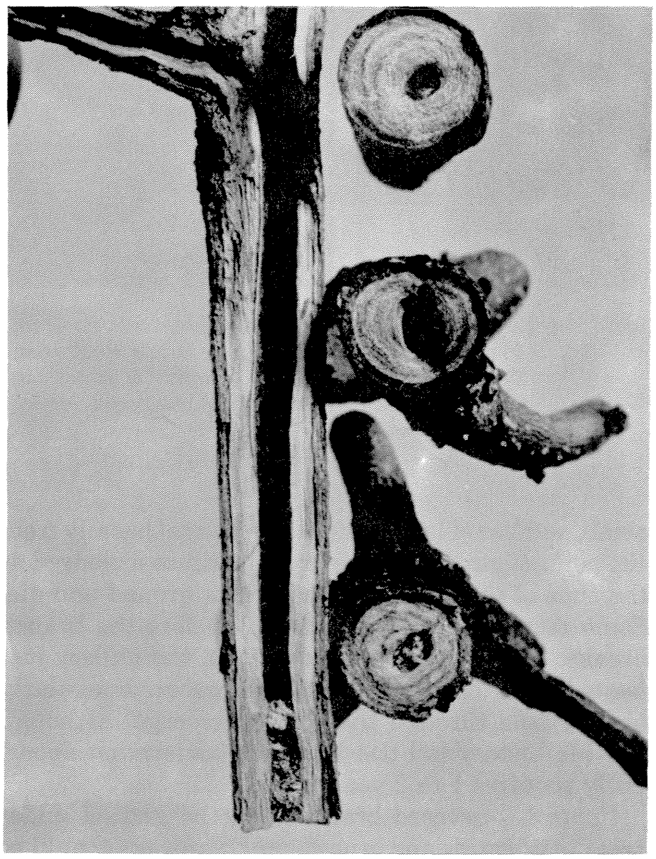

Figure 21.—*Larval gallery and ends of twigs severed by* Elaphidionoides *sp. Note oval holes with frass plugs in ends of severed twigs.*

BRANCH PRUNER

Psyrassa unicolor (Randall)

Importance.—The branch pruner, *Psyrassa unicolor* (Randall), attacks pecan and hickory, and to a lesser extent the oaks and a few other species throughout the Eastern United States from Minnesota south to Alabama and west to Texas (Linsley 1963). The larvae tunneling in the stems cut off or prune large branches. Pruned branches, due to their size and weight, usually drop to the ground; they seldom hang loosely from partially severed branches as seen with the twig girdler and the twig pruner. Although individually pruned branches are generally larger than those girdled by the twig girdler or the twig pruner, the number of pruned branches is usually less. Although individual shade and ornamental trees and occasionally orchard trees may be seriously pruned, entire stands or groves seldom sustain economic damage.

Description.—The narrow, elongate adults are colored light to reddish brown, have short and inconspicuous pubescence, and are coarsely punctured (fig. 22A) (Linsley 1963). The antennae are about as long as the body in the female and slightly longer in the male. In length, females range from 9 to 13 mm and males 7 to 11 mm. In width, females average 2.2 mm and males 1.8 mm. The larvae (fig. 22B) are slender, elongate, cylindrical, and whitish with dark-brown mandibles; they have yellowish thoracic shields, very short rudimentary thoracic prolegs, and measure about 12 to 18 mm long at maturity.

Evidence of Infestation.—Branches are pruned and fall to the ground during spring as opposed to summer, fall, and winter for those cut off by the twig pruners and twig girdler. Pruned branches are often much larger than those cut off by other pruners and girdlers, ranging from 10 to 50 mm in diameter and 0.6 to 3.6 m long. Pruned branches generally fall free to the ground, seldom hanging from the tree by the severed end as is true for the other pruners and girdlers (fig. 23A). The cut made by the branch pruner is similar to that of the twig pruner in that is is made from the inside by the larva, which chews a uniformly smooth, circular cut in the wood, leaving only the

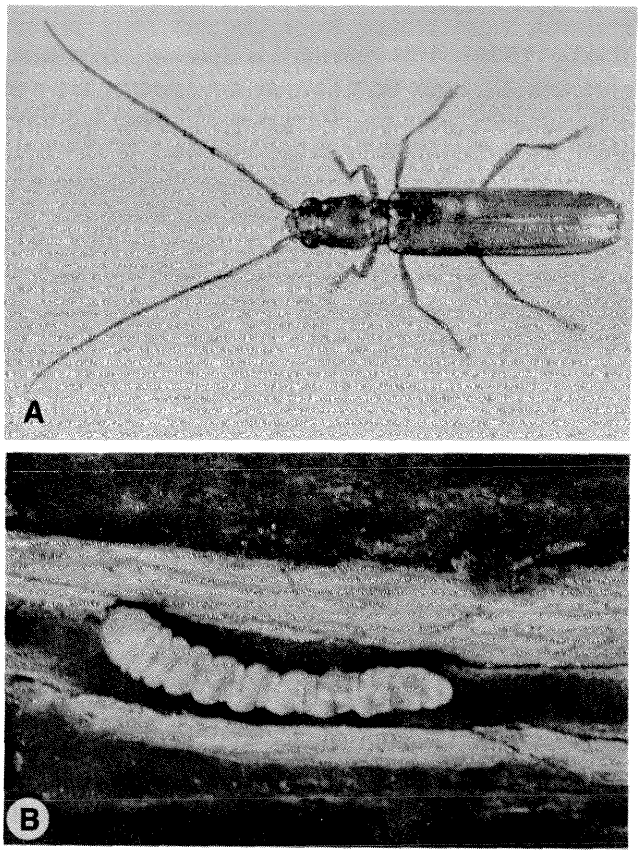

Figure 22.—*Life stages of* Psyrassa unicolor: *(A) adult beetle; (B) matura larva.*

bark intact (fig. 23B). It differs from the twig pruner in that the larval hole is not at the center of the twig, but instead is near one side, usually just below the bark near a small side-twig, and the hole is often plugged with frass. Although the larva usually tunnels in the pruned branch, it will sometimes tunnel in the pruned stub still on the tree.

Biology.—Adults emerge from late April to early June. Eggs are deposited on small twigs that arise from a larger branch 10 to 50 mm in diameter. The young larva tunnels down the center of the twig toward its base, but it does not hollow out the small twig as completely as *Elaphidionoides* spp. Upon reaching the larger branch, it bores into the branch and begins to girdle it. The girdle is completed during late winter and spring when the larva makes a smooth, uniform concentric circular cut, often completely severing the wood, but leaving the bark intact (fig. 23B). Severed branches may break at any time, but breakage occurs mostly during spring windstorms. If breakage does not occur immediately, the larva usually tunnels into the severed portion of the branch just beneath the bark near the junction of the small twig. Here it tunnels toward the center of the stem for 15 to 30 mm then back toward the surface, and finally tunnels distally just under the bark for 30 to 80 mm (fig. 23C). A

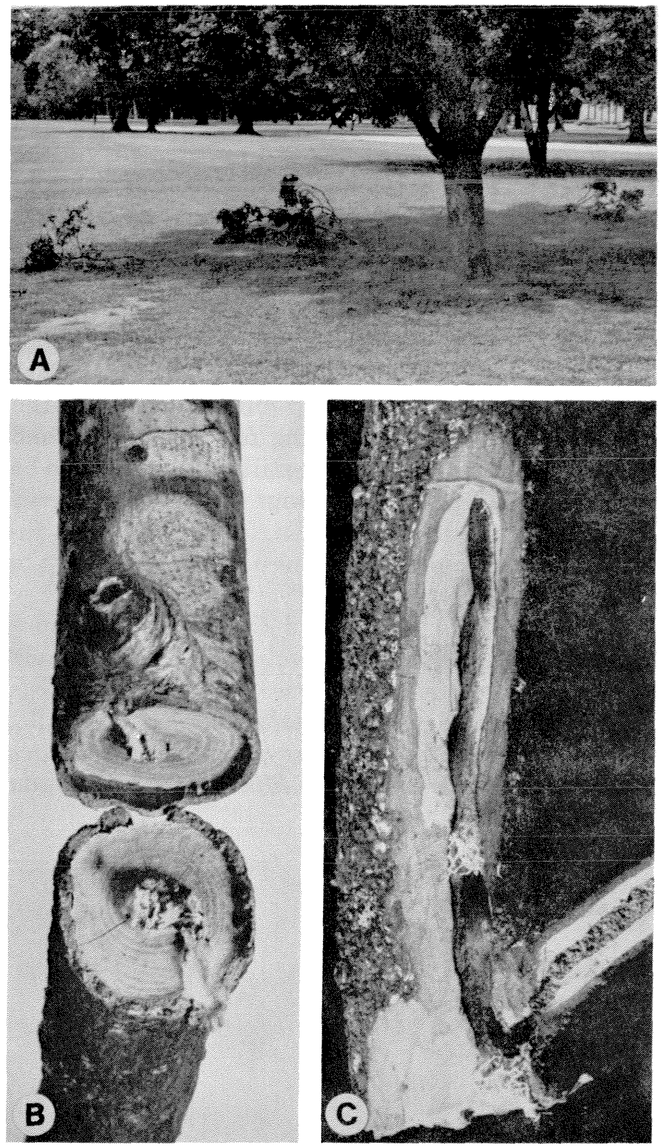

Figure 23.—*Evidence of infestation by* Psyrassa unicolor *in pecan: (A) large severed branches have fallen to ground; (B) severed branch illustrating nature of larval cut; (C) larval gallery extending from small side branch into severed main branch.*

small number of larvae, however, tunnel basally from the point of girdle. Larvae are sometimes dislodged at the time of the break and fall to the ground and die. Some retreat into the small twig before the branch breaks. Pupation takes place within the gallery just beneath the bark. The adult chews an irregularly shaped hole through the bark to emerge. Although the life history is little known, a generation apparently requires 1 to 2 years.

Control.—Severed branches on the ground under trees in orchards and ornamental plantings should be picked up in the spring and destroyed before the adults emerge in late spring and early summer. To be most effective, the pick-up and destroy practice should be done for the entire orchard, woodlot, or neighborhood. Direct control in natural forest stands is rarely needed. Two icheumonid parasites of *P. unicolor*, *Labena grallator* Say and *Agronocryptus discoidaloides* Viereck, help to reduce infestations (Linsley 1963).

HICKORY SPIRAL BORER
Agrilus arcuatus Say

Importance.—The hickory spiral borer, *Agrilus arcuatus* Say, is primarily a pest of pecan and hickory but occasionally attacks other deciduous species throughout the eastern half of the United States (Beal and Massey 1942, Brooks 1926). Twigs, branches, and terminals up to 40 mm in diameter on trees of all sizes may be severed. Many of the severed branches break and drop to the ground. Serious damage to large trees results in reduced nut production, ragged appearance, and poor tree symmetry. Repeated attacks on young reproduction may cause stunted, misshapened, crooked, and forked stems. Although individual trees may be seriously damaged, entire stands, groves, nurseries, and other plantings are seldom badly damaged. Serious damage is most likely to be found in plantings adjacent or close to forested tracts containing many heavily infested hickories.

Description.—The adults are dark, slender buprestid beetles (fig. 24A) (Brooks 1926). The head and thorax of the male are greenish bronze, the wing covers are purplish black, and the underparts are brassy; the female is bronze in color throughout. The average length of males is 8 mm and that of females about 10 mm. Eggs are flat, disklike in shape, 0.8 to 1.1 mm in diameter, and glued firmly to the smooth bark of the twigs. They resemble the shield of a small scale insect. Initially the eggs are smooth and pale yellowish green, but before hatching they become slightly wrinkled and almost black. The larva is a slender, flat, legless grub, with full-grown specimens reaching 15 to 20 mm long and 2 mm wide (fig. 24B). They are yellowish white except for dark brown or black mouth parts and tail forceps.

Evidence of Infestation.—Branches and terminals are severed during the winter and spring (fig. 25) (Baker 1972, Brooks 1926). The portion above the girdle usually dies in the spring before the foliage appears, the injury becoming apparent as the rest of the tree puts forth leaves. Severed branches may break and fall to the ground either before or after bud-break in the spring. Stems 8 to 40 mm in diameter and 0.5 to 2.5 m long may be severed; although many of these stems are larger than those girdled by twig girdlers and twig pruners, on the average they are slightly smaller than those pruned by the branch pruner. The spiral cut made by the larva is a characteristic winding, concentric cut from the inner bark to the heart of the branch or stem, the coils of the thin burrow joining and completely severing the wood except for the bark and sometimes a slender fiber of wood at the center (fig. 26A).

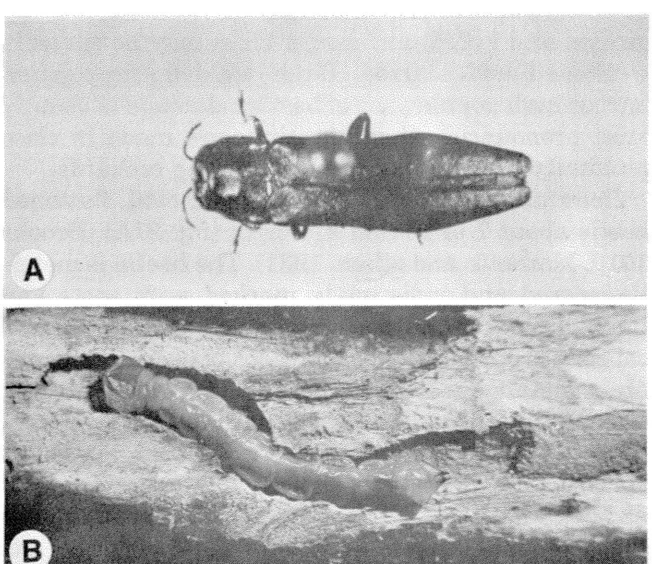

Figure 24.—*Life stages of* Agrilus arcuatus: *(A) adult beetle; (B) nearly mature larva.*

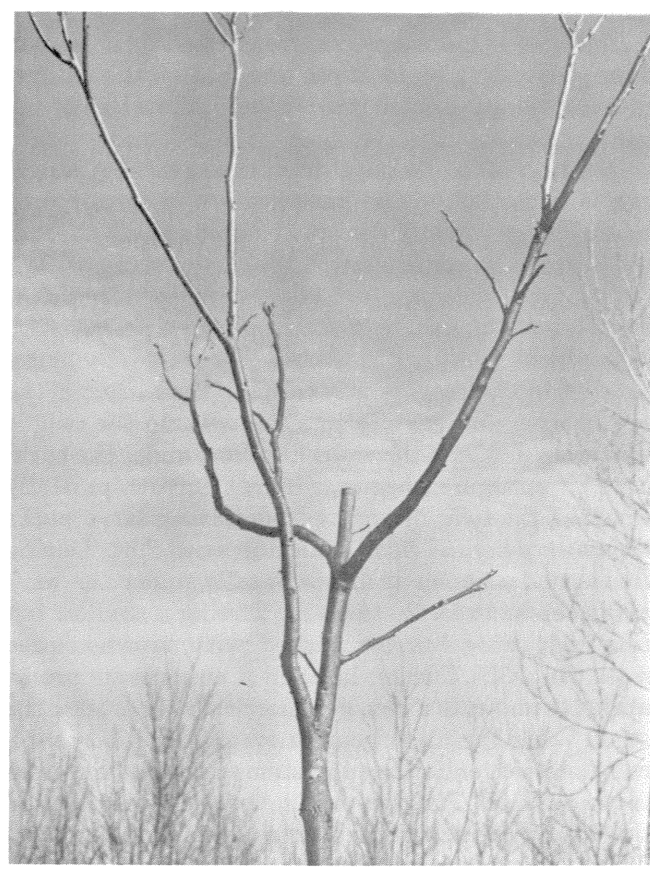

Figure 25.—*Young hickory with main stem severed by* Agrilus arcuatus.

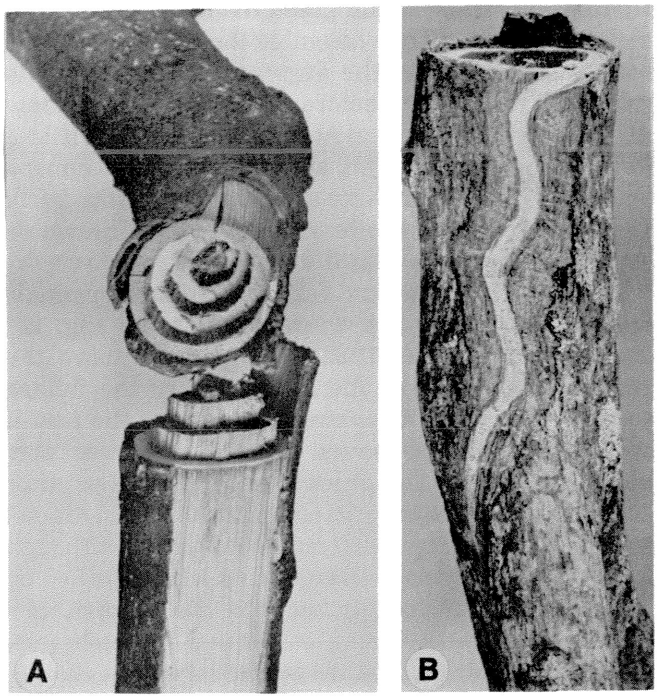

Figure 26.—*Characteristics of injury by* Agrilus arcuatus *in hickory: (A) severed branch illustrating spiral cut made by the larva; (B) bark removed to expose larval mine leading to the spiral cut.*

Biology.—Adults emerge from late April to late June, depending on location, and feed on the foliage, making elongate notches and slits in the edges of the leaves (Brooks 1926, Ruggles 1918). Females begin oviposition 10 to 14 days after emergence. A single egg is deposited on the bark surface of terminal or lateral twigs, usually near the base of a small shoot of the current season's growth, and is covered with a transparent secretion that glues the egg to the bark. Each female lays from 2 to 55 eggs over a period of 1.5 to 2 months. The eggs hatch in 3 to 4 weeks. The larva hatches by chewing its way through the bottom of the egg chorion and directly into the twig. In the twig it makes an elongate threadlike burrow under the bark. Late in autumn it begins a spiral burrow, partially severing the twig by spring. The mining larva packs the gallery behind itself with fine wood dust. During the second summer it mines basally under the bark along the stem for 20 to 60 cm leaving a shallow but relatively wide burrow packed with brown-colored frass (fig. 26B). During late fall it changes its course abruptly and cuts a thin symmetrical ring around the stem. When the first circuit is completed, it bores spirally inward, encircling the stem until the stem center is reached. The larva then turns upward toward the bark where it mines under the bark for 25 to 76 mm where it forms a crescent-shaped pupal chamber. The ends of the chamber extend to the bark, and the bottom curves toward the stem center. Both ends of the pupal chamber are plugged with frass. Pupation occurs during May and June and lasts about 3 weeks. The adult gnaws a D-shaped hole in the bark 25 to 76 mm above its spiral burrow to emerge from the pupal chamber. A generation requires 2 years.

Control.—Young trees in heavily infested nurseries and orchards should be pruned to remove the killed branches and terminals as soon as leaves develop in the spring in order to collect and destroy the larvae (Beal and Massey 1942, Brooks 1926, Ruggles 1918). Special care should be taken to remove the small dead twigs that have been severed by the first-winter larvae. Such twigs should be clipped several centimeters below the dead part in order to make sure of getting the borer. Also, any severed branches or terminals should be picked up and destroyed promptly before adult emergence begins. Three parasites: an ichneumonid, *Labena apicalis* Cress., a braconid, *Monogonogastra agrili* Ashm., and pteromalid, *Zatropus* sp. (near *nigroaeneus* Ashm.), help reduce populations (Brooks 1926).

FLATHEADED APPLETREE BORER

Chrysobothris femorata (Olivier)

Importance.—The flatheaded appletree borer, *Chrysobothris femorata* (Olivier), is a pest of pecan and hickory as well as many other deciduous trees, extending from Mexico throughout the United States into Canada (Baker 1972, Brooks 1919). It generally attacks trees that have recently been transplanted, stressed from various causes, or have bark that has been damaged by tools, disease, rodents, sun scald, or other insects. Injury results from the larvae tunneling in the bark and cambium area. Trees of all sizes may be attacked; those 5 cm or less in diameter may by girdled and killed, and larger trees may be severely weakened and scarred. Since wooded tracts often harbor high populations of beetles, damage is usually most pronounced when plantings are made in close proximity to woodland or old declining orchards.

Description.—The adult is a broad, oval, flattened beetle about 7 to 16 mm in length (fig. 27A) (Brooks 1919, Moznette and others 1931). The beetle is metallic colored and indistinctly marked with spots and irregular bands of dull gray. The underside is a coppery-bronze color and the sides beneath the wings are a metallic greenish blue. The egg is pale yellow, flattened, disklike, wrinkled, and about 1.5 mm in diameter. It is firmly attached to the bark by its flat surface. The larva is yellowish white, legless, and about 25 mm long when fully grown (fig. 27B). The three thoracic segments are much broadened and compressed, giving the larva the appearance of having a large flattened head, which accounts for the name "flathead." The larvae within their galleries

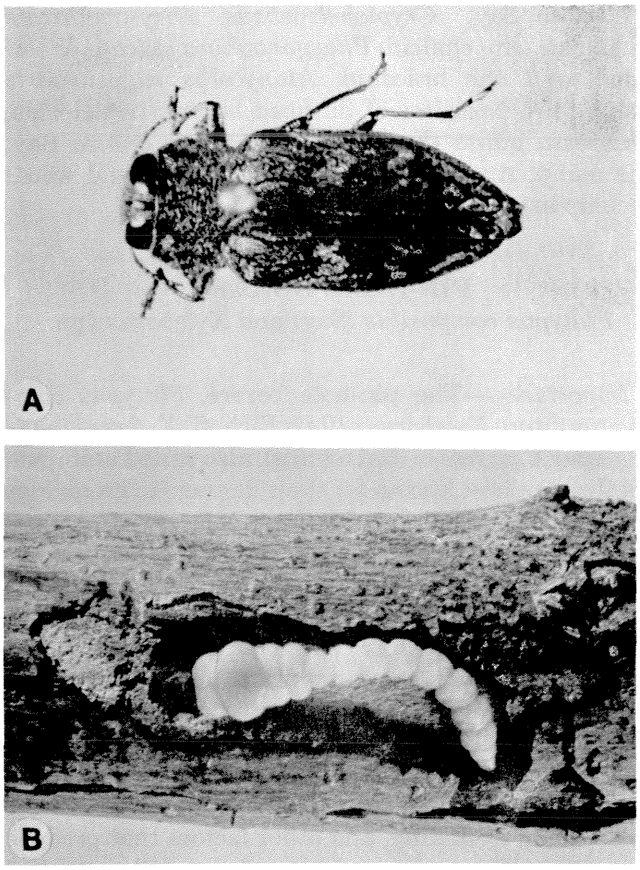

Figure 27.—*Life stages of* Chrysobothris femorata: *(A) adult beetle; (B) nearly mature larva.*

Figure 28.—*Signs of infestation by* Chrysobothris femorata: *(A) frothy sap oozing from bark is early symptom of infestation; (B) bark depressions, loosened bark, and oval exit hole provide evidence of infestation.*

nearly always assume the curved shape of a horseshoe. The pupa is somewhat more yellow than the larva and resembles the adult in structure.

Evidence of Infestation.—Points of infestation can usually be detected by white, frothy sap oozing from cracks in the bark (fig. 28A) (Fenton 1942, Brooks 1919, Moznette and others 1931). The bark gradually assumes a darkened, wet or greasy appearance. Little or no frass is ejected except at cracks in the bark. Injured areas usually become depressions, and later the bark may split at the injured sites (fig. 28B). Attacks occur most often on the sunny aspect of the tree. The burrows under the bark are broad and irregular and filled tightly with fine, sawdustlike frass. In young trees with thin bark, the tunnels are usually long and winding, sometimes encircling the tree. In older trees with thick bark, the burrows are confined to a circular area under the bark. Wounds may be enlarged year after year by succeeding generations. As mentioned previously, attacks are often associated with injuries. Trunks may be attacked at any point above ground level; branches may also be attacked.

Biology.—Adults appear from March to November, but they are most abundant during May and mid-August to mid-September (Fenton 1942, Moznette and others 1931). Beetles are active, run rapidly, and take flight quickly when disturbed. On hot, clear days, they may be found on the sunny side of trunks and larger branches. The female spends much time running over the surface, probing the bark with her ovipositor for places to oviposit. Females mate and begin ovipositing in 4 to 8 days; they live about 1 month after emergence. Each female lays about 100 eggs, depositing them singly in cracks or crevices of the bark, under bark scales, and at bark injuries. Eggs hatch in 8 to 16 days. The newly hatched larva chews through the bark and feeds in the phloem and surface of the sapwood. In trees sufficiently weakened, the larvae produce long tortuous burrows and develop rapidly. In more vigorous trees, larval development is slow and many larvae die, probably due to heavy sap ooze. As soon as the larva is fully developed, it tunnels from the cambium area radially into the sapwood where a pupal chamber is prepared by plugging the burrow tightly with frass. Here it overwinters as a larva. The larva pupates during the following spring or summer. The pupal stage lasts about 8 to 14 days. Adults emerge by cutting small oval emergence holes through the bark (fig. 28B). Normally there is one generation per year, but some generations require 2 to 3 years.

Control.—Because flatheaded borers rarely injure healthy, vigorous trees, cultural methods should be selected that keep trees vigorous, such as proper transplanting, cultivation, fertilization, spraying, pruning, thinning, and irrigation (Baker 1972, Brooks 1919, Fenton 1942, Moznette and others 1931). Since young transplanted trees are under stress and particularly susceptible, additional measures may be warranted such as wrapping the trunks with a double thickness of newspaper, burlap, or crepe paper from the ground to the lower limbs to prevent oviposition (fig. 29), or by shading the trunks from sunlight to deter the ovipositing females. Painting the trunks white to reduce injuries from sun scald may also help. Injuries by equipment, storm, frost, and other causes should be minimized and any fresh wounds promptly painted with pruning compound. Borers may be removed from individual trees with a knife, being careful to avoid unnecessary cutting and damage. All dead and dying trees and all pruned branches should be removed from ornamental and orchard plantings to reduce breeding sites for the beetles. Natural enemies also help to reduce flatheaded borer populations. Two ichneumonids, *Labena grallator* Say, *Cryptohelcostizus chrysobothridis* Cushman, one chalcid, *Phasgonophora sulcata* Westwood, and one braconid, *Atanycolus rugosiventris* Ashm., are parasites of flathead borers; two clerids, *Chariessa pilosa* (Foster) and *C. pilosa onusta* Say, one asilid, *Andrenosoma fulvicauda* Say, and woodpeckers are predators.

Figure 29.—*Wrapping trunk of young transplanted pecan tree with crepe paper for protection from* Chrysobothris femorata.

PIN-HOLE BORERS

Platypus compositus (Say) and *Xyleborus* spp.

Importance—The pin-hole borers, *Platypus compositus* (Say), *Xyleborus affinis* Eichoff, *X. ferrugineus* (F.), and *X. saxeseni* (Ratzeburg), also called ambrosia beetles, are best known for their damage to green logs and unseasoned lumber. They inhabit the trunks and branches of pecan and hickory as well as many other deciduous trees (Baker 1972, Bright 1968). The *Xyleborus* spp. are widely distributed from Canada throughout the eastern half of the United States. *Platypus compositus* is found from Mexico throughout the Southern United States northward to West Virginia. Ambrosia beetles seldom attack healthy, vigorous trees; their attacks are largely limited to stressed trees weakened from drought, disease, old age, insect defoliation, wounding, and other factors that produce tree stress. Thus, when trees are successfully attacked by ambrosia beetles, one can be sure that the trees have been under stress of some sort. The beetles tunnel through the bark directly into the sapwood and sometimes even into the heartwood, especially *P. compositus*. Although ambrosia beetles are not tree killers, the physical wounds produced by large numbers of beetles provide ports of entry for disease agents that may cause tree death. The pinholes and associated stain quickly degrade the wood for lumber and other wood products.

Description.—Adults of the *Xyleborus* spp. are small, brown, reddish-brown, or black elongate beetles with compact cylindrical bodies that vary from 1.5 to 3.0 mm in length (Bright 1968, Chamberlin 1939, Blackman 1922). The adults of *P. compositus* can be distinguished by having longer and more slender bodies and wide heads flattened in front (fig. 30A). The first segment of the tarsus is as long as all the other tarsal segments combined and about 4.5 mm in length. The eggs are elongate oval and pearly white. The larvae of *Xyleborus* spp. are C-shaped, legless, white to cream colored, and reach 3 to 4 mm in length; larvae of *P. compositus* (fig. 30B) are straight to only slightly C-shaped, legless, white to cream colored, and reach 5 to 6 mm in length.

Evidence of Infestation.—Infested trees are usually attacked by numerous beetles that bore many uniform, round (0.8- to 1.7-mm diameter) holes directly

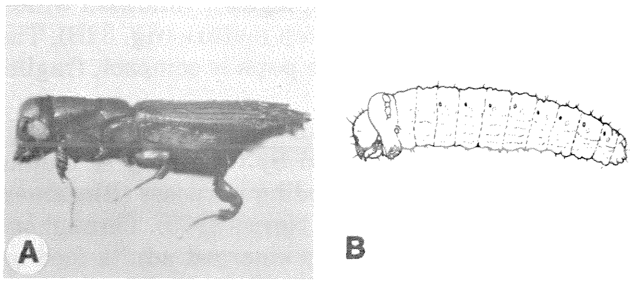

Figure 30.—*Life stages of* Platypus compositus: *(A) adult beetle; (B) nearly mature larva.*

through the bark into the wood (Chamberlin 1939). As the beetles construct their galleries, they push the fibrous (*P. compositus*) or granular (*Xyleborus* spp.) boring dust to the outside through the entrance holes (fig. 31A). The boring dust is usually in evidence on the bark just below the entrance holes or in loose piles at the base of the tree; during humid weather it may stick together as it is pushed out to form string-like masses. Sap frequently oozes from many of the entrance holes, staining the bark around and below the entrances. Active galleries are kept free of boring dust and are light colored; vacated galleries are stained black by fungi. The galleries extend directly into the sapwood and then branch several times—the branching pattern depending on the species (fig. 31B). These galleries cause dark-stained pinholes that will show up as defects in sawn lumber (fig. 31C).

Biology.—In the deep South the beetles are active most of the year, but further north they hibernate in brood galleries in the host tree (Chamberlin 1939). In the spring the adults emerge and initiate new attacks on the same tree or on different trees. Both adults and larvae feed on moldlike fungi that they culture in the galleries. The insects carry the specific inoculum from one tree to another and grow the fungi in pure culture on the walls of the tunnels. Galleries 0.8 to 1.6 mm in diameter are bored horizontally into the sapwood, then branch several times for a distance of 10 to 40 cm. Galleries of *P. compositus* are much more extensive and extend deeper into sapwood and heartwood than those of *Xyleborus* spp. Females deposit eggs in loose clusters in the galleries and may lay up to 200 eggs each. The eggs hatch in 6 to 10 days, and the young larvae wander freely about the mines and feed on the ambrosia fungus. Several adults may occupy each gallery. Both adults and larvae help to excavate and extend the galleries. When full-grown, the larvae of *P. compositus* excavate cells along the main gallery in which they transform to pupae and adults; those of *Xyleborus* spp. pupate freely in the galleries without making cells. Development from egg to adult during the summer requires 5 to 8 weeks. There are several generations per year in the Gulf Coast States. Successive broods may continue to attack a tree as long as it remains suitable. Infested trees that die

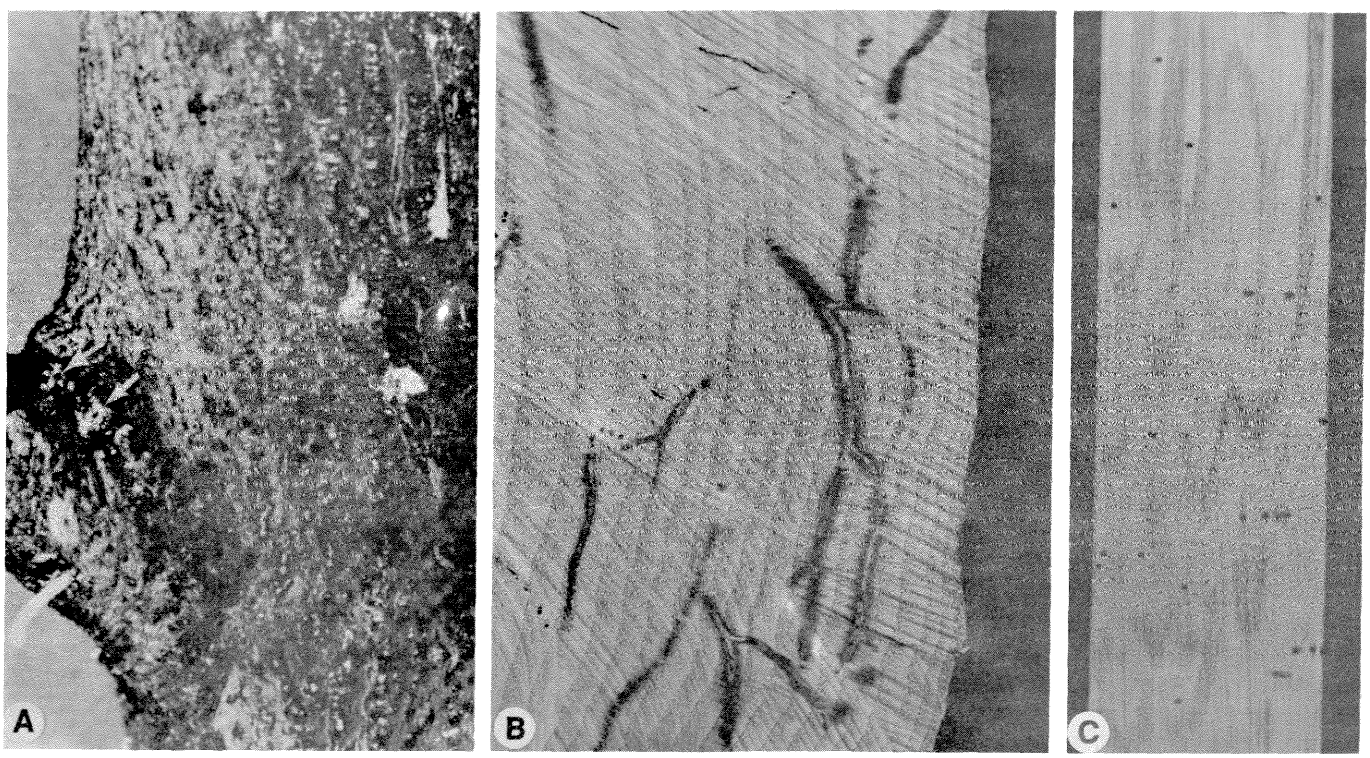

Figure 31.—*Evidence of infestation by* Xyleborus *and* Platypus *spp. in pecan: (A) fresh white frass at pinhole entrances in trunk; (B) black-stained branching galleries in sapwood; (C) pinhole defects in sawn lumber.*

become unsuitable for brood development as soon as the moisture content drops below about 48 percent.

Control.—Since ambrosia beetles rarely attack healthy vigorous trees, good cultural practices should be followed to promote and maintain tree vigor (Baker 1972, Payne and others 1979). Trees that are weakened or stressed apparently emit fermenting-like odors that attract ambrosia beetles. Because healthy trees do not emit these odors, they remain unattractive. Insecticides may be needed occasionally.

HICKORY BARK BEETLE
Scolytus quadrispinosus Say

Importance.—The hickory bark beetle, *Scolytus quadrispinosus* Say, is a pest of pecan and hickory and reportedly butternut and black walnut (McDaniel 1933, Goeden and Norris 1964). However, it shows a strong preference for the hickories and is reported to be the most important pest of this group of trees (McDaniel 1933). It is found from Quebec southward throughout the eastern half of the United States to the Gulf Coast States and westward to Texas. Both adults and larvae produce galleries between the bark and wood of trunks and branches. When attacks are numerous, the galleries soon girdle the tree. Trees stressed and weakened from drought, fire, storm, disease, or other cause are most susceptible to attack. Vigorous trees are seldom attacked except when large beetle populations are produced from nearby brood material. Although heavy infestations usually kill the tree, light infestations may only girdle branches or a portion of the trunk, causing top dieback.

Description.—The adult is a short, 4- to 5-mm long, stout, thickly cylindrical, black to reddish-brown, almost hairless beetle (fig. 32A) (Goeden and Norris 1964, McDaniel 1933). There is a short curved spine or hook on the front tibia. The venter of the male is deeply excavated; the third abdominal segment is armed with three spines, the fourth with one large median spine. The venter of the female is without spines. The egg is ellipsoidal, cream colored, and barely visible to the naked eye. The larva is short, curved or slightly C-shaped, legless, yellowish white, and 5 to 8 mm in length when mature (fig. 32B). The body appears wrinkled. The pupa is compact, fragile, and white.

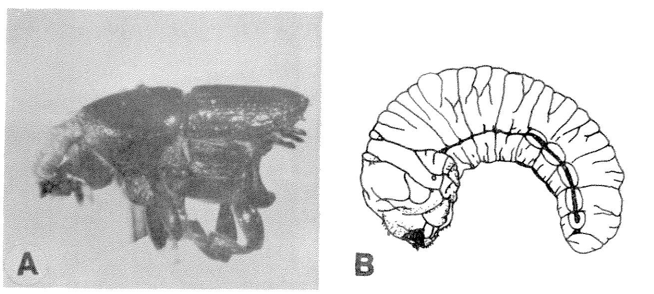

Figure 32.—*Life stages of* Scolytus quadrispinosus: *(A) adult beetle; (B) mature larva.*

Evidence of Infestation.—Damage occurs from feeding in terminal growth and by tunneling in trunks and large branches for breeding purposes (Blackman and Ellis 1915, Goeden and Norris 1965). Throughout the summer months, newly emerged adults feed on twigs in the tree crown. Their short food tunnels are mainly confined to axillary buds and leaf bases in the current year's growth and the junctions of current and 1-year-old growth. Heavy twig feeding may cause yellowing and premature dropping of leaves and broken twigs scattered throughout the crown, but this seldom seriously weakens the tree.

The most serious damage results from tunneling and reproducing in the trunks (fig. 33). In the fall and winter after initial attack, the presence of numerous round, 3-mm diameter entrance holes in the bark are often the only signs of attack. During winter and spring, woodpecker holes in the bark are good indicators of infestation; in spring, sparse or yellowed foliage are signs of beetle attack. Dead or dying trees with bark perforated by numerous 3-mm holes from which beetles have emerged also indicate the beetles' presence along with galleries beneath and within the bark of such trees. The inner bark and wood surfaces are engraved with peculiar centipede-shaped designs consisting of broad vertical galleries with narrow bur-

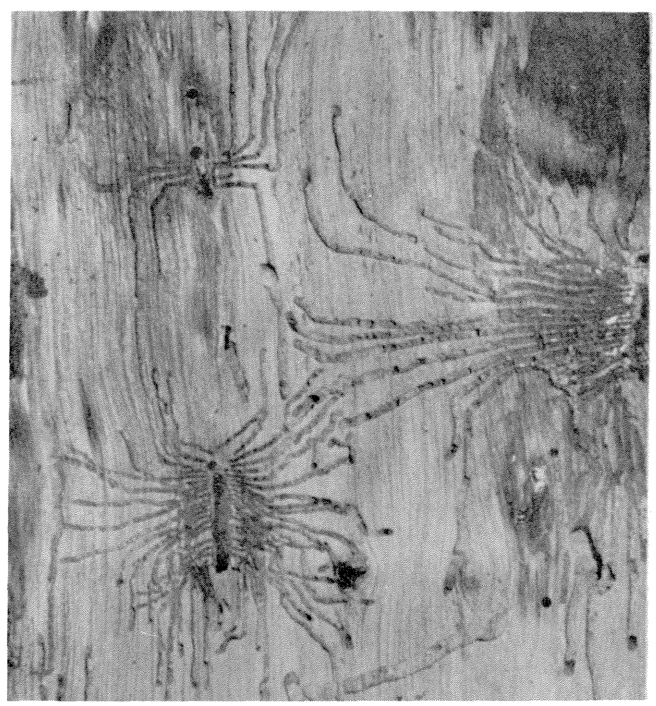

Figure 33.—*Galleries of* Scolytus quadrispinosus *beneath bark of hickory. Note vertical egg gallery with larval galleries radiating outward.*

rows radiating outward like centipede legs from either side of them. The foliage of heavily infested trees turns red within a few weeks after attack and finally turns brown as the tree succumbs (fig. 34).

Biology.—The beetles overwinter as larvae in various developmental instars (Goeden and Norris 1964, 1965, McDaniel 1933). During spring the oldest larvae transform to pupae in elliptical chambers terminating each larval tunnel just beneath the bark surface. Beetles emerge from May through late August. The beetle population and seasonal activity reach a maximum during July and early August. The newly emerged beetles fly to the crowns of host trees and feed mainly in terminal and twig growth for 10 to 15 days. Sexually mature beetles are then attracted to low-vigor trees where they bore into the trunks and branches for breeding purposes. Here the females excavate short (12 to 50-mm) vertical egg galleries between the bark and wood. Mating and egg laying continue throughout the summer, with each female depositing 20 to 60 eggs singly in small niches along either side of the egg gallery. Each egg is covered with a plug of macerated frass. The eggs hatch in 10 to 12 days. The larvae mine at right angles to the main gallery and parallel to each other, but as the larvae become larger their galleries diverge more and more,

Figure 34.—*Hickory (right) dying from* Scolytus quadrispinosus *attack.*

resembling an engraving of "centipede legs." Larval mines extend 76 mm or more away from the egg gallery, severing the trees' food and water conducting tissues. Mature larvae leave the cambium and bore into the outer bark where they construct pupation cells. There is one generation per year in the northern range and two per year in the southern distribution.

Control.—Since hickory bark beetles rarely attack healthy trees, good cultural practices such as thinning, pruning, fertilization, and irrigation are important for promoting and maintaining good tree vigor (Goedon and Norris 1964, Hopkins 1912). The most effective means of controlling a hickory bark beetle infestation is by destroying trees in which larvae are overwintering. Infested trees should be cut and burned or submerged in water, have the bark peeled, or be sprayed with an insecticide before beetle emergence begins in May or June. To protect high-value trees, thoroughly spraying the trunks and large branches with an insecticide during early July will curtail most breeding attacks.

RED-SHOULDERED SHOTHOLE BORER
Xylobiops basilaris (Say)

APPLE TWIG BORER
Amphiceris bicaudatus (Say)

Importance.—The red-shouldered shothole borer, *Xylobiops basilaris* (Say), and apple twig borer, *Amphiceris bicaudatus* (Say), are found throughout the United States east of the Rocky Mountains and in southern Canada (Baker 1972, Gill 1924, Moznette and others 1931). Pecan and hickory are among their favored hosts, but they also attack several other deciduous hosts. They generally attack severely stressed and dying or recently dead trees. Trunks of healthy trees growing in close proximity to heavily infested trees are occasionally attacked but seldom with success; however, *A. bicaudatus* may tunnel the twigs and small branches causing them to wither and die back. Although these borers may cause some twig dieback and possibly hasten the death of trees already stressed or dying from other causes, the threat to healthy living trees is minimal.

Description.—The adults of *X. basilaris* are 3 to 5 mm long, black, and bullet-shaped, with many small punctures over the body. The basal part of the elytra is dull reddish or yellow—hence the name "red-shouldered." The wing covers end in an oblique angle at the posterior end, the edges of which are armed with three conspicuous teeth on each side. The adults of *A. bicaudatus* (fig. 35A) are similar to *X. basilaris* except they are larger, range from 6 to 11 mm long, are dark brown, and lack the reddish marking on the wing covers. The larvae of both species are white and

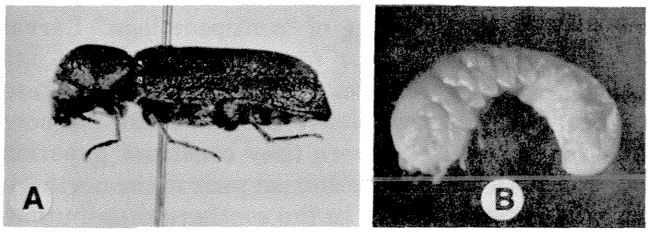

Figure 35.—*Life stages of* Amphiceris bicaudatus: *(A) adult beetle; (B) mature C-shaped larva.*

C-shaped; when full-grown, *X. basilaris* is about 5 to 6 mm long and *A. bicaudatus* is 6 to 12 mm long (fig. 35B). The head of the larva is globular and greatly enlarged into the prothorax, the mouthparts extend forward, and there are three pairs of thoracic prolegs.

Evidence of Infestation.—The adults of *X. basilaris* make small round exit holes 2 to 3 mm in diameter; the holes of *A. bicaudatus* are 3 to 4 mm in diameter and generally much less numerous (Payne and others 1979, Baker 1972, Gill 1924). The holes give a tree trunk the appearance of having been hit by birdshot, hence these borers are often referred to as "shothole" borers (fig. 36A). Light sawdust particles may be observed coming from the holes. The borings or frass of the larvae are very fine and powderlike in appearance; they are firmly packed or compressed within the galleries, which run parallel with the grain of the wood (fig. 36B). Trees cut back so severely that the trunk becomes saturated with sap are susceptible to infestation by *X. basilaris*. Twigs that have withered and brown leaves usually contain single, round entrance holes 2 to 4 mm in diameter adjacent to a bud or leaf base (fig. 36C). Dissection of the twigs usually reveals a hollow twig that is often occupied by a single adult beetle from late fall to late spring.

Biology.—Adults emerge during the summer and fly in search of suitable host trees where they bore through the bark and into the sapwood (Gill 1924, Lugger 1899, Baker 1972, Dean 1920). Tunnels are constructed across the grain just under the wood surface in the sapwood. These tunnels may completely girdle small-diameter limbs and trunks (fig. 36D). Eggs are deposited at intervals along the sides of the tunnel. The larvae feed mostly in the sapwood and to some extent in the heartwood. Larval mines run parallel with the grain and are packed with fine, white, powderlike dust. Feeding may continue until the wood is quite dry. The winter is spent mostly as ma-

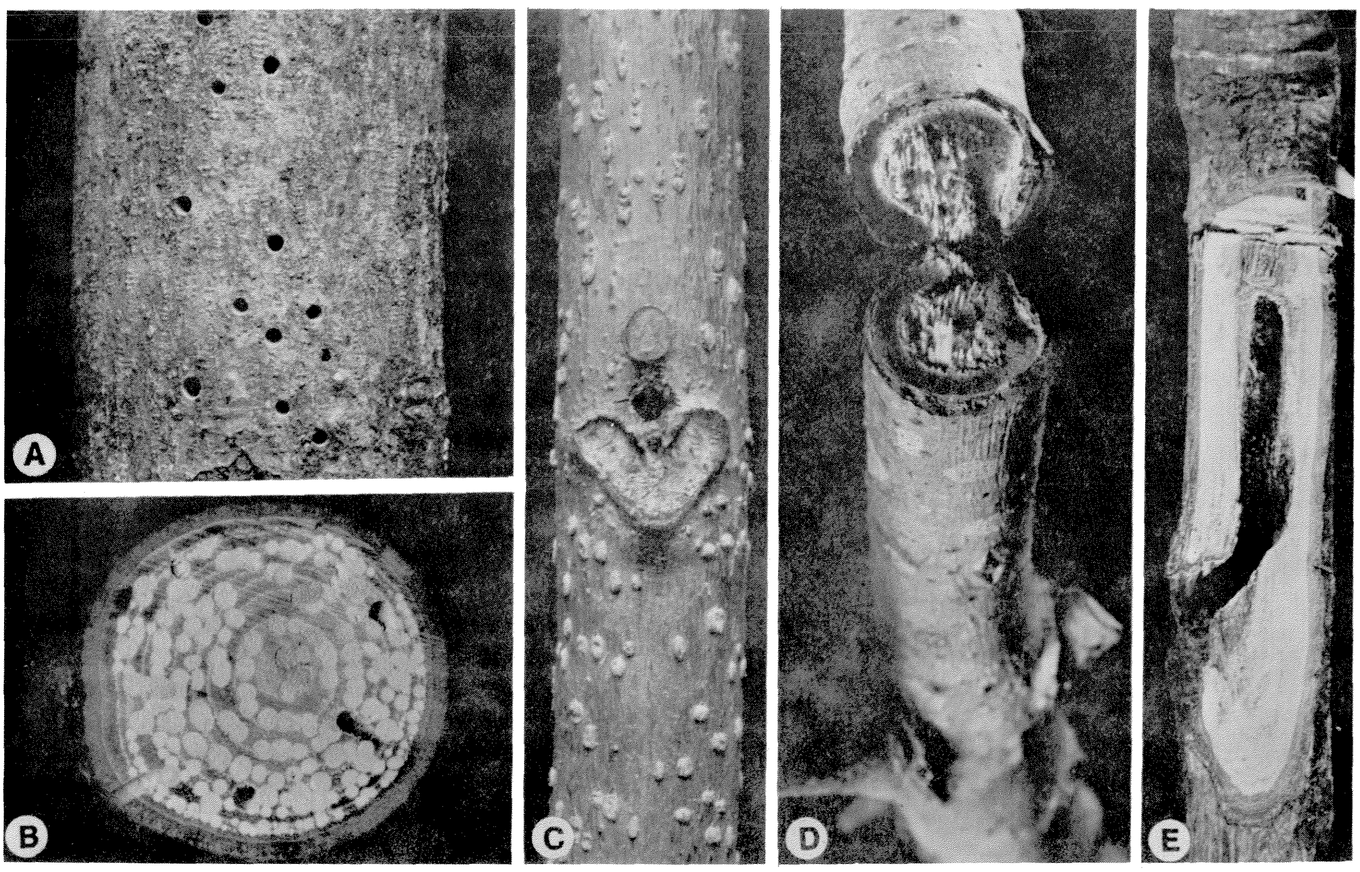

Figure 36.—*Habits and signs of attack by* Xylobiops basilaris *and* Amphiceris bicaudatus *in pecan: (A) exit holes (shotholes) in bark; (B) cross-section of stem showing ends of frass-packed larval galleries; (C) adult entrance hole between leaf scar and bud; (D) girdling tunnel made just beneath bark by adult beetle; (E) overwintering gallery made by adult of* Amphiceris bicaudatus.

ture larvae in mines; larvae pupate and emerge as adults the following spring and summer through circular holes cut in the bark. Adults of *A. bicaudatus* often bore into twigs for food and shelter and commonly spend the fall, winter, and spring in galleries within the twigs (fig. 36E). A generation can develop from egg to adult in 1 year under optimum conditions, but longer periods of time are sometimes required.

Control.—These borers present little threat to healthy well-kept trees; therefore, good cultural practices should be followed to maintain tree vigor (Dean 1920, Moznette and others 1931). Sources of infestation can be eliminated by promptly removing and destroying all dead and dying twigs and branches, prunings, and dead trees.

YELLOW-BELLIED SAPSUCKER
Sphyrapicus varius L.

Importance.—The yellow-bellied sapsucker, *Sphyrapicus varius* L., pecks small holes in tree bark, causing injuries that are often mistaken for insect borers—hence its coverage in this paper. This pest is found over most of the United States and southern Canada, but its damage is best known in the Eastern United States. It attacks pecan and hickory as well as over 250 other trees and shrubs (Beal and McAtee 1922). As portions of the bark and cambium are removed by numerous pecked holes, the vitality of the tree is lowered. When the injury is extensive, individual branches or the entire tree may be completely ringed or girdled and killed. Sapsucker pecking disfigures ornamental trees and gives rise to holes, to sap spots, and subsequently to gnarled bark deformities that ruin the aesthetic appearance of the trees. Disease and wood-boring insects often become established at sapsucker wounds. The greatest damage done by sapsuckers, however, is to cause defects in the wood of trees cut for lumber, veneer, and handle stock. Economic losses to the lumber industry in hickory alone have been estimated at 1.2 million dollars annually (Dale and Krefting 1966).

Description.—The yellow-bellied sapsucker is a member of the woodpecker family (Picidae) and resembles the woodpeckers in appearance (fig. 37A). However, its habits are detrimental as opposed to the generally beneficial habits of woodpeckers. The identifying field markings of adult birds are a black crescent on the breast, pale yellow belly, longitudinal white stripe on the mostly black wings, and crimson

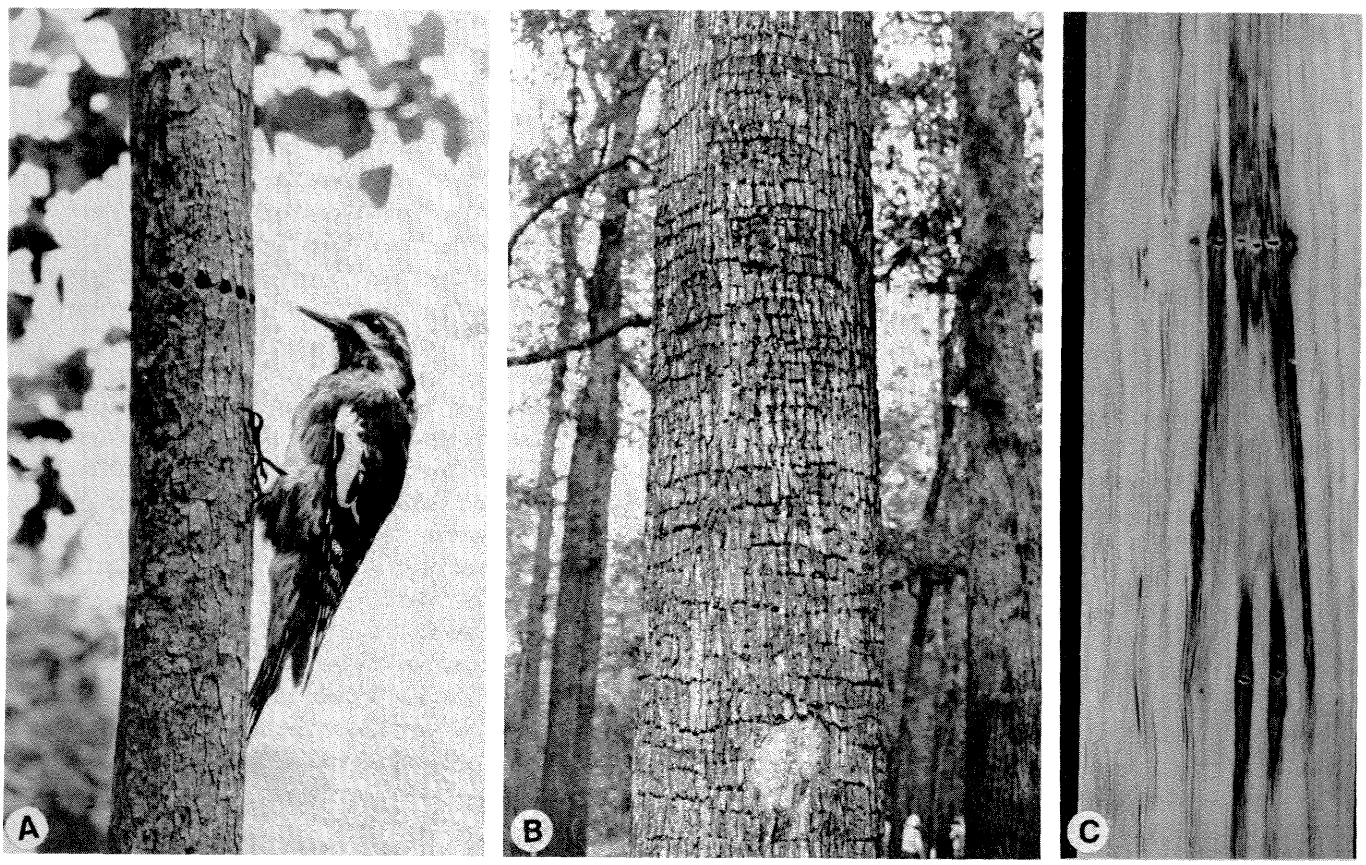

Figure 37.—*Characteristics of injury by* Sphyrapicus varius *in pecan: (A) bird pecking trunk of young tree; (B) heavy bird-peck injury to trunk of large tree; (C) bird-peck defects in sawn lumber.*

red crown (Peterson 1947, Ostry and Nicholls 1976). Although it most closely resembles the hairy and downy woodpeckers and is between the two in size, it is the only woodpecker with a red forehead in combination with a black patch on the breast. In addition, the male has a crimson chin and throat that distinguish him from the female whose chin and throat are white.

Evidence of Infestation.—The yellow-bellied sapsucker pecks a series of small holes about 5 mm in diameter in the bark (Beal and McAtee 1952). Generally, the holes are made in horizontal rings (full or partial) around the trunk or branches (fig. 37B). The holes extend through the bark to the cambium, sometimes penetrating the sapwood to a depth of 3 mm. Occasionally the holes in a series are gradually enlarged until they girdle or partially girdle the stem. Dissections of trees that have suffered from repeated yearly attacks reveal characteristic symptoms of previous damage by sapsuckers. The evidence consists of uniformly spaced peck-marks surrounded by dark vertical stains, often with small pockets of ingrown bark and decay. These defects degrade the lumber sawn from damaged trees (fig. 37C). Attacks may be seen at any point on the trunk and branches but are perhaps most common on the bole area just below the lower branches. Small trees are particularly susceptible to attack.

Biology.—Although the yellow-bellied sapsucker is a member of the woodpecker family, it has a short brush tongue in contrast to that of true woodpeckers, which have long tongues equipped with barbed tips for preying upon wood-boring grubs. The sapsucker's staple diet is the living cambium layer, inner bark, and sap that flows from the pecked wounds (Dale and Krefting 1966). After settling in a locality, each bird pecks many trees but then selects a few trees for most of its feeding. Pecked holes are revisited several times daily to drink sap oozing from the wounds and to eat small insects attracted to the sap. On favored trees, holes are often enlarged as the sapsucker feeds on the cambium to freshen the wound and to stimulate sap flow. The yellow-bellied sapsucker is a migratory bird that spends its summers and nests primarily in the Northern States and southern Canada (Peterson 1947). In the fall it migrates southward, sometimes as far as the Gulf Coast.

Control.—Control is difficult, but several remedies have been used with some success on high-value trees (Ostry and Nicholls 1976, Beal and McAtee 1922). Trunks of individual trees may be wrapped with burlap or some other material to prevent attacks. Painting damaged trees with tree-wound paint will sometimes discourage the birds. Commercially available repellents have been used successfully in repelling sapsuckers. Spraying the trunk periodically with a soap solution has also helped to discourage attacks. Often only a single bird is responsible for damage to a shade or ornamental tree; thus, if it can be discouraged or eliminated, the problem is solved.

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Appendix—Common and Scientific Names

CLASS: INSECTA

Lepidoptera
  Cossidae
    Pecan carpenterworm, *Cossula magnifica* (Strecker)
  Sesiidae
    Dogwood borer, *Synanthedon scitula* (Harris)
  Pyralidae
    American plum borer, *Euzophera semifuneralis* (Walker)
    Acrobasis shoot borers, *Acrobasis* spp.
Coleoptera
  Curculionidae
    Hickory shoot curculio, *Conotrachelus aratus* (Germar)
  Cerambycidae
    Hickory borer, *Goes pulcher* (Haldeman)
    Broadnecked root borer, *Prionus laticollis* (L.)
    Tilehorned prionus, *Prionus imbricornis* (Drury)
    Twig girdler, *Oncideres cingulata* (Say)
    Twig pruner, *Elaphidionoides villosus* (F.)
    Oak twig pruner, *Elaphidionoides parallelus* Newman
    Branch pruner, *Psyrassa unicolor* (Randall)
  Buprestidae
    Hickory spiral borer, *Agrilus arcuatus* Say
    Flatheaded appletree borer, *Chrysobothris femorata* (Olivier)
  Platypodidae
    Pin-hole borer, *Platypus compositus* (Say)
  Scolytidae
    Pin-hole borers, *Xyleborus* spp.
    Hickory bark beetle, *Scolytus quadrispinosus* Say
  Bostrichidae
    Red-shouldered shothole borer, *Xylobiops basilaris* (Say)
    Apple twig borer, *Amphiceris bicaudatus* (Say)

CLASS: AVES

Piciformis
  Picidae
    Yellow-bellied sapsucker, *Sphyrapicus varius* L.

Solomon, J. D.; Payne, J. A. A guide to the insect borers, pruners, and girdlers of pecan and hickory. Gen. Tech. Rep. SO-64. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station; 1986. 31 p.

The importance, identification, biology and indirect control of insects attacking shoots, branches, trunks, and roots of trees are presented. Damage due to and control of the yellow-bellied sapsucker is discussed.

Additional keywords: *Carya*, impact, identification, pests, control, bird damage, yellow-bellied sapsucker.

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Forest Service

**Southern Forest
Experiment
Station**

New Orleans,
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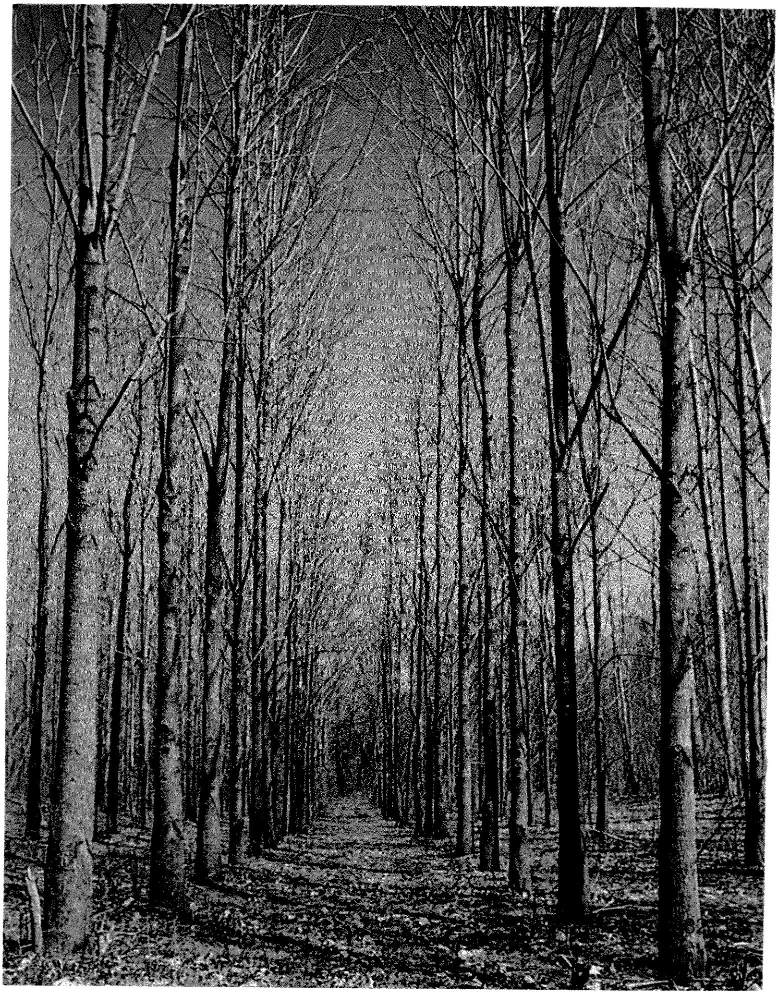
Ash Pests

A Guide to Major Insects, Diseases, Air Pollution Injury, and Chemical Injury

J. D. Solomon, T. D. Leininger, A. D. Wilson,
R. L. Anderson, L. C. Thompson, and
F. I. McCracken



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CONTENTS

Ash Pests

A Guide to Major Insects, Diseases, Air Pollution Injury, and Chemical Injury

J. D. Solomon, T. D. Leininger, A. D. Wilson, R. L. Anderson, L. C. Thompson, and F. I. McCracken

INTRODUCTION

The ashes (*Fraxinus* spp.) are one of our more valuable hardwood resources—some 275 million board feet of ash lumber are sawn annually in the United States. White ash (*F. americana* L.) and green ash (*F. pennsylvanica* Marsh.), widely distributed throughout the Eastern United States and southern Canada, are the two most important species. Black ash (*F. nigra* Marsh.) is an important timber species in the Northeastern United States and southeastern Canada. Ash wood—tough, strong, and resistant to shock—is used for handles, oars, baseball bats, and furniture. Green, white, and black ashes grow best on fertile, moist, well-drained soils. But green ash, the most adaptable of the ashes, grows naturally on a wide range of sites from clay soils flooded up to 40 percent of the time to sandy, dry, harsh sites. Because of its hardiness, adaptability, and drought tolerance, green ash is used widely as an ornamental, in shelterbelts of the Great Plains, and for revegetation of strip-mining spoil banks. Green and white ashes are among only a few hardwood species being used to establish commercial timber plantations.

Insects, diseases, and pollutants are continuing problems for the ashes, but few actually threaten their widespread use. Disease, simply stated, is a condition of abnormal growth resulting from infection by a biotic agent (fungus, bacterium, or virus), or induced by an abiotic stress such as drought or air pollution. Fungi are the most com-

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J. D. Solomon is supervisory research entomologist and project leader, T. D. Leininger and A. D. Wilson are research plant pathologists, and F. I. McCracken was principal research plant pathologist (retired) at Southern Hardwood Laboratory, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Stoneville, MS 38776. In cooperation with: Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group. R. L. Anderson is field office representative, Southeast Area, U.S. Department of Agriculture, Forest Service, State and Private Forestry, Asheville, NC 28802; L. C. Thompson is professor of forest protection, University of Arkansas-Monticello, AR 71655.

mon causes of diseases of trees. Diminished growth and vigor, brought on by one or more biotic or abiotic factors, are perhaps the most serious problems of white ash. Wood boring insects, the most damaging pests of green ash, have damaged shelterbelt plantings in the Great Plains and caused considerable degrade losses in logs and lumber in the South. An estimated one-third of the ash trees larger than pole size contain some heartrot. Seed insects sometimes destroy up to 90 percent of the seed crop. Insects and diseases that destroy foliage can be disfiguring and cause growth loss, but seldom cause widespread damage. Because the gypsy moth, *Lymantria dispar* (L.), rarely feeds on ashes, ash species are often favored for planting in both forest and urban settings in the Northeastern States.

Cultural practices that maintain and promote tree health are encouraged to minimize losses. Control measures are not always feasible or needed for some ash pests covered in this guide, especially when light infestations or infections occur. The best procedure in these cases is to prevent problems by promoting and maintaining healthy trees. To this end, some recommendations are provided in the back of this guide in a section called "Maintaining Tree Health." However, chemical controls may become necessary as a last resort when all else fails.

This booklet will help nursery workers, resource managers, pest control personnel, and homeowners to prevent, identify, and control ash pests. The major insect and disease pests of ashes in the Eastern United States are emphasized. Descriptions and illustrations of the pests and their damage are provided to aid in identification. Brief notes are given on their biology and control to aid in assessing damage and making control decisions. Lists of chemical controls are provided, but recommendations are subject to change as certain compounds are discontinued and new materials approved. The chemical control section (tear sheet) in this booket can be removed and discarded when outdated as indicated by registered uses on pesticide labels. For further information on pesticides or additional assistance with ash pests, contact your State forester, county extension agent, or the nearest office of the USDA Forest Service, State and Private Forestry, Forest Pest Management.

Blackheaded Ash Sawfly, *Tethida barda* (Say)
Brownheaded Ash Sawfly, *Tomostethus multicinctus* (Rohwer)
Spiny Ash Sawfly, *Eupareophora parca* (Cresson)

Importance.—The ash sawflies are widely distributed throughout eastern North America and westward to the Great Plains. Young trees in new plantations and ornamental plantings seem particularly susceptible to defoliation.

Identifying the Insects.—Larvae of the blackheaded (fig. 1a) and brownheaded ash sawflies have greenish- to yellowish-white bodies. The spiny ash sawfly larvae (fig. 1b) have dark heads and gray bodies with numerous forked, dark spines. Larvae of all these species are about 16 to 19 mm long at maturity. Adults are typical sawflies, with mostly black bodies marked with red and white, and measure 6 to 8 mm in length.

Identifying the Injury.—The larvae feed gregariously in groups of 4 to 20, often lined up in rows feeding side by side. Young larvae chew holes in the leaflets, and older larvae eat entire leaflets. Heavily infested young trees may be completely defoliated in 1 to 2 weeks. Older trees may be so ragged that most of the leaves drop prematurely.

Biology.—In the spring, adults lay eggs in slits cut along the outer margins of young leaflets. Larvae feed and mature in early to mid-May in the South, later in the North. When mature, they drop to the ground where they make earthen cocoons in the soil and spend the summer, fall, and winter. In the spring, larvae pupate and emerge as adults to begin the cycle again. There is one generation per year.

Control.—Natural enemies usually keep sawfly densities low. Insecticides are effective in young plantations and ornamental plantings when severe infestations occur.

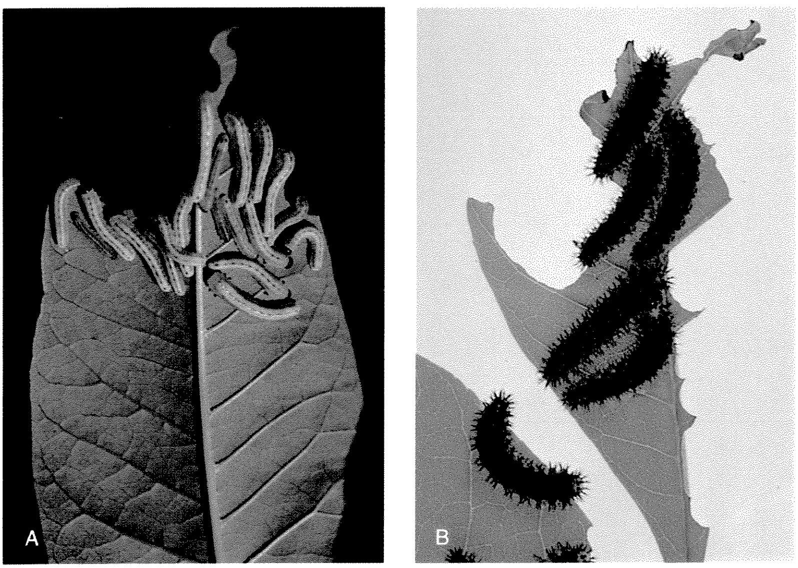


Figure 1.—*(a) Blackheaded ash sawfly larvae; (b) spiny ash sawfly larvae.*

Ash Sphinx, *Manduca jasminearum* (Guerin)
Great Ash Sphinx, *Sphinx chersis* (Hübner)
Waved Sphinx, *Ceratomia undulosa* (Walker)

Importance.—Sphinx larvae are seldom serious pests, but they are readily noticed because they are large and ornate caterpillars. All three species occur in the Eastern United States. The great ash sphinx ranges from coast to coast and has been known to concentrate locally on clumps of saplings, young trees, and sprouts.

Identifying the Insects (fig. 2a).—Sphinx larvae (hornworms) become quite large, reaching 75 mm in length. They have a distinctive horn-shaped spine on their distal end. Color markings are mostly pale green, usually with diagonal yellow or white markings. Adults are large moths with stout, spindle-shaped bodies; wings are narrow and brown or gray with dark and light bands. They are very strong fliers and are commonly known as hawk moths or hummingbird moths.

Identifying the Injury (fig. 2b)—Larvae typically consume the entire blade of tender leaves; midribs and major veins may be left on older leaves. Feeding begins and is most noticeable on the young leaves of terminals and branch ends and progresses toward the older foliage.

Biology.—Adults emerge during May and June and lay eggs on the foliage. Larvae may be found feeding from June to September. Mature larvae burrow into the soil to pupate. There are two generations per year in the South and only one in the North. Overwintering occurs in the pupal stage in the soil.

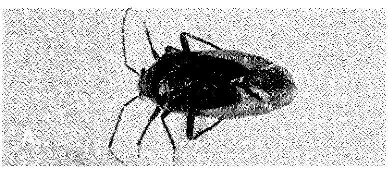
Control.—Natural enemies usually keep hornworm populations in check. Insecticides are rarely needed to protect seedlings and small trees.

Figure 2.—*(a) Sphinx larva (hornworm); (b) feeding injury on young sapling.*

Ash Plant Bugs, *Tropidosteptes* spp.

Importance.—Three species of ash plant bugs, *Tropidosteptes amoenus* Reuter, *T. tricolor* Van Duzee, and *T. cardinalis* Uhler, are mainly eastern species occurring west to Texas and the Great Plains; whereas two, *T. illitus* Van Duzee an *T. pacificus* Van Duzee, are western species. They suck the juices from buds, leaves, seeds, and shoots, causing distortion and premature shedding.

Identifying the Insects (fig. 3a).—Adults are elongate-oval, soft bodied, 3 to 6 mm long, with piercing-sucking mouthparts. They vary in color by species from black and white, to red and black, to light or dark brown. Nymphs are smaller than adults and are wingless.



Identifying the Injury.—Initial injury is caused mainly by the nymphs, which feed on the opening buds and new leaves. Later instars feed on leaves, flowers, and seeds. Concentrated feeding on buds and small expanding leaves causes them to become discolored, distorted, and stunted (fig. 3b). Feeding on older leaves causes stippling with black excrement spots (fig. 3c).

Biology.—Ash plant bugs overwinter as eggs laid in the thin bark of twigs. In the spring, these eggs hatch as the buds are opening. Nymphs feed mostly on the undersides of leaves and take 4 to 5 weeks to reach the adult stage. First generation adults begin the cycle again by laying their eggs mainly on the midribs of leaves. Typically, two broods are produced each year, although *T. illitus* produces only one.

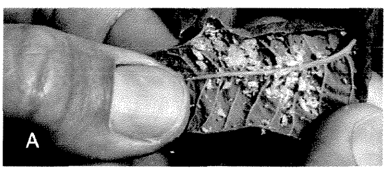
Control.—Dormant oil sprays have been used during the winter months to kill the eggs. Insecticides can be used to control nymphs and adults in the spring.

Figure 3.—*(a) Adult ash plant bug* (Tropidosteptes cardinalis); *(b) injury to young expanding leaves; (c) stippling injury to full-grown leaves.*

Woolly Ash Aphid, *Prociphilus fraxinifolii* (Riley)

Importance.—This aphid occurs in the Eastern United States and west to Colorado. Heavy aphid infestations cause premature defoliation and stunt growth. The distorted foliage, along with accompanying honeydew and sooty mold, mar the beauty of ornamentals and make nursery plants unsalable.

Identifying the Insects (fig. 4a).—Aphids are 2.0 to 2.5 mm long, soft bodied, and pear shaped to globular, with a pair of tubes projecting from the abdomen. They are yellowish green to pale yellow with brown head and legs. Both winged and wingless forms occur. White, waxy secretions often cover the aphids, giving them a "woolly" appearance.



Identifying the Injury.—Aphids suck the sap from the undersides of tender, developing leaves of terminals and branch tips (fig. 4b). Feeding causes leaves to curl downward (fig. 4c). Unfolding the tightly curled leaves will reveal clusters of aphids. Heavily infested leaves may drop prematurely. A whitish, sticky honeydew produced by the aphids frequently coats the foliage and supports the growth of black, sooty mold.

Biology.—Overwintering occurs as eggs in bark crevices. The eggs hatch in the spring into wingless females that reproduce without mating. Several generations are produced each year. During fall, winged adults deposit the overwintering eggs. The largest populations are usually present during early summer.

Control.—Natural enemies routinely keep most aphid populations under control, but insecticides may be needed to protect nursery stock and ornamentals.

Figure 4.—*(a) Closeup of aphids under curled leaf; (b) heavily infested ash terminal; (c) heavily curled leaves caused by aphids.*

Ash Borer (terminal borer), *Podosesia syringae* (Harris)

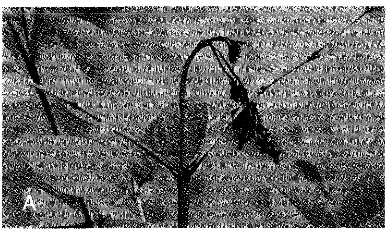
Importance.—The ash borer is found throughout eastern North America. Spring feeding on tender shoots causes mortality of terminals resulting in forked trunks. When plantations are established to produce sawlogs, forked or deformed trunks are unacceptable losses. (This insect is also covered as a trunk pest in the insect borer section.)

Identifying the Insect.—Tiny larvae found burrowing in terminals are white to yellowish with the dark gut visible. Larvae vary from 1.5 to 5.0 mm in length. After vacating the shoots, they feed elsewhere on the trunk and branches and may reach 34 mm in length. Adults are brown to reddish clearwing moths with a wingspan of 25 to 38 mm.

Identifying the Injury (fig. 5a).—The earliest symptom is a sudden wilting of succulent green shoots, which become shriveled and dark within 4 to 8 days (fig. 5b). Tunnels are typically 1 to 3 cm long before the shoot is vacated. It takes less than 1 month for the terminal to wilt, darken, shrivel, die, and break away, often resulting in forked stems in new growth (fig. 5c).

Biology.—Adult moths begin emerging in March in the South and oviposit on the shoots and bark. Newly hatched larvae tunnel into the succulent shoots during April and May. In the South, shoot injury peaks by mid-May, declines in late May, and ceases by early June. Young larvae are present in the shoots for only 2 to 3 weeks; then they vacate the galleries and become trunk borers.

Control.—Natural enemies help reduce borer populations. Insecticides may be necessary in new plantings, especially those surrounded by heavily infested ashes.



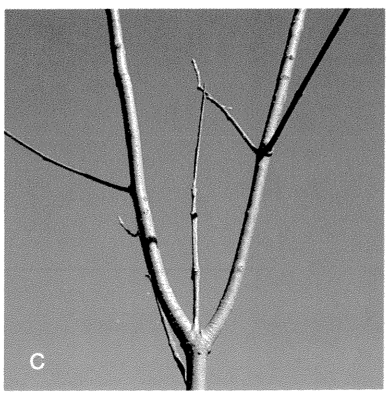


Figure 5.—*(a) Early symptoms of ash borer infested terminal; (b) terminal killed by ash borer; (c) fork resulting from killed terminal.*

European Fruit Lecanium, *Parthenolecanium corni* (Bouché)
Oystershell Scale, *Lepidosaphes ulmi* (L.)
White Peach Scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti)

Importance.—Scale insects are common pests of ashes and are distributed throughout the United States. These insects suck the sap from plants, weakening them and making them susceptible to other pests. Scales often kill branches and occasionally individual trees.

Identifying the Insects.—Scale insects appear as protrusions on the branches and twigs. Mature oystershell scales are 3 mm long, brownish to purplish gray, narrow, and rounded toward the rear with concentric bands (fig. 6a). White peach scales are 1.5 mm wide, circular, and white to gray or yellowish (fig. 6b). European fruit lecaniums are 4.7 mm wide, circular, reddish to dark brown, and often covered with white powder (fig. 6c).

Identifying the Injury.—Crown dieback is the principal symptom of severe infestations. Honeydew may be produced, which supports a black, sooty mold that turns leaves and branches black. Heavily infested plants produce pale foliage and few new shoots and exhibit twig and branch dieback.

Biology.—Females lay eggs under waxy domes. The newly hatched nymphs, called crawlers, crawl to new sites on the bark and begin feeding. The oystershell scale overwinters in the egg stage. Two generations occur in Maryland, where crawlers are present in May and June and again in mid-July. The white peach scale has four generations per year in Florida and three in Maryland. The crawlers are present in May, July, late August, and early September. The European fruit lecanium produces one generation per year.

Control.—Contact insecticides are effective when timed with the appearance of crawlers. Dormant oil sprays will kill overwintering scales.

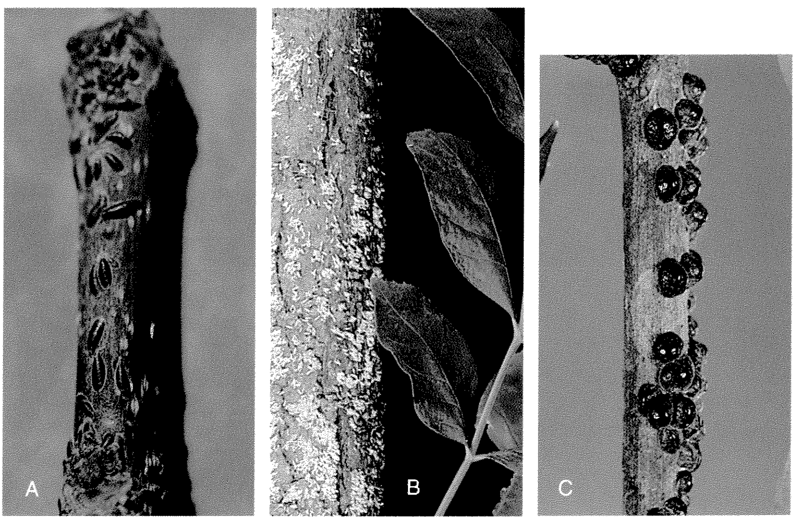


Figure 6.—*(a) Oystershell scales; (b) white peach scales; (c) European fruit lecaniums.*

Flatid Planthoppers: *Acanalonia conica* (Say), *Anormenis septentrionalis* (Spinola), *Metcalfa pruinosa* (Say)

Importance. – Flatid planthoppers occur throughout the Eastern United States, west to the Great Plains; one species, *Metcalfa pruinosa,* ranges from coast to coast. Planthoppers suck the sap from small diameter stems, but damage is usually minor. Oviposition injuries sometimes kill seedlings.

Identifying the Insects (fig. 7a). – Adult flatid planthoppers are pale or yellowish green to brown or black but are usually covered by white, powdery wax, which imparts a whitish-gray or bluish-green appearance. They have large prominent wings held at an acute, rooflike angle over the body and range from 6 to 13 mm long. Nymphs are wingless, slightly elongate, slightly flattened, and partially to completely covered with filaments of white, woollike wax (fig. 7b).

Identifying the Injury. – Feeding by large populations causes seedlings and terminals of older plants to wilt. Although sap-feeding may slow plant growth, it rarely causes widespread dieback. However, clusters of oviposition punctures along stems may cause mortality of seedlings and shoot dieback on older plants.

Biology. – Overwintering eggs hatch during the spring. Nymphs feed singly or in clusters on tender shoots. Adult flatid planthoppers appear by June or July and are present until fall. They deposit their eggs in a series of short slits in the bark. There is only one generation per year.

Control. – Natural enemies help keep populations in check. On young plants, pruning and destroying shoots that contain oviposition punctures (before the eggs are able to hatch) provides some control.

Figure 7. – *(a) Adult flatid planthoppers; (b) flatid planthopper nymphs.*

Ash Borer (trunk borer), *Podosesia syringae* (Harris)

Importance.—This borer is a destructive pest throughout eastern North America. Trunk infestation rates of 50 percent are common in shelterbelts of the Great Plains. In the South, trees intended for wood products are degraded and reduced in value. Shade and ornamental trees may be scarred, seriously weakened, or killed.

Identifying the Insect.—Adults are clearwing moths that mimic paper wasps in appearance and flight. The wingspan of the moth is about 25 mm. The wings and body are brownish black, and the legs are marked with black, orange, and yellow. Larvae are white, except for an amber-colored head and thoracic shield, and are about 25 to 34 mm long at maturity.

Identifying the Injury (fig. 8a).—The first evidence of attack is sap mixed with fine frass oozing from small holes in the bark. Later, the frass is extruded in small clumps. Circular adult exit holes, often with pupal skins protruding, are found above the irregularly shaped entrance holes. Infestation is greatest in the lower trunk. Lumber sawn from infested trees may exhibit numerous dark-stained, pencil-sized holes (fig. 8b).

Biology.—Adults begin emerging during February in Florida and during July in the North. Emergence is completed by the end of July. There is a single brood per year. Eggs, deposited singly or in small clusters in bark crevices, hatch in 11 days. Young larvae mine in the phloem and cambium, then excavate galleries 7.5 to 13.0 cm long in the wood.

Control.—Natural enemies, wound prevention, brood tree removal, burlap trunk wraps, and insecticides help to reduce populations. Pheromone traps are used to monitor moth flights in order to time insecticide applications.

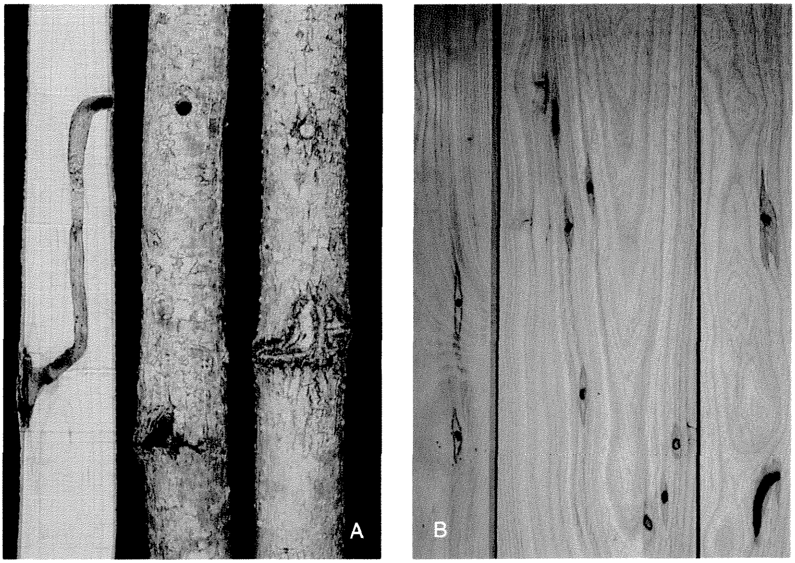


Figure 8.—*(a) Ash borer gallery, entrance and exit holes, and bark scars of entrance and exit holes; (b) ash borer defects in lumber.*

Importance.—This clearwing is similar in distribution and appearance to the ash borer and causes similar damage to boles and branches. Its populations are smaller and more scattered than those of the ash borer.

Identifying the Insect (fig. 9a).—Adult clearwings are slightly larger than adult ash borers and have forewings that are violet brown and mostly dark. The body is brownish black, but abdominal segment 4 is bordered at the rear with a distinct, narrow, upward-tapering, bright orange-yellow band. The larvae can be distinguished from ash borer larvae because they have fewer crochets on the abdominal legs (12 to 16 per row vs. 16 to 20 per row, respectively).

Identifying the Injury (fig. 9b).—Injury is similar to that of the ash borer, but the seasonal occurrence is markedly different. Females lay eggs in late summer. Soon after, and continuing into the fall, larvae begin feeding, causing sap to ooze and fine frass to be extruded from attack sites. The next spring and summer, the frass becomes coarse and granular and is extruded in small clumps (fig. 9c). Pupal skins may be found protruding from exit holes in the bark from late summer to winter.

Biology.—Adults emerge from August to December, whereas those of the ash borer emerge during spring and summer. Emergence peaks from mid-September to early October. Larvae overwinter as second instars within their mines in the phloem-cambium area.

Control.—Woodpeckers, other natural enemies, and good cultural practices help to reduce populations. Insecticides must be applied in late summer and fall to kill newly hatched larvae.

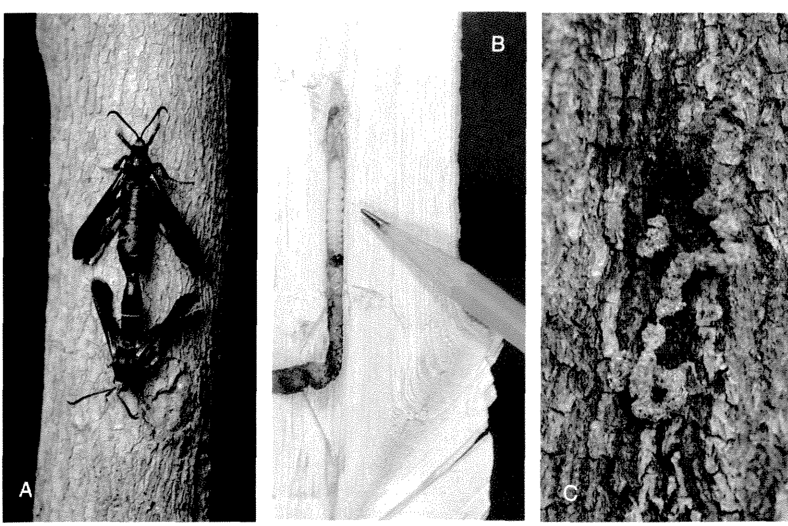


Figure 9.—*(a) Mating pair of banded ash clearwings; (b) partially completed gallery; (c) entrance hole in bark with frass clumps.*

Carpenterworm, *Prionoxystus robiniae* (Peck)

Importance.—Carpenterworms, widely distributed through the United States and southern Canada, bore into trunks and branches. For years, they were recognized mainly as pests of shade, ornamental, and shelterbelt trees, but their impact through log and lumber defects is even more important.

Identifying the Insect (fig. 10a).—Young larvae are reddish pink. Mature larvae are creamy white with a shiny, dark-brown head and black mandibles, and are 50 to 75 mm long. Adults are large, grayish moths with black and gray mottled wings; males have an orange spot on their hind wing.

Identifying the Injury.—The earliest signs of attack are sap spots with fine boring dust. Later, frass is discharged from entrance holes. Larvae chew cavelike burrows 50 mm in diameter (fig. 10b) and galleries 12 to 22 cm long in the wood (fig. 10c). Oval to irregularly shaped bark scars are evident. Damage in sawn lumber appears as pockets of ingrown bark and stained holes 12 mm in diameter.

Biology.—Adult moths appear from April to June and deposit 400 to 800 eggs in bark crevices. Eggs hatch in 10 to 12 days, and young larvae tunnel into the bark and wood. Pupation occurs within the tunnel and lasts 3 weeks. A life cycle requires 1 to 2 years in the South, and 2 to 4 years in the North.

Control.—Open-grown trees are most susceptible, thus stands should be kept well stocked. Brood trees should be identified and removed. Injuries during logging should be prevented or minimized. Natural enemies provide some help. Insecticides can protect ornamental trees.

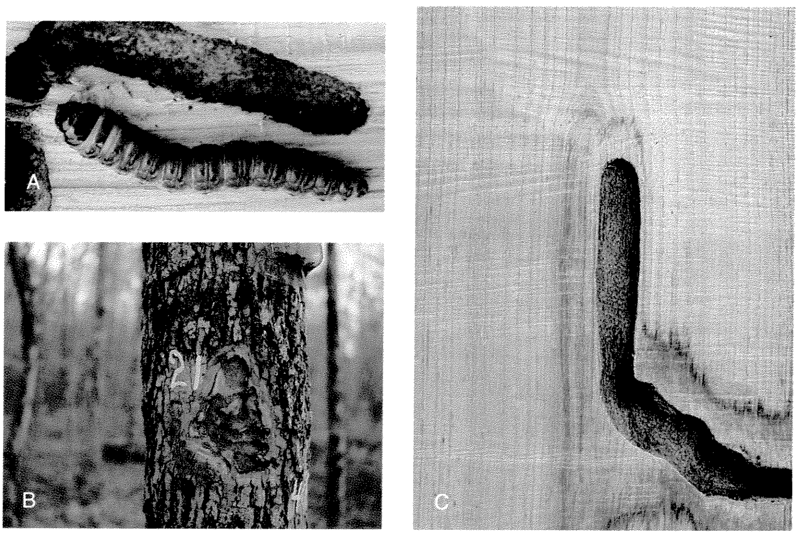


Figure 10.—*(a) Carpenterworm larva; (b) large, cave-type burrow under bark; (c) gallery in bole.*

Banded Ash Borer, *Neoclytus caprea* (Say)
Redheaded Ash Borer, *Neoclytus acuminatus* (Fabricius)

Importance.—These borers infest weakened, dying, and recently dead ash trees, but are most destructive to recently cut sawlogs. They occur throughout most of the United States, but are most common in the East.

Identifying the Insects (fig. 11a).—Adults of both species are elongate, tapered in form, and vary from 4 to 18 mm in length. The redheaded ash borer is reddish with yellow bands; the banded ash borer is black with yellowish-white bands. Larvae of both species are creamy white, short, robust, and 10 to 22 mm long.

Identifying the Injury (fig. 11b).—Round adult exit holes in the bark and wood and mines under the bark are evidence of infestation (fig. 11c). The principal injury is from larval tunnels in the sapwood; the oval tunnels are tightly packed with frass. Injury to recently felled trees and logs is often confined to the shaded bottom half.

Biology.—Adults of the redheaded ash borer emerge from May to August in the North and from February to November in the South. Eggs, deposited under the bark, hatch in 1 week. Larvae penetrate the sapwood to feed and overwinter in their tunnels. There are two to three generations per year in the South and one to two in the North. The banded ash borer has one generation per year.

Control.—Keeping ornamentals healthy will help prevent infestation. Sawlogs may become infested within 20 days of felling during the summer and must be processed promptly.

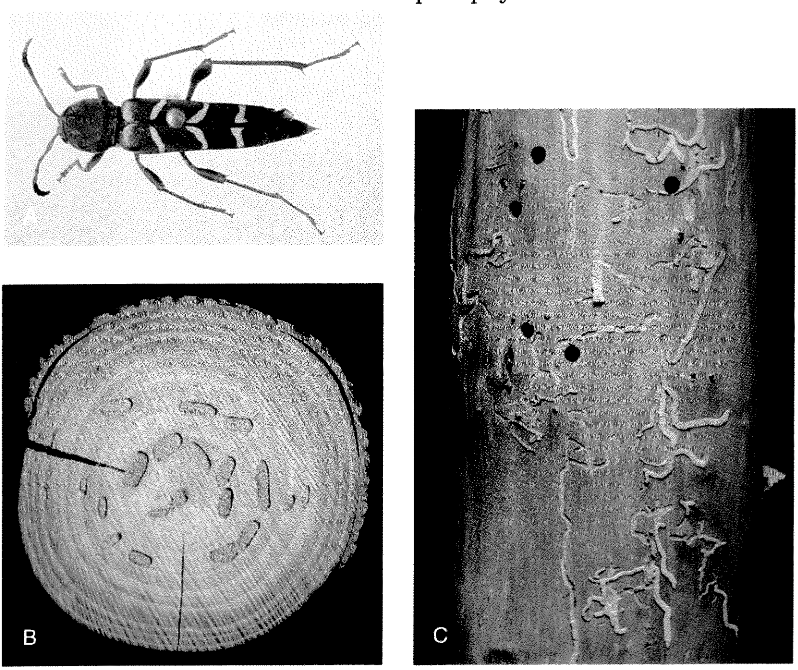


Figure 11.—*(a) Adult of redheaded ash borer; (b) cross section of oval, frass-packed tunnels; (c) larval mines and exit holes on sapwood surface.*

Ash Cambium Miner, *Phytobia* sp.

Importance.—Maggots of this fly mine in the cambium of tree boles and roots in the Eastern United States. They cause defects consisting of small, light to dark streaks evident in tangential cuts of wood or specks known as pith ray flecks, worm tracks, or glassworms as seen in cross-sectional cuts. Such defects cause quality degrade when the wood is used for veneer, cabinets, baseball bats, or tool handles.

Identifying the Insects (fig. 12a).—The larvae are long, narrow maggots, somewhat laterally flattened, and measure about 25 mm long when fully grown. Adults look somewhat like small, hairy house flies.

Identifying the Injury (fig. 12b).—The maggots make long threadlike mines in the cambium of branches, boles, and roots. Mines are most common in the basal 90 cm of the trunk and in the roots within 1.5 m of the bole (fig. 12c). Mining in living trees is detectable only by removing the bark. In lumber and veneer, mines appear as zigzag tracks lighter or slightly darker than the natural wood.

Biology.—Eggs are laid in small twigs. Maggots mine in the cambium and inner bark down the stem and into the roots. Second-instar maggots overwinter in the roots. Full-grown maggots exit through the bark and form puparia in the soil. In the North, pupation occurs in May and June, whereas in Mississippi, it occurs from February to April. The life cycle is completed in 1 year.

Control.—Dead maggots have been found in their mines following unusually cold winters. Other natural controls are unknown, and direct controls have not been investigated.

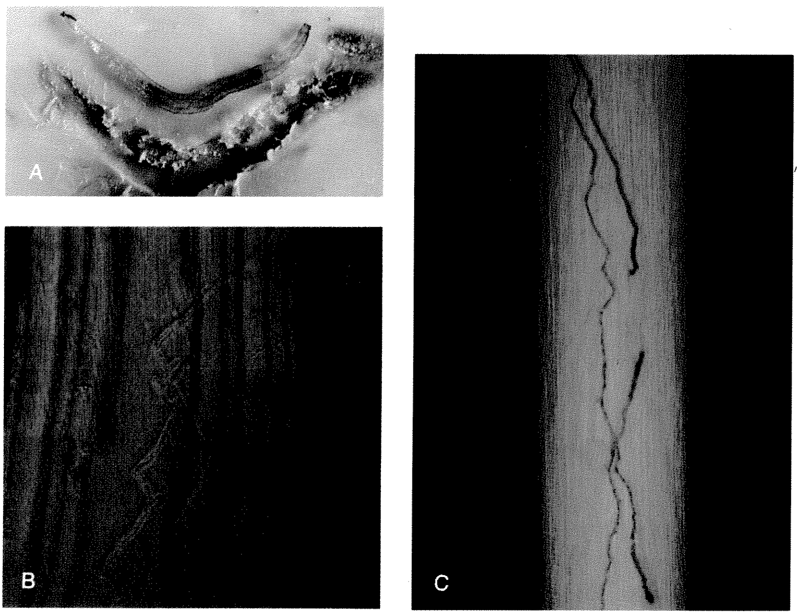


Figure 12.—*(a) Ash cambium miner larva; (b) zigzag glassworm tracks in ash veneer; (c) threadlike mines on sapwood surface.*

Eastern Ash Bark Beetle, *Hylesinus aculeatus* (Say)
Northern Ash Bark Beetle, *Hylesinus criddlei* Swaine
White-Banded Ash Bark Beetle, *Hylesinus fasciatus* (LeConte)

Importance.—One or more species of ash bark beetles are found in any given region of the United States. They attack and breed in weakened, felled, and storm-damaged trees; only occasionally do they attack healthy trees. On some sites of the dry Great Plains, the western ash bark beetle causes severe branch- and top-kill.

Identifying the Insects (fig. 13a).—Adult beetles are slightly elongate, cylindrical, and 2.0 to 3.4 mm long. Dense areas of light- and dark-colored scales produce mixed bands or spots. Larvae are legless grubs with a white, slightly curved body and a light-brown head (fig. 13b).

Identifying the Injury (fig. 13c).—Injury to trees results from tunneling in the inner bark and surface of the sapwood. The large egg gallery has two branches extending across the wood grain in opposite directions from the bark entrance. Larval galleries radiate outward from the egg gallery. The bark may be peppered with 1-mm, round exit holes (fig. 13d).

Biology.—Overwintering adults fly to susceptible trees in the spring where they burrow into the bark and begin laying eggs. Larvae pupate in small cells at the end of their tunnels. New adults burrow out to the bark surface. There are one to two generations per year. Adults overwinter in short feeding tunnels in the bark of living or recently felled trees.

Control.—Direct controls are rarely needed. Cultural controls include debarking felled trees and logs and/or burning them to prevent brood emergence. To prevent attacks insecticides may be applied to the bark.

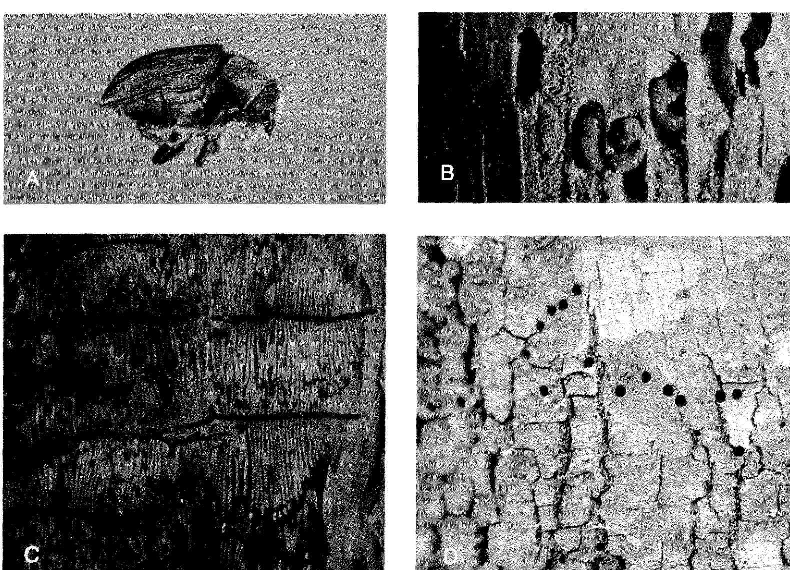


Figure 13.—*(a) Eastern ash bark beetle; (b) larvae in galleries; (c) horizontal egg galleries with vertical larval galleries; (d) adult exit holes.*

FLOWER AND SEED INSECTS AND MITES

Ash Flowergall Mite, *Aceria fraxiniflora* Felt

Importance.—This eriophyid mite attacks male flower clusters, turning them into masses of lumpy, distorted galls. Infestations do little damage to trees, but the galls are unsightly and may markedly detract from the appearance of ornamentals. The mite is distributed throughout the United States and southern Canada.

Identifying the Mite.—The mites are minute, about 0.5 mm long, soft bodied, wormlike or spindle shaped, and white to straw colored. They are so small as to be largely invisible to the unaided eye and are frequently overlooked, even with a 10x magnifier.

Identifying the Injury (fig. 14).—Feeding by the mites on the male flower clusters causes swelling of the tissues. Flower stems elongate, pedicles of individual flowers often fuse, and all parts curl and twist. Infested flower clusters become irregularly branched, fringed, gall-like masses. Galls are initially green but darken and become black later in the season, and many persist until the following spring.

Biology.—In the spring, overwintering females move to the developing flowers to feed and deposit eggs. Nymphs live and feed in protected crevices of the gall tissue. There are several generations during the spring and summer. In the fall, fertilized females move to bark crevices and beneath bud scales to overwinter.

Control.—High-valued trees can be sprayed in the early spring as soon as they begin to flower.

Figure 14.—*Male flower clusters converted to gall-like masses by ash flower gall mites.*

Ash Seed Weevils, *Lignyodes* spp.

Importance.—Three ash seed weevils, *Lignyodes bischoffi* (Blatchley), *L. helvolus* (LeConte), and *L. horridulus* (Casey), occur throughout the United States and Canada. These weevils feed on the seeds of ashes and lilac. Over 60 percent of the ash seeds in the Northeastern States and up to 95 percent in the Great Plains may be destroyed.

Identifying the Insects (fig. 15a).—Adults are elongate-oval and 2.3 to 4.0 mm long. The pronotum is narrower than the base of the elytra, and the snout is curled with elbowed antennae. The pronotum and elytra are covered with brown to yellow scales. Color patterns distinguish the species. Larvae are white and legless with a curved body and brown head (fig. 15b).

Identifying the Injury.—Infested seeds are difficult to distinguish with the naked eye. With magnification, small, raised, puncture marks partially covered with dark excrement can be observed on the seedcoat (fig. 15c). Cutting open the seed will reveal the feeding larvae (fig. 15d). Small oval to irregular holes are left in seeds by emerging larvae.

Biology.—The weevils overwinter as larvae in the soil or in fallen seeds. Pupation occurs in the soil during spring and summer and lasts about 12 days. Adults emerge during July and August and are present until autumn. Females deposit eggs singly within the seed and seal the openings with excrement. Eggs hatch in 2 days, and the larvae completely consume the seed contents. Mature larvae exit the seed during fall, winter, or spring and burrow into the soil to pupate. There is one generation per year.

Control.—Natural controls keep most populations in check. Direct controls are rarely justified.

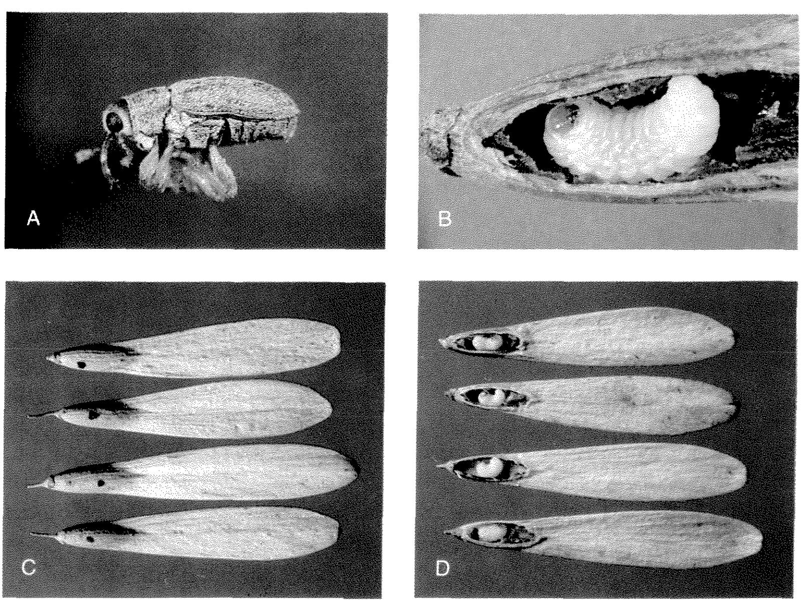


Figure 15.—*(a) Adult ash seed weevil; (b) ash seed weevil larva; (c) infested ash seeds with egg punctures; (d) seeds cut open to expose larvae.*

Leafroll Midges

Pest.—Leafroll midges, *Dasineura* spp.; larvae are small, white maggots 2 to 3 mm long; occur in the Eastern United States; produce one to two generations per year.

Injury.—Several tiny maggots feed together in young, unfolded leaves of ashes in early spring, etching the tender epidermis and keeping the leaves from unfolding; damaged leaves roll, curl, distort, and may fall off (fig. 16a).

Prevention and Control.—Natural control is usually adequate; trees should be kept in vigorous condition; direct controls are rarely needed.

Leaf Beetle

Pest.—Leaf beetle, *Octotoma plicatula* (Fab.); a black, wedge-shaped beetle 4 to 5 mm long, with a distinctive, irregular design of ridges on its wing covers; adults are active from early May through August.

Injury.—Long, narrow patches of epidermis about 2 mm wide and 4 to 10 mm long are eaten from the undersides of leaves (fig. 16b). Heavily damaged leaves turn brown and drop prematurely in late summer.

Prevention and Control.—Trees should be kept in vigorous condition; direct controls are rarely needed.

Spring Cankerworm

Pest.—Spring cankerworm, *Paleacrita vernata* (Peck); caterpillars are typical loopers; brown to black with yellow stripes (fig. 16c); occur in the Eastern United States and southern Canada; 25 to 48 mm long; produce one generation per year.

Injury.—In the spring, young larvae eat holes in the leaves; later the whole leaf is eaten except for the midrib and major veins; defoliation stresses the trees.

Prevention and Control.—Sticky bands around tree trunks will trap the wingless females; chemical or biological controls are occasionally needed.

Fall Webworm

Pest.—Fall webworm, *Hyphantria cunea* (Drury); mature larvae are 25 mm long, pale yellow to greenish and with hairy, red or black heads; occurs throughout the United States and southern Canada; produces one to four generations per year.

Injury.—Caterpillars make webbed nests around leaves at branch ends, living and feeding in groups inside the nests; populations and webbed nests are most abundant in late summer and fall (fig. 16d).

Prevention and Control.—Natural enemies are usually effective; webbed nests can be pruned from small trees; chemical or biological controls may be needed.

Forest Tent Caterpillar

Pest.—Forest tent caterpillar, *Malacosoma disstria* Hübner; caterpillars have a dorsal row of keyhole-shaped, white spots bordered by pale-bluish lines (fig. 16e); mature larvae are 50 mm long; occurs throughout the United States and Canada; produces one generation per year.

Injury.—Caterpillars begin feeding on ash foliage as it emerges in early spring; first noticeable signs of attack are sparse crowns and falling frass; caterpillars feed for 4 to 6 weeks.

Prevention and Control.—Parasites, predators, and diseases keep most infestations in check; chemical and biological controls may be needed.

Ashleaf Gall Mite

Pest.—Ashleaf gall mite, *Aceria chrondriphora* Keifer; mites are elongate, spindle shaped, and soft bodied; hardly visible to the naked eye; live inside leaf galls throughout the United States and southern Canada.

Injury.—The galls on the upper surface of leaves are greenish yellow, 2 to 3 mm in diameter (fig. 16f), reniform in shape, solitary but numerous, scattered along the lateral veins, and reduce esthetic value of trees.

Prevention and Control.—Natural controls are usually adequate; fallen leaves should be raked and destroyed; direct controls are rarely needed.

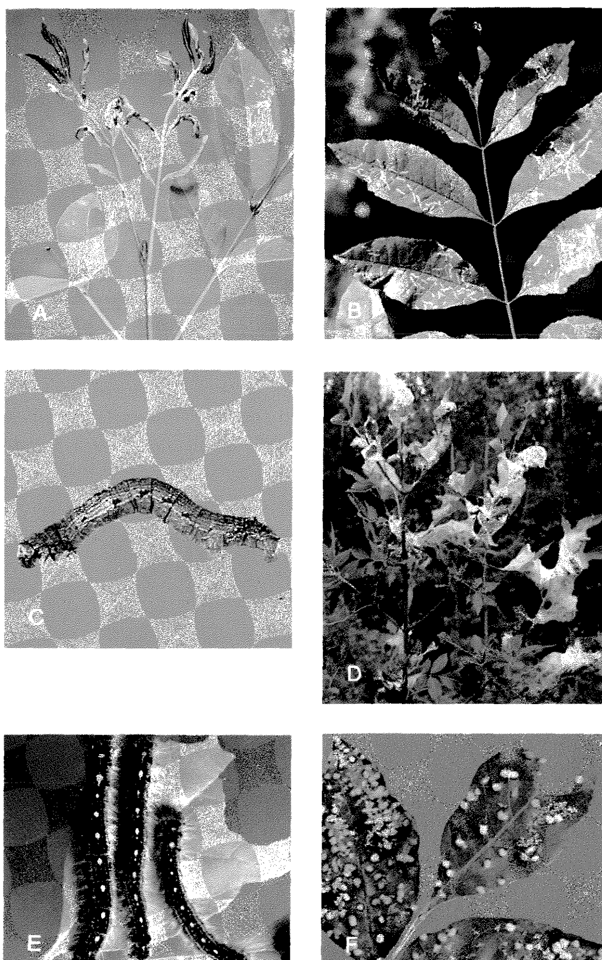


Figure 16.—*(a) Curled leaves from leafroll midge; (b) leaf beetle feeding symptoms; (c) spring cankerworm; (d) fall webworm tents in young ash; (e) forest tent caterpillars; (f) leaf galls caused by ashleaf gall mites.*

Damping-Off, *Cylindrocladium* spp., *Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp.

Importance.—Damping-off is the most important and widespread disease of ash seedlings in tree nurseries. The disease is most prevalent in cool, low-lying areas where standing water persists, in acidic soils, and under any conditions where seedling growth is poor. Seedling density may be reduced up to 25 percent or more when poor cultural practices are used.

Identifying the Disease.—Damping-off may prevent the emergence of seedlings from the soil as the seeds or hypocotyls are attacked. Seedlings attacked after emergence fall over because the hypocotyls are rotted at or below the soil line (fig. 17). Both types of damping-off result in reduced seedling survival causing nonuniform seedling sizes and densities.

Identifying the Fungi.—Many fungi prevalent in soils can cause damping-off. *Fusarium* spp., *Pythium* spp., and *Phytophthora* spp. are most active in cool, wet soils, whereas *Cylindrocladium* spp. and *Rhizoctonia* spp. are more common in warm, wet soils.

Biology.—The soil-borne fungi that cause damping-off of seedlings are able to survive in the soil in the absence of a host. All produce resistant spores or sclerotia that survive in the soil until root exudates stimulate their germination or growth, leading to the infection of seeds or seedlings.

Control.—Damping-off can be controlled with cultural practices. Seeds should be planted on well-drained sites or in raised beds at soil temperatures above 15 °C, avoiding dense stands. Nitrogen fertilizers should not be applied until seedlings are 6 weeks old. Soil acidity should be maintained at pH 6.0 or slightly above. Soil fumigation or seed treatment with fungicides is sometimes necessary for adequate control.

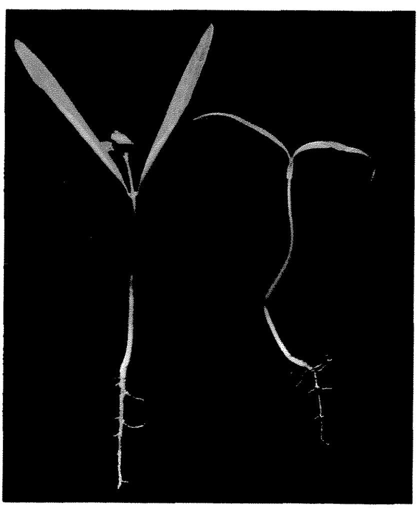


Figure 17.—*Ash seedlings with symptoms of postemergence damping-off.*

Anthracnose, *Gnomoniella fraxini* Redlin & Stack

Importance.—Ash anthracnose may be the most common foliar disease of ashes in the United States. It is most important in landscape and street-side plantings and in plantations, and is less important in natural forest stands.

Identifying the Disease.—Round to irregular blotches, greenish brown at first, but turning brown with age, appear along margins and midribs of leaflets (fig. 18a). Affected leaflets appear scorched and may curl and drop from the tree. Small cankers and dieback may occur on twigs of trees severely defoliated for several years. Numerous small, round lesions with gray centers and purple-brown margins (frogeye leaf spots) may develop late in the season (fig. 18b).

Identifying the Fungus.—Acervuli, colorless initially and darkening with age, can be found on leaflets shortly after infection. Acervuli are also common on previous-year petioles (fig. 18c) and twig cankers. Masses of dull-white, to pale-pink conidia may be seen exuding from mature acervuli. Black perithecia develop over winter on petioles, leaves, and twigs on the ground.

Biology.—Expanding leaflets and shoots are infected in the spring by rain-splashed conidia from acervuli on dead petioles remaining on trees from the previous year. Additional infections may augment the disease during the growing season. Anthracnose is favored by cool, wet, spring weather and a lack of air circulation around susceptible tissues.

Control.—Direct control is rarely needed.

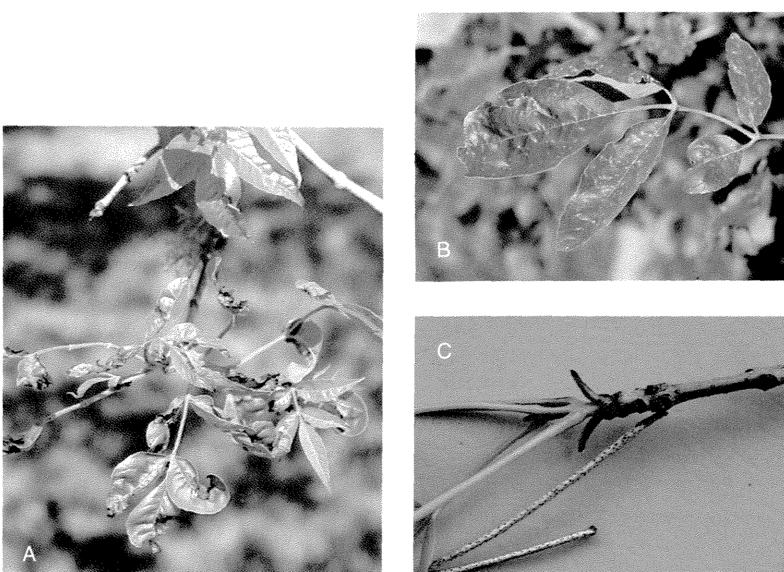


Figure 18.—*(a) Shoot infected with anthracnose, some leaflets have already fallen; (b) frogeye leaf spots; (c) acervuli on previous-year petioles.*

Ash Rust, *Puccinia sparganioides* Ellis & Barth

Importance.—Ash rust attacks most ash species growing east of the Rocky Mountains. It is most severe near coastal areas where its alternate hosts, cord and marsh grasses (*Spartina* spp.), are abundant. Severe damage is infrequent since trees usually recover, although repeated infections have been reported to cause dieback and tree mortality.

Identifying the Disease.—From mid-April to mid-June, the upper surfaces of leaves develop yellow-orange spots, while chlorotic spots develop on petioles and current-year twigs (fig. 19a). Swelling of diseased tissues leads to distortion and necrosis of leaves, bending of petioles, and development of galls on twigs. Trees with severe infections appear scorched, and affected leaves often drop prematurely.

Identifying the Fungus.—Clusters of aecia containing orange-yellow aeciospores appear prominently on twigs, petioles, and lower surfaces of leaves (fig. 19b). Yellow uredinia develop on alternate hosts and are replaced in the fall by dark-colored telia.

Biology.—This fungus has five spore stages of which two must occur on alternate hosts for infection of ashes. In the spring, teliospores that overwintered on alternate grass hosts produce basidiospores that infect the current-year tissues of ashes, causing spermogonia and then aecia to develop. Aeciospores are blown to and infect alternate hosts on which uredinia develop in early summer. During the summer, urediniospores repeatedly infect cord or marsh grass. Uredinia eventually develop into brownish-black telia in the fall.

Control.—To control severe infections in valuable trees, fungicide sprays should be used at 2-week intervals in the spring starting at bud break.

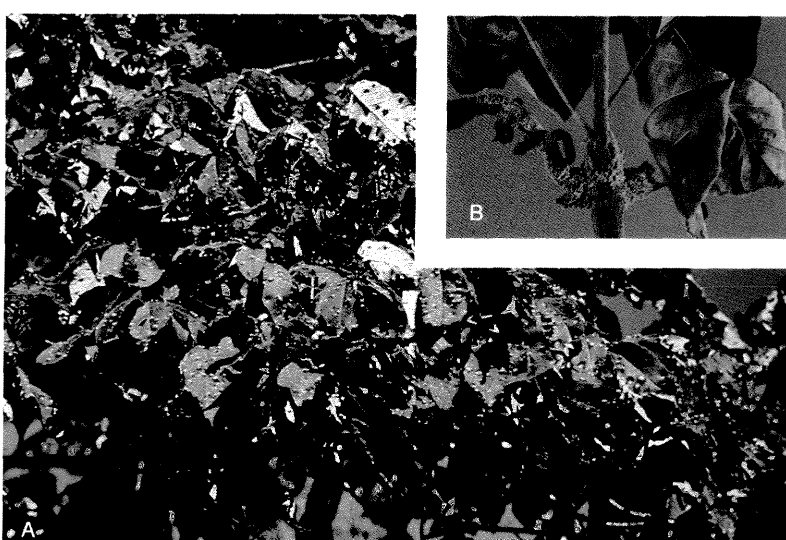


Figure 19.—*(a) Multiple aecial infections on foliage; (b) aecia on twigs and petioles.*

Mycosphaerella Leaf Spots, *Mycosphaerella effigurata* (Schwein.) House, *Mycosphaerella fraxinicola* (Schwein.) House

Importance.—Leaf spots cause premature defoliation of ash seedlings, and forest and shade trees in North America. Mycosphaerella leaf spot, heretofore called "Piggotia leaf spot," is most common in nurseries. Infection by *Mycosphaerella fraxinicola,* previously called "Phyllostica leaf spot," is a problem in large trees.

Identifying the Disease.—Leaf spots caused by *M. effigurata* appear in June as flecklike, yellow spots, 1 to 3 mm in diameter, on upper leaf surfaces. Hundreds of flecks may occur on a single leaflet (fig. 20a, b). By late summer, dark asexual stromata give lower leaf surfaces a sooty appearance. Seedlings may defoliate prematurely near the end of the growing season. Initial leaf spots caused by *M. fraxinicola* are pale-green, irregular blotches, 5 to 15 mm in diameter (fig. 20c). Spots sometimes coalesce and entire leaflets may die. Trees may appear scorched due to necrotic blotches on foliage. Severe infections can result in premature defoliation.

Identifying the Fungus.—Both *M. effigurata* and *M. fraxinicola* have two asexual fruiting stages. Those of *M. effigurata* develop earlier in the growing season than those of *M. fraxinicola. Mycosphaerella fraxinicola* produces cylindrical, colorless conidia in contrast to the two-celled, colorless conidia of *M. effigurata.* Both species produce two-celled, colorless ascospores in pseudothecia that mature and overwinter in fallen leaves. Ascospores of *M. effigurata* are 1.5 to 2.0 times longer than those of *M. fraxinicola.*

Biology.—Ascospores dispersed by wind from fallen leaves initiate primary infections on new leaves in the spring. Wet weather increases the severity of the disease.

Control.—There is no practical control available for these leaf diseases.

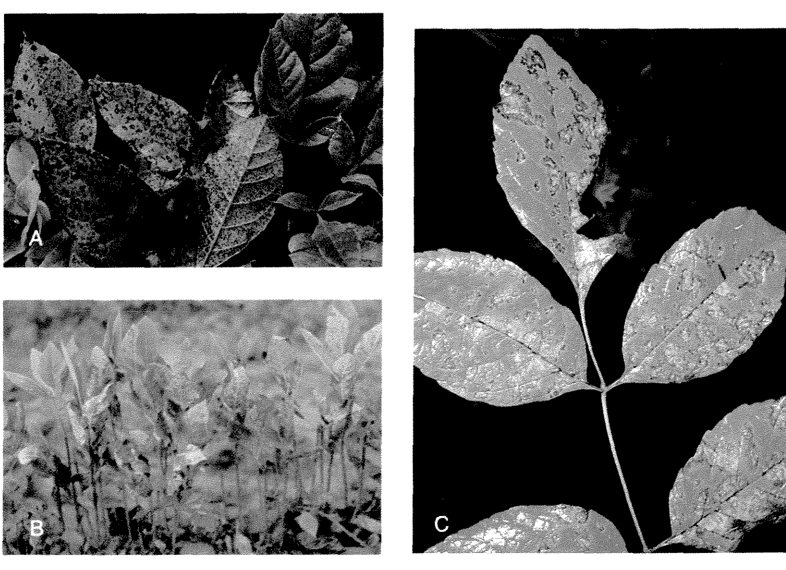


Figure 20.—*(a)* Mycosphaerella effigurata *on white ash seedlings; (b)* M. effigurata *on green ash in nursery; (c) leaf spots caused by* M. fraxinicola.

Powdery Mildews, *Phyllactinia guttata* (Wallr.:Fr.) Lév and other species.

Importance.—Powdery mildews cause only minor damage to ashes in the Eastern United States. On shade and ornamental trees and seedlings, progression of the disease can reduce vigor, but it does not substantially reduce annual growth. Damage to forest trees is negligible.

Identifying the Disease.—Severe infections can cause distortion of tender, late season shoots, as well as chlorosis, foliar browning, and premature defoliation.

Identifying the Fungi.—Powdery mildews are easily identified by the white or light-colored, powdery fungal growth that develops on upper or lower leaf surfaces (fig. 21a, b). Identification of species is based on microscopic examination of cleistothecia, conidia, and conidiophores. Cleistothecia are minute, yellow to black, sexual fruiting structures usually found late in the season on the lower surface of leaflets. Cleistothecia of *P. guttata* have straight appendages with a bulbous base and asci that contain two spores.

Biology.—Powdery mildews are most prevalent where cool to warm, humid weather persists with little rainfall. Primary infection of ashes occurs by ascospores released from overwintered cleistothecia on fallen leaves. Conidia can cause repeated infections during the growing season.

Control.—No control is usually needed for this disease.

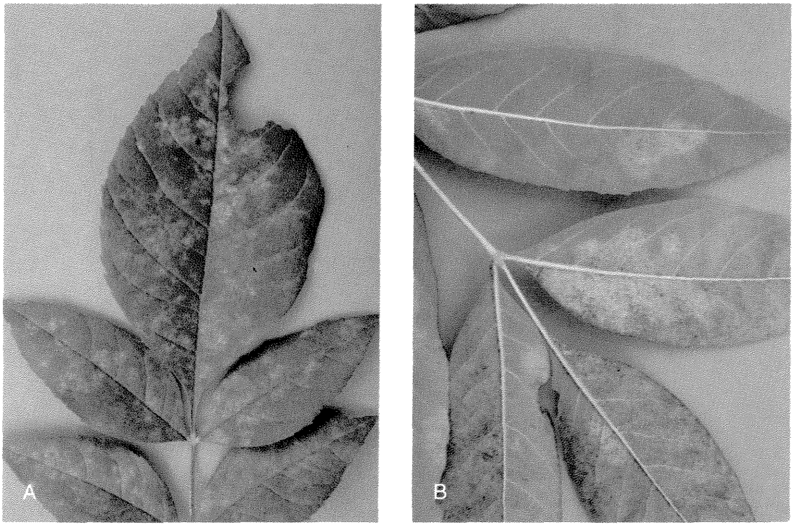


Figure 21.—*(a)* Powdery mildew infection on upper leaf surface; (b) infection on lower leaf surface.

Ash Yellows, Mycoplasmalike organisms (MLO's)

Importance.—Ash yellows causes substantial growth reduction, decline, and mortality of white ash in the Northeastern United States. Green ash appears to be more tolerant of ash yellows. Symptoms similar to those of ash yellows have been reported in Georgia and Louisiana. Trees of all ages and sizes in landscape plantings, hedgerows, and forests are susceptible.

Identifying the Disease (fig. 22a).—Symptoms vary with host susceptibility and disease progression, but in general, initial symptoms are reduced radial (fig. 22b) and shoot growth. Sustained infections can cause branch dieback, thin chlorotic crowns, epicormic sprouting, bark cracks, early fall coloration, and premature death. These decline symptoms, however, can develop from other causes. Witches' brooms (fig. 22c) are definitive, although inconsistent, symptoms of ash yellows.

Identifying the Pathogen.—Identification is based on finding MLO's in stained sections of phloem using a microscope. Tentative field diagnosis can be made by the presence of witches' brooms.

Biology.—Ash yellows is caused by MLO's that inhabit phloem tissue. MLO's are similar in nature to bacteria but lack cell walls. While infections are systemic, it is unclear how MLO's enter ash trees; insect vectors are one possibility. Infected white ash appears to be more susceptible to other stresses such as drought.

Control.—Merchantable white ash with ash yellows dieback should be harvested. Infected landscape trees without severe dieback may respond favorably to fertilization and irrigation.

Figure 22.—*(a) Crown thinning, dieback, and epicormic sprouting; (b) growth decline (12 annual rings are present between the arrow and the cambium); (c) witches' broom at base of white ash.*

Ash Dieback, Various causal agents

Importance.—White ash and green ash trees in forests, shelterbelts, and landscape plantings of the Northeastern and North Central United States are affected substantially by this malady.

Identifying the Disease (fig. 23a).—Symptoms of abnormal growth are similar to those described for ash yellows. Epicormic sprouts and witches' brooms, indicators of MLO infection, have been associated with ash dieback. Stem and branch cankers (fig. 23b) caused by various fungi often lead to progressive crown dieback.

Identifying the Causal Agents.—Decline of ashes in the absence of MLO infection is usually due to multiple biotic and abiotic agents. Drought may be the primary cause of dieback in many areas. A list of other possible causal agents includes at least three viruses (fig. 23c), two fungal pathogens (*Cytospora pruinosa* and *Fusicoccum* spp.), freeze damage, and air pollutants.

Biology.—The initial development of ash dieback frequently involves drought stress, which may be aggravated by freeze damage, or the presence of one or more opportunistic fungal pathogens or viruses. Stress induced by other agents may be worsened by MLO infectons in white or green ash.

Control.—In forests, sites should be carefully selected and species composition managed to avoid having mature ashes on droughty sites. Tree stress may be reduced in landscape plantings by fertilization and irrigation during dry weather.

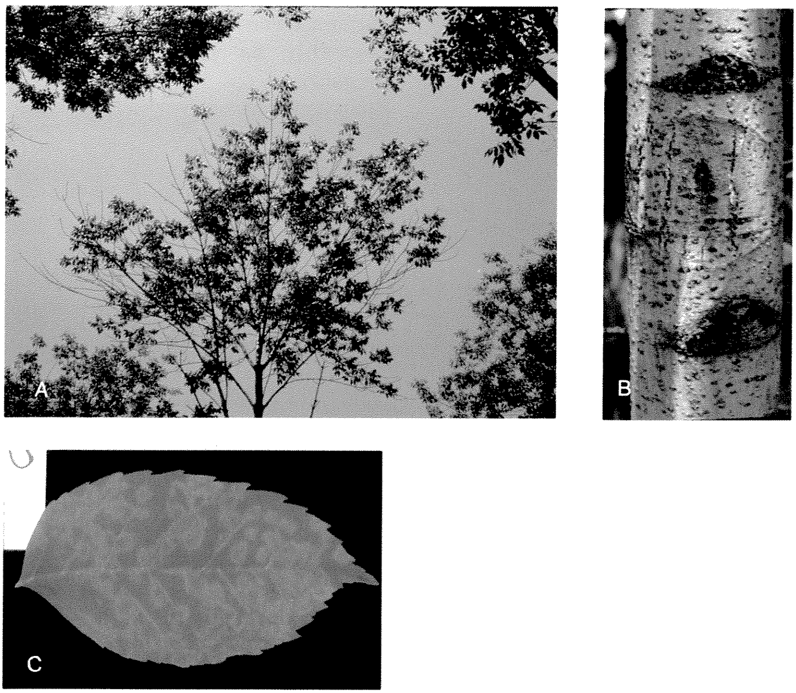


Figure 23.—*(a) Dieback and thinning in white ash; (b) stem canker caused by* Cytospora pruinosa; *(c) ringspots caused by tobacco ringspot virus.*

Verticillium Wilt, *Verticillium albo-atrum* Reinke and Berthier and *Verticillium dahliae* Kleb

Importance.—This disease is prevalent in nurseries and landscape plantings of white and green ashes in the Northeastern and Midwestern United States. Rarely has it been described in forest stands.

Identifying the Disease (fig. 24a, b).—Sudden wilting of foliage on one or several branches is typically the earliest visible symptom. Leaves turn pale green to yellow and may appear scorched before falling, although green leaves may drop before they wilt. Additional symptoms include sparse foliage, stunted growth, and dieback. Infected sapwood often exhibits brown streaking, but this symptom is not always present. Trees with extensive wilt symptoms in much of the crowns will usually die before the end of the growing season.

Identifying the Fungus.—Fungal hyphae and conidia are visible with magnification in the conducting tissue of infected wood. Black microsclerotia or resting hyphae (15 to 100 µm in diameter) and the whorled (verticillate) arrangement of conidiophore branches can be seen in culture.

Biology.—*Verticillium* spp. survive periods of cold and drought by producing thick-walled microsclerotia, which may be dispersed in diseased plants and plant parts, eventually infesting the soil. Hyphae from microsclerotia penetrate ash roots growing next to them in the soil. The fungus also invades the host through wounds but spreads most rapidly when conidia move in the sap stream of conductive tissue. In this way, multiple infections can occur in large trees, eventually reducing or stopping vascular flow in diseased branches.

Control.—Depending on their availability, plant cultivars that are resistant to verticillium wilt should be used.

Figure 24.—*(a) Dieback and leaf scorch in upper right crown caused by Verticillium wilt; (b) scorched leaves.*

Fusicoccum Canker, *Fusicoccum* spp.

Importance.—Cankers and dieback caused by *Fusicoccum* spp. are most severe on sites where trees are growing poorly. Small branches are most affected, although the bole can be attacked. Canker development is usually arrested on trees with vigorous growth; however, cankers may girdle small limbs resulting in dieback and wind breakage.

Identifying the Disease.—Annual cankers appear pale brown when young, but eventually turn dark brown with a distinct boundary between the living and dead tissues. Old, inactive cankers appear sunken and may be surrounded by callus. Dead bark may separate from the wood and disappear from old cankers not covered by advancing callus. Symptoms alone are sometimes insufficient to identify this disease.

Identifying the Fungus.—The fungus forms white masses of conidia within minute, asexual fruiting bodies (pycnidia) embedded in cankers of diseased branches (fig. 25). Conidia must be examined microscopically for identification.

Biology.—The biology of this disease is incompletely known. Numerous conidia, produced and exuded from pycnidia in cankers during wet periods, are spread by splashing rain and mechanical means. They germinate and produce hyphae that enter wounds on branches resulting from insects, frost, or mechanical damage. Stressed trees are more easily infected and colonized.

Control.—Cankers can be minimized through wound prevention, pruning out and removing limbs with cankers from landscape trees during winter, and establishing vigorous planting stock on good sites.

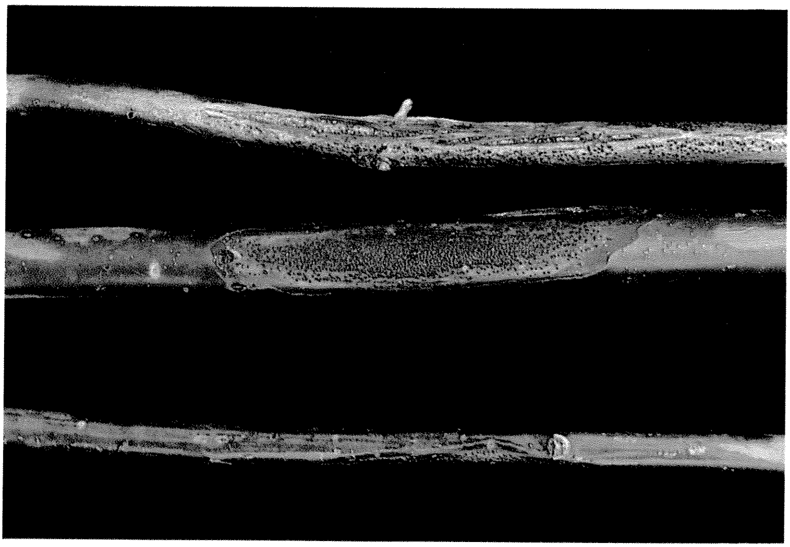


Figure 25.—*Fusicoccum canker on ash stems with pycnidia embedded in necrotic tissue.*

Nectria Canker, *Nectria galligena* Bres. in Strass.

Importance.—Perennial Nectria canker is among the most common and easily recognized diseases of ashes and other hardwood trees in the East and South. The disease is prevalent in cool, humid climates or where isolated pockets of cool air collect, especially on poorly drained soils.

Identifying the Disease.—Cankers begin as small, inconspicuous, dark depressions on young stems. The fungus penetrates the cambium and establishes a perennial infection. It repeatedly kills callus tissue that forms annually at the edge of the lesion, giving rise to a targetlike, perennial canker with concentric rings of dead callus (fig. 26). Cankers seldom girdle the bole.

Identifying the Fungus.—The small (1 to 2 mm diameter), bright-red to orange perithecia form from autumn through spring, near young cankers with bark, in bark crevices, or at the margins of old cankers lacking bark. Occasionally, microscopic cream-colored sporodochia form during moist weather.

Biology.—Ascospores expelled from perithecia during rainy periods in the spring and autumn are dispersed by wind and water to wounds such as frost cracks, sunscald lesions, leaf scars, hail wounds, and senescing lower branches. The ascospores germinate to produce hyphae that infect stems and initiate canker development throughout the growing season. The fungus overwinters as mycelia in cankers and as ascospores in perithecia.

Control.—Nectria canker can cause significant damage to individual trees, but the low incidence and minimal losses attributed to this disease rarely warrant control. This disease is easily prevented by avoiding bark wounds during cool, humid conditions.

Figure 26.—*Perennial target canker caused by* Nectria galligena.

DECAYS

BUTT ROTS

Importance.—Decay of the butt log in living trees is the most serious cause of cull loss for logging because it affects the highest valued log and weakens the tree. The incidence of butt rot in green ash is less than the 40-percent average for other southern hardwoods. The extent of decay in the stem increases with wound size and age.

Identifying the Diseases.—Hollows, abnormal swellings, butt bulge, old basal wounds, or fruiting bodies indicate butt rot. Decayed wood may be soft or brittle and brown to white. The decay column may extend vertically for several meters (fig. 27). Affected trunks are weakened and subject to breakage.

Identifying the Fungi.—Numerous fungi cause butt rot in ashes. The most common are *Ganoderma lucidum* (Curtis:Fr.) P. Karst., *Laetiporus sulphureus* (Bull.:Fr.) Murrill, *Lentinus tigrinus* (Bull.:Fr.) Fr., *Phellinus igniarius* (L.:Fr.) Quél., *Pleurotus ostreatus* (Jacq.:Fr.) P. Kumm., *Postia tephroleuca* (Fr.:Fr.) Jülich, *Rigidoporus lineatus* (Pers.) Ryvarden, and *R. ulmarius* (Sowerby:Fr.) Imazeki in Ito. Fruiting bodies form less frequently on ashes in the South than in northern regions, usually requiring isolation from the wood for identification.

Biology.—Exposed wounds are sites of entry of decay fungi. Spores from fruiting bodies are wind disseminated to wounds where they germinate, producing hyphae that penetrate the tree. The rate of decay varies with the fungus, wound size, host vigor, and environmental conditions.

Control.—Wound prevention is essential because most infections occur through injuries including mechanical wounds, fire scars, and frost cracks extending into the wood. Trees should be harvested before pathological rotation age to minimize degrade. Severely decayed trees should be cut and removed.

Figure 27.—*Butt rot of mature ash arising from wounds in the lower bole.*

Varnish Fungus Rot, *Ganoderma lucidum* (Curtis:Fr.) P. Karst. [Syn. *Polyporus lucidus* (Curtis:Fr.) Fr.]

Importance.—This pathogen causes a serious rot of the lower bole and roots of green and white ashes throughout North America. *Ganoderma lucidum* can kill even the largest trees.

Identifying the Disease.—Trees affected by varnish fungus rot exhibit yellowing, wilting, or undersized leaves and dead branches. Affected wood of the lower bole becomes soft, spongy, and light colored in advanced stages of decay, increasing susceptibility to windthrow.

Identifying the Fungus.—The fungus produces annual, reddish-brown basidiocarps, singly or in clusters and with or without stalks, often near the bases of trees (fig. 28). The upper surface has a smooth, lacquered appearance and a distinct, lighter margin that turns darker with age. The undersides of basidiocarps have a white, porous surface when fresh. However, basidiocarps do not necessarily indicate extensive decay or imminent death.

Biology.—Brown spores released from basidiocarps are dispersed throughout the summer during humid periods. Wounds on root flares and the lower bole are primary infection courts. Spores germinate and produce mycelia that attack the sapwood of all major roots and the butt section of the bole. Tree vigor may decline as decay of the sapwood advances. Rates of decay appear to be determined by tree vigor, which is often influenced by environmental stresses.

Control.—In urban settings, phenoxy-type herbicides applied in lawn fertilizers can sometimes predispose trees to varnish fungus rot. Cultural practices to reduce drought, water stress, and wounding are recommended.

Figure 28.—*Basidiocarps of* Ganoderma lucidum *developing on trunk and roots of ash with varnish rot.*

Sulfur Fungus Rot, *Laetiporus sulphureus* (Bull.:Fr.) Murrill [Syn. *Polyporus sulphureus* (Bull.:Fr.) Fr.]

Importance. – The sulfur fungus causes one of the most important rot diseases of ashes and many other hardwoods in the Eastern and Southern United States.

Identifying the Disease. – A reddish-brown, cubical rot of the heartwood may develop in the roots, butt, or upper stem of the tree (fig. 29a). The outward growth of the fungus from decaying heartwood may kill zones of vascular cambium and sapwood to form elongated cankers appearing as depressions in the bark.

Identifying the Fungus. – The fungus annually produces bright-yellow to orange, shelflike basidiocarps, 20 to 60 cm wide, during the summer and autumn on living trees in advanced stages of decay (fig. 29b). These fruiting bodies often develop in overlapping clusters from stem cankers and persist throughout the winter in the South. Their presence usually indicates extensive decay of the heartwood.

Biology. – Fruiting bodies release spores during wet, winter months in the South. Basidiospores germinate and produce mycelia that infect trees through dead branch stubs and wounds of trunks or occasionally through roots. The white to pale-yellow mycelium develops an extensive rot column for many years before fruiting bodies are produced.

Control. – Bark wounds in forest stands should be avoided, and protuberant dead branch stubs should be removed from high-valued trees in urban areas to accelerate formation of callus over branch stub wounds.

Figure 29. – *(a) Brown cubical rot of heartwood and sapwood in the upper trunk caused by the sulfur fungus; (b) basidiocarp of* Laetiporus sulphureus *on upper trunk of green ash.*

Perenniporia Stem Rot, *Perenniporia fraxinophila* (Peck) Ryvarden [Syn. *Fomes fraxinophilus* (Peck) Sacc.]

Importance.—Perenniporia stem rot causes a white, mottled heartrot of all major species of ashes from Tennessee westward to Arizona and northward into Canada. It is a major contributor to the decay of green ash stems in the shelterbelts of the Great Plains.

Identifying the Disease.—Heartwood decayed by this fungus is straw yellow to yellowish white, soft, and crumbly (fig. 30a). Trees in advanced stages of decay are susceptible to breakage and windthrow, especially in the shelterbelts of the Great Plains.

Identifying the Fungus.—Perennial, bracket-shaped basidiocarps usually form on the bole and major branches near branch stubs (fig. 30b). Basidiocarps are initially dirty white on the upper surface, but darken and become cracked with age. The lower surface is white and porous. They may grow to over 25 cm in diameter.

Biology.—Basidiospores released from basidocarps during wet periods germinate to produce hyphae that infect trees mainly through branch stubs and grow down the branch trace to the heartwood to initiate decay. Fruiting bodies may develop and accumulate on the bole for many years as the decay column expands. The incidence of basidiocarps on ashes is often directly proportional to trunk diameter.

Control.—Infection can be reduced by preventing wounds and trimming branch stubs to allow callus to cover the wounds, particularly in older, less vigorous landscape trees. Precautions should be taken to protect healthy crop trees during thinning and harvesting operations in forest stands.

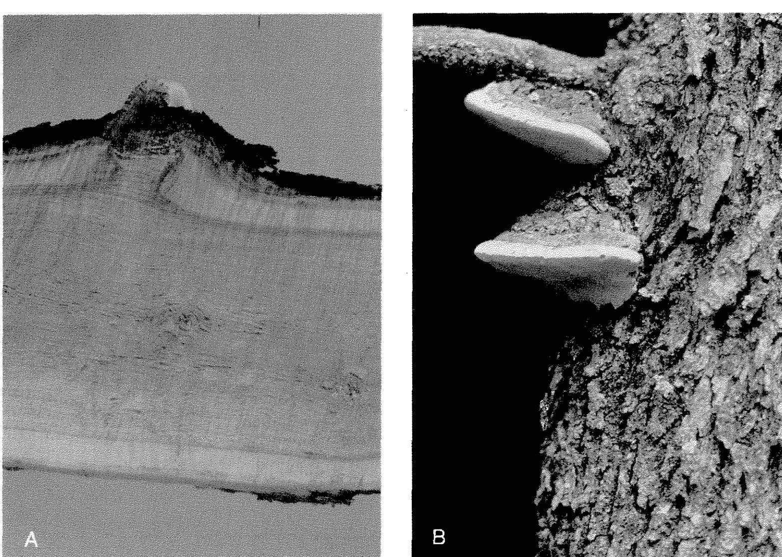


Figure 30.—*(a) Heartwood decay caused by* Perenniporia fraxinophila; *(b) perennial conk under branch stub on living green ash.*

TOP ROTS

Importance.—Top rots result from invasion of limbs by many of the same fungi that cause butt rots. The incidence of top rot is typically lower than that of butt rot. Top rot often follows limb damage by ice or snow. Decaying limbs and tops may break, creating a hazard to people and property in urban areas. Losses of wood volume are usually insignificant.

Identifying the Disease.—Broken or decayed limbs and branch scars often indicate top rot. The vertical extent of decay behind young or small branch scars is typically insignificant, but may extend into the bole and exceed 1 m behind old, larger branch scars.

Identifying the Fungi.—Fruiting bodies can be used to identify these fungi, but they may not always be present. Identification by cultural characteristics instead of from fruiting bodies has been used with limited success because of the difficulty in isolating these fungi from the wood.

Biology.—The life cycles of decay fungi causing top rots are similar to those of fungi causing butt rots. However, different pioneer micro-organisms are usually associated with the decay process in limbs than in trunks. Basidiospores are often disseminated from conks on hardwood species other than ashes. The spores produce hyphae that infect branch stubs, wounds, and scars, initiating decay.

Control.—Recognizing top decay and early harvesting of infected trees are useful means of reducing losses. Minimizing logging injuries can help reduce top rot in growing stock. Management alternatives should favor good growth to reduce the prospect of infection. Forest stands should be managed with proper stocking to reduce storm damage.

ROOT DISEASES

Corticium Root Rot, *Scytinostroma galactinum* (Fr.) Donk [Syn. *Corticium galactinum* (Fr.) Burt]

Importance.—This soil-borne pathogen has a wide range of hosts and causes a white root rot of ashes and many other hardwoods and conifers. It has the potential to cause extensive damage to trees growing on poor sites, but green ash is generally less susceptible to this disease than many other species.

Identifying the Disease.—The first symptoms usually include loss of vigor and thinning of crowns. Adventitious sprouts from roots or stems and small leaves may appear before the tree dies. Trees that die typically retain dead leaves until the next year. Trees with extensive white root rot are susceptible to windthrow (fig. 31a).

Identifying the Fungus.—The fungus produces very small, inconspicuous fruiting bodies on affected roots and the root collar. Fruiting bodies can be observed only with magnification. However, a white, mycelial mat, which covers the root collar and roots below the soil line, can easily be detected by removing soil from the base of the tree (fig. 31b).

Biology.—The fungus can survive on dead roots and stumps and spread to living roots. Insects may also disseminate the fungus to healthy trees. Spores released from fruiting bodies may germinate to produce hyphae that invade dead, woody tissue. The disease gradually kills roots, resulting in decline and sometimes death of infected trees.

Control.—Control measures are not economically feasible in natural stands. In plantations or urban settings, diseased trees and affected roots should be removed to reduce the spread of the disease to adjacent trees. The triazole systemic fungicides show promise for reducing spread in high-valued trees.

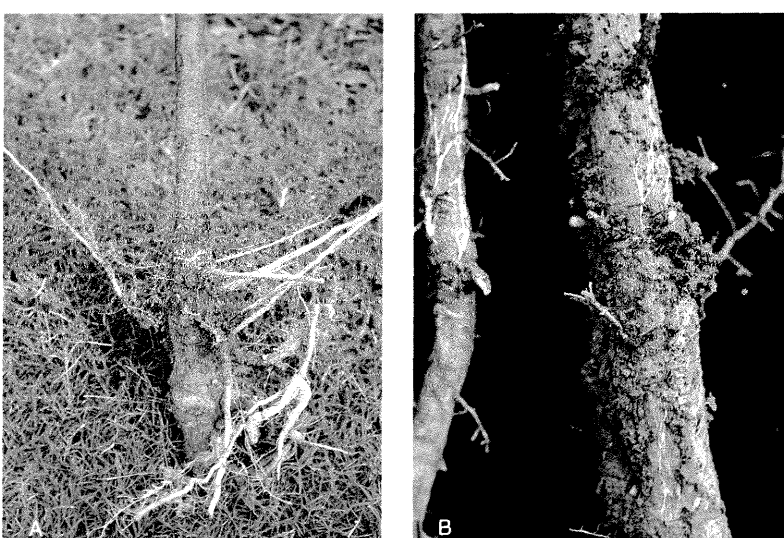


Figure 31.—*(a) Corticium root rot of small green ash tree; (b) white mycelial mat on roots.*

Texas Root Rot, *Phymatotrichopsis omnivora* (Duggar) Hennebert [Syn. *Phymatotrichum omnivorum* (Shear) Duggar]

Importance.—The Texas root rot pathogen has a wide range of broad-leaved hosts throughout certain areas of the Southwestern United States. Ashes planted in old fields or residential areas may be affected by this disease.

Identifying the Disease.—The disease is characterized by sudden wilting and death of infected seedlings (fig. 32). Older trees may exhibit reduced growth and vigor. Coalescing, necrotic lesions on roots may appear down to a soil depth of 30 cm. The inner bark and cambium turn brown or black and mushy, and the root collar may be girdled. As the roots die, leaves of affected trees turn yellow or bronze before they wilt. Dieback and thin crowns are common.

Identifying the Fungus.—Spore mats develop on the soil surface during warm, wet periods. Infected roots are covered by yellowish, fluffy mycelia that penetrate the bark. Mycelial strands, with distinct, cross-shaped hyphae, are the best diagnostic microscopic feature. Black sclerotia formed from compact hyphae on dying roots may be found in the soil.

Biology.—The fungus persists in the soil for many years as sclerotia, which germinate to produce infectious hyphae that enter roots through natural openings and wounds. The hyphae colonize the root and grow up to 9 cm per year along infected roots and in the soil. The fungus is favored by warm, calcareous soils with high clay content and a pH of 7.2 to 8.5.

Control.—Soil amendments to increase soil acidity in alkaline soils inhibit growth of the fungus. Ammonium sulfate or ammonium phosphate fertilizer should be applied at 4.5 kg per 9.3 m^2. The soil should then be soaked to 30 to 60 cm. Planting trees in infected areas or on land previously planted in cotton should be avoided.

Figure 32.—*Texas root rot of ash seedlings in a commercial nursery.*

Mushroom Root Rot, *Armillaria tabescens* (Scop.) Dennis, Orton & Hora [Syn. *Clitocybe tabescens* (Scop.) Bres.]

Importance.—Mushroom root rot causes losses in more than 200 plant species in the Southern United States from Oklahoma eastward. Ash trees are more commonly attacked when growing slowly and already weakened by wounding or defoliation.

Identifying the Disease.—Leaves turn yellow, become sparse or are undersized, and drop prematurely. Roots may be partially decayed or completely girdled at the root collar. Basal lesions may extend up to 30 cm or more above the soil line. Affected trees show general loss of vigor and dieback and have increased susceptibility to windthrow.

Identifying the Fungus.—Clusters of yellow mushrooms develop at the base of infected trees from June through October, usually associated with summer rain and moist soil (fig. 33a, b). Mushrooms produce white basidiospores. The root collar must be excavated for diagnosis if mushrooms are not present. White to tan mycelial mats form under the bark (fig. 33c). Narrow, black mycelial strands (rhizomorphs) occasionally develop in bark fissures or under dead bark above mycelial mats on the root surface.

Biology.—The fungus can persist in dead or dying root tissues for many years. The rhizomorphs spread through the soil, attach to roots, and produce hyphae that penetrate healthy tree roots. Infected roots gradually die, resulting in decline and mortality of the tree. Mushrooms may be produced when large roots or the stem dies.

Control.—Cultural practices that reduce tree stress should be used. Mortality can be minimized by regular fertilization and irrigation. Infected trees and roots should be removed from the soil before replanting.

Figure 33.—*(a) Mushroom root rot in the lower trunk of mature green ash; (b) closeup of basidiocarps arising from roots in the soil; (c) root and bole rot showing white mycelium under the bark of decayed wood.*

Mistletoe, *Phoradendron* spp.

Importance.—Extensive infections and mortality are uncommon in ashes. However, infections occur typically in open-grown trees. This true mistletoe is used as greenery in Christmas decorations.

Identifying the Injury.—Affected branches may be galled or swollen at the site of infection, and multiple infections may result in loss of growth. Branches beyond the mistletoe may be stunted or die back.

Identifying the Parasite (fig. 34a, b).—The mistletoe plant has stout, green stems and dark-green, leathery leaves. It is seen best in winter growing on major and minor branches and twigs of the host. The plant has opposite branching and inconspicuous flowers and produces white berries in the fall.

Biology.—This perennial, evergreen plant grows as a parasite on tree branches. The seeds are covered with a sticky, gelatinous coating and are spread by birds and small mammals. The seeds lodge on young branches and germinate. A rootlike, penetrating structure grows into the young branch and produces a mistletoe plant. One species, *Phoradendron serotinum,* affects many other broad-leaved trees in the South and East, but is limited by temperature in its northern range (Kansas to New Jersey). Several other species of *Phoradendron* occur in the West.

Control.—Control normally is not needed in ashes, but pruning affected branches at least 30 cm below the point of infection may provide some control.

Figure 34.—*(a) Multiple infections by mistletoe in mature crowns; (b) mistletoe on main stem.*

AIR POLLUTION AND CHEMICAL INJURIES

Air Pollution Injury (fig. 35a)

Ashes vary in sensitivity to air pollutants, but in general, are intermediate in sensitivity to sulfur dioxide and hydrogen fluoride emitted during various types of manufacturing processes. Sulfur dioxide kills the leaf tissue between veins, whereas hydrogen fluoride kills the leaf margins. White ash is sensitive to ozone, which causes purple stippling on upper surfaces of older foliage. Extremely sensitive cultivars may experience growth loss. The main precursors of ozone originate from automobile exhaust.

Chemical Injury (fig. 35b, c)

Ash trees are sensitive to many chemicals, but the most frequent damage is caused by herbicides. Symptoms are highly variable and include leaf curl, chlorosis, partial leaf necrosis, and premature leaf fall. Affected branches or the entire crown may drop its leaves and refoliate repeatedly during a single growing season. Young trees may be killed by acute exposures. Symptoms of air pollution or chemical injury may be difficult to distinguish from symptoms induced by other abiotic agents or infections caused by biotic agents.

Figure 35.—*(a) Purple stippling caused by ozone; (b) leaflet curling and scorching caused by an herbicide; (c) marginal necrosis caused by ammonia.*

PESTICIDES

Registered chemicals for control of insects that attack ashes. (See labels for dosages, application methods, and restrictions.)

Insect	Insecticide
Ash sawflies	Acephate Carbaryl Chlorpyrifos Diazinon Malathion
Sphinxes	Acephate Carbaryl Chlorpyrifos Diazinon
Ash plant bugs	Acephate Chlorpyrifos Diazinon
Woolly ash aphid	Acephate Carbaryl Chlorpyrifos Diazinon Malathion
Borers	Chlorpyrifos Lindane
Scale insects	Carbaryl Chlorpyrifos Diazinon Methoxychlor
Planthoppers	Carbaryl Diazinon
Ash bark beetles	Chlorpyrifos Lindane
Mites	Acephate Carbaryl Diazinon Dicofol
Seed weevils	Acephate Carbaryl Diazinon
Leafroll midges	Carbaryl Diazinon
Spring cankerworm Fall webworm Forest tent caterpillar	*Bacillus thuringiensis* Chlorpyrifos Diazinon

Registered chemicals for control of diseases that attack ashes. (See labels for dosages, application methods, and restrictions.)

Disease	Fungicide	Disease	Fungicide
Damping-off	Captan (seed treatment) Chloroneb Dazomet Etridiazol Methyl bromide + chloropicrin (Preplanting soil fumigation)	Leaf spots	Benomyl Captan Dodine Ferbam
		Powdery mildews	Benomyl Chlorothalonil Lime sulfur
		Ash dieback	Treat for causal agent
Anthracnose	Benomyl Metallic copper Zineb	Root rots	Captan Etridiazol
Ash rust	Captan Ferbam		

MAINTAINING TREE HEALTH

Trees should be managed to optimize vigor because healthy trees are less susceptible to attack and injury by insects and diseases. The following cultural practices, singly or in combination, can be used to promote and maintain good tree health in forest stands, plantations, nurseries, shelterbelts, and ornamental plantings:

1. Match ash species and seed source with their adapted sites.
2. Use vigorous planting stock, and select pest-resistant cultivars when available.
3. Ensure that trees receive sufficient water, nutrients, and sunlight through irrigation, fertilization, and proper spacing.
4. Maintain proper stocking in forest stands.
5. Use sanitation practices such as pruning out and removing dead and symptomatic limbs and branches, and raking and removing insect-infested and diseased leaves; this reduces levels of hibernating insects and overwintering inoculum reservoirs that initiate new infections the following year.
6. Prevent or minimize injuries and wounding from harvesting, fire, or other sources that can create easy entry points for ash pests.
7. Utilize cultural practices that favor natural controls such as birds and other predators, parasites, and insect pathogens.
8. Exercise caution in the use of broadleaf herbicides on lawns around ornamentals and shade trees because these herbicides have the potential to damage ash trees.
9. Be aware of early insect feeding or disease symptoms; this will allow for the greatest number of options in managing a pest problem.
10. Use pesticides only when and where they are absolutely needed and avoid using more than the recommended rates to prevent development of pest resistance.

GLOSSARY

Acervulus(-i)—a saucer-shaped, fungal structure embedded in host tissue in which conidia form.

Aeciospore—a type of spore formed in an aecium of a rust fungus.

Aecium(-ia)—a cuplike, fruiting body produced by rust fungi.

Ascocarp—the sexual, fruiting body of Ascomycetes.

Ascospore—the sexual spore of Ascomycetes.

Basidiocarp—the sexual, fruiting body of Basidiomycetes.

Basidiospore—the sexual spore of Basidiomycetes.

Bole—the main stem or trunk of a tree.

Butt—the lower bole of the main stem.

Callus—a protective tissue that forms to cover wounds on stems and branches.

Cambium—a thin layer of cells between the phloem and xylem.

Canker—a definite, localized, necrotic lesion of the bark and cambium.

Conidium(-ia)—an asexual, fungal spore.

Conidiophore—a fungal structure bearing asexual spores.

Conk—a basidiocarp of wood decay fungi.

Crochet—a tiny hook on the prolegs of caterpillars.

Damping-off—a necrotic disease of seedlings that causes rotting of the hypocotyl and prevents emergence of the new shoot or causes the new shoot to fall over.

Dieback—the gradual dying of a tree crown usually from the top down and from the outside in.

Elytra—the hard forewings (wing covers) of beetles.

Frass—wood fragments mixed with borer excrement.

Gallery—a long passage chewed in the bark, cambium, or wood.

Hypha(-e)—a single filament of a fungus mycelium.

Infection court—the point where a pathogen enters its host.

Inoculum(-a)—the spore, mycelium, or other propagule of a pathogen that initially infects a host.

Maggot—a legless larva of various flies.

Mycelium(-ia)—a collection of hyphae that make up a fungus body.

Necrotic—composed of dead cells.

Pathological rotation—the harvesting of trees before the age at which the rate of wood volume loss due to decay fungi exceeds the annual production of new wood.

Perennial canker—a canker that expands indefinitely.

Perithecium(-ia)—a flask-shaped ascocarp in which ascospores are formed.

Phloem—the food-conducting vascular tissue under the bark of trees.

Pronotum—the upper surface of the prothorax.

Pseudothecium(-ia)—the flask-shaped ascocarp similar to a perithecium but without a definite fungal wall.

Rhizomorph—a compact mass of vegetative hyphae that have fused together to form a thick, usually dark, rootlike strand.

Sapwood—the outer, water-conducting wood (xylem) of the tree stem.

Sclerotium(-ia)—a firm, often rounded, compact mass of fungal hyphae that form a resistant survival structure.

Spermatium(-ia)—a nonmotile, uninucleate spore (gamete) required for sexual reproduction in some fungi.

Spermogonium(-ia)—a fungal structure in which spermatia are produced.

Sporodochium(-ia)—a cushion-shaped stroma covered with conidiophores.

Stroma(-mata)—a mass or mat of hyphae in or on which fruiting bodies form.

Teliospore—the spore of a rust fungus from which basidia and basidiospores form.

Telium(-ia)—a fruiting structure producing teliospores of rust fungi.

Urediniospore—the spore of a rust fungus, formed in a uredinium, that can repeatedly infect its host.

Uredinium(-ia)—a fruiting structure of a rust fungus that gives rise to urediniospores.

Witches' broom—an abnormal growth of branches forming a broomlike cluster.

Solomon, J.D.; Leininger, T.D.; Wilson, A.D.; Anderson, R.L.; Thompson, L.C.; McCracken, F.I. 1993. Ash pests: A guide to major insects, diseases, air pollution injury and chemical injury. Gen. Tech. Rep. SO-96. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 45 p.

This booklet will help nurserymen, resource managers, pest control personnel, and homeowners to prevent, identify, and control ash pests.

Keywords: Biology, borers, control, defoliators, *Fraxinus*, fungi, identification.

CAUTION

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray materials near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried in an approved sanitary land-fill dump.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

United States
Department of Agriculture

Forest Service

Southern Forest
Experiment Station
701 Loyola Ave., Rm.T-10210
New Orleans, LA 70113-1931

U.S. Department of Agriculture
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INSECTS

DISEASES

INSECTS AND DISEASES OF COTTONWOOD

R. C. Morris, T. H. Filer, J. D. Solomon,
F. I. McCracken, N. A. Overgaard, and M. J. Weiss [1]

Insects and disease organisms are a continuing threat to cottonwood *(Populus deltoides* Bartr.), especially during the tree's first 5 years. The danger is intensified in large plantings of a single species and age because rapid buildup of damaging agents can occur. This booklet will help forest nurserymen and plantation managers identify and control pest problems. The major insects and diseases are illustrated; and information on their importance, signs of infestation, biology, and natural control is presented. Brief mention is made of other pests which may be of local or sporadic concern.

A list of registered chemical controls is also provided. This list is subject to change as new materials are approved, and revisions will be made available at periodic intervals.

For further information, contact your State forester, county agent, or the nearest office of State and Private Forestry, U. S. Forest Service.

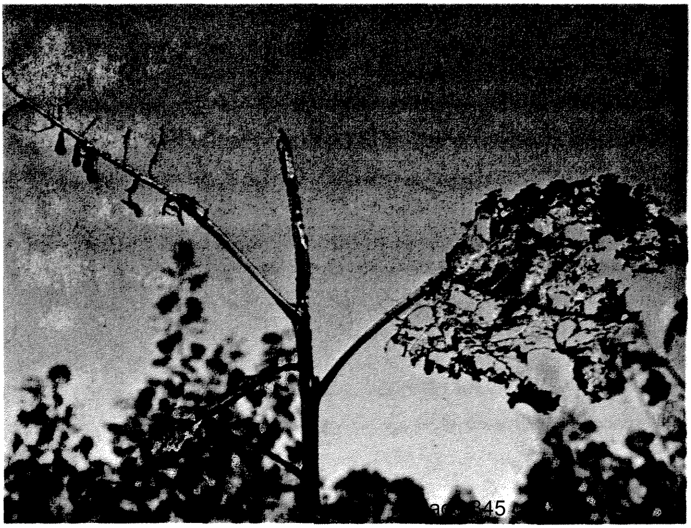
[1] Morris, Filer, Solomon, and McCracken are stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group. Overgaard and Weiss are members of the Forest Pest Management Group, Southeastern Area, State and Private Forestry.

COTTONWOOD LEAF BEETLE
Chrysomela scripta F.

The cottonwood leaf beetle is one of the most serious pests of young trees in nurseries and plantations and occasionally causes severe damage in natural stands. In the nursery, the insect stunts height growth and reduces the yield of cuttings. First- and second-year plantations are weakened by early defoliation and may be overtopped by weeds. Continuing partial defoliation through the summer reduces tree growth and vigor. Serious damage occurs at the end of the growing season, when heavy populations feed on terminal tissues and buds, killing as much as 10 inches (25 cm) of the terminals. Lateral buds sprout below the injured terminals, and branches may grow above the dead terminal even before the season ends. These branches grow rapidly the next year, resulting in multiple-forked tops that have little potential for the production of quality wood for logs and pulpwood.

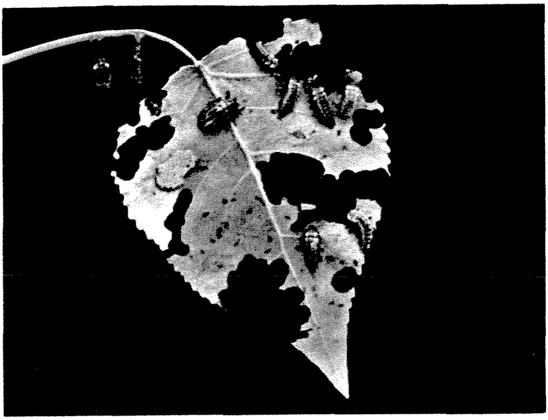
Often the sudden appearance of ragged foliage near branch ends and terminals of young cottonwoods will announce a leaf beetle attack. Some leaves will have brown patches where young larvae ate the green tissues. On other leaves, only the veins and midrib will remain. Heavy damage results in dead, black terminals from which the leaves and tissues are eaten. Other signs of the leaf beetle are black droppings on leaves and the unmistak-

Terminal killed by cottonwood leaf beetle.



able, pungent odor the larvae release when disturbed.

Adult beetles are oval, yellow, and about ¼ inch (6 mm) long with slender black markings on their wing covers. Egg clusters are bright yellow, and newly hatched larvae are black. As they develop, they turn brown, and prominent white scent gland spots appear along their sides.



Cottonwood leaf beetles.

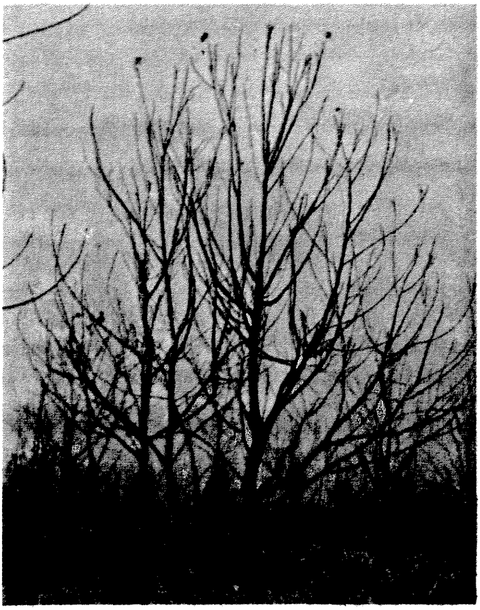
Adults spend the winter under fallen leaf debris or in clumps of weeds. In early spring they emerge and feed on unfolding leaves or on tender bark at the tips of twigs. The female lays a cluster of 15 to 75 eggs on the undersides of leaves. The newly hatched larvae feed side by side and skeletonize the leaves. Older larvae feed separately and consume the entire leaf except for the larger veins. At maturity they attach themselves to leaves, bark, or to weeds and grass beneath the trees to pupate. In 5 to 10 days they emerge as adult beetles. There are several generations per year, each lasting about 35 days.

The spring generation of the leaf beetle may be greatly reduced by the red lady beetle *Coleomagilla maculata,* which feeds on the eggs and pupae. However, as the season progresses, the ladybugs disperse to feed on aphids and other prey and do not affect later broods of leaf beetles. Several predaceous bugs feed on leaf beetle larvae, and a parasitic wasp also attacks them. Effective chemical controls are available.

COTTONWOOD TWIG BORER
Gypsonoma haimbachiana Kft.

The cottonwood twig borer, one of the most destructive insects of young trees, occurs throughout the host species' range from Ontario to the Gulf of Mexico and west to the Great Plains. Larval feeding in the terminal tissues prevents normal elongation and may kill the growing tip. The stunted terminals are rapidly overtopped by vigorous, undamaged laterals, resulting in a tree top with two to six forks. Later, one fork may assert dominance and become a new terminal, but a crook usually develops where the new terminal originates. Heavily damaged trees may be stag-headed bushes of little value.

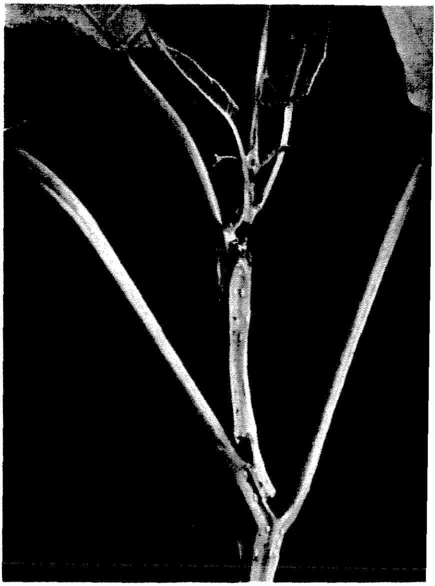
Stunted terminals and short brown tubes of silk and borings near leaf bases indicate twig borer damage. Lateral branches overtop the terminal, which persists as a short stub in the forked top. Small, red swollen areas along leaf veins and midribs show where newly hatched larvae fed in the



Twig borer damage in 3-year-old tree.

vein tissues before molting and entering the branch and terminal tips.

Adults moths are ash grey and have a wingspan of ½ inch (12 mm). The forewing has a dark grey base and a dark spot on its outer tip. Full-grown larvae are ½ inch (12 mm) long and pale in color with a brown head.



Brown frass tubes at borer entrances.

Moths emerge from cocoons in April or May. Females deposit eggs singly or in small groups on the upper surface of leaves along the midrib and veins. Newly hatched caterpillars feed in the midrib or vein until their first molt, then move to the base of the first developing leaf and tunnel into the tender shoot. When they are fully grown, they move down the trunk and spin thin cocoons in bark crevices or in litter under the trees.

Successive generations—as many as five in Mississippi—develop through the summer; and with each generation the twig borer population increases. By September there may be 20 or more larvae of 4 different ages in a 15-inch (38-cm) cottonwood terminal. Winter is spent as tiny second-stage larvae in shelters of silk and trash in old entrance scars near branch ends, under corky ridges below leaf bases, or near leaf buds. In spring the small larvae migrate to the new shoots and complete their growth.

Natural controls of the twig borer include the potter wasp (*Eumenes* sp.), which preys on larvae, and other parasites and predators of the eggs, larvae, and pupae. These are inadequate for protecting nurseries and plantations from serious economic loss; therefore, chemical controls may be needed.

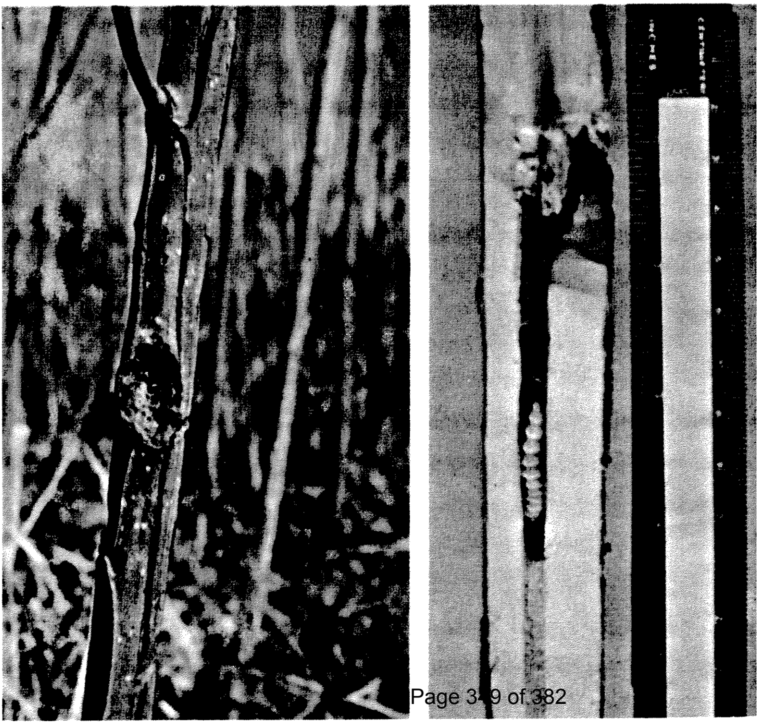
CLEARWING BORERS

Paranthrene dollii dollii (Neum.) and *P. tricincta* (Harris)

Two clearwing borers prevalent in the Southern United States cause serious losses in cottonwood plantations and nurseries. *P. dollii* damages the tree base, and weakened trees may break off at the ground. *P. tricincta* attacks terminals, and breakage can occur at the entrance hole 18 to 24 inches (45 to 60 cm) below the terminal tip. The borer holes also provide infection sites for stem canker diseases caused by a complex of fungi.

Nursery plants become infested during their first year. Populations build up during the second and third years in the stools left after cuttings are harvested. Heavily infested stools cannot support vigorous growth from sprouts, and large stems break off and die before cuttings are harvested. Borer attacks also develop in the basal third of the shoots, and cuttings made from this material are rejected. As many as 10 percent of the cuttings produced may be damaged and discarded.

Clearwing borer, entrance (left) and stem sectioned to show larva and gallery (right).



Early signs of clearwing attack are sap flow from entrance holes and borings (frass) pushed out by the caterpillar. These signs will appear at the base of young trees infested by *P. dollii* or about a foot below the tip of terminals and branches attacked by *P. tricincta*. As the larvae grow, their galleries enlarge, and piles of frass accumulate at the tree base. A swelling of the stem may indicate the presence of *P. tricincta* in a terminal. When the terminal breaks off, the borer will be in the stub below the break. Evidences of adult emergence are brown pupal skins protruding from the exit holes. Infested trees will be drilled by woodpeckers feeding on the caterpillars during the winter.

Borer damage and frass at base of young cottonwood.

The adult of *P. dollii dollii* has narrow, dark brown forewings and partly transparent hindwings. Its wingspan is about 1¼ inches (32 mm). The body is brown, and orange crossbands bordered with yellow and dark brown mark the thorax and abdomen. The eggs are dark brown and oval. White to pinkish larvae with brown heads attain a final length of 1 to 1¼ inches (25 to 32 mm).

The adult *P. tricincta* has blue-black forewings, nearly transparent hindwings, a black body with three lemon yellow crossbands in the female and two in the male, and a wingspread of about 1 inch (25 mm).

The life cycles of both species are similar. The female lays eggs in bark crevices, especially near trunk scars. The larvae molt fives times while tunneling in the wood and pith and then prepare pupal cells at the gallery ends. Larvae overwinter in the galleries and pupate in early spring. Adults emerge in April, leaving the empty pupal skins protruding from their exit holes. Adult emergence peaks again in August, indicating two generations per year. There is, however, considerable overlapping; and larvae of several stages can be found in the trees during the late summer and fall.

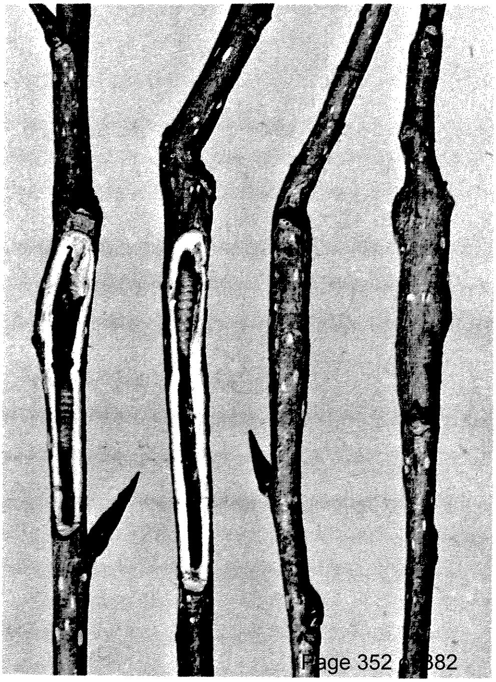
Control.—There are no effective natural controls. Woodpecker predation reduces populations in nurseries and plantations but may aggrevate the damage by providing oviposition sites and additional entries for canker fungi. Sanitation measures in nurseries, especially burning infested cull stems, tips, and stools, will help hold down borer populations. Control chemicals are listed in the insert.

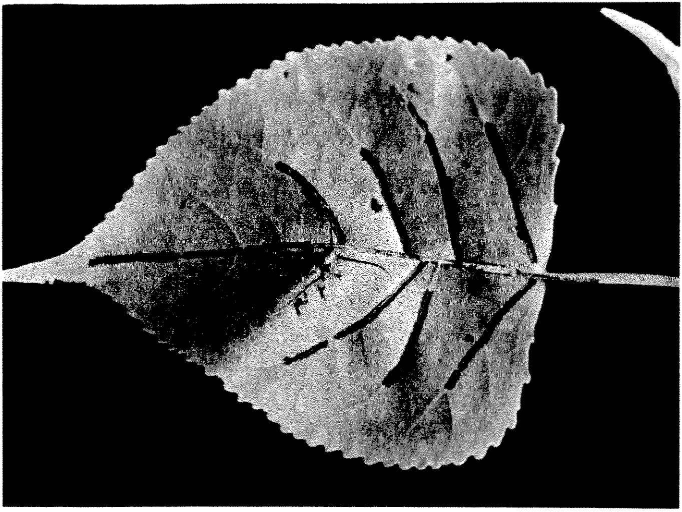
BRANCH BORERS
Oberea schaumii LeConte and *O. Delongi* Knull

Two branch borers attack cottonwood and other poplars throughout much of the United States. Although both species may occur together, *O. delongi* is more prevalent in the South, and *O. schaumii* is more common further north. Small stems and branches are tunneled and sometimes weakened so that breakage occurs. Terminal breakage often results in crooked trunks, forking, and heavy branching.

Egg niches, the earliest signs of attack, may remain in evidence on stems and branches for several weeks. Later, frass protrudes from the entrance, particularly during attacks of *O. schaumii; O. delongi* ejects little frass. Infested stems may appear swollen. This symptom is most noticeable with *O. delongi,* which causes some stems to become greatly enlarged and gall-like. The adults typically feed on the midribs and branch veins of the leaves; such feeding is conspicuous and indicates stem infestation.

Oberea delongi **attacks in cottonwood branches.**





O. delongi **adult feeding on cottonwood.**

The adults are elongate long-horn beetles. *O. schaumii* ranges from ½ to ⅝ inch (12 to 16 mm) in length; *O. delongi* is slightly smaller. Both species are variable in coloration. In *O. schaumii* the thorax is yellowish to orange with four dark, smooth spots; the wing covers vary from yellowish to black. In *O. delongi* the thorax varies from yellowish orange to black, and the wing covers are black. The larvae of both species are legless, narrow, and yellowish white. Larvae of *O. schaumii* reach a length of ½ to 1 inch (12 to 25 mm); those of *O. delongi* reach ⅜ to ⅝ inch (10 to 16 mm). The pupae of both species are yellowish white.

Adult beetles emerge from April to June and feed on the foliage before laying eggs in niches gnawed in the bark. *O. schaumii* selects stems and branches up to 1½ inches (38 mm) in diameter, but *O. delongi* prefers smaller stems (usually current year's growth) up to ½ inch (12 mm) in diameter. The eggs hatch in about 2 weeks, and the larvae begin tunneling down the center of the stem. Pupation occurs within the gallery. Adults cut circular holes to exit. The life cycle of *O. schaumii* varies from 1 to 3 years; that of *O. delongi* is 1 year.

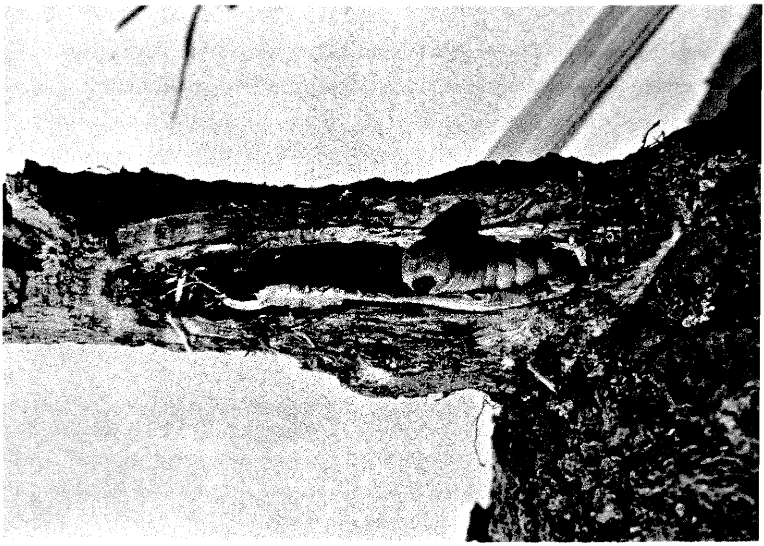
Branch borer damage is usually kept at low levels by natural enemies. Woodpeckers, particularly downy woodpeckers, have been observed to destroy large numbers of *O. delongi* larvae in some stands. Larval diseases kill many borers during some years.

COTTONWOOD BORER

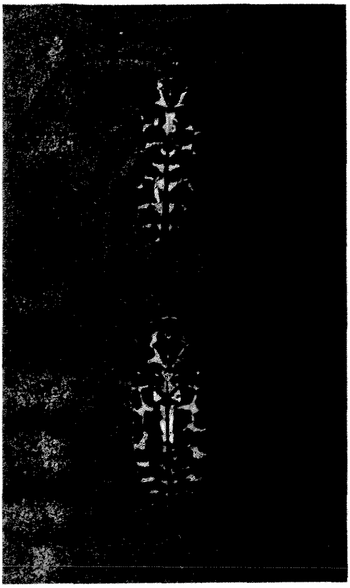
Plectrodera scalator (Fab.)

The cottonwood borer is a pest throughout the Southeastern States. It attacks the root collar and main roots. Young trees may be girdled or so structurally weakened that breakage occurs. Severe damage has been observed in young natural stands growing on sandy soils along the Mississippi River.

Light brown, fibrous frass is sometimes ejected from bark openings at or slightly above the ground line and accumulates in piles at the base of the tree. But since most attacks occur at or below the ground line and most larvae tunnel downward, infestations often go unnoticed unless breakage occurs. However, when the soil is removed from the root collar and shallow roots, wounds filled with protruding frass can be found in the bark. Also, because of their large size and conspicuous color, the adult beetles are easily spotted while feeding and ovipositing during the summer.



Lateral root with larva and gallery of cottonwood borer.



Adult cottonwood borer.

The adult is a large, robust, long-horn beetle ranging from 1 to 1½ inches (25 to 38 mm) in length and ⅜ to ½ inch (10 to 12 mm) in width. The body is black with white cross-stripes. A strong spine is located on each side. The antennae are about as long as the body in the female and slightly longer in the male. The eggs are elliptical, white, and about ⅛ inch (3 mm) long. The larvae are legless, elongate, moderately robust, and yellowish white; they reach a maximum length of 1¼ to 1½ inches (32 to 38 mm).

Adult beetles emerge during late spring and summer and begin feeding on the bark of tender cottonwood shoots. To oviposit, the female digs away the soil at the base of the tree to a depth of ⅜ inch (10 mm) or more, cuts a niche in the bark, and deposits one or more eggs. Upon hatching, the larvae mine downward in the inner bark, later tunneling into the wood. Taproots of small trees may be completely hollowed. In large trees, some larvae excavate irregular cavities and others produce long tunnels. Portions of the mines or galleries may be packed with excelsior-like frass. Pupation occurs within the gallery. The new adult chews through the pupal chamber and digs its way to the soil surface to escape. A life cycle is completed in 2 years.

Since most grubs are below the ground line, they are well protected from both predators and parasites. Woodpeckers capture a few larvae exposed above the ground line. Although a fungus disease has been found, it does not appear to be common. Extended flooding will kill many larvae. Damage can usually be kept to a minimum by planting on good sites and utilizing cultural practices that maintain a vigorous, healthy stand.

POPLAR BORER
Saperda calcarata Say

The poplar borer is a serious pest of cottonwood and other poplars throughout the United States and Canada. It attacks the trunks of trees 3 years and older. Clusters of larvae tunneling close together may riddle portions of the trunk. Woodpecker excavations and decay fungi further weaken damaged stems. Badly infested trees may be so structurally weakened that wind breakage occurs. The value of infested trees sawn for lumber may be greatly reduced.

The most conspicuous early sign of attack is the appearance of sap spots on the trunk. Later, oozing sap mixed with fine frass is extruded through small openings in the bark. Although attacks may occur singly, they are typically clustered. After the bark is mined by a cluster of larvae, it begins to split or break irregularly as radial growth progresses. As the larvae grow, the frass becomes fibrous and excelsior-like. Coarse frass is usually conspicuous in large quantities at gallery entrances, lodged in bark crevices, and in piles around the base of the tree. Woodpeckers frequently excavate several holes in the wood and remove much of the loose bark in the vicinity of a larval cluster. Scars resulting from overgrown attacks remain for several years.

Trunk attacked by poplar borers. Note frass on ground and woodpecker holes above attack area.

The adult is a long-horn beetle, elongate, moderately robust, and ranges from ⅞ to 1⅛ inches (22 to 30 mm) in length. The body is grayish blue and heavily stippled with fine brown dots and yellowish spots. The antennae are about as long as the body. The eggs are slender, creamy white, and about ⅛ inch (3 mm) long. The larvae are legless, elongate, cylindrical, yellowish white, and 1⅛ to 1⅜ inches (30 to 35 mm) long. The pupae are yellowish white.

Poplar borer in sectioned cottonwood trunk.

Adult beetles appear during late spring and early summer. After feeding on the tender shoots of young cottonwood they mate and begin laying eggs in niches cut in the bark. Eggs hatch in 2 to 3 weeks, and the larvae begin mining beneath the bark. Later, they tunnel into the sapwood and heartwood and produce extensive galleries. The larvae overwinter behind frass plugs within the galleries. The pupal stage lasts 2 to 3 weeks. The new adults exit through the gallery entrances. Two years are required for the life cycle.

Parasites, predators, and disease help keep infestations in check. Considerable natural mortality also occurs among eggs and early instars because of heavy sap flow, which is enhanced by high soil moisture and tree vigor. Woodpeckers destroy many grubs in some stands and are probably the most important natural enemy once the larvae have established galleries in the wood. Brood trees, scarred by repeated attacks and harboring heavy populations of borers, should be removed to prevent or reduce spread to uninfested trees.

COTTONWOOD LEAF CURL MITE
Aculus lobulifera Keifer

Attacks by leaf curl mites seriously reduce growth and vigor of young cottonwoods in nurseries and plantations. Mites feed on terminal foliage and stems, causing stunting and malformation of leaves, terminal tips and buds as well as the loss of immature foliage. The pest has been observed in cottonwood throughout most of its commercial range.

Leaf damage symptoms appear in early summer and intensify as the hot, dry weather continues. Heavily attacked leaves become stunted with red veins and crinkled, purplish-green blades, which are brittle and curled. The petioles become scaly and brown. Terminal shoots are also stunted, scaly, and brown. Small, developing leaves commonly break off, leaving several inches of the terminal shoot leafless.

Typical foliage and stem damage by leaf curl mites. Normal foliage on the right.

Leaf curl mites are minute, four-legged, and straw-colored; they look like dust flecks on the leaves. They develop two alternating forms: hibernating mites and foliage-feeding mites, the primary form. The majority of the mites perish with leaf fall; but a few find hibernation shelters in bark crevices, branch scars, and at the base of the trunk. Early the next spring, the hibernating mites leave their shelters, feed on green tissues, and lay eggs, which produce primary forms on the new foliage. The primary mites multiply rapidly; and all stages, eggs to adults, are found together on the foliage and tender terminals. Heavy populations develop during dry periods, especially from June through August and in October.

Heavy rains disseminate mite populations, and new growth with normal foliage may follow; however, this pest may reappear with dry weather in the fall. No other natural controls are known. Some improved cottonwood clones show evidence of possible resistance, and these are being investigated further. Artificial controls are available and may reduce populations significantly.

VICEROY BUTTERFLY

Limentis archippus (Cramer)

The viceroy butterfly is a common defoliator in cottonwood plantations throughout the United States. During most of the growing season, caterpillars feeding on leaves are of little concern; but later when few new leaves are being formed, caterpillars eat tender terminal tissues and buds, killing 8 to 10 inches (20 to 25 cm) of the terminals. New growth from lateral buds results in multiple-forked crowns the next year. These malformed trees will produce less pulpwood, saw logs, and veneer than healthy trees. The viceroy is normally not a serious pest in nurseries.

The first signs of attack are caterpillars on ragged, partly eaten leaves near branch ends. Late in the season, damaged terminals turn black and die. During the winter, leaf petioles fastened to the branch by silk will have small tubes of rolled leaf blade in which small caterpillars are hibernating.

The orange and black adult resembles the monarch butterfly but is smaller. It has a narrow black line across the hindwings and one row of white spots in the black marginal band of the wings. The full-grown caterpillar is about 1½ inches (38 mm) long and has a large, bilobed, pale green head. The body is olive green and white or brown and white. Two barbed, club-shaped, brown tubercles on the thorax are topped by two smaller tubercles armed with spines.

Eggs are laid on the leaves. The solitary caterpillars each consume several leaves during their growth. The full-grown larva secures itself to a leaf stem or branch and changes to a shiny brown and white chrysalis (pupa) from which the adult butterfly emerges after a few days. Two generations per year are recorded, but more may occur in the deep South.

In late fall, a small caterpillar fastens a leaf petiole to the branch with silk and then cuts away all but the base of the leaf blade. This part of the blade is rolled and fastened into a short tube in

Larva of viceroy butterfly.

which the ½-inch (12 mm) long caterpillar spends the winter. In spring, the caterpillar emerges and feeds on new leaves.

No natural controls are known.

POPLAR TENTMAKER

Ichthyura inclusa Hbn.

The poplar tentmaker occurs from southern Canada to the Gulf of Mexico and west to Colorado. It may seriously defoliate young trees in nurseries and plantations, especially during the first year. Height growth is stunted, resulting in fewer cuttings from nursery stock. Stunted plantation trees may be overtopped by weeds.

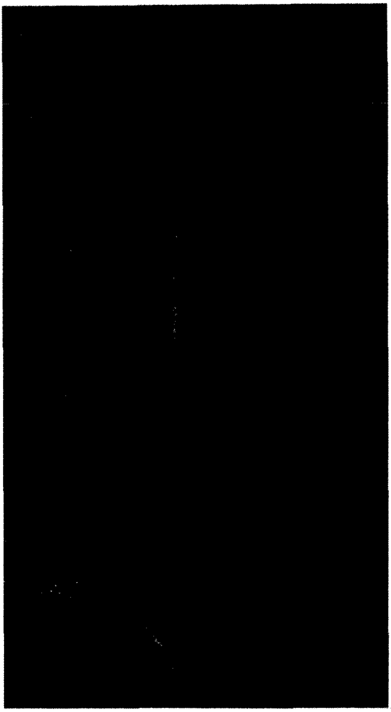
Attacks are announced by the presence of tents made of one or more leaves lined with silk and harboring the caterpillars.

Brownish-grey adult moths have three white lines across each forewing and a crest of brown hairs on the thorax. The wingspread is about 1 inch (25 mm). Caterpillars are dark brown with four yellow lines on the back and a bright yellow line on each side. They reach 1½ inches (38 mm) in length when fully grown and have black tubercles on the first and eighth abdominal segments.

There are two or more generations in the South. Adults appear in the spring and again in midsummer. Eggs are laid in clusters on the undersides of leaves. The larvae feed from May to October, then crawl to the ground and pupate in loose cocoons during the winter.

Parasites and predators usually control tentmakers in natural stands, but rapid build-ups can occur in plantations before the problem is recognized

Larva of poplar tentmaker and tent on cottonwood leaf. (Picture courtesy of R. F. Anderson, Duke University.)



LEAFHOPPERS

Cicadellidae homalodisca coagulata (Say),
Oncometopia orbona (Fab.),
Cuerna costalis (Fab.),
and *Aulacizes irrorata* (Fab.)

Four species of large leafhoppers injure young cottonwood trees by piercing plant tissues with their mouth parts and sucking the juices. Heavy feeding removes large quantities of sap from the trees, and this loss of sap can be especially harmful during dry periods in midsummer, when foliage is heavy. In addition, three of the four leafhoppers are known vectors of the virus causing Phony Peach Disease and may carry other viruses to cottonwoods.

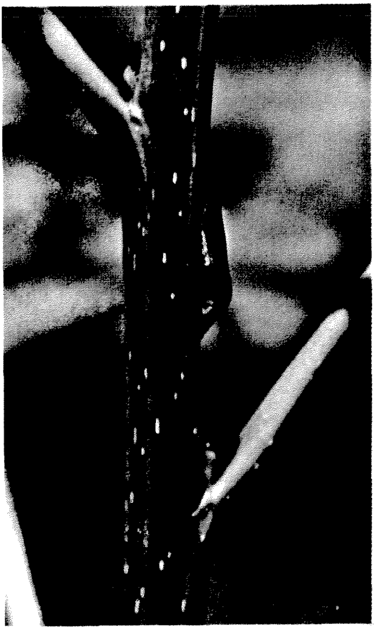
There is an obvious sign of leafhopper activity: leaves below the feeding sites may be wet by fluid squirted from the leafhoppers.

Adult leafhoppers are about ½ inch (12 mm) long, bullet-shaped, and have strong jumping legs. The two species most common in midsummer are *H. coagulata,* which is brown, and *O. orbona,* which is blue with orange markings.

All four species spend the winter as adults or occasionally as nymphs under trash and debris in woodlands and along ditchbanks. In spring they become active, leave the woods, and feed on a variety of plants. Later they move to preferred herbaceous plants. Females lay eggs in clusters between the upper and lower leaf surfaces. The nymphs feed on various hosts during their development through five stages to the adult form.

No natural controls are known, but there are some approved chemical controls.

Homalodisca coagulata **on cottonwood terminal.**



OTHER INSECTS

The pests described below are usually not serious threats to cottonwoods. However, large populations occasionally build up in limited areas or on individual trees and cause considerable damage. Normally natural controls are sufficient, but to suppress periodic buildups in localized areas, artificial controls may be required.

The first four insects are moths. The adults are inconspicuous and do no damage, but the larvae feed on cottonwood.

Blotch leafminers, Paraleucoptera albella.—This insect probably occurs throughout the commercial range of cottonwood. Eggs are laid in clusters of 3 to 12 on the upper leaf surface. Groups of small, white larvae tunneling between the upper and lower leaf surfaces consume the green tissues and cause conspicuous brown blotches. Periodic heavy infestations may destroy half the total leaf surface and reduce growth of young cottonwoods. Full-grown larvae leave the mine and spin small white tent cocoons at leaf margins.

Serpentine leafminers, Gracillariidae.—The tiny, flat larvae construct winding mines in leaf blades and consume the green tissues. Their attacks late in the season are often noted, but their damage is usually negligible., Mature larvae spin small, flat-topped, white cocoons in curved leaf margins.

Leaf rollers, Tortricidae.—Pale green larvae about ¼ inch (6 mm) long fold over leaf margins and tips, fastening the edges with silk to form shelters in which they feed. Late in the season, new leaves may be conspicuously attacked, but damage to the tree is minor.

Epidermal miner, Marmara sp.—Tiny larvae mine immediately beneath the epidermis in phloem tissues and do not damage cambium or xylem. Larval mines appear as meandering brown lines on the smooth bark of 1- to 2-year-old trunks and branches. The injury is probably insignificant, but its presence can cause rejection of cuttings subject to quarantine examination for shipment.

Aphids or plant lice (Aphididae).—These small sucking insects are widely distributed and often cause local damage. Most forms suck the sap from leaves and tender terminal tissues. While feeding, they exude droplets of honeydew, which attract ants. Sooty mildew develops on leaves and tips covered with honeydew, and serious growth retardation may result. Other aphids feed on bark in the spring, injuring the bark and cambium. Others cause the formation of galls on leaf petioles, where they are feeding, and may cause premature leaf fall.

Night-feeding leaf beetles, Metachroma sp.— These beetles appear sporadically and can damage new plantings by killing tender new leaves, terminal tips, and buds. Adults are brown and smaller than cottonwood leaf beetles. In Mississippi they appear after mid-May and disappear after mid-June. They hide during the day and feed at night, cutting many small holes in the leaves. Older leaves remain, but new leaves turn black and drop off; terminal tips also turn black and die. The larvae are root feeders, and little is known of their biology.

Leaf curl midge, Prodiplosis morrisi Gagne.— Maggots of a fly midge feed in the tightly rolled margins of developing cottonwood leaves and damage the tender tissues, causing them to turn black and die. The leaves cannot develop and usually drop off. Some may appear stunted and crinkled, with only their tips developed normally. Attacks typically occur in June and can slow the growth of first-year plantings. Heavy rains reduce outbreaks, and normal foliage development follows.

A host of other insects also attacks cottonwoods. Most are inoccuous and appear infrequently. Some are capable of building to damaging levels in large plantings. Such outbreaks can occur without warning and should be reported promptly so that potential damage can be anticipated and minimized.

CANKER DISEASES

Canker diseases cause losses of about 20 percent during the first season in plantations established with unrooted cottonwood cuttings. Cankers are most severe on poor sites and under conditions of environmental stress.

Septoria musiva Peck. is considered the pioneer organism. *Fusarium solani* (Mart) Snyder & Hans., *Cytospora chrysosperma* Fr., *Phomopsis macrospora* Kobayshi & Chiba, and *Botryodiplodia theobromae* Pat. usually invade the small Septoria cankers. Although these fungi are secondary in the ecological succession, they singly or collectively cause mortality.

Septoria stem canker on young cottonwood.

The four fungi are indigenous to most areas and can infect nursery stock by means of wind-borne spores. They overwinter as mycelia or spores on cottonwood cuttings stored for spring planting. No fruiting structures are associated with *F. solani*.

Phomopsis macrospora **producing tiny, yellow strings of spores.**

The other three fungi produce inconspicuous, tiny, flask-shaped fruiting structures, which protrude through the epidermis and produce numerous spores. When these infected cuttings are planted, they may leaf-out and appear healthy; but many die before developing a root system. Mortality is increased by enviornmental conditions that limit plant growth or cause plant stress.

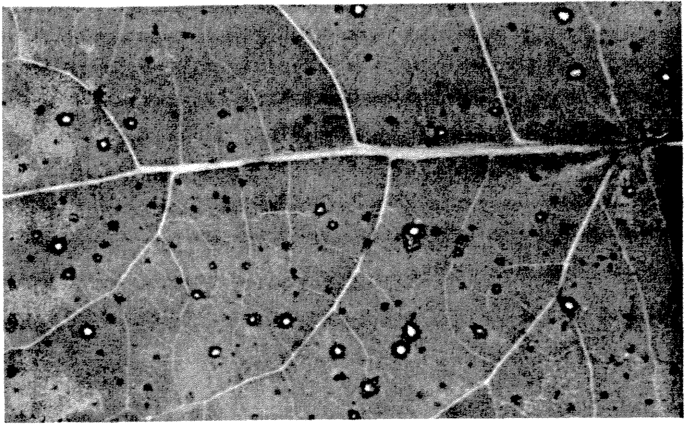
Inoculum enters older trees through wounds or insect borings. Cankers on stems of 2- and 3-year-old trees are easily detected. They usually develop in fall and by spring are 3 to 6 inches (7.5 to 15 cm) in diameter. On vigorous trees, cankers are arrested during the growing season and usually callus over. On slow-growing trees, cankers can girdle the stem, and leaves above the cankers will wilt but do not drop until late summer. The stem below the cankers may remain green until fall when it dies back to the root crown. Often such trees develop root sprouts the following spring.

Cytospora canker girdling 3-year-old cottonwood.

On trees older than 4 years, cankers usually develop in the crown. Yeast, bacteria, and other microorganisms quickly invade the sap flow from the cankers and cause a fermentation. Foresters refer to the unsightly wounds as "crud cankers." Generally cankers do not girdle the tree, but wind breakage occurs at the wound.

Extreme care should be taken to select only healthy, canker-free cuttings for planting. Proper storage and handling of cuttings will minimize losses. Cuttings should not be allowed to dry out and should be stored at 34 to 40° F until time of planting. Cultivation of 1-year-old plants reduces competition for moisture and nutrition by weeds and thus reduces losses from cankers. Preliminary results show that improved clones may have resistance to *Septoria,* the pioneer organism in the canker complex.

Fusarium canker on 4-year-old cottonwood.



Septoria leaf spots.

SEPTORIA LEAF SPOT

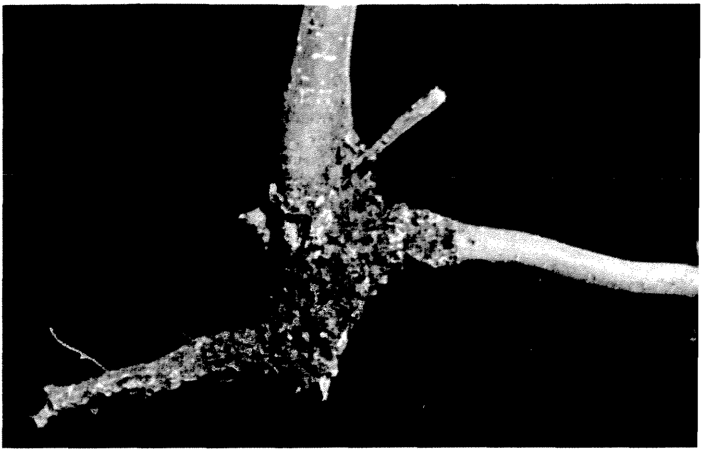
Septoria musiva Peck causes leaf spots as well as the cankers described earlier. The disease is common throughout the United States, parts of Canada, and Argentina. It is a serious threat to nurseries because it provides entry for other disease organisms. In plantations it reduces growth by causing premature defoliation.

Septoria musiva overwinters in fruiting bodies in fallen leaves or branches. In spring, during periods of high humidity, spores are shot into the air. They infect new leaves at bud break. Leaf spots develop 1 to 2 weeks later. Spots first appear as depressed black flecks. Under favorable moisture conditions, flecks increase in size. Spots merge on leaves with multiple infections, and as much as 50 percent of the leaf tissue can be affected. As the dead tissue dries, it fades to light tan or white in the center. Three or 4 weeks after initial infection, spore-producing pycnidia appear as small, black, inconspicuous flecks in the centers of leaf spots. Spores from these pycnidia spread the infection to other cottonwoods.

Control measures would be economically justified in nurseries but probably not in plantations. After cottonwood cuttings are harvested from nursery beds, all debris should be removed or plowed under to destroy infected plant parts and to prevent new shoots from being infected in the spring. Native poplars in or near nurseries should be removed to prevent infection by airborne spores.

OYSTER MUSHROOM ROT

Pleurotus ostreatus (Fr.) Quel., the oyster mushroom, decays both sapwood and heartwood of several broadleaf tree species throughout the world. Because of its wide occurrence and its ability to attack both root and stem of cottonwood, it is potentially dangerous to cottonwood plantations.



White fungus mycelium of Pleurotus ostreatus **on decayed roots.**

Presence of sporophores (fruiting bodies) on trunks indicate infection. These are 2 to 6 inches (5 to 15 cm) broad, fleshy, smooth, shiny or satiny when dry, and white to grey in color. The cap is convex, with or without an off-center stalk, and has gills on the lower surface where spores are produced. Spores are carried by wind to other areas where they germinate readily under favorable conditions. The fungus enters trees through wounds in stems or roots. A white, flaky rot results. Trees with infected root systems show top symptoms characteristic of root disorders, i.e., a growth decline, unthrifty condition, and a thin crown. Diseased trees do not compete well with adjacent trees, become suppressed, and die within a few years.

Pleurotus ostreatus **fruiting body.**

This disease can be reduced by avoiding wounds to the root system and basal stem of trees. Removal of infected trees and wood debris harboring the fungus would also help reduce its spread.

LUCIDUS ROOT AND BUTT ROT

Polyporus lucidus Leys. ex Fr. causes rot in roots and the basal stem of hardwood trees in the United States, Europe, the Phillippines, other parts of Asia, and North Africa. The fungus has been observed on cottonwood cuttings but not on established trees. However, since inoculum will be present in many sites intended for cottonwood, infection of established cottonwoods is anticipated.

Polyporus lucidus **fruiting body on decayed cutting.**

If attacked, cottonwood would probably develop moderate to slight disease symptoms such as thin crowns and stunted foliage. Later, sporophores will be produced on or near the base of infected trees in late summer or fall.

These mushroom-shaped sporophores are a glossy reddish brown with a white, round margin. The undersurface is whitish with numerous small pores. The stalk is also glossy. dark red. Sporophores vary from 1 to 6 inches (2.5 to 15 cm) high and from 1 to 10 inches (2.5 to 25 cm) in diameter. Brown microscopic spores are released from the fine tubes in the undersurface of the sporophore cap. These spores are carried by wind and germinate on wood debris, stumps, or open wounds on living trees. As the fungus grows, it can penetrate the root system or collar of nearby susceptible trees. The wood decay is a soft, spongy, white rot with black spots.

No practical control is known for this disease. However, avoiding mechanical injuries to roots and tree bases, avoiding sites with known infections of natural stands, or removing infected trees helps reduce infections.

Typical P. lucidus **fruiting bodies growing above diseased roots.**

CLITOCYBE ROOT ROT

Root rot caused by *Clitocybe tabescens* Bres. occurs on many woody plants in the Southeastern States and elsewhere throughout the world. The disease has been observed in cottonwood plantations, but its full impact on this species has not yet been assessed.

First noticeable symptoms may be a decline of the crown and yellowing leaves, which fall prematurely or remain small and scant. On small trees, all foliage may die. White, fan-shaped mycelial fungus mats may form on the roots and root collar, causing decay. These mats extend upward between bark and wood and cause rot in both heartwood and sapwood.

Root system decayed by Clitocybe tabescens.

In fall dense clusters of yellow-brown mushrooms develop at the base on the infected tree. These mushrooms are 4 to 6 inches (10 to 15 cm) high and have a broad, brown, scaly cap ½ to 2/3 inch (12 to 17 mm) in diameter and whitish gills. They produce wind-borne spores that germinate on exposed tissue of living or dead trees. The fungus spreads through the roots of infected trees and penetrates living roots of adjacent, healthy trees through root grafts or wounds.

Suppressed or off-site trees are apparently most subject to attack. Thus, the best control is to maintain a vigorous stand through site selection, spacing, and thinning. Site preparation should include removal of all roots that might harbor the fungus. Removal of infected trees may be of value in young stands; however, care must be taken to avoid spreading fungus inoculum.

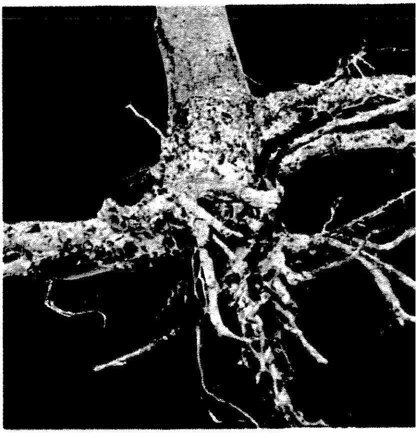
C. tabescens **fruiting bodies above diseased roots.**

CORTICIUM ROOT ROT

White root rot, or Corticium root rot, caused by *Corticium galactinum* (Fr.) Burt. attacks numerous woody and herbaceous perennial species in the United States, Europe, the West Indies, and Japan. Only a few cases of this disease have as yet been observed on cottonwood in plantations, but it is potentially destructive because of its wide occurrence and ability to spread from tree to tree.

Infected trees may only appear unthrifty with thin crowns. However, foliage may turn brown suddenly and die, accompanied by death of twigs and main stem. The sporophore appears on the root surface as a white or cream-colored layer of fungal growth without definite form or features and may persist for some time. The exposed sporophore surface may appear dry and cracked. Spores are wind disseminated. Under favorable conditions, they germinate and invade dead woody tissues or may even invade living root tissues. The fungus then spreads through the tissues, killing living cells and decaying the wood. Wood of affected roots often shows concentric spots, and roots may appear knotted or gnarled. Diseased trees occur singly or in small randomly located groups.

There are no practical control measures for this disease. However, avoiding sites where native stands are known to be infected and removing diseased trees from plantations are beneficial measures. Care should be taken so that pieces of infected roots or other inoculum are not spread to other areas. Replacement of plantation trees killed by this disease is generally not effective.



Corticium galactinum **fruiting bodies on decayed roots.**

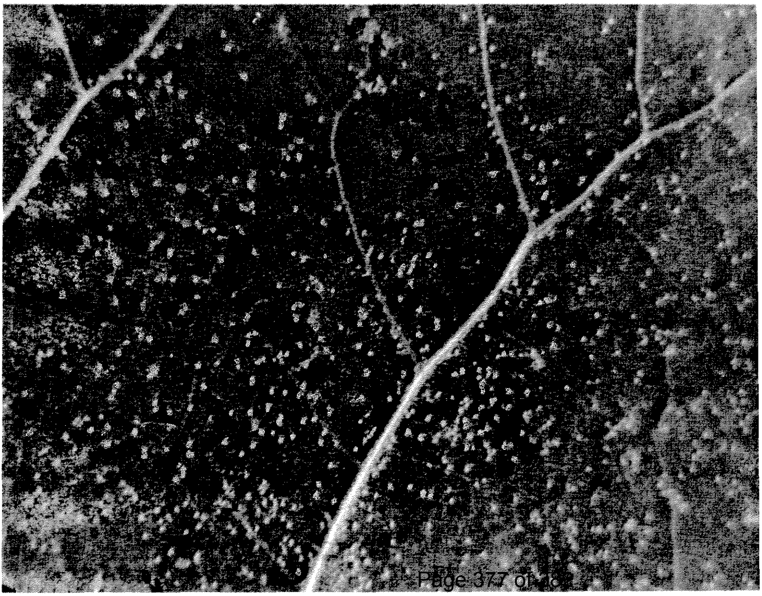
MELAMPSORA LEAF RUST

Leaf rust caused by *Melampsora medusae* Thum causes economic losses in nursery stock throughout the geographic range of cottonwood. Above latitude 40°, rust may cause premature defoliation in plantations. This defoliation not only causes growth losses; it weakens the trees and predisposes them to other pathogens, which cause cankers and mortality.

Cottonwood leaves are infected in early spring by wind-borne spores produced on conifers or by spores that overwintered on cottonwoods in frost-free areas. The first evidence of the disease is small yellow spots (masses of spores) on the lower leaf surfaces. These rust spores can be blown to new leaves and cause additional infections. If humidity is high, infection may spread until the entire leaf is covered by yellow spores. Defoliation usually occurs when rust covers over 50 percent of the leaf. Late in the season, the disease is easily detectable by the vast amount of rust spores, which give the leaves a dusty yellow color.

Rust-resistant clones developed by the Southern Forest Experiment Station in Stoneville, Mississippi, are available through several State forest nurseries. Stoneville clones 75 and 92 are not defoliated by rust and should be favored in areas when summer defoliation occurs.

Melampsora rust spores.



Alternaria leaf blight.

ALTERNARIA LEAF AND STEM BLIGHT

Leaf and stem blight caused by *Alternaria tenuis* Nees occurs in the United States, Canada, and Mexico. It was first reported on cottonwood in North Dakota in 1918. It now appears to be an important disease in nurseries and plantations. Losses among unrooted, green-tip cuttings in mist beds can be as high as 65 to 95 percent.

The fungus overwinters as mycelia on plant debris. In spring wind-borne spores are carried to new leaves; they germinate within 1 to 2 hours when relative humidity is 100 percent and temperature is between 40 and 95° F. The spore can penetrate epidermal tissue of young leaves and stems, but it usually enters through leaf margins and insect wounds, turning tissue brown. Within 5 to 7 days, mycelia have formed, and new spores are being produced. The infested area now appears as a sooty, irregularly shaped blotch.

Rotation and sanitation of nursery planting beds will reduce incidence of this disease by eliminating fungus which overwinters on plant debris. Early spring cultivation of stool beds to turn-under plant debris will greatly reduce subsequent infections.

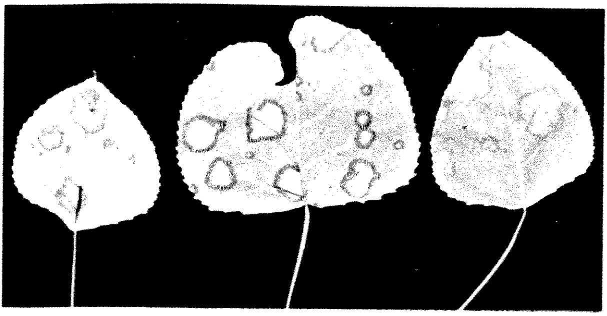
MINOR LEAF DISEASES

Several fungi cause leaf diseases on cottonwood throughout its geographic range. Leaf spot diseases may become epidemic during a wet spring and summer. Although the unsightly leaves and excessive leaf fall can be spectacular, they usually cause only minimal growth loss. A leaf disease is a serious problem only when more than half the leaf surface is infected or defoliation removes more than half the leaves. Heavy infections for several successive years can predispose the tree to other pathogens, which could cause death.

The most common fungi which cause damage are *Taphrina populina* Fr., *Phyllosticta* sp., *Cercospora populina* E. & E., *Colletotrichum gloeosporioides* Penz. These fungi overwinter on fallen leaves or twigs. In early spring spores are produced which infect leaves, causing death of leaf tissue. The affected area may be as small as a pinpoint or up to several inches in diameter. It can appear as a spot, ring, blotch, anthracnose, leaf curl, or leaf blister. Often more than one leaf disease is present on a single leaf.

Sanitation reduces the possibility of epidemics by reducing the amount of inoculum. In most cases, the disease is sporadic, and epidemics do not occur annually. If heavy defoliation occurs in successive years, chemical control may be needed to reduce subsequent infections.

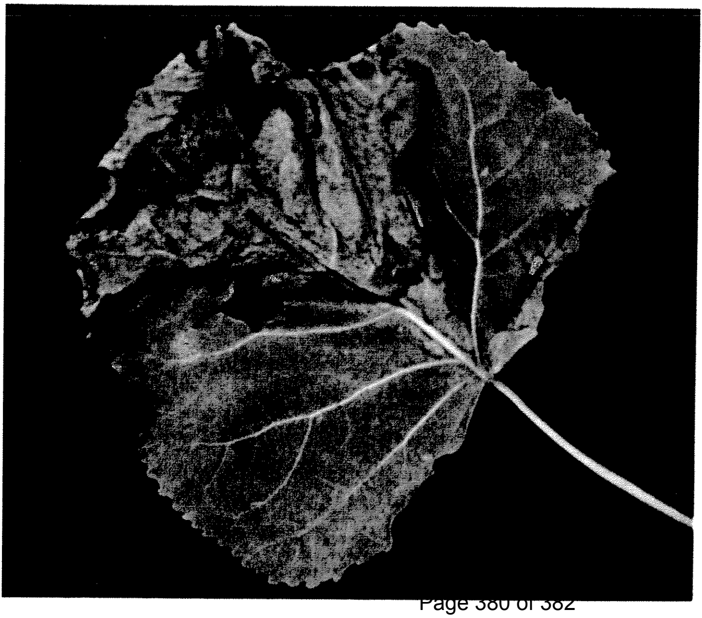
Leaf blister caused by Taphrina populina.



Phyllosticta ring spot.

Leaf spot caused by *Cercospora populina.*

Anthracnose caused by *Colletotrichum gloeosporioides.*



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