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

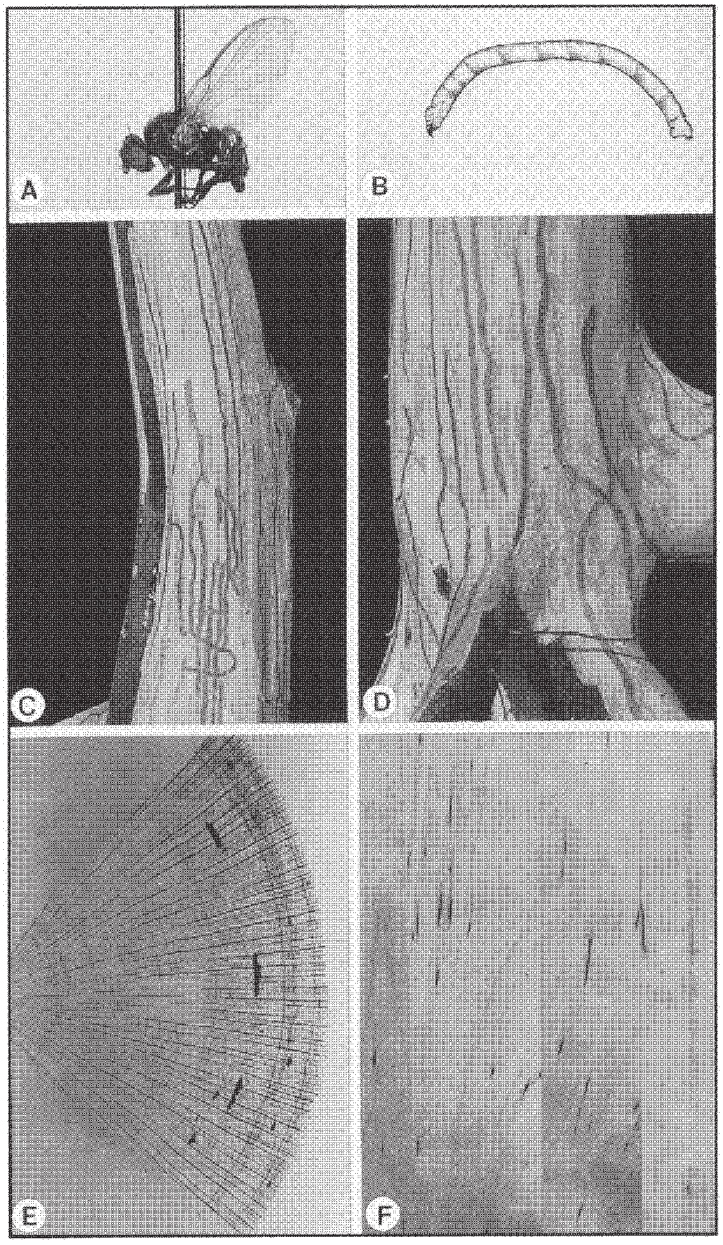

Figure 240—Phytobia setosa, *[maple cambium miner]: A, adult; B, larva; C, bark removed exposing larval mines on sapwood; D, mines extending into roots; E, cross section of stem with pith flecks; F, brown streak defects in maple veneer (A, specimen courtesy R. Peterson; E, specimen courtesy W. Wallner).*

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 1.5 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

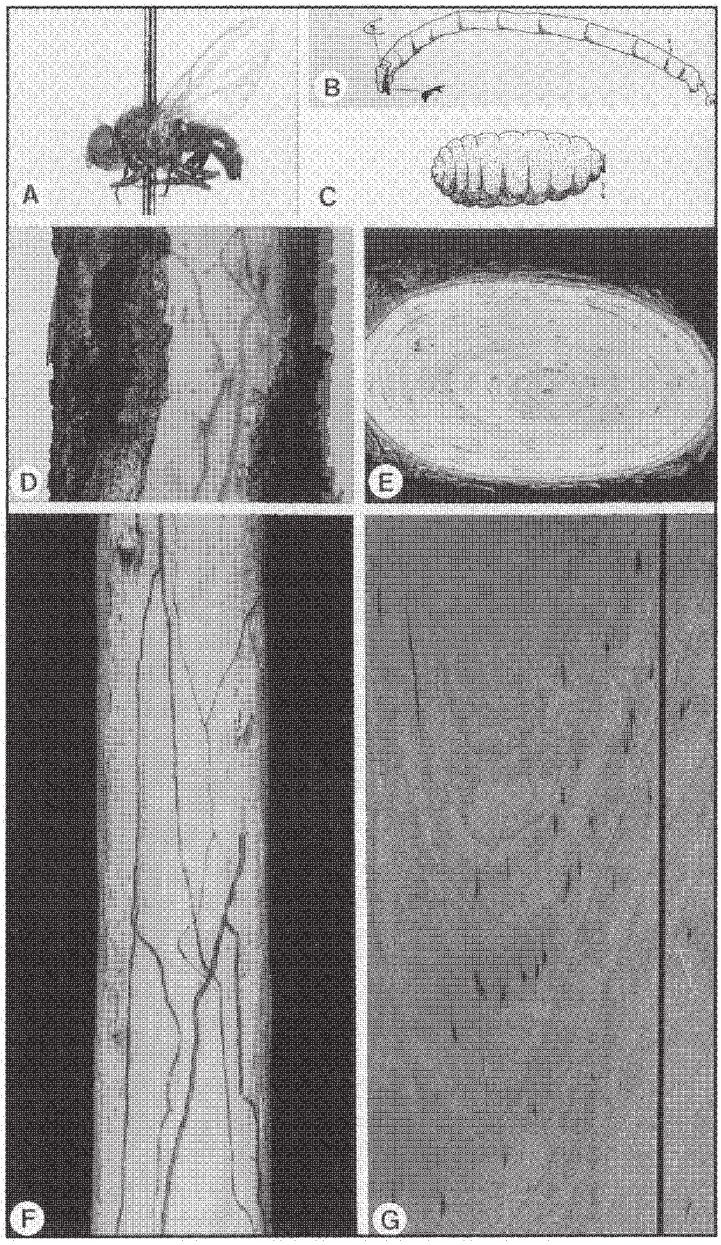

Figure 241—Phytobia betulivora, *[birch cambium miner]: A, adult; B, larva; C, puparium; D, bark removed to expose larval mines; E, cross section with many pith flecks; F, long, narrow mines on bole; G, brown streak defects in lumber (A, specimen courtesy R. Peterson; B & C, after Greene [1914]).*

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

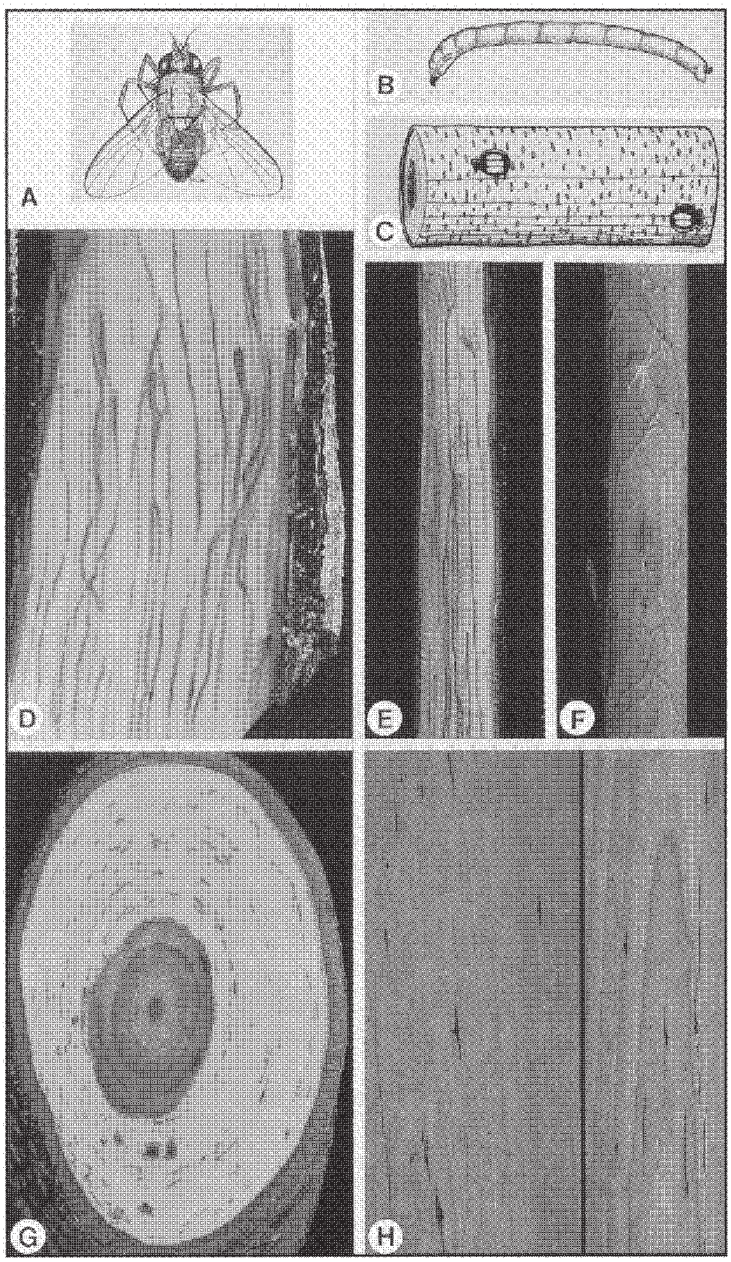

Figure 242—Phytobia pruni, *[cherry cambium miner]: A, adult; B, larva; C, eggs; D, wide larval mines near tree base; E, threadlike mines in upper bole; F, crisscrossing mines beginning to heal in midbole; G, cross section with pith-fleck defects; H, pith fleck and gum spots in cherry lumber (A-C, after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

(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

(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-

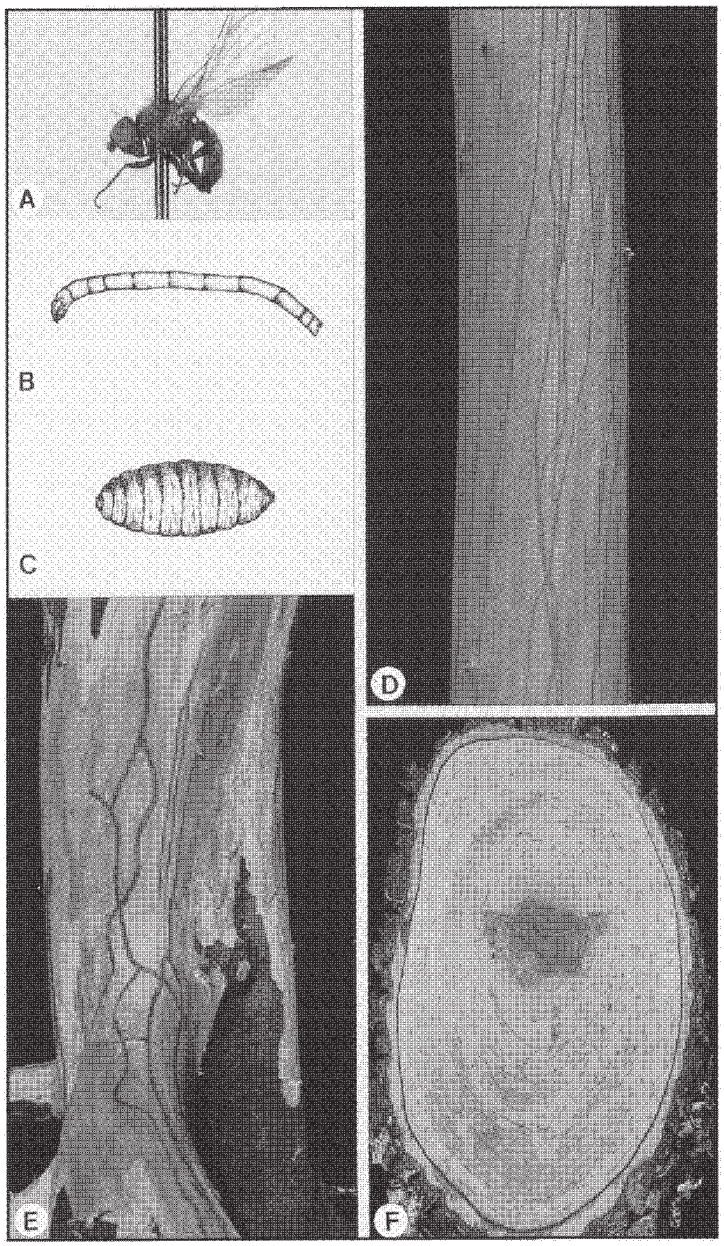

Figure 243—Phytobia amelanchieris, *[serviceberry cambium miner]: A, adult; B, larva; C, puparium; D, narrow, straight larval mines in upper bole; E, broad, meandering mines at base of tree; F, cross section with many pith flecks (A, specimen courtesy R. Peterson; B & C, after Greene [1917]).*

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 mid-stems, 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-

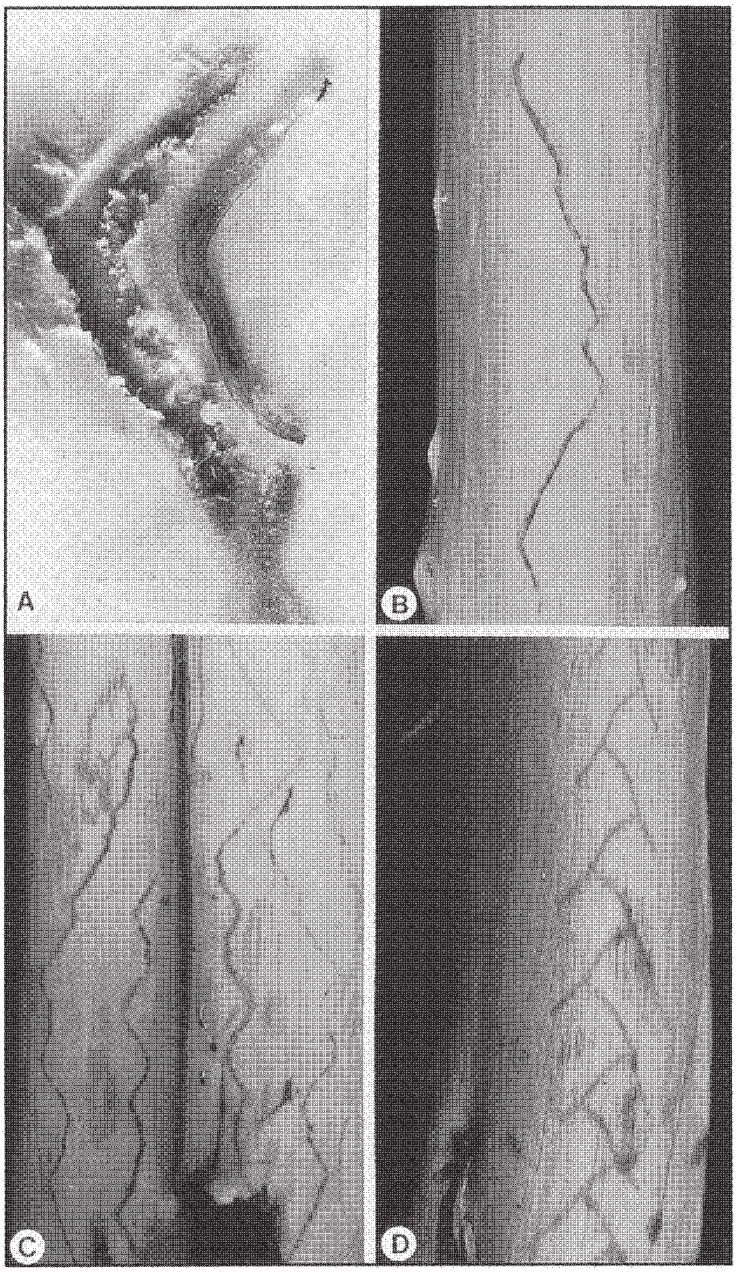

Figure 244—Phytobia *sp., [ash cambium miner]: A, larva beside its burrow in cambium and phloem; B, sinuate mine on surface of green ash sapwood; C, multiple zigzag mines on underside of bark; D, bipectinate larval mine in ash root.*

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.