A Guide to Insect Injury of Conifers in the Lake States

U.S. Department of Agriculture
Forest Service
Agriculture Handbook No. 501

A GUIDE TO INSECT INJURY OF CONIFERS IN THE LAKE STATES

by

Louis F. Wilson, Principal Insect Ecologist
North Central Forest Experiment Station

Agriculture Handbook No. 501

Forest Service
United States Department of Agriculture

Washington, D.C. May 1977

FOREWORD

This booklet updates and replaces the popular 1962 bulletin "Identification of Conifer Insects by Type of Tree Injury, Lake States" by H. J. MacAloney and D. C. Schmiege, published as Station Paper 100 of the Lake States Forest Experiment Station. The original publication included about 60 major insect pests important primarily to several forest conifers in the Lake States. This fully revised and expanded version includes descriptions of more than 165 insect pests and several important diseases (that could be easily confused with insect damage) found on 19 conifers in the Lake States. It is basically a pictorial key of conifer injury to assist Extension entomologists, forest managers, and plant inspectors in identifying insect and disease problems.

Cover: Red pine with severe post-horn injury from European pine shoot moth.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $3.15 (paper cover)
Stock Number 001-000-03611-4
Class A 1.76:501

CONTENTS

	Page
INTRODUCTION	1
Tree Damage	1
How To Use This Manual	1
INJURY DIAGNOSIS	2
Symptoms and Signs	2
Types of Injury	2
IDENTIFICATION KEY TO CONIFEROUS TREES OF THE LAKE STATES	4
DEFOLIATING INSECTS	9
Sawflies	9
Leaf Beetles	24
Grasshoppers and Walkingsticks	25
Webless Moths	26
Budworms, Tubeworms, and Webworms	28
Budworm Moths	30
Needle Miners	33
SAPSUCKING INSECTS, MIDGES, AND MITES	36
Spittlebugs	37
Scales	41
Plant Lice	44
Gall Aphids	46
Thrips	49
Midges	49
Mites	51
SHOOT, STEM, AND ROOT INSECTS	53
Shoot and Bud Moths	53
Pitch-Mass and Blister Makers	56
Weevils	58
Bark and Ambrosia Beetles	67
Wood Borers	73
Ants and Termites	77
White Grubs	78
CONE INSECTS	80
Cone Beetles	81
Cone Moths	82
Coneflies	84

Page

NONINSECT MALADIES EASILY CONFUSED WITH INSECT DAMAGE 84
Diseases 85
Animals 89
Other Agents 91
PLATES 95
PLATE PHOTO CREDITS 204
INDEX TO INSECTS, BY HOST PLANTS 207
GLOSSARY 214
GENERAL INDEX 215

PLATES

	Page
Plate 1.—Conifers	96
Plate 2.—Conifers	98
Plate 3.—Conifers	100
Plate 4.—Foliage injury without webbing	102
Plate 5.—Foliage injury without webbing	104
Plate 6.—Foliage injury without webbing	106
Plate 7.—Foliage injury without webbing	108
Plate 8.—Foliage injury with webbing	110
Plate 9.—Foliage injury with webbing	112
Plate 10.—Foliage injury and webbed concealments	114
Plate 11.—Foliage injury and webbed concealments	116
Plate 12.—Foliage discolored	118
Plate 13.—Foliage discolored	120
Plate 14.—Foliage malformed	122
Plate 15.—Foliage spotted or discolored	124
Plate 16.—Foliage spotted	126
Plate 17.—Scales and aphids	128
Plate 18.—Scales and aphids	130
Plate 19.—Scales and scalelike fruit	132
Plate 20.—Woolly aphids and scales	134
Plate 21.—Aphids	136
Plate 22.—Frothy concealments	138
Plate 23.—Galls	140
Plate 24.—Galls	142
Plate 25.—Galls	144
Plate 26.—Galls	146
Plate 27.—Galls	148
Plate 28.—Galls	150
Plate 29.—Bud injury	152
Plate 30.—Shoot injury	154
Plate 31.—Shoot injury	156
Plate 32.—Shoot injury	158
Plate 33.—Shoot injury	160
Plate 34.—Shoot injury	162
Plate 35.—Branch injury	164
Plate 36.—Branch injury	166
Plate 37.—Pitch exudates (tubes)	168
Plate 38.—Pitch exudates (blisters)	170
Plate 39.—Pitch exudates	172
Plate 40.—Pitch exudates	174
Plate 41.—Pitch exudates	176

Page

Plate 42.—Stem injury 178
Plate 43.—Stem injury 180
Plate 44.—Stem injury 182
Plate 45.—Stem injury 184
Plate 46.—Stem injury 186
Plate 47.—Root and bark injury 188
Plate 48.—Root collar injury 190
Plate 49.—Wood injury 192
Plate 50.—Wood injury 194
Plate 51.—Wood injury 196
Plate 52.—Wood injury 198
Plate 53.—Cone injury 200
Plate 54.—Cone injury (red pine) 202

INTRODUCTION

Tree Damage

Insects, abundant and important members of natural communities, often feed and live on trees, sometimes damaging them. Conifers have economic value for lumber, paper, and Christmas trees, as well as aesthetic value around homes, along roadsides, and in parks. Insects and disease can reduce the value of this resource.

The term *damage* often connotes an undesirable condition that requires remedial action, but this is not always the case. Trees and insects have evolved together through eons of time and are adapted to one another. Trees can tolerate surprising amounts of insect damage with little or no effect on growth and survival. The damage described in this guide does not always imply the need for insect suppression or control, but insect damage does sometimes become intolerable; remedial action is then indeed required.

The insects and the host conifers treated in this publication are confined principally to the three Lake States—Minnesota, Wisconsin, and Michigan. A few insects from bordering States and adjacent Canadian Provinces are included because they injure the same conifers and are therefore potential Lake States pests.

Most insects that inhabit conifers can be identified easily by entomologists, but because insects are elusive and secretive creatures, they are not always available for identification when the injury is discovered. More often than not, the Extension entomologist, forest manager, or plant inspector is confronted with an injured conifer but no visible insect; thus, a practical guide is needed to help identify conifer insects by the damage they do. This manual attempts to be that guide.

How to Use This Manual

Read the first part for background information about injury diagnosis, then go to the next section on identifying the host tree, if you do not know what species it is. After identification, either turn to the section of the guide that is appropriate for the part of the tree that is injured or examine the plates, generally arranged by the part of the tree that is injured, until something appears similar to the injury. Compare the symptoms and signs given in the text or shown on the plate with those observed on the host to determine if they match. If the injury appears serious, consult a specialist to determine the course of action. Do not rely on this guide alone where high values or costs are of concern, unless you are experienced with the pests involved.

INJURY DIAGNOSIS

Symptoms and Signs

Accurate diagnosis of tree injury and identification of the cause are based on skillful observation and interpretation of available information. When the causal agent is not present or is difficult to observe, the diagnostician must rely entirely on *symptoms* and *signs*. Experience is the greatest asset in diagnosis.

The *symptoms* of an injury, such as unusual color, missing foliage, malformations, etc., are signals that something is wrong with a tree. Symptoms are helpful in diagnosis and often give some clue to the probable causes, but are seldom relied on entirely because many insects, diseases, and other agents produce similar symptoms and one agent may produce several different symptoms. Symptoms also change; yellow foliage may give way to brown foliage and then later to missing foliage if the tree or affected part dies. Furthermore, two or more agents may injure the tree simultaneously, producing not only their usual symptoms but also new ones from their interactions. Sometimes a primary agent that has unrecognizable symptoms may weaken the host; then secondary insects or diseases invade and destroy the host while showing only their symptoms.

Signs of attack, on the other hand, are more useful for identification than symptoms and are often the only way to distinguish and separate one type of agent from another. Signs include artifacts (webs, cases, bags), debris (cast skins), excretions, pitch exudations, galleries, associated insects or fungi such as ants and sooty mold, colored streaks, etc. Of course, if two insects have the same symptoms and signs, the agents themselves must be identified.

The primary agent becomes more and more difficult to identify as time elapses after injury because both symptoms and signs change. If vigorous, a tree will attempt to heal itself and may mask or outgrow the injury; if weak, it will suffer attack from other insects and fungi. Signs such as webs, excrement, cast skins, etc., also deteriorate with time, but some may remain intact for a year or more. The descriptions and illustrations presented here are mostly for fresh symptoms and signs; whenever feasible, later symptoms and signs are also given.

Types of Injury

Discolored foliage.—Discolored foliage is a symptom that can be caused by injury anywhere in the tree—roots, trunk, branches, or needles. Discolored single needles or small groups of needles usually indicate that the injury is on the needle itself. When a

cluster of needles is discolored (flagging), the injury is likely to be found within or at the base of the discolored section of the twig or branch. Sometimes flagging is also caused by nutrient deficiencies or root injury from certain insects and diseases. Blackened foliage and bark are indicative of soft scales, aphids, or spittlebugs, and are caused by a sooty mold fungus that grows on the sugary honeydew and spittle of these insects. Discoloration of needles or shoots can also be due to the eggs or bodies of the insects themselves; that is, there may be yellow eggs or red-brown scale insects present. In these instances you can identify the pest directly.

Missing foliage.—Missing foliage results not only from insect feeding but also from climatic, insect, or disease injury on other parts of the tree. Notched, broken, or hollowed-out needles are signs of direct feeding. A cluster of missing needles may indicate a defoliator if the surrounding foliage or area beneath the injury shows frass, webs, cocoons, or cast skins. The pattern of defoliation is diagnostic for some defoliators, but they are sometimes difficult to identify from signs alone.

Stunted and deformed tissues.—Galls, swellings, and fasciations are abnormal growths on needles, shoots, stems, roots, or cones that result directly from recent injuries. Excessive branching, forking, and crooking are symptoms of past injury. Reduced tree growth or stunting can result from injury anywhere in the tree. Stunting may occur gradually or be delayed until a year after the insect causing it has departed. Diagnosis is sometimes difficult.

Pitch exudations, artifacts, excretions.—Although not types of injury *per se,* signs such as exudates, artifacts, and excretions are useful in pinpointing the site of the injury and the insect pest, or at least where it was. Insects feeding or tunneling in the shoots or stems of living conifers often have a pitchy exudate surrounding or flowing from their point of entry. Those insects dwelling in dying or dead stems or shoots of trees often eject fine sawdust or coarse excelsiorlike wood shavings. Piles of this material on the ground or streaks of it adhering to the bark pinpoint the location of the insects' tunnel. Small pellets of frass (insect excrement) occur in the vicinity of or beneath damage by defoliators. Several species of defoliators construct protective artifacts such as bags, cases, or webs that are distinctive. White frothy masses resembling spittle, which occur on the twigs or branches of some trees, are excretions of spittlebug nymphs. Careful parting of a mass will reveal the insect within.

As insects develop, they grow larger by periodically shedding their outer skin. Skins of the nymphs, larvae, or pupae, as well as old eggshells, sometimes are present near the point of injury and are useful in diagnosing the species of pest.

IDENTIFICATION KEY TO CONIFEROUS TREES OF THE LAKE STATES

Coniferous trees in the Lake States include pine, spruce, fir, tamarack, hemlock, yew, arborvitae (cedar), and juniper. Many people refer to them as "evergreen trees" because all except tamarack, which is deciduous, have green, needlelike, scalelike, or awl-shaped leaves that persist for more than 1 year. Conifer seeds are borne in cones, or on yew and juniper, in berrylike structures. Most of the native Lake States conifers (except eastern redcedar) occur most abundantly north of a line through central Minnesota, central Wisconsin, and central lower Michigan. Some native and introduced species are frequently planted throughout the Lake States in forest or Christmas tree plantations, and as ornamentals in parks, yards, and along roadsides.

Determining the species of conifer attacked is the first and most helpful step in identifying injury, because a certain species may be attacked by only one kind of wood borer, cone insect, etc. The following annotated key uses some simple characteristics of healthy trees to help identify the 19 conifers most common to the Lake States.

Beginning with key number 1, select either leaves needlelike ***or*** leaves scalelike or awl shaped.

To the right of your selection is another key number. Refer to that number and repeat the selection process until the host tree species is identified.

KEY NO.		*REFER TO KEY NO.:*
1.	Leaves needlelike	2
	Leaves scalelike or awl shaped	21
2.	Leaves in bundles or in clusters	3
	Leaves not in bundles or in clusters	12
3.	Leaves in bundles of two to five	4
	Leaves numerous in cluster — TAMARACK (plate 2, *D*)	

Tamarack, *Larix laricina* (DuRoi) K. Koch, or larch, occurs throughout the Lake States, mostly in isolated stands on moist organic soils such as bogs. It is commonly associated with black spruce. An outstanding feature of tamarack is its deciduous foliage that turns yellow in autumn before falling.

4. Leaves in bundles of two to three 5
Leaves in bundles of five ..... EASTERN WHITE PINE (plate 1, *B*)

Once the commonest pine in the Lake States, eastern white pine, *Pinus strobus* L., is now found in remnant stands of medium to large trees, in scattered forest plantings, and occasionally as an ornamental. Young trees are commonly under hardwoods.

5. Leaves 4 inches long or longer 6
Leaves less than 4 inches long 9

6. Leaves flexible, 5 to 11 inches long, not sharp to the touch 7
Leaves rigid, 4 to 6 inches long, sharp to the touch, large buds with silver scales ..... AUSTRIAN PINE

Austrian pine, *Pinus nigra* Arnold, is an introduced European species planted occasionally as an ornamental or for Christmas trees.

7. Leaves 5 to 11 inches long, two or three per cluster, buds gray, bark brown 8
Leaves 5 to 6 inches long, two per cluster, buds brown, bark tan, needle breaks when folded double ..... RED PINE (plate 1, *A*)

Red pine, *Pinus resinosa* Ait., sometimes called Norway pine, is the predominant reforestation species in the Lake States. It occurs abundantly in forest plantations in the boreal forest zone of the Lake States and is commonly planted along roadsides.

8. ..... PONDEROSA PINE

Ponderosa pine, *Pinus ponderosa* Laws., is an introduced species from western North America that is planted occasionally as an ornamental.

9. Conifer is distinctly a tree 10
Conifer is a prostrate shrub ..... MUGO PINE

Bushy and seldom over 3 feet tall, mugo (or mugho) pine, *Pinus mugo* Turra, is cultivated as an ornamental throughout the Lake States.

10. Leaves ¾ to 1¼ inches long; cones closed, curved, and projecting toward tip of branch; bark black 11
Leaves 1¼ to 3 inches long, cone curved and projected toward trunk, bark orange to red brown .....
SCOTCH PINE (plate 1, *D*)

Scotch pine, *Pinus sylvestris* L., is the most common introduced European species in the Lake States. It is planted widely for Christmas trees and occasionally as an ornamental in yards or along roadsides.

11. ..... JACK PINE (plate 1, *C*)

Jack pine, *Pinus banksiana* Lamb., is abundant on sandy soils in the boreal region of the Lake States, especially in areas repeatedly burned. Plantations and pure stands are common. Other pines and hardwoods are sometimes associated with jack pine.

12. Leaves four sided in cross section 13
Leaves not four sided in cross section, flattened 17

13. Leaves nearly square in cross section 14
Leaves diamond shaped in cross section, twig orange from below, buds orange ..... NORWAY SPRUCE

Norway spruce, *Picea abies* (L) Karst, is a widely planted, introduced species used as an ornamental and in windbreaks.

14. Leaves on sterile shoots (no cones) up to ¾ inch long 15
Leaves on sterile shoots (no cones) longer than 1 inch, rigid, tips sharp to the touch, commonly colored dull bluish green, dark steel blue, or silvery white .....
BLUE SPRUCE (plate 2, *B*)

Blue spruce, *Picea pungens* Engelm., is introduced from western North America and commonly planted as an ornamental around homes because of its attractive color.

15. Leaves blunt and projecting evenly around shoot, appearing like a bottle brush; buds short, dark brown ---- 16
Leaves pointed, crowded on upper surface because lower leaves bend upward; buds tan ---- WHITE SPRUCE (plate 2, *A*)

White spruce, *Picea glauca* (Moench) Voss, grows commonly in the boreal zone of the Lake States on various soils. It is often associated with black spruce, balsam fir, and aspen. Sometimes grown in plantations and along roads.

16. ---- BLACK SPRUCE

Black spruce, *Picea mariana* (Mill.) B.S.P., occurs commonly in the boreal zone of the Lake States on organic and mineral soils. Usually the most common tree in bogs where it may grow pure or with tamarack. Upland black spruce commonly grows with balsam fir and white spruce.

17. Leaves with a petiole ---- 18
Leaves without petiole, dark brown above and silvery white below; buds tan and rounded; flush round leaf scar; stem with pitch blisters ---- BALSAM FIR (plate 2, *C*)

Balsam fir, *Abies balsamea* (L). Mill., occurs commonly in the boreal zone of the Lake States on podzolic soils and frequently grows with white and black spruce and aspen.

18. Buds oval or rounded ---- 19
Buds long, pointed, and dark brown; bracts on cones extending beyond scales; bark reddish brown ---- DOUGLAS-FIR

Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, was introduced from western North America principally for Christmas trees. Some varieties are planted as ornamentals.

19. Leaves pea green below, a shrub, red berrylike fruit ---- 20
Leaves not pea green below ----

EASTERN HEMLOCK (plate 3, *A*)

Eastern hemlock, *Tsuga canadensis* (L.) Carr., occurs mostly in the boreal regions of Michigan and Wisconsin and in scattered stands in northern Minnesota. It grows on podzolic soils and is commonly found on moist sites. Many horticultural varieties have been cultivated for ornamental plantings.

20. ---------- CANADIAN YEW (plate 3, *B*)

Canadian yew, *Taxus canadensis* Marsh, is a low shrub cultivated in various forms for ornamental plantings.

21. Branchlets four angled or rounded in cross section; blue, berrylike fruit ---------- 22
Branchlets flattened in fanlike sprays, scale leaves only NORTHERN WHITE-CEDAR (ARBORVITAE) (plate 3, *C*)

Northern white-cedar, *Thuja occidentalis* L., is known as "cedar" in the wild state and "arborvitae" in horticulture. It occurs naturally throughout the boreal area of the Lake States. At least 50 varieties are cultivated as ornamentals.

22. Leaves awl shaped from 1/3 to 1/2 inch long, a shrub ---- 23
Leaves mostly scalelike and tight to branchlets, about 1/16 inch long ---------- EASTERN REDCEDAR (JUNIPER) (plate 3, *D*)

Eastern redcedar, *Juniperus virginiana* L., or juniper occurs naturally in the lower half of the Lake States. There are many natural varieties and races of this species and many forms have been cultivated for ornamentals.

23. ---------- COMMON JUNIPER

Common juniper, *Juniperus communis* L., is a low shrub that occurs in Minnesota commonly in the wild state on limy soils, and throughout the Lake States as an ornamental.

DEFOLIATING INSECTS

Sawflies

Sawflies are so called because the adult female has a saw-toothed cutting structure used to make slits in needles in which she lays her eggs singly or in rows (plate 16, *A* and *B*). The larvae, which feed either singly or in groups called colonies, cause the injury.

Some species of sawflies are very destructive. These are principally the "summer" sawflies—ones that may have more than one generation per year and consume foliage of all ages. Such sawflies can completely defoliate trees in a single season. When this occurs, it will kill any of the Lake States coniferous species except tamarack. Most of the less destructive species belong to the "spring" sawfly group. These rarely kill trees directly because they feed early in the spring before the new foliage has fully appeared. Consequently, they eat only old foliage of earlier years, so the trees are never completely denuded. If defoliated repeatedly, or if under stress, such trees may succumb or become subject to attacks by other insects or diseases.

Symptoms of injury are similar for most species of sawflies, so larvae are needed to identify species (figs. 1, 2, and 3). An exception is the larch sawfly, which is easily identified because it is the only sawfly that feeds on larch foliage.

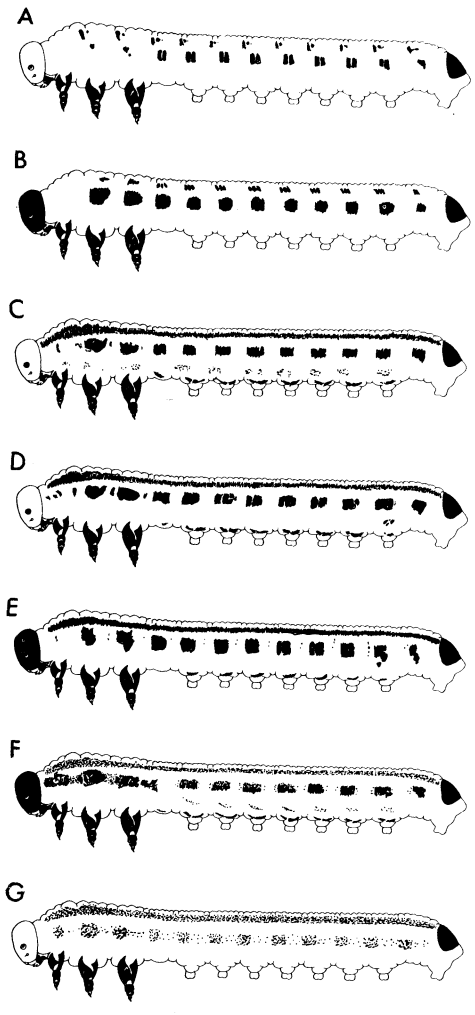
The first symptom of typical sawfly injury is brown, dried-up tufts of needles (plate 5, *A*) skeletonized by the young larvae. These tufts may contain only a few skeletonized needles if the sawfly feeds solitarily, or many needles if the sawflies feed in colonies. Parts of needles missing or needles missing down to the needle sheaths of pines (plate 5,*B*), or down to the twig on other conifers are characteristic signs of feeding by older larvae. Branches may be completely bare later in the season after injured needles and sheaths fall off. Single branches or entire trees may be completely stripped of old or both old and new foliage when sawflies are numerous (plate 4, *C*). The bark of twigs in the feeding zone may be nibbled also.

Sawfly defoliation can also be confused with defoliation by a few other insects, especially the pine tussock moth (plate 6, *C*) and the hemlock looper (plate 4, *A*). The skeletonizing done by the young sawflies (plate 5, *A*) is distinctive, but skeletonized needles remain intact for only a few weeks. Signs such as frass, cocoons (fig. 4), or cast larval skins are useful and sometimes necessary for positive identification. The full-grown larva (fig. 5) of most species of sawflies attains a length of ¾ to 1 inch.

FIGURE 1.—Conifer sawfly larvae coloration and feeding periods.

NAME	LARVAL DESCRIPTION
A. Redheaded pine sawfly, *Neodiprion lecontei* (Fitch), p. 16.	Head: Reddish brown. Body: Yellow with rows of black spots.
B. White pine sawfly, *Neodiprion pinetum* (Norton), p. 16.	Head: Black. Body: Pale yellow with rows of black spots.
C. Redheaded jack pine sawfly, *Neodiprion rugifrons* Middleton, p. 17.	Head: Reddish brown. Body: White with black spots and stripes, seven pairs of prolegs.
D. Brownheaded jack pine sawfly, *Neodiprion dubiosus* Schedl, p. 17.	Head: Reddish brown. Body: Yellow with black spots and stripes, seven pairs of prolegs.
E. A pine sawfly, *Neodiprion maurus* Rohwer, p. 17.	Head: Black. Body: Yellow green with dark-green stripes and squarish spots, seven pairs of prolegs.
F. Jack pine sawfly, *Neodiprion pratti banksianae*, Rohwer, p. 18.	Head: Black. Body: Yellow green with two pale green stripes and a third that tends to break into spots.
G. Swaine jack pine sawfly, *Neodiprion swainei* Middleton, p. 19.	Head: Brown. Body: Yellow green with two faint stripes and faint spots.

FULL-GROWN LARVA



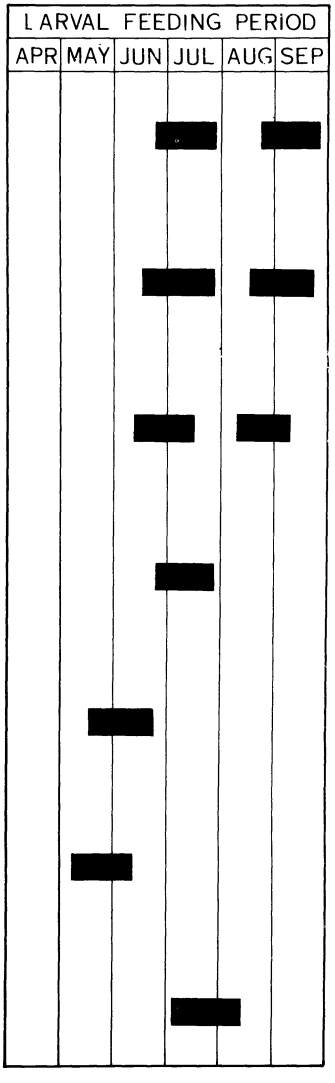
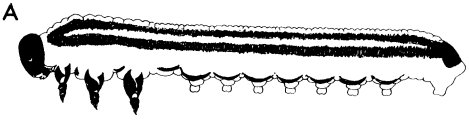


FIGURE 2.—Conifer sawfly larvae and feeding periods.

NAME	LARVAL DESCRIPTION
A. A pine sawfly, *Neodiprion nigroscutum* Middleton, p. 19.	Head: Reddish brown to black. Body: Yellow green with two broad, dark-green stripes.
B. A pine sawfly, *Neodiprion compar* (Leach), p. 19.	Head: Dark brown with mask-marked face. Body: Yellow green with two broad, dark-green stripes.
C. Abbott's sawfly, *Neodiprion abbottii* (Leach), p. 20.	Head: Black with light spot on front. Body: Yellow green with two broad, dark-green stripes.
D. Nursery pine sawfly, *Gilpinia frutetorum* (F.), p. 20.	Head: Reddish brown with black triangular marking on front. Body: Light green with green stripes.
E. Red pine sawfly, *Neodiprion nanulus nanulus*, Schedl, p. 21.	Head: Black. Body: Gray green with green stripes of various shades.
F. European pine sawfly, *Neodiprion sertifer* (Geoff.), p. 21.	Head: Black. Body: Gray green with light and dark-green stripes.
G. Balsam fir sawfly, *Neodiprion abietis* (Harris), p. 21.	Head: Dark brown to black. Body: Dull green with dark-green stripes.

FULL-GROWN LARVA

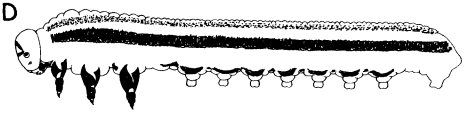
A



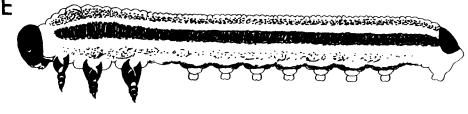
B SAME AS ABOVE

C SAME AS ABOVE

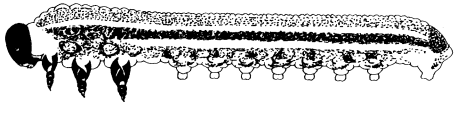
D



E



F



G

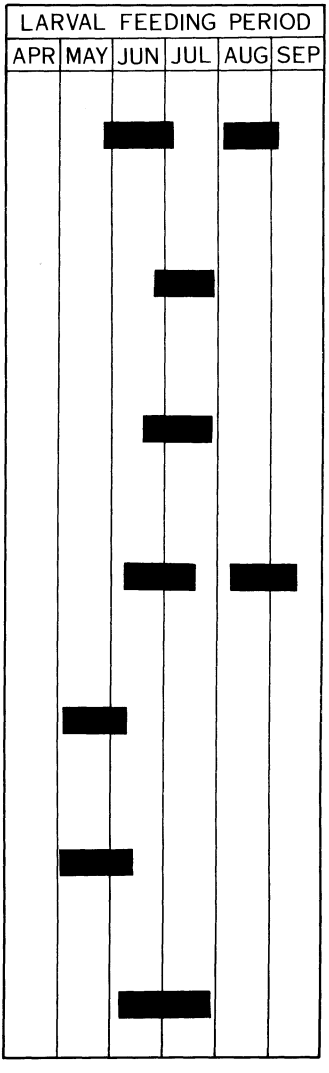
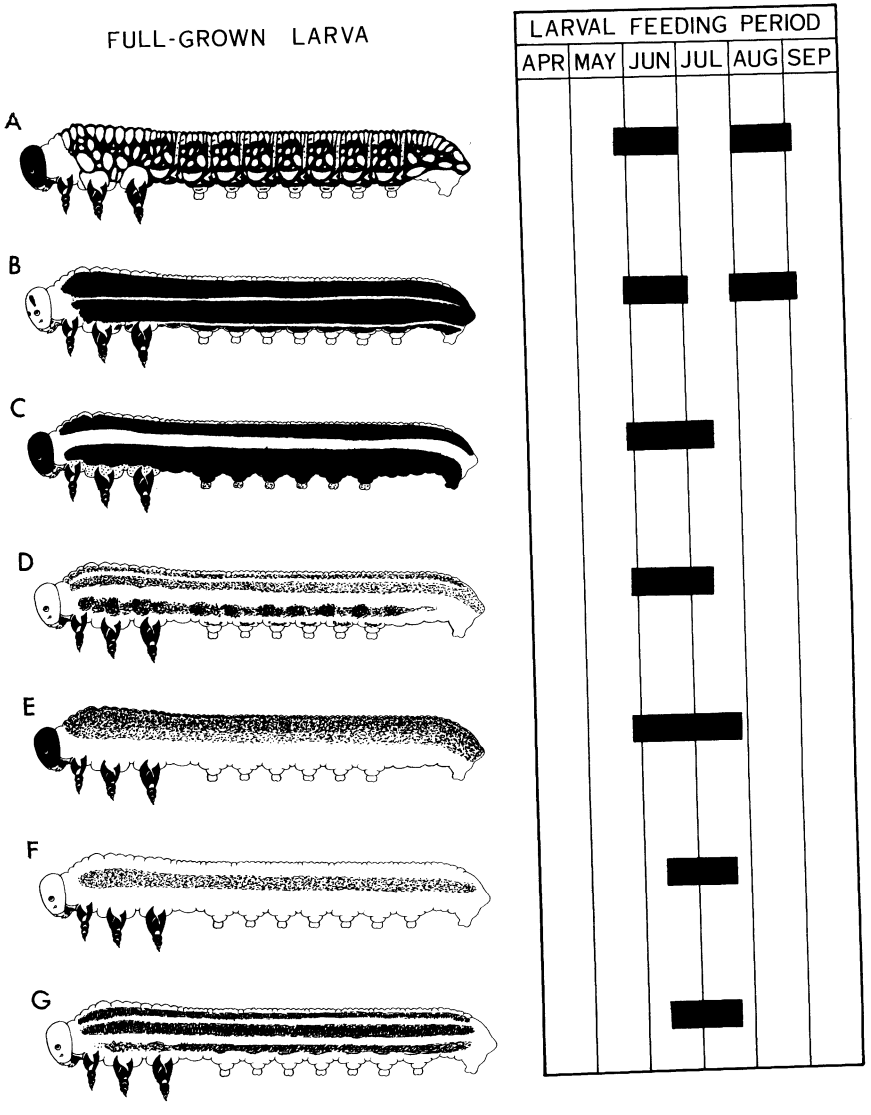


FIGURE 3.—Conifer sawfly larvae and feeding periods.

NAME	LARVAL DESCRIPTION	
A. Introduced pine sawfly, *Diprion similis* Hartig, p. 21.	Head:	Black.
	Body:	Yellow green with black stripe above yellow and white spots.
B. European spruce sawfly, *Diprion hercyniae* Hartig, p. 22.	Head:	Yellow brown with black marks.
	Body:	Dark green with five white lines.
C. Greenheaded spruce sawfly, *Pikonema dimmockii* (Cresson), p. 22.	Head:	Green.
	Body:	Dark green with light-green stripe.
D. Yellowheaded spruce sawfly, *Pi-* 22.	Head:	Yellow to reddish brown and mottled.
	Body:	Waxy, olive green with six stripes.
E. Larch sawfly, *Pristiphora erichsonii* (Hartig, p. 23.	Head:	Black.
	Body:	Dull-gray green above, paler green below.
F. Arborvitae sawfly, *Monoctenus juniperinus* MacG., p. 23.	Head:	Reddish brown.
	Body:	Yellow with light-green stripe.
G. Eastern cedar sawfly, *Monoctenus melliceps* (Cresson), p. 23.	Head:	Light brown.
	Body:	Dull green with dark-green stripes.


FULL-GROWN LARVA
A
B
C
D
E
F
G
LARVAL FEEDING PERIOD
APR
MAY
JUN
JUL
AUG
SEP

Redheaded pine sawfly ***Neodiprion lecontei* (Fitch)**

This is the most destructive pine sawfly in the Lake States. It attacks several pines of all sizes, but prefers jack and red pine, especially in plantations or in windbreaks less than 15 feet tall. The larvae feed in colonies. Their defoliation is typical for colonial sawflies, but the old foliage is eaten first, then the new foliage, especially where a second or partial second generation occurs. Tufts of dried skeletonized needles are first formed, then needles are consumed down to the needle sheaths. Some partially consumed needles, however, are left on the shoots (plate 4, *C*). Tree mortality often occurs in pockets or along edges of stands, particularly where trees are under stress.

Look for the larvae between mid-June and late July and between mid-August and late September. The full-grown larva has a reddish-brown head; the body is yellow with six rows of irregular square black spots (fig. 1).

White pine sawfly ***Neodiprion pinetum* (Norton)**

This insect seldom causes economic loss, but it can be destructive. It prefers eastern white pine, but sometimes it feeds on red and mugo pines. It feeds in colonies on both new and old foliage,

F–507932

FIGURE 4.—Sawfly cocoons.

and occasionally kills trees by complete defoliation. Defoliation is typical of colonial sawflies (plates 5, *B* and 4, *C*) ; tufts of needles are first left, then needles are eaten down to the needle sheaths. Look for the larvae between mid-June and late July and between mid-August and late September. The fully grown larva has a black head; the body is white to pale yellow with four rows of nearly square black spots (fig. 1).

Redheaded jack pine sawfly ***Neodiprion rugifrons* Middleton**

This sawfly is a serious pest on pole-size jack pine in "long summer" years, when it has two generations. In one-generation years, only the old foliage is consumed and trees are seldom killed even if heavily defoliated. In two-generation years, both the old and new foliage are consumed and trees die if larvae are abundant enough to strip them completely. The larvae are strongly gregarious and feed in large colonies—often of 125 or more. Defoliation is typical of colonial sawflies, but the location of the injury varies depending on whether there are one or two generations (plates 5, *B* and 4, *C*).

Look for the larvae of the first generation between early June and mid-July, and the second generation between early August and mid-September. The full-grown larva has a reddish-brown head; the body is white with black stripes and spots (fig. 1). The markings are nearly the same for *N. dubiosus,* but the body color differs.

Brownheaded jack pine sawfly ***Neodiprion dubiosus* Schedl**

This sawfly prefers jack pine for egg laying, but larvae may feed on red pine growing with jack pine. Its known range is northern Wisconsin and adjacent upper Michigan.

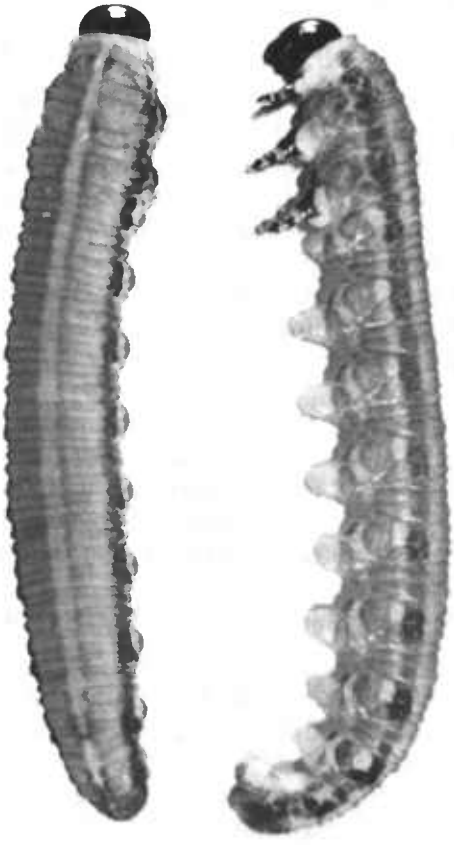
This species severely defoliates windbreak trees on occasion. The larvae are colonial, but full-grown larvae are atypical because they tend to feed in loose aggregations (plate 5, *B*).

Look for the larvae between late June and late July. The full-grown larva has a reddish-brown head; the body is yellow with black stripes and spots (fig. 1). The markings are nearly the same for *N. rugifrons,* but the body color differs.

A pine sawfly ***Neodiprion maurus* Rohwer**

Seldom a serious pest, this sawfly feeds on jack pine in Wisconsin, Minnesota, and the Upper Peninsula of Michigan. The larvae feed in colonies and consume mostly old foliage. The defoliation pattern is typical of colonial sawflies feeding on old foliage (plate 5, *B*). Young larvae skeletonize the needles leaving tufts of dry needles. The older larvae devour the needles down to the sheaths.

Look for the larva from late May to early July. The full-grown larva has a black head; the body is yellow green with dark-green stripes and squarish spots (fig. 1).



F-508525

FIGURE 5.—Sawfly larvae.

Jack pine sawfly ***Neodiprion pratti banksianae* Rohwer**

This insect occurs throughout the range of jack pine in the Lake States. It prefers jack pine but will feed on red and Scotch pine when these hosts are growing near jack pine. Occasionally it becomes abundant and causes moderate defoliation. Open-grown, even-aged stands are preferred, but the trees of all sizes are vul-

nerable to attack. Young trees seldom die even if heavily defoliated because the sawfly feeds only on the old needles. Old trees, however, sometimes die after two or more heavy defoliations because they weaken and put on insufficient new growth to sustain them.

The defoliation pattern is typical of colonial sawflies feeding on old foliage (plates 4, *B*, and 5, *B*). Look for the larvae from early May to late June. The full-grown larva has a black head; the body is yellow green with two pale greenish-gray stripes and a third darker stripe that tends to break up into spots (fig. 1).

Swaine jack pine sawfly ***Neodiprion swainei* Middleton**

This insect occurs throughout the range of jack pine in the Lake States and is occasionally destructive. It lays eggs only on jack pine as far as known, but the larvae occasionally feed on red, eastern white, and Scotch pine when these trees are grown with jack pine.

The female sawfly lays 1 to 6 eggs per needle in clusters of 30 to 80 eggs. The young larvae typically skeletonize the needles first and older larvae consume entire needles down to the fascicles (plate 5, *B*). Old foliage, however, is preferred, and new foliage is only nibbled on, producing ragged injury to the new shoots. Partially defoliated trees may dieback at the top.

Look for the larvae from late June to mid-August. The full grown larva has a brown head; the body has two faint stripes and rows of faint spots (fig. 1).

A pine sawfly ***Neodiprion nigroscutum* Middleton**

Seldom abundant, this sawfly feeds mostly on jack pine foliage. Highest populations occur on windbreaks; scattered colonies occur in natural stands. The larvae feed singly or in small colonies of rarely more than 10 insects, mainly because eggs are laid in small clusters on only one to three needles. Larvae eat both old and new foliage like the more typical colonial sawflies (plates 4, *C*, and 5, *B*), except fewer needles are consumed because there are fewer larvae.

Look for the larvae between late May and early July and between early August and early September. The full-grown larva (fig. 2) has a reddish-brown to black head; the body is yellow green with two broad dark-green stripes. The markings on this insect are almost the same as those of *N. abbotii* and *N. compar*. The latter two, however, have a white spot on the front of the head.

A pine sawfly ***Neodiprion compar* (Leach)**

This poorly known sawfly has never been a serious defoliator. It prefers jack pine but will feed on red pine. Because it commonly

feeds alone but is also found in colonies, damage can be either of the solitary or colonial sawfly type (plates 7, *D*, and 5, *B*).

Look for the larva from late June to late July. The full-grown larva (fig. 2) has a dark-brown head with a prominent white spot, giving it the appearance of being masked; the body is yellow green with two broad, dark-green stripes. The body markings on this insect are almost the same as those of *N. abbottii* and *N. nigroscutum*.

Abbott's sawfly ***Neodiprion abbottii* (Leach)**

Reported from Wisconsin, this sawfly feeds on all the hard pines. It has not been abundant in the Lake States, but it is potentially destructive.

The female sawfly lays 15 to 20 eggs close together on a single needle. The young larvae feed gregariously on surrounding needles but seldom consume this needle, so it is a distinctive sign for identifying this species in the field (plate 5, *D*).

The early larval defoliation, which is manifest as tufts of skeletonized needles, is typical of these and other colonial sawflies. Because its larval colonies are small, however, and seldom have more than 25 insects, the tufts are smaller. The older larvae tend to feed singly and thus defoliate small isolated patches of needles.

Look for the larvae from mid-June to the end of July. The full-grown larva (fig. 2) has a black head with a faint light spot on the front; the body is yellow green with two, broad, dark-green stripes. The markings on this insect are virtually the same for *N. nigroscutum* and *N. compar*. *N. nigroscutum* differs by having a reddish brown to black head without a frontal spot; *N. compar* differs by having a dark-brown head and an additional white marking on the lower part of the face.

Nursery pine sawfly ***Gilpinia frutetorum* (F.)**

This sawfly occasionally causes heavy defoliation in red and Scotch pine stands. It is sometimes called the solitary pine sawfly because it feeds singly. Light infestations are not readily detected because the larvae blend well with the foliage. Excrement or green needle fragments on the ground beneath infested trees commonly betray their presence before they are seen. Defoliation takes the form of missing needles in small patches (as in plate 7, *D*) that coalesce when larvae are abundant. Larvae eat both old and new foliage, especially if there is a second generation.

Look for the larvae between early June and early July and between late July and early September. The second to the last larval stage (fig. 2) has a reddish-brown head with a black triangular marking on the front; the body is light green with a dark and

light stripe. The full-grown, last-stage larva is marked the same but lighter.

Red pine sawfly ***Neodiprion nanulus nanulus* Schedl**

This insect occasionally becomes abundant in red and jack pine stands. It attacks trees of all sizes in open and closed stands, but rarely are they injured permanently because the sawfly feeds only on old needles. The larvae feed in colonies, but the injury is atypical of colonial sawflies. Injury differs because the larvae consume just about three-fourths of the needles, leaving needle stubs ¾ to 1¼ inches long on red pine and ¼ to ⅓ inch long on jack pine (plate 5, *C*). This sawfly can be identified from these stubs that remain on the branches throughout the year.

Look for the larvae from early May to mid-June. The full-grown larva has a black head; the body is dull gray green with stripes of various shades of green (fig. 2).

European pine sawfly ***Neodiprion sertifer* (Geoff.)**

This sawfly was introduced in eastern North America from Europe and is now present in Michigan and Wisconsin. Commonly abundant on pines of all sizes, it causes heavy defoliation, but because it feeds only on old needles, trees seldom die—even after repeated defoliation. It prefers Scotch pine but will attack red, jack, and sometimes other pines.

The defoliation pattern is typical of colonial sawflies feeding on all foliage (plates 5, *B*, and 4, *B*). Look for the larvae from early May to mid-June. The full-grown larva has a black head; the body is gray green with several light- and dark-green stripes that tend to break up into spots (fig. 2).

Balsam fir sawfly ***Neodiprion abietis* (Harris)**

This sawfly is occasionally destructive to ornamentals and forest stands of balsam fir. This species, or perhaps a closely related species, sometimes attacks spruce. Outbreaks have occurred but they have neither been extensive nor serious. The larvae feed in colonies and consume old foliage first and new foliage later. The defoliation pattern is typical of colonial sawflies(plate 5, *B*).

Look for the larvae between early June and early August. The full-grown larva (fig. 2) has a dark-brown to black head; the body is dull green with dark-green stripes. The cocoons are generally spun on the foliage.

Introduced pine sawfly ***Diprion similis* Hartig**

This insect was introduced in eastern North America and has since spread throughout most of the Lake States coniferous forests.

Its favorite host is eastern white pine, but occasionally it injures Scotch, jack, and red pine. It attacks trees of all sizes, preferring ornamental, nursery, and plantation trees. The young larvae feed in colonies; the older ones feed alone. Consequently, early defoliation manifested as dried needle tufts is typical of colonial sawflies (plate 5, *B*), and late defoliation is more like that of solitary sawflies (plate 7, *D*). Defoliation appears as missing needles that coalesce into larger patches when larvae are abundant. First-generation larvae feed on old foliage; second-generation larvae feed on old and new foliage.

Look for the larvae between late May and early July and between late July and early September. The full-grown larva has a black head; the body is yellow green with a black double stripe above and numerous yellow and white spots (fig. 3). The markings are unique and easily distinguished from those of other sawflies on conifers. The egg cluster of this species is distinctive because it is covered with a mucilaginous substance.

European spruce sawfly ***Diprion hercyniae* Hartig**

Introduced from Europe, this sawfly has caused extensive defoliation and mortality in eastern North America, and has been detected in Wisconsin. It feeds on white, black, and other spruces of all sizes. It prefers old foliage but will consume either old or new when the larvae are nearly mature. Injury is similar to that of solitary sawflies (plate 7, *D*). Heavily infested trees are commonly completely defoliated and killed.

Look for the larvae between mid-May and late June and between mid-July and late August. The full-grown larva has a yellow-brown head with black marks on the front and sides; the body is dark green (fig. 2). Five narrow white lines run the length of the body in all stages except the last.

Greenheaded spruce sawfly ***Pikonema dimmockii* (Cresson)**

An uncommon insect, this sawfly has never caused serious defoliation. It is known in Ontario and may occur in the Lake States. It feeds on white, black, and blue spruce.

Look for the larvae from early June to early August. The full-grown larva has a green head; the body is striped light and dark green (fig. 3).

Yellowheaded spruce sawfly ***Pikonema alaskensis* (Rohwer)**

When abundant, this sawfly is very destructive to white, black, and blue spruce. It prefers open-grown trees. Most dense stands,

natural or planted, typically remain free from attack. Damage is most severe on windbreaks, ornamentals, nursery seedlings, young plantations, and trees in naturally regenerated cutover areas. The larvae are semicolonial—they feed in loose clusters on the new foliage first and then on the old foliage. Tips of infested branches appear ragged (plate 7, *D*) and contain brown needle stubs. Trees that are completely defoliated by midsummer die; those with some foliage remaining may live, but usually lose some branches.

Look for the larvae from late May to mid-July. The full-grown larva has a yellow to reddish-brown head that is mottled; the body is waxy, olive green, with six gray-green stripes of various widths (fig. 3).

Larch sawfly ***Pristiphora erichsonii* (Hartig)**

This is one of the most destructive sawflies in the Lake States. It kills some tamarack stands yearly, especially in Minnesota. Tamarack, however, because it is deciduous and refoliates every year anyway, does not die readily from the effects of defoliation. Nonetheless, even apparently vigorous trees will die after 6 to 8 years of moderate defoliation. Less thrifty trees may succumb after only 3 or 4 consecutive years of attack. The larvae feed in colonies (as in plate 5, *B*) but even then they are difficult to see because they are the same color as the foliage. Before defoliation is readily noticed, frass and needle remnants beneath the tree betray the insect's presence. Trees may be completely defoliated by the time the larvae are fully grown.

This is the only sawfly in the Lake States that lays its eggs in the new shoot twigs instead of the needles (plate 31, *A*). The injured shoots become curved or curled as they grow (plate 31, *B*). This so-called "pigtailing" is a good sign of an impending infestation before the larvae appear.

Look for the larvae from early June to late September. Larvae vary widely in size during this period. The larva (fig. 3) has a black head; the body is dull gray-green above, paler below.

Arborvitae sawfly ***Monoctenus juniperinus* MacG.**

This sawfly is an occasional pest of ornamental juniper and aborvitae. The larva feeds singly and destroys small groups of needles. Look for the larvae during June and July. The full-grown larva has a reddish-brown head; the body is yellow with a light-green stripe (fig. 3).

Eastern cedar sawfly ***Monoctenus melliceps* (Cresson)**

This sawfly occasionally causes minor defoliation on juniper and arborvitae and is usually a pest on ornamentals. The larvae feed

singly, destroying leaves partly to completely. Look for the larvae during June and July. The full-grown larva has a light-brown head; the body is dull green with darker-green stripes (fig. 3).

Leaf Beetles

Adult leaf beetles are foliage feeders. Outbreaks are seldom severe and are usually localized. Because these beetles feed mostly on new foliage, few trees die. Usually the trees are weakened and lose some growth.

Pine chafer — *Anomala oblivia* Horn

The pine chafer sometimes becomes abundant and defoliates sapling pines in natural and planted stands in Michigan. It prefers jack pine but commonly attacks red, eastern white, and Scotch pine.

F–521434

FIGURE 6.—Pine chafer adult.

The adult beetles gnaw the side of the needles through the fascicles. Feeding usually stops before the needle is severed, causing it to droop (plate 6, *A*). New needles are injured in June and July before full development; old needles are eaten only after most of the new ones are destroyed. Afflicted needles turn brown so from

a distance heavily infested trees appear scorched. The portion of the needle above the injury later falls off, leaving an irregular needle stub. Although the injury may superficially resemble "needle blight" midge (p. 51), needle droop (p. 86), or the pine needle sheathminer (p. 34), it differs from the foregoing pests in that it occurs earlier in the year, it lacks webbing, and the beetles gnaw through the fascicle.

Look for the adult beetles, which feed during the daytime, during June and July. They are ¼ to ⅜ inch long; the female (fig. 6) is tan or light brown; the male is dark brown.

Pine chrysomelid ***Glyptoscelis pubescens*** **(Fab.)**

This beetle occasionally becomes abundant in pine stands and causes heavy defoliation and growth loss. It prefers eastern white, red, jack, and Scotch pine. Spruces and hemlock are occasional hosts.

On pines, the male cones (plate 53, *A*) are destroyed by early feeding. Later damage is to clusters of very young developing needles that are eaten down to the needle sheath (plate 7, *B*). Older needles are notched at various intervals along their lengths (plate 7, *A*). These turn brown later and break off. Notched needles on pine are diagnostic for this insect. The needle damage resembles that of the adult black vine weevil and strawberry root weevil (plate 6, *B*), but they do not attack pine. In the spring look for the small adult beetles, which are brown with a brassy sheen and covered with short hairs.

Grasshoppers and Walkingsticks

Conifers are not the normal host plants for grasshoppers and walkingsticks—at least in the Lake States. Both, however, feed on conifers when their normal food source is depleted.

Grasshoppers ***Melanoplus*** **spp.**

Both nymphs and adults of grasshoppers sometimes defoliate conifers. Seedlings and windbreak trees are most susceptable to injury, especially if growing adjacent to fields of small grains. Grasshoppers may destroy seedlings but usually injure older trees only in the lower few whorls.

Clusters of needles chewed off near the middle or notched and broken over are symptoms of attack (plate 6, *D*). Bark of the young stems may be nibbled. Most injury occurs in late summer after grain fields are harvested.

The walkingstick rarely attacks conifers. The adult walkingstick, however, sometimes moves to and feeds on conifers growing beneath or near hardwoods—their normal hosts. They have been found feeding on Scotch pine and eastern white pine. The latter is commonly planted beneath hardwoods.

Needles that are partly chewed off give the tree a ragged appearance, the main symptom of attack. This damage is indistinguishable from defoliation of most solitary sawflies (as plate 7, *D*). The adult is thin and sticklike. Walkingstick eggs, which are small and seedlike, are laid on the soil beneath injured trees and indicate the presence of this insect. Finding these eggs requires careful sifting of the soil.

Webless Moths

Webless moths—insects that produce little or no webbing except when spinning their cocoons—defoliate conifers and include loopers, tussock moths, and the giant silkworms.

Loopers are so called because the larvae "loop" the midportion of their bodies while walking. This they must do because they have only two or three pairs of prolegs on the abdomen instead of the usual five or mroe of most caterpillars (fig. 7). Tussock moths are so called because the larvae are tufted with short brushes and long

F–521506

FIGURE 7.—Looper larva.

pencils of hairs. Giant silkworms are a group of large moths whose larvae usually feed on hardwoods; one species is occasionally found on pine.

Hemlock looper ***Lambdina fiscellaria fiscellaria* (Guen.)**

The hemlock looper mounts severe and prolonged outbreaks in mature and overmature stands. It prefers eastern hemlock and balsam fir, but will attack a wide variety of conifers and hardwoods.

Browning of the foliage in July is a prominent diagnostic sign of an attack. This coloring is due to the browning of the remains of needles partly devoured by the larvae. Young larvae feed on current year's foliage and older larvae on the old foliage. Nearly all needles may be damaged or devoured on a severely infested branch or tree (plate 4, *A*). Trees that lose more than 90 percent of their foliage die the folowing winter. In a typical outbreak small patches of heavily infested trees are surrounded by untouched stands.

The larvae are typical loopers (as fig. 7), and are mottled with colors ranging from greenish yellow to brown to black.

Pine tussock moth ***Dasychira plagiata* (Walker)**

The pine tussock moth is a serious pest that commonly attacks large acreages of sapling and pole-sized conifers, especially in northern Wisconsin. It prefers jack pine but attacks red and eastern white pine, too. Spruces and firs are occasional hosts.

The young larvae feed in the male cones (plate 53, *A*). The feeding damage done by the older larvae is similar to that of the solitary sawflies but generally more ragged (plate 6, *C*). New and old foliage is eaten down to the needle sheath so that small stubs remain on the twigs. When larvae are abundant, they completely defoliate and kill the trees.

The larvae, cocoons, or egg masses on the foliage are easily identified. The larva is a gray brown, hairy caterpillar (fig. 8) up to 1½ inches long, with four tufts of grayish hairs on the back. Gray-brown cocoons (plate 6, *C*), made of silk and hairs, and whitish egg masses are attached to the needles.

Imperial moth ***Eacles imperialis* (Drury)**

Usually a rare insect, the larvae of this variety of imperial moth may become locally destructive. They defoliate eastern white, red, and jack pine and sometimes juniper, preferring open-grown saplings. The damage is nearly typical of solitary defoliators—needles of all ages are removed in patches, but mostly on the noth side of the tree. The damage resembles that of the pine tussock moth and some sawflies (plates 6, *C*, and 7, *D*).

The larvae is needed for positive damage identification. It is at least 2 inches long when fully grown, pale to dark green with reddish-purple markings. The body is covered with short stiff hairs; there are spines on the second and third abdominal segments.

F-523402

FIGURE 8.—Pine tussock moth larva.

Bagworms, Tubeworms, and Webworms

This group includes a heterogenous array of defoliators that construct conspicious concealments (bags, tubes, or webs) from which they feed. Most of these are moths, but certain sawflies (*Acantholyda* spp., *Cephalcia* spp.) are also included here because

their habits are unlike typical sawflies, and their nests are similar to and easily confused with the true webworms. All are injurious in the larval stages.

Bagworm ***Thyridopteryx ephemeraeformis*** **(Haw.)**

The bagworm is a serious defoliator of sapling trees and shrubs in urban areas. It also attacks forest trees but seldom is economically important. It is uncommon in the Lake States. The bagworm prefers arborvitae but commonly attacks juniper. Other conifers are seldom attacked. This pest also feeds on hardwoods.

The conspicious bags are diagnostic for this species (plate 10, *B*). They are 1¾ to 2 inches long and consist of a silken case covered with pieces of needles. They differ slightly in appearance depending on the host tree. Needles are stripped from trees by the larvae, usually from the tree top down. Trees die when heavily defoliated. Shoot flagging also occurs because of the tight silken band around the twig with which the larva attaches the bag. Bags may remain attached to the tree for a year or more after they are abandoned.

Pine tube moth ***Argyrotaenia pinatubana*** **(Kft.)**

The pine tube moth is occasionally abundant on eastern white pine of all sizes, but it is not economically important. At worst the trees are unsightly because of the webbed tubes.

The cylindrical tubes made from foliage and silk are diagnostic for this insect. The tubes are comprised of 5 to 20 needles bundled together to form a chamber (plate 10, *C*). Young larvae mine the needles. The older ones feed on the tips of the needles, keeping them all flush on the free end. When the tube has been shortened to about 1 inch, the larva abandons it and makes a new one. Tubes are formed all summer because there are two generations each year.

Juniper webworm ***Dichomeris marginella*** **(D. & S.)**

The juniper webworm is a pest introduced from Europe. It is sometimes a serious defoliator of nursery seedlings and sapling ornamentals. It feeds on all varieties of junipers but prefers *Juniperus squamata* var. *Meyeri,* a dense shrub.

The young larvae are needle miners (plate 9, *A*). The older larvae live in nests, which are diagnostic for this species. Nests are 2 to 3 inches long and consist of twigs webbed together with threads spun by several small, light-brown larvae (plate 11, *A* and *B*). The larvae feed on foliage in and near the nest. Hundreds of nests may occur on the same tree. Look for the larvae in the nests from April to early June and in September.

Pine webworm ***Tetralopha robustella* Zell.**

The pine webworm occasionally becomes serious on pine seedlings and saplings; it is of no economic importance on larger trees. It prefers jack, red, eastern white, and Austrian pines.

The conspicuous elongated or globular mass of excrement held together by silk and honeycombed with silken tubes is evidence of this insect (plates 10, *D*, and 11, *D*). This nest may contain 25 or more larvae and be up to 6 inches long. The larvae skeletonize or chew off the needles surrounding the nest. The nest and damage can easily be confused with those of the nest-making sawflies, *Acantholyda* and *Cephalcia*. However, the yellowish-brown striped webworm larvae are readily distinguished from the sawfly larvae by its eight pairs of legs and no spines. The sawflies have only three pairs of legs and a pair of short spines on the sides of the last segment.

Pine false webworm ***Acantholyda erythrocephala* (L.)**

The pine false webworm is an introduced pest that is now the commonest nest-building sawfly in the Lake States. It has never been a severe pest, however, even when locally abundant. It favors eastern white pine but will feed on red, Scotch, and other pines.

Conspicious nests or shelters up to 6 inches long are formed of loose silk and filled with much excrement (plate 11, *C*). Look for larvae living singly or in small colonies in the nests. The nests are similar to those of the pine webworm and the nesting pine sawfly. The larvae are distinctive. The *A. erythrocephala* has three pairs of legs, a yellow head with brown spots, green body, and purplish-red stripes.

Nesting pine sawfly ***Acantholyda zappei* (Rohwer)**

The nesting pine sawfly (*A. zappei*) and other nesting sawflies (*Cephalcia* spp.) are seldom found on conifers in the Lake States. They are usually economically unimportant. *A. zeppei* prefers jack, red, and Austrian pines. *Cephalcia* spp. feed on most conifers.

The frass-filled nests of *A. zappei* are similar to those of the pine false webworm and pine webworm (plate 11, *C* and *D*) but smaller and usually solitary (plate 10, *D*). The larva has three pairs of legs, a brown head, and a green body.

Budworm Moths

Budworms, the larvae of certain moths, are so called because when young they bore into and destroy the buds of conifers. Older larvae feed on the foliage. There are three destructive and two less

important species in the Lake States. All species do similar damage, but they are easily separated by their hosts and their different larvae.

Spruce budworm ***Choristoneura fumiferana*** **(Clemens)**

This insect is the most widely distributed forest defoliator in eastern North America. It has mounted severe outbreaks at frequent intervals during the past 150 years and killed millions of trees. Mature and overmature trees are most susceptible to attack but trees of all sizes, including seedlings, are injured or killed during an outbreak. Balsam fir and white spruce are the preferred hosts in the Lake States, especially in the boreal forests of Minnesota. The insect also feeds on other spruces, larch, and pines if they are growing along with the preferred hosts.

FIGURE 9.—Budworm pupal case.

F–521435

Symptoms of an outbreak are heavily defoliated, dead, dying, and top-killed trees. Browning or reddish foliage is loosely webbed onto the shoots by larval threads. This browning foilage consists of remnants of needles mined by young larvae and partly consumed needles fed on by the older larvae (plate 8, *A*). Besides the needle remnants, the webbing contains frass, cast larval skins, pupal cases (fig 9), and other debris that are useful for identification when the

larvae are absent. The young larvae also mine the buds (plate 29, *D*) and male flowers (plate 53, *A*).

Young larvae are light brown with black heads; mature ones are gray-brown with small cream-colored spots along the sides (plate 8, *A*). They resemble larvae of the jack pine budworm on pine, but they are readily distinguished by their different hosts.

Jack pine budworm ***Choristoneura pinus*** **Freeman**

This pest is the most important defoliator of jack pine in the Lake States. Large and small outbreaks occur frequently. The larvae also feed on red, Scotch, and eastern white pine if growing beneath or adjacent to infested jack pine. They attack jack pines of all sizes, but especially ones with abundant male flowers (plate 53, *A*).

Symptoms of an outbreak are heavily defoliated, dead, and dying trees. Browning or reddish foilage, loosely webbed onto the shoots, consists mostly of partly consumed needle remnants (plate 8, *B*). The webbing also contains frass, cast larval skins, pupal cases (fig. 9), and other debris useful for identification when larvae are absent. The young larvae mine fascicles of new needles. After the supply of new foliage has diminished, the large larvae feed on the older needles.

Young larvae are brown with black heads; mature ones are reddish brown with small cream-colored spots along the sides. They resemble larvae of the spruce budworm on spruce and balsam fir (plate 8, *A*) but can be readily distinguished by their different hosts.

Eastern blackheaded budworm ***Acleris variana*** **(Fern.)**

This insect attacks trees of all ages and when conditions are favorable, it increases in numbers sufficiently to kill them. Sometimes there are large-scale outbreaks in mature and overmature forests. It prefers balsam fir but attacks white and black spruce during epidemics.

Symptoms of its injury are typical for budworms. Trees are defoliated, the top is killed, or they die, depending on severity of attack. Partially eaten needles, which are reddish, cling to twigs by loose webbing similar to that of the spruce budworm (plate 8, *A*). Larvae prefer new foliage but will feed on old and mine the buds. The webbing also contains frass, cast larval skins, pupal cases (fig. 9), and other debris that are useful for identification when larvae are absent.

The damage of the blackheaded budworm (plate 8, *A*) is similar to that of the spruce budworm on the same hosts. The larvae, how-

ever, are different and should be used for identification. The immature larva of the blackheaded budworm is pale yellow with a black head; the full-grown one is yellow green with a light-brown head.

A tip moth ***Tortrix pallorana* (Rob.)**

This insect is rare but sometimes becomes abundant locally. It prefers eastern white pine but will attack red, jack, and Scotch pine. Young saplings 3 to 7 years old are most commonly attacked.

The larva of this insect webs two or more new shoots together before they are fully expanded. It eats only part of the needles within the web and tunnels into and kills one or more of the shoots. These dying shoots droop in mid-May, (plate 30, *A*) but webbing is present. The injury to the needles from feeding (plate 8, *C*) resembles that of the jack pine budworm, but the *Tortrix* larva is yellow brown in contrast to the brown or reddish-brown budworm larva.

Needle Miners

The true needle miners are small moths that excavate tunnels within needles during their entire larval period. True needle miners are identified by the presence of a few to several mined needles adjacent to one another. Injured needles are yellowish and when held up to the light they appear hollow. Presence of a pupal case in a mine is also diagnostic.

The larvae of certain other moths cause insignificant damage as needle miners during their early stages. However, they are more noteworthy by the damage they do later by boring in expanding buds and cones, or by direct defoliation, and are therefore discussed under those damage categories. Representative species include the spruce budworm (p. 31), the jack pine budworm (p. 32), the spruce coneworm (p. 83), the juniper webworm (p. 29), and the pine tube moth (p. 29).

Spruce leafminer ***Epinotia nanana* (Treit.)**

This is a needle miner common on most species of spruce. It occasionally causes heavy defoliation in forests but is more commonly a pest of ornamentals. Look for four to eight needles mined from the base to the apex. Some loose silk webbing is spun among the mined and adjacent needles (plate 9, *C*). Most of the insect's frass is accumulated around a silken tube within which the insect pupates. Characteristically for this species, some frass is present inside the needle mines. The small larva is dirty white to reddish and has a black head.

Spruce needleminer ***Taniva albolineana* (Kft.)**

This species will attack forest-grown spruce in the Lake States but it is mostly a pest of ornamentals. Look for numerous mined needles along the shoot that are densely webbed together at their bases. The webbing is heavily filled with frass (plate 9, *B*). Several larvae usually live together in the webbing. Mined needles contain no frass but may be severed at their bases and entangled in the webbing. The small larva is greenish to greenish brown with a yellow-brown head.

Spruce leafminer ***Pulicalvaria piceaella* (Kft.)**

This miner is common on spruces but it is more often a pest of ornamentals than forest stands. Look for four to six old needles in a cluster, each needle mined from the base to the top. A loose web is spun between mined and undamaged adjacent needles (as plate 9, *C*). Characteristically, there is no frass in the mines and only a few frass pellets adhere to the webs. The small larva is reddish to light brown with a light-brown head.

Pine needleminer ***Exoteleia pinifoliella* (Chamb.)**

This insect has been collected from red, Scotch, and other pines besides jack pine, which it prefers. It occasionally becomes sufficiently abundant to be a threat to jack pine. Continuous severe attacks over a period of years will destroy its hosts. It attacks pole-size trees most often.

Usally new needles are attacked first, old ones later. Each pine needleminer larva destroys only three needles that are usually close together. The mined portion of the needles turns yellow (plate 7,*C*). Look for yellow needles that hang on overwinter and break off the next year. Old infested shoots look ragged and discolored because of the remaining needle stubs. This insect leaves no webbing.

Pine needle sheathminer ***Zelleria haimbachi* Busck**

Sometimes called the jack pine needle miner and pine needle cutter, this insect may become a pest of jack and ponderosa pines and supposedly will attack spruce and balsam fir also. It rarely causes heavy defoliation and has not yet become important in the Lake States.

Terminal needles hollowed out at their bases from summer through spring indicate the presence of this pest. Injured needles are usually near a male flower cluster (plate 53, *A*). Look for a silken tube across the bases of several needles, a small hole in the

needle sheath (plate 8, *D*), and drooping or broken off needles (plate 6, *A*) in the spring and summer. One larva may destroy up to 14 needles in a cluster. Needles are immature at the time of attack, but they do not bend over and fall off until they mature. Drooping needles resemble damage done by the pine chafer, needle droop, and needle blight, but damage from the miner can be distinguished by the holes in the fascicles and silken tubes. Pupae and cast pupal cases are found in the silken tubes in June and July.

A pine needleminer ***Argyrotaenia tabulana* Freeman**

This species is a minor pest of jack and ponderosa pine. The larva first mines a single needle from the tip to the base, then it ties a bundle of needles together and lines the cavity with silk. It adds new needles to the bundle and mines them as it develops. Look for a needle bundle that somewhat resembles that of the pine tube moth (plate 10, *C*). The latter, however, makes its bundle on eastern white pine.

A pine needleminer ***Evagora resinosae* Freeman**

This insect attacks red pine but is probably unimportant as a forest pest. Known in Canada just north of Minnesota, it probably is present in Minnesota.

One or more needles mined from the base or center to the tip is evidence of this insect. Look for a short, flimsy, silk tube constructed around the entrance hole on the flattened surface of the needle and attached to an adjacent unmined needle. Frass is ejected from the entrance hole and from one or two other holes located on the surface of the needle.

Larch casebearer ***Coleophora laricella* (Hbn.)**

This insect is a serious defoliator of larch, second only to the larch sawfly in North America. A native of Europe, it was discovered on the east coast in the 1880's and has since spread westward. Several severe outbreaks have caused extensive tree mortality in some parts of its range. It attacks native and exotic larches of all ages.

Infested stands may have dead and dying trees with brownish foliage, as if scorched by fire or late frost. Foliage discoloration occurs in the spring when the needle tips are mined by the larvae. These mined needles drop prematurely. Unless severely weakened, the trees will refoliate the same year. Severe and repeated attacks, however, kill branches and trees.

Look for small gray cases (¼ inch long), each comprised of parts of a hollowed-out needle and silk. These cases (plate 10, *A*),

which are attached to the twigs during the summer, fall, and winter, are diagnostic for this species. The larva lives inside this case.

Arborvitae leafminer ***Argyresthia thuiella* (Pack.)**

Severe infestations of this insect sometimes occur on cedar but they are unlikely to cause permanent injury in forest stands. It is important on ornamental arborvitae because the abundant brownish needles are unsightly. Heavy infestations kill branches and cause foliage to drop prematurely.

In the fall or winter look for partly developed mines in the foliage near branch tips (plate 4, *D*). Frass is present but confined to the outer tips during this period. In spring and summer, the mining is extended and the frass ejected.

A juniper needleminer ***Phalonia rutilana* Hbn.**

This species, originally introduced into the eastern United States from Europe in the 1870's now occurs as far west as the Lake States. It sometimes becomes abundant on common juniper, but it seldom causes more than some needle browning. It has been economically important only on ornamentals.

Look for the damage that first consists of several mined needles, but later includes needles hollowed out from the concave surface. Frass ejected from the mines adheres to the silk strands of webbing spun between the mined and adjacent needles (plate 9, *A*).

A hemlock needleminer ***Pulicalvaria abietisella* (Packard)**

This insect is the most commonly observed leaf miner of hemlock in the Lake States, but it has not been an important pest. Its damage is characterized by six or more mined needles tied loosely together. In addition, look for an elongate silken tube constructed on the underside of the branchlet at the bases of the mined leaves. Nearly mature larvae hollow out the lower surface, mostly because they become too large to mine the flat hemlock needles.

SAPSUCKING INSECTS, MIDGES, AND MITES

The organisms in this category injure conifers by feeding on their fluids. Many have specialized piercing and sucking mouthparts that withdraw plant fluids through the needles, shoots, or stems when inserted into the host.

Damage by some aphids, spittlebugs, and mites resemble disease injury and may be mistakenly regarded as disease-caused if the insects are absent. The destructive stage of the organism is usual-

ly required for precise identification, but sometimes the presence of feeding punctures, sooty mold, nondestructive stages of the pest (e.g., eggs), fine webbing, etc., may suffice for identification or at least for distinguishing the injury from that of a disease. Some sapsucking insects produce characteristic galls or pitch exudations that identify them.

Scales are usually identified directly from the scale insect itself. The female scale remains attached to the host for a long time, even after death.

Spittlebugs

Spittlebugs are unique insects whose nymphs cover themselves with a frothy mass of bubbles composed of eliminated plant juices. Both adults and nymphs feed on plant fluids, but only the nymphs make spittlemasses. Some spittlebugs feed on just one host species in both the nymphal and adult stages; others require different host species for different stages. Two spittlebugs belonging to the genus *Aphrophora* are especially destructive in the Lake States.

Saratoga spittlebug ***Aphrophora saratogensis* (Fitch)**

The Saratoga spittlebug kills sapling pines. It prefers red and jack pine, but sometimes attacks Scotch pine. These hosts are susceptible to injury when growing with abundant ground cover, particularly sweetfern (fig 10), which is important to spittlebug

F–502131

FIGURE 10.—Sweetfern plant.

population buildup. Most other plants (except grasses, lichens, and sedges) support Saratoga spittlebug nymphs, too, but to a lesser degree. Trees taller than 15 feet are seldom attacked, mainly because they shade out the ground cover.

Trees die from the top down in heavy infestations. Symptoms include dead tops, flagged branches (plate 12, *B*), wavy and stunted stems, and shortened stem and branch internodes. In general, injury commonly resembles injury from the pine spittlebug, *Scleroderris* canker, and drought. Look for reddish flecks and pitchy scars (plate 33, *B*), which are associated with adult feeding wounds and can be observed by scraping the bark off branches with a knife. These are diagnostic for this spittlebug and separate it from all other insect and noninsect injury.

Also, look for the nymphal stages feeding from mid-May to early July in spittlemasses at the bases of low-growing plants nearby (plate 22, *C* and *D*), which are essential for the insect's survival. Young nymphs are red and black; older ones are chestnut brown and sometimes in aggregations of up to 50 in a spittlemass. The adults have a white "arrow" covering the head and thorax (fig 11),

F–516023

FIGURE 11.—Saratoga spittlebug adult.

which easily separates them from related species. Adults are present on the trees from late June to early September. The teardrop-shaped eggs overwinter and can be easily found under the scales of larger buds (fig 12).

F–489363

FIGURE 12.—Saratoga spittlebug eggs.

Pine spittlebug ***Aphrophora parallela*** **(Say)**

The pine spittlebug feeds on conifers of all sizes, including seedlings, but it most commonly attacks saplings and poles. It prefers eastern white, Scotch, and jack pine; but may attack several other pines as well as spruces, larch, hemlock, and fir. It rarely attacks red pine. Outbreaks are usually localized.

Trees may die from heavy infestations. The primary symptom is branch flagging starting on the new growth and progressing to the trunk (plate 12, *B*). Lower branches generally flag first. In general, injury to saplings of jack and Scotch pine resembles injury of the Saratoga spittlebug. Look for reddish flecks and scars (plate 33, *B*) caused by adult feeding. Such flecks on the inner bark are diagnostic for this spittlebug and can be observed by cutting and peeling back the bark of branches. The nymphal stages feed from mid-May to July in spittlemasses on the host tree (plate 22, *A* and *B*). Trees appear to be covered with snow during severe infestations. Many needles become black from a sooty mold (plate 12, *D*) that grows on the sugary spittle dripping from the spittlemass. The young nymphs (plate 22, *B*) are orange and black; older ones range from light brown to black. More than one nymph may occupy

a spittlemass. Adults resemble other species of *Aphrophora,* but lack the "arrow" of *A. saratogensis* (fig. 11).

Signoret spittlebug ***Aphrophora signoreti* (Fitch)**

This is a rare insect that causes little damage. It feeds on pine and larch saplings and has been collected from white spruce and balsam fir. Nymphs feed on low-growing plants near the adult host similar to the Saratoga spittlebug (plate 22, *C* and *D*). The young nymphs resemble those of the Saratoga spittlebug; the last instar nymph, however, has a brownish yellow to pink abdomen. The adult is similar to, but more robust and darker than, either the Saratoga spittlebug (fig 11) or the pine spittlebug.

A pine spittlebug ***Clastoptera testacea* (Fitch)**

This species is seldom injurious. Pines are the preferred hosts. Look for the nymphs feeding in small spittlemasses (plate 22, *A*) in June. The adults are small and oval (similar to fig. 13).

FIGURE 13.—Juniper spittlebug. (Photo courtesy of the Michigan Department of Agriculture.)

A juniper spittlebug ***Clastoptera juniperina* (Ball)**

This species, introduced from western North America, is seldom injurious. It prefers junipers and arborvitae—especially ornamental varieties. Look for the nymphs feeding in small spittlemasses (plate 22, *A*) on juniper or arborvitae in June and July. The adults are small and oval (fig. 13).

Scales

Scale insects are so called because some secrete a scalelike wax coating over their back and others resemble bark scales. Scales are commonly grouped as soft, armored, or woolly, depending on the nature of their covering. All injure their hosts by extracting plant fluids and injecting toxic saliva into the tissues. Some scales cause extensive mortality in forest stands; others are mainly pests of ornamentals. Symptoms of scale injury are typical of other sucking insects: the host becomes devitalized, branches flag, some trees die. Surviving trees are stunted and distorted. A black, sooty mold (plate 12, *D*) that grows on honeydew (an excretion given off only by the soft scales) is helpful for identifying a soft scale infestation. However, for positive identification the scale itself should be found because this sooty mold is also associated with honeydew of aphids and the spittle of spittlebugs.

Most scales are easy to identify because they differ in shape and size and remain on the host for a year or more. The female is usually used for identification. Scales are flattened, hemispherical, helmetlike, saclike, globular, elongate, or rounded. Some are covered with a white or yellow wax that looks like powder or a cottony mass. The latter ones resemble certain aphids wth similar structures. Do not confuse fruit such as juniper berries (plate 19, *D*) with scales.

Pine tortoise scale — *Toumeyella numismaticum* (P. & McD.)

The pine tortoise scale is very destructive in forest stands of jack and Scotch pines, particularly to sapling and pole-sized plantations. It also attacks Austrian and red pine, but less severely. Sooty mold (plate 12, *D*) (growing on the honeydew that covers the needles and twigs) is commonly associated with this insect and is often the first symptom observed. Ants or bees may be found feeding on the honeydew. Trees under attack first appear devitalized, then branches flag and lose their needles. Trees may die after only 2 or 3 consecutive years of attack.

The adult female scale is diagnostic for this species. It looks like a small (⅕ to ¼ inch), reddish-brown helmet or tortoise stuck to the new or old twigs of its host (plate 19, *A*). It is usually clustered together with other females and small, whitish, elongate males (plate 19, *B*). In the summer, the bark and needles may be covered with small reddish specks that resemble red pepper to the naked eye. These are crawlers, or the first nymphal stage of the scale, that move around before settling down.

Pine needle scale ***Phenacaspis pinifoliae* (Fitch)**

The pine needle scale commonly destroys conifers of all sizes. Eastern white and mugo pines are very susceptible; other pines, spruces, fir, hemlock, and yew, are also attacked. Early symptoms are yellowing and browning of infested needles, followed by early needle fall. Heavy attacks kill twigs, branches, and trees. The scales appear to the naked eye as small (1/8 inch long) white flecks on the needles (plate 16, *C*). On closer examination the scale is elongate, flattened, and white with a small orange or yellow cap at one end (plate 16, *D*). A white, waxy secretion given off by the scales makes the foliage look gray.

Black pineleaf scale ***Nuculaspis californica* (Coleman)**

This insect is widely distributed and sometimes causes extensive outbreaks in western North American pine forests. In the Lake States, it injures jack and mugo pines of all sizes. Unlike in the West, infestations are generally localized, sometimes confined to just a few trees. Infestations are commonly associated with environmental conditions harmful to the hosts, such as fumes, smog, smoke, and dust. Viewed from a distance, infested trees resemble those attacked by bark beetles (i.e., clusters of dead trees). Infested trees are most noticeable in the spring when the discoloration of injured needles becomes most pronounced and is not obscured by new foliage. Injured needles turn yellow and finally drop off prematurely. Sparse, short needles characterize a persistent infestation (plate 13, *B*).

Close examination reveals grayish-brown to black scales packed tightly on the needles (plate 17, *A*). Each scale is less than 1/16 inch long and has a small "nipple" on its back (plate 17, *B*).

Juniper scale ***Diaspis carueli* Targ.-Tozz.**

This scale is a serious pest of ornamental varieties of juniper and arborvitae. Injury appears as yellowing of needles, branch flagging, and tree mortality. The scales, which are commonly in dense clusters on the needles, twigs, and cones, appear as white flecks to the naked eye. Close up, each scale is glistening white to gray, flattened, nearly circular, and about 1/20 inch in diameter (plate 18, *D*).

Fletcher scale ***Lecanium fletcheri* Ck11.**

A common pest of yew, this scale also attacks arborvitae and juniper. When abundant, it causes yellowing of foliage, premature needle drop, and eventual death of branches or the entire tree. Sooty mold (plate 12, *D*) growing on honeydew on the foliage is

associated with the scale. The scales feed in clusters on the stem between the needles. The female scale is yellowish to reddish brown, helmet shaped, and about $^1/_8$ to $^1/_6$ inch long (plate 18, *A* and *B*). Many are slightly wrinkled.

Spruce bud scale ***Physokermes piceae* (Schr.)**

This scale, when abundant, kills twigs and branches of spruces. It thrives on weak trees and further reduces their vitality. Sooty mold, (plate 12, *D*) growing on honeydew exuded from the scales, is commonly present. The scales feed at the bases of branchlets. They are globular, reddish brown with irregular flecks of yellow (plate 19, *C*), and easily mistaken for abnormal buds.

Hemlock scale ***Aspidiotus abietis* Comst.**

This scale injures hemlock but is seldom serious. At worst it causes some needle discoloration and premature needle drop. Sooty mold (plate 12, *D*) grows on the honeydew given off by this insect. The scales feed mostly on the lower surface of hemlock foliage. Fully developed scales are dark gray to black with light edges.

Woolly pine scale ***Pseudophilippia quaintancii* Ckll.**

This scale, rare in the Lake States, attacks young pine saplings. Large clusters of scales on the new needles cause the shoot to flag. This scale has been found on red and mugo pine and probably attacks other pines. Sooty mold (plate 12, *D*) commonly grows on the honeydew it gives off. The scales are woolly (plate 20, *B*) and found in large clusters on the shoots and needle bases.

A balsam fir scale ***Pulvinaria* (?) sp.**

Little is known about this scale, found on balsam fir in the Lake States. Like most scales, it is potentially destructive. This woolly insect clusters on the underside of the needles (plate 20, *C*).

Taxus mealybugs ***Pseudococcus* spp.**

Mealybugs are closely related to scales; several species are common pests of yew in the Lake States. The heaviest infestations occur on hosts having compact, dense foliage. Greenhouse trees are more susceptible than forest or ornamental trees. Feeding discolors the needles, and if it is intensive and prolonged, kills the trees. Most species secrete honeydew, which is covered with sooty mold (plate 12, *D*).

Unlike scales, these insects retain their appendages and can move about slowly. The bodies are oval, about ¼ inch long, and

generally covered with a powdery wax. Also, wax filaments project from their sides forming a fringe around them. Some species have long, waxy, taillike projections. Superficially, they look like woolly scales and woolly aphids (plates 18, *C*, and 20, *A* through *D*).

Plant Lice

Plant lice or aphids are small sucking insects (plate 21, *D*) usually grouped in clusters on the needles, shoots, or stems of the host. They are serious forest pests, able to kill trees of all sizes. Many are naked (plate 21, *D*); others are covered with a woolly wax (plate 18, *C*) as are some scale insects. Some produce honeydew, which drips onto surrounding foliage and becomes covered with a black sooty mold (plate 12, *D*). This sooty mold is also associated with the soft scales and spittlebugs. Ants and bees feed on the honeydew and are commonly found with or near the aphids. Some aphids move to an alternate host plant after one or more generations. Other aphids produce galls on spruce and some of these have alternating generations on other conifers. These gall aphids are discussed in the next section.

Pine bark aphid ***Pineus strobi* (Htg.)**

This aphid was probably imported into North America from Europe. It is a serious pest of nursery, ornamental, and planted eastern white pine. Infestations are heaviest on large pines, especially in well shaded areas. Other pines have been recorded as hosts of this insect, but these infestations probably were of the closely related *P. coloradensis*.

The pine bark aphid feeds on the bark of the stem and branches. Heavily infested trees, especially if young, become stunted, bushy, or die. Look for the aphids, which appear as scattered patches of white flecks, on the bark of the stem (plate 43, *A*) and the lower side of limbs (plate 21, *A*). A white waxy secretion hides the body of the small dark aphid.

A pine needle aphid ***Pineus coloradensis* (Gillette)**

This aphid closely resembles the pine bark aphid and may be a serious pest of pines. It prefers red pine but can survive and develop on eastern white, jack, and Scotch pine.

This aphid feeds on the new needles of its hosts, causing the trees to become stunted and flagged. New eastern white pine needles collapse from feeding. Look for the aphids, which appear as white patches on the new needles (similar to plate 21, *A*). Sometimes during August a sooty mold (plate 12, *D*) grows on the waxy secretion of the aphids causing the wax to appear almost black.

Spotted pine aphid ***Eulachnus agilis*** **(Kaltenbach)**

This insect is not yet important in the Lake States, but it has injured Scotch and Austrian pines in adjacent States. The aphids feed in colonies on both old and new needles causing them to blotch, turn yellow and brown, and drop prematurely. The aphids (similar to plate 21, *D*) are green with red eyes and a spotted body.

White pine aphid ***Cinara strobi*** **(Fitch)**

This insect is present throughout the Lake States and is commonly abundant in Michigan on eastern white and Scotch pine. It causes flagging and mortality, especially of young trees. Abundant honeydew covered with sooty mold (plate 12, *D*) is associated with these aphids. The aphids are dark brown to black with white markings. They are clustered on the shoots and branches (plate 21, *D*). Look for the aphid's black shiny eggs (plate 21, *B*) laid in rows on the needles.

A pine aphid ***Cinara pini*** **(L.)**

This large and conspicuous aphid occasionally injures Scotch pine—especially young trees in Michigan. The aphids occur in colonies (plate 21, *D*) and are reddish brown and flecked with dark specks.

Balsam twig aphid ***Mindarus abietinus*** **Koch**

This aphid sometimes becomes abundant on balsam fir. It has also been reported on Scotch pine and blue spruce. When the aphids are abundant, the shoots flag and die. Young needles become curled and expose their undersides. Honeydew, covered with sooty mold (plate 12, *D*), is commonly on the foliage near the attack.

Look for large females, known as stem mothers, that are covered with a white woolly wax in the spring (as plate 18, *C*). The rest of the summer the aphids are naked, pale green, and located in clusters on the needles and shoots (plate 21, *D*).

Aborvitae aphid ***Cinara tujafilina*** **Del G.**

This insect is very destructive on arborvitae. Branches of heavily attacked trees flag and die. Look for the hairy, amber-brown aphids, which are about ⅛ inch long and have their upper surface covered with a white, powdery film making them inconspicuous. They feed in large colonies (plate 21, *D*) on the bark of the shoots. Honeydew is secreted copiously and sooty mold (plate 12, *D*) is usually present.

Red cedar aphid ***Cinara sabinae*** **(Gill. & Palm.)**

This aphid occasionally becomes abundant on junipers, and kills mostly branches. Few trees are killed directly by the aphids, but they are often weakened enough that the cedar bark beetle (p. 71) attacks and kills them.

The aphids feed in colonies (plate 21, *D*) on the new shoots. They are about 1/8 inch long, brown, and not easily seen on the tree's reddish bark. Their presence is more easily determined by the glossy honeydew and sooty mold (plate 12, *D*) that grows on it. The aphids leave the tree in summer, usually before the damage is apparent.

Pine root aphids ***Prociphilus*** **spp.**

Aphids of the genus *Prociphilus* are occasionally found on roots of pine seedlings and young saplings up to 5 feet tall. Infested trees may be stunted (plate 31, *C*) and have yellowing foliage. Look for the light-colored aphids in clusters (plate 21, *D*) feeding on large roots a few inches below the root collar.

Gall Aphids

These aphids (or adelgids) all produce conspicuous, enlarged growths or galls on the shoots of various spruce species. Some require one or more alternating generations on an alternate host such as pine, larch, or fir. They do not produce galls on the alternate hosts, but appear as colonies of plant lice (plate 21, *D*) on the needles or shoots.

The aphid galls on spruce seldom become abundant enough to cause serious damage in forest stands, but they are often unsightly on ornamentals. Galls differ in shape, size, and location on the host depending on the species of aphid. Some galls are loosely developed, others are conelike or resemble small pineapples. They range from 1/3 inch to several inches long and most are green or purple while developing but become reddish brown later after they are vacated. Inside the galls are numerous chambers in which the nymphs develop. Many injured shoots become deformed or die. The spruce gall midge (p. 51) causes a gall similar to aphid galls.

Eastern spruce gall aphid ***Adelges abietis*** **(L.)**

Galls of this insect are commonly observed on white, Norway, and black spruce saplings. All stages occur on spruce and no alternate host is required. Forest stands are not significantly injured by attack, mainly because the buds on the injured shoots are not

damaged. The galls are unsightly and disfigure the shoots on ornamentals. Many hundreds of galls may occur on one tree, and a tree that is attacked is often repeatedly and heavily galled. Some trees are conspicuously immune to attack even when growing adjacent to injured ones.

Look for this gall, which is ½ to 1 inch long, at the base of the new shoot (plate 23, *A*). When fresh, the gall is green with a reddish line around the mouth of each of the chambers. The needles comprising the gall are shortened to about half normal length.

The winged female adults are sometimes seen as whitish flecks on the needles (plate 17, *C*). The females die while egg laying and remain attached to the needles (plate 17, *D*). The "spring nymphs" are typically aphidlike, but are covered with a white, woolly wax (similar to plate 18, *C*), as are the eggs (plate 20, *A*).

Cooley spruce gall aphid ***Adelges cooleyi* (Gill.)**

The gall of this insect is common and important on blue spruce planted as an ornamental. Very young spruces may be severely deformed or weakened during heavy attacks because the buds die on the gall-infested shoots. This insect may have alternating generations on Douglas-fir, but it is able to complete its life cycles on either host.

On spruce, look for the gall, which is 1 to 3 inches long, loosely structured, and always occupies the end of the shoot (plate 23, *B*). When fresh, the gall is light green to dark purple and the needles comprising it are nearly as long as normal ones.

On Douglas-fir the insects act like typical plant lice and feed in clusters at the bases of the needles. The insects are dark green to brown and exude large amounts of dense, woolly wax (plate 18, *C*). Their feeding causes yellow spots on the needles. Later, entire needles may become yellow and drop prematurely. Attacks may kill nursery seedlings and very young trees. Infestations on large trees are commonly confined to the lower branches.

Woolly larch aphid ***Adelges strobilobius* Kalt.**

This insect, introduced from Europe, is a minor pest on black spruce and occasionally becomes a pest on eastern larch—the alternate host.

On black spruce look for the rounded gall, up to an inch long (plate 23, *D*), at the tip of the new shoot. The needles of the gall are shortened. When fresh, the gall is pink to green.

On larch in the fall, the small, dark insects appear in thick clusters at the bases of needle clusters (plate 21, *C*) or on the underside of shoots. Spring aphids (fig. 5) and their egg clusters are on the

needles and are mostly covered with a white, woolly wax (plate 20, *D*).

Pine leaf chermid ***Pineus pinifoliae* (Fitch)**

This insect is not serious on black spruce in forest stands, but on ornamental Norway spruce the galls sometimes become numerous. Eastern white pine is the usual alternate host; red and other pines possibly also serve as alternate hosts. It often injures the pines.

On spruce, look for a compact gall resembling a true cone on the tip of the new growth (similar to plate 24, *B*). It varies from ¾ to 1¾ inches long, and when fresh, is purple or green. The gall deforms the tree because the buds are killed and the shoot dies.

On eastern white pine, the aphids settle on the new needles or shoots in early summer and become covered with a woolly wax (plate 20, *B*). Twig tips flag where feeding is excessive.

Red spruce aphid ***Pineus floccus* (Patch)**

This aphid produces galls on black spruce but has never been an important pest. It requires eastern white pine as the alternate host. On spruce, look for the conelike, loosely structured gall, that comprises the entire new shoot (plate 23, *C*). The gall is green and may have a dark-purple tinge near the needle bases giving it a purple cast at a distance. The length ranges from ¾ to 1½ inches and the needles of the gall are nearly normal in length.

On pine, the aphids are typical plant lice covered with a flocculent, white, woolly wax (plate 24, *B*). They settle and feed on the old shoots and needles.

Spruce gall aphid ***Pineus similis* (Gillette)**

Seldom an important pest, this insect produces galls on white, black, Norway, and blue spruce. An alternate host is not known. The gall comprises the entire new growth but it is loosely structured and from ¾ to 1¾ inches long (plate 24, *A*). Superficially, it resembles the gall formed by the spruce gall midge (p. 51), but if cut open, can be distinguished by the young aphids instead of the legless fly maggots (plate 26, *B*).

Unknown spruce gall aphids ***Adelges* spp. *et al.***

Several unknown aphids produce galls on spruce. None, however, are important pests. The various galls are shown in plates 24 and 25.

Thrips

These minute insects are common in the flowers of many species of plants, but are seldom noticed because of their small size. They are rarely injurious in forests but occasionally become a pest to ornamentals, nursery seedlings, and Christmas trees. Only one species has been important in the Lake States.

Pine thrips ***Gnophothrips* sp.**

Pine thrips of one or more species attack Scotch and Austrian pines. They are sometimes especially abundant in Christmas tree plantings and nurseries. Their feeding damage appears as small brown patches up to ¼ inch long on the new needles (plate 14, *D*). Heavy attacks stunt and distort the needles and shoots (plate 14, *C*), and cause needle yellowing and premature needle fall. On the needles, search for the adult thrips, a black, winged insect about 1/16 inch long (plate 14, *D*). Immature thrips are similar in shape but lack wings and are orange yellow.

Midges

Midges are small mosquitolike flies that are injurious in the larva or maggot stage. Some cause conspicuous galls on the needles or twigs of conifers. Others live in shallow pits in the twigs or at the needle bases, and are commonly covered with a pitch exudate. A few bore into and destroy needles.

A pine pitch midge ***Cecidomyia reeksi* Vockeroth**

This is the most prevalent pitch-forming midge in the Lake States. It attacks jack pine of all sizes, but prefers open-grown saplings, especially on poor sites. Most injury occurs to young reproduction, which can be killed outright. On older trees, terminals and branch tips may be killed. Injured trees become stunted and deformed.

Look for flagged shoot tips occurring with one or more resin masses at or near the base of the flagged portion of the shoot (plate 39, *A* and *B*). These semifluid exudates, which may be up to ½ inch in diameter, contain a few to many yellow-orange midge larvae or pupae, or cast skins, depending on the time of examination.

A pine pitch midge ***Cecidomyia banksianae* Vockeroth**

A minor pest, this insect is occasionally observed on jack pine in the Lake States. It feeds close to the bud in a cavity filled with

resin. Usually only one larva occurs in each cavity, but several may be present. Infested shoots die in the spring. Look for dead buds or short, discolored shoots that bend downward at the point of injury (similar to plate 37, *B*).

Gouty pitch midge ***Cecidomyia piniinopis* (O.S.)**

The gouty pitch midge severely deforms and sometimes kills its host. It has been reported on 4- to 16-foot jack pine in Michigan. Small trees are generally not injured severely.

Dead needles, dead or dying shoot tips, and twisted terminals are evidence of this insect. In the early stages of injury, dead needles appear in tufts on the new growth (plate 13, *C*). Heavily infested shoots flag, die, and drop off.

Damage superficially resembles that of other insects but can be distinguished simply by examining the attack sites of the midges. Look between the needles of the new growth for slight swellings on the bark. Each swelling contains a small pit or pocket (⅛ inch diameter) enclosing a single orange-red larva emersed in resin (plate 39, *C* and *D*). The resin commonly exudes over the surface of the twig. The needles surrounding the pits are the first to die.

Balsam gall midge ***Dasineura balsamicola* (Lint.)**

The balsam gall midge is rarely important except to Christmas tree balsam firs. The injured needles of the new growth drop off prematurely after cutting. Look for the characteristic gall (plate 26, *C*), a globular swelling near the base of the new needles. Each gall contains a small yellow larva in the summer.

Red pine needle midge ***Thecodiplosis piniresinosae* Kearby**

This insect causes needle injury commonly called "fall browning." Red pine is its only known host. It attacks trees of all sizes but prefers open-grown saplings, particularly those of low vigor. Growth loss and shoot mortality occur in outbreaks lasting 3 or 4 years.

First evidence of this insect is usually a swelling (plate 26, *D*) of the current year's needle bases beneath the fascicles where one or more orange larva feeds. Infested needles, which are about 40 percent shorter than normal, turn yellow and then brown in October about the time the larvae drop to the ground. Look for the galled needle bases and exit holes in the fascicles (plate 26, *D*) of the short, reddened needles, which are diagnostic characteristics for this insect. In heavy infestations more than 75 percent of the current year's needles may die and fall during the winter. When heavy attacks occur, the buds fail to grow the following year. This

produces crooks and forks in the terminals and laterals. This insect is often associated with the needle blight midge (p. 51) and needle droop (p. 86)—two other maladies of red pine.

A "needle blight" midge **Unknown species**

This unnamed midge causes extensive needle injury to red pine saplings and may destroy up to half of the current year's needles.

New needles become sharply bent or hooked in the fascicle region (plate 6, *A*). Some drop to the ground while still green, others turn yellow and then drop in August and September. These needles accumulate on the foliage below, increasing discoloration of the tree. Look for a constricted necrotic zone inside the fascicle attended by yellowish midge maggots. Needle drooping caused by this insect superficially resembles injury by the pine chafer (p. 24). Injury by this midge, however, occurs later in the season.

Juniper tip midge ***Oligotrophus betheli* Felt**

This midge is known to occur in Michigan and occasionally becomes a serious pest of ornamental junipers, particularly in nurseries. The growing shoot tips are attacked (plate 13, *A*) but seldom are more than the buds injured. When many tips are infested, the tree becomes dense and bushy. Look for a small, light-yellow maggot in each infested shoot tip during most of the warm season.

Spruce gall midge ***Mayetiola piceae* (Felt)**

This midge produces a gall on the shoots of white spruce, sometimes causing sufficient shoot injury to require attention. It attacks trees of all sizes.

The galled part of the new shoot (plate 26, *A*) resembles certain aphid galls, especially those of the spruce gall aphid (p. 48). The gall is loosely structured and about twice the thickness of the normal shoot. It may cause the shoot to twist. The larval cells appear as hemispherical swellings between the needles (plate 26, *A* and *B*). The galled shoot may die and drop its needles during the season of attack or it may survive to produce a new shoot the next year. When the latter occurs, the new growth either dies or grows crooked into a drooping "pigtail."

Look for the legless maggots present in the swollen areas of the gall during the summer (plate 26, *B*). If there is a small hole in each swelling, the insects have emerged.

Mites

Mites are arthropods more closely related to spiders than insects. The injury they cause, however, is similar to that caused by

sapsucking insects. Both the adult and immature stages feed on plant fluids. When abundant, mites weaken and kill trees of all sizes. Forest nursery seedlings and ornamentals are commonly attacked; forest trees less so.

Because some mites are very small (1/50 inch or less) they go undetected, and the injury they cause is sometimes diagnosed as caused by drought or nutrient deficiency. A 10- or 15-power hand lens is usually required to see them on conifer foliage. A simple method of checking for exposed mites is to shake or strike an injured branch over a piece of white paper. The mites will appear as tiny, moving, and yellow, green, or red specks on the paper.

Spruce spider mite ***Oligonychus ununguis* (Jacobi)**

This mite is the most important mite of conifers in the Lake States. It is usually a serious problem on planted conifers—especially in stands where insecticides have been used repeatedly to control defoliating insects and thereby also have killed the predators of the mites. It prefers white and blue spruce, but will attack black spruce, larch, balsam fir, arborvitae, hemlock, juniper, and some species of pine.

The mite causes mottled, yellowish discolorations on the needles (plate 9, *D*). Severely infested foliage is dingy yellow or brownish; many of the needles dry up or drop off. Injury starts on the lower branches and progresses upward. Look for fine webbing that usually coats the needles of injured branches (plate 9, *D*). Dust particles, pollen, shed needles, etc., in the webbing add to the unhealthy appearance of the trees. Mite damage is severest in warm, dry weather—heavy rains tend to wash mites off the trees.

The adult is about 1/50 inch long; immature stages are smaller. The body is bluish to almost black with yellowish to pink extremities.

Twospotted spider mite ***Tetranychus urticae* Koch**

This mite, sometimes simply called a red spider, can be very destructive to many species of conifers. The symptoms of attack are similar to those of other mites. The foliage fades, turns brown, and then falls prematurely. Look for signs of the mites such as webbing on the foliage which contains considerable debris (similar to plate 9, *D*). Using a hand lens, examine the foliage for the mites. This species is 1/50 inch long, spiderlike, and usually greenish but sometimes yellowish or reddish. There are two large black spots on its back.

A red pine eriophyid mite ***Setoptus* sp.**

This mite has become an important pest of red pine in recent years, especially in plantations in Michigan. The same or a closely related species attacks eastern white pine. Its injury is sometimes wrongly ascribed to drought or nutrient deficiency because there is no telltale webbing and the mites are difficult to detect with the naked eye.

Injured foliage is yellowish at a distance. Close up, the needles have a blotchy, pale yellow, stippled appearance. The tips of the injured needles are twisted or hooked (plate 14, *A*) and may be brownish if the injury has progressed sufficiently. With a hand lens, look for the mites between the needles or inside the needle sheath. The mites are elongate and wormlike (plate 15, *B*), only 1/125 inch long, and vary from creamy white to orange yellow.

Tipdwarf mite **Calepiterimerus thujae (Garman)**

This mite is a pest of junipers and arborvitae, mainly on ornamentals. It occurs in the growing tips, which become constricted and crooked. Affected trees are slightly discolored to rusty brown depending on the severity of attack. Using a hand lens, look for small, wormlike, grayish mites (similar to plate 14, *B*) in crevices or on the foliage. The mites are more triangular than elongate when young. They are seldom seen on the foliage surface unless the weather is humid and the temperature is 60°F or lower.

SHOOT, STEM, AND ROOT INSECTS

Insects in this category gnaw on the surface of or inside shoots, stems, and roots of conifers, and cause malformations, degrade, and mortality. Many are "primary" insects that injure healthy trees, but also included here are the "secondary" insects—ones that successfully attack only trees that are weakened, dying, or dead from other causes. Wood borers and bark beetles are mostly secondary insects, although these groups contain a few species that can attack and survive in apparently healthy trees.

Shoot and Bud Moths

The larvae of this group of moths bore into buds and shoot tips of pines. Their feeding does not kill the tree but does cause malformation of the main stem and branches. Some species are extremely destructive.

European pine shoot moth ***Rhyacionia buoliana* (Schiff.)**

This is one of the most destructive shoot-boring moths in the Lake States. Introduced from Europe, it has spread from the East into Michigan and Wisconsin. It prefers red pine but readily attacks Scotch, Austrian, and ponderosa pine; it rarely injures jack and eastern white pine. Seedlings and young planted saplings and ornamentals are especially susceptible to attack, but trees more than 15 feet tall are rarely attacked.

First evidence of attack is a few dead needles on the terminal or lateral branches near the buds in late summer. Later the larva injures the bud (plate 29, *A*) and produces a small, pitchy blister (plate 38, *D*) composed of pitch-infiltrated webbing at the base of the larger buds. Look for this blister that covers a small, brown larvae feeding on the bud or new growth tissues (plate 29, *A*). In the spring, elongating shoots bend over and die, or grow crooked (plate 30, *A* and *B*), developing into a characteristic deformity called a "post horn" (plate 36, *A*). Bushy tips (plate 36, *D*) develop when all buds in a cluster are killed. Crooks and forks (plates 36, *B* and *C*, and 42, *C*) develop when one or more lateral shoots gain dominance. Bushy or spike-top trees (plate 32, *D*) are typical of advanced infestations. Many trees are irregularly shaped, have especially long lateral branches, and some nodes depleted of branches (plate 36, *C*).

Other pine shoot moths ***Rhyacionia* spp.**

Three species of lesser importance than the European pine shoot moth attack pines in the Lake States: *R. adana* Heinrich, *R. buscckana* Heinrich, and *R. sonia* Miller. All three species cause similar damage. Also the larvae are similar, so adults must be reared for positive identification.

Only *R. adana* has caused noticeable damage in the Lake States, especially on very young trees. Young larvae first mine old needles near the bud, then later mine out the young developing shoot shortly after new needle growth has begun. Several larvae may bore into one shoot and kill it before it elongates. Look for a small hole (plate 29, *B*) at the base of the injured shoot. Typically, new growth becomes stunted and it flags in midsummer. Heavily attacked trees become stunted and distorted like those attacked by the European pine shoot moth.

Eastern pineshoot borer ***Eucosma gloriola* Heinrich**

Also known locally as the American pine shoot borer, the jack pine shoot borer, and the white pine tip moth, this insect has long been a moderately injurious pest of pine in the Lake States. It has

been reared on eastern white, jack, red, Scotch, mugo, and Austrian pine and white spruce and Douglas-fir. The insect prefers new shoots of saplings but it will attack shoots of trees up to 30 years old. Many Christmas tree plantings are heavily attacked.

The larva of this insect attacks the new growth on laterals and terminals of its host in May and June before the shoot has fully elongated. One or occasionally several larvae hollow out most of the pith of the new shoot (plate 33, *D*) and emerge through an oblong or circular exit hole (plate 34, *C*), often before the damage is noticeable. Look for this exit hole—a sure sign of this species. Injured shoots turn yellowish and then reddish after mid-June (as plate 33, *C*). Many terminals and some laterals fall over (plate 35, *A*) or break off 1 to 3 inches above the old growth leaving a short flat stub. Some shoots, especially on red pine and Douglas-fir, may wilt and droop (similar to plate 37, *B*) before yellowing. Small attacked shoots, which may die before mid-June, are usually ones in which the insects have died prematurely. Such shoots contain only a partially excavated pith gallery and are heavily pitch soaked.

Crooks and forks develop when the terminal is killed. Old injury appears as deformed or crooked trees.

Pine candle moth ***Exoteleia nepheos* Freeman**

Discovered only a few years ago, this pest has become destructive to young Scotch pine plantings, especially in Michigan. It also attacks sapling Austrian, red, and mugo pine but to a lesser degree.

The damage externally resembled that of the *Rhyacionia.* Look for dead buds or short, wilted, new-growth shoots (plate 30, *C*) caused by larvae feeding in the old shoot tissues. Most injured shoots die and give branches a tufted appearance. When leaders are attacked, forks develop in the main stem. The larvae also attack and feed on the male flowers (plate 53, *A*).

This insect's damage can be distinguished from that of *Rhyacionia buoliana* by the lack of a pitch blister (plate 38, *D*) at the attack site. *Exoteleia* spins a loose web near the point of attack (plate 29, *C*) on the buds or male flowers, but is evident only during the early feeding stages.

A bud borer ***Petrova pallipennis* Mcd.**

This insect has never been economically important except in localized stands on jack pine. The larva destroys one or more buds on its host. Damage is readily evident in the spring when the hollowed-out buds fail to elongate like normal ones. Look for a small, round hole, which is closed with webbing if the larva is inside, near the base of the bud (plate 29, *C*). Branches developing from surviving buds become crooked or forked.

Pitch-Mass and Blister Makers

This is a heterogeneous group of boring insects (exclusive of certain bark beetles, midges, and shoot moths) that produce *conspicuous* pitch masses or pitch blisters on the trunk, branches, or shoots of living conifers. These masses consist of coagulated resin, and they are either solid accumulations or blisterlike structures located at the attack site. All these insects are injurious in the larval stages.

Zimmerman pine moth — *Dioryctria zimmermani* (Grote)

The Zimmerman pine moth severely damages saplings of several native and introduced pines and occasionally injures pole-sized pines. It prefers Scotch pine but will attack red, jack, eastern white, Austrian, mugo, and other pines. This insect bores inside the base of the terminal shoot, lateral shoots, or any branches. On jack pine, it commonly bores into the globose galls of the eastern gall rust (plate 28, *A*). Damage may result in a forked branch or death of the shoot, depending on location of attack.

Signs of attack on the terminal or upper shoots are accumulations of coarse "sawdust" in loose webbing at the bases of branches (plates 35, *B*; 40, *C*; and 42, *D*) accompanied by pitch. Branches hang down and flag (plate 35, *B*) or break off at the point of attack. This damage resembles that of the eastern pineshoot borer (plate 35, *A*) and snow damage (plate 35, *C*) but differs by having the characteristic pitch. Lateral shoot tips that are attacked flag (as plate 35, *C*) and have a small pitch tube (plate 40, *D*).

A large (2 to 3 inches), solid, pitch mass (plate 41, *A*) or cluster of masses at a node characterize an attack on the bole. The pitch mass is whitish, irregular, and located between or below branches or at wounds. It resembles the pitch masses of the pitch mass borer (plate 41, *B*) and pitch mass beetle (plate 41, *C*), but it is usually smaller than the former and more irregular than the latter. Stem mining beneath the pitch mass may kill adjacent branches and part or all of the tree above the attack site. The tree may break at this location if the girdling weakens it sufficiently.

The bole of surviving trees may be forked, crooked, or constricted (plate 42, *A*). Heavily injured trees have a burllike growth above the attack location (plate 42, *A*).

Look for the larva than can be found under the pitch mass or in the pith of a shoot (plate 33, *D*). It is easily distinguished from most other stem and shoot insects. The body ranges from pink to gray to yellow and has rows of small dark spots. Pupae or cast pupal cases in the shoots or stem are also diagnostic for this species.

Pitch mass borer *Vespamima pini* **(Kellicott)**

The pitch mass borer injures primarily eastern white pine but it also attacks Scotch, Austrian, and red pine, and spruces. It prefers pole-sized trees, particularly those that have been pruned or wounded. Trees are killed only when there are abundant and repeated attacks at the same locality. Defects are formed under the bark and in the sapwood as a result of the burrowing larvae. Pupation occurs in the pitch mass.

A very large (3 to 4 inch), solid, pitch mass at the attack site is characteristic. The attack site is on the bole, commonly at a pruning scar (plate 41, *B*) or wound. The pitch mass is similar to, but often larger than, that of the Zimmerman pine moth (plate 41, *A*) and much more irregular than that of the pitch mass beetle (plate 41, *C*).

Look for the larva that is present beneath the pitch mass for 2 or more years. It is distinguishable from other pitch mass borers by having legs, and a pinkish-white body lacking dark spots.

Pitch mass beetle *Chrysobothris orono* **Frost**

This wood borer attacks nonvigorous red and jack pine saplings but it has never been economically important. It destroys a small amount of bark and cambium and excavates a short (2 inches), shallow, L-shaped gallery in the sapwood, which would of course show up as a defect in lumber.

The solid pitch mass (plate 41, *C*), up to 2 inches long, is similar to the pitch mass of the Zimmerman pine moth and pitch mass borer, but more oval or rounded and often pinkish. It is located on either the node or internode of the main stem and usually on the south-to-southwest side of the tree.

Look for the white legless larva (plate 41, *D*) that lives singly under the pitch mass the first year and in the wood gallery the second year. It is a typical flatheaded borer, easily distinguishable from the other pitch mass makers that have legs.

Northern pitch twig moth *Petrova albicapitana* **(Busck)**

This insect, also called the pitch nodule maker or pitch blister moth, is the commonest of the pitch mass and blister-making insects in the Lake States. It occasionally injures the branches of sapling jack and Scotch pines, preferring trees grown in open stands.

Look for a hollow, thin-walled, brownish pitch "blister" (1 to 1½ inches in diameter) located at the crotch of two or more twigs (plate 38, *A* and *B*). This is the second year "blister" and the one most commonly observed in the field. The pitch blister made the

first year is smaller (less than ½ inch) and located on the new shoot near the bud. The first and second year blisters may be on the same branch. The first-year blister resembles early blisters formed by the shortleaf pitch blister moth and is difficult to distinguish from it. However, the second-year blister differs greatly from the fully formed blister made by the shortleaf pitch blister moth.

Tips of shoots above first-year blisters sometimes flag. Tips of branches above the second-year attack site usually flag and break off due to girdling of the bark by the small reddish larva (plate 38, *B*). This injury results in a forked branch or forked tree if the terminal is killed. A branch not completely girdled grows crooked and may break off—even several years later.

A pitch blister moth ***Petrova houseri* Miller**

Normally this insect attacks shortleaf pine south of the Lake States, but the moth has been reared from jack pine in the Lake States. It attacks current-year shoots, but the significant damage appears the year following. Look for the brownish pitch blister (plate 38, *C*), formed the first summer and enlarged the following spring. It differs from that of the northern pitch twig moth by being much heavier walled, smaller (½ to ¾ inch diameter), commonly packed with debris, and located between the nodes instead of at a branch crotch.

The larva tunnels for an inch or more in the bark and pith. Girdling of the bark under the pitch blister causes the shoot to flag.

Weevils

The weevils or snout beetles are readily distinguished from other adult beetles by the head, which is more or less prolonged into a beak (figs. 14, 15). The larvae are legless white grubs, typically curved when at rest (fig. 16).

Some weevils are among the most destructive pests in the Lake States. All the larvae are bark, wood, or root feeders; some live only in dead wood or stumps. The adult weevils, however, all feed on bark or foliage and thus some destroy conifer reproduction. Some adults feed at night or on cloudy days and therefore are not readily seen.

Two major groups of weevils, the *Pissodes* and *Hylobius* genera, are especially important. The adults of one group are easily distinguished from the other (figs. 14, 15), but separation of those within each group usually requires taxonomic skill. A few species are morphologically inseparable and require other means of

FIGURE 14.—*Pissodes* weevil adult. (Photo courtesy of Michigan State University, negative number 4907.)

identification. The grubs or larvae of all weevils are similar and difficult to distinguish. The larval damage of most species differs, however, and the species can usually be identified from it. Adult *Pissodes* weevils make pin holes in the bark (similar to plate 34, *B*) and excavate the tissues beneath it; *Hylobius* weevils destroy bark in ragged patches (plate 34, *D*).

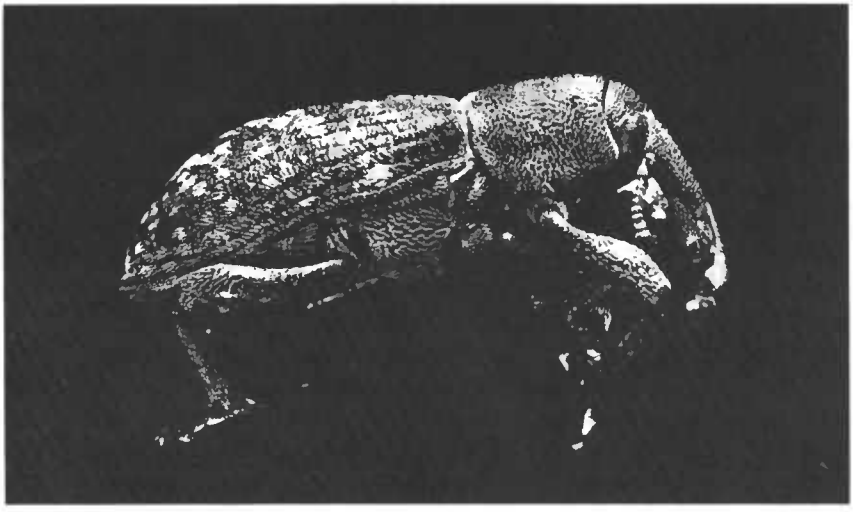
The other groups of weevils that attack conifers are separable from *Pissodes* and *Hylobius* weevils as adults and by their injuries.

White pine weevil ***Pissodes strobi* (Peck)**

This weevil is the most destructive species of the genus in the Lake States. It prefers eastern white pine but attacks other pines and spruces. It breeds in and destroys the terminal growth (leader), which causes forking and crooking of the tree. Open-grown trees from 2 to 20 feet tall are preferred.

Look for larval injury, which is diagnostic for this species. The new growth either barely elongates (plate 32, *B*) or elongates but curls into a "shepherd's crook" and dies (plate 32, *A* through *C*). Larval galleries occur in the new or previous year's growth starting at the top and meandering down into one or more stem internodes. When feeding occurs below a node, branches at that node die too (plate 32, *B*). The larvae feed collectively down the stem in the inner bark. They pupate in niches (plate 33, *A*) under chip cocoons in the woody tissues in the lower end of the feeding area.

Adults prefer feeding on the previous year's terminal in the spring, and on laterals in summer and fall. Feeding damage appears as small punctures in the bark covered with exuding or hardened pitch globules (plate 40, *A*). The location of adult and larval feeding damage distinguishes this insect on jack pine from the closely related lodgepole terminal weevil. The adult is difficult to distinguish from other *Pissodes* weevils (fig. 14).



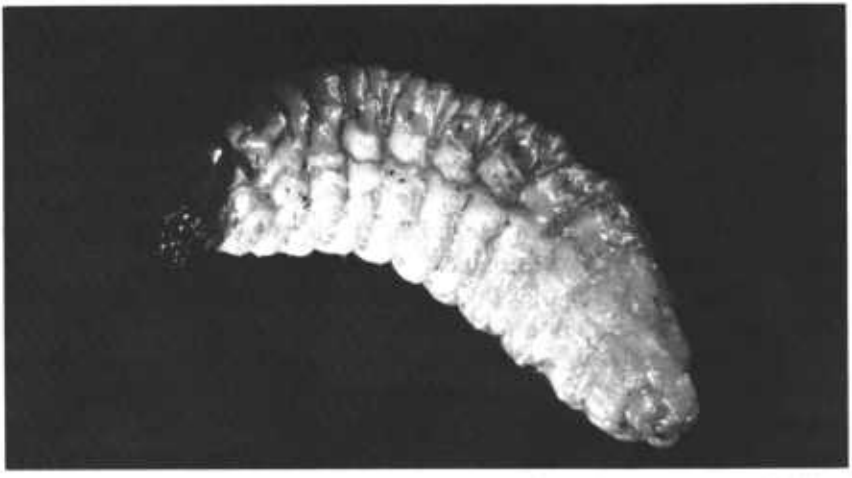
F–488105

FIGURE 15.—*Hylobius* weevil adult.

Lodgepole terminal weevil ***Pissodes terminalis*** **Hopping**

This insect commonly attacks lodgepole pine. It also attacks jack pine in the forests of Saskatchewan and probably occurs in jack pine stands in northern Minnesota. It breeds in and destroys the new terminal, which causes forking and crooking of the tree. Open-grown trees 4 to 20 feet tall are preferred.

Look for symptoms of larval attack, which are diagnostic for this species. Part or all of the new leader turns red, then brown, and may break off during the summer. Tip curl (shepherd's crook), similar to that of the white pine weevil (plate 32, *A*),



F–488106

FIGURE 16.—Weevil larva.

occurs on less than 40 percent of the injured trees. Larval galleries begin anywhere along the leader and extend upward in the inner bark. This upward rather than downward boring distinguishes the damage from that of the white pine weevil. The larva feeds singly and pupates in chip cocoons in the woody tissues of the leader (plate 33, *A*).

Adults confine their feeding to the new growth. The feeding injury resembles that of the white pine weevil—small punctures exuding pitch (plate 40, *A*). The adult is difficult to distinguish from other *Pissodes* weevils (fig. 14).

Northern pine weevil ***Pissodes approximatus* Hopk.**

This weevil attacks pines and spruces of all species and ages in the Lake States. The Larvae develop in logs, stumps, and decadent standing trees weakened or killed by drought, insects, diseases, or other agents. The adults feed on the bark of young trees 0.5 to 10 feet tall. On trees less than 2 feet tall, adults feed only on the main stem; on larger trees the lower branches are usually attacked. Adults prefer trees in young, open stands or the edge trees of closed stands.

The larvae make galleries in the inner bark on the main stem and into larger branches, but they rarely extend more than a few inches below the root collar. They are never in the leader as white pine weevil and lodgepole terminal weevil galleries are. Look for the chip cocoons (plate 49, *C*) on the wood surface. In seedlings the center of the stem is used for pupation. Adult feeding is like that of other *Pissodes* spp.; they make small holes in the bark of the stems and branches (plate 34, *B*).

The adult is a small brownish weevil that is difficult to distinguish from other species of *Pissodes* (fig. 14).

Balsam bark weevil ***Pissodes dubius* Rand.**

This insect is common in areas where balsam fir is abundant. It attacks dead and dying balsam fir and is therefore a secondary pest. Standing trees are attacked in the lower half and especially in the lower one-fifth of the bole.

Small punctures for egg laying on the bole, exuding pitch if the tree is still alive, indicate an attack. Larval galleries are long and straight or slightly wavy. They radiate from a common point just beneath the bark. The pupal cell—a wide area at the end of the gallery—occurs on the wood surface under the bark. The adult beetle is gray brown and mottled black and white (similar to fig. 14).

A pine weevil ***Pissodes affinis* Rand.**

This weevil sometimes becomes abundant. It breeds in stumps, logs, and large dying trees. It commonly attacks stands of old eastern white, red, jack, and Scotch pine. The adults do little damage to old trees, but may cause some injury to shoots on young trees less than 10 feet tall.

Larval galleries in the inner bark (plate 50, *B*) are characteristic of this species. On stumps or dead trees, they start near the root collar and extend in various directions. The galleries are narrow, shallow, tortuous, packed with light-brown frass, and may extend into the roots or up the tree for 2 feet. The pupal pits at the ends of the tunnels are covered by a chip cocoon (plate 49, *C*). Adult feeding is typical of *Pissodes* species; they make small holes (fig. 14) in the bark on the old growth of branches and consume as much of the inner bark as they can reach with their beaks.

Small spruce weevil ***Pissodes rotundatus* LeC.**

This is a rare insect infrequently found attacking white spruce and perhaps other spruces. It prefers young saplings. The larvae feed under the bark near the root collar; most galleries are vertical (similar to plate 49, *D*). The adult is similar to, but somewhat broader than, other species of *Pissodes* (fig. 14).

Pine root collar weevil ***Hylobius radicis* Buch.**

This weevil is the most destructive species in this genus in the Lake States. It attacks and kills Scotch, red, jack, Austrian, and

a few ornamental pines. Eastern white pine is practically immune, although some are attacked when interplanted with the favored hosts. Complete stands of pines, especially Scotch pine which suffers the most once attacked, have been wiped out by the larvae of this pest. It prefers open-grown trees 2 to 20 feet tall.

Often the first evidence of attack is dying or leaning trees. Look for entire trees turning yellow (plate 12, *A*) or brown, or trees leaning or broken off at the root collar (plate 48, *B*). The root collar beneath the duff and soil is commonly constricted (plate 52, *D*) and irregular larval galleries occur in the bark and cambium of the root collar and primary roots. The soil around the root collar is pitch-infiltrated and blackened (plate 48, *A*). Larvae are in the root collar or in tunnels in soil nearby; pupae usually are in earthen cells in the pitch-infiltrated soil.

Adults feed on the bark of branches (plate 34, *D*) but cause no important injury. The adults are similar to other *Hylobius* weevils (fig. 15) and require someone skilled in taxonomy for positive identification.

Root tip weevil ***Hylobius rhizophagus*** **M.B.&W.**

A destructive species locally in Michigan and Wisconsin, this weevil attacks and kills seedling- to pole-size pines. Closed stands of pole-size pines are especially susceptible. The insect prefers jack pine but will attack red and Scotch pine. Eastern white pine is also injured when grown with the preferred hosts, but it is rarely killed.

First evidence of attack are flagged, stunted shoots (but with normal-size needles) scattered throughout the crown. Either a few inches of the tip or the entire branch can be affected. This symptom superficially resembles attacks of the Saratoga spittlebug and *Scleroderris* canker (plate 12, *B*), but the lack of feeding scars (plate 33, *B*) and lack of discolorations beneath the bark (plate 45, *D*) distinguishes it. Trees appear tufted and may be spike-topped (plate 22, *D*). Proof of weevil attack consists of finding the larvae or root damage. Look for small roots that are chewed off; large ones are debarked or hollowed out and filled with frass (plate 48, *D*). Larvae do not feed on the root collar. A small amount of pitch-infiltrated soil may surround the injury. The pupal cell consists of a shallow excavation in the xylem of the root base covered by a chip cocoon.

Adults feed on the bark of branches (plate 34, *D*) of all hosts but red pine. They will eat the new bark of seedlings, killing some shoots. The adults are similar to other *Hylobius* weevils (fig. 15) and require taxonomic skill for positive identification.

Warren's collar weevil ***Hylobius warreni* Wood**

This northern species, common in Canada, is known to attack and kill pines, spruces, fir, and tamarack in Upper Michigan. Pole-size trees are particularly susceptible, but all trees more than 2 feet tall may be attacked, especially if growing on wet sites.

Larvae feed in the bark and cambium of the root collar and large roots. Roots more than 2 inches in diameter are girdled; small trees may be girdled at the root collar. Injury to pines superficially resembles injury by the pine root collar weevil (p. 62). Trees turn yellow and die when attacks are heavy (plate 12, *A*). However, the larvae of *H. warreni* form large pitch tubes or masses at the root collar (plate 48, *C*) which are not formed by other weevils.

Adults nibble the bark of roots and twigs (plate 34, *D*) and needles of the host, but seldom enough to be destructive. The adults cannot fly but otherwise are similar to other *Hylobius* species (fig. 15) and usually require taxonomic skill for positive identification.

A pine weevil
***Hylobius congener* Dalla Torre, Schenkling and Marshall**

This weevil occurs throughout the Lake States where it inhabits stumps and logs of red, eastern white, and Scotch pine. It does not injure living trees and so is distinguishable from most other *Hylobius* weevils which do.

The larvae feed in the bark—the galleries follow the grain of the wood and are filled with frass (plate 49, *D*). Look for the pupal cells, which are diagnostic for this species. Instead of being on the surface of the wood as in some related species, they are about ¼ inch beneath the wood surface and parallel to the grain. A short tunnel connects each cell with the surface. This weevil packs wood chips from the excavation into the old feeding tunnels and does not form a true chip cocoon like some other weevils do (plate 49, *C*).

Adults feed on the bark of logs and slash, causing no important damage. The adults are similar to other *Hylobius* weevils (fig. 15) and require taxonomic skill for positive identification.

Pales weevil ***Hylobius pales* (Herbst.)**

This widely distributed weevil attacks several species of pines, spruces, firs, and junipers, and tamarack. The larvae are of little importance when they feed in recently cut stumps. However, the larvae will leave the stumps and invade the roots of living trees and cause flagging of the branches (as plate 12, *B*). This flagging

is always associated with freshly cut tree stumps nearby. The adults, too, are important because they destroy seedlings and young saplings up to 3 feet tall by debarking them. The insect is primarily a Christmas tree pest in the Lake States because of selective cutting, which provides a continuous supply of stumps as primary breeding material.

Larvae feed in the bark of stumps above and below the ground line. Chip cocoons covering pupal cells on the wood surface beneath the ground (plate 49, *C*) indicate the insect's presence. Some *Pissodes* weevils construct similar chip cocoons, but they are slightly smaller and more compact than those of *Hylobius* and occur both above and below ground.

The adults consume the stem and branch bark of seedlings (plate 47, *A*) and saplings, preferring eastern white pine. On seedlings, the heaviest feeding is usually on the stems near the litter line. On saplings, adults feed on the branches causing the branch to flag from the injury to the tip. Needles often fail to elongate on new growth. Stems that are nibbled may exude pitch (plate 40, *B*). The adults feed at night and typically cannot be easily distinguished from the other *Hylobius* weevils (fig. 15).

Pitcheating weevil ***Pachylobius picivorus* (Germ.)**

This insect, uncommon in the Lake States, in injurious in the adult stage. The larvae inhabit roots and stems of felled and dead conifers. The adults consume the bark of the stems and branches of seedlings (plate 47, *A*) and saplings. Seedlings die and saplings flag from the branch tip back to the injured area. The symptoms resemble those of the more common pales weevil, which may also occur with the pitcheating weevil. The adult *Pachylobius* closely resembles *Hylobius* weevils (fig. 15) but differs by having very few scattered scales on its upper surface.

Pine gall weevil ***Podapion gallicola* Riley**

This weevil differs markedly from all others in the Lake States because it produces galls on the branches of red pine. It occasionally kills branches but it is important only as an eyesore on ornamental red pines. The gall appears as an offcenter swelling on a branch internode behind the new growth. About 1 inch in diameter, it may be oval (plate 27, *A*) or spherical and have needles growing from it. Galls farther back on the branch may even be larger and not attended by needles. Sometimes two or more galls nearly coalesce.

Podapion galls superficially resemble galls caused by some disease organisms (plates 27, *D*, and 28, *A* and *B*). However, *Poda-*

pion galls are found only on the branch internodes of red pine and contain one to eight small larval cells under the bark (plate 27, *B*).

A pine twig weevil ***Magdalis perforatis* Horne**

This weevil sometimes heavily attacks dying branches and slash of red, eastern white, and Scotch pine. It prefers trees 1 to 12 feet tall dying from insect or disease attacks, and dead lower branches of older trees in closed stands. It breeds only in dead material, but when the weevil is abundant, the adults may cause serious damage to new shoots of young living trees. Adults feed on the soft green tissues at the base of needle fascicles leaving small circular holes on the new shoots (plate 34, *A*). Heavy feeding destroys many needle bundles and sometimes stunts shoots.

The larvae feed in recently dead branches. The larval tunnels, which occur in the pitch from the branch tip back toward the base, are packed with frass, and may be up to a foot long (similar to plate 33, *D*).

The adult weevils, occasionally seen in June and July, are about ¼ inch long, bluish black, and wedge-shaped.

Black vine weevil ***Brachyrhinus sulcatus* (Fab.)**

This insect is commonly called the taxus weevil because it is a common pest of yew (*Taxus*). It also attacks hemlock. It is most destructive in commercial landscape nurseries and around homes where heavily infested trees die.

Both the adults and larvae feed on the tree. Look for adult feeding consisting of notched or partly chewed off needles (plate 6, *B*), especially in the lower part of the tree. This damage is inconsequential but indicates the pest's presence. The adults feed only at night so they are rarely seen. The larvae, small curved grubs (fig. 16), injure seedlings and young saplings destroying the rootlets (plate 47, *B*). Trees first turn yellow from the shoot-tips back, then die (plate 13, *D*). The damage and habits of this insect are similar to those of the closely related strawberry root weevil, but the adult female (fig. 17) (no males known) of the black vine weevil is nearly twice as large (½ inch) as the strawberry root weevil.

Strawberry root weevil ***Brachyrhinus ovatus* (L.)**

This insect is very destructive to conifers in nurseries. The larvae, small white curved grubs (fig. 16), feed on the rootlets of hemlock, spruce, yew, and arborvitae. The foliage of injured trees turns pale yellow, then brown. Heavily infested trees die. The

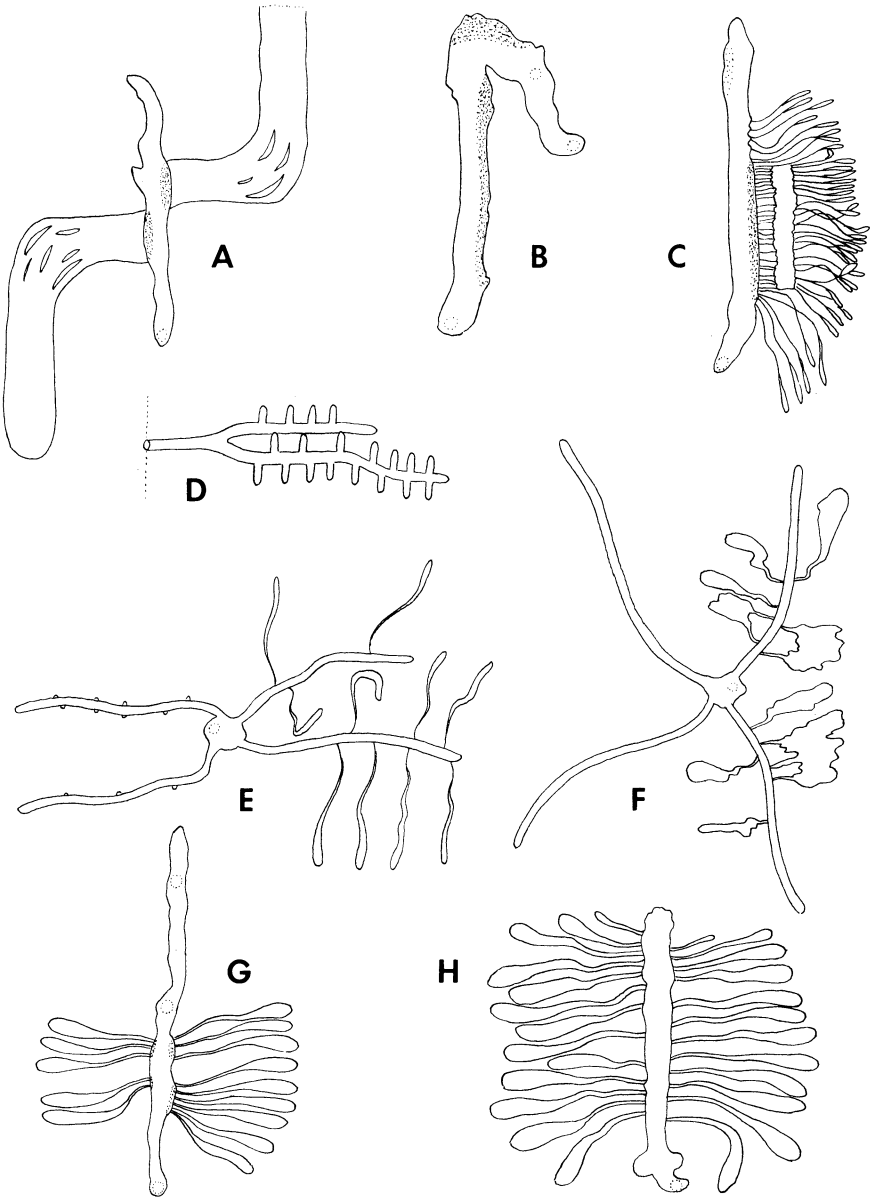
adults feed on the foliage only at night. Look for their damage, which consist of partly chewed and notched needles (plate 6, *B*). This injury is harmless to the tree but indicates the insect's presence. The overall damage and habits of this insect are similar to those of the black vine weevil, but the adult female (fig. 17) (no males known) of the strawberry root weevil is only one-half as large (¼ inch) as the black vine weevil.

FIGURE 17.—*Brachyrhinus* weevil adult female. (Photo courtesy of Michigan State University.)

Bark and Ambrosia Beetles

These two groups contain the most destructive insects in North America. The bark beetles are especially damaging, primarily to overmature trees. Occasional small outbreaks have occurred in the Lake States, particularly when man or other agents weaken or kill trees. The lack of large areas of overmature trees has probably prevented large outbreaks. Bark beetles attack all parts of the tree, but usually only if the tree is weakened, dying, or dead. These beetles are important pests when they hasten the death of weakened trees and when they attack apparently healthly ones during population explosions.

Bark beetles are difficult to separate without aid from experts, but their galleries, which are mostly constructed on the inner bark and surface of the wood, make identification easier. Each genus and most species make unique gallery patterns (plate 52, *A*; fig. 18). Entrance and exit holes and pitch tubes (plates 37, *C* and *D*, and 46, *D*) are signs of attack. A few species do not make galleries, but attack shoot tips and cones instead.



Many bark beetles are associated with other forest insects and diseases because they prefer trees weakend by such agents. Wood borers (p. 73) may also be present in trees infested by bark beetles. Small, colorfully banded, predatory beetles are sometimes found in bark beetle infested material.

Ambrosia beetles are similar to bark beetles, but most of them form galleries inside the wood perpendicular to the surface (fig. 18). Galleries may be straight, winding, or branched. Their galleries are also distinguishable by the presence of a black ambrosia fungus that lines the walls.

There are more than 50 species of bark and ambrosia beetles in the Lake States. A few of the most commonly encountered species are described here.

Red turpentine beetle ***Dendroctonus valens* LeC.**

This beetle is the largest species in this genus and the most widely distributed bark beetle in North America. Outbreaks have been neither extensive nor severe because the insect usually is in competition with more aggressive species. In general, it is a secondary enemy of pine and spruce, but on occasion it attacks and kills apparently healthy trees, preferring pole-size ones but including all sizes. Red and jack pine are preferred but the beetle will attack many other conifers including tamarack and firs.

Look for single or small groups of dead or dying trees with foliage that is uniformly off-color—usually because of *other* bark beetles associated with it. Injured trees reveal white-to-yellow pitch tubes (plate 37, *D*) up to 2 inches in diameter concentrated in the basal 6 feet of the tree (plate 37, *C*). Reddish boring dust may be present on the bark or ground. If the tree survives, "cat faces" (partially healed scars) will occur at the tree base where the bark has been killed.

The galleries are extremely variable. The egg gallery, on the inner bark and wood surface, commonly resembles an inverted

FIGURE 18.—Bark and ambrosia beetle galleries. Adult bark beetles excavate one or more egg galleries in the bark or wood surface. Larvae, individually or in congress, excavate distinct types of tunnels or mines away from these galleries. (Larval tunnels are shown for all but B below, adult entrance holes are represented by dotted circles). Pupation occurs in cells at the ends of the tunnels or mines. Eggs are laid in small niches along the gallery (as in E) or in frass along the gallery wall (stippled areas of A, B, C, and G). Drawing D is an ambrosia beetle gallery found in the wood perpendicular to the wood surface (dotted line). Galleries are *not* drawn to scale. *A, Dendroctonus murranae* (p. 70); *B, Dendroctonus valens* (p. 69); *C, Dendroctonus rufipennis* (p. 71); *D, Trypodendron* sp. (p. 72); *E, Pityokteines sparsus* (p. 72); *F, Ips pini* (p. 70); *G, Dendroctonus simplex* (p. 70); *H, Phloeosinus* sp. (p. 71).

"J" (fig. 18). The larval tunnels are large, broad, tabular areas commonly extending several feet up or down the stem. The adult beetles (⅓ inch long) are reddish brown and are in the galleries during the summer. Adults, pupae, and larvae appear as in plate 52, *B*.

Pine engraver ***Ips pini* (Say)**

The commonest bark beetle on conifers in the Lake States, this beetle can be found in injured or weakened trees in many conifer stands. It normally attacks dying trees, dead branches, and slash, but it will attack and kill trees weakened from drought or other agents. Eastern white pine is apparently preferred, but the insect will attack most other pines and spruces.

Look for small patches of dead or discolored trees. The insect attacks all parts of the tree but sometimes the lower crown may be spared and survive. Pitch tubes (plate 37, *D*) rarely form, but red boring dust is commonly seen on the ground and bark beneath the entrance holes.

Three to five egg galleries radiate from a central chamber (plate 52, *A*; fig. 18) depending on the number of females present. Egg galleries up to 6 inches long are mined generally along the grain of the wood but most larval tunnels cut across the grain. The dark-brown adult beetles are found in the galleries during most of the year.

Lodgepole pine beetle ***Dendroctonus murryanae* Hopkins**

This beetle attacks jack pine and eastern white pine in the Lake States but has not been destructive. It prefers stumps, windfalls, and weakened pole-size trees. Trees weakened by other bark beetles are often attacked.

On standing trees, look for the attacks on the bole in the lower 2 feet of the crown; on prostrate trees, the attacks are on the lower side of the bole.

The egg gallery is vertical and 4 to 8 inches long. Larval mines start out perpendicular to the egg gallery but become parallel a short distance away (fig. 18). The larvae feed in a group producing mines several feet long up or down the tree from the point of attack. Characteristic islands of unexcavated bark remain at the angle where the mines turn. The adult beetles, found in the egg galleries, are dark brown with reddish-brown wing covers.

Eastern larch beetle ***Dendroctonus simplex* LeC.**

Not usually economically important, this insect is one of the more common bark beetles attacking tamarack. It usually attacks

dying and weakened trees, although it occasionally attacks apparently healthy, mature trees. It is a beneficial insect in that it helps the breakdown of stumps, fallen trees, and forest debris.

Look for the galleries of this insect in dead or extremely weakened tamaracks. Seldom are there pitch tubes (plate 37, *C* and *D*) because of the tree's weakened condition at the time of attack, but there will be abundant red boring dust on the bark. The egg gallery (fig. 18) is elongate, vertical, and up to 9 inches long. Larval tunnels occur in groups of three to six or more and do not cross one another. Adult beetles (¼ inch long) are dark brown, often with a reddish cast, and are found in the galleries during the summer.

Spruce beetle ***Dendroctonus rufipennis* (Kirby)**

The most destructive of the spruce bark beetles, this insect destroys millions of dollars worth of standing spruce yearly in eastern North America. It attacks all spruces, but it has not yet been a serious pest in the Lake States because overmature trees are not plentiful. Even though apparently healthy trees are attacked, this insect is chiefly found in windfalls and weakened trees.

Look for dead and dying spruces with discolored foliage. Attacks start on the lower third of the bole (except for the first 2 to 3 feet above the ground) and progress up the bole. There may be up to 24 attacks per square foot of bark during an infestation. Pitch tubes (plate 37, *C* and *D*) form on the bark if the tree is alive when attacked. Reddish boring dust is found on the bark and ground beneath entrance holes.

The egg gallery (fig. 18) is vertical and 10 to 18 inches long; the larval mines are perpendicular to the gallery, often communal for a short distance, and many cross one another. The adult beetles (⅕ inch long) are reddish brown to black and found in the galleries most of the year.

Cedar bark beetles ***Phloeosinus* spp.**

The redcedar bark beetle (*P. dentatus* (Say)) and the northern cedar bark beetle (*P. canadensis* Swaine) are the commonest bark beetles attacking junipers and arborvitae in the Lake States. They prefer limbs, stumps, logs, and tops of unthrifty trees.

Look for the galleries under the bark (fig. 18). They are up to 2 inches long and cut across or are oblique to the grain. Small turning niches occur at the base of the egg gallery near the entrance hole.

Balsam fir bark beetle ***Pityokteines sparsus* (LeC.)**

This insect is considered one of the primary enemies of balsam fir. It also attacks tamarack and spruce. Like most bark beetles, it prefers dead trees and slash but will attack weakened trees of all sizes. Look for fading trees with tops dying first. Sap seeps from the entrance tunnels on the bark.

The egg galleries radiate 1 to 1½ inches from a central chamber (fig. 18) across the grain of the wood. Larval tunnels are widely spaced and mostly constructed along the grain of the wood.

Jack pine tip beetle ***Conophthorus banksianae* McP.**

This insect causes extensive shoot tip mortality on pines. It prefers shoots of sapling jack pine but will attack shoots of red and Scotch pine saplings, especially if planted near jack pine.

A small pitch tube (plate 37, *A* and *B*) about ½ inch behind the bud or new shoot is a sure sign of attack. After June these injured shoot tips turn red. Elongating shoots droop (plate 37, *B*). The dead shoot tips fall to the ground in autumn. A small, dark-brown bark beetle or a group of small, white larvae is found in the shoot tip during the spring and summer.

Attacked branches terminate abruptly where the tips have broken off. Branches and terminal shoots become forked where lateral buds develop and assume dominance.

The beetle *Cimberis elongatus* (LeConte) is sometimes associated with *C. banksianae.* This insect kills buds and shoots directly itself but it often also feeds in the new shoot tips (as plate 37, *A*) already attacked by *Conophthorus.* It injures the tissues near the tip of the shoot. The small larva lives in the bud, in the needle inside the sheath, or in the shoot. *Conophthorus,* in contrast, feeds near the base of the injured new shoot.

A few lesser known bark beetles (*Myelaborus* and *Pityophthorus*) also cause injury similar to *Conophthorus,* but the adult insects are needed for precise identification and should be examined by a taxonomist.

A gall beetle ***Unknown species***

Little is known about this beetle except that it causes galls at the base of shoots on arborvitae (plate 27, *C*). Small shoots above the gall flag and drop off. It is not considered to be economically important.

Ambrosia beetles ***Trypodendron* sp., *et al.***

The striped ambrosia beetle (*T. lineatum* (Oliv.)) and others are important pests of coniferous trees to be used for wood pro-

ducts. They prefer dying and injured trees, or recently cut logs. They do not attack seasoned wood.

Look for pin holes in the wood leading to galleries lined with a black fungus called ambrosia. The wood has to be cut to see the straight or branched galleries and short larval cradles (fig. 18).

Wood Borers

This group consists of several families of insects that bore into and destroy the woody tissues of conifers. Included here are the flatheads, roundheads, horntails, and powder-post beetles. Most of these are "secondary" insects; that is, they attack only trees that are weakened, dying, or dead from other causes. Some of these borers can attack a dead tree only if it has fresh bark attached. Other ones, like the powder-post beetles, prefer dry, well-seasoned wood so they are mostly a problem in forest products.

Several species of wood borers can inhabit the same host simultaneously because their requirements are similar. Bark beetles (p. 67) may also be present at the same time.

Flatheaded borers — *Melanophila* spp., *et al.*

At least 30 species of flatheaded borers attack conifers of all kinds in the Lake States. Important genera include *Melanophila, Buprestis, Chalcophora, Dicerca,* and *Brachys.* The larvae, which cause the damage, are somewhat flattened in the area of the thorax behind the head—hence the name "flatheads" (fig. 19). The adult beetles (fig. 20) are called metallic wood borers because many are irridescent and brightly colored.

FIGURE 19.—Flatheaded wood borer larva. (Photo courtesy of Michigan State University.)

The best known and most important flathead of conifers in the Lake States is the hemlock borer, *Melanophila fulvoguttata* (Harris). Principally a pest of eastern hemlock, it also attacks dying eastern white pine, tamarack, balsam fir, and red, white, and black spruce. It is generally a local pest but sometimes attains epidemic numbers when trees over large areas are weakened or killed by drought, windthrow, insects, or diseases.

FIGURE 20.—Flatheaded wood borer adult. (Photo courtesy of Michigan State University.)

Attacked trees first show yellowing of shoot tips, then dieback of the uper crown. Look for larvae and their characteristic galleries on the surface of the sapwood beneath the bark (plate 50, *A*). The galleries are larger than those of bark beetles and differ from roundheaded borers by being packed tightly with fine dark excrement and wood particles. From the outside, the bark may show woodpecker holes (plate 46, *C*) or small oval holes (⅛ to ¼ inch diameter) through which the adult beetles have emerged. Armillaria root rot may be associated with the attack and appear as mushrooms at the tree base (plate 44, *B*) or as mycelial fans (i.e., white patches of fungal tissue) or black rhizomorphs (threads) under the bark.

Roundheaded borers ***Monochamus* spp., *et. al.***

Three species of *Monochamus* and at least one species of *Prionus* attack conifers in the Lake States. The wood-destroying larvae (plate 49, *B*) are not especially flattened in the thoracic area and are thus distinguishable from the closely associated flatheaded

borers (plate 50, *A*). The larvae and damage are similar for all species discussed here.

The most common roundheaded borer that attacks conifers in the Lake States is the white-spotted sawyer, *Monochamus scutellatus* (Say) (fig. 21). Other frequently observed species are the

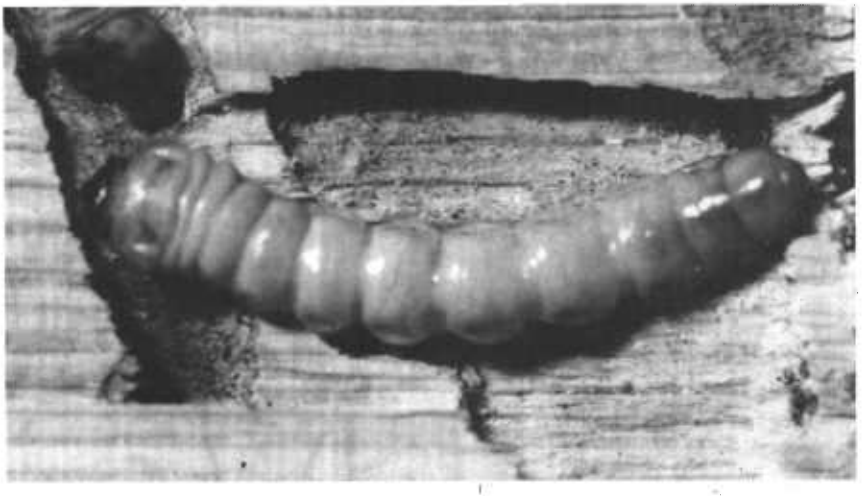


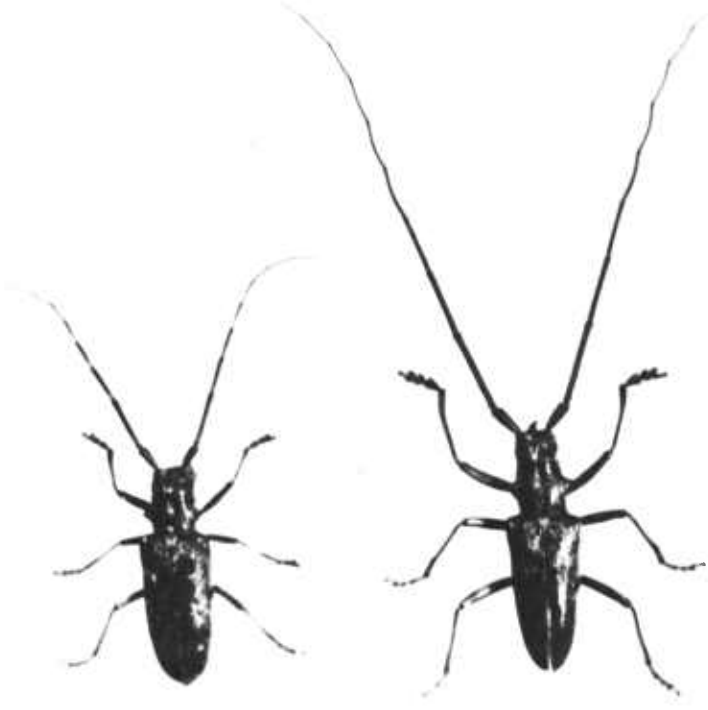
FIGURE 21.—Roundheaded wood borer larva. (Photo courtesy of Michigan State University.)

northeastern sawyer, *M. notatus* (Drury), and the balsam fir sawyer, *M. marmorator* Kby. The adults are large beetles with long antennae (fig. 22). The white-spotted sawyer and the northeastern sawyer attack dead and dying pines, spruce, and balsam fir, and perhaps other conifers. The balsam fir sawyer attacks some green and standing, but probably weakened or dying, balsam fir.

Live but infested trees lose their color and die from the top down. Look for the larvae (fig. 21) or their characteristic gallaries and tunnels beneath the bark (plate 49, *A* and *B*). The gallaries and tunnels are large, generally irregular, and may contain coarse, loosely packed frass and excelsior-like wood shavings (plate 49, *B*). Boring dust may accumulate in piles (plate 51, *D*). Oval holes in the wood indicate tunnel entrances (plate 49, *A*). From the outside, the bark may show woodpecker holes (plate 46, *C*) or round holes (¼ to 3/16 inch diameter) through which the adult beetles have emerged. Associated pests may include bark beetles (p. 67), flatheaded borers (p. 73), and shoestring root rot (p. 89).

Adult sawyers (fig. 22) also injure conifers by feeding on the bark of twigs. The shoot tips sometimes flag above the wounds. This flagging resembles that caused by several other insects and diseases but can be distinguished by the nibbled bark (plate 47, *D*) below it.

Pine-bark borers (*Acanthocinus* spp. and *Stenocorus* spp.) are often found under the bark of pine. Neither are injurious because they feed only in the bark of dying or dead trees. If present during extensive bark beetle outbreaks, *Acanthocinus* is actually beneficial because it destroys the inner bark, thereby preventing development of bark beetles. The unusual pupal cell (plate 52, *C*) distinguishes these insects from other borers.



F–496927

FIGURE 22.—Roundheaded wood borer adult.

The broadnecked root borer, *Prionus laticollis* (Drury), is sometimes observed in the wood of pines. Though seldom destructive on a large scale it can be destructive locally. It tunnels in the roots of living pines but also feeds in stumps and logs. The yellowish-white larva is up to 2½ inches long, and pointed on the rear end, which distinguishes it from other related borers.

Horntails ***Urocerus* spp.**

Of several horntails in the Lake States, the white-horned horntail, *Urocerus albicornus* (F.), is the most frequently observed in conifers. It attacks extremely weak or dead pines, spruces, and cedar.

The larvae damage wood that may be used for lumber. The galleries are made entirely within the wood and can only be observed by sawing or splitting infested logs. Look for the characteristic galleries that are round (up to ¼ inch) in cross section and packed behind the larvae with fine whitish frass (plate 50, *C*). Circular holes in the wood surface are where the adults emerge.

The whitish larvae of these wasp-related insects are rounded in cross section, up to ¾ inch long, and have a small pointed spine on the rear end.

Powder-post beetles ***Stephanopachys* spp., *et al.***

Various species of powder-post beetles destroy coniferous wood in the Lake States. They attack and breed in well-seasoned wood and bark and are especially important in furniture, lumber, or other wood products.

These insects are so named because the wood or bark they feed on is gradually reduced to a fine, flourlike powder. Their presence is indicated by pin holes (plate 50, *D*) in the wood. Look for a fine, powdery sawdust that sifts almost constantly from these holes. Their damage can be distinguished from bark beetles by their irregular tunneling inside the wood or bark, and not in regular patterns along the cambium.

The adults are small (⅕ to ½ inch long) brownish beetles; the larvae are smaller and whitish.

Ants and Termites

Ants and termites are social insects that live in colonies in wood or in the soil. Subterranean termites both excavate and eat wood. Carpenter ants only excavate wood for a domicile and forage forth from this home to collect food. Other species of ants build large mounds and destroy all vegetation in the vicinity of these nests. Some other species are indirectly destructive because they protect colonies of tree-destroying aphids in order to feed on the aphids' honeydew. Still other ants are beneficial because they prey on forest insect pests.

Black carpenter ant ***Camponotus pennsylvanicus* (DeGeer)**

This carpenter ant destroys living conifers and wood products. It commonly infests northern white-cedar and balsam fir. The adults excavate large cavities in the heartwood of pole and sawtimber trees.

Damage consists of irregular galleries (plate 51, *B*) that honeycomb the wood and sometimes nearly hollow out the center of the

tree. The walls are smooth and not coated with a whitish substance —a characteristic of termites. The galleries are kept clean of debris. Coarse, fibrous borings are extruded from the galleries through small "pushout" holes (as plate 51, *D*). The adult ants are black and up to ½ inch long.

Allegheny mound ant ***Formica exsectoides* Forel**

This ant sometimes destroys seedling and sapling conifers—especially if its moundlike nest is located in plantations or clearings. Pines, spruces, cedars, and other conifers from 2 to 15 years old may be killed if near the ant nests. These ants commonly kill all vegetation, except pole-size or larger trees, up to 20 feet around their nests. Formic acid injected into the bark by the adult ant kills the trees. Before the tree dies, a small lesion or gall resembling a fungus canker develops where the tree was injected. This ant or closely related species such as the thatch ant, *F. obscuripes* Forel, builds large earthen mounds or nests that may be 2 feet high and 6 to 8 feet in diameter (fig. 23).

Eastern subterranean termite ***Reticulitermes flavipes* (Kollar)**

This widely distributed termite is an occasional pest of conifers in the Lake States. Although usually associated with dead wood and forest products, it sometimes attacks living trees.

Damage consists of irregular galleries that more or less honeycomb the wood (plate 51, *A*). Most of the galleries follow the softer spring wood. These cavities may be coated with a hardened whitish substance and lined with soil and debris. Termites always leave a shell of surface wood to protect them from dry air and they do not push wood particles to the outside like ants and roundheaded borers do. Earthen shelter tubes associated with the damage are sure signs of termites. The majority of the termites in the colony are whitish and about ¼ inch long (plate 51, *A*).

White Grubs

White grubs ***Phyllophaga* spp.**

White grubs are the larvae of the familiar Junebug or May beetle. The larvae of the genus *Phyllophaga* and a few related genera are sometimes serious pests of young conifer plantations. They feed on the roots and injure all species of conifer seedlings and very young saplings up to about 4 years after planting. Most seriously attacked are first- and second-year plantings established in open grassy fields where white grubs are abundant at the time of planting.

F–521449

FIGURE 23.—Mound ant nest.

Seedlings and young saplings that are attacked become discolored in late summer and early fall and die. These reddish-brown dying and dead trees resemble drought-killed or diseased trees, but digging exposes their damaged lateral and tap roots that have the tips chewed off or girdled (plate 47, *C*).

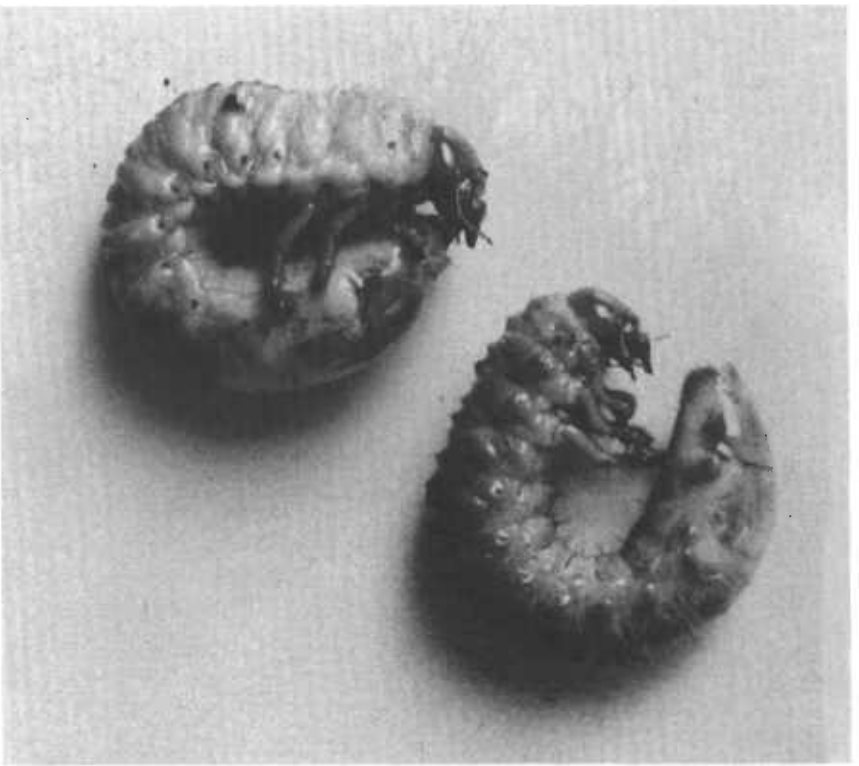


FIGURE 24.—White grubs. (Photo courtesy of Michigan State University.)

White, C-shaped larvae (fig. 24) up to 1 inch long are found in the soil near the seedlings during the summer and fall. The adult beetle rarely injures conifers; it usually feeds nocturnally on the leaves of deciduous trees near its breeding site.

CONE INSECTS

Cone beetles, moths, and flies destroy conifer seeds directly by feeding on them, or indirectly by feeding in and killing part of all of the female flowers (cones). The cone insects of pine and spruce are best known because these trees are most commonly planted.

The cone insects discussed in this section feed within the cones during most of the larval period. Certain other insects feed on cones only incidentally and are more important as defoliators or shoot borers; e.g., the spruce budworm (p. 31). A few insects feed on the inner or outer surfaces of the cone scales but are not cone pests. These, however, may be encountered along with primary cone insects. When examining injured cones to identify primary cone insects, one should keep in mind that different cone insects can attack a cone at the same time or in sequence.

Cone Beetles

Cone beetles are easily distinguished from other cone insects by their black, ⅛-inch long adults, or their smaller, white, C-shaped, legless larvae, both of which may be found in attacked cones. There is one important species on red pine and one on eastern white pine.

Red pine cone beetle ***Conophthorus resinosae* Hopk.**

This insect is the most destructive pest of red pine cones in the Lake States. Although variable from place to place and year to year, it is commonly severe enough to make commercial seed collecting uneconomical. Second-year red pine cones are preferred, but current-year's red pine shoots and occasionally second-year jack pine cones are attacked by the larvae. Red pine shoots are also attacked by the adult beetle for overwintering quarters.

Attacked cones are smaller than normal (plate 53, *D*) and dead. Look for a groove (plate 54, *A*) at the base of the cone leading from a hole in the axis to the outer margin of the cone. Internally, the axis is mined longitudinally. Also, the seeds are destroyed and the cavity contains fine granular frass.

Shoots used by the adults for overwintering are damaged in the fall. Look for green shoot tips that have a small hole just behind the bud (similar to plate 29, *B*). These shoot tips break off and fall to the ground before winter. The adult beetle is found in the bud of the severed shoot.

White pine cone beetle ***Conophthorus coniperda* (Schwarz)**

A pest of eastern white pine cones, this insect may damage the seed crop badly in years when only light or moderate seed set occurs. During severe infestations many shoot tips are also killed.

Damaged cones contain a hole at the base that leads to a tunnel up the axis (plate 53, *C*). Seeds are destroyed and the cavity contains fine granular frass. After July, look for the cones that have aborted and fallen to the ground.

Cone Moths

Cone moths are small moths whose larvae feed in conifer cones. The larvae are typical caterpillars having three pair of regular legs in front and five pair of false legs along the body, which distinguish them from other cone insects. Pupae, cast pupal skins, and cocoons may sometimes be found inside the injured cone or outside nearby.

Red pine coneworm ***Dioryctria disclusa* Heinrich**

This insect infests second-year red, jack, and Scotch pine cones, but is only locally destructive. Most infested cones die, but a few survive and produce seeds. Usually each larva attacks two cones before it matures. Early larval feeding is confined to male flowers (plate 53, *A*) until pollen is disseminated.

Cones attacked by this insect are distinguishable from those of other pine cone insects by a silk web spun between the cone and nearby needles and a single entrance hole near the cone base (plate 54, *E*). Look for a heavy accumulation of reddish-brown frass in the webbing. The cone contains a large internal cavity in the seed-bearing region (plate 54, *F*). The cavity may become partially filled with dried resin, frass, and webbing.

A red pine coneworm ***Eucosma monitorana* Heinrich**

This insect is occasionally abundant in red pine stands. Before it matures each larva attacks two cones and stops seed development within them. There may be 25 or more young larvae in the first cone at the beginning of an attack, and up to five in the second cone.

Damaged second-year cones wither and become discolored. Look for numerous tiny holes in the cone exterior or one or more larger, oblong ones between the scales in the side of the cone (plate 54, *B*). A small amount of frass may protrude from the holes. There is no webbing. Internally there is extensive tunneling in the seeds and tissues, plus a mixture of resin and frass (plate 54, *C*). A stub remains on the branch if the cone aborts.

A pine seed moth ***Laspeyresia toreuta* (Grote)**

This species is a minor pest of second-year red and jack pine cones in the Lake States. It is the only pine cone pest that destroys seed without injuring the cone. Some seeds escape attack. The cone scales are not injured during feeding so the cones open normally and release undamaged seeds.

Detection of this insect is difficult because the cones appear normal and the entrance holes between the scales cannot be seen with the naked eye. The cone must be opened to be certain of attack. Inside, look for clean tunnels and mined-out seeds (plate 54, *G*) tightly packed with debris.

Spruce coneworm ***Dioryctria reniculella* (Grote)**

This is a relatively common insect on white, black, and blue spruce, and an occasional pest of balsam fir, Douglas-fir, tamarack, and pine. It is particularly destructive on small, open-grown trees; both the cones and young terminal shoots are hollowed out by this pest. Shoots are attacked when cones are scarce.

Look for the cone damage, which is striking and readily recognizable when feeding is near completion. Then only a shell remains consisting of the outer parts of the scales held together with silk. Coarse frass in webbing is abundant on the cone surface (plate 53, *B*). Mined shoots of new growth are attended by a delicate silk tent covered with coarse frass (plate 10, *D*). These injured shoots curl as they develop and form a "pigtail" (plate 31, *B*).

Spruce seed moth ***Laspeyresia youngana* (Kft.)**

This insect is a common pest of white, red, and blue spruce. It is an important seed destroyer in years when cones are scarce—sometimes all cones may be infested. As in the case of the pine seed moth, seeds that are not eaten are shed normally.

Damage consists of destroyed seeds, mostly near the cone base, and a hollowed-out cone axis. Usually one larva, but sometimes more, inhabit a cone. Frass is packed in the tip of the tunnel and in the depleted seed coats. Look for an exit hole near the base of the cone, attended by a short silk tube leading to the outside between the scales. This tube, which is made just before pupation in the fall, is diagnostic for this insect.

Fir coneworm ***Dioryctria abietella* (D. & S.)**

This insect infests cones, shoots, and bark of many different conifers but fir and pine are commonly attacked. It may cause heavy seed loss. Young larvae feed in cones previously infested by other species; older larvae each directly attack one or more cones.

Cones attacked by this insect show frass-filled webbing (plate 54, *D*) connecting the cone and adjacent needles and one or more ragged holes in the side of the cone. The interior may be tunneled extensively and may contain some webbing but is generally free of debris.

Cone Flies

This group consists of small midges and flies that attack the seeds of conifer cones. The larvae, which cause the damage, are very small legless maggots, distinct from other cone insects. A few species of cone flies feed in cones but do not injure the seeds. Such species are usually found feeding on or in the scales of the cone.

Spruce cone maggot ***Pegohylemia anthracina* Czerny**

This is the commonest fly attacking white spruce cones in the Lake States. In years when cones are scarce, all of the cones in an area may be infested by this pest.

There is little evidence of attack from the outside, except for small exit holes (similar to plate 54, *B*) on the sides after the larvae have departed in July. Internally, the damage is evident as one or more narrow tunnels that start near the cone base and spiral around the axis through the developing seeds toward the cone tip. The tunnels are filled with frass and resin.

A red pine cone midge ***Rubsaamenia* sp.**

This little-known insect sometimes causes minor damage to red pine cones. It is capable of infesting cones by itself but it usually inhabits cones already attacked by other insects.

Damaged cones exude resin that crystalizes into white flakes between the shriveled scales (plate 54, *H*). Internally there is no tunneling or debris (plate 54, *I*).

NONINSECT MALADIES EASILY CONFUSED WITH INSERT DAMAGE

Before one can properly identify insect damage, it is necessary to rule out noninsect damage that looks as if it were caused by insects. So, as a guide, various groups of noninsect maladies are described below. Included are those commonly encountered and some that are associated—or easily confused—with insect damage in the Lake States.

Natural needle fall should not be confused with any malady. Tamarack is the only conifer in the Lake States that sheds all its needles annually. The annual yellowing and dropping of tamarack needles is a natural physiological function not to be confused with yellowing caused by insects or diseases. All other conifers in the Lake States retain their needles from 2 to 7 years, depending on the species. The oldest needles nearest the stem turn yellow and are shed each fall, but never all at one time.

Diseases

Diseases are caused by living pathogens—mostly fungi—that injure conifers. Many disease-causing organisms produce signs and symptoms similar to insect attack. Like insects, a disease organism can cause more than one symptom. Typically, diseases kill tissues (necrosis), retard development (atrophy), or cause overgrowths such as galls or cankers (hypertrophy). Disease injuries differ from insect injuries by not having the insect or insect artifacts and debris. Insects, however, are frequently associated with diseases—especially the wood borers, bark beetles, and others that attack weakened trees. Such insects should be recognized as secondary pests and not the primary cause of the host's ailment. Also, a primary insect may be attacking the host along with a disease, thus the insect may mask the effects of the disease or vice versa.

Foliage diseases

Several sooty molds (*Dimerosporium* spp., *et al.*) blacken the foliage of conifers making them appear as if they were exposed to dense smoke (plate 12, *D*). These molds develop on honeydew of aphids and scales (p. 41) and near the "spittle" of spittlebugs (p. 37). Presence of sooty mold is a good sign of one of these pests, even after the pests have left the host. Although the sooty leaves are unsightly and interfere slightly with photosynthesis, this fungus does not injure the tree.

Many diseases infect conifers and cause needle rusts, needlecasting, or drooping. Needle rusts (*Coleosporium* spp., *et al.*) cause old needles of pine to die and be shed prematurely. These rusts sporulate in the spring or early summer and form yellow, white, or orange pustules on the needles (plate 15, *A* and *B*). These pustules, unless examined closely, may be mistaken for aphids, scales, or sawfly eggs.

Brown spot, *Scirrhia acicola* (Dearn.) Siggers, is a common needle blight on pine seedlings and saplings. In the Lake States, it is particularly damaging on young Scotch pines where it causes needlecast. On young trees, the fungus primarily affects only the foliage within 18 inches of the ground—especially on the north side of the tree (plate 12, *C*). The infected needles, which are encircled by a brown band, can be found beneath the tree and thus may be used to distinguish this disease from an insect defoliator that would consume them.

The needlecast disease *Hypodermella ampla* (Davis) Dearn., is a common disease of jack pine. Infection may be severe enough to cause all the old needles to die and drop. This disease may super-

ficially resemble a scale infestation at first glance. In the spring and early summer, the old needles contain light buff-colored areas with one or more short, dull-black, elliptical spots (*hysterothecia*) (plate 15, *C*) that resemble scale insects.

Lophodermium needlecast, *Lophodermium pinastri* (Schard. ex Fr.) Chev., causes partial to complete defoliation of red, Scotch, and jack pine. Infected trees drop their needles, which, if found, will distinguish the injury from insect defoliation. Infected needles contain hysterothecia (similar to plate 15, *C*) that should not be mistaken for small scale insects.

There are several diseases known generally as "needle droop" that are of unknown cause. Symptoms are yellowing and browning needles bent downward or drooping from the base (plate 6, *A*). This injury resembles injury from the pine chafer (p. 24), an unknown midge (p. 51), and the pine needle sheathminer (p. 34). See these specific maladies for specific identifiers.

Branch and stem diseases

The important branch and stem diseases of conifers are the rusts that sometimes produce cankers, witches-brooms, or galls, or all three. The symptoms of these diseases resemble symptoms of several stem-feeding and sapsucking insects.

Scleroderris canker (*Scleroderris lagerbergii* Gremmen) is one disease responsible for the widespread and severe dieback of conifers in nurseries and young plantations in the Lake States. This pathogen commonly infects red and jack pines; less commonly, it infects eastern white pine, Scotch pine, black spruce, and white spruce. The injury is most severe in depressions and frost pockets.

Symptoms of flagging and top kill on red pine from scleroderris canker look exactly like injury from Saratoga spittlebug feeding (as plate 12, *B*). It is possible to have the disease and the spittlebug together, but the spittlebug injury can be easily identified by scraping off the bark and looking for reddish feeding scars (plate 33, *B*). The disease can often be identified by examining the dead tissues at the point of attack (see below). New shoots sometimes droop on infected branches giving the impression of localized frost injury (plate 30, *D*). Symptoms on jack pine are usually different; entire trees may die without flagging first, thus resembling injury from other diseases, pine root collar weevils (p. 62), or bark beetles (p. 67).

The usual symptom of Schleroderris is a small, discrete, sunken area or canker on the stem or branch. A diagnostic feature of this disease is the characteristic yellow-green discoloration under the bark in the zone between living and dead tissues (plate 45, *D*). Look

for this sign by scraping away the bark behind the flagged portion of the branch or at a canker.

White pine blister rust (*Cronartium ribicola* J. C. Fischer) is an important disease of eastern white pine and can severely damage the host in areas where the local climate favors establishment and spread of the disease. First the needles are infected and then the branches flag, a symptom that resembles injury from Saratoga spittlebug and pine spittlebug (plate 12, *B*). Cankers develop on the stems (plate 43, *G*). Old cankers appear as dead areas on the bark and are associated with bark beetles and wood borers.

Commandra blister rust (*Cronartium commandrae* Peck) occasionally attacks jack, Austrian, and Scotch pines, but is seldom a serious disease in the Lake States. The disease is manifested by a spindle-shaped swelling on the stem that is covered with orange blisters in May when mature (plate 43, *D*). In large stem infections, resin usually exudes from the canker. Resin flow often increases as a result of feeding on the infected bark by squirrels and porcupines. Insects such as the Zimmerman pine moth (p. 56), bark beetles (p. 67), and wood borers (p. 73) may be associated with the injured tissues.

The eastern gall rust (*Cronartium quercuum* (Berk.)) is common on 2-and 3-needle pines in nurseries, plantations, and natural stands in the Lake States. It is found primarily on jack and Scotch pines, but is also found on Austrian pine. Red, white, and black oaks are alternate hosts of the fungus. The disease is readily detected by its globose galls on pine (plate 28, *A* and *B*). Galls developing on the main stem may kill the host, especially if it is a seedling. Branch galls kill the branches or subject them to easy breakage. The gall resembles the gall of the pine gall weevil (plate 27, *A*) but the latter is found on red pine. The Zimmerman pine moth commonly attacks the galled areas of injured pines; attacked trees show frass and pitch exudations (plate 41, *A*). The insect does no form galls but its feeding in the gall may hasten the death of the branch or tree.

The cedar-apple rust (*Gymnosporangium juniperi-virginianae* Schw.) produces galls on eastern redceder and other junipers. It is primarily a pest of ornamental trees, usually only spoiling their appearance but occasionally becoming serious enough to retard normal development or even kill the tree. The galls may be up to 1 inch in diameter (plate 28, *C*). Before maturity, they are greenish brown with depressions on the surface. During mid- to late May the galls develop numerous orange, conspicuous, gelatinous growths called spore horns (plate 28, *D*) that may be 1½ inches long.

Cedar-quince rust (*Gymnosporangium clavipes* Cke. & PK.) makes swollen, elongate, spindle-shaped galls in the branches of several juniper species. Diseased twigs become swollen and deformed. The gall enlarges yearly as the fungus remains active for many years. During rainy periods in April and May, orange-colored gelatinous masses called spore horns appear on the gall (similar to plate 28, *D*).

Sweetfern rust (*Cronartium comptoniae* Arth.) is a common disease of red, jack, Austrian, and Scotch pines in the Lake States. Sweetfern (fig. 10) and sweetgale are the alternate hosts for this fungus that causes cankers that kill many young trees. Surviving trees become malformed along the stems and often harbor decay fungi that cause heart rot, and secondary insects such as bark beetles and wood borers. The symptoms on seedlings are elongate swellings (plate 27, *D*) that resemble galls of the pine gall weevil (plate 27, *A*).Older trees have elongate grooves (plate 42, *B*) in the bark resembling callous growth following a lightning strike.

Hemlock twig rust is a conspicuous disease that sometimes kills hemlock, especially in nurseries. The pathogen kills new shoots and causes them to curl into pigtails that resemble larch sawfly oviposition injury (plate 31, *B*).

Witches'-broom rusts (*Melampsorella* spp., *et al.*) cause broom-like malformations on conifers, which may be associated with galls, swellings, or cankers similar to (plate 44, *D*). Shoots infected by witches'-brooms are dwarfed (plates 43, *B*, and 44, *A*) and the needles are sometimes discolored. Old witches'-brooms are without needles. Many kinds of insects may live inside a witches'-broom.

Many kinds of fungi cause rots or decays in conifers. Among the most important are those that destroy the heartwood of conifers causing weakening of the tree and loss in volume. Advanced decay appears as soft, punky heartwood (plate 51, *C*). Decay in standing trees is commonly evident from conks (fruiting bodies) growing on the sides of trees. Carpenter ants may be associated with rots and live in the diseased portions (plate 51, *B*).

Root diseases

Two root diseases are commonly associated with insects of conifers. Fomes annosus root rot, *Fomes annosus* (Fr.) Cke., is potentially an important pest of red pine in the Lake States, particularly in 20- to 30-year-old plantings on formerly cultivated land. This fungus commonly attacks trees weakened by insects, although it can kill trees by itself. Infected trees often die in patches so that herbaceous and woody weeds cover the area as a result of the opening.

Fomes annosus root rot can be recognized by the fruiting bodies (conks) attached to the bases of dying trees or stumps (plate 44, *C*). The conks differ in size and occur under the duff. Remove the duff and look for irregular fruiting bodies that are tan, brown, or reddish brown above and chalky white below. Needles and twigs may be incorporated in the conks, which are difficult to tear. The pores on the undersurface are large enough to see with the naked eye and the texture is rubbery or leathery. Very young conks may be mere white buttons on the roots or stem.

Shoestring root rot *Armillaria mellea* (Vahl ex. Fr.) Kummer, infects most conifer species in the Lake States, especially plantation trees weakened by insects and other agents. It can, however, attack and kill healthy trees and is especially troublesome in stands where broadleaf trees have been felled recently. Wood borers and bark beetles are associated with Armillaria-injured trees.

Infected trees show typical decline in vigor and growth, followed by yellowing of the foliage and death of the tree. Resin exudes from the root collar and infiltrates the surrounding soil. White mycelial fans can be found under the bark at the base of the tree. Reddish brown or black, cylindrical, rootlike rhizomorphs grow on the root surfaces under the soil. The fruiting body (mushroom) appears in September or October, usually in clumps from the base of the standing trees or stumps (plate 44, *B*).

Animals

Warmblooded animals seldom seriously injure conifers but their damage often closely resembles or is identical to damage done by certain insects, particularly bark beetles and shoot and root borers. These insects may also attack a tree damaged by animals.

Birds

The yellow-breasted sapsucker injures sapling- and pole-size conifers. It favors hemlock but pecks Scotch pine, and often feeds repeatedly on a favorite tree until it becomes riddled with holes. The circular holes resemble bark beetle holes at first glance, but are shallow and arranged in horizontal rows around the tree (plate 46, *A* and *B*). Insects such as the Zimmerman pine moth (p. 56) are sometimes attracted to and attack sapsucker-injured trees at the point of injury.

Woodpeckers cause minor injury to conifers. Their feeding, however, indicates that boring insects are present and thus the tree is already weakened or dead. They make conical holes (½ inch or larger) in the bark (plate 46, *C*) trying to reach wood borers in tunnels and galleries beneath the bark.

The pine grosbeak, when abundant, can injure stands of young pines and spruces by feeding on buds and breaking new shoots. Young terminals may be broken (as plate 35, *B*) by grosbeaks resting on them. Debudded and broken terminals develop into crooked and forked trees similar to trees injured by shoot moths (p. 53).

Mammals

Mice, pocket gophers, rabbits, and porcupines cause damage that at a distance resembles injury from the pine root collar weevil, pine root tip weevil, and Zimmerman pine moth. These mammals gnaw the stem and major roots stunting growth, discoloring foliage, and causing death by girdling. Bark removed in patches and toothmarks are signs of damage by mammals. The location and size of the toothmarks help determine the pest. Mice, gophers, and rabbits, which have small teeth, gnaw near the base of the tree (plate 45, *A*), though rabbit gnawing may be a foot or more from the ground; porcupines, which have larger teeth, usually gnaw in the upper crown (plate 45, *B*).

Squirrels removing cones commonly cause the shoots above the cone site to flag as if damaged by shoot-boring insects. Ripped tissues, however, provide evidence of cone removal by squirrels (plate 35, *D*). Shoots may be scattered on the ground beneath the tree. Squirrels occasionaly gnaw on disease cankers also.

Deer sometimes injure conifers. Many conifers, especially cedars, are browsed by deer when other food is scarce. Twig tips of browsed trees on the lower 5 feet have splintered, ragged ends. Heavily browsed young trees become crooked and misshapen. Deer also pull the needles off young pines causing injury that resembles sawfly feeding (p. 9). Male deer injure an occasional tree, usually a small sapling, by rubbing their antlers against the bark. This "buck rub" appears as shredded bark on one side of the stem, usually within 3 feet of the ground (plate 45, *C*).

Bears occasionally rub, gnaw, or chew the bark of large saplings and poles. They usually strip the bark vertically with their teeth or claws.

Man, directly or indirectly, causes more injury to conifers than any other mammal. Climbing trees, he breaks branches and scars the bark. When collecting cones, he rips the shoot tissues (as plate 35, *D*) and kills the shoots. With snowmobiles or other vehicles, he drives over young conifers and skins off their bark in a manner resembling buck rub (plate 45, *C*). Often an entire row of pine or spruce may exhibit this symptom. During logging, equipment and vehicles (including horses) crush seedlings and damage

branches and boles, predisposing them to secondary insects and diseases.

Other Agents

Damage from physical or mechanical causes sometimes resembles insect damage. Abnormal temperatures, water, weed killers, and nutritional agents are most often at fault. The absence of insects or lack of frass, emergence holes, tunnels, etc., is usually enough to rule out insect damage. Note, however, that secondary insects such as borers and bark beetles may be present because they attack trees weakened or dead from any cause.

Abnormal temperatures

Perhaps the most common temperature malady is frost damage. Frost causes different kinds of injury depending on the time of year and susceptibility of the host. Greatest injury is caused by late spring frosts—ones that occur during the period of development of the tender new shoots. Young trees are often harder hit than older ones. Spruces and balsam fir are particularly susceptible. The most conspicuous injury of late spring frost is the discoloration, wilting, and death of the new shoots (plate 30, *D*). The pith of frosted shoots usually turns black or dark brown. The trees recover but may develop forks and crooks. Trees repeatedly frost injured become stunted and bushy. Frost can also kill cones.

Although rare in the Lake States, high temperatures can kill needles and shoots of conifers causing needle browning and flagging damage similar to that caused by sucking insects. Fire, of course, may also kill the tree or scorch the foliage in the lower crown. The presence of charred bark would distinguish it from insect damage.

Winter drying or needle burn is caused by excessive transpiration from warm winds in winter. The needles turn yellow and resemble needles injured by sucking insects. Eastern white pine is especially susceptible.

Harmful chemicals

Oils, herbicides, and insecticides can cause "needle burn" and occasionally needle droop (as plate 6, *A* but more severe) when improperly or excessively applied. Usually the needle tips are affected, but entire needles may yellow and drop prematurely. This damage may resembre the pine chafer or sap sucking insects at a distance.

Roadside conifers are commonly injured by salt spray. Eastern

white pine is particularly susceptible; blue spruce and Austrian pine are highly resistant. Injury shows up in early spring, when the conifers appear from a distance to have been injured by an outbreak of sapsucking or tip boring insects. Look for injured needles that are bright orange yellow for various distances from the tips down. The side of the tree facing the road or highway is almost always injured the worst. Only the lower part of the tree is injured on tall trees. The symptoms diminish by summer. Herbicides sprayed on conifers along roadsides produce similar symptoms, but the damage usually occurs later in the summer. Because most conifers can tolerate moderate dosages of herbicides, they usually recover by the following year.

Conifers are very sensitive to industrial smoke and fumes. Dusts and metallic fumes cause only minor damage, but sulphur-bearing gases are highly destructive. At a distance the injury resembles damage from sucking insects or the pine root collar weevil. Smoke damage is usually downwind from a smelter or industrial plant. Look for trees, usually in a group, with bright red-orange needles; or bare trees; or trees with sparse foliage. Lightly injured trees may recover, but growth is stunted. The needles turn brighter red than winter-burned needles, and the damage develops more slowly or later in the year.

Air polution is the cause of chlorotic dwarf disease of eastern white pine. Affected trees have stunted roots and shoots, and short, mottled, needles that are shed prematurely and resemble injury from aphids or scales (plate 13, *B*). New foliage is light green, becomes mottled, and may exhibit tip burn.

Abnormal water conditions

Drought can both retard growth and kill trees. Wilting sometimes precedes reddening of the foliage, the most striking symptom, which occurs in late summer, fall, or early winter. Crowns die from the tips down and from the inside out and often contain secondary insects—bark beetles and wood borers. Young trees are in the soil. Cedars and hemlocks are particularly susceptible.

Conifers that are flooded for long periods are killed or die shortly after the water recedes. The foliage turns red and drops off. When water is above the root collar, a "water line" is left on the tree.

Nutrition

Deficient or excess nutrients can cause symptoms similar to sapsucking insect damage. Deficiencies generally affect the foliage most. Needles become chlorotic, turning pale or yellow at the tips

or along the sides, depending on the specific deficiency (plate 15, *D*).

Overnutrition may cause abnormal, flattened growth called fasciations (plate 31, *D*), or overabundant cones or shoots in certain parts of the tree. Certain types of witches'-broom (plate 44, *A*) may be due to overnutrition. These problems are localized and not detrimental to the tree.

Mechanical

Few trees attain maturity without some mechanical damage. Falling trees and branches injure standing trees; logging equipment breaks branches and gashes bark, causing wounds that provide excellent entries for diseases and secondary insects before they heal. The weight of ice and snow may break the branches and leaders of conifers; small trees and the lower branches of large trees suffer most from this. Branches tend to be torn out (plate 35, *C*), and so differ from drooping branches caused by insects such as the Zimmerman pine moth and eastern pineshoot borer (plate 35, *A* and *B*). Hail causes defoliation, debarking, branch breakage, and tree wounding, and even kills very young trees, so at first glance hail-injured trees appear to be insect injured. Look for scars or damage to the branches and stem on one side of the tree.

PLATES

PLATE 1.—Conifers.

A. Red pine.

B. Eastern white pine.

C. Jack pine.

D. Scotch pine.

PLATE 1

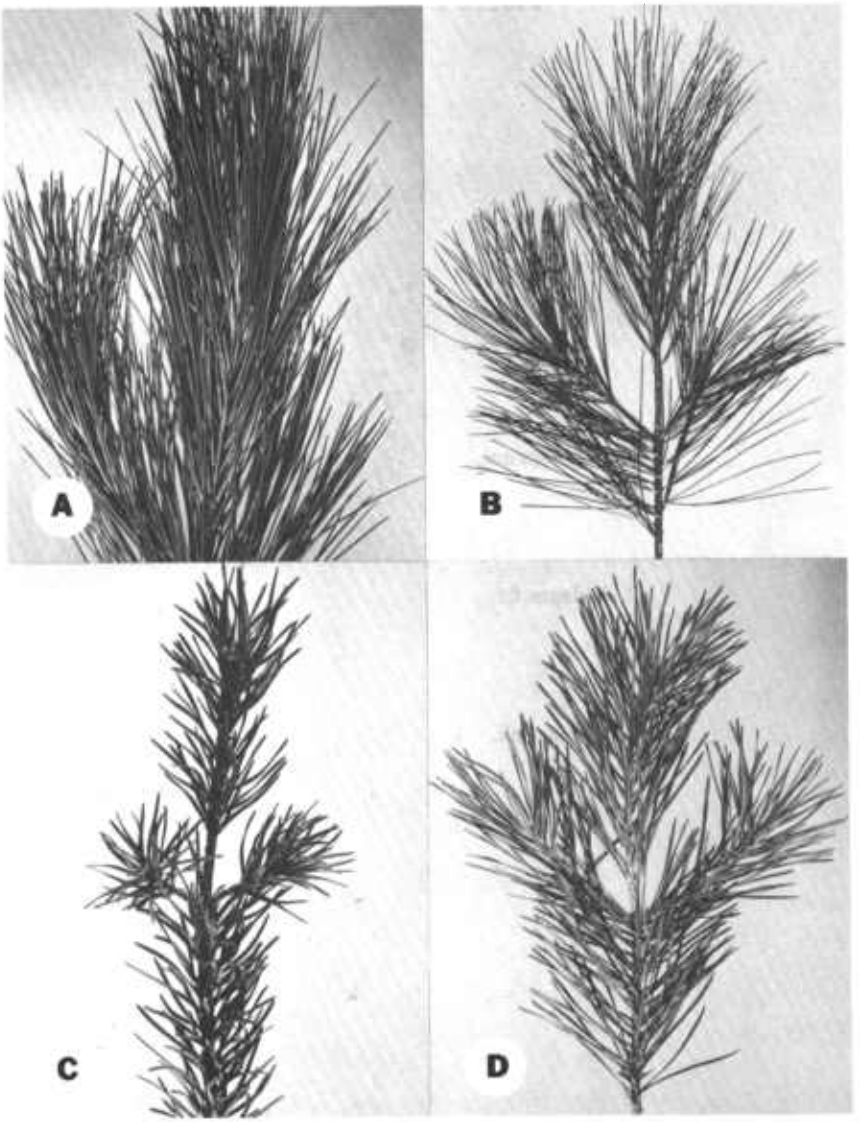


PLATE 2.—Conifers.

A. White spruce.

B. Blue spruce.

C. Balsam fir.

D. Tamarack.

PLATE 2

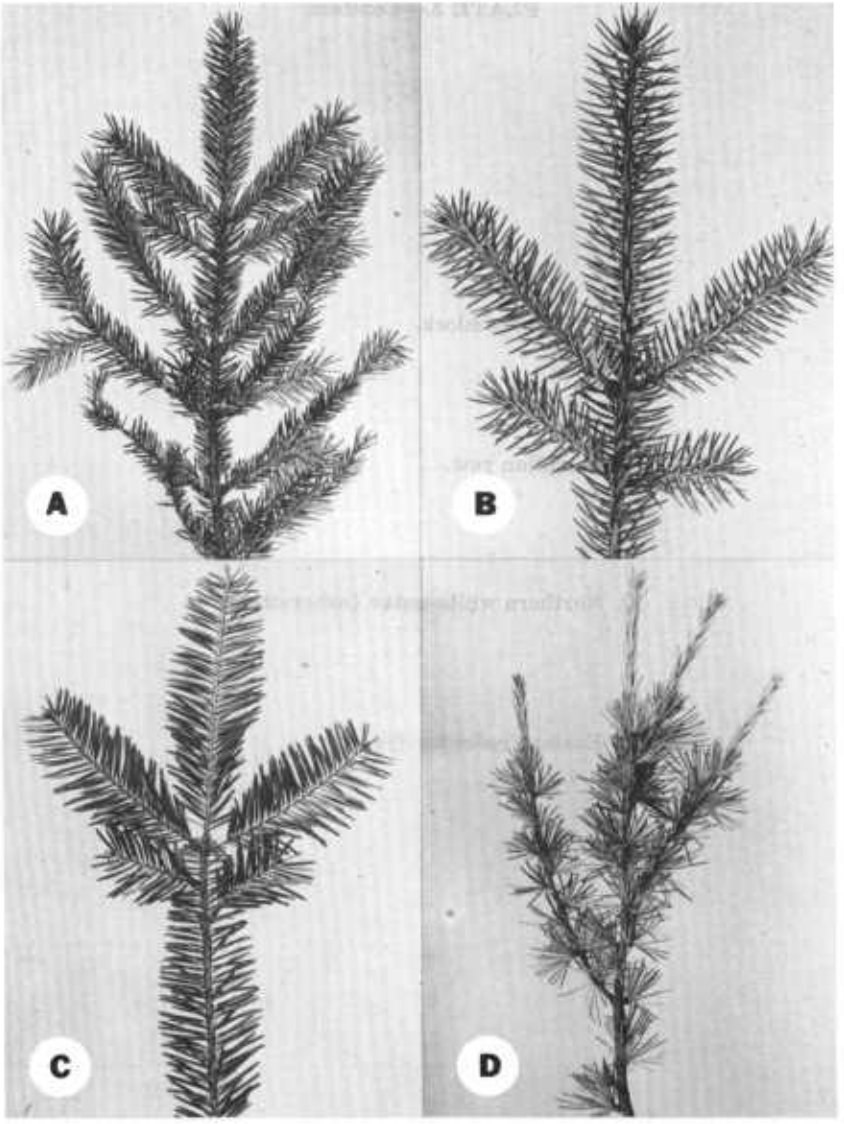


PLATE 3.—Conifers.

A. Eastern hemlock.

B. Canadian yew.

C. Northern white-cedar (arborvitae).

D. Eastern redcedar (juniper).

PLATE 3

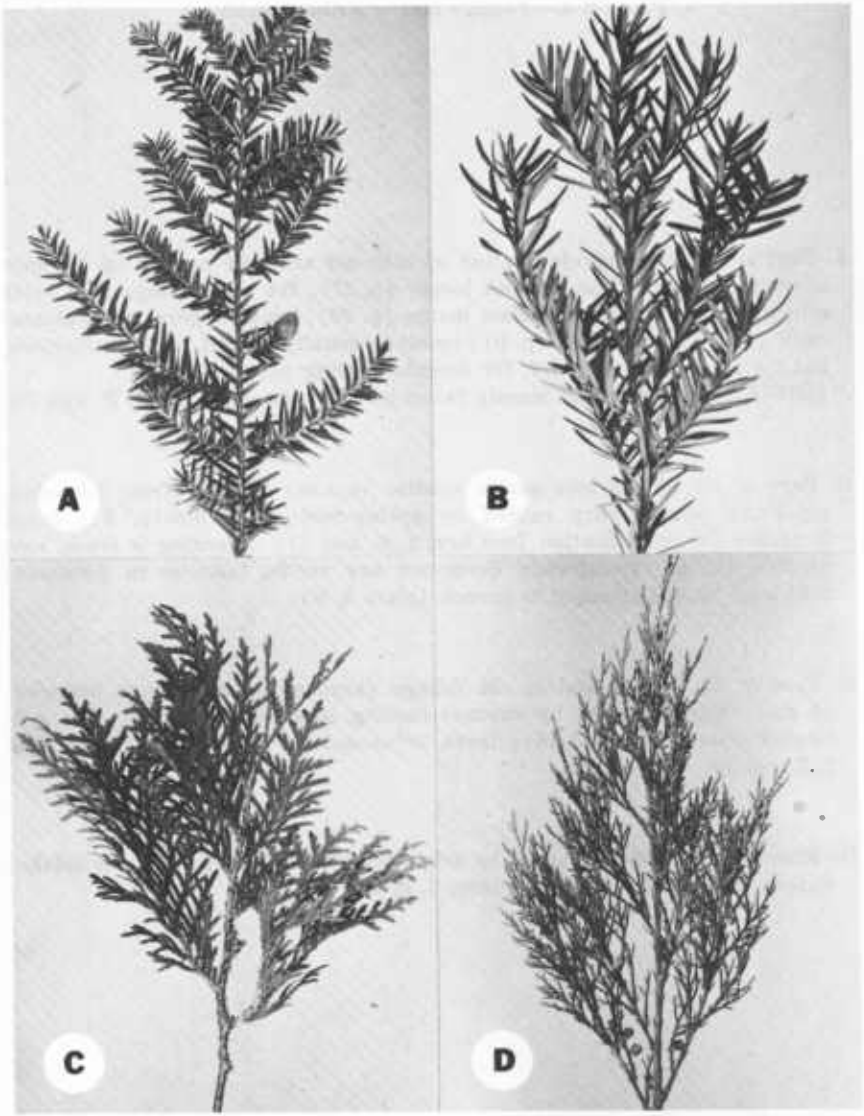


PLATE 4.—Foliage injury without webbing.

A. Partial and complete defoliation of both old and new needles on hemlock branches caused by the hemlock looper (p. 27); for similar injury on hosts other than hemlock, see webless moths (p. 26), grasshoppers and walking-stick (p. 25), or sawflies (p. 9); insect is usually needed for identification, but see plates 4, 5, 6, and 7, for specific feeding patterns.
(NOTE: If needles have simply fallen off tree, see plate 12, *A*, *B*, and *C*).

B. Part or all of previous year's needles (arrow) missing from branches, especially pine; injury caused by spring-feeding sawflies (p. 9); larva is needed for identification (see figs. 1, 2, and 3); if feeding is fresh, new needles will be incompletely developed and needle fascicles in defoliated zone may be still attached to branch (plate 5, *B*).

C. Part or all of new and/or old foliage (arrows) missing from branches of pine; injury caused by summer-feeding sawflies, most likely the red-headed pine sawfly (p. 16); larva is needed for identification (see figs. 1, 2, and 3).

D. Mined leaves (arow) caused by arborvitae leafminer (p. 36); for related miners on other conifers, see plates 7, 9, and p. 33.

PLATE 4

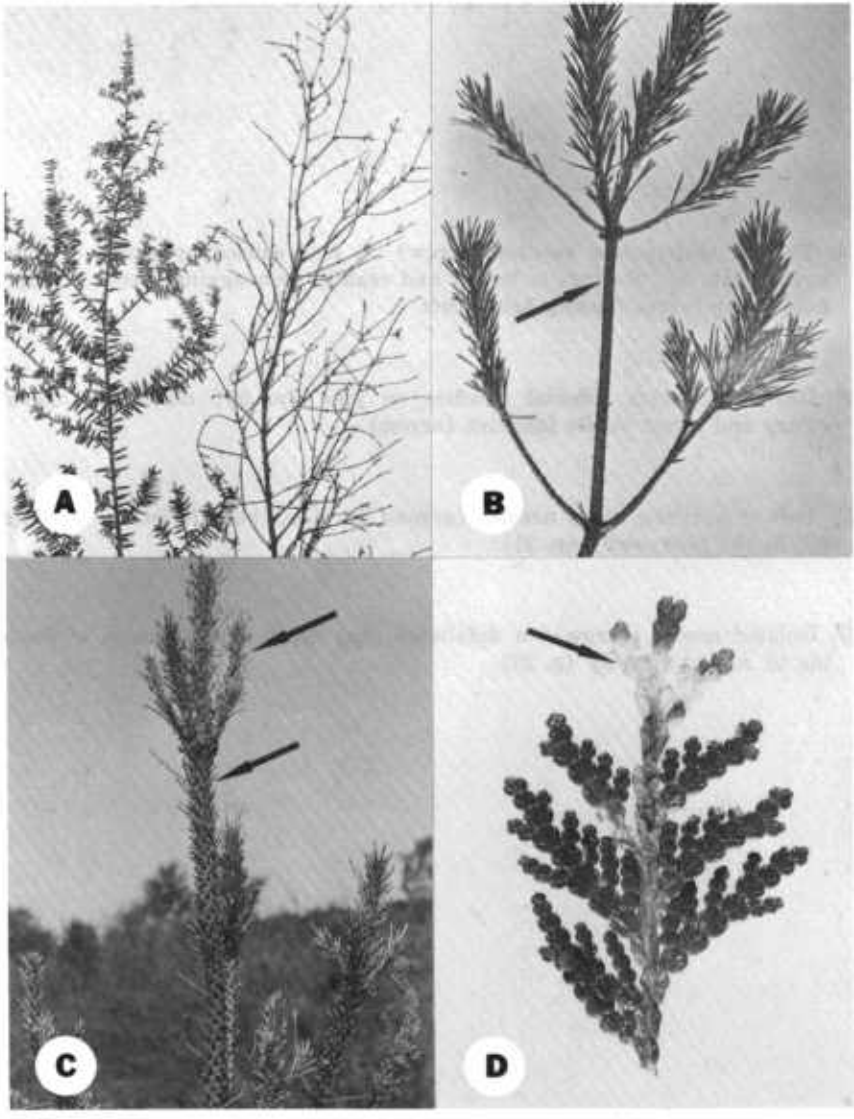


PLATE 5.—Foliage injury without webbing.

A. Tuft of skeletonized needles (arrow) on pine caused by young colonial sawflies (p. 9); the tuft is brown and readily seen against green foliage; note young larvae feeding below tuft.

B. Defoliation from colonial sawflies on pine (p. 9); notice the larval colony and intact needle fascicles (arrow).

C. Tuft of partially eaten needles (arrow) on pine, characteristic of feeding by the red pine sawfly (p. 21).

D. Isolated needle (arrow) on defoliated pine shoot, characteristic of feeding by Abbott's sawfly (p. 20).

PLATE 5

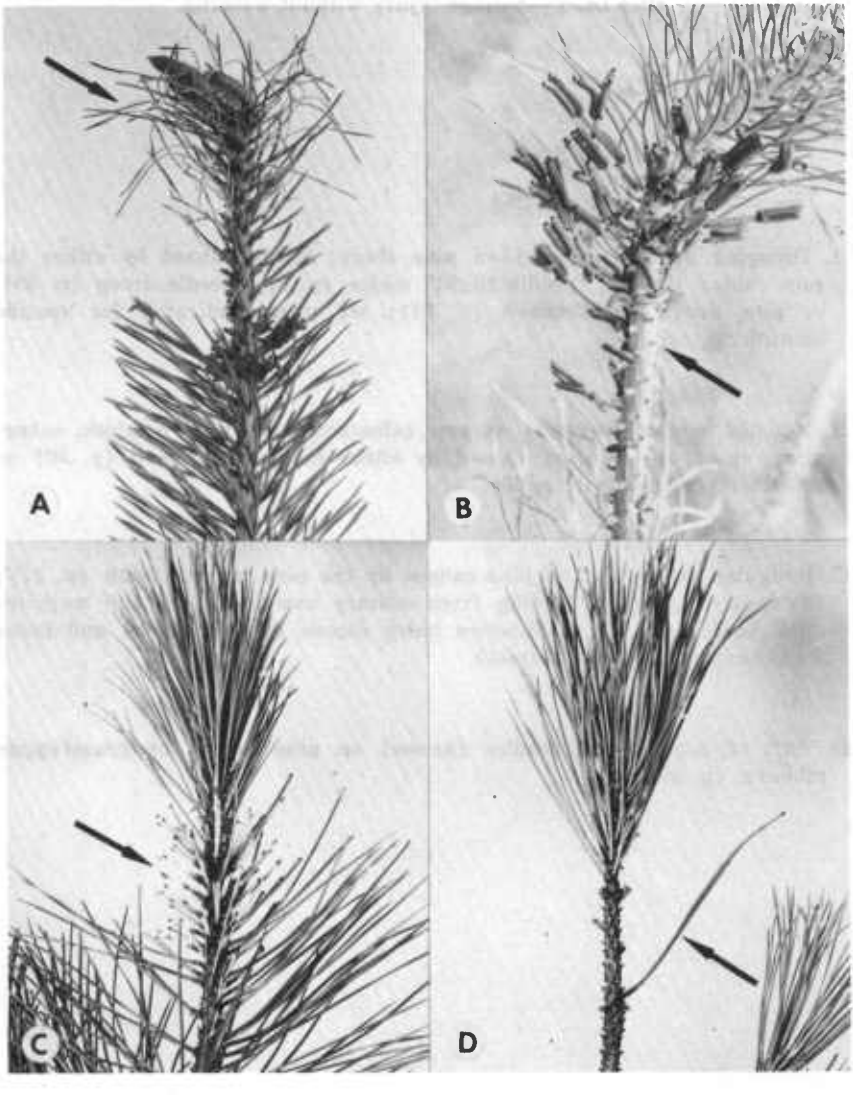


PLATE 6.—Foliage injury without webbing.

A. Drooping needles (arrow) on pine shoot; injury caused by either the pine chafer (p. 24), "needle blight" midge (p. 51), needle droop (p. 86), or pine needle sheathminer (p. 34); see pages indicated for specific identifiers.

B. Notched needles (arrows) on yew (also occasionally on hemlock, arborvitae, or spruce); injury caused by either black vine weevil (p. 66) or strawberry root weevil (p. 66).

C. Irregular defoliation on pine caused by the pine tussock moth (p. 27); the injury resembles feeding from solitary sawflies (p. 9) and walkingstick (rare) (p. 26); distinctive hairy cocoon (upper arrow) and larva (lower arrow) identify the moth.

D. Tuft of clipped new needles (arrow) on pine caused by grasshopper nibbling (p. 25).

PLATE 6

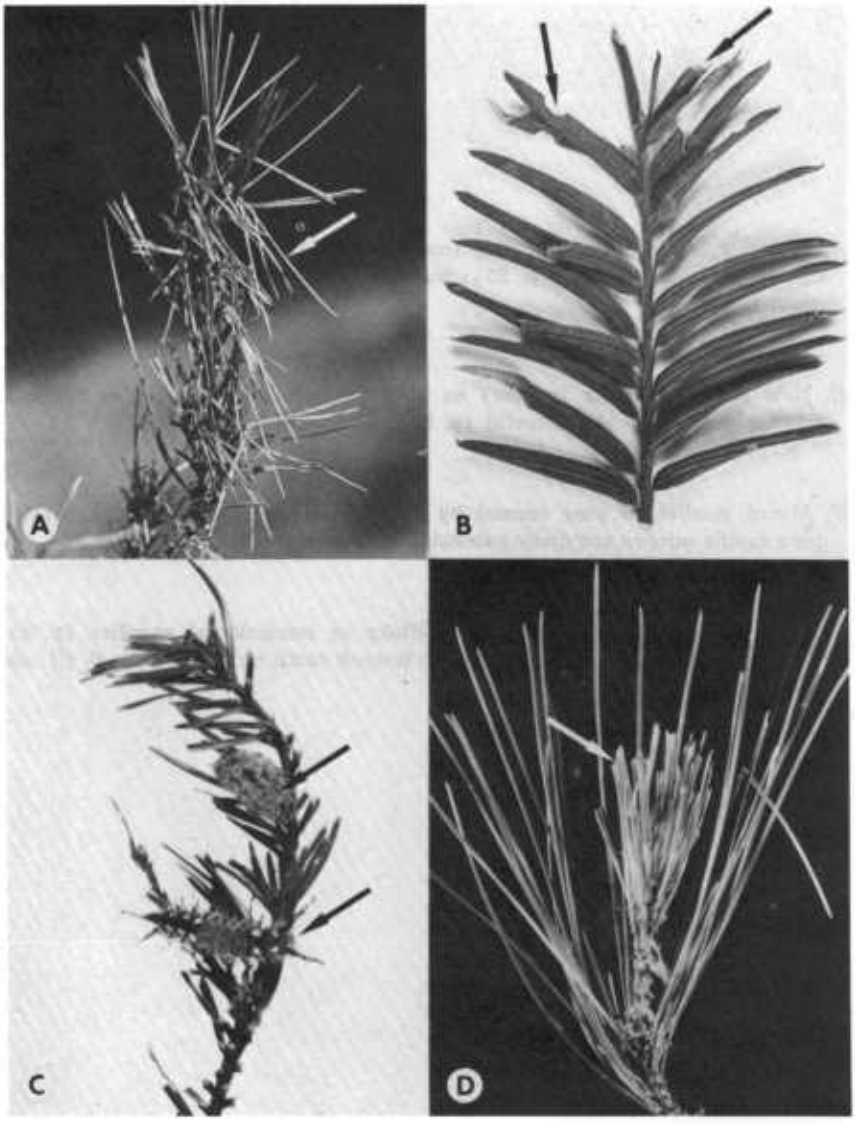


PLATE 7.—Foliage injury without webbing.

A. Notched old needles on pine (occasionally hemlock or spruce) caused by the pine chrysomelid (p. 25); male cones may be injured also (also see plate 7, *B*).

B. New needles missing (arrow) on pine (occasionally hemlock or spruce), caused by the pine chrysomelid (p. 25) (also see plate 7, *A*).

C. Mined needles of pine caused by the pine needle miner (p. 34); other pine needle miners are distinguishable by the injury they cause (p. 35).

D. Irregular defoliation caused by solitary or semicolonial sawflies (p. 9); the injury resembles that of the pine tussock moth on pine (plate 6, *C*) and walkingstick (rare) (p. 26).

PLATE 7

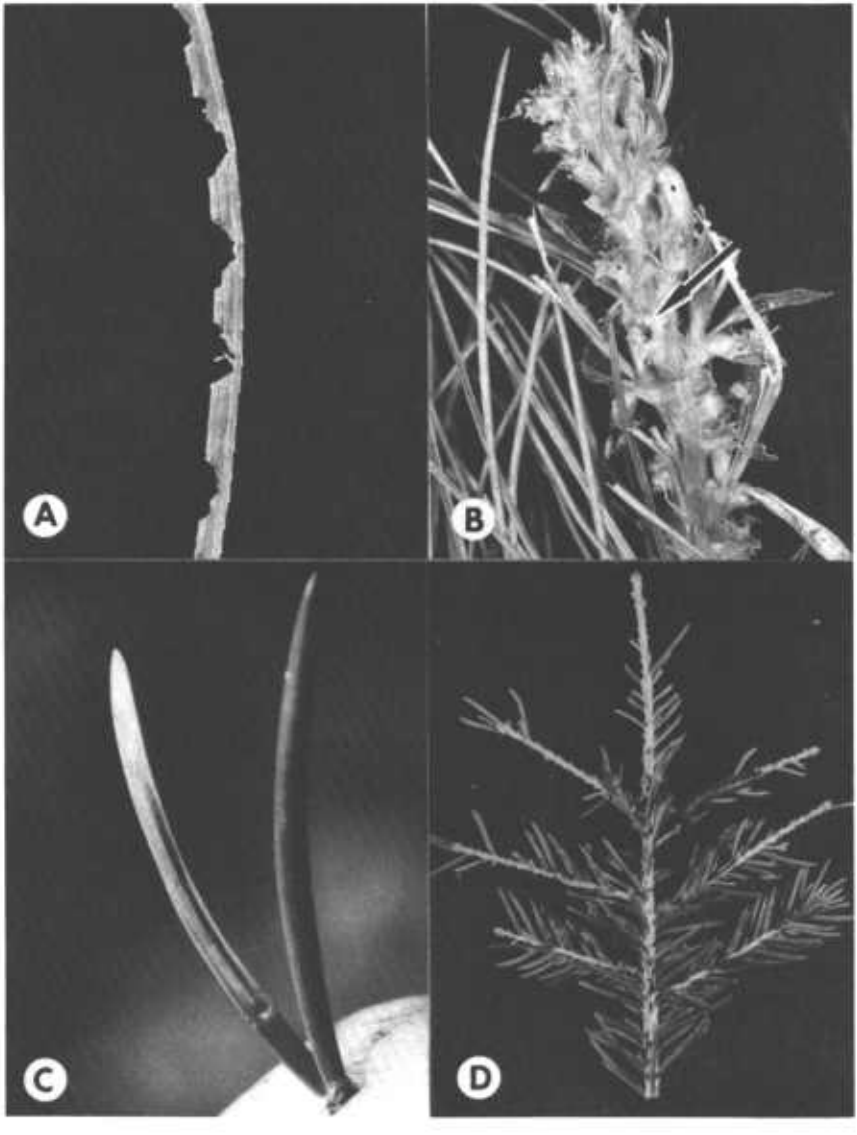


PLATE 8.—Foliage injury with webbing.

A. Webbed foliage of balsam fir (similar on spruce) caused by the spruce budworm (p. 31); the injury is similar to that of the eastern blackheaded budworm (p. 32); the larva (arrow) is distinctive; also look for distinctive signs such as debris, frass, pupal cases after June.

B. Webbed foliage of pine caused by the jack pine budworm (p. 32); look for debris, frass, and pupal cases (arrow) after June; larva is similar to that of spruce budworm (plate 8, *A*).

C. Webbed foliage (arrow) and shoots of pine caused by the tip moth *Tortrix pallorana* (p. 33); after shoots are tunneled, they wilt and droop, resembling those in plate 30, *A*, but webbing is present.

D. Webbed and mined terminal needles of pine caused by the pine needle sheathminer (p. 34); small hole (arrow) occurs near base of each mined needle; mined needles later droop from the base resembling injury by several other agents (see plate 6, *A*).

PLATE 8

PLATE 9.—Foliage injury with webbing.

A. Webbed and mined foliage on juniper caused by the *young* larvae of the juniper webworm (p. 29); older larvae produce large and distinct nests (see plate 11, *A*); a juniper needleminer (p. 36) and a hemlock needleminer (p. 36) cause similar injury.

B. Webbed and mined foliage on spruce caused by the spruce needleminer (p. 34); other spruce miners cause similar injury; see p. 33 and 34 for characteristics.

C. Webbed and mined foliage on spruce caused by the spruce leafminer (p. 33); other spruce miners cause similar injury; see p. 33 and 34 for characteristics; also see spruce budworm (p. 31), especially if feeding is on the shoot tips.

D. Webbed foliage on spruce caused by the spruce spider mite (p. 52); foliage may be discolored but needles are not mined out.

PLATE 9

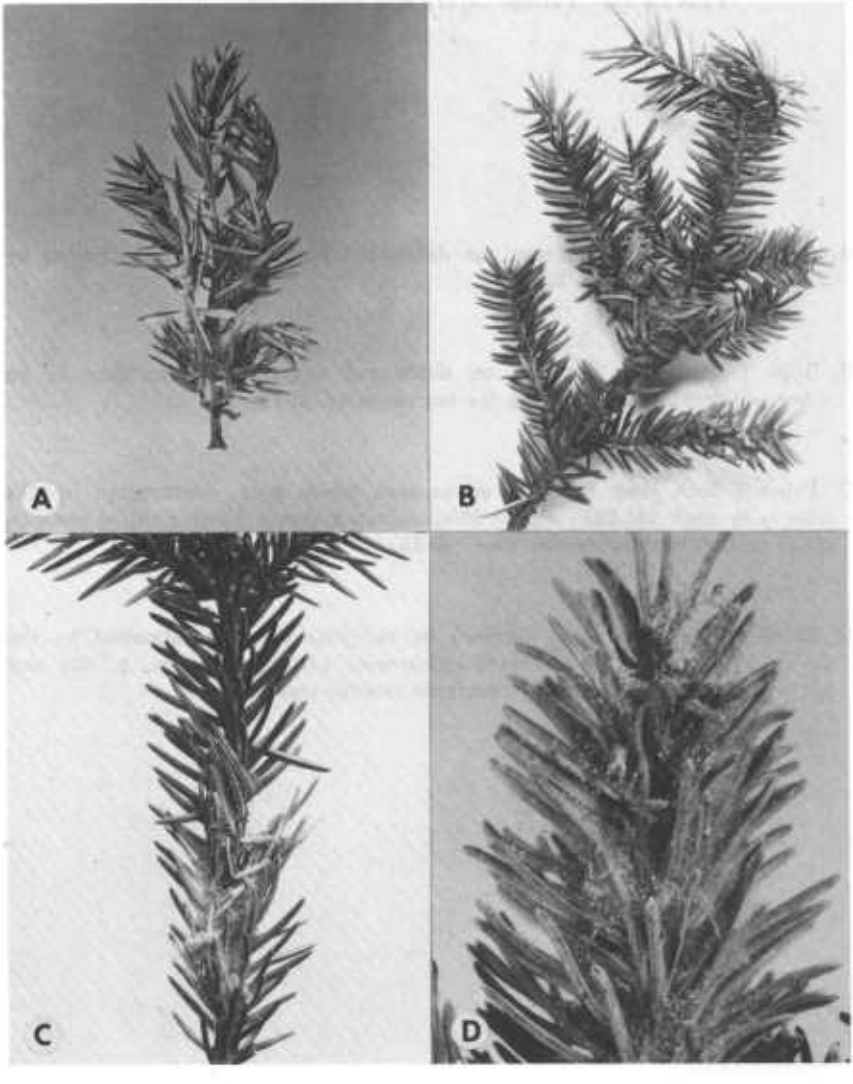


PLATE 10.—Foliage injury and webbed concealments.

A. Cases ¼ inch long (arrow) on defoliated larch branch, constructed by the larch casebearer (p. 35).

B. Bags 1 inch long (arrow) on defoliated arborvitae (also may be on other conifers) constructed by the bagworm (p. 29).

C. Tubes 1 inch long (arrow) on eastern white pine, constructed by the pine tube moth (p. 29); a pine needleminer makes a similar tubed concealment on jack and ponderosa pine (p. 35).

D. Small nest ¾ inch long (arrow) on red pine shoot, constructed by the pine webworm (p. 30); certain coneworms (*Dioryctria* spp., p. 82) and nesting pine sawflies (p. 30) construct similar small nests.

PLATE 10

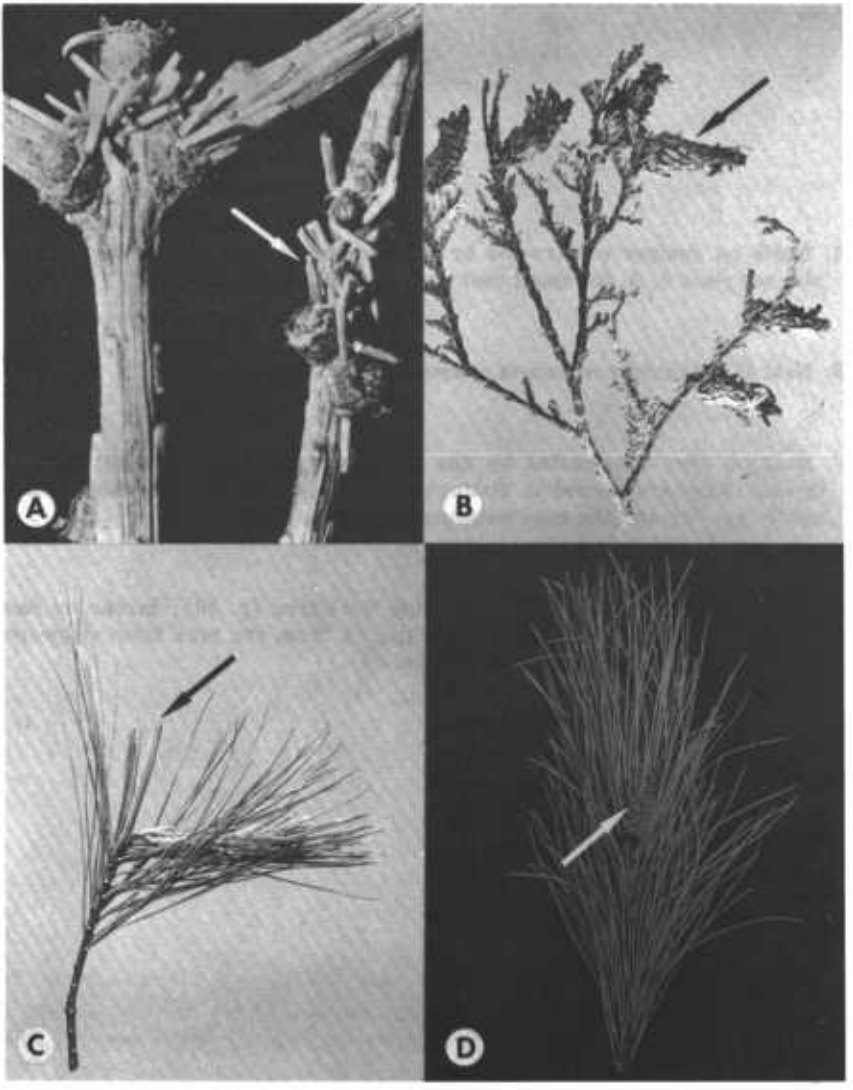


PLATE 11.—Foliage injury and webbed concealments.

A. Nests on juniper constructed by the juniper webworm (arrow) (p. 29) also see plate 9, *A*, for small nest and plate 11, *B*, for larvae.

B. Nest of the juniper webworm opened to show larvae.

C. Nest on pine constructed by the pine false webworm (p. 30); larvae or cast skins are needed to distinguish this species from the nesting pine sawfly (p. 30) and the pine webworm (p. 30).

D. Nest on pine constructed by the pine webworm (p. 30); larvae or cast skins are needed to distinguish this species from the pine false webworm (p. 30) and the nesting pine sawfly (p. 30).

PLATE 11

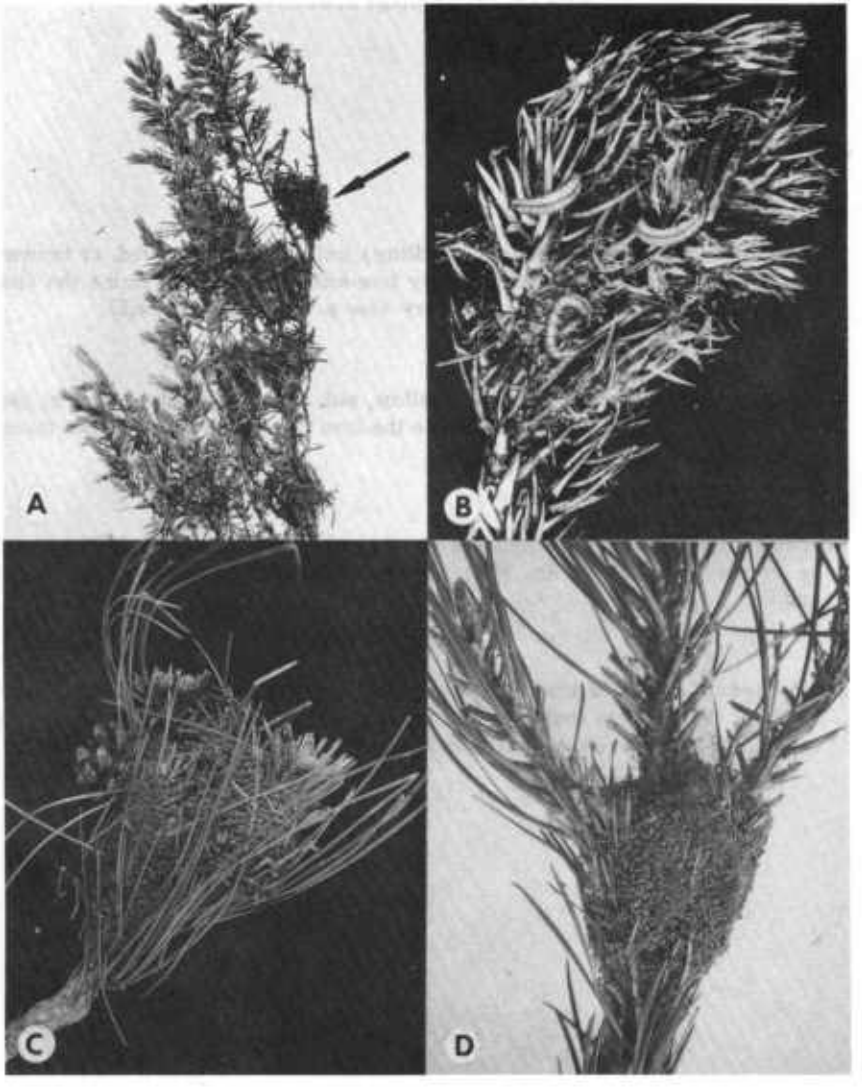


PLATE 12.—Foliage discolored.

A. Upper crown or entire tree (or seedling) uniformly yellow, red, or brown; this symptom can be caused by many tree-killing agents; examine the tree closely for signs of the insect or injury (see p. 2 for instructions).

B. Shoot tips or branches flagging—yellow, red, or brown; this symptom can be caused by several agents; examine the tree closely for signs of the insect or injury (see p. 2 for instructions).

C. Lower crown (arrow) discolored (or bare because of needle fall) caused by brown spot disease (p. 85); also see other needlecast diseases, p. 85 and 86.

D. Foliage on shoots or branches blackened (arrow) by a sooty mold fungus (p. 85); this fungus indicates the presence or recent occupancy of aphids (p. 44), soft scales (p. 41), or spittlebugs (p. 37).

PLATE 12

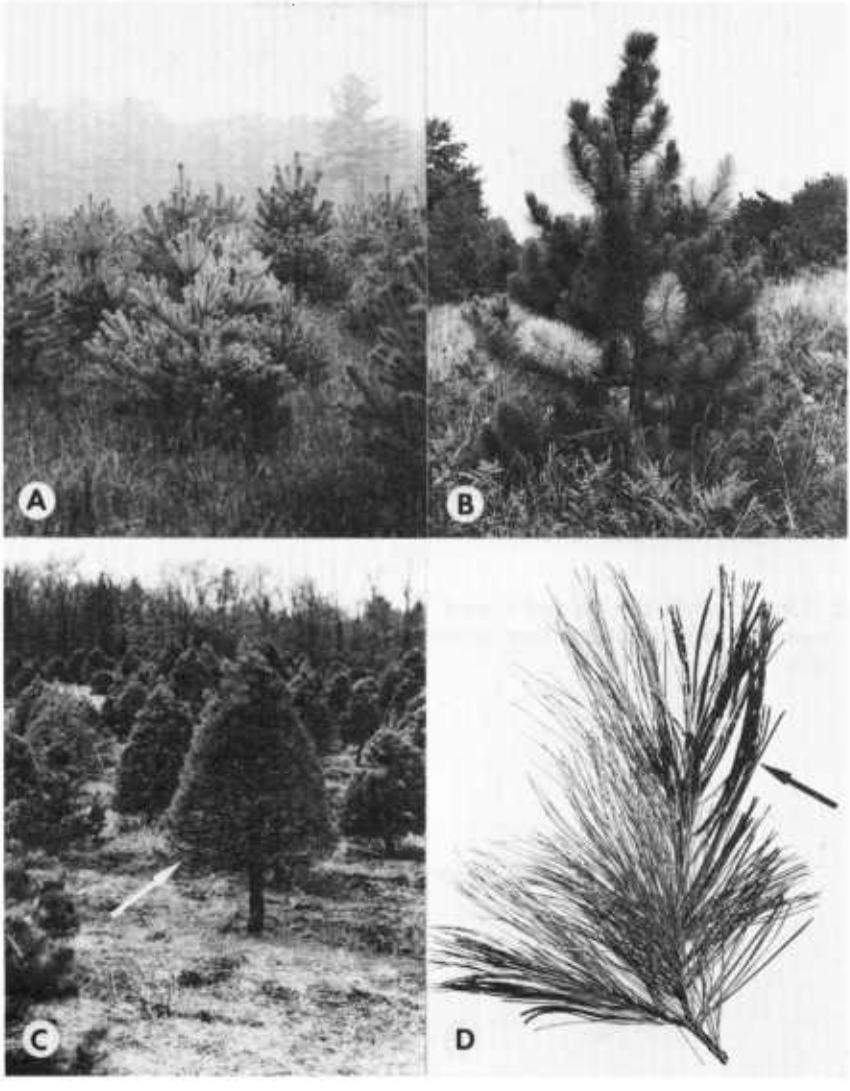


PLATE 13.—Foliage discolored.

A. Flagged shoot tips (arrow) of juniper caused by the juniper tip midge (p. 51).

B. Pale, thin foliage on pine caused by the black pineleaf scale (p. 42) (also see plate 17, *A* and *B*, of the scale).

C. Flagged shoot tips on pine caused by the gouty pitch midge (p. 50) (also see plate 39, *C* and *D*, for specific identifiers).

D. Flagged shoot tips on yew caused by black vine weevil larvae feeding on roots (p. 66); similar injury is caused by the strawberry root weevil (p. 66).

PLATE 13

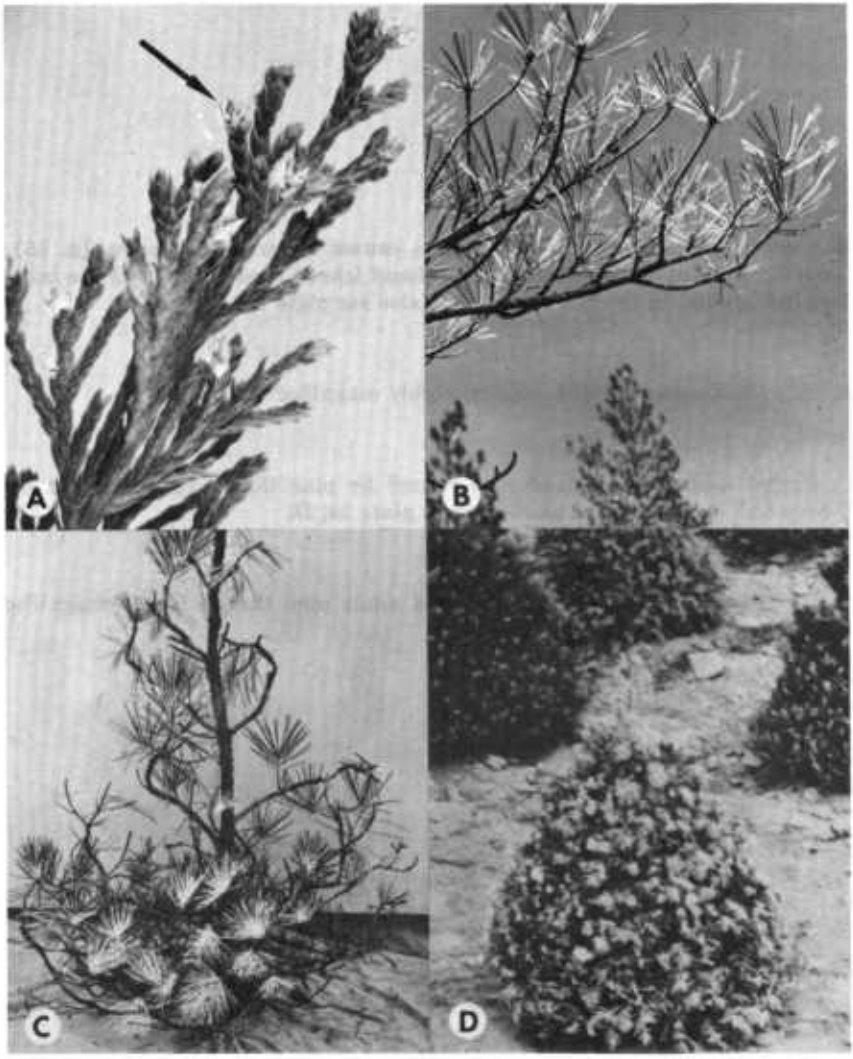


PLATE 14.—Foliage malformed.

A. Curled needle tips (arrow) of pine caused by eriophyid mites (p. 53); needle tips are usually discolored; a hand lens is needed to detect the mites on the needles in the fascicle region (also see plate 14, *B*).

B. Eriophyid mites on pine needles, highly magnified (p. 53).

C. Curled needles (arow) of pine caused by pine thrips (p. 49); look for brownish wounds on the needles, as in plate 14, *D*.

D. Wound on pine needle (arrow) and adult pine thrips, highly magnified (p. 49); immature thrips are yellow.

PLATE 14

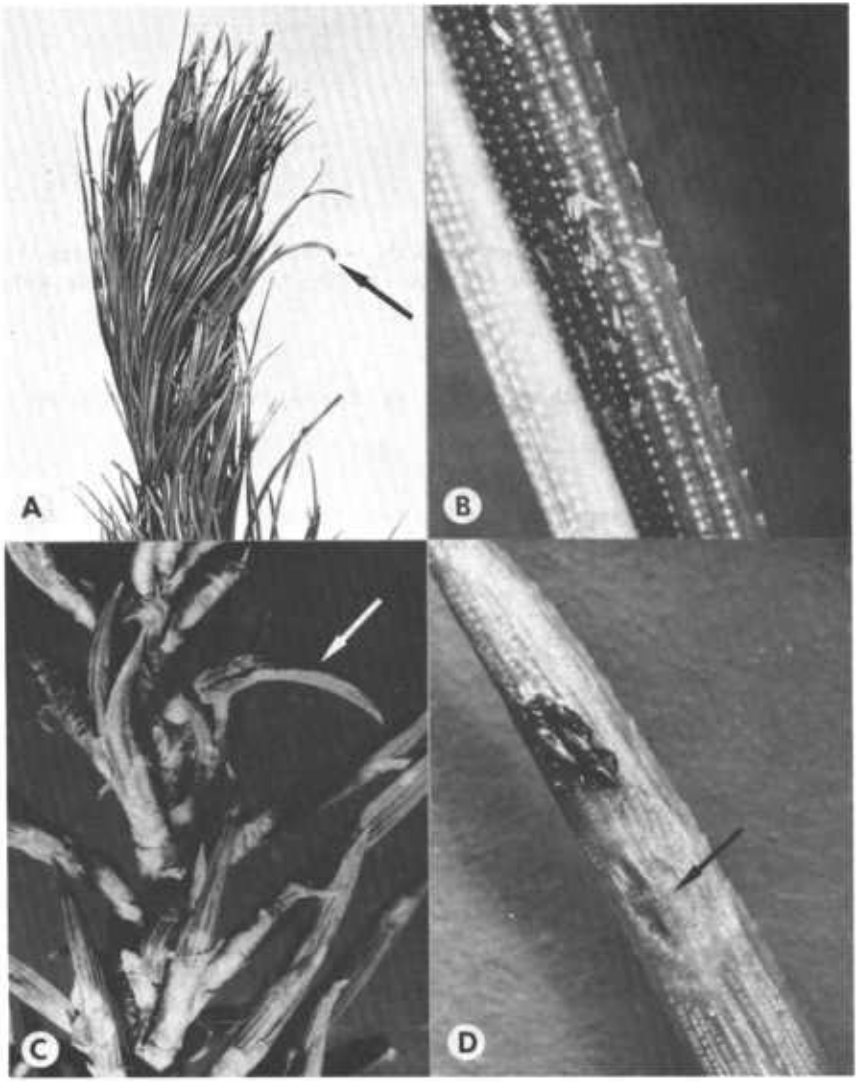


PLATE 15.—Foliage spotted or discolored.

A, B. Red pine infected with pustules of the red pine needle rust (a disease); similar rusts occur on other conifers (p. 85); these may resemble scale insects at first glance.

C. Jack pine infected with needlecast (a disease), showing hysterothecia (arrow) (p. 85).

D. Spruce showing symptoms of a nutrient deficiency (arrow); symptoms vary somewhat depending on the nutrient involved (p. 92).

PLATE 15

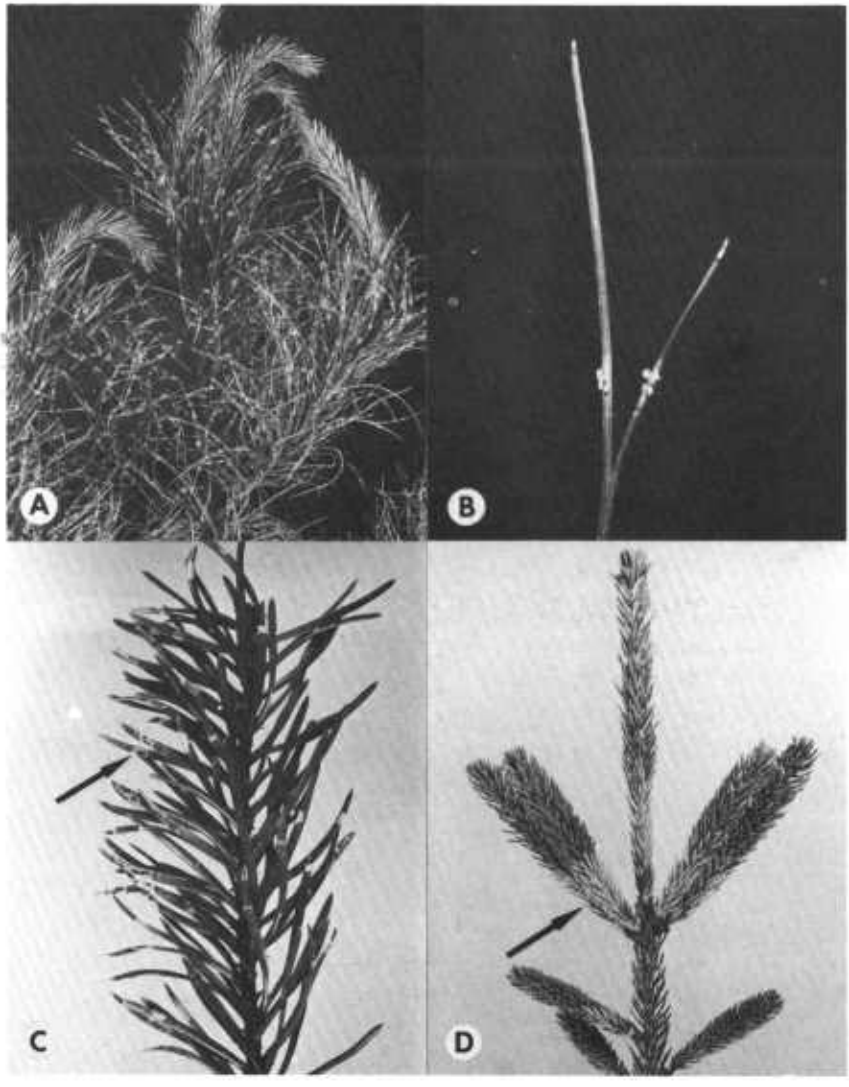


PLATE 16.—Foliage spotted.

A, B. Egg cluster of a colonial sawfly (p. 9); these eggs superficially resemble scale insects but are *in* the needles rather than *on* them.

C, D. Pine needle scale on needles of pine (also found on other conifers) (p. 42).

PLATE 16

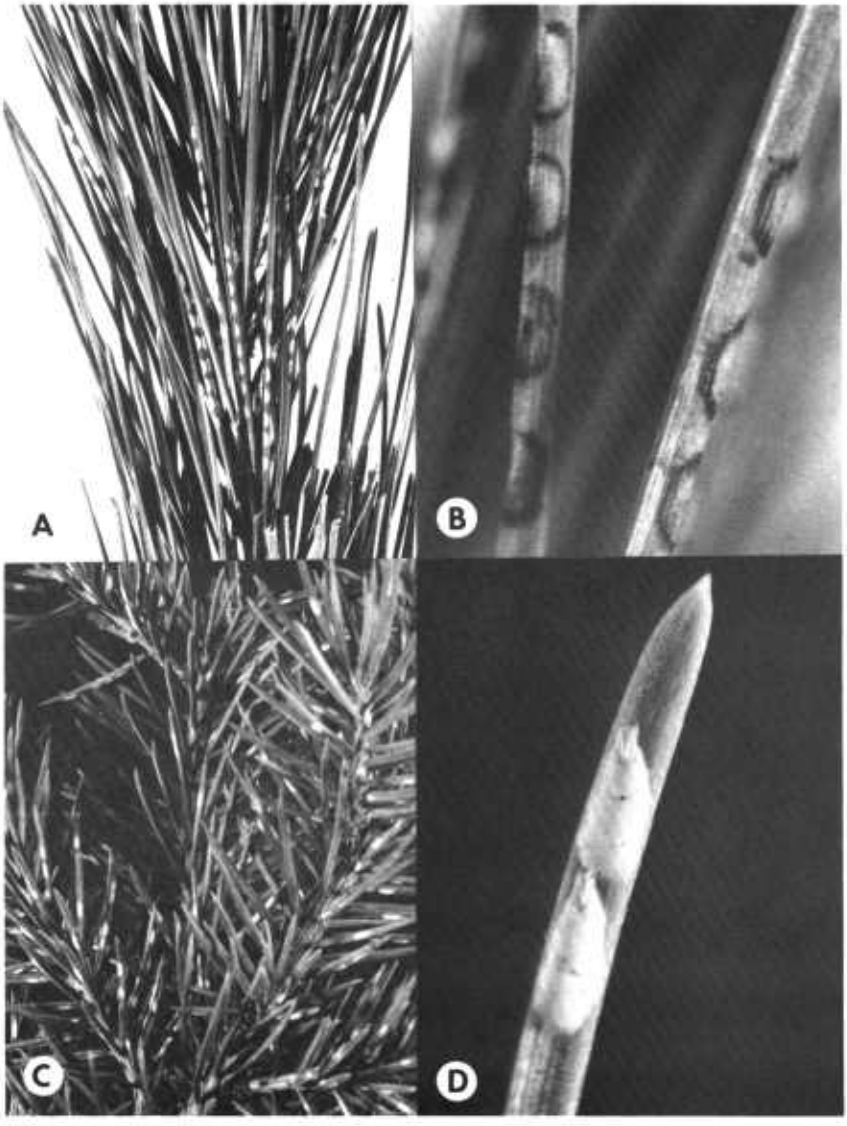


PLATE 17.—Scales and aphids.

A, B. Black pineleaf scales (arrow) on pine needles (p. 42).

C, D. Eastern spruce gall aphid adults (arrow) on spruce needles; migrant adults of other species of gall aphids are similar (p. 46).

PLATE 17

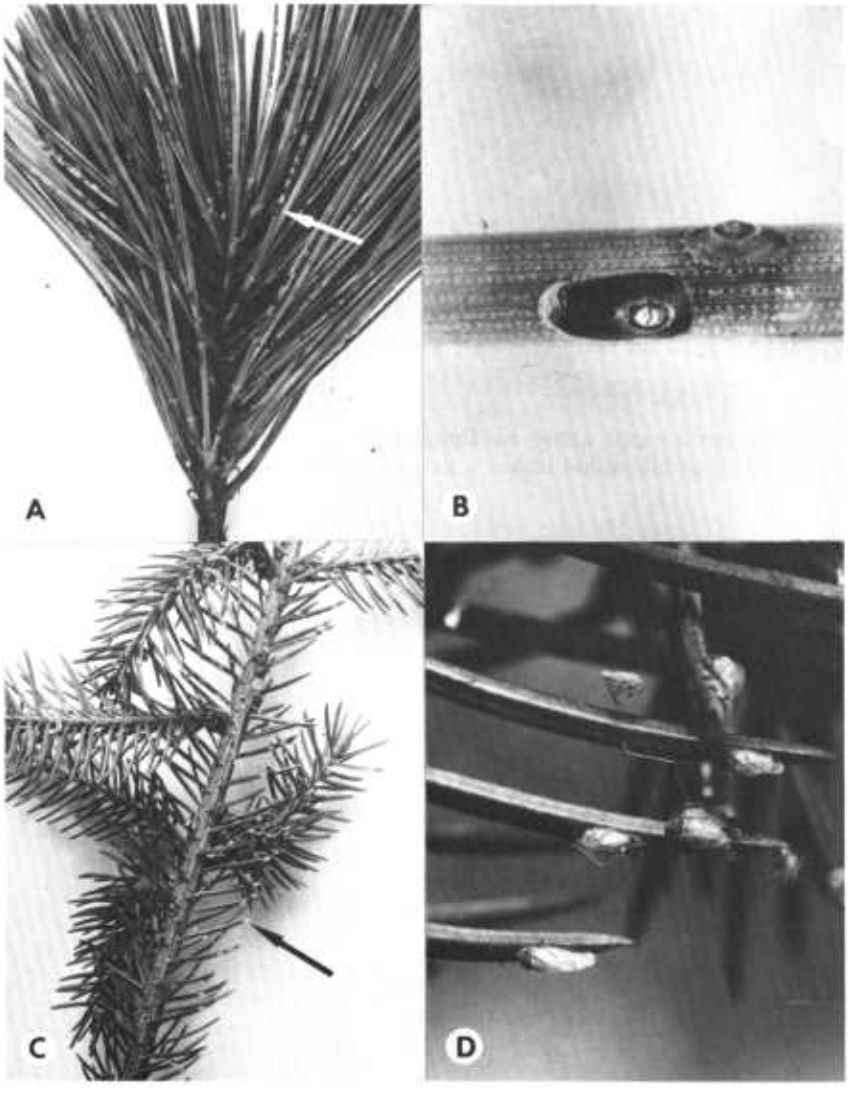


PLATE 18.—Scales and aphids.

A. Fletcher scale (arrow) on arborvitae foliage (p. 42) (also see plate 18,*B*).

B. Fletcher scale on juniper shoot (p. 42) (also see plate 18, *A*).

C. Cooley spruce gall aphid on Douglas-fir needles (p. 47); the alternate generation of this aphid makes a gall on spruce (see plate 23, *B*).

D. Juniper scale (arrow) on juniper foliage (p. 42).

PLATE 18

PLATE 19.—Scales and scalelike fruit.

A. Female pine tortoise scales (arrow) on pine shoot (p. 41).

B. Male pine tortoise scales on pine shoot (p. 41).

C. Spruce bud scales on spruce shoot (p. 43); observe carefully to distinguish them from true buds.

D. Juniperberries on juniper; although these are the fruit of juniper, they are occasionally mistaken for scales (p. 41) or disease galls (p. 87).

PLATE 19

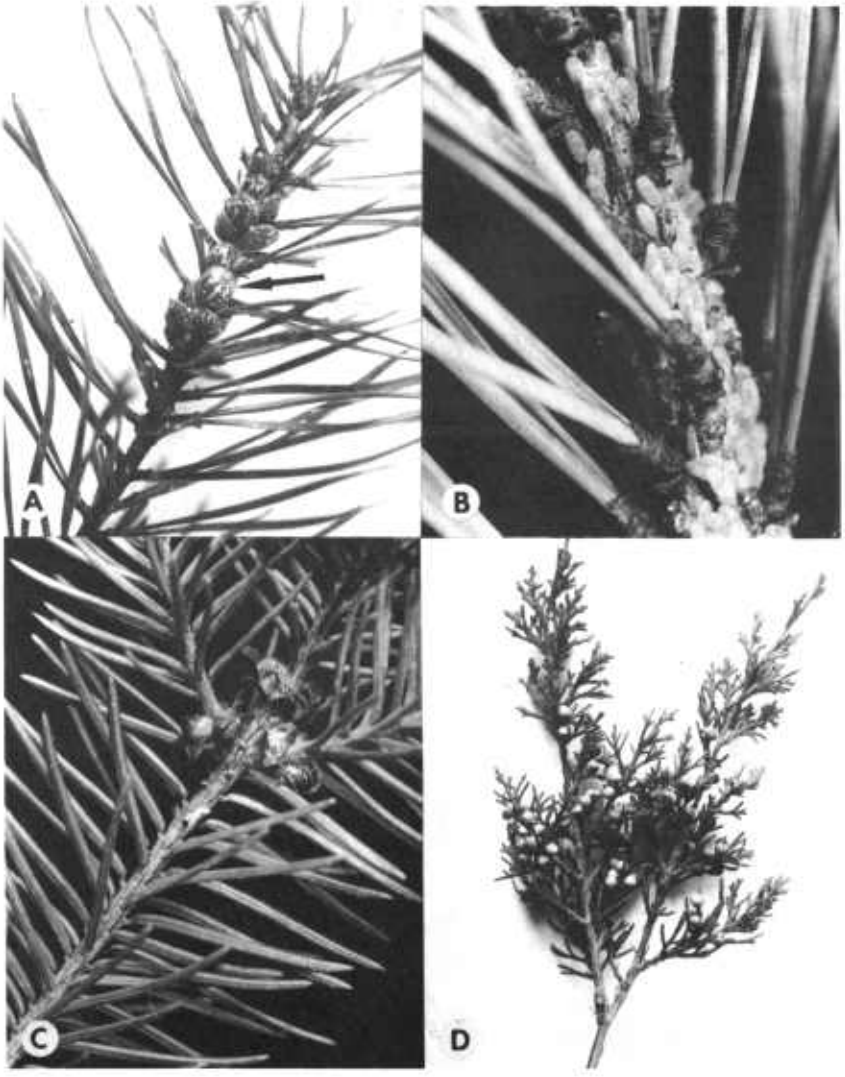


PLATE 20.—Woolly aphids and scales.

A. Eastern spruce gall aphid egg cases on spruce (p. 46).

B. Woolly pine scale on red pine (p. 43).

C. Possible *Pulvinaria* sp. (arrow) on balsam fir (p. 43).

D. Woolly larch aphids on larch (p. 47).

PLATE 20

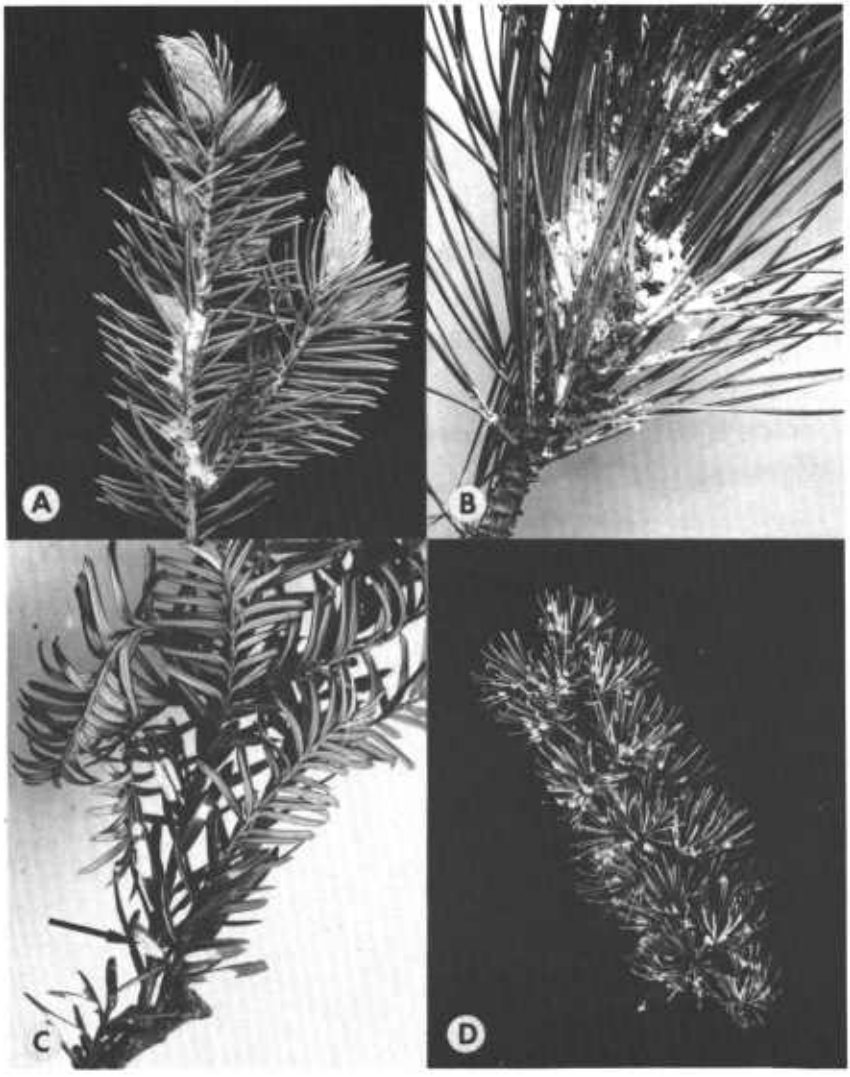


PLATE 21.—Aphids.

A. Pine bark aphids on pine twig (p. 44).

B. Aphid egg clusters on pine needles (p. 44).

C. Woolly larch aphid colonies (arrow) clustered at base of larch shoots (p. 47).

D. Typical colony of naked aphids (or plant lice) (p. 44) on conifer twig.

PLATE 21

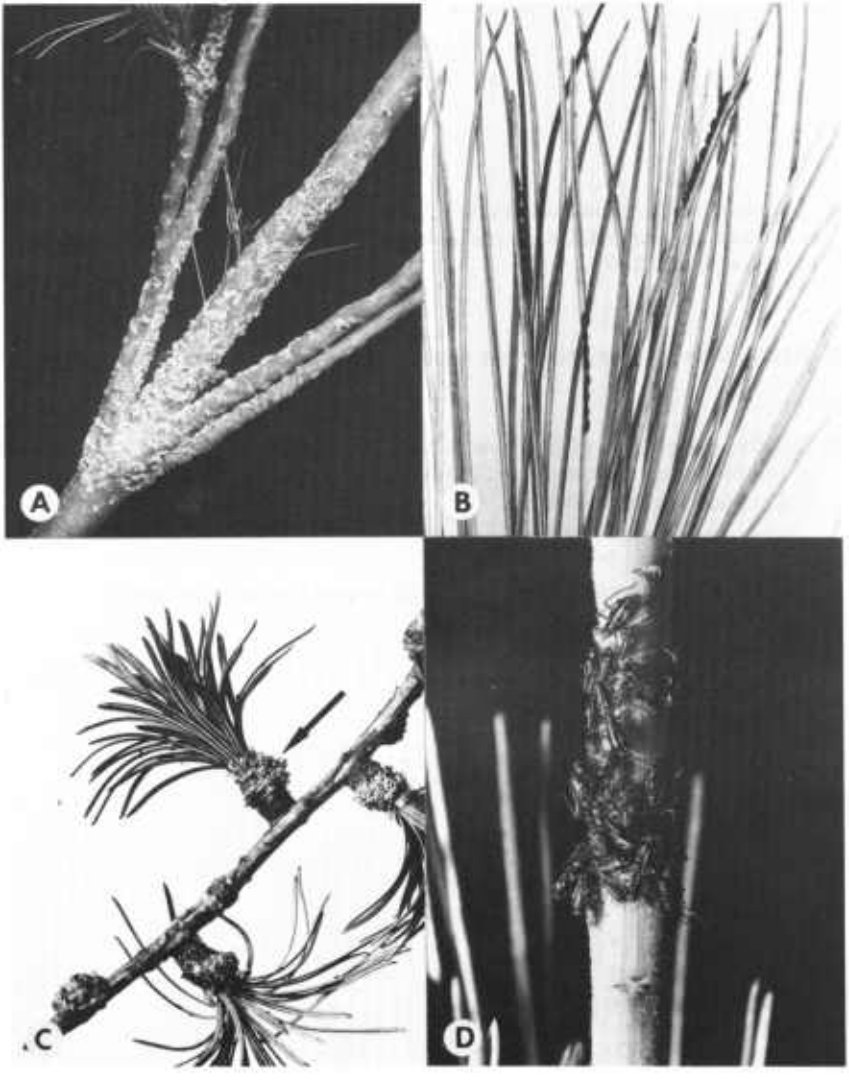


PLATE 22.—Frothy concealments.

A. Spittlemass on pine constructed by the pine spittlebug (p. 39), which resembles the rarer *Clastoptera* spittlemasses on pine and juniper (p. 40) (also see plate 22, *B*).

B. Spittlemass of pine spittlebug opened to show the nymph (arrow).

C. Spittlemass at base of herbaceous vegetation (in a pine stand) constructed by the Saratoga spittlebug (p. 37), resembling the less common spittlemass of the Signoret spittlebug (p. 40) (also see plate 22, *D*).

D. Spittlemass of the Saratoga spittlebug opened to show the nymph.

PLATE 22

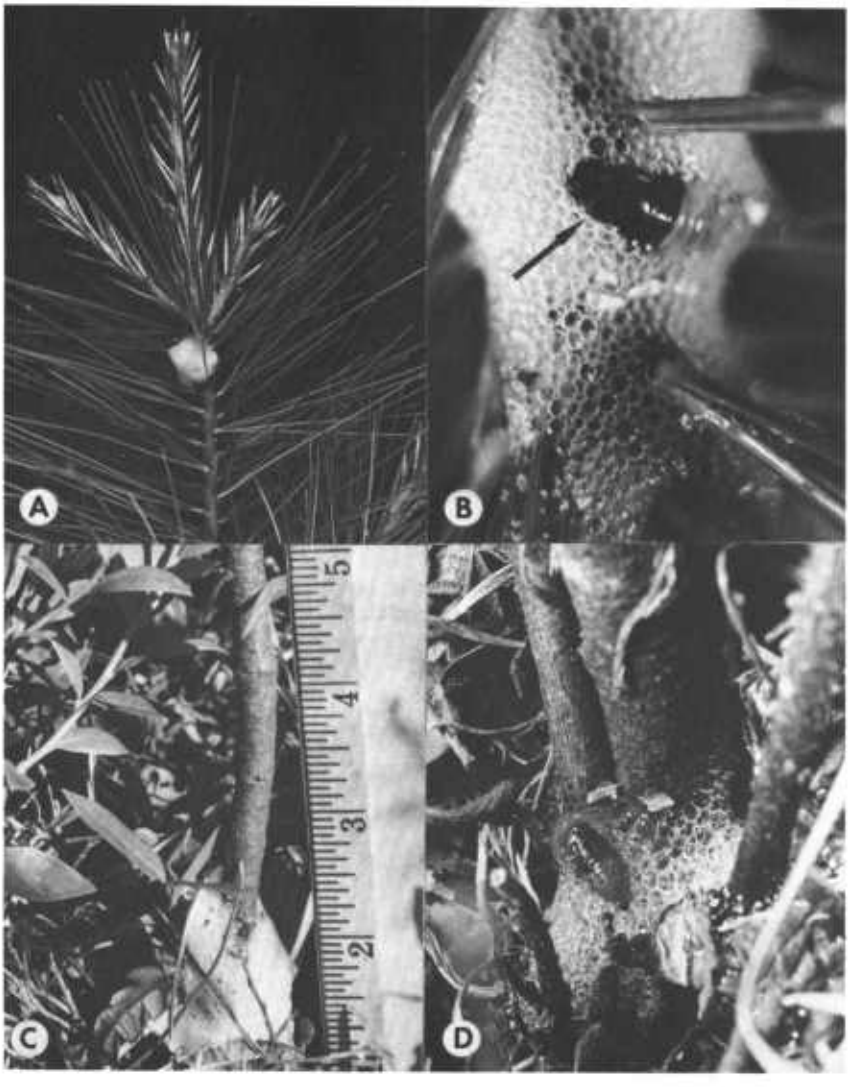


PLATE 23.—Galls.

A. Galls on spruce (arrow) of eastern spruce gall aphid (p. 46).

B. Gall on spruce of Cooley spruce gall aphid (p. 47); the alternate generation aphids occur on Douglas-fir (see plate 18, *C*).

C. Gall on spruce (arrow) of the red spruce aphid (p. 48); the alternate generation aphids occur on eastern white pine.

D. Gall on spruce (arrow) of the woolly larch aphid (p. 47); the alternate generation aphids occur on larch (see plate 21, *C*).

PLATE 23

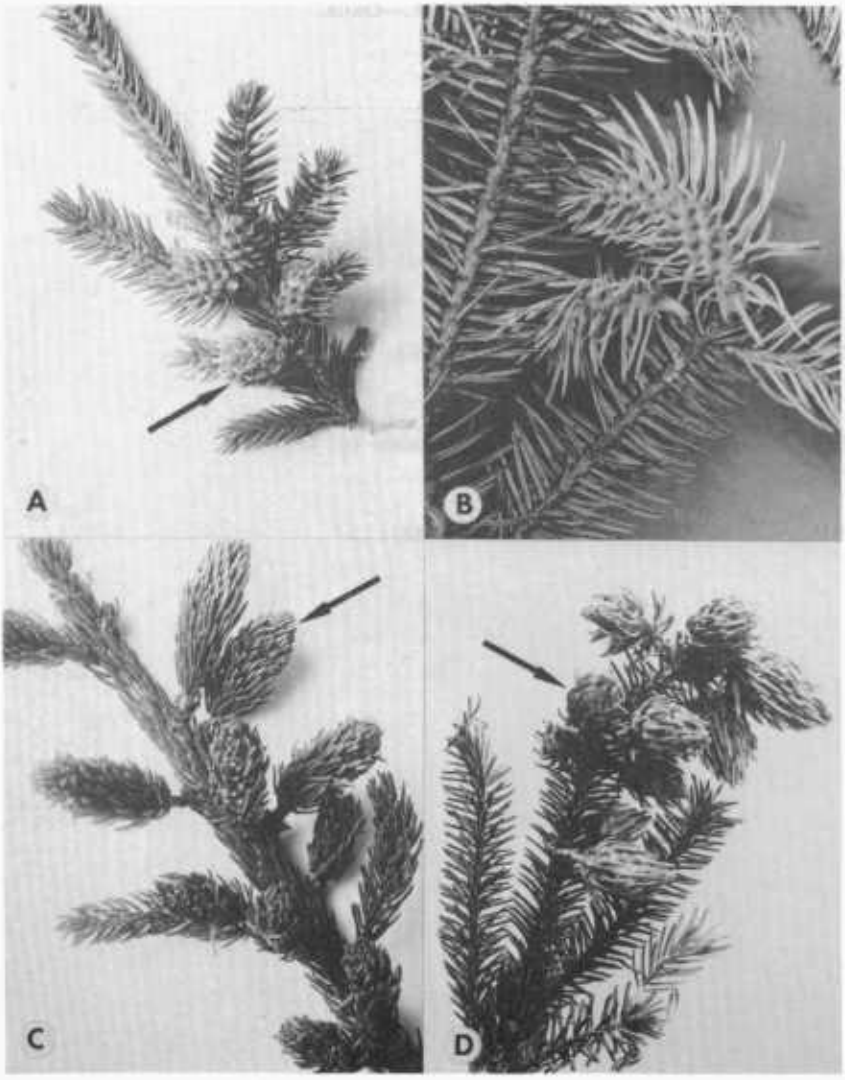


PLATE 24.—Galls.

A. Gall on spruce (arrow) of spruce gall aphid (p. 48).

B. Gall on spruce, aphid unknown (p. 48).

C. Gall on spruce (arrow), aphid unknown (p. 48).

D. Gall on spruce, aphid unknown (p. 48).

PLATE 24

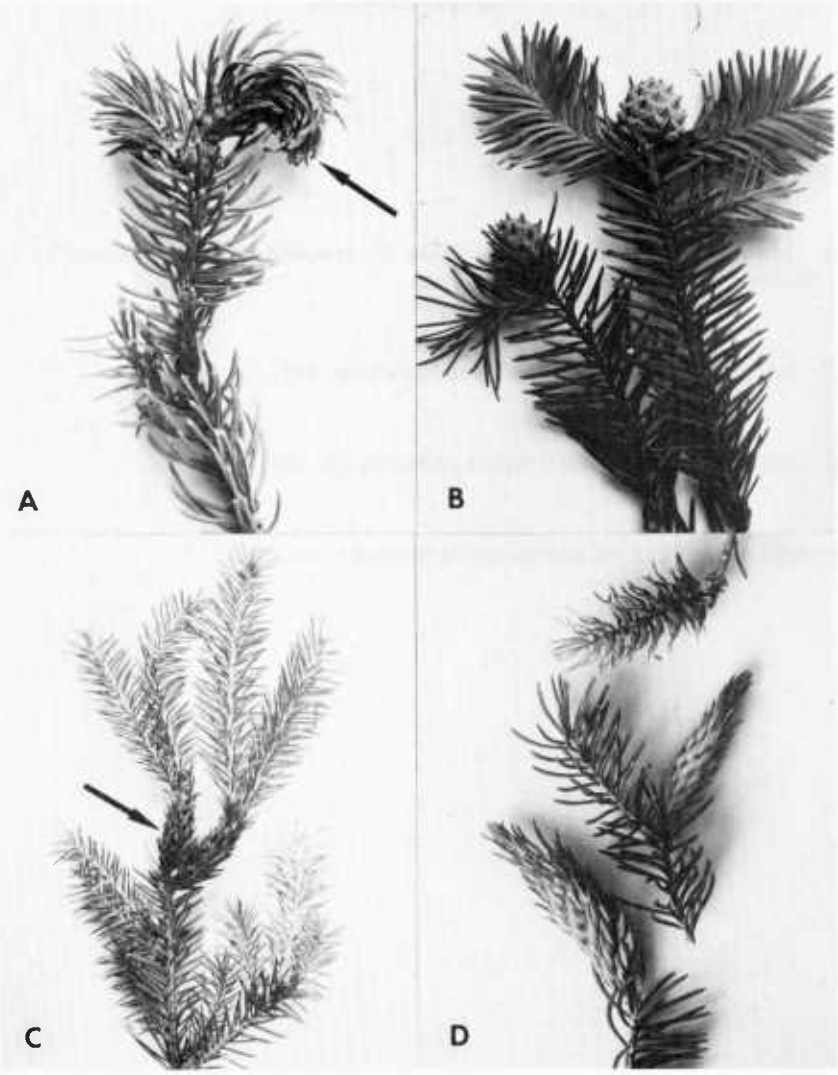


PLATE 25.—Galls.

A. Curled needles (arrow) of balsam fir resembling a gall caused by the feeding of an unknown aphid (p. 48).

B. Gall on spruce (arrow), aphid unknown (p. 48).

C. Gall on spruce (arrow), aphid unknown (p. 48).

D. Old, opened gall on spruce, aphid unknown (p. 48).

PLATE 25

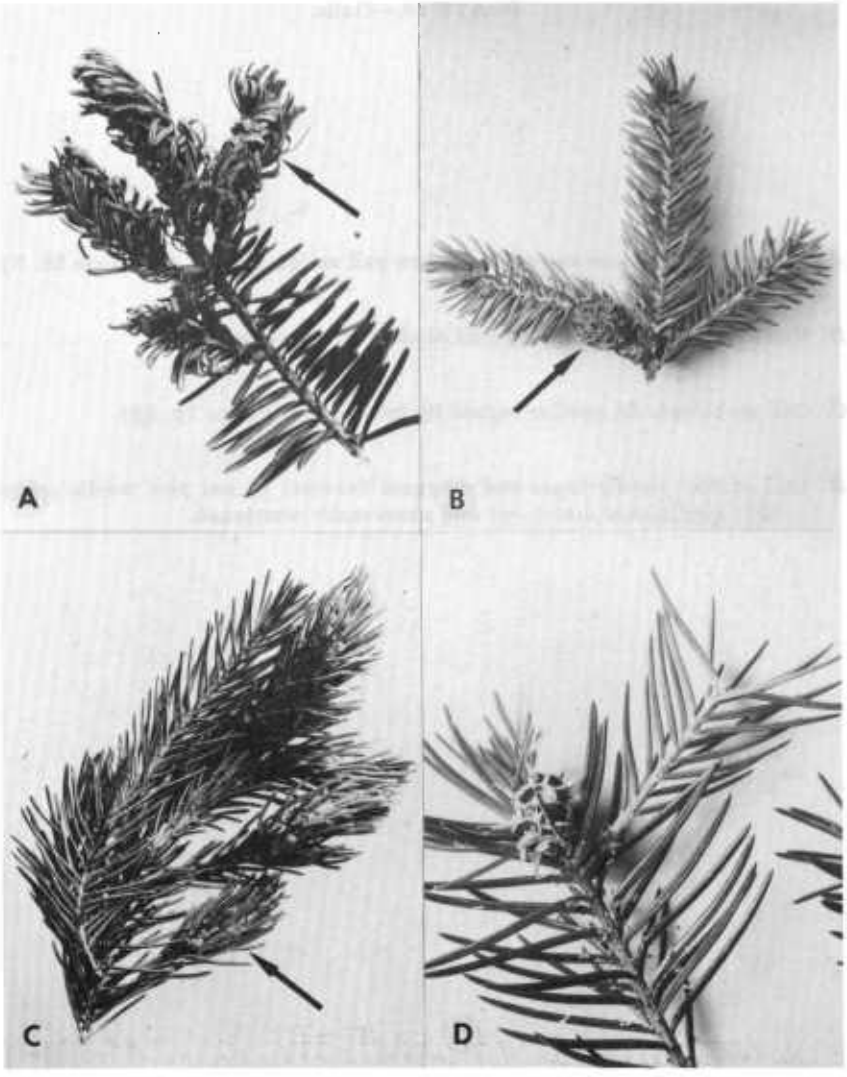


PLATE 26.—Galls.

A. Gall on white spruce caused by spruce gall midge (p. 51) (see plate 26, *B*).

B. Gall of spruce gall midge, opened to show maggots (arrow).

C. Gall on balsam fir needles caused by balsam gall midge (p. 50).

D. Gall on pine needle bases and maggots (arrow) of red pine needle midge (p. 50); needles are discolored and abnormally shortened.

PLATE 26

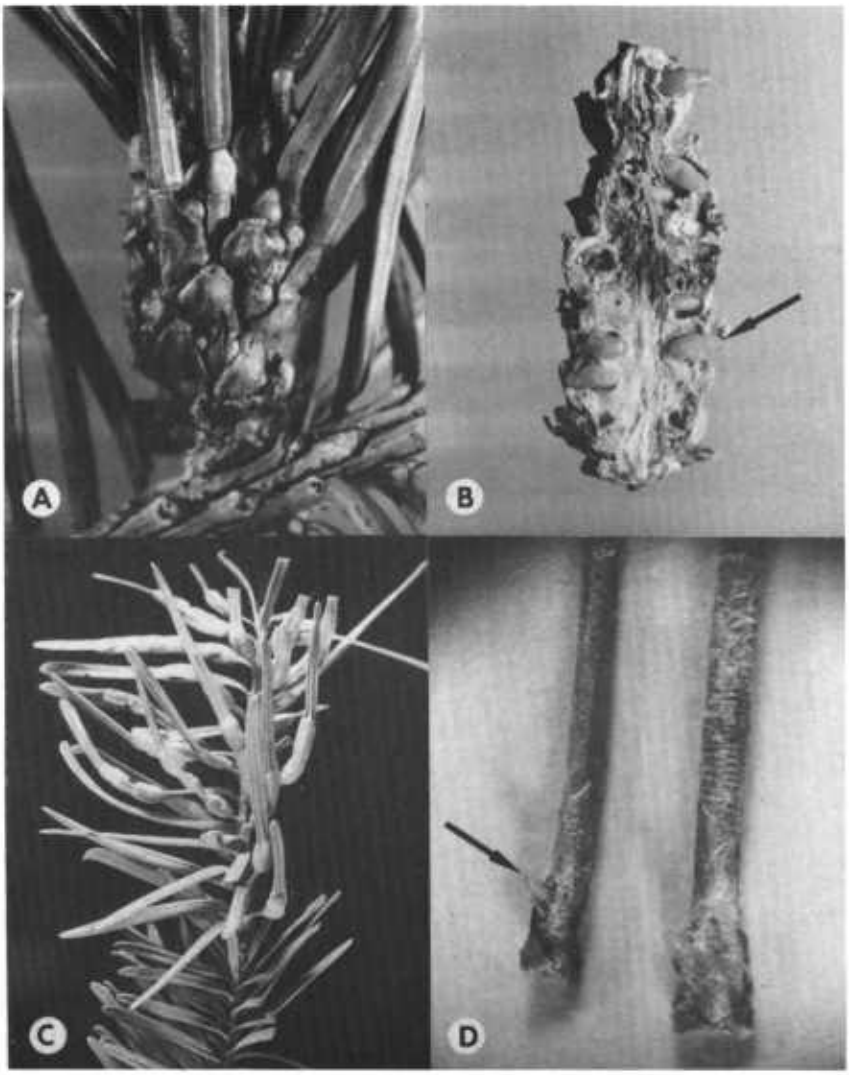


PLATE 27.—Galls.

A. Gall on red pine shoot (arrow) caused by the pine gall weevil (p. 65) (also see plate 27, *B*).

B. Gall of pine gall weevil with bark removed to show larval cells (p. 65) (also see plate 27, *A*).

C. Gall on arborvitae (arrows) caused by bark beetles (p. 72).

D. Gall on pine seedlings caused by sweetfern rust, a disease (p. 88).

PLATE 27

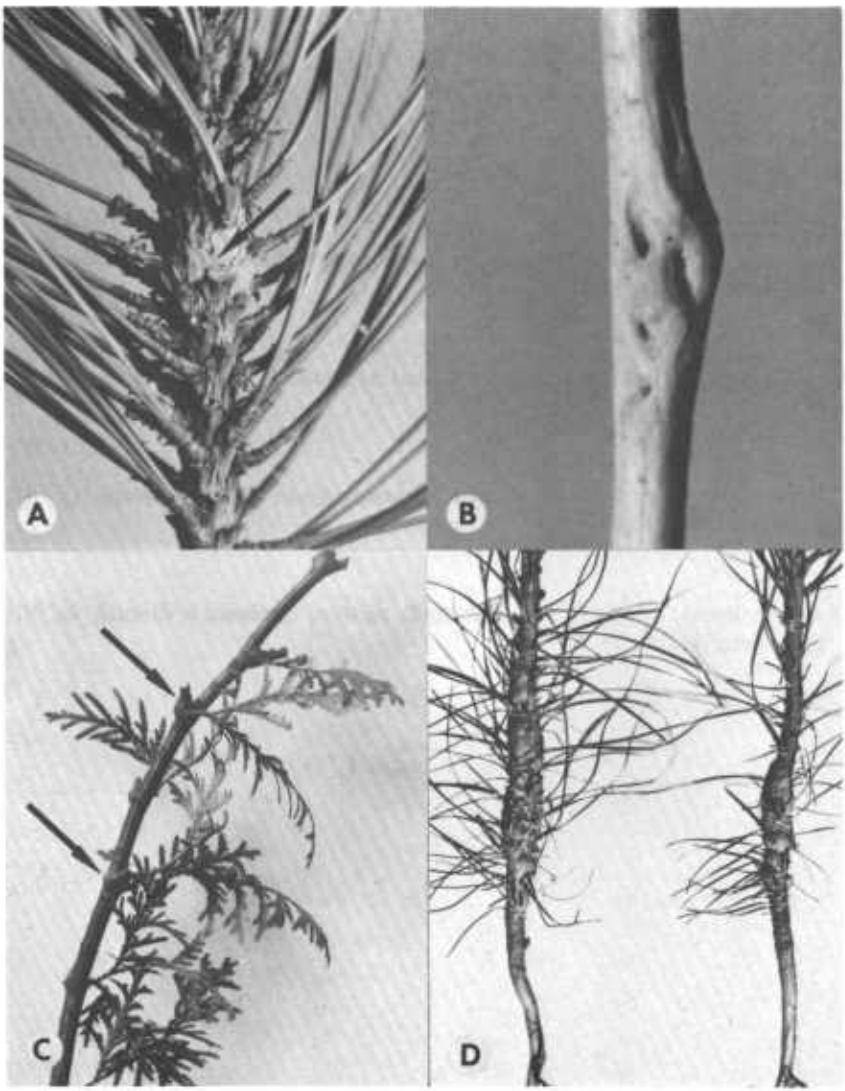


PLATE 28.—Galls.

A. Gall on jack pine (also occurs on Austrian and Scotch) caused by eastern gall rust, a disease (p. 87).

B. Gall on pine seedlings (arrow) caused by eastern gall rust, a disease (p. 87).

C. Gall on juniper (arrow) caused by cedar-apple rust, a disease (p. 87) (also see plate 28, *D*).

D. Spore horns (orange) of cedar-apple rust on juniper, a disease (p. 87) (also see plate 28, *C*).

PLATE 28

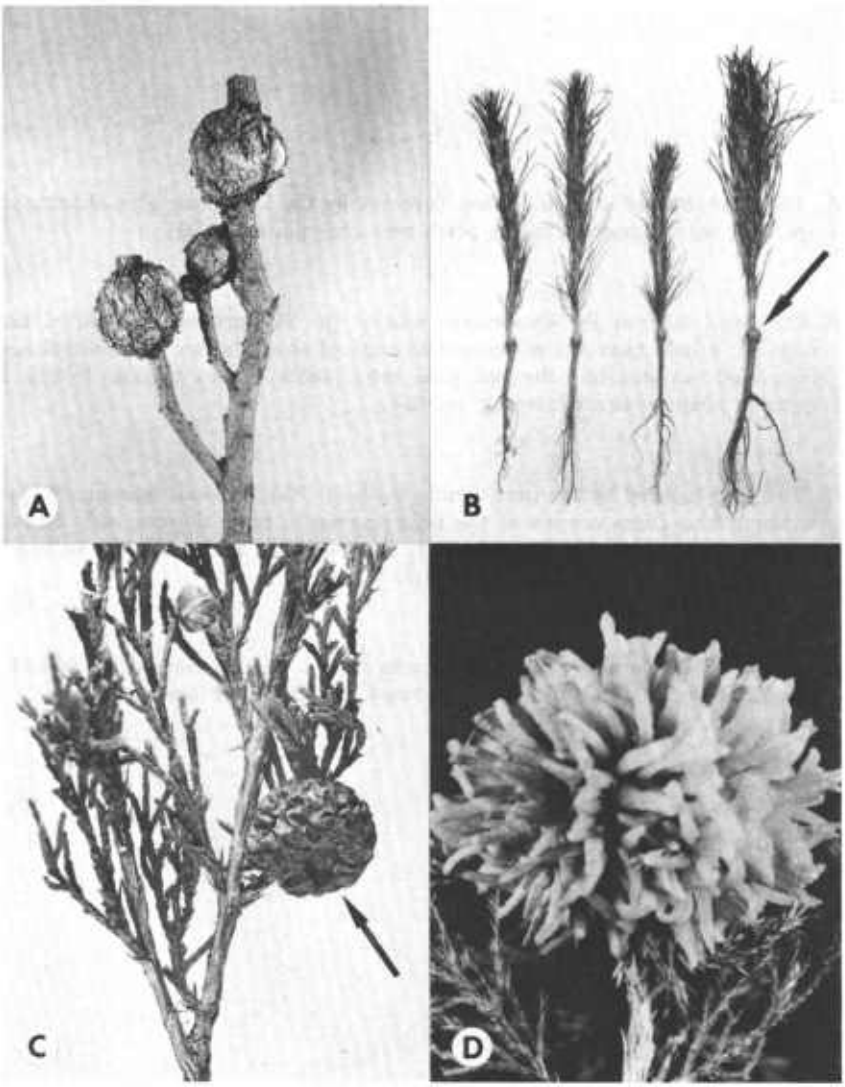


PLATE 29.—Bud injury.

A. Pine bud injured at side or base (arrow) by the European pine shoot moth (p. 54); injury may include a pitch tent (see plate 38, *D*).

B. Pine bud injured by *Rhyacionia adana* (p. 54) producing stunted new needles; a hole (arrow) is present at base of shoot; a few old needles may be mined out nearby; the red pine cone beetle causes similar injury in autumn prior to overwintering (p. 81).

C. Pine bud injured by the pine candle moth (p. 55); a small amount of loose webbing and frass occurs at the base (arrow); male flowers may also be attacked (see plate 30, *C*). (Note: If the bud is on jack pine, the injury is caused by *Petrova* bud borers, p. 55).

D. Buds hollowed out by the spruce budworm (p. 31) or eastern blackheaded budworm (p. 32) look like cups (arrow) on balsam fir (and spruce).

PLATE 29

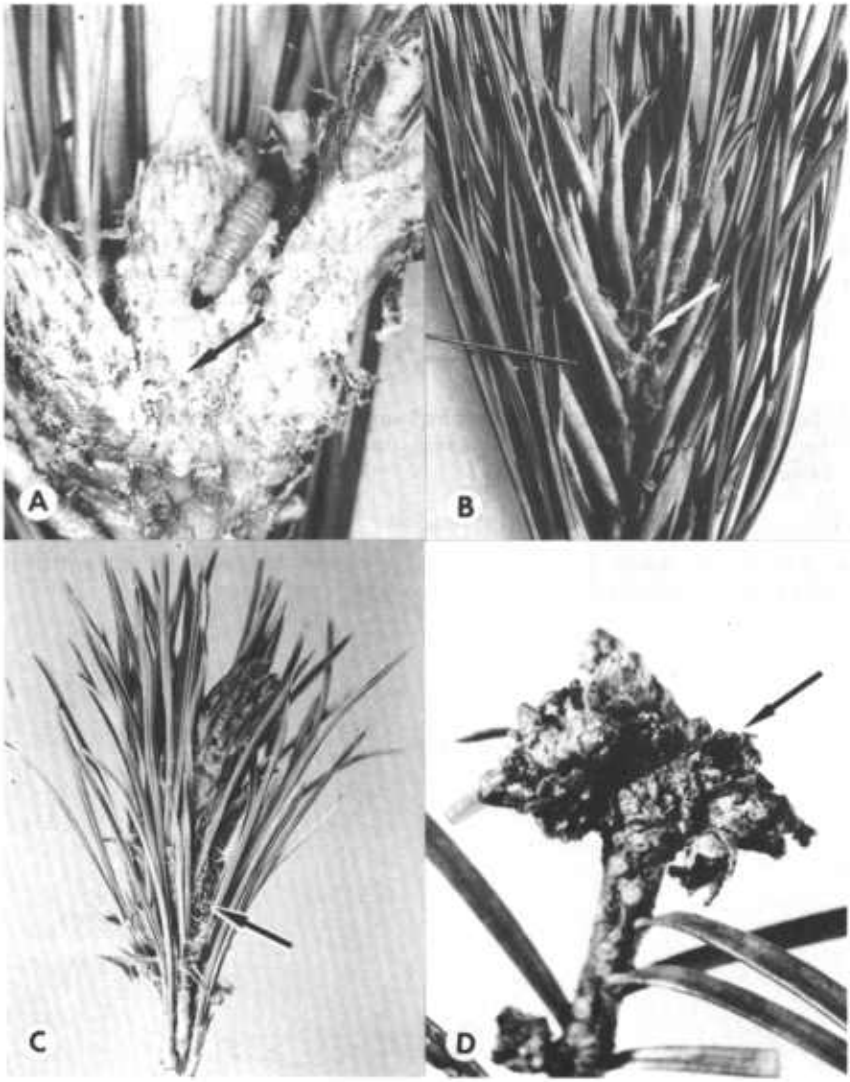


PLATE 30.—Shoot injury.

A, B. Drooping, stunted, and distorted terminals and laterals on pine, caused by European pine shoot moth (p. 54); plate 30, *B* specimen opened to show pupa in tunnel (arrow); other types of injury should be apparent also (see plate 36).

C. Drooping, stunted new shoot (arrow) on pine caused by pine candle moth (p. 55) (also see plate 29,*C*); larval tunnel is in the old growth tissues below the injury.

D. Wilted new shoots (arrow) of conifer caused by frost (p. 91); wilted shoots should occur on all or most of the tree.

PLATE 30

PLATE 31.—Shoot injury.

A. Early shoot curl of larch caused by eggs (arrow) of the larch sawfly (p. 23) (also see plate 31, *B*).

B. Shoot curl (pig-tail) of larch indicating egg site of the larch sawfly (p. 23) (also see plate 31, *A*).

C. Stunted shoot with stunted discolored needles caused by aphids (p. 44).

D. Distorted flattened shoots (fasciation) caused by abnormal nutrition (p. 92).

PLATE 31

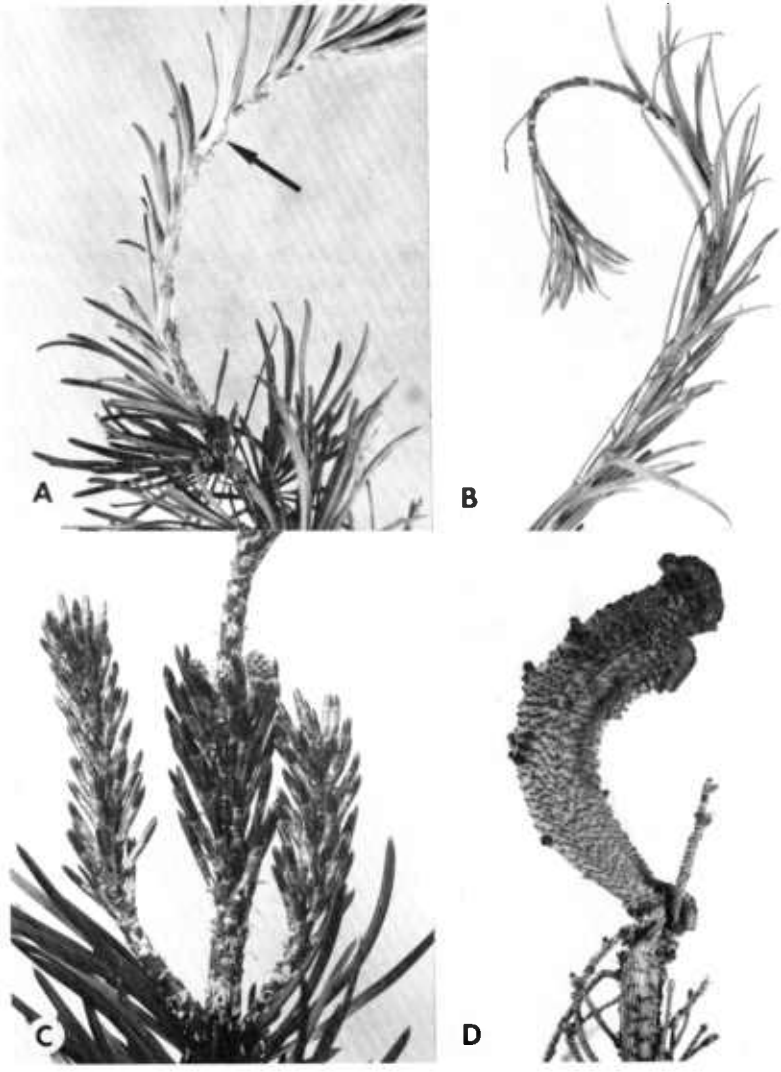


PLATE 32.—Shoot injury.

A, B. Wilted terminal and lateral shoots (shepherd's crooks) of pine caused by the white pine weevil (p. 59); bark on the stem below the wilted area will have small pin holes that exude droplets of pitch (see plate 50, *A*); remove the bark to find larval galleries and pupal cells (see plate 33, *A*).

C. Wilted terminal shoot of spruce caused by the white pine weevil (p. 59). Remove the bark to find larval galleries and pupal cells (see plate 33, *A*).

D. Dead terminal and upper crown (spike top) caused by any of several agents; look for more specific types of injury (see p. 2 if foliage is discolored, or p. 3 if foliage is missing.

PLATE 32

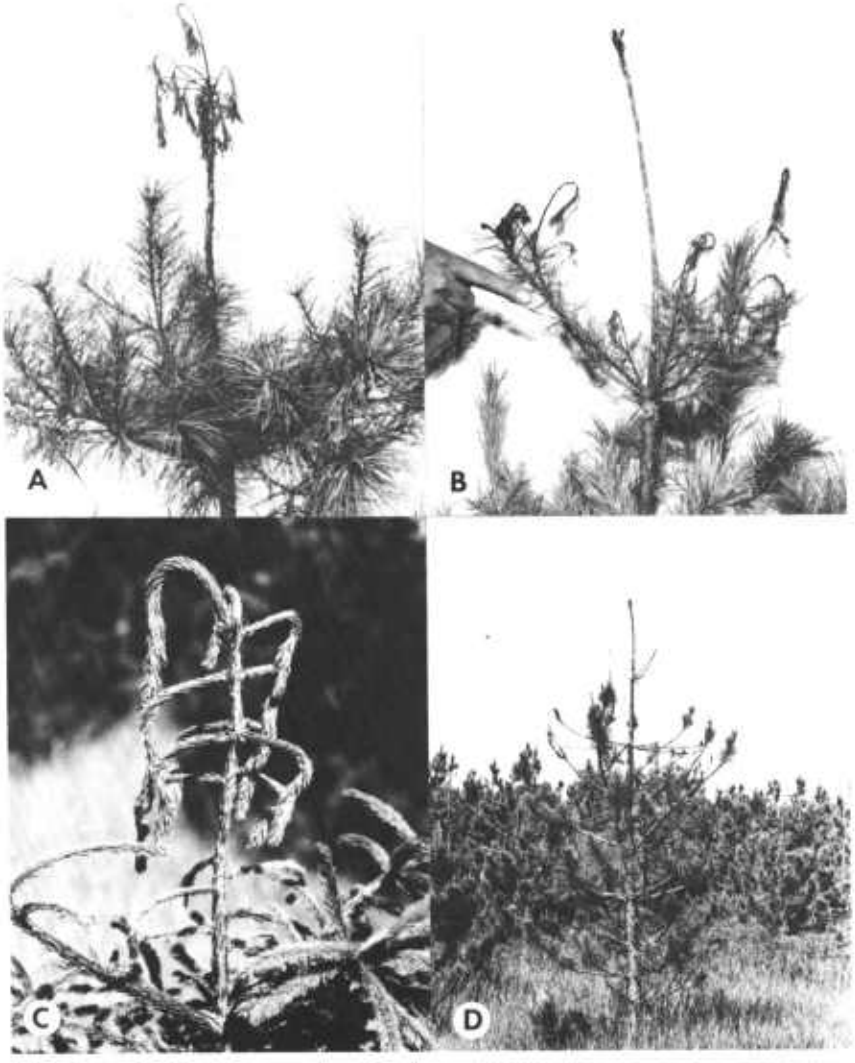


PLATE 33.—Shoot injury.

A. Galleries and pupal cells (arrow) in pine leader (bark removed) made by the white pine weevil (p. 59) (also see plates 32, *A*, *B*, and *C*, and 40, *A*).

B. Feeding puncture scars on the wood of a pine shoot (bark removed) made by Saratoga spittlebug (p. 37); similar scars are also made by the pine spittlebug, but on the inner surface of the bark (note two normal shoots for comparison).

C. Discolored, stunted pine shoot (arrow); injury caused by one of several possible agents; look for the insect, signs of other agents, or more definitive injury in other photos; cut shoot open and remove bark for other signs (see p. 2).

D. Hollowed-out pine shoot made by one of several possible agents; look for the insect, signs of other specific agents, or more definitive injury in other photos (see p. 2).

PLATE 33

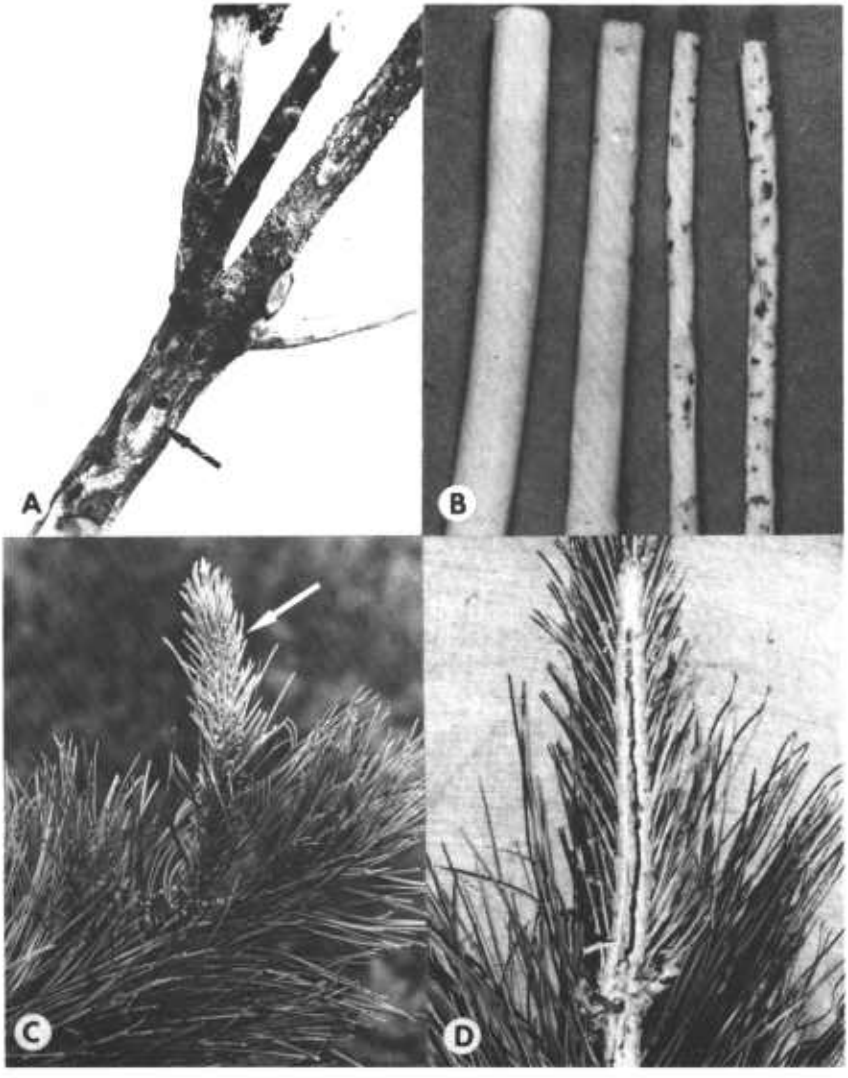


PLATE 34.—Shoot injury.

A. Holes in current-year shoots (arrow) of pine, caused by feeding of adult *Magdalis perforatis* (p. 66); shoot may be stunted and needles shortened.

B. Holes in previous-year shoots and branches of pine, caused by feeding of adult *Pissodes* weevils (p. 59); holes may have small pitch exudations, as in plate 40, *A*.

C. Exit hole (⅛ to ¼ inch) of eastern pineshoot borer (p. 54) on flagged or broken pine shoot (also see plate 35, *A*).

D. Ragged hole in bark on shoot or branch of pine caused by adult *Hylobius* weevils (p. 59); if needles have obviously been chewed off, too, the injury is from sawfly larvae (p. 9); injury resembles sawyer beetle injury (plate 47, *D*).

PLATE 34

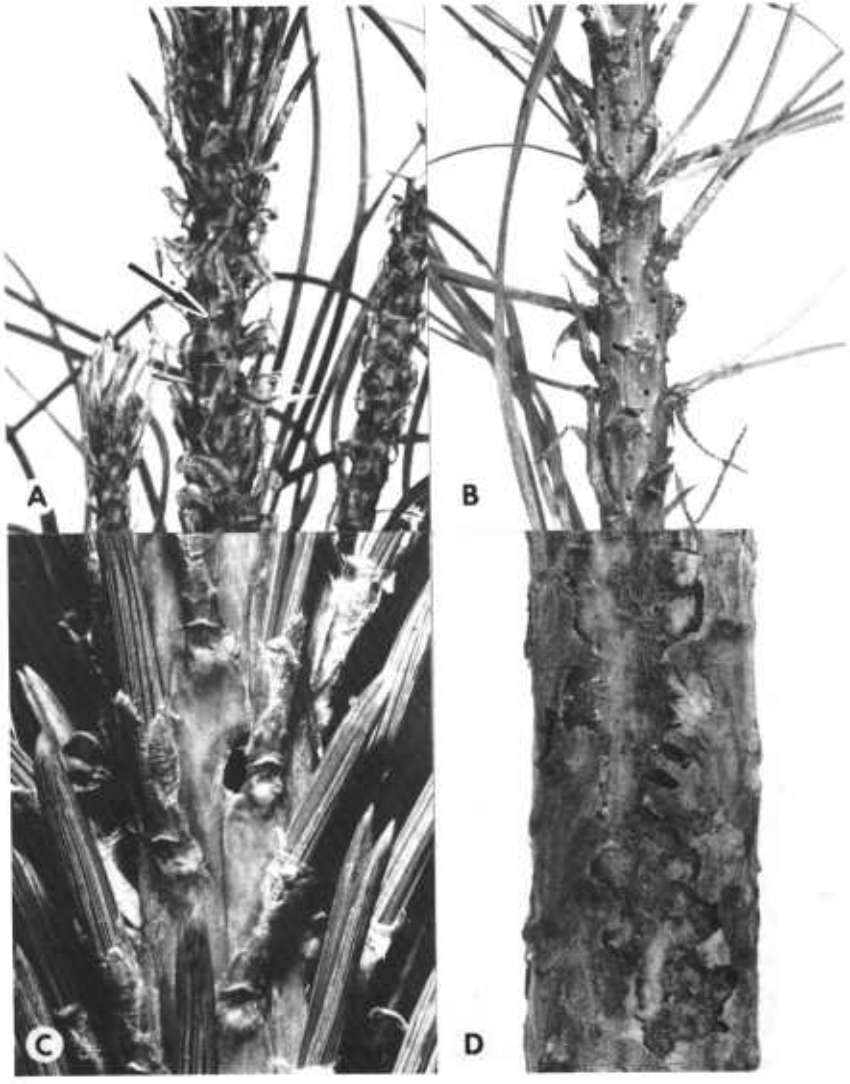


PLATE 35.—Branch injury.

A. Broken terminal or lateral shoots on pine, caused by eastern pineshoot borer (p. 54). Look for an exit hole (plate 34,*C*) on lower flagged portion of shoot.

B. Broken terminal or lateral shoot on pine, caused by Zimmerman pine moth (p. 56). Broken area has a whitish or pinkish pitch exudate. (Also see plates 40, *C*, 40, *D*, 41, *A*, 42, *A*).

C. Broken branches caused by heavy snow or ice accumulation. Base of branch is torn from stem (p. 93).

D. Wound near shoot tip (arrow) caused by small mammals (p. 90) or man (p. 90) removing cones. Bark tissues are torn.

PLATE 35

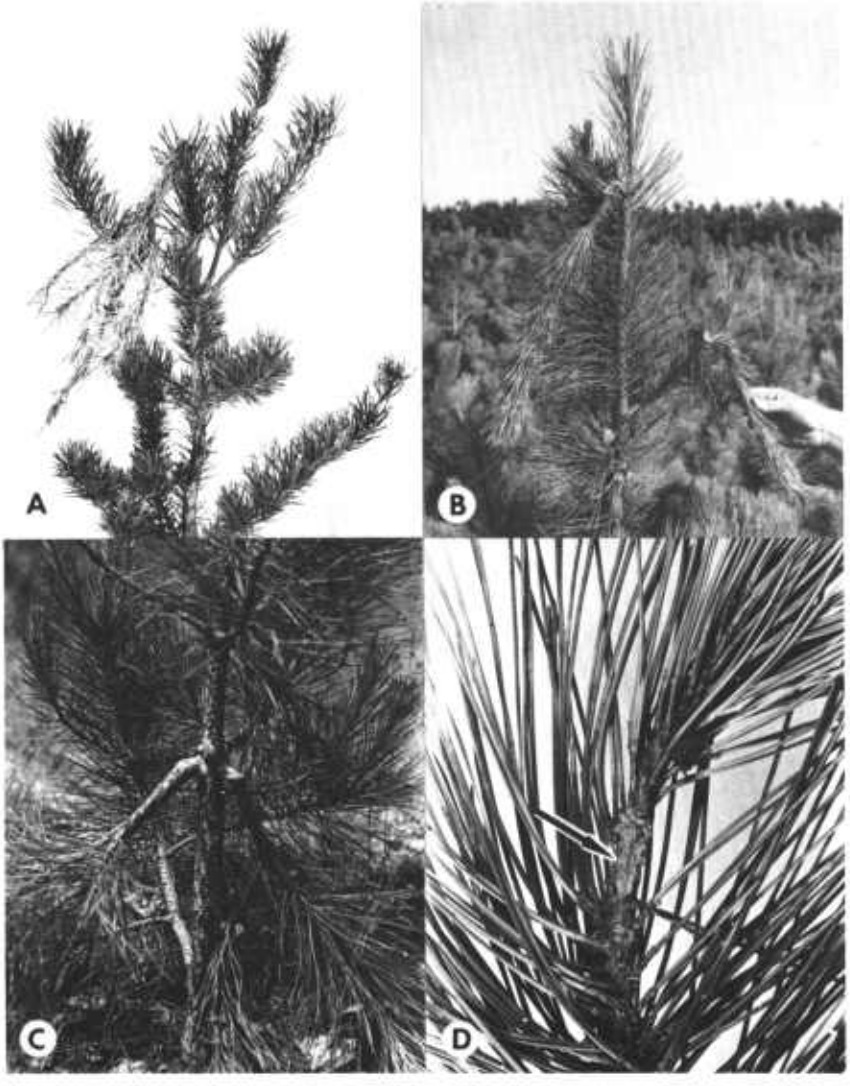


PLATE 36.—Branch injury.

Posthorn, forks, and bushiness caused by European pine shoot moth (p. 54) (also see plate 42, *D*); similar injuries can be caused by other agents that injure terminal shoots or buds.

PLATE 36

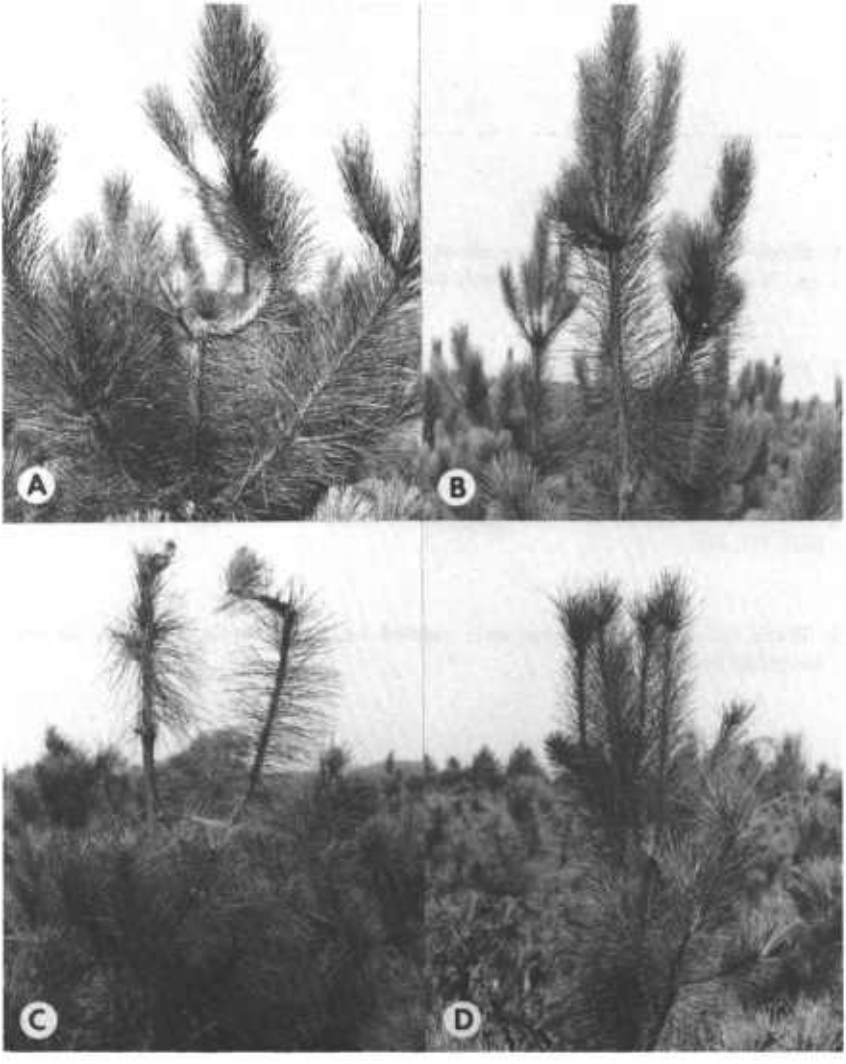


PLATE 37.—Pitch exudates (tubes).

A. Pitch tube (arrow) on pine shoot tip, caused by the jack pine tip beetle (p. 72); shoot tip above the pitch tube flags (also see plate 37, *B*).

B. Pitch tube (arrow) on pine shoot, caused by jack pine tip beetle (p. 72); new shoot above pitch tube wilts and flags (similar wilting injury is caused by *Cecidmyia banksianae*, a midge, p. 49).

C. Pitch tubes on conifer bole, caused by bark beetles (p. 67) (see closeup plate 37, *D*).

D. Pitch tube on bark (closeup), caused by bark beetle (p. 67), showing entrance hole.

PLATE 37

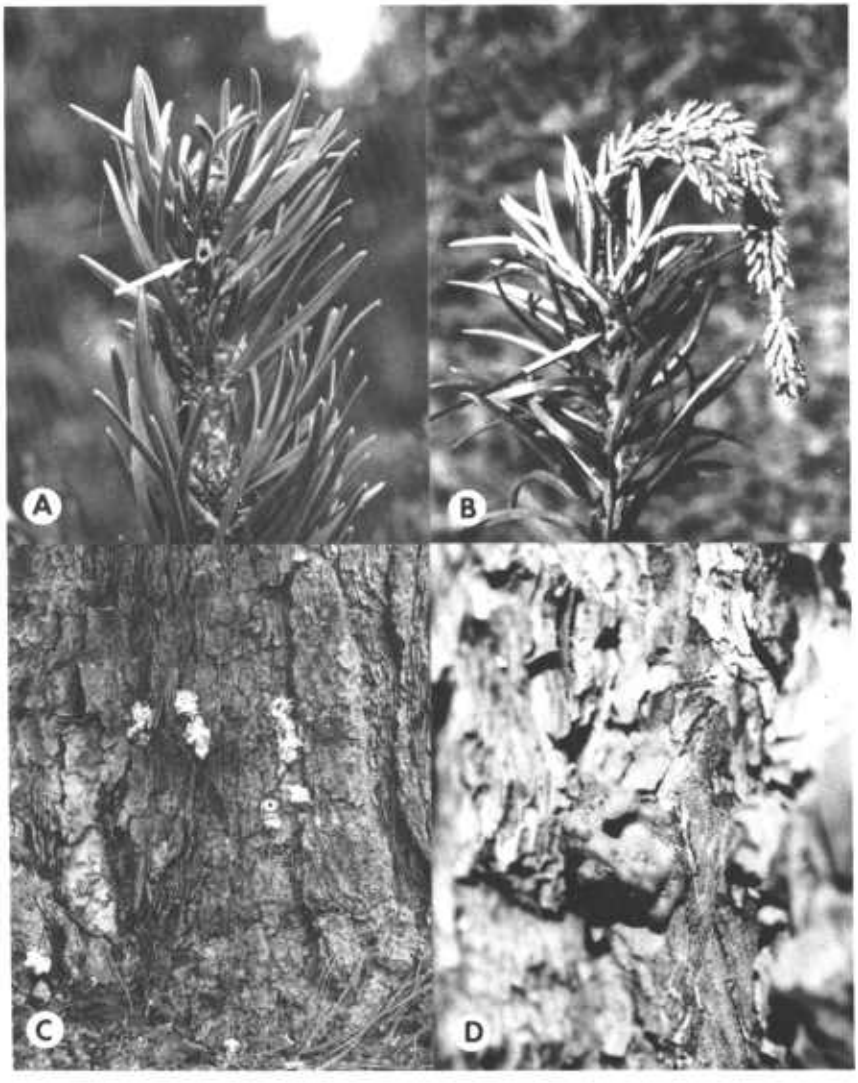


PLATE 38.—Pitch exudates (blisters).

A, B. Pitch blister on pine constructed by the northern pitch twig moth (p. 57); the hollow blister is found in the crotch of pine twigs and houses the larva.

C. Pitch blister on pine shoot constructed by a pitch blister moth (p. 58); the blister is thick walled and not in a twig crotch.

D. Pitch "tent" (arrow) at base of pine bud, constructed by the European pine shoot moth (p. 54).

PLATE 38

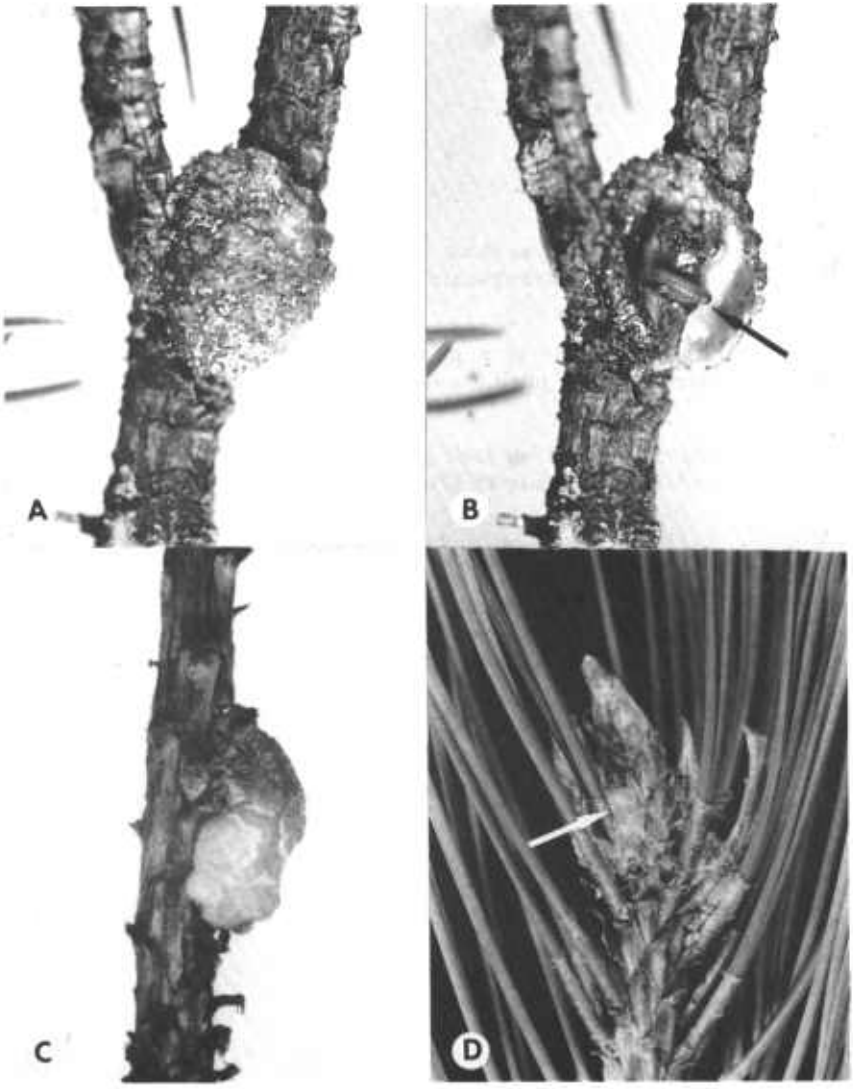


PLATE 39.—Pitch exudates.

A. Pitch exudate on jack pine shoot, caused by a pine pitch midge (p. 49); shoot tip usually flags above exudate (also see plate 39, *B*).

B. Pitch exudate (closeup) of a pine pitch midge (p. 49); yellow-orange maggots (arrow) in the pitch are usually visible to the naked eye.

C. Pitch exudates (arrow) on jack pine shoot, caused by the gouty pitch midge (p. 50) (also see plate 39, *D*).

D. Maggots of gouty pitch midge (arrows) in cells (p. 50), shoot cut open.

PLATE 39

PLATE 40.—Pitch exudates.

A. Pitch exudates (arrow) on terminal of conifer, caused by white pine weevil feeding (p. 59); exudates are similar for lodgepole terminal weevil (p. 60); aphids may cause similar exudates on shoots, but feeding punctures are almost invisible (p. 44).

B. Pitch exudates on conifer twig or stem, caused by pales weevil feeding (p. 64); feeding scars are larger than those for *Pissodes* weevils(see plate 40, *A*).

C. Pitch exudate (arrow) at base of pine branch caused by Zimmerman pine moth (p. 56); branch usually breaks and flags (also see other kinds of injury from this insect, plates 40, *D;* 35, *B;* 42, *A;* and 41, *A*).

D. Pitch tube (arrow) near center of pine shoot caused by Zimmerman pine moth (p. 56); it is larger than the pitch tubes of the jack pine tip beetle (plate 37, *A* and *B*).

PLATE 40

PLATE 41.—Pitch exudates.

A. Amorphous pitch mass (up to 3 inches diameter) on pine bole, caused by Zimmerman pine moth (p. 56); the pitch mass is usually at the node and is especially associated with pruning or bark wounds.

B. Amorphous pitch mass (up to 4 inches diameter) on pine bole, caused by pitch mass borer (p. 57); pitch mass is commonly associated with injuries or pruning wounds.

C. Ovoid or spherical pitch mass (up to 2 inches diameter) on red or jack pine bole, caused by the pitch mass beetle (p. 57) (also see plate 41, *D*).

D. Larva of pitch mass beetle in cell (pitch mass removed). (See also plate 41, *C*).

PLATE 41

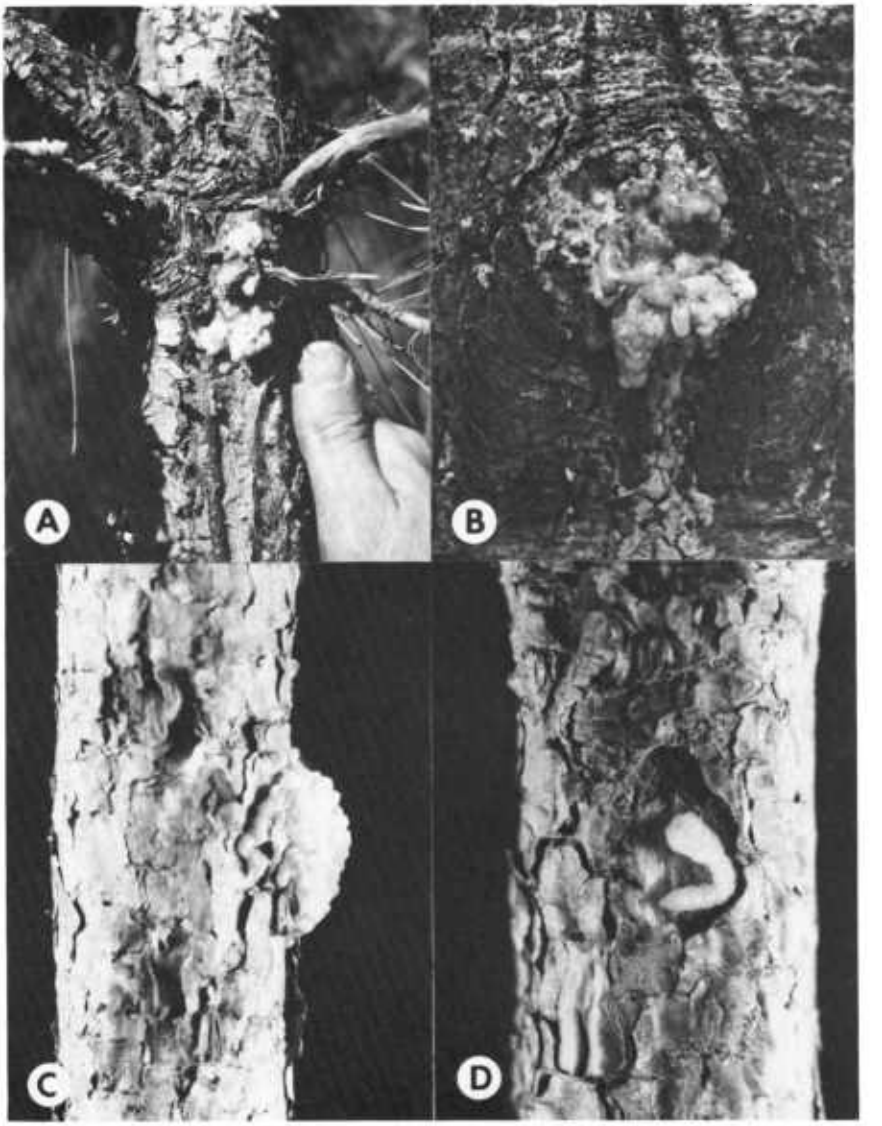


PLATE 42.—Stem injury.

A. Swollen node of pine caused by Zimmerman pine moth (p. 56); injury usually results in a pitch exudate (arrow).

B. Vertical trunk scars (arrow) caused by sweetfern rust (p. 88); lightening causes similar injury (p. 93).

C. Branch fork, caused by one of several possible agents that killed the terminal; it is difficult to determine the cause of a fork this old (see p. 3).

D. Old posthorns caused by the European pine shoot moth (p. 54); such deformities tend to disappear as the stem grows in diameter.

PLATE 42

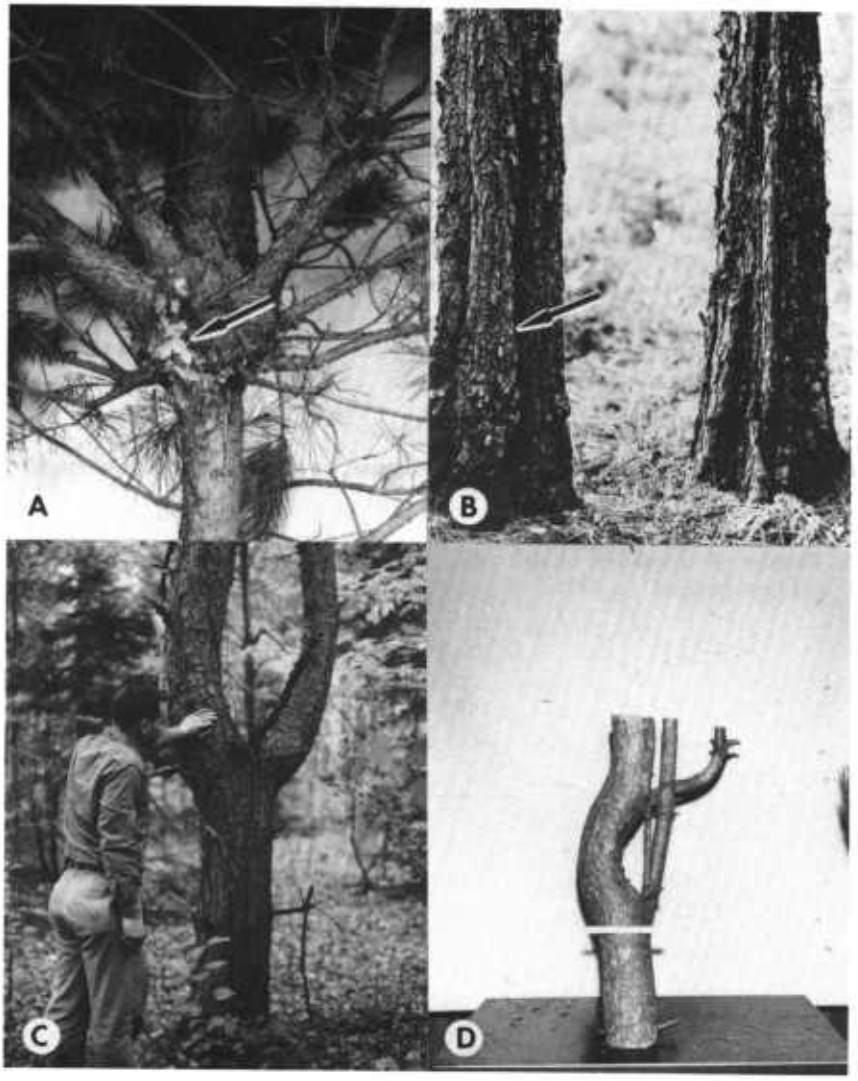


PLATE 43.—Stem injury.

A. Pine bark aphids on stem of pine (p. 44) (also see plate 21, *A*).

B. Fir broom rust, a disease, on stem of balsam fir (p. 88); note swelling and associated witches'-broom (arrow).

C. Canker of white pine blister rust, a disease, on eastern white pine (p. 87).

D. Canker of comandra blister rust, a disease, on jack pine (and Austrian and Scotch pine) (p. 87).

PLATE 43

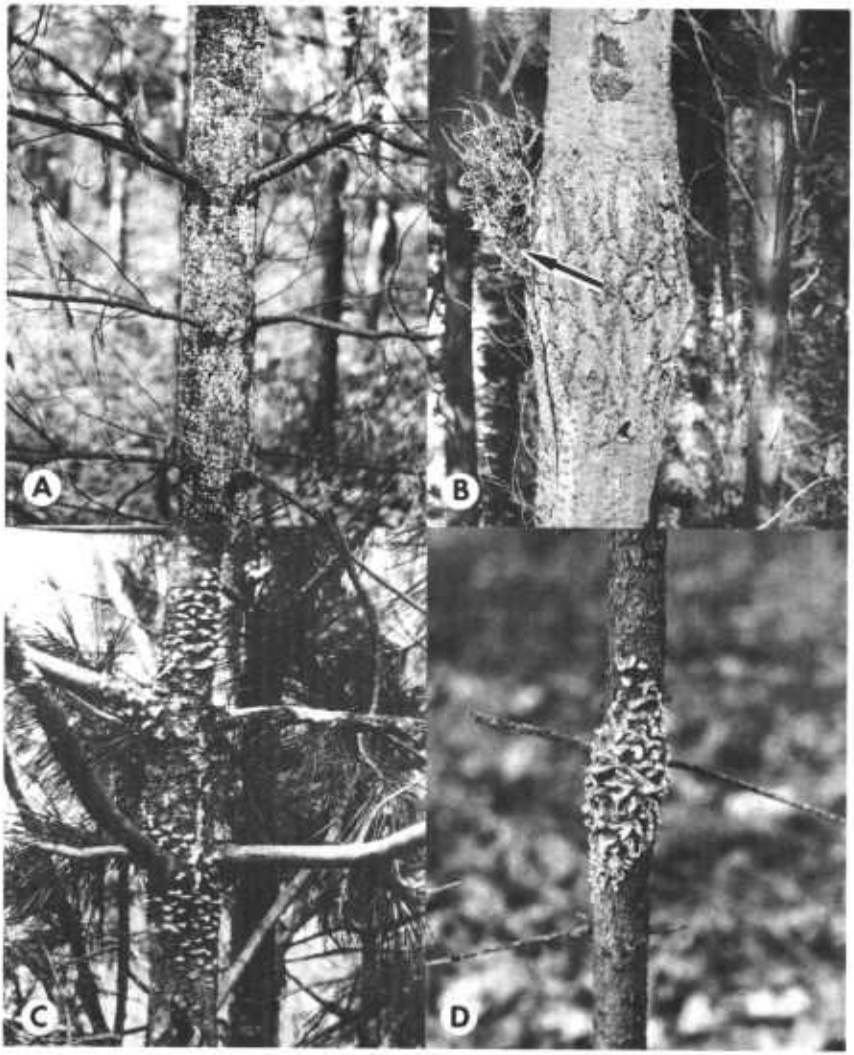


PLATE 44.—Stem injury.

A. Witches'-broom caused by rust fungi, a disease (p. 87).

B. Mushrooms at base of conifer indicating Armillaria root rot, a disease (p. 89); remove bark at ground line to observe white fans of mycelia.

C. Mushroom (conk) at base of conifer, indicating *Fomes* sp. and related root rots, a disease (p. 88).

D. Abnormal growth on conifer stem, cause unknown (p. 86).

PLATE 44

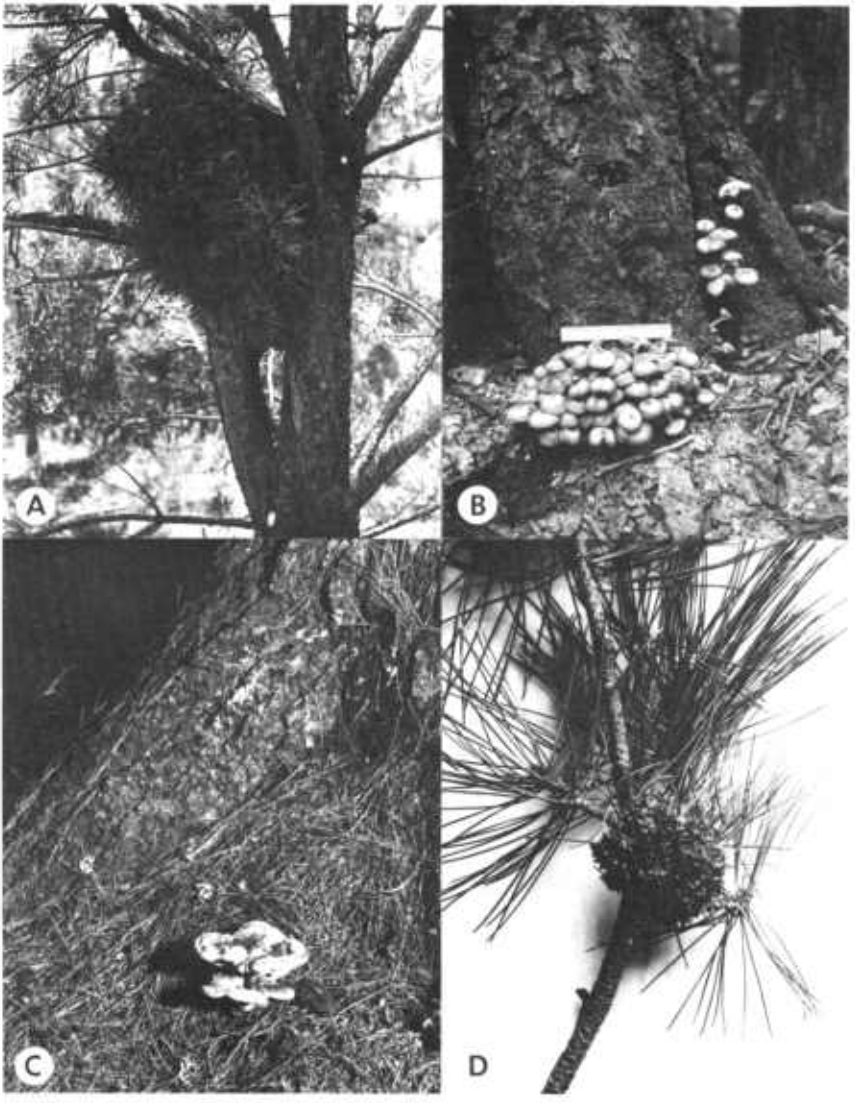


PLATE 45.—Stem injury.

A. Bark missing from stem near base of conifer (arrow); injury caused by rodents or rabbits (p. 90); look for toothmarks or clean-cut tissues.

B. Bark missing from upper part of stem (arrow); injury caused by porcupines (p. 90); look for toothmarks or clean-cut tissues.

C. Bark missing from one side of stem; injury caused by deer scraping antlers (buck rub) against bark (p. 90); bark is torn or shredded; similar injury is caused by bears (p. 90), mechanical devices, or vehicles (p. 90).

D. Dead and discolored wood (arrow) on stem or branch of pine (bark removed), caused by *Scleroderris* canker (p. 86); tree may be flagged or off color (plate 12, *A* and *B*).

PLATE 45

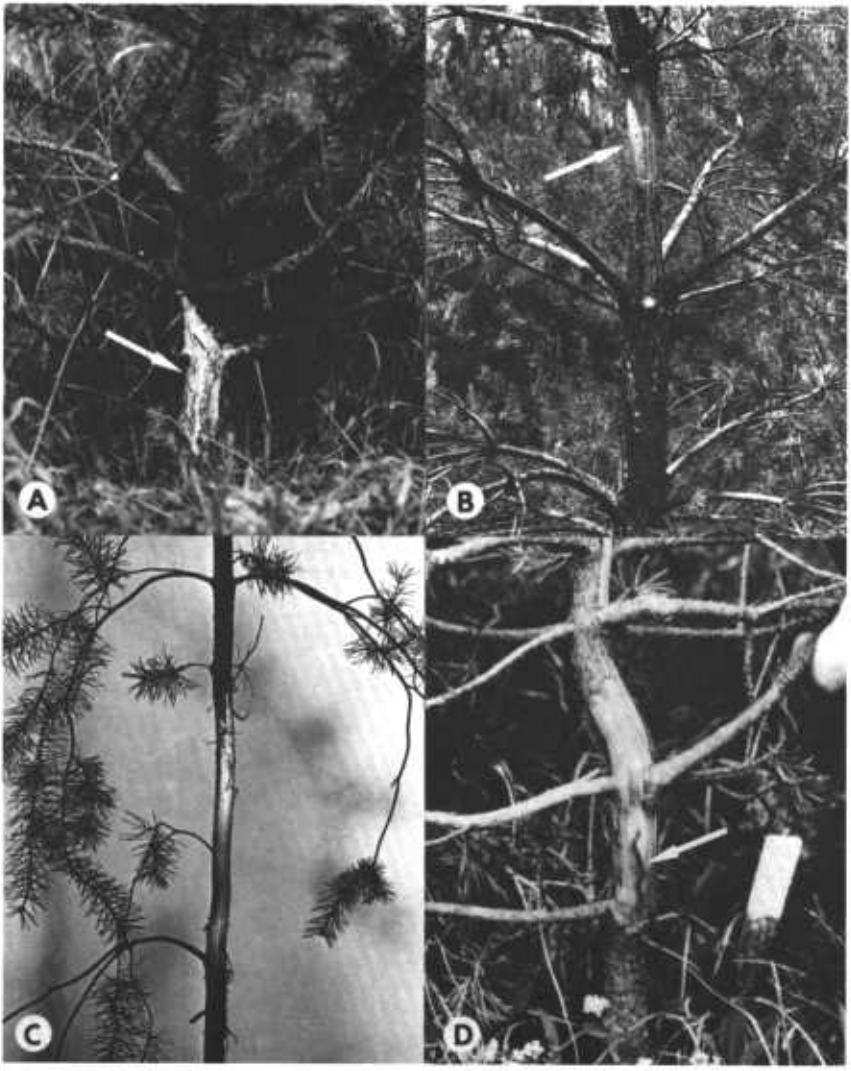


PLATE 46.—Stem injury.

A, B. Holes in bark (⅛ to ¼ inch in diameter), often arranged in rows or columns, caused by sapsucker (birds) feeding (p. 89).

C. Large conical hole in bark (½ to 1 inch in diameter) caused by woodpecker feeding (p. 89); the hole is found in weakened or dead trees infested with bark beetles or wood borers.

D. Holes in bark (1/16 inch diameter) extending into the wood, caused by adult bark beetles (p. 67); remove bark to see if there are galleries as in plate 52, *A* or figure 18, to confirm that damage is by bark beetles.

PLATE 46

PLATE 47.—Root and bark injury.

A. Bark missing (arrow) from seedling, caused by pales weevil (p. 64); this injury is associated with weevil-infested stumps nearby (see plate 49, *C*).

B. Root bark (arrow) and rootlets missing from yew (also hemlock or other conifers), caused by adult black vine weevil (p. 66), or adult strawberry root weevil (p. 66); seedlings are discolored or dead; adult weevils are needed for positive identification.

C. Rootlets missing (arrow) from seedlings, caused by white grubs (p. 78); seedlings usually are discolored or dead.

D. Bark missing from twigs and small branches caused by adult sawyer beetles (roundheaded borers (p. 74); shoot tips are usually flagged, especially on eastern white pine or balsam fir; injury resembles weevil injury (plate 34, *D*).

PLATE 47

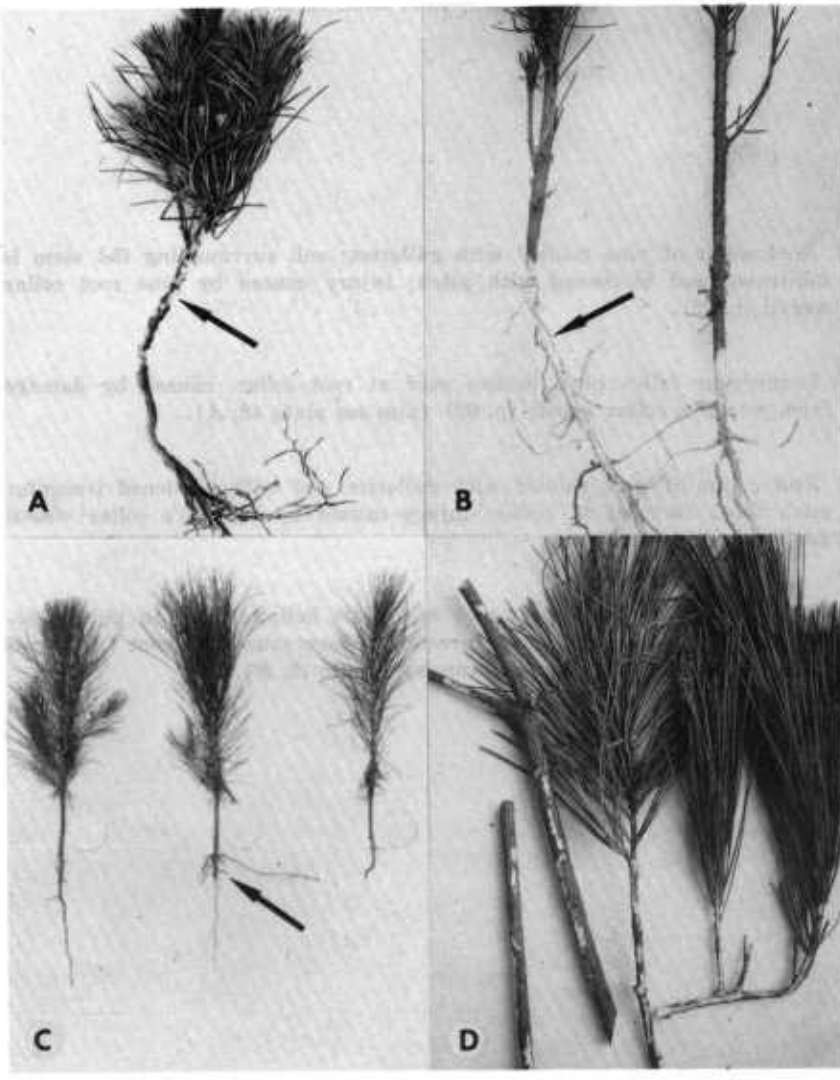


PLATE 48.—Root collar injury.

A. Root collar of pine riddled with galleries; soil surrounding the stem is infiltrated and blackened with pitch; injury caused by pine root collar weevil (p. 62).

B. Leaning or fallen pine, broken over at root collar, caused by damage from pine root collar weevil (p. 62) (also see plate 48, *A*).

C. Root collar of pine riddled with galleries and with hardened irregular pitch tubes (arrow) at collar; injury caused by Warren's collar weevil (p. 64).

D. Root tips severed (right arrow) and roots hollowed out on pine, associated with pitch exudate (left arrow); injury caused by root tip weevil (p. 63); tree may have flagged branches (plate 12, *B*).

PLATE 48

PLATE 49.—Wood injury.

A. Galleries on wood surface (arrow) and tunnels of roundheaded wood borers (p. 74) (also see plate 49, *B*).

B. Tunnels of roundheaded wood borers in wood tissues (p. 74) (also see plate 49, *A*).

C. Chip cocoons (arrow) of northern pine weevil (p. 61); similar cocoons are constructed by other *Pissodes* and *Hylobius* weevils (p. 58), but location differs for most.

D. Gallery (arrow) of *Hylobius congener* in bark (p. 64); gallery of *Pissodes rotundatus* in spruce is similar (p. 62).

PLATE 49

PLATE 50.—Wood injury.

A. Galleries of hemlock borer (p. 74); other flatheaded borers (p. 73) make similar galleries.

B. Galleries of *Pissodes affinis* in pine (p. 62).

C. Galleries of wood wasps (horntails) (p. 76); frass is usually packed tightly in the galleries.

D. Pin holes (1/16 to ⅛ inch diameter) of powder-post beetles in seasoned wood (p. 77); fine, powdery, boring dust accumulates in and below the holes.

PLATE 50

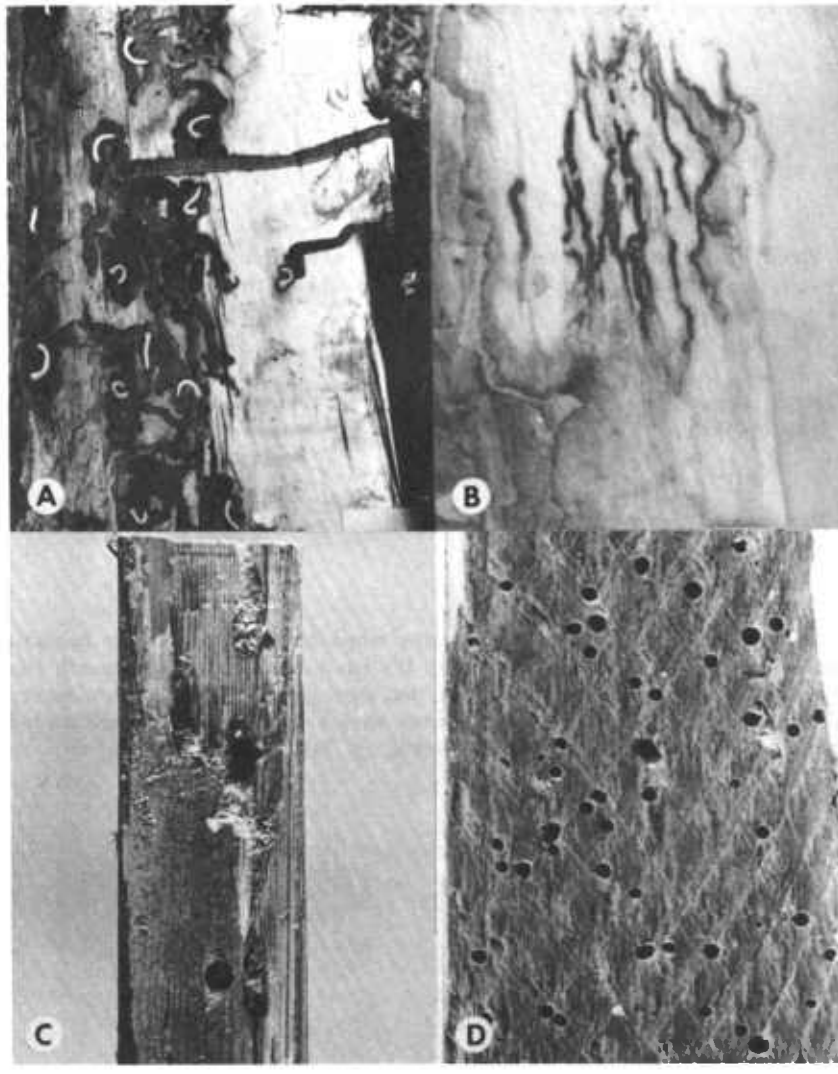


PLATE 51.—Wood injury.

A. Wood honeycombed by termites (p. 78); a whitish substance coats the wood; the galleries often contain soil and debris; the whitish insects are the termites.

B. Wood honeycombed by carpenter ants (p. 77); the galleries are kept clear of debris.

C. Heartwood decayed by heart rot fungi, a disease (p. 88); the wood is soft and punky.

D. Sawdustlike debris (arrow) indicates wood borers are feeding beneath bark; beetles can be distinguished by the coarseness of debris beneath the bark as follows: powder-post beetles, fine dust (p. 77); bark beetles, coarse dust (p. 67); flatheaded borers, coarse slivers (p. 73); and roundheaded borers, very coarse slivers, loosely packed (p. 74).

PLATE 51

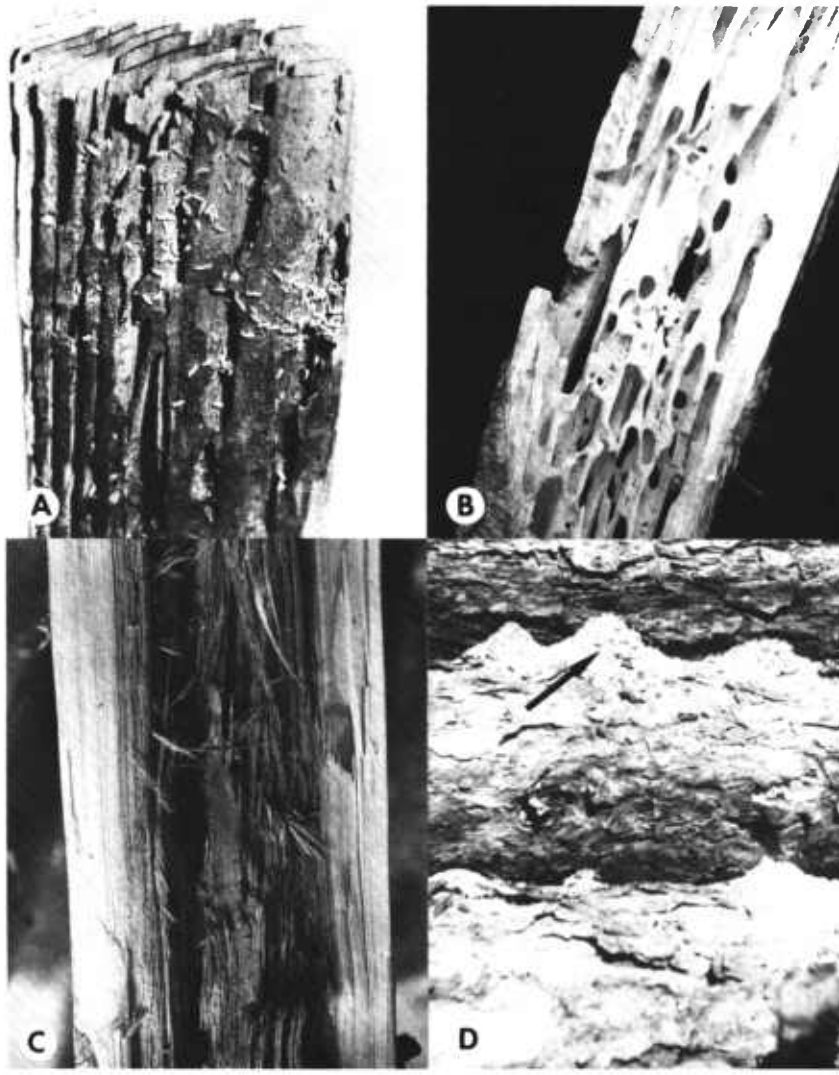


PLATE 52.—Wood injury.

A. Galleries of pine engraver (p. 70) (see fig. 18 for galleries of other bark beetles).

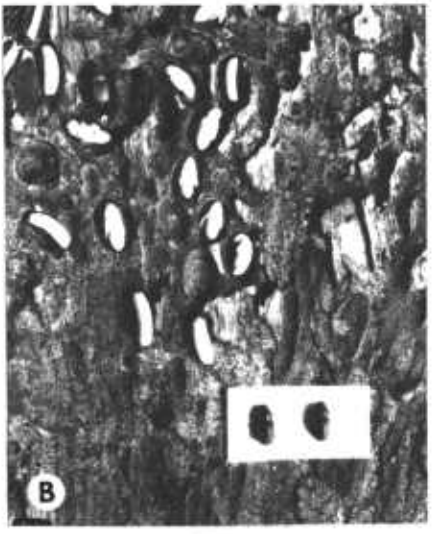
B. Galleries and cells of red turpentine bark beetle containing larvae, pupae, and adult beetles (p. 69).

C. Pupal chamber of *Acanthocinus* in spruce (p. 76).

D. Root collar region (cross section) of pine stem killed by pine root collar weevil (p. 62).

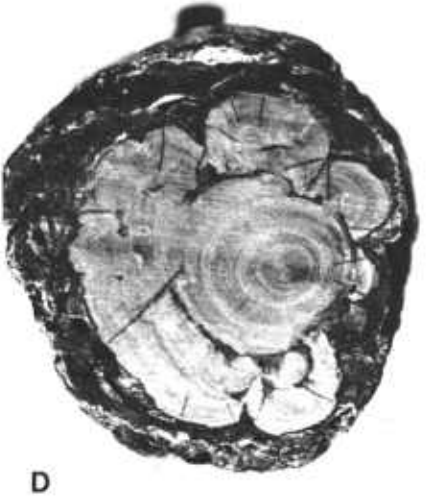
PLATE 52

A



B

C



D

PLATE 53.—Cone injury.

A. Uninjured male flower (cone) of pine; several insects feed inside the male cones of conifers (see budworms, p. 30).

B. Douglas-fir cone injured by the spruce coneworm (p. 83); note excrement on cone (arrow); for other spruce cone insects see p. 83.

C. White pine cones injured by the white pine cone beetle (p. 81); note gallery in central axis (arrow).

D. Red pine cones injured by the red pine cone beetle (p. 81); injured cones (upper) are soft, stunted, and brown; lower cone is normal (see also plate 54, *A*).

PLATE 53

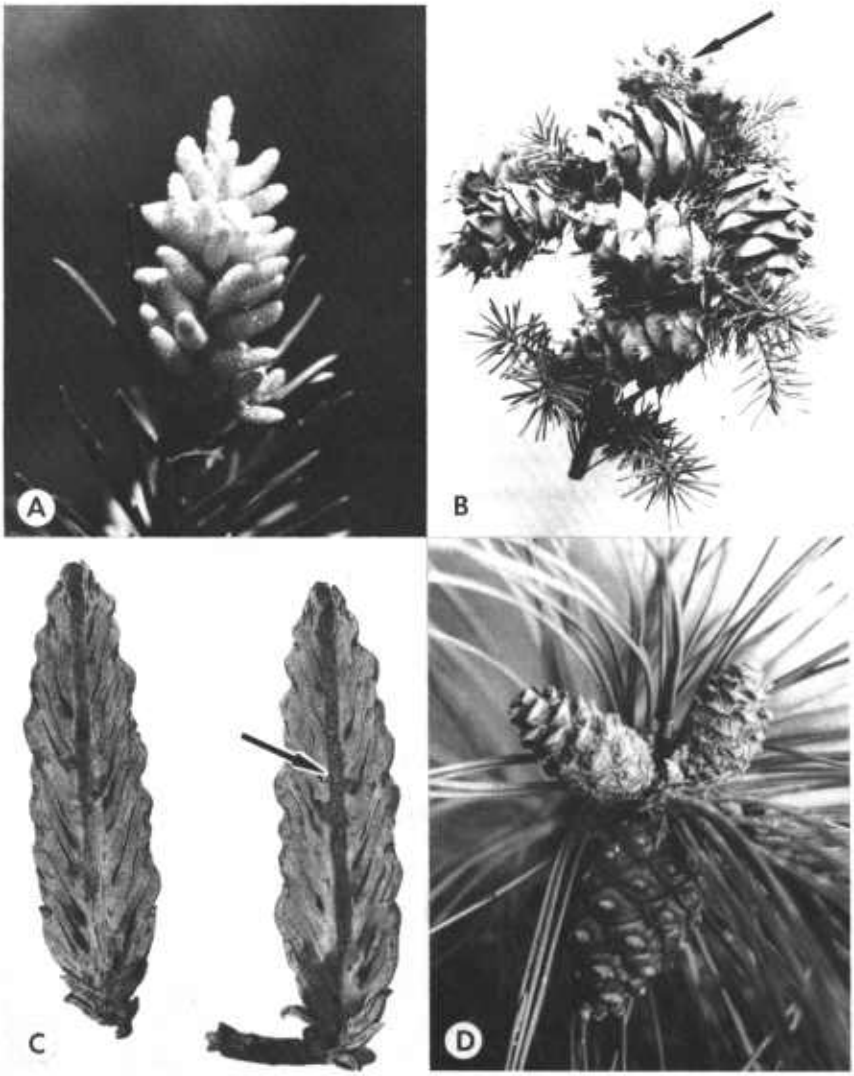


PLATE 54.—Cone injury (red pine).

A. Conophthorus resinosae injury showing basal groove (also see plate 53, *D*, p. 81).

B. *Eucosma monitorana* injury showing exit holes between scales (arrow) (p. 82); if spruce, see *Pegohylemia* (p. 84).

C. Eucosma monitorana injury (internal) (p. 82).

D. Dioryctria abietella injury showing frass in webbing (p. 83).

E. Dioryctria disclusa injury showing basal hole (arrow) (p. 82).

F. Dioryctria disclusa injury (internal) (p. 82).

G. Laspeyresia toreuta injury (internal); cones appear normal externally p. 82).

H. Rabsaamenia sp. injury showing pitch globule (arrow) (p. 84).

I. Rabsaamenia sp. injury (internal) (p. 84).

PLATE 54

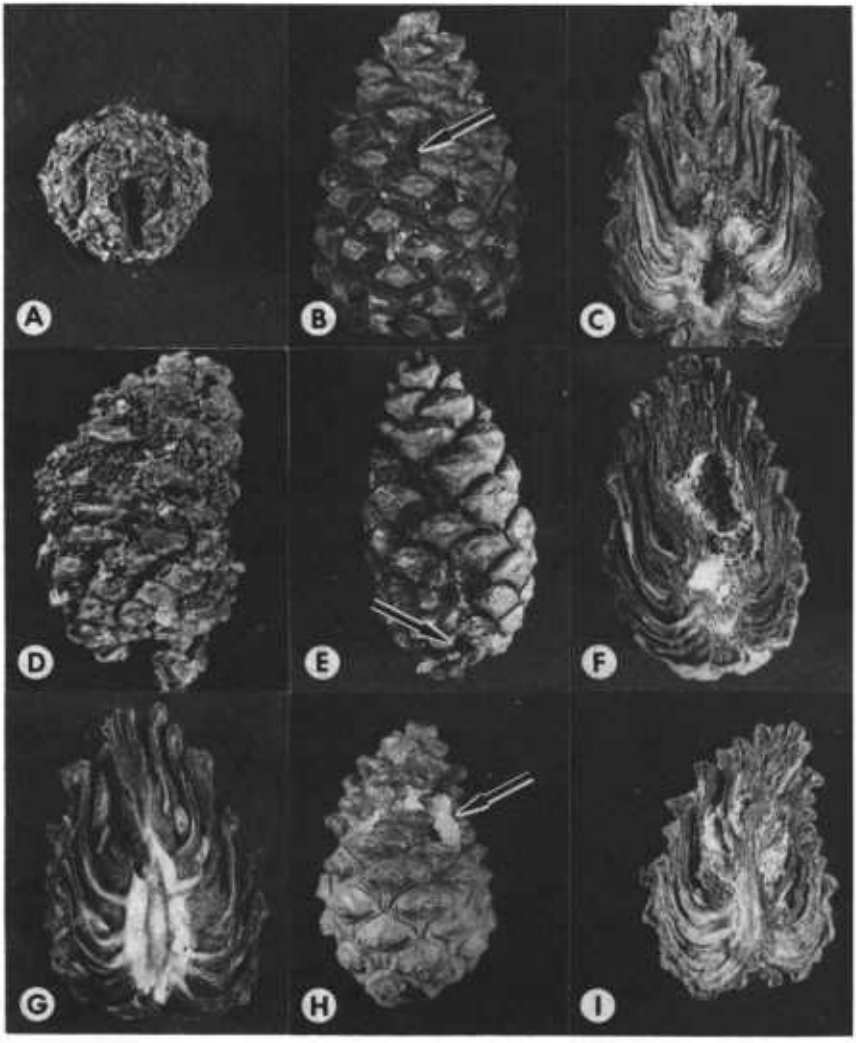


PLATE PHOTO CREDITS

Plate 1: (A) F-521438, (B) F-521437, (C) F-521440, (D) F-521439.

Plate 2: (A) F-521441, (B) F-521442, (C) F-521444, (D) F-521443.

Plate 3: (A) F-521446, (B) F-521445, (C) F-521448, (D) F-521447.

Plate 4: (A) Photo courtesy of the Ontario Region, Department of Fisheries and Forestry, negative number 2167, (B) F-521511, (C) F-521510, (D) Photo courtesy of Michigan State University, negative number 703116-1.

Plate 5: (A) F-508527, (B) F-508529, (C) F-521501, (D) F-521500.

Plate 6: (A) F-521504, (B) F-521503, (C) F-521502, (D) F-516559.

Plate 7: (A) Photo courtesy of the University of Wisconsin, negative number 32195-C-1, (B) Photo courtesy of the University of Wisconsin, negative number 32192-C-1, (C) Photo courtesy of Michigan State University, negative number 702730, (D) F-519844.

Plate 8: (A) F-501800, (B) Photo courtesy of Michigan State University, (C) Photo courtesy of Michigan State University, negative number 5728, (D) F-498343.

Plate 9: (A) F-521499, (B) Photo courtesy of Michigan State University, negative number 4783, (C) Photo courtesy of Michigan State University, negative number 4063, (D) Photo courtesy of the Canadian Forest Service.

Plate 10: (A) F-509463, (B) F-521497, (C) F-521496, (D) F-521498.

Plate 11: (A) Photo courtesy of the Illinois Natural History Survey, negative number 161789, (B) Photo courtesy of Michigan State University, negative number 3496, (D) Photo courtesy of the Connecticut Agricultural Experiment Station.

Plate 12: (A) Photo courtesy of the Michigan Department of Agriculture, (B) F-521494, (C) Photo courtesy of Michigan State University, negative number 70968-2, (D) F-521495.

Plate 13: (A) Photo courtesy of the Ohio Agricultural Research and Development Center, (B) F-506705, (C) F-493083, (D) Photo courtesy of the Ohio Agricultural Research and Development Center.

Plate 14: (A) F-521493, (B) Photo courtesy of Michigan State University, negative number 7153-1, (C) Photo courtesy of Michigan State University, negative number 71746, (D) Photo courtesy of Michigan State University.

Plate 15: (A) F-521508, (B) F-521509, (C) F-521492, (D) F-521491.

Plate 16: (A) F-501798, (B) F-521489, (C) F-521490, (D) F-501802.

Plate 17: (A) F-506704, (B) F 506706, (C) Photo courtesy of Michigan State University, negative number 4879, (D) Photo courtesy of Michigan State University, negative number 4878.

Plate 18: (A) Photo courtesy of Michigan State University, negative number 4904a, (B) Photo courtesy of Michigan State University, (C) Photo courtesy of Michigan State University, (D) Photo courtesy of Michigan State University, negative number 5184.

Plate 19: (A) Photo courtesy of Michigan State University, negative number 4906, (B) Photo courtesy of Michigan State University, negative number

3082, (C) Photo courtesy of Michigan State University, negative number 3084, (D) Photo courtesy of Michigan State University, negative number 4661.

Plate 20: (A) Photo courtesy of Michigan State University, negative number 3752, (B) Photo courtesy of Michigan State University, negative number 4005, (C) Photo courtesy of Michigan State University, (D) Photo courtesy of Michigan State University, negative number 5331.

Plate 21: (A) Photo courtesy of Michigan State University, negative number 3405, (B) F-521488, (C) Photo courtesy of Michigan State University, negative number 1094, (D) F-521487.

Plate 22: (A) F-521484, (B) F-521485, (C) F-489365, (D) F-521486.

Plate 23: (A) Photo courtesy of Michigan State University, (B) Photo courtesy of Michigan State University, negative number 17922-7, (C) Photo courtesy of Michigan State University, (D) Photo courtesy of Michigan State University, negative number 5185.

Plate 24: (A) Photo courtesy of Michigan State University, negative number 4740, (B) Photo courtesy of Michigan State University, negative number 4743, (C) Photo courtesy of Michigan State University, negative number 4844, (D) Photo courtesy of Michigan State University, negative number 4914a.

Plate 25: (A) Photo courtesy of Michigan State University, negative number 6014, (B) Photo courtesy of Michigan State University, (C) Photo courtesy of Michigan State University, negative number 5186, (D) Photo courtesy of Michigan State University, negative number 4847.

Plate 26: (A) F-501806, (B) F-521482, (C) F-521483, (D) Photo courtesy of the University of Wisconsin.

Plate 27: (A) F-521480, (B) F-521481, (C) Photo courtesy of Michigan State University, negative number 6315, (D) F-502134.

Plate 28: (A) F-501562, (B) F-501561, (C) F-521479, (D) Photo courtesy of Michigan State University.

Plate 29: (A) Photo courtesy of Michigan State University, negative number 17886-3, (B) Photo courtesy of the Michigan Department of Natural Resources, (C) F-521478, (D) F-494389.

Plate 30: (A) F-492261, (B) F-501807, (C) F-421477, (D) Photo courtesy of Michigan State University.

Plate 31: (A) F-485947, (B) Photo courtesy of the Canadian Forestry Service, negative number 3258, (C) Photo courtesy of Michigan State University, (D) F-523430.

Plate 32: (A) F-500834, (B) F-480420, (C) Photo courtesy of Michigan State University, negative number 67722, (D) F-521476.

Plate 33: (A) Photo courtesy of Michigan State University, negative number 4034, (B) F-501804, (C) F-521475, (D) F-521469.

Plate 34: (A) Photo courtesy of the Canadian Forestry Service, negative number 3247, (B) Photo courtesy of the Canadian Forestry Service, negative number 3246, (C) Photo courtesy of Michigan State University, (D) Photo courtesy of the Canadian Forestry Service, negative number 3322.

Plate 35: (A) F-492898, (B) F-521470, (C) F-521467, (D) F-521468.

Plate 36: (A) F-490260, (B) F-521471, (C) F-521473, (D) F-521472.

Plate 37: (A) F-519677, (B) Photo courtesy of Michigan State University, negative number 707730-2, (C) F-494420, (D) Photo courtesy of Michigan State University, negative number 692605-1.

Plate 38: (A) F-521465, (B) F-521466, (C) Photo courtesy of Michigan State University, negative number 7090, (D) Photo courtesy of the Ohio Agricultural Experiment Station.

Plate 39: (A) Photo courtesy of Michigan State University, negative number 4037, (B) F-521462, (C) F-493085-A, (D) F-493085-B.

Plate 40: (A) Photo courtesy of Michigan State University, negative number 63800-2, (B) F-314142, (C) F-492959, (D) F-521464.

Plate 41: (A) F-492960, (B) F-521463, (C) F-518186, (D) F-518188.

Plate 42: (A) Photo courtesy of Michigan State University, (B) F-502130, (C) F-493926, (D) F-490253.

Plate 43: (A) F-692605, (B) F-504409, (C) F-487420, (D) Photo courtesy of Michigan State University, negative number 70968-5.

Plate 44: (A) F-521457, (B) F-514871, (C) F-501574, (D) Photo courtesy of Michigan State University, negative number 5335.

Plate 45: (A) Photo courtesy of the Michigan Department of Agriculture, (B) F-521460, (C) F-521461, (D) Photo courtesy of Michigan State University, negative number 70968-7.

Plate 46: (A) Photo courtesy of the Michigan Department of Agriculture, (B) F-521505, (C) F-521459, (D) F-521458.

Plate 47: (A) F-514140, (B) Photo courtesy of Michigan State University, negative number 4804, (C) F-494653, (D) Photo courtesy of Michigan State University, negative number 6266.

Plate 48: (A) Photo courtesy of the Michigan Department of Natural Resources, (B) F-521454, (C) Photo courtesy of William Turnock, Canada, (D) F-521455.

Plate 49: (A) F-496926, (B) Photo courtesy of Michigan State University, (C) F-521453, (D) Photo courtesy of the Canadian Forestry Service.

Plate 50: (A) F-514869, (B) Photo courtesy of the Canadian Forestry Service, (C) F-521452, (D) F-521451.

Plate 51: (A) F-494578, (B) Photo courtesy of Michigan State University, negative number 5013, (C) F-508004, (D) F-501809.

Plate 52: (A) F-501931, (B) F-494429, (C) Photo courtesy of Michigan State University, negative number 6267, (D) F-521450.

Plate 53: (A) Photo courtesy of Michigan State University, negative number 70968-3, (B) Photo courtesy of Michigan State University, negative number 4315, (C) F-505549, (D) F-519679.

Plate 54: (A) F-506524, (B) F-506525, (C) F-506525, (D) F-506523, (E) F-506522, (F) F-506522, (G) F-506527, (H) F-506526, (I) F-506526.

INDEX TO INSECTS BY HOST PLANTS

	Page
Arborvitae (see northern white-cedar)	
Cedar, Eastern red (Juniper)	
Borers, root	
Pales weevil	64
Borers, shoot and stem	
Northern cedar bark beetle	71
Redcedar bark beetle	71
Leaf feeders	
Bagworm	29
Imperial moth	27
Juniper webworm	29
Sucking insects	
Fletcher scale	42
Juniper scale	42
Juniper tip midge	51
Red cedar aphid	46
Spruce spider mite	52
Tipwarf mite	53
Cedar, Northern white (Arborvitae)	
Borers, shoot and stem	
Allegheny mound ant	78
Northern cedar bark beetle	71
Redcedar bark beetle	71
Borers, wood	
Black carpenter ant	77
Urocerus sp.	76
Gall insects	
"Gall beetle"	72
Leaf feeders	
Bagworm	29
Eastern cedar sawfly	23
Strawberry root weevil	66
Leaf miners	
Arborvitae leafminer	36
Root feeders	
Strawberry root weevil	66
Sucking insects	
Arborvitae aphid	45
Fletcher scale	42
Juniper scale	42
Spruce spider mite	52
Tipwarf mite	53
Fir, Balsam	
Borers, root	
Pales weevil	64
Warren's collar weevil	64
Borers, shoot and stem	
Balsam fir bark beetle	72
Borers, wood	
Black carpenter ant	77
Eastern subterranean termite	78
Melanophila fulvoguttata	73
Monochamus marmorator	74
Monochamus notatus	74
Monochamus scutellatus	74
Cone insects	
Fir coneworm	83
Spruce coneworm	83
Gall insects	
Balsam bark weevil	62
Balsam gall midge	50
Leaf feeders	
Balsam fir sawfly	21
Eastern blackheaded budworm	32
Eastern hemlock looper	27
Pine tussock moth	27
Spruce budworm	31
Leaf miners	
Pine needle sheathminer	84
Root feeders	
White grubs	78
Sucking insects	
Balsam twig aphid	45
Pine needle scale	42
Pine spittlebug	39
Pulvinaria scale	43
Signoret spittlebug	40
Spruce spider mite	52
Fir, Douglas	
Borers, root	
Pales weevil	64
Cone insects	
Fir coneworm	83
Spruce coneworm	83
Leaf feeders	
Spruce budworm	31
Sucking insects	
Cooley spruce gall aphid	47
Hemlock, Eastern	
Borers, wood	

	Page
Hemlock, Eastern—continued	
Melanophila fulvoguttata	73
Leaf feeders	
Black vine weevil	66
Hemlock looper	27
Strawberry root weevil	66
Leaf miners	
Pulicalvaria abietisella	34
Root feeders	
Black vine weevil	66
Strawberry root weevil	66
Sucking insects	
Hemlock scale	43
Pine needle scale	42
Pine spittlebug	39
Spruce spider mite	52
Juniper, Common	
Borers, shoot and stem	
Northern cedar bark beetle	71
Redcedar bark beetle	71
Leaf feeders	
Juniper webworm	29
Leaf miners	
Phalonia rutilana	36
Sucking insects	
Fletcher scale	42
Juniper scale	42
Tipdwarf mite	53
Larch (see tamarack)	
Pine, Austrian	
Borers, root	
Pine root collar weevil	62
Borers, shoot and stem	
Eastern pineshoot borer	54
European pine shoot moth	54
Northern pine weevil	61
Pine candle moth	55
Pitch mass borer	57
Zimmerman pine moth	56
Leaf feeders	
Abbott's sawfly	20
European pine sawfly	21
Pine false webworm	30
Pine webworm	30
Nesting pine sawfly	30
Sucking insects	
Pine thrips	49
Pine, Austrian—continued	
Pine tortoise scale	41
Spotted pine aphid	45
Pine, Eastern White	
Borers, root	
Pales weevil	64
Pine root collar weevil	62
Borers, shoot and stem	
Ambrosia beetles	67
Eastern pineshoot borer	54
European pine shoot moth	54
Hylobius congener	64
Lodgepole pine beetle	70
Magdalis perforatus	66
Northern pine weevil	61
Pine engraver	70
Pissodes affinis	62
Pitch mass borer	57
White pine weevil	44
Zimmerman pine moth	56
Borers, wood	
Eastern subterranean termite	78
Melanophila fulvoguttata	73
Monochamus spp.	74
Cone insects	
White pine cone beetle	81
Leaf feeders	
Imperial moth	27
Introduced pine sawfly	21
Jack pine budworm	32
Pine chafer	24
Pine chrysomelid	24
Pine false webworm	30
Pine tube moth	29
Pine webworm	30
Pine tussock moth	27
Swaine jack pine sawfly	19
Tortrix pallorana	33
Walkingstick	26
White pine sawfly	16
Root feeders	
White grubs	78
Sucking insects	
Pine bark aphid	44
Pine leaf chermid	48
Pine needle scale	42
Pine spittlebug	39
Pineus coloradensis	44
Prociphilus spp.	46
Red spruce aphid	48
White pine aphid	45

	Page
Pine, Jack	
Borers, root	
Pales weevil	64
Pine root collar weevil	62
Root tip weevil	63
Warren's collar weevil	64
Borers, shoot and stem	
Cimberis elongatus	72
Eastern pineshoot borer	54
European pine shoot moth	54
Jack pine tip beetle	72
Lodgepole terminal weevil	60
Myeloborus sp.	72
Northern pine weevil	61
Northern pitch twig moth	57
Petrova houseri	58
Petrova pallipennis	55
Pine engraver	70
Pissodes affinis	62
Pitch mass beetle	57
Pityophthorus sp.	72
Red turpentine beetle	69
White pine weevil	59
Zimmerman pine moth	56
Borers, wood	
Eastern subterranean termite	78
Monochamus spp.	74
Prionus sp.	76
Cone insects	
Fir coneworm	83
Laspeyresia toreuta	82
Red pine coneworm	82
Spruce coneworm	83
Gall insects	
Allegheny mound ant	78
Leaf feeders	
Abbott's sawfly	20
Brownheaded jack pine sawfly	17
European pine sawfly	21
Imperial moth	27
Introduced pine sawfly	21
Jack pine budworm	32
Jack pine sawfly	18
Neodiprion compar	19
Neodiprion maurus	17
Neodiprion nigroscutum	19
Nesting pine sawfly	30
Pine chafer	24
Pine, Jack—continued	
Pine chrysomelid	24
Pine false webworm	30
Pine tussock moth	27
Pine webworm	30
Redheaded jack pine sawfly	17
Redheaded pine sawfly	16
Red pine sawfly	21
Swaine jack pine sawfly	19
Tortrix pallorana	33
Leaf miners	
Argyrotaenia tabulana	35
Pine needleminer	34
Pine needle sheathminer	84
Root feeders	
White grubs	78
Sucking insects	
Black pineleaf scale	42
Cecidomyia banksianae	49
Cecidomyia reeksi	49
Clastoptera testacea	40
Gouty pitch midge	50
Pine needle scale	42
Pine spittlebug	39
Pine tortoise scale	41
Pineus coloradensis	44
Saratoga spittlebug	37
Signoret spittlebug	40
Pine, Mugo	
Borers, shoot and stem	
Eastern pineshoot borer	54
Northern pine weevil	61
Pine candle moth	55
Zimmerman pine moth	56
Leaf feeders	
Abbott's sawfly	20
European pine sawfly	21
Jack pine budworm	32
Pine false webworm	30
White pine sawfly	16
Sucking insects	
Black pineleaf scale	42
Pine needle scale	42
Woolly pine scale	43
Pine, Ponderosa	
Borers, root	
Pine root collar weevil	62
Borers, shoot and stem	
European pine shoot moth	54

	Page
Pine, Ponderosa—continued	
Northern pine weevil	61
White pine weevil	59
Zimmerman pine moth	56
Leaf feeders	
Abbott's sawfly	20
Argyrotaenia tabulana	35
European pine sawfly	21
Pine needle sheathminer	84
Pine, Red	
Borers, root	
Pales weevil	64
Pine root collar weevil	62
Pitcheating weevil	65
Root tip weevil	63
Warren's collar weevil	64
Borers, shoot and stem	
Allegheny mound ant	78
Ambrosia beetles	67
Eastern pineshoot borer	54
European pine shoot moth	54
Hylobius congener	64
Jack pine tip beetle	72
Magdalis perforatus	66
Northern pine weevil	61
Pine candle moth	55
Pine engraver	70
Pine gall weevil	65
Pissodes affinis	62
Pitch mass beetle	57
Pitch mass borer	57
Red turpentine beetle	69
Rhyacionia adana	54
Rhyacionia busckana	54
Rhyacionia sonia	54
White pine weevil	59
Zimmerman pine moth	56
Borers, wood	
Eastern subterranean termite	78
Monochamus spp.	74
Powder-post beetle	77
Prionus sp.	76
Urocerus spp.	76
Cone insects	
Eucosma monitorana	82
Fir coneworm	83
Laspeyresia toreuta	82
Red pine cone beetle	81
Red pine coneworm	82
Rubsaamenia sp.	84
Spruce coneworm	83
Gall Insects	
Allegheny mound ant	78
Pine gall weevil	65
Red pine needle midge	50
Leaf feeders	
Abbott's sawfly	20
Brownheaded jack pine sawfly	17
European pine sawfly	21
Grasshoppers	25
Introduced pine sawfly	21
Jack pine budworm	32
Jack pine sawfly	18
Neodiprion compar	19
Nesting pine sawfly	30
Nursery pine sawfly	20
Pine chafer	24
Pine chrysomelid	24
Pine false webworm	30
Pine tussock moth	27
Redheaded pine sawfly	16
Red pine sawfly	21
Swaine jack pine sawfly	19
Tortrix pallorana	33
White pine sawfly	16
Leaf miners	
Evagora resinosae	35
Pine needleminer	34
Root feeders	
White grubs	78
Sucking insects	
Clastoptera testacea	40
"Needle blight" midge	51
Pine tortoise scale	41
Pineus coloradensis	44
Prociphilus spp.	46
Red pine needle midge	50
Saratoga spittlebug	37
Setoptus mite	53
Signoret spittlebug	40
Woolly pine scale	43
Pine, Scotch	
Borers, root	
Pales weevil	64
Pine root collar weevil	62
Root tip weevil	63
Warren's collar weevil	64
Borers, shoot and stem	
European pine shoot moth	54
Hylobius congener	64
Jack pine tip beetle	72
Magdalis perforatus	66
Northern pine weevil	61

Page

Pine, Scotch—continued
- Northern pitch twig moth 57
- Pine candle moth 55
- Pine engraver 70
- *Pissodes affinis* 62
- White pine weevil 59
- Zimmerman pine moth 56

Borers, wood
- *Monochamus* spp. 74
- Powder-post beetles 77

Cone insects
- Red pine coneworm 82

Leaf feeders
- Abbott's sawfly 20
- European pine sawfly 21
- Introduced pine sawfly 21
- Jack pine budworm 32
- Jack pine sawfly 18
- Nursery pine sawfly 20
- Pine chafer 24
- Pine chrysomelid 24
- Pine false webworm 30
- Swaine jack pine sawfly 19
- *Tortrix pallorana* 33
- Walkingstick 26

Leaf miners
- Pine needleminer 34

Root feeders
- White grubs 78

Sucking insects
- Balsam twig aphid 45
- *Cinara pini* 45
- Pine needle scale 42
- Pine spittlebug 39
- Pine thrips 49
- Pine tortoise scale 41
- *Pineus coloradensis* 44
- Saratoga spittlebug 37
- Spotted pine aphid 45
- White pine aphid 45

Spruce, Black

Borers, shoot and stem
- Spruce beetle 71
- Northern pine weevil 61

Borers, wood
- *Melanophila fulvoguttata* 73

Cone insects
- Spruce coneworm 83

Gall insects
- Eastern spruce gall aphid 46
- Pine leaf chermid 48

Page

Spruce, Black—continued
- Red spruce aphid 48
- Spruce gall aphid 46
- Woolly larch aphid 47

Leaf feeders
- Eastern blackheaded budworm 32
- European spruce sawfly 22
- Greenheaded spruce sawfly 22
- Spruce budworm 31
- Yellowheaded spruce sawfly 22

Leaf miners
- Spruce leafminer (2) 33, 34
- Spruce needleminer 34

Sucking insects
- Spruce bud scale 43
- Spruce spider mite 52
- Twospotted spider mite 52

Spruce, Blue

Borers, shoot and stem
- Eastern spruce beetle 71
- Northern pine weevil 61
- Pitch mass borer 57

Cone insects
- Spruce coneworm 83
- Spruce seed moth 83

Gall insects
- Cooley spruce gall aphid 47
- Spruce gall aphid 46

Leaf feeders
- European spruce sawfly 22
- Greenheaded spruce sawfly 22
- Spruce budworm 31
- Yellowheaded spruce sawfly 22

Leaf miners
- Spruce leafminer (2) 33, 34
- Spruce needleminer 34

Root feeders
- White grubs 78

Sucking insects
- Balsam twig aphid 45
- Spruce spider mite 52
- Twospotted spider mite 52

Spruce, Norway

Borers, shoot and stem
- Eastern spruce beetle 71
- Northern pine weevil 61

Borers, wood

Page

Spruce, Norway—continued
Melanophila fulvoguttata 73
Gall insects
Eastern spruce gall aphid 46
Pine Leaf chermid 48
Spruce gall aphid 46
Leaf feeders
European spruce sawfly 22
Spruce budworm 31
Leaf miners
Spruce leafminer (2) 33, 34
Twospotted spider mite 52

Spruce, White
Borers, root
Pales weevil 64
Borers, shoot and stem
Balsam fir bark beetle 72
Spruce beetle 71
Northern pine weevil 61
Pine engraver 70
Pitch mass borer 57
Small spruce weevil 62
White pine weevil 59
Borers, wood
Eastern subterranean termite 78
Melanophila fulvoguttata 73
Powder-post beetles 77
Urocerus spp. 76
Cone insects
Spruce cone maggot 84
Spruce coneworm 83
Spruce seed moth 83
Gall insects
Allegheny mound ant 78
Eastern spruce gall aphid 46
Spruce gall aphid 46
Spruce gall midge 51
Leaf feeders
Eastern blackheaded budworm 32
European spruce sawfly 22
Greenheaded spruce sawfly 22
Pine tussock moth 27
Yellowheaded spruce sawfly 22

Page

Spruce, White—continued
Leaf miners
Pine needle sheathminer 84
Spruce leafminer (2) 33, 34
Spruce needleminer 34
Root feeders
Strawberry root weevil 66
White grubs 78
Sucking insects
Pine spittlebug 39
Signoret spittlebug 40
Spruce bud scale 43
Spruce spider mite 52

Tamarack (Larch)
Borers, root
Pales weevil 64
Warren's collar weevil 64
Borers, shoot and stem
Balsam fir bark beetle 72
Eastern larch beetle 70
Borers, wood
Melanophila fulvoguttata 73
Cone insects
Spruce coneworm 83
Leaf feeders
Larch casebearer 35
Larch sawfly 23
Spruce budworm 31
Leaf miners
Larch casebearer 35
Sucking insects
Pine spittlebug 39
Signoret spittlebug 40
Spruce spider mite 52
Woolly larch aphid 47

Yew, Canadian
Leaf feeders
Black vine weevil 66
Strawberry root weevil 66
Root feeders
Black vine weevil 66
Strawberry root weevil 66
Sucking insects
Fletcher scale 42
Pine needle scale 42
Taxus mealybugs 43

GLOSSARY

Alternate host. Another host plant required to complete development of an insect or disease pathogen.

Alternating generations. The habit of some insects that require one generation to develop on one host species and another generation on a different host species.

Bole. Stem or trunk of a tree.

Cast skins. Shed outer skin of a larva or nymph.

Chip cocoon. A cavity covered with wood splinters that some beetles construct to conceal the pupa.

Fascicle. Sheath at the base of a needle cluster, surrounding the needles.

Flagging. Discolored shoots or branches.

Frass. Solid insect excrement, usually in small pellets.

Gall. Enlarged, swollen growth of plant tissue.

Gallery. A passage, burrow, or mine excavated by an insect in plant tissue for feeding, oviposition, or exit.

Honeydew. Sugary liquid excretion of aphid and scales.

Internode. Portion of tree stem or branches between two or more nodes.

Larva. Immature form of an insect such as a caterpillar, grub, or maggot.

Lateral shoots. Side shoots of the tree's branches.

Mined foliage. Leaves or needles in which the inner leaf tissues are eaten by insects.

Mycelium. Vegetative part of a fungus; may be threadlike or paperlike.

New growth foliage. Foliage of the current or most recent growing season.

Node. Place on the stem of a tree where major branches are attached; or place on the branches where major branchlets are attached.

Nymph. Immature form of an insect resembling the adult except for incomplete wing development.

Old growth foliage. Foliage of all seasons except most recent.

Petiole. Stalk of a leaf.

Pole. A tree at least 5.0 inches in diameter at 4½ feet above the ground.

Prolegs. Fleshy false legs on abdomen of caterpillars; true legs are located on the thoracic segments behind the head.

Pupa. Inactive stage of an insect; a transition stage from larva to adult.

Pupal case. Shed outer skin of a pupa.

Sapling. A young tree 1 to 5 inches in diameter at 4½ feet above the ground.

Sawtimber. Trees that yield logs suitable for lumber; usually measure at least 8 inches in diameter at 4½ feet above the ground.

Seedling. Young tree less than 1 inch in diameter at 4½ feet above the ground.

Skeletonized foliage. Leaves or needles in which the soft tissues have been eaten by insects from between the veins, leaving only the veins.

Slash. Debris such as logs, bark, branches, etc., left after tree pruning or cutting.

Terminal shoot. Top-most shoot on the stem tip; also called the leader.

GENERAL INDEX

	Page
Abbott's sawfly	20
Abnormal temperatures	91
Abnormal water conditions	92
Acantholyda erythrocephala	30
Acantholyda zappei	30
Acleris variana	32
Adelges abietis	46
Adelges cooleyi	47
Adelges strobilobius	47
Air pollution	92
Allegheny mound ant	78
Ambrosia beetles	67
Animals	89
Anomala oblivia	24
Ants	77
Aphrophora parallela	39
Aphrophora saratogensis	38
Aphrophora signoreti	40
Arborvitae aphid	45
Arborvitae leafminer	36
Arborvitae sawfly	23
Argyresthia thuiella	36
Argyrotaenia pinatubana	29
Argyrotaenia tabulana	35
Armillaria mellea	89
Aspidiotus abietis	43
Bagworm	29
Balsam bark weevil	62
Balsam fir bark beetle	72
Balsam fir sawfly	21
Balsam gall midge	50
Balsam twig aphid	45
Bark beetles	67
Bears	90
Birds	89
Black carpenter ant	77
Black pineleaf scale	42
Black vine weevil	66
Brachyrhinus ovatus	66
Brachyrhinus sulcatus	66
Branch diseases	86
Brownheaded jack pine sawfly	17
Brown spot	85
Budworm moths	30
Calepiterimerus thujae	53
Camponotus pennsylvanicus	77
Cecidomyia banksianae	49
Cecidomyia piniinopis	50
Cecidomyia reeksi	49
Cedar-apple rust	87
Cedar bark beetles	71
Cedar-quince rust	87
Choristoneura fumiferana	31
Choristoneura pinus	32
Chrysobothris orono	57
Cinara pini	45
Cinara sabinae	46
Cinara strobi	45
Cinara tujafilina	45
Clastoptera juniperina	40
Clastoptera testacea	40
Coleophora laricella	35
Coleosporium spp.	85
Commandra blister rust	87
Cone beetles	81
Cone flies	84
Cone insects	80
Cone moths	82
Conifers	4
Conophthorus banksianae	72
Conophthorus coniperda	81
Conophthorus resinosae	81
Cooley spruce gall aphid	47
Cronartium commandrae	87
Cronartium comptoniae	88
Cronartium quercuum	87
Cronartium ribicola	87
Dasychira plagiata	27
Dasineura balsamicola	50
Deer	90
Defoliating insects	9
Dendroctonus rufipennis	71
Dendroctonus murryanae	70
Dendroctonus simplex	70
Dendroctonus valens	69
Diapheromera femorata	26
Diaspis carueli	42
Dichomeris marginella	29
Dimerosporium sp.	85
Dioryctria abietella	83
Dioryctria disclusa	82
Dioryctria reniculella	83
Dioryctria zimmermani	56
Diprion hercyniae	22
Diprion similis	21
Diseases	85
Eacles imperialis	27
Eastern blackheaded budworm	32
Eastern cedar sawfly	23
Eastern gall rust	87

	Page
Eastern larch beetle	70
Eastern pineshoot borer	54
Eastern spruce gall aphid	46
Eastern subterranean termite	78
Epinotia nanana	33
Eriophyid mite	53
Eucosma gloriola	54
Eucosma monitorana	82
Eulachnus agilis	45
European pine sawfly	21
European pine shoot moth	54
European spruce sawfly	22
Evagora resinosae	35
Exoteleia nepheos	55
Exoteleia pinifoliella	34
Fir coneworm	83
Flatheaded borers	73
Fletcher scale	42
Foliage diseases	85
Fomes annosus	88
Fomes annosus root rot	88
Formica exsectoides	78
Frost injury	91
Gall aphids	46
Gilpinia frutetorum	20
Glyptoscelis pubescens	24
Gnophothrips sp.	49
Gouty pitch midge	50
Grasshoppers	25
Greenheaded spruce sawfly	22
Gymnosporangium clavipes	87
Gymnosporangium juniperi-virginianae	87
Harmful chemicals	91
Hemlock looper	27
Hemlock scale	43
Hemlock twig rust	88
Horntails	76
Human injury	90
Hylobius congener	64
Hylobius pales	64
Hylobius radicis	62
Hylobius rhizophagus	63
Hylobius warreni	64
Hypodermella ampla	85
Imperial moth	27
Introduced pine sawfly	21
Ips pini	70
Jack pine budworm	32
Jack pine sawfly	18
Jack pine tip beetle	72
Juniper scale	42
Juniper tip midge	51
Juniper webworm	29
Lambdina fiscellaria fiscellaria	27
Larch casebearer	35
Larch sawfly	23
Laspeyresia toreuta	82
Laspeyresia youngana	83
Leaf beetles	24
Lecanium fletcheri	42
Lodgepole pine beetle	70
Lodgepole terminal weevil	60
Lophodermium needlecast	86
Lophodermium pinastri	86
Magdalis perforatis	66
Mammals	90
Mayetiola piceae	51
Mechanical injuries	93
Melampsorella spp.	88
Melanophila spp.	73
Melanoplus spp.	25
Mice	89
Midges	49
Mindarus abietinus	45
Mites	51
Monochamus spp.	74
Monoctenus juniperinus	23
Monoctenus melliceps	23
"Needle blight" midge	51
Needlecast disease	85
Needle droop	86
Needle miners	33
Needle rusts	85
Neodiprion abbottii	20
Neodiprion abietis	21
Neodiprion compar	19
Neodiprion dubiosis	17
Neodiprion lecontei	16
Neodiprion maurus	17
Neodiprion manulus nanalus	21
Neodiprion nigroscutum	19
Neodiprion pinetum	16
Neodiprion pratti banksianae	18
Neodiprion rugifrons	17
Neodiprion sertifer	21
Neodiprion swainei	19
Nesting pine sawfly	30
Noninsect maladies	84
Northern pine weevil	61
Northern pitch twig moth	57
Nuculaspis californica	42
Nursery pine sawfly	20
Nutrition	92
Oligonychus ununguis	52
Oligothrophus betheli	52

	Page
Pachylobius picivorus	65
Pales weevil	64
Pegohylemia anthracina	84
Petrova albicapitana	57
Petrova houseri	58
Petrova pallipennis	55
Phalonia rutilana	36
Phenacaspis pinifoliae	42
Phloeosinus spp.	71
Phyllophaga spp.	78
Physokermes piceae	43
Pikonema alaskensis	22
Pikonema dimmockii	22
Pine bark aphid	44
Pine candle moth	55
Pine chafer	24
Pine chrysomelid	24
Pine engraver	70
Pine false webworm	30
Pine gall weevil	65
Pine grosbeak	89
Pine leaf chermid	48
Pine needleminer	34
Pine needle scale	42
Pine needle sheathminer	84
Pine root collar weevil	62
Pine shoot moths	54
Pine spittlebug	39
Pine thrips	49
Pine tortoise scale	41
Pine tube moth	29
Pine tussock moth	27
Pine webworm	30
Pineus coloradensis	44
Pineus floccus	48
Pineus pinifoliae	48
Pineus similis	48
Pineus strobi	44
Pissodes affinis	62
Pissodes approximatus	61
Pissodes dubius	62
Pissodes rotundatus	62
Pissodes strobi	59
Pissodes terminalis	60
Pitcheating weevil	65
Pitch mass beetle	57
Pitch mass borer	57
Pitch-mass making insects	56
Pitch midges	49
Pityokteines sparsus	72
Plant lice	44
Pocket gophers	90
Podapion gallicola	65
Porcupines	90
Powder-post beetles	77
Pristiphora erichsonii	23
Prociphilus spp.	46
Pseudococcus spp.	43
Pseudophilippia quaintancii	43
Pulicalvaria abietisella	36
Pulicalvaria piceaella	34
Pulvinaria (?) sp.	43
Rabbits	90
Red cedar aphid	46
Redheaded jack pine sawfly	17
Redheaded pine sawfly	16
Red pine cone beetle	81
Red pine coneworm	82
Red pine needle midge	50
Red pine sawfly	21
Red spruce aphid	48
Red turpentine beetle	69
Reticulitermes flavipes	78
Rhyacionia buoliana	54
Phyacionia spp.	54
Root aphids	46
Root diseases	88
Root insects	53
Root tip weevil	63
Roundheaded borers	74
Rubsaamenia sp.	84
Salt injury	91
Sapsucking insects	36
Saratoga spittlebug	37
Sawflies	9
Scales	41
Scirrhia acicola	85
Scleroderris canker	86
Scleroderris lagerbergii	86
Setoptus sp.	53
Shoestring root rot	89
Shoot insects	53
Shoot moths	53
Signoret spittlebug	40
Small spruce weevil	62
Smoke injury	92
Sooty mold	85
Spittlebugs	37
Spotted pine aphid	45
Spruce beetle	71
Spruce bud scale	43
Spruce budworm	31
Spruce cone maggot	84
Spruce coneworm	83
Spruce gall aphids	46
Spruce gall midge	51

	Page
Spruce leafminer	33, 34
Spruce needleminer	34
Spruce seed moth	83
Spruce spider mite	52
Squirrels	90
Stem insects	53
Stephanopachys spp.	77
Strawberry root weevil	66
Swaine jack pine sawfly	19
Sweetfern rust	88
Taniva albolineana	34
Taxus mealybugs	43
Termites	77
Tetralopha robustella	30
Tetranychus urticae	52
Thecodiplosis piniresinosae	50
Thrips	49
Thyridopteryx ephemeraeformis	29
Tipdwarf mite	53
Tortrix pallorana	33
Toumeyella numismaticum	41
Trypodendron sp.	72
Twospotted spider mite	52
Tubeworms	28
Urocerus spp.	76
Vespamima pini	57
Walkingstick	26
Warren's collar weevil	64
Webworms	28
Weevils	58
White grubs	78
White pine aphid	45
White pine blister rust	87
White pine cone beetle	81
White pine sawfly	16
White pine weevil	59
Witches'-brooms	88
Wood borers	73
Woodpeckers	89
Wood-rotting fungi	89
Woolly larch aphid	47
Woolly pine scale	43
Yellowheaded spruce sawfly	22
Zelleria haimbachi	34
Zimmerman pine moth	56

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977 D — 221-229