United States
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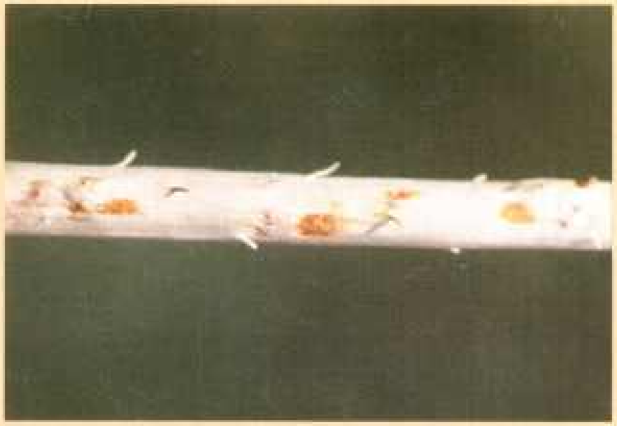
Agriculture
Handbook 695

Pine Spittlebug— Its Ecology and Management

Front cover (clockwise from top left)—Adult pine spittlebug; feeding scars on twig; shoot injured by the spittlebug; spittlemass on larch shoot.

Pine Spittlebug—Its Ecology and Management

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October 1991

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Introduction

The pine spittlebug, *Aphrophora cribrata* (Walker), although described as a distinct species in 1851, remained unnoticed as an economic pest until Nace (1930) reported that it had killed most of the trees in a Scotch pine plantation in Pennsylvania, on what is now the Logan State Forest. Planted in 1909, the pines had grown to pole size by 1925, when they became heavily infested with spittlebugs and "looked as if they were covered with snow" (Speers 1941). By 1927, 70% of the trees had died.

Since then, this spittlebug has appeared in many pine plantations throughout eastern North America. Preferring older saplings and young pole-sized trees, it has ruined many stands in both the North and the South. Some researchers speculate that many trees die because of diseases transmitted either by the nymphs or adults. Surviving trees sometimes are so weakened that they succumb to secondary insects or disease pathogens.

Research has provided much information about the behavior, habits, and ecology of the pine spittlebug. Today, management guidelines compatible with contemporary forest management practices are available. Such information is assembled and presented in this publication. For the convenience of the forest entomologist and forest manager, this publication is divided into three major parts. The first part presents the biology and ecology of the spittlebug and describes the damage it causes. The second part discusses various control tactics and provides guidelines for monitoring the insect. The third part gives guidelines for managing the spittlebug in the forest, in Christmas tree plantations, and on ornamentals.

Biology, Distribution, Hosts, and Damage

Description of the Insect........

Taxonomy—*Aphrophora cribrata* (Walker) is a froghopper in the order Homoptera, family Cercopidae, subfamily Aphrophorinae. The approved common name in North America (Entomological Society of America) is pine spittlebug. Before standardization, the name varied greatly. At first this insect was called the parallel-marked Lepyronia (Fitch 1851), the parallel spittle-insect (or parallel spittle insect) (Fitch 1856, Weiss 1916, Nace 1930), or just spittle insect (Girault 1904, Felt and Bromley 1930). Later names included spittle bug (McIntyre 1939, Pirone 1941), pine spittle bug (Knull 1932, MacAndrews 1939, Speers 1941, Craighead 1950, Gesell 1951, Kerr 1959), and pine spittlebug (Doering 1942, Hanna and Moore 1966). The French name, used primarily in Quebec, is *cercope du pin* (Benoit 1975).

Walker (1851) originally described this cercopid as *Ptyelus cribratus.* Nearly all the literature on the pine spittlebug, however, is presented under the nomenclature of *A. parallela* (Say) or its synonyms. Hamilton (1982b) states that *A. cribrata* is a synonym of *A. parallela* as presented by Walley (1928), but not one of *Cercopis parallella* [sic] of Say (Say 1824). The latter, he says, is really a spruce-feeding insect, and he calls it the spruce spittlebug, *A. parallella* (Say) [sic] (Hamilton 1982b). He adds that several distinctive characters, especially the inflated sucking pump, warrant segregating *A. cribrata* as the sole member of a new subgenus *Pinimber*. Moore (1956) places *parallela* (= *cribrata*) in the *salicis* group of spittlebugs, a group with holarctic distribution.

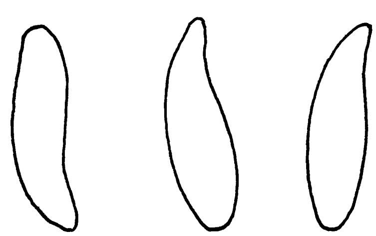

Figure 1—Pine spittlebug eggs.

Egg—The egg is an elongate tapering ellipsoid, shaped somewhat like a teardrop—rounded at the large end and pointed at the smaller end (fig. 1). One side is more strongly curved than the other. The egg measures about 2.0 mm long by 0.5 mm wide. Shortly after oviposition it is pearly white but later darkens to olive-buff (Speers 1941).

Nymphs—There are five nymphal instars. The first four instars are similar in markings and color; the fifth differs both in color and form and is easily distinguished from the others. Typical nymphs are shown in figure 2 and on the back cover. Body lengths of the first four instars range from 1.8 mm to 5.8 mm, overlapping between succeeding stages. Measurements of the width of the head-capsule are more accurate for distinguishing among instars. Speers (1941) also pictures the nymphs and lists the following body lengths (ranges) and mean head-capsule widths for the five instars:

Instar	*Body length (mm)*	*Head capsule width (mm)*
1	1.8–2.3	0.69
2	2.4–3.4	0.91
3	3.2–4.2	1.21
4	4.0–5.8	1.65
5 (males)	5.6–6.9	2.25
5 (females)	7.0–7.9	2.40

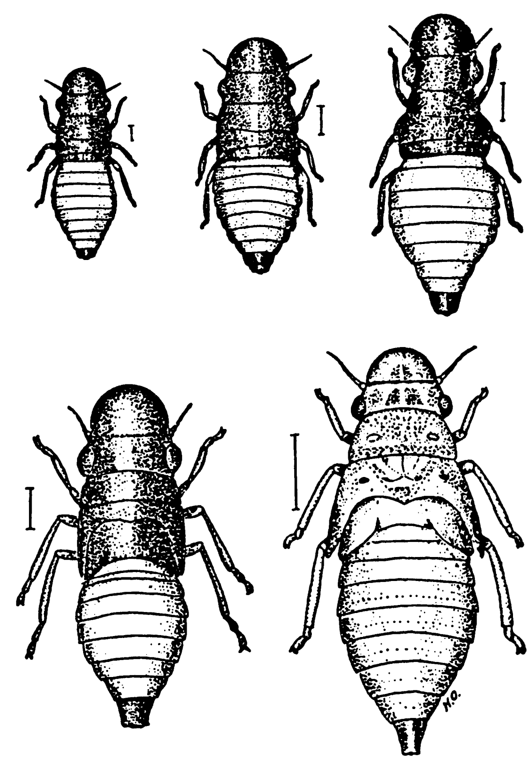

Figure 2—Five nymphal instars of the pine spittlebug (from Osborne 1916).

The general body shape of the first four instars is long and slender, with the base of the head and thorax approximately the same width. The head is heavily chitinized, prominent, large, and broadly rounded on the anterior two-thirds. The sub-oval eyes bulge from the sides of the head. The thorax is also heavily chitinized, parallel laterally. The abdomen has nine visible segments, broad at the base, expanding to the fourth, then narrowing to the final segment. Wing pads are evident on the fourth instar and much more prominent on the fifth (fig. 2).

On the first four instars the head, thorax, antennae, legs, labium, terminal tergal plates, and anal segment are shiny black. In contrast, the sternum of the thorax and abdomen, medial line of the head and thorax, and leg joints are pale orange. The abdominal pleurites and eyes are scarlet. The abdomen is mostly salmon-orange above on the first six segments and scarlet on the seventh and eighth segments.

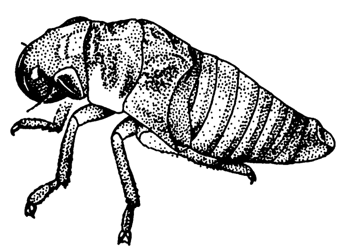

Figure 3—Fifth nymphal instar of the pine spittlebug (from Hamilton 1982b).

The body of the fifth instar is larger and broader than that of the other instars. The wing pads are clearly evident and extend posteriorly to the third segment of the abdomen (figs. 2 and 3). Length ranges from 5.6 to 9.0 mm, depending on the sex; females are longer on the average. Speers (1941) contrasts a light phase and a larger, dark phase of this instar that, he says, are due to sexual dimorphism. In both phases the general background color of the head, thorax, and legs is cream, mottled and streaked with various shades of brown. The antennae are black; the eyes are carmine to red. The first five abdominal pleurites are scarlet fading to cream dorsally. The abdominal sternites are also cream colored, but portions of the last abdominal segment are brown to black. In the dark phase the markings are a deeper shade, so the dorsal portion of the abdomen may be sepia to blackish (Speers 1941).

After molting, the nymphs are soft and pale; the thorax and head are yellow, and the abdomen is yellow near the head and reddish along the sides and

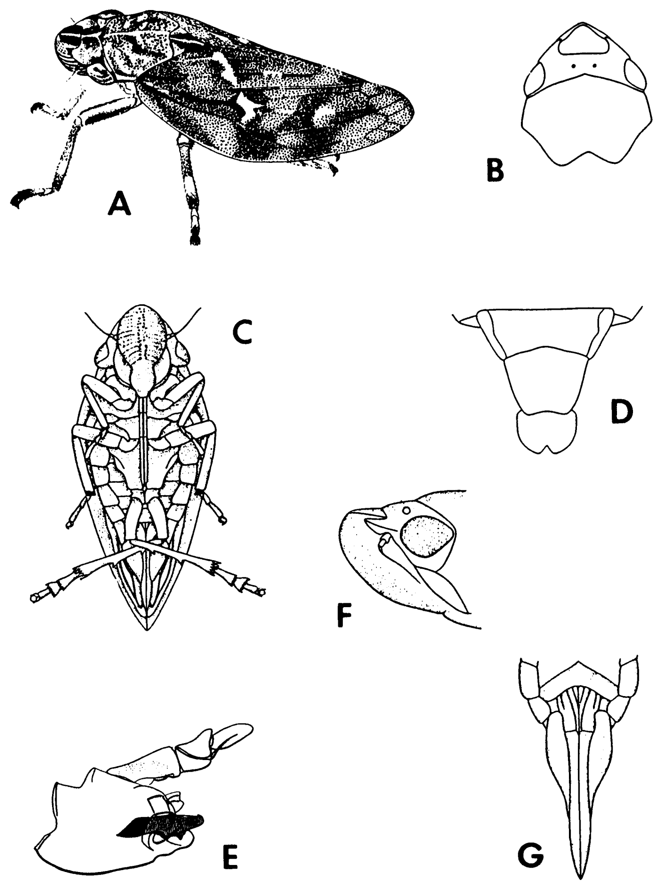

Figure 4—Morphological characteristics of the adult pine spittlebug: A—Adult (lateral view). B—Head and thorax (dorsal view). C—Adult female (ventral view). D—Male genitalia. E—Male genitalic capsule and anal tube (lateral aspect). F—Head (lateral view). G—Female genitalia. (A & E, from Hamilton 1982a; B & D, from Doering 1941; C, F, & G, from Doering 1930.)

beneath. The eyes are black. The legs and beak are mostly yellow. Color returns to normal usually within 1.5 hours (Girault 1904).

Adults—The adults of both sexes are boat-shaped insects (figs. 4A and C). Each has a conical head (fig. 4B). The body usually is brown and heavily overlaid with black spots and streaks; the forewings have irregular whitish blotches (fig. 4A and front cover). Each forewing has a narrow, oblique, light band usually bordered by a darker band. These bands may be broken with spots. This species is easily separated from others of the genus by the long crown and the glabrous sucking pump that sticks out beyond the head (fig. 4F) (Stearns 1917; Doering 1930, 1941; Speers 1941; Hamilton 1982b).

Females are generally larger than males and can be readily distinguished by their sword-like ovipositor (figs. 4C and G). Stearns (1917) measured adults as 8 to 12 mm long and 3.5 to 5 mm wide. Females average 10.3 mm long and males average 9.8 mm (Hamilton 1982b). Speers (1941) gives the ranges as 9.5 to 11.0 mm long for females and 8.5 to 10.5 mm for males.

Ball (1898) characterizes the genitalia as follows: Female pygofers are long and narrow, exceeded a full millimeter by the ovipositor (fig. 4G). The ultimate ventral segment of the male is short, its length about equalling its basal breadth, narrowing apically, the margins curving up and the lateral angles produced in the form of style-like appendages as long as the plates. The plates are nearly square, and the posterior angles are rounded (figs. 4D and E).

Metcalf (1917) discusses the wing structure and venation of the Cercopidae, and Speers (1941) presents the same for *A. cribrata.*

Distribution........

The pine spittlebug is native to North America, and its distribution generally corresponds to the range of its major hosts. In Canada, according to Hamilton (1982b), the pine spittlebug occurs from Nova Scotia westward through the lower portions of all provinces to the Meadow Lake region of Saskatchewan. In the United States, it occurs in all States east of the Great Plains from Minnesota south to eastern Texas. Because of limited location records, Ball (1898) thought that Missouri and Arkansas were outside this spittlebug's range. Gass and Luley (1988), however, reported the pine spittlebug's presence in several counties in Missouri. Also, we have verified specimens from Arkansas. At the southern end of the insect's range, specimens have been collected by L. A. Hetrick and others in Florida and verified as *A. parallela (= cribrata)* by Moore (1956) and Mead (1990). The broad north–south range and the spittlebug's presence as far south as central Florida are not unusual because spittlebugs as a group are tropical insects and generally spread northward by adapting to northern climates (Hamilton 1982b).

Hosts........

Both the nymphs and adults feed on pines, larches, and occasionally other conifers (table 1). Adults have been taken from eastern hemlock, fir, and Douglas-fir and from a few hardwoods (Moore 1956). Hamilton (1982b) says that those found on species other than pine and larch are probably strays that have wandered from their primary hosts.

By all accounts in the literature, the pine species that is most susceptible to spittlebug attack and injury is Scotch pine, a Eurasian exotic introduced principally for Christmas trees and ornamentals (Osborn and Drake 1922; Knull 1932; Ball 1934; MacAndrews 1939; McIntyre 1939; Speers 1941; Putman 1953; Beckwith and MacAloney 1954, 1955; USDA 1985). Speers (1941) called this host 100% susceptible. There are numerous records of attacks on Scotch pine. One report from a Pennsylvania outbreak describes "200 insects per 7 ft tall tree" (USDA 1960), and various other accounts report "numerous" insects or "trees covered with spittle." Scotch pine is the only host that has shown consistently heavy injury and mortality from attack.

Henry and others (1938) rank host preference in the following order: Scotch pine, pitch pine, eastern white pine, jack pine, Virginia pine, red pine, and Norway spruce (table 1). The latter two, they say, are rarely attacked. Speers (1941) says that Scotch, pitch, jack, and white pines are "very susceptible"; and he categorizes all other hosts as "commonly susceptible, occasionally susceptible, or rarely susceptible." His categories list eight native, four western, and six exotic conifers. Felt and Bromley (1930) report that the spittlebug is abundant on Scotch pine, less common on white pine, and rare on red pine.

Generally, where Scotch pine is absent, jack and eastern white pines are the most susceptible native hosts in the North. Brown (1940) says that white pine is favored in Canada, but Gross (1985) reports that red pine is damaged more than white pine. European larch is usually attacked less than most of the susceptible pines.

Pitch pine, which ranges farther south than the boreal pines, is about as susceptible as white or jack pine, according to Walden (1917). In the Piedmont Plateau of North Carolina, loblolly and shortleaf pines are preferred hosts. Virginia pine seems to be slightly less susceptible there (Beal and others 1952).

Walden (1917) found a few spittlemasses on Norway spruce that were intermixed with pines in Connecticut. Speers (1941) notes that spittlemasses are common on white and black spruce in Canada. Some of

Table 1—Conifers listed as hosts of the pine spittlebug

COMMON NAME	SCIENTIFIC NAME
Pines	***Pinus***
Austrian pine	*nigra* var. *austriaca* (Hoess) Badoux.
eastern white pine	*strobus* L.
jack pine	*banksiana* Lamb.
Japanese black pine	*thunbergii* Parl.
Japanese red pine	*densiflora* Sieb. & Zucc.
limber pine	*flexilis* James
loblolly pine	*taeda* L.
lodgepole pine	*contorta* Dougl. ex Loud.
pitch pine	*rigida* Mill.
ponderosa pine	*ponderosa* Dougl. ex Laws.
red pine	*resinosa* Ait.
Scotch pine	*sylvestris* L.
shortleaf pine	*echinata* Mill.
slash pine	*elliottii* Engelm.
Virginia pine	*virginiana* Mill.
western white pine	*monticola* Dougl. ex D. Don
Larches	***Larix***
European larch	*decidua* Mill.
tamarack	*laricina* (Du Roi) K. Koch
Spruce	***Picea***
black spruce	*mariana* (Mill.) B.S.P.
blue spruce	*pungens* Engelm.
Norway spruce	*abies* (L.) Karst.
red spruce	*rubens* Sarg.
white spruce	*glauca* (Moench) Voss
Firs	***Abies***
balsam fir	*balsamea* (L.) Mill.
Fraser fir	*fraseri* (Pursh.) Poir.
white fir	*concolor* (Gord. & Glend.) Lindl. ex Hildebr.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Eastern hemlock	*Tsuga canadensis* (L.) Carr.

these reports, however, are most likely from the activity of the spruce spittlebug. Douglas-fir occasionally is attacked by the pine spittlebug.

Speers (1941) reports that lodgepole and ponderosa pines were fed upon in his studies, but only after second and third instars were transferred to them. He found that nymphs survived for only a short time on Austrian pine. On Norway spruce the transferred nymphs took a longer time to develop, and all died before maturing.

Life History and Habits........

The pine spittlebug is univoltine—that is, it has only a single generation each year. It overwinters in the egg stage. Because of its extensive north–south range, there is considerable variation in the length and period of the life cycle. For instance, in southern Canada the nymphs usually occur from late May to late July and the adults occur from early July through August (Rose and Lindquist 1980, Martineau 1984). In the Northern United States the nymphs are present from late April or early May to early July, and the adults feed from mid-July to early September (Fitch 1856, Walden 1917, Osborn and Drake 1922, Henry and others 1938, MacAndrews 1939, Craighead 1950, Kerr 1959, USDA 1985). At their southern limit in Florida, the nymphs appear in late March or early April and remain until mid-May. Adults occur from early May to late July. Seasonal variation, particularly in early spring, may retard or advance the life cycle by 1 to 2 weeks.

Phenological events are useful for determining the presence of nymphs or adults of the insect. For example, in Pennsylvania, Knull (1932) noted that egg hatching coincided with the last blossoming of service berry, *Amelanchier canadensis* L. Speers (1941) says flowering dogwood, *Cornus florida* L., blooms during egg hatching in New York. Mountain laurel, *Kalmia latifolia* L., is in full bloom in Pennsylvania when the adults emerge (Knull 1932).

Egg stage—The eggs mature about a week after adult eclosion, and then they are laid over 1 or 2 months—the life of the adult female. The exact fecundity is not yet known, but the average is probably about 30 eggs per female. Speers (1941) counted 31 eggs in one female. Eggs are present in the field from the onset of oviposition until the following spring.

Females insert most of their eggs under tender outer bark (see back cover) by using their swordlike ovipositor. Speers (1941) noted that some eggs were thrust into dead woody tissue parallel to the axis of the twig. Henry and others (1938) reported that eggs were placed in the base of newly formed buds. Because this is the only report of this phenomenon, Henry and his co-workers may have mistakenly identified the eggs of the Saratoga spittlebug, *A. saratogensis* (Fitch), or a similar species sympatric with the pine spittlebug.

Just before hatching, a bulge appears on the surface of the egg, marking the expansion of the egg-burster on the head of the pre-emergent first-instar nymph.

Nymphal stages—Nymphs appear in the spring as weather warms. Each nymph breaks out of the egg by pressing its hardened plate or egg-burster against the chorion (shell) (Hamilton 1982b). Young nymphs ramble over the host until they locate the shoots behind the new-growth tips. There they begin feeding at once by inserting their mouthparts. Speers (1941) noted that the nymphs first appear on the south side of trees, mostly on the lower branches. At first each feeds alone and forms a small spittlemass (fig. 5 and back cover); later several nymphs occupy a large common spittlemass that is usually on the older shoots or mainstem.

Speers (1941) estimated the average duration of the five nymphal stadia as 7, 8, 6, 9, and 12 days, respectively, or about 42 days (in New York) for the entire growth period of an average nymph. In Canada, these intervals are slightly longer; in the Southern States they may be shorter.

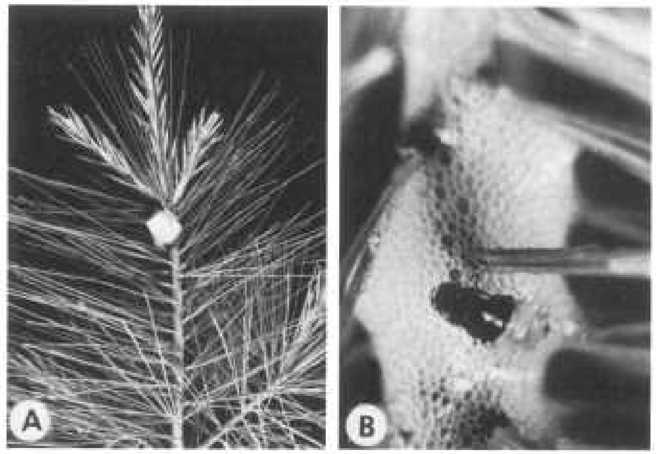

Figure 5—Spittlemass of the pine spittlebug on old-growth shoot of white pine (A) and showing nymph (B).

The first four instars molt within the spittlemass. According to observations by Speers (1941), molting occurs in the following manner. The line of weakness is already predetermined by the midline transversing the head and thorax. When the nymph is ready to molt, the thorax gradually expands and the skin splits along the median dorsal line. It parts first at the posterior margin of the thorax and progresses gradually toward the head, stopping on a line even with the bases of the antennae. This split gradually widens, and the greatest enlargement takes place above the metathorax. By expanding and contracting the thorax, the nymph works its head and thorax out through the opening in the old skin. After it works the old skin down over the head and eyes, it withdraws its legs and labium from their sheaths. At this same time the nymph, by sending muscular contractions along the abdomen, gradually works out of its thin, transparent, membranous covering. Complete ecdysis occurs within 3 to 5 minutes. After molting, the nymph goes through a coloration and hardening process before it is ready for the next instar.

When the fifth-instar nymph is ready to molt to the adult, it climbs onto a needle or fascicle. After finding a suitable position, preferably hanging down, it exudes a sticky fluid from the anal pore. The tip of the abdomen is then extended and placed in this substance, thus fastening the tip of the abdomen to the needle. The nymph remains motionless in this position for about 5 minutes, during which time the thorax gradually becomes swollen. Then the dorsal median line splits, and the adult emerges. Instead of emerging completely, the tip of the abdomen is left within the old exuvium, thus holding the adult suspended.

When the wings are withdrawn from the old skin, they stick out at an angle of about 90° to the body. At this time the wings are folded, but they unfold and extend out straight within half an hour. Also around this time the ivory-colored adult begins to crawl about. One hour after the nymph assumes adult form, its color begins to appear, reaching completion in approximately 3 hours. The empty nymphal skin often clings to the needles for 1 or 2 weeks after emergence, but it may be detached by rain or wind (Speers 1941).

The position of the nymph generally assumed during feeding, especially by the younger instars, is with the head closely appressed to the base of the needles, facing the base of the branch. Occasionally a nymph feeds on a needle, and then it faces the needle base. By feeding in these positions, the nymph takes advantage of gravity. When partly digested sap is excreted with the abdomen upward, this fluid tends to flow downward and keeps the body completely covered. In the later instars, as the nymphs move about, they choose their feeding places with less regard to position (Speers 1941).

Much more sap is ingested than digested. A filter chamber in the esophagus (Snodgrass 1935) passes much of the excess water and some sugar directly to the posterior part of the gut (Hamilton 1982b). The excretion is tasteless or slightly salty (Girault 1904), and its pH is 7.8 (Knull 1932).

Early observers determined that the spittlemass was formed by movements of the nymph that caused air bubbles to be inserted into the excreted fluids (Morse 1900, Ball 1901, Girault 1904). Speers (1941) details the spittle-making process in the following manner. After inserting its beak for feeding, the spittlebug extends its abdomen backwards and upwards at an angle of about 30° . Then it excretes a clear liquid from the anal pore. This fluid flows forward over the top of the last three segments of the abdomen and down over the pleurites. As the spittlebug brings its abdomen back into normal position, the lips of the Y-shaped anal opening expand and contract. After a quantity of clear fluid collects under the body at the base of the legs, the spittlebug extends the metathoracic legs backwards, thus allowing the fluid to run on them. Then it brings these legs forward and rubs them against the other legs, transferring the liquid forward. The bubbles are formed by the abdomen being extended downward through the fluid, then backward, up and out. First the nymph moves its abdomen to one side and then to the other. As the abdomen passes through these motions, it expands the pleural folds on the up motion as it moves out of the fluid, thus taking in air. As the abdomen is brought back into the fluid it contracts, thus forcing the air out and forming an air bubble. Only one bubble forms at a time, but the nymph may produce 10 to 40 bubbles each minute. However, 70 to 80 bubbles per minute are common for other species of spittlebugs (Morse 1900).

For the nymph to breathe while in the spittlemass, it has a ventral tubelike canal, which is formed by the large plate fringing the abdomen. The spiracles lie within the canal, and the nymph replenishes air as needed by thrusting the tip of the abdomen outside the droplet (Hamilton 1982b).

Once young nymphs find suitable feeding places, they generally remain in their original spittlemass until they reach the third instar. If they do not find suitable sites, the nymphs may feed for varying intervals before settling down. Girault (1904) noted that of 80 new masses, 76 were just back of the new growth and the other 4 were farther back. In recently formed masses the bubbles are large due to the "imperfect state of the emulsion" and the fluid is clear; in older masses the bubbles are smaller and the fluid is opaque. The spittlemasses resist rain falling on them, but in moist air they readily drip. Liquid flows down the trunk of the tree from large masses on the bole (Knull 1932).

The size of the spittlemass depends mostly on the number and size of nymphs. For a single nymph in its own mass, the diameter of the mass of the first instar is 2 to 3 mm; the second instar, 4 to 5 mm; the third instar, 7 to 8 mm; the fourth instar, 9 to 10 mm; and the fifth instar, 15 to 16 mm (Speers 1941). Also, the older the insect, the larger the air bubbles.

Because this species aggregates in a common spittlemass, the group mass may become as large as 200 mm long by 100 mm wide. Knull (1932) reports that nymphs in the fifth instar congregated in groups of hundreds or more on the trunks of Scotch pine in Pennsylvania. Wandering nymphs encounter other masses and produce more bubbles as they enter them.

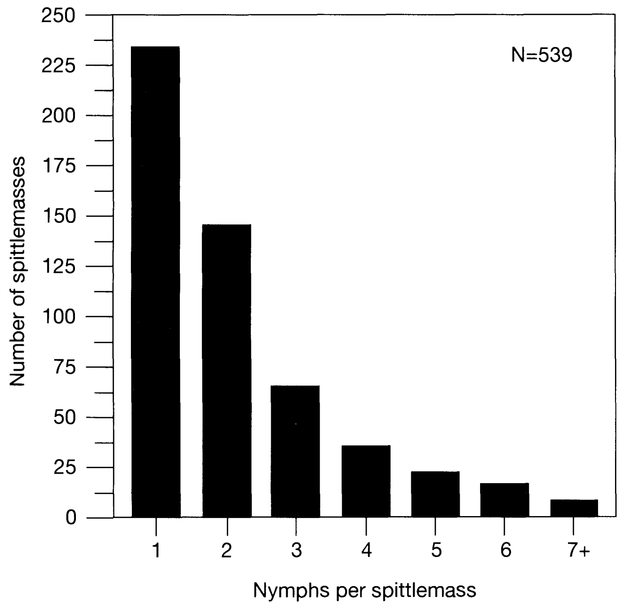

Figure 6—Frequency of nymphs of the pine spittlebug by spittlemasses.

Speers (1941) sampled one young Scotch pine tree in late May and found 539 spittlemasses containing 1,361 nymphs in the first and second instars. The masses contained 1 to 16 nymphs, but 229 masses, or 42%, had only 1 nymph each (fig. 6).

Adult stage—Most adults live for about 30 to 40 days after they emerge, but some live up to 60 days (Speers 1941). The sex ratio is 1:1 as determined from collections in July in New York.

During good weather the adults spend most of their time feeding on the host's needle-bearing shoots. They feed night and day if the weather is warm (20 to 30°C). To prepare for feeding, each adult generally faces the base of the shoot or branch, and then inserts its stylets into the bark to the secondary xylem. One adult may make several punctures each day and hundreds during its lifetime. Within 2 to 3 minutes of inserting its mouthparts, small droplets of liquid appear at the anal opening. Each adult excretes about 0.01 cm^3/min or 0.60 cm^3/hr, but this amount decreases if the insect remains feeding for a long time (more than several hours). Speers (1941) says that adults eject from 1 to 7 droplets at 3-second intervals. Girault (1904) states that there are about 4 drops every 2 to 3 seconds. When adults are abundant, the droplets can be felt beneath the tree as a fine mist. When dried on the tree, the glistening droplets, called honey dew, support the growth of a sooty mold (*Dimerosporium* spp. and others) that blackens the foliage. As the adult ejects the droplets over its head, it produces a faint crackling sound (Mundinger 1946).

The pine spittlebug makes soft, repetitious, monotonous noises under various circumstances. It can produce sound by vibrating its tergal abdominal timbals. Both sexes have timbals, but only the sounds of females are known (Moore 1961). Female sounds occupy a narrow band of frequencies around 2.5 kilohertz with a timbal-vibration rate of about 80 per second, and consist of phrases from 2 to 10 timbal-vibrations arranged in groups lasting up to 4 to 5 seconds. Females call less often when alone than when together with other females, because the call of one stimulates the others calling. Acoustical behavior seems to be for species recognition, courtship, and sexual response (Moore 1961).

Host Damage........

The pine spittlebug can cause serious injury to conifers of all sizes, from small nursery stock to mature forest trees. However, the economic importance of this insect is easy to underestimate because the injury it causes may not be apparent at first. Damage may result from: (1) excessive extraction of the sap by the nymphs for food and for their protective spittlemasses; (2) excessive extraction of sap by adults to meet their metabolic requirements; (3) injection of toxic substances by the adults while feeding; (4) transmission of disease organisms while feeding; (5) feeding puncture wounds that cause mechanical damage and predispose the tree to attack by bacteria, fungi, and secondary insects (Hanna 1970); and (6) slits in the bark made for depositing the eggs.

Both nymphs and adults wound the tree. While feeding on the shoots, the stylets of the mouthparts of the larger nymphs and adults pass through the cells of the bark, penetrating beyond the cambium into the xylem (Knull 1932). Because the stylets are narrow, they leave little evidence of a feeding puncture wound on the bark. Adult punctures, however, may bleed sap (MacAndrews 1939), especially on white pine (Speers 1941). Generally, the only subclinical evidence of injury is a small scar on the surface of the shoot and sometimes a slight swelling of the shoot (Knull 1932). Fresh punctures, particularly from the adults, can be seen on the inner bark and surface of the xylem as squarish light brown discolorations 3.0 to 4.0 mm across (front cover). These scars form by tissue necrosis adjacent to the puncture wounds and probably are caused by an enzyme in the adult salivary glands. Heavily injured shoots retain wound scars in the wood.

Flagging of the shoot tips is the first symptom of attack. Branches die progressively from tip to trunk (Craighead 1950). Lower branches usually die first, followed by other branches progressively up the tree until the whole tree succumbs. Highly susceptible Scotch pines die 2 to 3 years after heavy and repeated attacks. Those weakened by drought, poor soil, inadequate nutrients, overstocking, and/or competing vegetation may succumb even sooner.

Because both nymphs and adults feed on the host tree and these stages occur over several months, even a moderate population of insects can cause considerable injury. Knull (1932) says that nymphs weaken the old growth and adults weaken the new growth. Nymphs are somewhat sedentary and tend to feed in one location for long periods; the mobile adults feed at several different locations daily. Osborn and Drake (1922) speculate that the nymphs withdraw more liquid than the adults. However, because the adults are larger and feed longer, they may withdraw about the same amount as the nymphs. Feeding puncture wounds transform to resin-filled scars that restrict water and nutrient transport, causing moisture stress. Drought and poor water-holding capacity of the soil can further contribute to moisture stress. Stressed trees synthesize different and inadequate metabolites that predispose them to insects and diseases (McDaniel 1937). Severin (1950) noted that various spittlebugs, including species of *Aphrophora*, are disease transmitters. The burn-blight fungus *Scoleconectria cucurbitula* (Tode:Fr.) Booth has been found with Saratoga spittlebug–injured red and jack pine, and it may be associated with the pine spittlebug (Moore 1955).

Because of the large number of feeding punctures made by nymphs and adults, they probably act as infection sites for some invasive pathogens, especially when the tree is weak (Waterman 1943). Pine spittlebug is often associated with sphaeropsis (= diplodia) shoot blight, *Sphaeropsis sapinea* (Fr.:Fr.) Dyko & Sutton in Sutton, formerly *Diplodia pinea* (Desmaz.) J. Kickx. fil., on Scotch, Austrian, and eastern white pine (USDA 1985). Speers (1941) found sphaeropsis shoot blight killing Scotch pines in spittlebug-infested stands, but he could not tell if the spittlebug instigated the fungal infection.

The general external symptoms of attack are the same for sphaeropsis and pine spittlebug, so it is difficult to separate each one's contribution. However, trees attacked by both decline more rapidly than trees attacked by either sphaeropsis or pine spittlebug alone.

MacAndrews (1939) found mites, *Oligonychus ununguis* (Jacobi) (= *Paratetranychus ununguis* (Jacobi)) and *Tetranychus telarius* (L.), in large numbers on spittlebug-infested Scotch pines after a drought in 1938. He believed that these mites contributed to the death of the pines because the damage was noticeably less where the mites were absent.

Mechanical injury, such as occurs during oviposition, may open additional sites for invasive pathogens. The sugary nymphal froth and adult excretions encourage growth of sooty mold. Although this fungus is not invasive, it coats the foliage and retards photosynthesis.

Heavily infested young Scotch pines may have 3 to 4 spittlemasses per shoot, but 8 to 10 are not uncommon (Felt and Bromley 1930). Severe infestations may kill trees in pockets of 1 acre or more (Battenfield 1982). Nace (1930) and Knull (1932) report that infested Scotch pine stands in New York lost 70 to 100% of their trees in just a few years. After the outbreak, entire stands turned brown or looked scorched. Surviving trees were stunted and distorted. On some, the bark swelled and cracked (MacAndrews 1939).

Surveillance and Control

Detection........

The purpose of a detection survey is to learn whether the pine spittlebug or its damage is present at any particular time or place. The survey can be made casually or systematically, whichever the observer desires. Usually it is a ground survey, but you can make it from the air when the gross symptoms of injury are obvious. Ground checks, however, may also be needed to verify spittlebug damage because other insects and some diseases either cause similar symptoms or are associated with spittlebugs. Because sphaeropsis shoot blight is sometimes associated with pine spittlebug, you should learn to detect its symptoms and signs as well.

Conducting one or more of the following detection surveys from the ground requires the pictures in this handbook, a knife, a few vials, and an insect sweep net. (This collecting net has a muslin bag instead of the typical delicate bag used mostly for butterfly collecting.) Also, carry a leaflet or manual that describes sphaeropsis shoot blight fungus and its symptoms. (See Peterson 1981, Palmer and Nicholls 1983, USDA 1983.)

Detect damage—Look for gross symptoms of spittlebug damage such as flags (reddish shoot tips), dead branches, or dead trees (any time of year). If the new shoots are stunted and curled, sphaeropsis shoot blight may be present. These symptoms are commonly present on Scotch, Austrian, and jack pines, especially when both the insect and the fungus attack the trees (front cover). Shoots may look sooty. (Note: Check branches closely because scale insects and aphids are also associated with sooty mold.)

When damage is pronounced, it can be detected from low-flying aircraft or from aerial color photographs. Follow this up with ground checks to verify that the damage is from the spittlebug and/or sphaeropsis.

Detect injury—Examine 1-year-old shoots for feeding wounds and scars of the spittlebug (any time of the year) (front cover). Look for resin-soaked wood in the new shoots to detect sphaeropsis blight. You will need to scrape off the bark of the shoot with a knife to see these injuries. Search for black spots (fruiting bodies) on the dead needles and check for cankers—oblong sunken areas on the branches or stem. If girdling has occurred, the top of the tree above the canker will be dead. Cut into the dead areas and look for olive-green streaking on the resin-soaked tissue beneath the bark. (Refer to leaflet or manual to verify sphaeropsis.)

Detect eggs—Search for eggs (fall to spring). Examine the bark of the shoot tips for small elongated bumps (back cover). Cut into the bumps with a knife to verify the presence of eggs.

Detect nymphs—Observe spittlemasses on the shoots and trunk (spring only). The nymphs will be inside the spittlemasses (back cover). This is the easiest and best way to identify this insect.

Detect adults—Use an insect sweep net and sample one or several trees for adults (summer). Rapidly sweep the net up the tips of the foliage; at the end of the swing, flip the end of the net over the ring to close the bag. You may need to transfer the adults to a vial to identify them because they will attempt to fly away when the bag is opened. Compare specimens with drawings and photos in this handbook. Do not confuse the collected insects with the related, similar-looking Saratoga spittlebug, which is lighter in color and has a whitish arrow-shaped mark on its head and thorax. (Refer to Wilson 1987 to identify the Saratoga spittlebug.)

"Black light" (that is, ultraviolet light) and CO_2 traps may be used to detect the adult pine spittlebug if it is not particularly abundant. When set out for other purposes, both kinds of traps have captured the adults (Mead 1963).

Control Tactics........

The various means that have been proposed or tried to control spittlebug outbreaks are presented here. A few have proven useless, others are outmoded, and some are of historical value only. Certain approaches, however, show promise for present and future spittlebug management programs.

Biological control—McIntyre (1939) says that the extensive 1938 outbreak in the Hudson Valley Region of New York subsided from a fungal disease. The disease occurred in July and caused a sudden reduction in spittlebugs. Henry and others (1938) identified the disease organism as *Entomophthora aphrophorae* Rostrup.

They speculated that heavy buildup of the fungus should occur at about 9-year intervals—the period the insect seemed to cycle in New York and Pennsylvania. A species of *Hirsutella* attacked the spittlebug in Florida, an ideal location for a fungal infection because of the high humidity (Wilkinson 1900).

Many insects and spiders prey on the spittlebug. Adults and nymphs that leave the spittlemass are most amenable to predation. Prebble (1933) found a second-instar nymph of the pentatomid *Podisus serieventris* Uhler attached to an adult pine spittlebug that was flying when captured. He notes that the young nymphs of the bug are especially active and aggressive predators. Speers (1941) said a species of *Podisus* was the most numerous predator in his studies, and he saw them feeding on nymphs on several occasions. Speers (1941) also noted another bug of the genus *Nabis* and spiders feeding on the nymphs. Knull (1932) saw a reduviid bug, *Pselliopsis cinctus* Fab., and a specid wasp, *Hoplisus atricornis* Pack., feeding on adults. He said that many mites were often on the bodies of the adults.

Cultural control—Henry and others (1938) proposed early thinning to increase the vigor of Scotch pine trees. Speers (1941) suggested thinning stands as they begin to close. This, he said, would work because it would warm the stand and allow the trees to grow better. He suggested that warmth and the additional air circulation would increase insect mortality and also recommended not mixing other conifers with Scotch pine. He proposed removing dead and dying branches to destroy egg sites because he noted that pruned stands showed much less injury than dense unpruned stands. Wilson and Mosher (1981) also recommended thinning to increase vigor but discouraged planting Scotch pine except for Christmas trees. They suggested cutting all abandoned Scotch pine Christmas tree plantations and replanting them with less susceptible species.

Augmenting a pine stand by fertilization has not been attempted as a means to manage the spittlebug. In the future it may become practical to apply nitrogen and minerals from excess municipal waste water and sludge. However, caution is needed when adding nitrogen. Nitrogen is essential for tree growth, but nitrogen in tree sap is used as food by spittlebugs.

Chemical control—The pine spittlebug became a serious pest only after Scotch pine was widely planted. Arsenical pesticides, although they were readily available, are stomach poisons and not effective for controlling this insect. At first, most experts recommended simply hosing small trees with a strong stream of water to dislodge the nymphs, a practice that is still recommended today for ornamentals (McDaniel 1937, Beal and others 1952). Once the nymphs hit the ground, most find it difficult to reestablish themselves on the trees. However, researchers soon concentrated on the botanical insecticides. But, because of limited technology, treatments worked only in young stands and in small ornamental plantings where spraying equipment was capable of providing enough pressure to penetrate the spittlemasses.

Nace (1930) was the first to try nicotine sulfate as a soapy solution on infested ornamentals. Shortly after, Knull (1932) tested pyrethrin in 50 gallons of water and 1.5 pounds of laundry soap, and got 100% control of the late-instar nymphs. When he tested "Levosol" as a dust formulation, it failed to control the nymphs and it burned the foliage. Later, Felt and Bromley (1937) tested oil solutions of nicotine sulfate and pyrethrin. They found that 40% nicotine sulfate in summer oil gave only partial control, but a solution of nicotine sulfate as a pine oil emulsion gave complete control. Pyrethrin soap with crystal oleate also gave complete control. These treatments were recom-

Table 2—Toxicity of several chemical insecticides to nymphal pine spittlebugs on pitch pine

Insecticide (wettable powder)	Concentration (lbs/100 gal H_2O)	Percent mortality
DDT (50%)	2.0	95.1
Methoxychlor (50%)	2.0	100.0
Malathion (25%)	1.0	100.0
Dieldrin (50%)	1.0	100.0
Lindane (25%)	1.0	100.0
Lindane (25%)	0.5	100.0

Data taken from Kerr (1956).

mended by Pirone (1941) as the best to date. McDaniel (1937) suggested that applying the chemicals at 400 to 500 pounds of pressure at double the dosage used for aphids would control the nymphs. Henry and others (1938) recommended pyrethrin extract at 1 pint per 50 gallons of water as the standard level for nymphs. Craighead (1950) echoed his recommendations in 1950. Attempts to control the adults with the botanicals generally failed because the adults jumped away at the first sign of disturbance (Speers 1941).

Although forest entomologists knew since 1944 that DDT controlled the adults of the closely related Saratoga spittlebug, they did not recommend DDT and other chlorinated hydrocarbon insecticides for the pine spittlebug until the 1950's. Gesell (1951, 1955) suggested using BHC, lindane, and dieldrin on the nymphs just after they emerged, rather than on the adults. Kerr (1956) scientifically tested DDT, methoxychlor, malathion, dieldrin, and lindane on the late nymphal stages and got 95 to 100% control (table 2). He used wettable powder with a wetting-spreading-sticking resin (Triton B-1956). Later he recommended applying any of these against the nymphs as soon as the spittlemasses appeared (Kerr 1959). Janes and others (1958) suggested treating nymphs with lindane or DDT at standard prescribed rates and formulations. Rose and Lindquist (1973, 1977, 1980) suggested using contact insecticides applied under high pressure for nymphs.

Wallner and Butcher (1973) and Wallner (1975) were the first to recommend suppressing the adults instead of the nymphs in Christmas tree plantings. They suggested using either carbaryl or malathion. Additional pesticides recommended later for use on nymphs and adults were chlorpyrifos, thymet, lindane, and naled (USDA 1983). Merrill and Cameron (1986) learned from surveys that Christmas tree growers in the Northeastern United States were using lindane, carbaryl, and malathion to control spittlebugs on Austrian and Scotch pine.

Management Guidelines

Pine spittlebug management should be an integral part of forest management to prevent or control a spittlebug problem and thus maintain a productive forest. This is equally true of Christmas tree plantations. Preventive and control tactics developed for the spittlebug are compatible with current pine management practices, and can be used as needed in planning new pine or larch plantations or in managing existing plantations.

Spittlebug management begins when selecting the tree species to be planted. Although several pines and other conifers are spittlebug hosts, Scotch pine is the most vulnerable to injury and mortality. Scotch pine is also highly susceptible to several other insect pests and to sphaeropsis shoot blight and canker, so other species of trees should be considered for planting. Sphaeropsis enters the tree through wounds made by spittlebugs. Shoot infections kill current shoots and seedlings. Repeated infections, especially on the boles, initiate stem-girdling cankers that kill the trees. Scotch pine plantations attacked by both the spittlebug and sphaeropsis canker have little chance of becoming productive forests, even with repeated applications of pesticides to control these pests. Because Austrian pine is also very susceptible to infection by sphaeropsis blight, it too should be avoided as a forest plantation species.

Large monoculture plantings tend to encourage spittlebug and sphaeropsisoutbreaks. However, mixtures of pines by age and species are no better—and often worse—because damage increases on the younger or less susceptible species. Most conifers, other than Scotch pine and larch, are more tolerant of the spittlebug and somewhat less injured by sphaeropsis blight, and these may be planted with less concern of a severe problem. When the occasional problem arises, an application of an appropriate pesticide can curtail the spittlebug or the fungus on these less susceptible trees.

Existing forest stands of Scotch pine injured by the spittlebug (and sphaeropsis) should be clearcut and replaced by less susceptible species. Seldom is it economical to treat the spittlebug on Scotch pine once the stand begins to deteriorate. Early infestations might be curtailed with a pesticide (and fungicide), but one might consider clearcutting when no later than in the pulp stage to lower maintenance costs.

Forest Plantations........

- Do not plant Scotch pine or Austrian pine as a forest species.
- Plant the correct tree on the proper site. Spittlebug damage and sphaeropsis shoot blight are worse on stressed trees planted on the wrong sites.
- Do not mix a highly susceptible tree species with a less susceptible one. When practical, alternate blocks of conifers and hardwoods.
- Thin forest stands at the proper time to maintain vigor.
- Clearcut badly damaged forest stands and replant the area with more-resistant species.
- To control adult spittlebugs, apply a registered insecticide when 95% have emerged. Use a mist blower or hydraulic sprayer for small jobs, use aircraft for larger jobs.
- To control sphaeropsis, apply a registered preventive fungicide two to four times during the period of shoot elongation. Apply the fungicide at 2-week intervals.

Christmas Trees........

- Plant pest-free stock.
- Avoid planting susceptible tree species, especially on poor sites where they will be even more vulnerable to the insect and fungus.
- Do not plant trees next to windbreaks infested with the insect or the fungus.
- To control spittlebug nymphs, apply a registered insecticide with a hydraulic sprayer when the spittlemasses are present.
- To control adult spittlebugs, apply a registered insecticide with a mistblower, hydraulic sprayer, or by aircraft when 95% have emerged.

- To control sphaeropsis, apply a registered preventive fungicide two to four times during the period of shoot elongation. Apply the fungicide at 2-week intervals.

- Wash off black discoloration caused by sooty mold by spraying the affected tree parts with a solution of 4 ounces of liquid detergent mixed in 100 gallons of water. Apply under high pressure in late afternoon. Leave overnight and rinse trees with water the next morning.

- Do not grow Scotch or Austrian pines beyond Christmas tree size in areas where the pine spittlebug is a problem. Pole-size trees are especially susceptible. Clearcut these trees.

Ornamentals........

- Spray small trees with water at high velocity to dislodge nymphs from spittlemasses. Repeat a week or two later if necessary.

- Apply an appropriate registered insecticide with a high-velocity hydraulic sprayer to control the nymphs in the spittlemasses. Or, spray for the adults shortly after they emerge. Thoroughly spray all parts of the tree with a contact insecticide.

- If sphaeropsis is also injuring the tree, apply a registered preventive fungicide at the time of shoot elongation. You may need four applications at 2-week intervals.

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Notes

Pesticide Precautionary Statement........

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, drink, or smoke until you have washed them thoroughly. If you swallow a pesticide or get it in your 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 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 landfill dump, or crush and bury them in a level, isolated place.

Note: This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered.

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 United States Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Back cover (clockwise from top left)—Last instar nymph of the pine spittlebug; eggs under bark; scotch pine showing moderate injury; nymph in a spittlemass.