United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

General Technical Report NE-129

Forestry Canada
Forêts Canada

Sugarbush Management: A Guide to Maintaining Tree Health

David R. Houston
Douglas C. Allen
Denis Lachance

North American Sugar Maple Decline Project (NAMP)

Abstract

Many pests and other stresses affect maple trees growing in a sugarbush. Some pests can markedly reduce sap quantity; others, although conspicuous, are not important. Stresses can result from activities by people and from natural phenomena. Recognizing problems and understanding the factors that contribute to their occurrence, development, and significance are necessary to maintain tree health. This report brings together current information on the living agents and nonliving factors that can cause problems in sugarbushes. Insects, diseases, improper forest stand management, and unwise sugaring practices are illustrated, and ways to prevent or reduce their effects are described.

The Authors

DR. DAVID R. HOUSTON is a principal plant pathologist and Project Leader of a team conducting research on dieback and decline diseases at the Center for Biological Control of Northeastern Forest Insects and Diseases, a laboratory of the USDA Forest Service's Northeastern Forest Experiment Station at Hamden, Connecticut. For the past 30 years Dr. Houston's research has focused on stress-initiated dieback and decline diseases of deciduous hardwoods, especially beech, maple, and oak.

DR. DOUGLAS C. ALLEN is a professor of forest entomology at the State University College of Environmental Science and Forestry, Syracuse, New York. His research for the past two decades has dealt primarily with northern hardwood insect ecology, with emphasis on sugar maple pests.

DR. DENIS LACHANCE is a senior forest pathologist with Forestry Canada, Quebec Region, at the Laurentian Forestry Centre in Quebec City. He has conducted research on stem cankers of hardwoods and root rots of trees before heading the Forest Insect and Disease Survey unit of the Region for the last 10 years. He also is Project Leader of a team studying the effects of environmental stresses on the forest, with emphasis on the problem of sugar maple decline.

Manuscript received for publication 23 January 1989

Northeastern Forest Experiment Station
100 Matsonford Road, Radnor, PA 19087
February 1990

Cette publication est disponible en français sous le titre Aménagement de l'érablière: guide de protection de la santé des arbres. Il est possible d'obtenir sans frais un nombre restreint d'exemplaires auprès de:

Forêts Canada, Région du Québec
Centre de foresterie des Laurentides
1055, rue de P.E.P.S., C.P. 3800
Sainte-Foy (Québec)
Canada G1V 4C7

Sugarbush Management: A Guide to Maintaining Tree Health

FOREWORD

The episodes of localized sugar maple decline in the Northeastern United States and the more widespread decline occurring in Quebec, Canada, resulted in the 1987 creation of the International North American Sugar Maple Decline Project (NAMP), a joint effort between the United States and Canada. NAMP was initiated by the USDA Forest Service under its Eastern Hardwoods Research Cooperative in cooperation with Forestry Canada. The primary goal of this project is to monitor tree-health condition in sugarbushes and undisturbed maple stands in the United States and Canada through 1990. This manual was developed in support of this goal of evaluating and maintaining tree health.

We hope that you find this guide of value in managing your sugarbush. We view a sugarbush as a complex system, where many diverse and interrelated factors operate over time to influence tree growth, health, and productivity. Every operation conducted in a sugarbush, no matter how trivial, affects not only the trees but all other forms of life as well. It is important, therefore, to "stand back from the trees" and view the "forest" in a holistic sense. We believe this guide is best read leisurely. It is not intended as a set of prescriptions or formulae for handling each and every set of problems that may occur. Each sugarbush is too unique for that. Rather, it is intended to provide a conceptual framework, for we believe that in the long run, a general understanding of relationships between sugar maple and its environment is the best guide for recognizing and preventing problems.

CONTENTS

INTRODUCTION

One of the most difficult, often frustrating, tasks of the sugarbush owner is maintaining and protecting the health of sugar maple trees. Methods for tapping trees, extracting and transporting sap, and producing syrup are relatively well understood. However, when we attempt to manipulate biological systems such as a stand of sugar maple, or a population of defoliating insects, the techniques for success are less clear and tend to reflect a combination of science, art, and intuition.

The ability to sustain a maple syrup operation depends largely on forest management decisions. Decisions on whether the site is suitable for growing sugar maple, how and where roads and trails should be made, when and to what extent the stand should be thinned, and when to control pests will determine the ultimate health, productivity, and efficiency of a sugarbush operation.

In this report we summarize current information on managing sugarbushes to keep them healthy. Sugarbush operators who follow these guidelines should leave their successors a healthy, productive, and lasting resource.

Good forest management requires a team effort. Researchers continually strive to better understand sugarbushes as biological systems, and foresters and extension specialists disseminate the findings from their studies. But it is the sugarbush owners and operators who ultimately must take the responsibility of implementing state-of-the-art practices that they deem useful.

Throughout this guide we emphasize concepts embodied in Integrated Pest Management (IPM). We extend these concepts to include the consequences of stresses caused by human activity and abiotic extremes. IPM strives to address pest problems in ecologically sound and socially acceptable ways. It views insects and diseases as natural components of the forest, and recognizes that cost-effective and ecologically sound pest management must be based on an understanding of the pests and the forest, and how these interact.

IPM is best defined as a "decisionmaking process" based on an understanding of the pest-forest system. As part of this process, sugarbush operators use a set of tools (information, actions, etc.) to answer certain questions that affect the series of management decisions that usually attend each problem. These tools are provided by forest and pest management specialists. For example:

Question: Can a certain insect defoliator significantly reduce sap volume in my bush?

Tool: A description of past impacts produced by that insect on similar sites or stands.

Question: What is the current status of the defoliator population?

Tool: Survey the insect and monitor its status.

Question: If important damage seems likely, how can I control the insect?

Tool: Microbial or chemical insecticides.

Question: What should I do?

Tool: Read about each insecticide and base decisions on the likely degree of control, possible side effects, local social pressures, etc.

Question: Did the treatment work?

Tool: Check the extent of defoliation and monitor the residual insect population.

It is important to note that protection should be an integral part of sugarbush management and that the sugarbush manager must make the decisions. The IPM approach should look at problems that stem from human activities in the sugarbush as well as those caused by insects, diseases, and animals. In the sugarbush, IPM should be used in ways that prevent or reduce problems that could affect the health and well being of maple trees. The program must fit an individual's sugarbush conditions, economic requirements, and management objectives.

To anticipate and prevent problems the sugarbush operator must become familiar with the major pests, their potential for damage, and management options for controlling them. The operator also must be aware of the consequences of human activities that occur in the sugarbush. In the sugarbush, human activities surpass those of any other managed forest, so it is important in a management program to anticipate problems arising from these activities. Integrated Pest Management, therefore, becomes Integrated Problem Management in the context discussed in this report.

SUGARBUSH STRUCTURE AND DEVELOPMENT

Most active sugarbushes have been passed down from one generation to the next or have been leased by a series of operators for many decades. The owner or operator has little choice but to work with what is available and to manage the stand as effectively as possible. Sometimes, however, a new sugarbush must be developed in a new location. In this situation the manager is able to carefully select its location and guide its development.

STAND SELECTION

Because sap collection is a major cost of syrup production, one must first consider the accessibility of the stand and its distance from the sugarhouse. Several site and stand features also must be evaluated. Three important ones are aspect, slope (steepness), and soil type.

Aspect refers to the direction in which the bush slopes. Aspect may influence tree growth as it influences the amount of heat, light, and moisture received by the trees. In turn, these factors affect the duration and periodicity of sap flow. So long as soil conditions are favorable, sugarbushes ideally should be established on eastern to southern exposures. This is a good compromise between suitable growing conditions and good sap production. The optimum slope depends on practical considerations. If the producer wishes to install a tubing system that relies on gravity feed, a reasonable slope is necessary. Even artificial vacuum systems are more effective on a gradual slope. Relatively level ground is desirable when buckets are used. The tree itself will grow well and remain vigorous on a range of aspect and slope conditions so long as the soil is suitable for the species and moisture and drainage are adequate.

Sugar maple grows best on moderately coarse-textured, moist, well-drained, deep soils (Figs. 1-2). Soil depth refers to the thickness of a layer of soil within which moisture and aeration are suitable for root growth. Stoniness has little if any effect on sugar maple growth where the soil is adequate for root growth.

Sugar maple will regenerate and grow on less than optimal sites. For example, many nearly pure maple stands are growing on cool, wet bottomlands. Yet on these sites the natural regeneration of red maple, ash, basswood, or even balsam fir indicates clearly that sugar maple has been constantly favored over these species by forest management. Such management creates an unstable situation as sugar

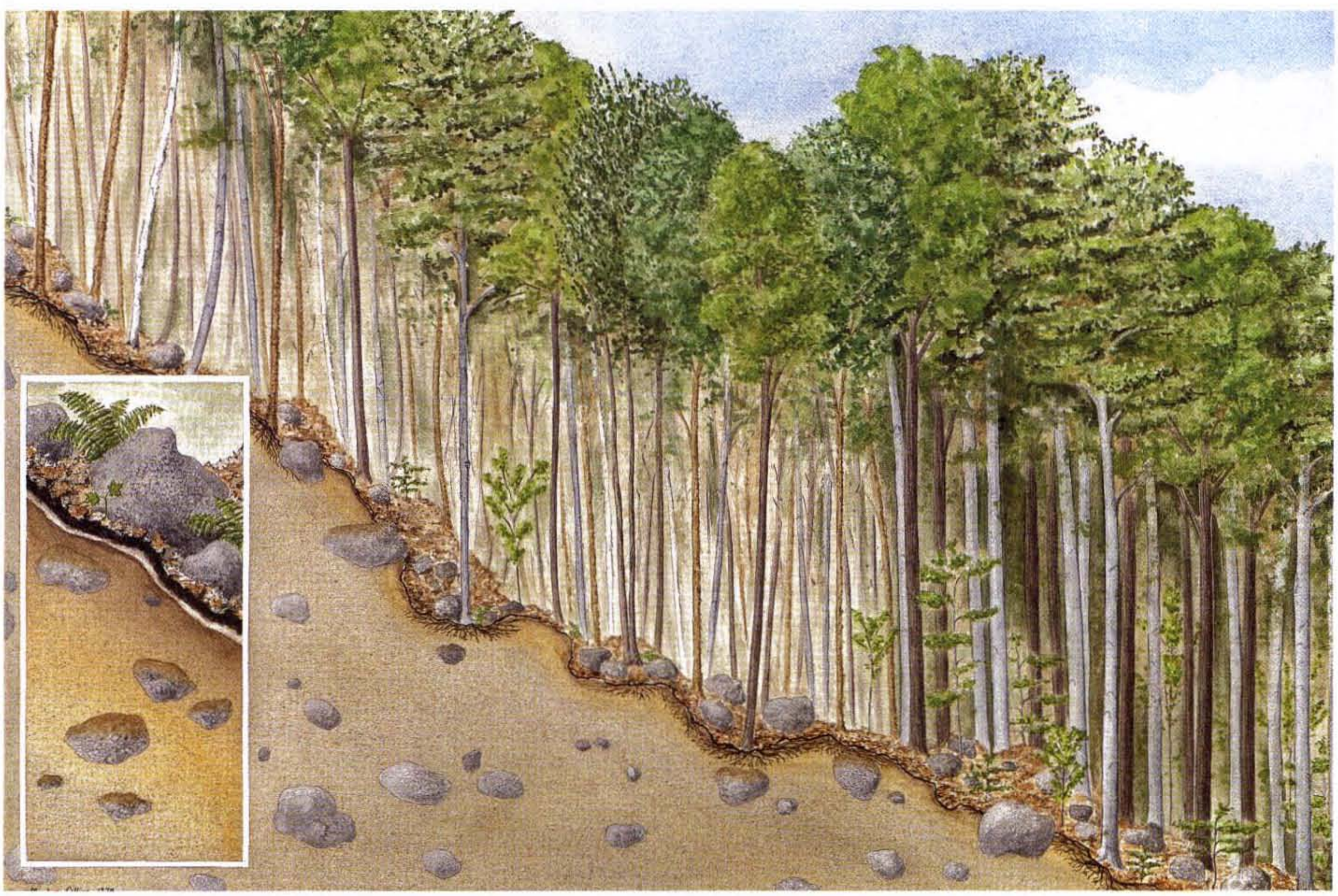

Figure 1.—In New Hampshire, sugar maple grows well on fine tills.

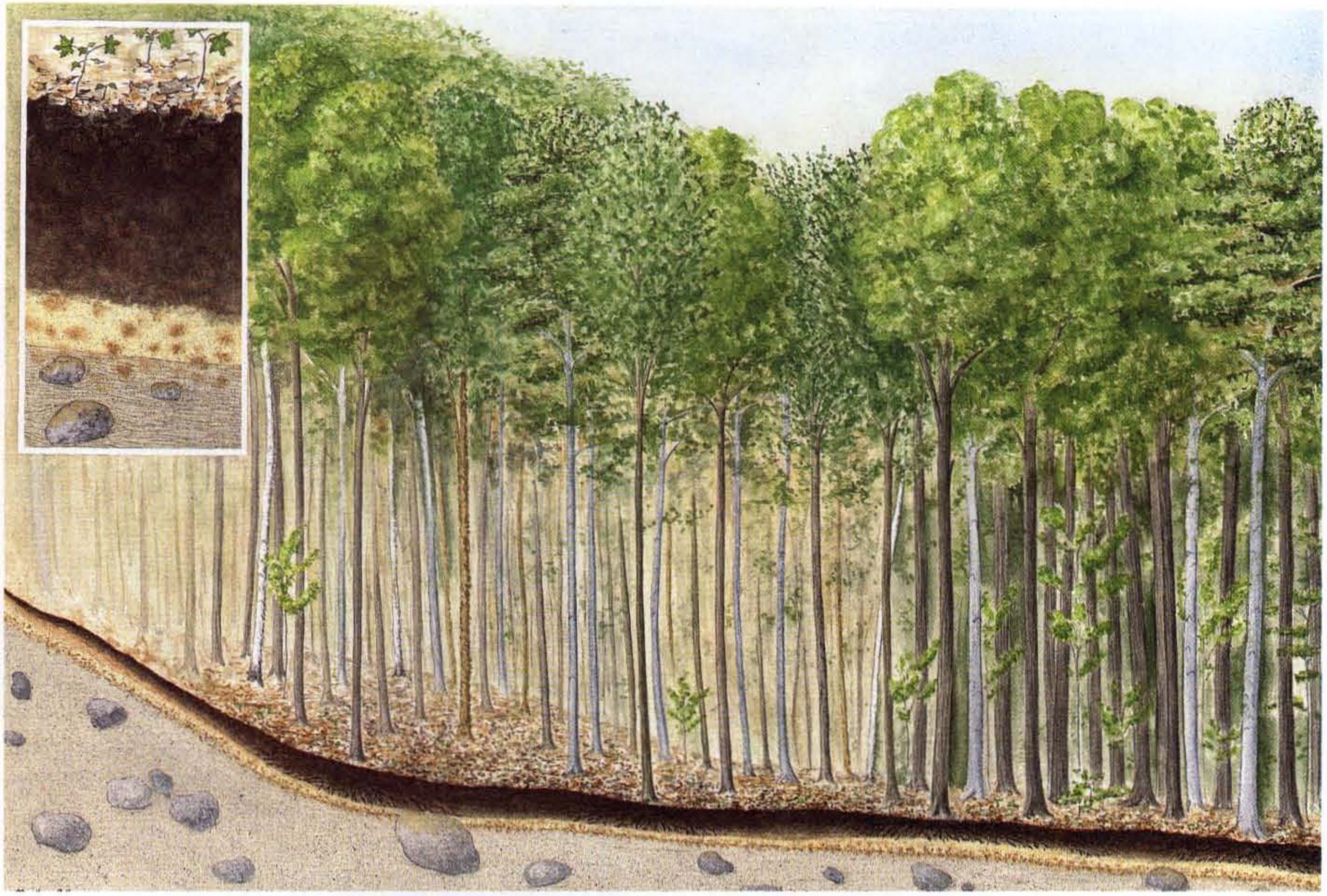

Figure 2.—Sugar maple also grows well on enriched soil habitats.

maple is neither long lived nor vigorous on wet or dry soils, and is extremely sensitive to biotic or abiotic stresses under these conditions. On off-site situations, sugar maple may be favored but not to the extent of eliminating all associated species, which act as stabilizing elements in these ecosystems and may even ameliorate damage to a maple stand growing under poor conditions. It is acceptable to discriminate against associated species on good sugar maple sites, such as on a midslope. In all situations, associated species should not be removed prematurely as this might create large openings that would encourage unwanted vegetation or promote excessive soil drying.

STAND STRUCTURE

The structure of the sugarbush refers to the numbers, kinds, and ages of trees present at different stages of its development. Since sugarbushes should be managed for the largest volume of sugar-rich sap over a given area, a goal is to have an optimum number of sugar maple trees on the site that produce high volumes of sweet sap.

It is important to know which trees will produce the largest volume of sugar-rich sap. Desirable trees are vigorous and fast growing, with large crowns well exposed to sunlight. Trees growing 1 inch (2.5 cm) in diameter every 2 to 5 years yield as much as 30 percent more sap than those that grow an inch in 7 to 10 years. Of two trees with the same stem diameter, one with a crown diameter 50 percent larger than the other can yield twice as much sap. And trees with greater crown length relative to height also produce more sap. In other words, trees with large crowns produce and accumulate more food energy reserves during the summer months. In turn, these reserves provide the sugar the following spring.

Trees with sweeter sap usually yield larger quantities of sap. The sugar content of maple sap ranges from 0.5 to 8.0 percent; the normal range is 1.5 to 4.0 percent. Sap sweetness is primarily genetically controlled. Sap sweetness differs significantly from hour to hour, day to day, and throughout the season. But trees that at any point in time are "sweet" relative to their neighbors will always be sweeter. Sap-sugar content should be considered in tree selections as it will have a significant and long-lasting effect on sugarbush productivity and income. Sap-sugar content is best measured in the spring with a sugar refractometer (Fig. 3). The use of this simple instrument is described in the Appendix.

The amount of direct sunlight received by the crown also influences sap sweetness. Trees in the open have a higher

Figure 3.—A sugar refractometer, used for measuring sap sweetness, in the open position.

sap-sugar content than similar-size trees in dense forests. Sugarbush management, therefore, should focus on selecting trees that produce the sweetest sap, and encouraging the development of their crowns by carefully thinning the stand.

An axiom of ecology states that the stability of a forest community is somehow enhanced by diversity. Stands with high and low species diversity are affected differently by climatic extremes or biotic agents. Presumably, this is the result of differences among tree species in susceptibility to these factors.

But a single-species sugarbush defies this axiom. The advantages of a maple monoculture are convenience and economy of operation. However, the single-species stand and, often, the steps needed to create it can lead to problems. These include: (1) rapid development of insect defoliators that are specific to sugar maple or are favored by it; (2) increased vulnerability to vascular disease; (3) rapid spread of root pathogens that may possess strains especially adapted to sugar maple; and (4) gradual adverse changes (perhaps depletion) in certain nutrient relationships. As suggested earlier, sugar maple monocultures on poor sites often are affected more adversely by these and other problems than are sugarbushes on good sites. Understandably, for economic reasons, sugarbush operators tend to encourage monocultures. Because this practice may increase susceptibility to various maple problems, it is important to monitor stand conditions and pest activities more frequently and carefully than in other forests.

In general, insect defoliators can be controlled directly with insecticides, and vascular diseases can be controlled indirectly by preventing the wounds that allow infection to occur. Preventing damage by root rot fungi is more difficult and depends largely on maintaining trees in good vigor (by preventing stress) and reducing the number of large stumps that harbor and provide energy for root fungi.

Protecting sugarbushes exposed to wind can be important for good sap production, both in terms of good growth during summer and quick daytime warming during the tapping season. The adverse cooling and drying effect of winds in spring can be reduced by leaving a windbreak of trees at least 25 feet (8 m) wide on the side of the sugarbush that faces the prevailing winds. Naturally occurring conifers such as balsam fir or spruce (Fig. 4) should be encouraged or even planted for this purpose. Where feasible, a separate coniferous windbreak (plantation) could be developed alongside the existing sugarbush.

Figure 4.—Coniferous windbreaks can modify harsh environments and provide better conditions for tree growth and sap production.

STAND DEVELOPMENT

The goal of sugarbush development is to ensure sufficient numbers of well-spaced, high-quality, productive sugar maple trees. Ideally, crop trees should be chosen as early as possible as this will allow greater flexibility in tree selection. Regardless of the stage of stand development (sapling, pole, or sawtimber size), the following steps for developing a sugarbush are recommended:

1. Select the location of potential crop trees at a spacing of 25 to 30 feet (7.5 to 9.0 m) in all directions. This should result in a stocking of approximately 64 trees per acre (158/ha) when they are about 12 inches (30 cm) in diameter at 4.5 feet (1.4 m) or at "breast height" (d.b.h.).

2. Find the tallest maple trees with the widest and longest crowns at each of these locations. From among these candidates, choose the one with the fewest crown or stem injuries, deformities, or cankers.

3. Measure the sap-sugar content of the selected tree in the spring and compare it to that of other candidates at that location (see Appendix). If its sap is as sweet or sweeter than the others, it becomes a crop tree. If the sap-sugar content is significantly lower (1 percent or more), it may be advisable to repeat the selection process (steps 2 and 3) from among the other candidates.

4. Release the selected crop tree if necessary by cutting any tree whose branches touch its crown. This can be done in several steps if removing all competing trees at once would create undesirable large openings. Caution also should be taken so that the removal of non-competing trees does not create overly large openings.

5. Repeat release cuttings when the branches of surrounding trees once again begin to touch the crown of the crop trees. Eventually, only crop trees will remain. Once this point is reached, no further thinning should occur. Providing space for crown development allows the maximum production of sugar-rich sap with minimum disturbance to the site.

6. Monitor the conditions of the crop trees each year. Remove only diseased, badly damaged, or dead trees. Removing these trees will reduce sources of infection, help prevent uncontrolled damage to in-place tubing systems, allow crown expansion of the remaining trees, and encourage the development of regeneration.

Should damage or the death of large numbers of trees make it necessary to regenerate the sugarbush, seek advice from a professional forester.

FERTILIZATION

A question asked by many sugarbush operators is: can fertilization increase the growth rate and health of trees in my sugarbush? Sugarbushes do appear to be appropriate forest stands to fertilize because they generally are not large, are easily accessible, and yield an annual monetary return.

Trees need the essential elements nitrogen, phosphorus, sulfur, calcium, potassium, and magnesium, as well as several minor elements. When all of these elements are plentiful in the soil, growth (vigor) will be at a maximum. But where there is a deficiency (or excess) of even one essential element, tree growth and vigor may be impaired.

Fertilization is one means of correcting such nutrient imbalances. In practice, however, fertilizing a sugarbush is risky, and results of experiments have been mixed. Negative effects usually result from using the wrong fertilizer or combination of elements, and worsening any nutrient imbalance that existed.

Fertilization should be considered only when growth is poor or vigor is low, and even then it would be a last resort. No fertilization program should be undertaken before a foliar and/or soil analysis has been conducted. Foliar symptoms may indicate deficiencies, but they are not always reliable. In addition, the severity of the deficiency and the amount of nutrient required to correct it cannot be determined from the symptoms. Moreover, because the nutrient content of the foliage varies during the growing season and, for some elements, with the location within the tree crown, a precise sampling methodology must be followed. Generally, about 50 leaves from each of 5 to 10 trees collected in midsummer at a given height in the crown will suffice for establishing the nutrient status of a stand. Check with a specialist before sampling to learn about particular sampling requirements.

Recent analyses have revealed deficiencies in foliar nutrients in some trees with maple decline, and fertilization studies to determine the relationship of these deficiencies to decline are underway.

An increase in soil acidity often has been suggested as a cause of maple decline. Liming the soil as a corrective measure has been suggested, but liming never has been a permanent cure for poor stand vitality. Too much lime may decrease the availability of certain nutrients and inhibit mycorrhizae, those fungi that live in close association with tree roots and enhance the ability of trees to take up nutrients. In general, the outcome of fertilization of sugarbushes is uncertain at best, and risky if done without adequate chemical analyses of soil and foliage.

TAPPING

Trees can be tapped year after year for decades if tapping is done properly. Improper tapping can seriously damage trees and reduce future sap yields. Concern for how tapping affects tree health is common, especially among new producers, or when new tapping techniques are used. Some of these "new" techniques of particular concern have been the use of power borers, tubing collection and vacuum pumping systems, and paraformaldehyde pellets to sanitize tapholes.

Wounds are serious and tapholes are wounds. It is the severing of cells that transport sap in the outer wood by the drill bit that creates the hemorrhage we call sapflow. Usually, tapholes are effectively "managed" by the tree and little internal damage results (Figs. 5-6). In vigorous trees, discoloration of wood is limited to a streak about 0.5 inch (1.25 cm) wide up to 18 inches (46 cm) or more above and below the taphole. Tapholes in vigorous trees usually close over in 2 to 3 years. However, tapholes sometimes are the source of serious internal problems that end in the rapid spread of discoloration and decay (Figs. 7-8). External damage also can result in the death of the cambium (a thin layer of cells between the bark and wood where diameter growth occurs) around the taphole.

Obviously, wounds must be made in trees to obtain sap, but it is logical to make these injuries in ways that will not counteract a tree's natural defense system. When trees are wounded they respond. Living cells in the wood begin to change in ways that protect the tree. Chemical substances are produced that limit the entrance of air and disease-causing microorganisms. These changes, together with alterations in the nature of new cells produced by the cambium after the wound is made, create barriers that effectively compartmentalize or "wall off" the injured area in healthy trees (Fig. 5). The faster this happens, the sooner wounds become unsuitable for extensive infection by discoloration

Figure 5.—Taphole wounds become "buried" as the tree closes them over and grows larger. Trees in good health can "wall off" these injuries quickly and prevent extensive discoloration and decay from developing.

Figure 6.—In radial section, discoloration in the wood extends for some distance above and below the taphole. Tapholes in sections marked "P" had been treated with parformaldehyde.

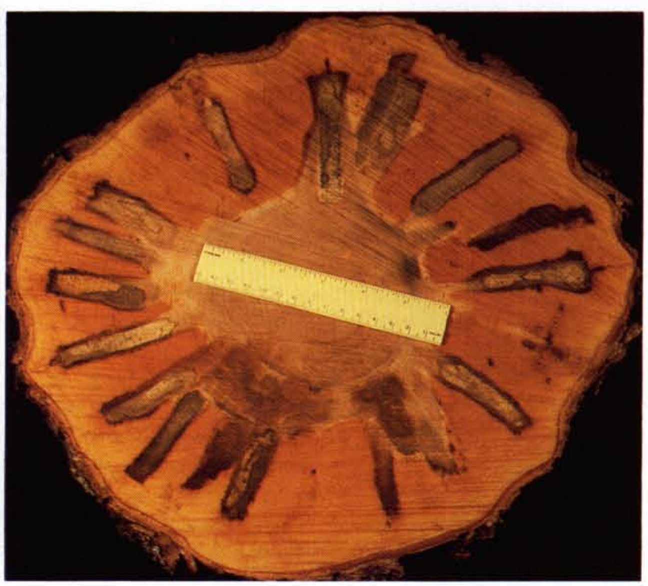

Figure 7.—Overtapping results in trees with too little area left to tap.

Figure 8.—When tapholes penetrate into pre-existing colums of decay, the decay can spread to the areas around the taphole.

and decay fungi. Even when compartmentalization is effective, zones of discoloration occur for some distance in the tissues above and below the tapholes (Fig. 6). Sugar maple usually is a strong compartmentalizer, but overtapping or "mistapping" can overcome defense barriers and lead to decay.

POWER BORING EQUIPMENT

The advent of gasoline or electric portable power-borer equipment for drilling tapholes made life a lot easier for maple syrup producers. The high speed of the power drill does not result in more damage than hand drilling. Yet the ease of tapping with mechanical equipment may have encouraged overtapping in recent years. While overtapping may not remove too much sap, it does cause more injuries. Too many holes result in too little undisturbed area for future tapholes (Fig. 7). Tapholes too close to each other result in columns of discoloration that coalesce inside the tree, creating extensive, decay-susceptible regions (Fig. 7).

Overtapping is a relative concept. It means putting too many tapholes in a particular tree, or area of tree trunk. Care must be taken to space the tapholes so that no new hole is drilled closer than 6 inches (15 cm) horizontally, or 2 feet (60 cm) vertically, from the nearest, old open taphole. Tapping guidelines that relate the number of allowable taps to tree diameter have become more conservative in recent years. Published guidelines indicate that trees less than 10 inches (25 cm) in diameter or 31 inches (79 cm) in circumference at the tapping zone should not be tapped. Other guidelines suggest that trees should not be tapped before they reach 12 inches (30 cm) in d.b.h., and that no more than two taps per tree be used on trees 18 inches (45 cm) or larger in d.b.h. We support this recommendation. It is wise to be as conservative as possible: if trees are not healthy or vigorous, if old tapholes did not close rapidly, or if a tree is damaged, the number of taps should be reduced.

Mechanical drilling also can create tapholes that are too deep. Although a taphole 3 inches (7 to 8 cm) deep is commonly recommended, one that is 2.5 inches (6 cm) deep is better. For trees that have been tapped heavily or injured, even these depths may penetrate compartmented, discolored, or decayed wood. Drilling into discolored columns should be avoided as it can lead to the rapid spread of decay into tissues surrounding the new taphole (Fig. 8). Whether the tapholes are bored by hand or by machine, or for use with bucket or tubing systems, they should be made with sharp bits and angled slightly upward. "Clean" tapholes run better and do not harbor as many microorganisms. Because holes that are angled upward drain better, they do not collect water and sap that will freeze and crack tissues, or that will encourage the buildup of bacteria, yeasts, or fungi. Tapping should not be done if the bark and wood is frozen. Frozen bark splits easily when spouts are driven (Fig. 9). Even nonfrozen bark will split if spouts are driven too deeply.

Figure 9.—Bark splitting can occur when spouts are driven into frozen bark and wood or when driven too deeply into nonfrozen tissue. A large wound sometimes results when the cambium dies back for some distance along the split.

TUBING COLLECTION SYSTEMS

The use of pipelines to collect sap has increased as improvements have been made in the durability and utility of tubing materials, in the use of permanently placed delivery systems, and in the use of vacuum systems for sugarbushes on flat or inaccessible land. In many ways, tubing systems have resulted in less mechanical damage to roots and lower stems of trees along haul roads because less traffic is required to haul sap. However, the incorrect use of tubing can create other problems. For example, when drop lines are too short, the tapable area within reach may be restricted. This can result in excessive tapping on one side of the tree. Drop lines should be long enough to allow an 18-inch (45-cm) drop to the main line and to allow tapping anywhere within the tapable zone of the tree.

VACUUM PUMPING SYSTEMS

Vacuum pumping systems have become more common in recent years, though operators often question whether this practice will adversely "drawdown" a tree's energy supply or harm its cell structure. The available evidence seems to indicate that when used correctly, vacuum systems are not harmful. Vacuum systems result in increased sap yields regardless of the season. Daily sap flows begin earlier and end later when vacuum is used. Because of this, vacuum pumping markedly enhances sap yields in poor seasons when daily weather conditions are marginal.

The use of vacuum, therefore, can help reduce the great variability in sap flow from year to year. Taphole "life" is extended when vacuum is used and thus can accomplish what paraformaldehyde does without the adverse effects attributed to that chemical.

PARAFORMALDEHYDE

Sap flow from sugar maple tapholes sometimes slows or stops before the end of the sap flow season, limiting sap production. Microorganisms are suspected as a major cause of this premature stoppage, because high microbial counts in tapholes are correlated with low sap yields.

The actual mechanism by which microorganisms restrict sap flow is not fully understood. There are several hypotheses to explain how yeasts, bacteria, or molds cause sap flow to stop. These range from simple physical plugging of vessels to physiological changes in living cells of sapwood. Regardless of the mechanism, the fact that microorganisms are involved led to trials to control them with growth inhibitors or sanitizers.

Many compounds were used. Because so many unrelated microorganisms were involved, the material had to have a broad range of antimicrobial activity. Also, it could not affect the flavor or color of the syrup produced, and had to volatize or be destroyed during the sap boiling process. Paraformaldehyde was selected as the most promising compound for commercial use: 250-mg pills became the standard maple-taphole sanitizer treatment.

Tests showed that tapholes treated with paraformaldehyde averaged 62 percent more sap than untreated tapholes over a 3-year period. Yields differed from year to year, but were greatest in warm seasons when conditions were most favorable for microbial growth. It is no wonder, then, that the use of paraformaldehyde became an accepted or recommended practice. It is registered for use in Canada and in most States. Yet there always was the possibility that the continued use of this (or any other) chemical in maple tapholes might have negative side effects. Numerous sugarmakers began to suspect that the dieback of cambium around tapholes or the inability of some trees to close tapholes might be due to the use of paraformaldehyde (Fig. 10).

Two studies were conducted to determine the long-term effects of paraformaldehyde in tapholes. The first study used sugar maple trees in six areas in Vermont. The second used sugar maple trees in Vermont, New York, Michigan, Maine, and Pennsylvania. The studies compared a taphole treated with 250 mg (one pellet) of paraformaldehyde with an untreated taphole on the same tree. Some of the study trees were dissected after 2 months and others at various intervals over the next 5 years. The length of the stain column and decayed wood and the microorganisms associated with each taphole were recorded. More decay (higher incidence and greater total length of column) was associated with the paraformaldehyde-treated tapholes than with the untreated tapholes (Fig. 6).

Paraformaldehyde apparently interferes with the tree's wound-defense mechanism. Because the chemical kills wood cells so quickly, the tree's protective chemicals that are antagonistic to wood-decaying fungi may not form. Also, because development of plugs in the vessels is delayed and compartmentalization of the taphole is retarded, paraformaldlehyde increases susceptibility to rot.

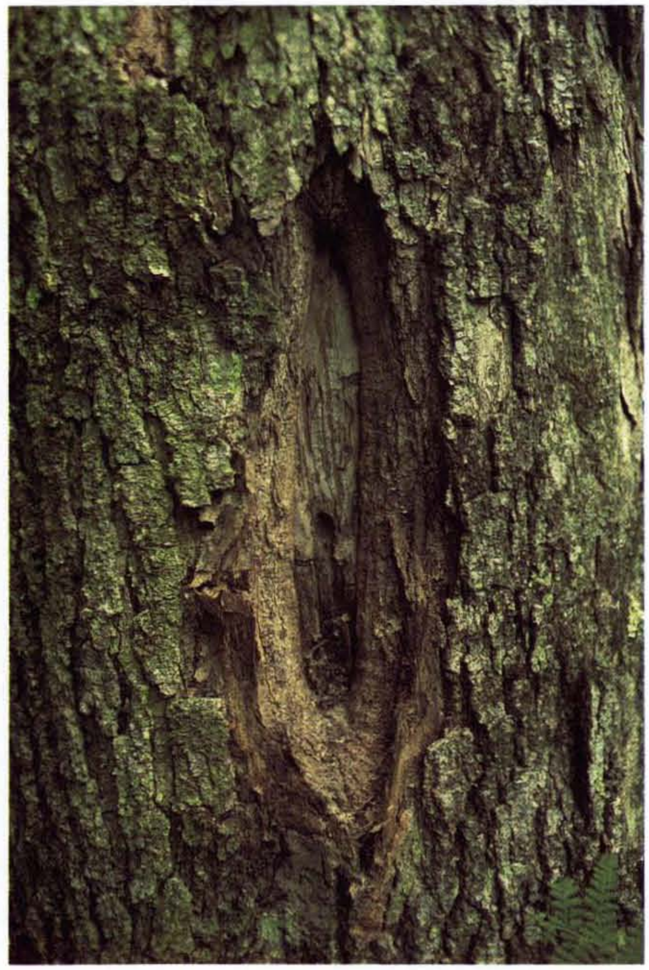

Figure 10.—Paraformaldehyde can injure the cambium around the taphole and cause dieback. It also can kill the wood around the taphole and promote decay.

Whether or not to use paraformaldehyde continues to be debated vigorously. The fact that many operators report observing no injury around treated tapholes suggests that other factors may influence susceptibility of tree tissues to the chemical. Our position is conservative. We recommend that, if possible, paraformaldehyde should not be used until the factors affecting its toxicity to maple tissues are understood.

TAPPING STRESSED TREES

It is unwise to tap trees that are under stress. Trees defoliated the previous summer, especially those defoliated in midsummer severely enough to trigger refoliation, usually enter the dormant season with depleted energy reserves, such as starch and sugars. Such trees are unable to compartmentalize taphole wounds internally, produce vigorous callus (new woody tissue) to close wounds externally, or manufacture the chemicals needed to thwart repeated invasions by opportunistic organisms. While the relationship between insect defoliation and energy depletion is well documented, other stress events such as drought, late-spring frost, and wind breakage also reduce the production of, or increase demand for, a tree's energy supply. Reduced energy reserves may be evident for several years after a severe defoliation.

Tapping stressed trees also is unwise economically. Sap from defoliated trees is lower in sugar content. More fuel and time is required for evaporating the greater quantities of water. The number of gallons of sap required to produce a gallon of syrup can be calculated by dividing the number 86 by the percent sap sugar. (Jones' "Rule of 86"; see References section). Thus, 43 gallons of 2-percent sap are needed compared to only 29 gallons of 3-percent sap. This same relationship applies when using the metric system.

The biological and economic consequences of tapping stressed trees seem to justify postponing tapping. How soon tapping can resume safely or economically depends on the severity and timing of the stress event(s), and the general vigor and age of the trees. While there are no definitive guidelines, it seems reasonable that the determining factor should be the energy reserve level of the trees. An assessment of the autumn starch reserve is a reliable way to determine if trees have recovered sufficiently to be tapped (i.e., starch levels are moderate to high). Additional information on this procedure is available in publications listed in this report. Stresses can result from both living and nonliving disturbances and from combinations of these. The most important stress factors affecting sugarbushes are discussed in the following section of this report.

ABIOTIC (NONLIVING) DISTURBANCES

NATURAL ORIGIN

Wound Injuries

Few sugarbush trees reach maturity without mechanical injury from natural events or human activities. Severe damage to crowns from wind, wet snow, or ice cannot be predicted or prevented (Figs. 11-12). Damage from ice storms may be evident decades later as misshapen crowns, crooked stems, or internal discoloration and decay. Some damage can be avoided by proper siting of the sugarbush. Sugar maple trees in stands located on high, exposed slopes and ridges that are subjected to recurring wind and ice storms usually are of low quality with small, often broken, crowns and internal decay. Such trees produce less sugar than trees in more protected locations.

Figure 11.—Heavy snow and ice storms can severely damage sugar maple trees.

Climatic Stresses

Sugar maple requires ample amounts of soil nutrients and moisture, and has limited ability to tolerate climatic adversity. It suffers from the stresses of drought (Fig. 13), frost, and deep soil freezing. In the 1950's, diebacks and declines in New York were attributed to severe soil-mositure shortages and subsequent attacks by secondary organisms. Also in New York, more recent insect defoliation and severe drought together resulted in severe tree mortality in many sugarbushes.

Figure 12.—Misshapen crowns and crooked stems result when branches are broken by snow or ice. Branch wounds are avenues of infection for microorganisms that cause discoloration and decay.

Figure 13.—Symptoms of drought stress on sugar maple (University of Wisconsin photo).

Normally, the roots of sugar maple in the northern parts of its range are well protected from freezing by an insulating blanket of snow. Occasionally, however, lack of snow during extreme cold spells results in killing of unusually large numbers of roots. Dieback and mortality of many tree species have been attributed to such root damage. An unusually severe episode occurred in New York, parts of New England, and Quebec in the late 1970's and early 1980's prior to the appearance of significant tree decline and mortality. What role, if any, root freezing or disturbance played in this mortality is not known.

Although mature sugar maple usually is not afffected by late-spring frost, saplings and small pole-size trees, which tend to leaf out earlier than mature, older trees, are sometimes badly damaged (Fig. 14). New leaves and shoots are killed and shrivel and blacken. Twig dieback can occur, and new leaves are produced, often on sprouts. If coupled with other stresses such as insect defoliation, frost damage can be serious.

Frost cracks (Fig. 15) generally are not important in sugar maple. However, since many frost cracks originate in root injuries, they can be common in sugarbushes where roots have been damaged. Cracking (splitting) of bark and wood above and below tapholes may occur when frozen tissues are tapped.

Too much heat also can be damaging. Sunscald occurs when tree bark is suddenly exposed to summer heat and drying when the shade from neighboring trees is removed. Summer sunscald is rare in forest situtations. Winter sunscald is more common and may severely damage maples. Bark and cambium on the south and southwest sides of trees can be killed by alternate freezing and thawing during periods with bright sunny days and cold nights (Fig. 16). Young, thin-barked trees are more susceptible than older trees. Sudden exposure of trees through thinning and harvesting operations may contribute to winter sunscald, particularly when shading conifers are removed.

Figure 14.—Young maple foliage is sensitive to late-spring frosts. These frost-killed leaves will soon shrivel and blacken.

DAMAGE BY PEOPLE

Injuries to Stems and Roots

Wounds to stems and roots by machinery used in road building, sap hauling, or log skidding create the avenues for pathogenic organisms to enter a tree. Sugarbushes are heavily trafficked. If strict attention is not given to the placement and use of haul roads, severe damage to trees can result (Fig. 17). While the use of tubing systems has materially decreased the amount of damage to roots and lower stems, care is necessary when tubing is installed or maintained, and when silvicultural activities are performed. Often these activities are carried out in the late spring or early summer when roads may be soft and root systems are especially vulnerable (Fig. 18).

Wounds often are made intentionally in the sugarbush. Tapholes are the most common; occasionally, wounds are created when branches are pruned to remove dead or damaged limbs, to facilitate travel through the bush, or to prevent damage to the tubing systems. Pruning should be done properly to avoid wounding main stem tissues (Fig. 19-20). Wounds of any sort should not be treated with paint or wound dressings. Studies have shown that untreated wounds close over better than treated ones and are less apt to become infected by stain or decay fungi.

Figure 15.—Frost cracks close poorly and eventually result in swollen "seams."

Figure 16.—Winter sunscald occurs when bark and cambium on the south and southwest sides of exposed trees are killed during sudden, alternating periods of freezing and thawing.

Figure 17.—Trees too close to skid trails or haul roads can be severely damaged by logs or heavy equipment.

Figure 18.—Damage to shallow maple roots can be severe if heavy equipment is driven through the sugarbush when soils are wet.

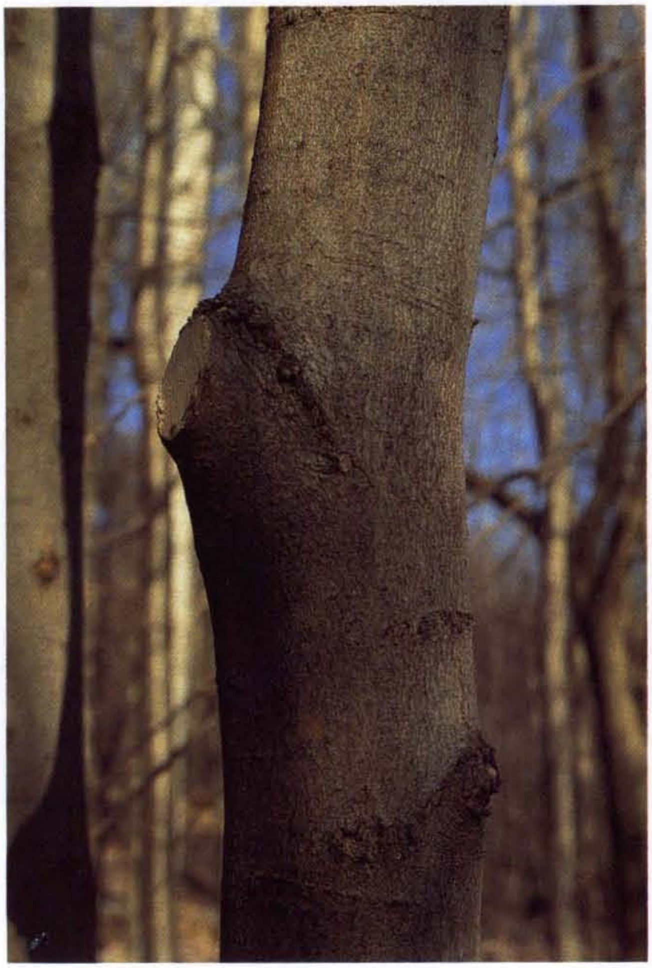

Figure 19.—Correct pruning, outside the bark ridge collar, enables the tree to readily close over the wound.

Figure 20.—Branches pruned too close to the trunk result in large wounds that close poorly; decay may become established.

Soil Compaction

Activities that compact soil can adversely affect tree health and sap production. Prolonged grazing by cattle or movement of heavy equipment through a sugarbush can compact soil so that it becomes more difficult for roots to obtain nutrients and water, or exchange oxygen and carbon dioxide. The extent to which compaction inhibits soil aeration and infiltration is determined by many factors. Soil texture, moisture content and depth, litter depth, and type, size, and frequency of use of heavy equipment all influence the degree that soil particles are rearranged under pressure. Soil texture markedly influences compactibility. Collectively, organic-matter content and the size and shape of soil particles determine soil texture. Soils with a wide range of particle sizes and shapes are susceptible to compaction. In such soils, the air-filled spaces (macropores) are easily eliminated, reducing soil permeability. In addition to the physical impedance that this presents to growing roots, reduced pore space inhibits gas exchange and the movement of moisture and nutrients. A high proportion of organic matter improves soil structure and makes most soils more difficult to compact.

When not disturbed repeatedly, coarse-textured soils (for example, high sand content) recover from compaction more quickly than fine-textured soils (for example, clays and silts).

Airborne Pollutants

Airborne pollutants are stress factors that possibly may adversely affect the overall health of forest stands. Low levels of a pollutant may occur for several hours or days in a stand and cause no definite symptoms. Even if symptoms do occur, it may be impossible to attribute them to a particular pollutant. The damage will vary among tree species or between individuals within a species, and be influenced by the physiological condition of the tree at the time of exposure.

Airborne pollutants can be dissolved in rainfall or occur as gases such as ozone, sulfur dioxide, and fluorides. We do not know the extent to which air pollutants damage sugarbushes, nor do we know how to prevent such damage.

Ozone

Because sugar maple is relatively tolerant, or even resistant, to ozone, visible damage is unlikely in a sugarbush. Ozone probably is the most widespread air pollutant. It is formed when nitrogen oxides and volatile hydrocarbons react with oxygen in the atmosphere in the presence of sunlight. The major sources of the two chemicals are fossil fuels burned to generate electricity and to power motor vehicles. High levels of ozone can occur relatively far from the source of the precursors. Small amounts of ozone also are formed naturally during thunderstorms and by the action of sunlight on oxygen in the upper atmosphere.

Stippling is the most common symptom on susceptible broad-leaved trees exposed to acute levels (high and brief) of ozone. This is caused by the development of dark pigment in individual cells or clusters of cells on the upper leaf surface. The pigmentation can be red, brown, purple, or black (Fig. 21). It usually is scattered throughout the leaf, but the veins are not affected. The coloration usually is characteristic for a species but can vary with the environmental and physiological conditions of the plant. The symptoms are more intense on leaves exposed to direct sunlight, and may be absent on shaded leaves of the same plant. They may appear only on the sunlit part of a given leaf. Leaves are most sensitive to ozone when they have just reached full size.

Figure 21.—The purple pigmentation on this milkweed plant is characteristic of ozone damage; milkweed is a "bioindicator" of this air pollutant (Pennsylvania State University photo).

Sometimes flecking may occur. Flecks are white to tan spots, up to a few millimeters in diameter, that usually appear on the upper leaf surface. Bleaching of large areas of the leaves and definite necrotic (dead) lesions may occur. The extent of symptoms depends on the degree to which photosynthesis is impaired.

Chronic levels (low, sustained) of ozone also affect plants, but often the only symptom is reduced growth. When leaf symptoms do appear, they develop over a period of days or weeks and include chlorosis (yellowing), light pigmentation, and premature senescence. Ozone affects leaf cell membranes and chloroplasts (the green pigment) and thereby generally reduces vigor and growth. Symptoms caused by chronic levels of ozone are difficult to diagnose because they are similar to symptoms caused by other stresses such as nutritional disorders, infestations by leafhoppers and spider mites, infections by leaf pathogens, and even herbicides.

The sensitivity of trees to ozone varies greatly among species. Ash, black cherry, and poplar generally are sensitive. Basswood, birch, beech, maple, and red oak are tolerant or resistant. Two "bioindicator" plants (expecially sensitive to ozone) that often grow in the vicinity of sugarbushes are the common milkweed *(Asclepias syriaca L.)* (Fig. 21) and poison-ivy *(Toxicodendron radicans (L.) Kuntze).* If severe symptoms appear on these plants, ozone levels high enough to damage sensitive trees may have occurred.

Sulfur Dioxide

Sugar maple is not sensitive to sulfur dioxide. This gas originates from many sources but primarily from burning coal to generate electrical power and manufacture steel. The type of damage from sulfur dioxide may depend on whether levels are acute or chronic. The gas enters the plant leaf through tiny pores (stomata) on the leaf surface. When concentrations are high (acute levels), the cells are killed rapidly. Symptoms on broad-leaved trees include large areas of yellow to ivory or tan dead tissue between the leaf veins. This typical symptom is more prevalent on sensitive plants and on plant parts exposed to air currents. The injury is visible on both the top and bottom sides of the leaves. The overall pattern of injury is determined by the pattern of leaf veination. On beech leaves, necrosis often is more pronounced near the margins. When symptoms appear, it usually is possible to locate a point source of emission of sulfur or sulfur dioxide within a few miles (kilometers) of where trees are affected. The severity of the symptom decreases with the distance from the source.

Injury from chronic levels and to relatively tolerant species appears as yellowed areas between the veins, in a general pattern similar to that of acute injury. However, this symptom is not reliable as other stresses can cause similar patterns of injury on tree leaves. Young full-size leaves of ash, aspen, beech, and birch are most sensitive to sulfur dioxide. Maple, poplar, and oak are intermediate in sensitivity, or tolerant.

Hydrogen Fluoride

Hydrogen fluoride damage usually is localized because this gas is absorbed quickly by soil and vegetation. Damage generally is restricted to within a 6-mile (10-km) radius of point sources such as aluminum smelters or glass, brick, or phosphate fertilizer plants.

Symptoms can result from exposure to high levels of hydrogen fluoride for a short period, or to low levels for several days or weeks. The pollutant is taken into leaves and transported to leaf tips and margins where concentrations accumulate to toxic levels. As cells are affected, leaf tips and margins become chlorotic and later turn reddish brown. The affected areas enlarge away from the margins as the accumulation of fluoride continues. Diagnosis can be made by testing the fluoride content of affected tissues.

The relative sensitivities of tree species to this pollutant are not well known.

Acid Rain

Much has been written about "acid rain," yet its role as an air pollutant remains unclear. Acid rain is rain and snow that contains high concentrations of sulfuric and nitric acids. These acids originate from the slow transformation of sulfur dioxide and nitrogen oxides in the atmosphere to particulate sulfates and nitrates. In turn, these react with water vapor to form sulfuric and nitric acids. A portion of the particulate sulfates and nitrates falls to the ground in dry form. This accounts for about 20 percent of the acidic materials falling on vegetation and ecosystems at large. The term acid percipitation refers to both wet acid rain and dry acid deposits. Sulfur dioxide and nitrogen oxides are produced in large quantities by different industrial processes, and can be carried over long distances in the atmosphere before they are transformed to acids. Every forest region of Eastern United States and Canada receives some acid precipitation.

No definite symptoms or damage to trees have been attributed precisely to acid rain, though there is much circumstantial evidence that it contributes to forest damage. Many hypotheses have been proposed to explain possible mechanisms for its effect. To obtain plant damage in controlled experiments, high levels of acidity seldom found in nature are required. But studies with several tree species on how two or more simultaneous stresses affect plants have demonstrated that exposures to several gaseous air pollutants (for example, ozone and sulfur dioxide) often cause more damage than the total produced by each one alone. Thus, in situations where chronic levels of ozone occur, affected cells may release nutrients such as calcium, potassium, and magnesium. In turn, these nutrients can be leached out by acid precipitation. It has been suggested that leaching of elements from both plants and forest soil might cause a general nutrient deficiency and a general loss of vigor and reduced growth. Because other common soil elements (especially aluminum, which, when abundant, can prevent the uptake of essential growth elements such as calcium) become more available under acid conditions, increased deposition of acidic substances might indirectly reduce a tree's growth and render it more vulnerable to natural enemies.

Managing Against Airborne Pollutants

The most effective way to prevent damage from airborne pollutants is to reduce the amount of these materials emitted at their source. This is a complex political and economic issue. Locally, however, preventive or corrective measures can be taken to help reduce potential effects of airborne pollutants. Where possible, sugarbushes should be established on sites best suited for sugar maple growth and development. Silvicultural treatments such as heavy thinning can produce a "stand adjustment" stress to the remaining trees for 5 to 7 years after treatment. To reduce this stress, thinnings should be light and frequent. It should be noted, however, that frequent entries to remove trees can increase the risk of injuring roots and stems. Because of this, thinning operations should be conducted only when it is necessary to release trees from competition as described earlier. Finally, should soil nutrient imbalances that affect tree health be shown to result from acid rain, it may be possible in the future to correct them by applying specifically formulated fertilizers.

BIOTIC (LIVING) DISTURBANCES

INSECT PESTS

A large and diverse group of insects feeds on sugar maple. Fortunately, populations of most of these potential pests usually remain at low levels due to the combined influences of habitat conditions, adverse weather, and natural enemies. Of the more than 150 species that feed on sugar maple foliage, fewer than a dozen cause economically significant damage. Yet each year, one or more of them has a major impact on sugarbushes somewhere in North America.

Damage Relationships

The insects mentioned in this report are grouped according to type and timing of damage, and relative importance. Most of the major insect pests of sugar maple are considered "primary," that is, they principally eat leaves or suck sap without regard to tree vigor. Successful establishment of "secondary" insects such as the sugar maple borer, however, depends on reduced host vigor.

This distinction between primary and secondary pests is important. Usually, primary insects do not cause tree mortality. Rather, they significantly reduce growth or vigor, which predisposes trees to attack by lethal secondary insects and fungi. The latter group are secondary only in a chronological sense. They require hosts weakened by factors such as drought, insect defoliation, air pollution, intense competition, and logging damage.

Practical and effective chemical methods are available for controlling populations of most primary insects. The protective measure can decrease the likelihood that populations of some secondary organisms will thrive. On the other hand, secondary organisms are more difficult to control chemically. Good silviculture helps promote healthy trees whose vigor enables them to better resist these organisms.

Response to Defoliation

The amount of foliage removed, frequency and timing of defoliation, stand and tree condition, and past stress and site quality all determine how trees will respond to defoliation. Heavy defoliation usually adversely affects sugar maple by inhibiting the production of energy necessary for growth, maintenance, and reproduction. Also, removing 50 to 60 percent or more of a maple tree's leaves weakens it to a point where it may be unable to withstand invasion by secondary agents.

Maples defoliated severely (more than 50 to 60 percent) through early August produce a second set of foliage during the same growing season. Terminal buds that are forming or have formed for next year open one season too soon. If defoliation occurs early in the growing season, a tree may produce a new set of foliage and new buds. Depending on when it occurs, defoliation/refoliation may result in some reduction of energy available for growth. If defoliation occurs late in the season, a second flush of foliage may occur, but new buds may not form or mature before winter. Late-season defoliation that does not trigger refoliation but causes buds to swell can be damaging. Swollen buds often are killed during winter, and dieback can occur the next year.

These physiological stresses can result in significant growth loss, reduced sap production, reduced sap-sugar content, crown dieback, or tree mortality.

Feeding Behavior

Insect defoliators are frequently categorized by the way they feed. Whole-leaf feeders (Fig. 22) eat all parts of a leaf, including the major veins. When the defoliators infest a broad-leaved tree like sugar maple, they usually feed along edges of the leaf. One family of moths, the loopers or inchworms, typically chew holes that give foliage a "shot hole" appearance (Fig. 23). Eventually, after heavy feeding, these insects consume the entire leaf blade.

Leafminers feed on tissues between the upper and lower outer layers of the leaves (Fig. 24). They leave foliage that, while intact, is discolored and sometimes distorted. By contrast, true skeletonizers eat everything except the major leaf veins. The damaged portion of a leaf appears lacy. More common, however, is a variation of skeletonizing called "window feeding" whereby the insect leaves most major veins

Figure 22.—Damage typical of that caused by a whole-leaf feeding insect.

Figure 23.—"Shot hole" feeding creates holes in the leaf (Pennsylvania Brueau of Forestry photo).

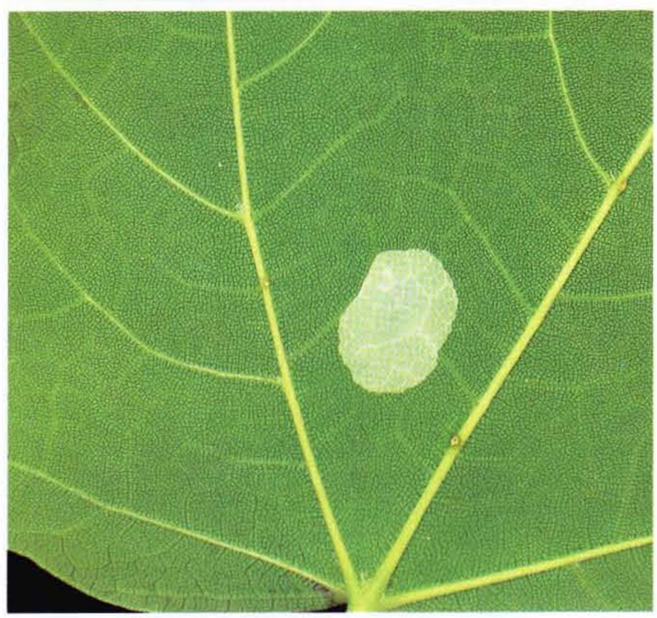

Figure 24.—Damage caused by a leafmining insect.

Figure 25.—"Window feeding." Note that the defoliator has consumed everything except one surface of the leaf and most veins.

and one surface of leaf intact (Fig. 25). Many leafrollers, leaf folders, and leaftiers are window feeders. Several defoliators that begin as miners or skeletonizers later become whole-leaf feeders.

Major Early-Season Defoliators

Members of this group usually overwinter as eggs on tree boles or branches. Caterpillars begin to feed at budbreak or shortly thereafter, and feeding usually is completed by late June.

Forest Tent Caterpillar *(Malacosoma disstria)*

Outbreaks of this insect occur periodically throughout much of North America. It is the principal defoliator of aspen in parts of Canada and the United States. Maple decline in Canada and the Northeastern United States has been linked to 2 to 3 years of severe defoliation by the tent caterpillar. Repeated defoliation seems to predispose the trees to later decline. For example, extensive decline and mortality in Vermont has occurred on 30,000 acres (12,000 ha) of sugar maple defoliated three or more times during the outbreak of 1978 to 1982.

The major effects of forest tent caterpillar are reduced growth and crown dieback. Mortality usually is uncommon. In northern hardwood forests, the insect primarily defoliates sugar maple and black cherry. However, forest tent caterpillars can survive on a variety of other species such as aspen, yellow birch, basswood, beech, and ash.

Following heavy defoliation by the tent caterpillar, sugar maple refoliates in 5 to 6 weeks. Still, sap quality (percent sugar) and sap yield (volume of sap per tap) are reduced significantly the following spring. If extensive dieback occurs, sap yield may be reduced for several years.

Dieback and mortality often are greatest in stands thinned immediately before, during, or right after an outbreak, so thinning should be postponed for a least 3 years after defoliation ends. This will allow surviving trees to recover from the stress of defoliation. Also, severely affected trees will be identified by the degree of crown dieback. Dying or severely weakened trees should be salvaged before they become significantly stained or decayed.

Sugar maple dieback following defoliation by the forest tent caterpillar often is most prevalent on sites that also suffer from drought. Recently, sugar maple in south-central New York was devastated following severe defoliation by the tent caterpillar. The infestation became evident in 1980 and peaked in 1982 after approximately 200,000 acres (81,000 ha) were heavily infested. Many overstory sugar maples were killed following a single year of complete, or nearly complete, defoliaton. Recent damage surveys indicate as much as 95-percent mortality in numerous stands, and many of the surviving trees continue to decline. This rapid and unusual mortality (i.e., it occurred following the first year of heavy defoliation) probably resulted from the combined effects of the defoliation and the severe drought that occurred the same year.

The stout-bodied adult of the forest tent caterpillar is a buff-brown moth with two dark brown, oblique bands near the center of each front wing. When extended, the forewings span 1.0 to 1.5 inches (25 to 37 mm) from tip to tip. Adults may be present from late June through July, and frequently congregate around outside lights at night. The full-grown caterpillar is approximately 2.0 inches (50 mm) long. It has conspicuous body hairs and a series of whitish keyhole or footprint-shaped marks on its dark back (Fig. 26). Narrow orange lines and relatively wide pale blue stripes extend along each side. The gregarious caterpillars congregate during midday on silken mats spun on the tree bole or at the base of a large limb. Unlike many of its relatives, the forest tent caterpillar does not construct a true tent. The overwintering eggs are laid in compact masses that encircle small twigs. This cylindrical, glossy egg band (Fig. 27) is the stage commonly sampled for survey purposes.

Figure 26.—Forest tent caterpillar.

Figure 27.—Egg mass of the forest tent caterpillar.

Fall Cankerworm *(Alsophila pometaria)*

Cankerworms belong to a family of moths whose larvae often are called measuringworms, spanworms, loopers, or inchworms due to their unique way of crawling. They have fewer legs than most caterpillars and walk with a "looping" motion, appearing to "inch" along. The caterpillar arches its back as it brings the rear portion of its body forward immediately behind the front legs. It then attaches itself by the hind legs, releases the front legs, stretches the body forward, and so forth.

Loopers are easily disturbed by the wind or by something brushing against an infested branch. They crawl rapidly or tumble to the leaf edge and drop on a silk thread anchored at one end to a leaf or twig. When a thread breaks, it acts like a sail and can transport the insect a significant distance in a wind. In species with wingless females, this is the primary means of dispersal.

Fall cankerworm is one of the longest known native defoliators of broad-leaved trees in Eastern North America. It is primarily a pest of oak, elm, and apple. However, cankerworms frequently defoliate northern hardwood stands, including sugarbushes, that contain high proportions of sugar maple.

Outbreaks usually appear suddenly and collapse quickly. They typically begin in small and scattered locations but can rapidly expand, coalesce, and encompass large areas. In 1984, more than 200,000 acres (81,000 ha) were defoliated in Maine, and defoliation was heavy throughout 30,000 acres (12,000 ha) in Wisconsin. Evaluation of a recent outbreak in Pennsylvania indicated that sugar maple dieback can result from cankerworm defoliation. In this instance, the most severely affected stands were on sites with poor soil and at a high elevation. Such sites are considered marginal for sugar maple.

Typical of many inchworms, female fall cankerworm moths are wingless (Fig. 28). They are rotund and approximately .03 inch (8 to 10 mm) long, uniformly ash-gray, and glossy. The moths emerge from their pupal stage in the soil and ascend nearby trees to lay eggs. Then, the overwintering

Figure 28.—Female fall cankerworm moth.

eggs are laid in a cluster on the bark of twigs or branches. The male, a typical moth, has a slender body and a wingspan of 1.0 or 1.2 inches (25 to 30 mm). The glossy forewings are a mottled, brownish-gray; the hindwings are uniformly light grayish-brown. Moths are active between October and December (hence the common name) normally after the first heavy frost in the northern range of sugar maple, but they may not emerge until January in more southern areas. The caterpillars are present in the spring. Fully developed caterpillars are 0.8 to 1.0 inch (20 to 25 mm) long and are light green (Fig. 29) to dark blackish-green (Fig. 30). Light-colored forms have several distinct longitudial whitish lines, and dark forms have a black stripe down the back. Young caterpillars skeletonize the foliage. Older caterpillars consume most of the leaf blade except for the midrib and larger veins.

Bruce Spanworm *(Operophtera bruceata)*

The Bruce spanworm is distributed over a wide area and has many hosts. It has recently defoliated sugarbushes across extensive parts of Eastern Canada and New England, and is an important sugarbush pest in Quebec. During a recent outbreak in Vermont, heavy defoliation was limited to understory sugar maple and the lower crowns of overstory trees. Outbreaks frequently involve other loopers, including fall cankerworms.

Female Bruce spanworms are wingless. The body is 0.2 to 0.3 inch (6 to 8 mm) long, grayish-brown, and marked with white spots. Males have a wingspan of 1.0 to 1.2 inches (25 to 30 mm). Their light brown forewings are slightly transparent and crossmarked with wavy brown and gray

Figure 29.—Light-green phase of the fall cankerworm.

Figure 30.—Dark phase of the fall cankerworm.

Figure 31.—Bruce spanworm caterpillar.

bands. The overwintering eggs hatch in the spring about the time that sugar maple buds open. Caterpillars chew on the underside of leaves or feed on leaves they have bundled together using webs of silk. The larvae chew large holes between major veins of the leaf blade, giving the branch a tattered look. Most caterpillars are pale green but some may be a bright green to brown. Most have three distinct yellowish stripes along each side of the body. Full-grown caterpillars (Fig. 31) are 0.8 inch (18 mm) long.

Major Late-Season Defoliators

Defoliators that feed late in the growing season usually overwinter as pupae in the soil or in leaf litter. The pupa is an inactive, nonfeeding stage. During pupation, the caterpillar transforms into a moth. Eggs usually are deposited on maple foliage during late June or early July. After hatching, larvae may continue feeding into early fall. Many of these caterpillars are "window feeders" at first, later becoming whole-leaf feeders.

Saddled Prominent *(Heterocampa guttivitta)*

Major outbreaks of the saddled prominent (Fig. 32) were first documented in New England in 1907. Since that time they have been reported in parts of the Northeastern United States or Canada at intervals of 10 to 12 years. During the most severe and widespread outbreak on record (1967 to 1971), nearly one-half of the northern hardwood forests in central and eastern New York were defoliated heavily. Extensive areas of Canada, Massachusetts, Pennsylvania, and Vermont also were affected.

Rarely during outbreaks is this species found alone. Rather, it is the dominant member of a defoliator complex. Apparently, conditions suitable for an increase in saddled prominent populations also favor other defoliators. The whitemarked tussock moth *(Orgyia leucostigma)* is a frequent associate in the Maritime Provinces of Canada. In Ontario, the greenstriped mapleworm *(Dryocampa rubicunda),* several loopers, and *Heterocampa biundata* (a species similar to saddled prominent) are common members of the complex. As many as nine species have been associated with the saddled prominent during outbreaks in Maine. Usually, *H. biundata* (Fig. 33) and *D. rubicunda* (Fig. 34) have been the primary associates.

On good sites, healthy dominant and codominant sugar maples usually survive 2 successive years of defoliation, though the understory trees may suffer heavy mortality. In Maine, tree mortality occurred in intermediate and suppressed crown classes, but crown damage occasionally was extensive on dominant and codominant trees after 2 years of defoliation. Crowns may recover within 3 years after the outbreak collapses. Diameter growth usually is reduced by at least 50 percent during the period of defoliation.

A recent episode of 2 years of heavy defoliation in New Hampshire resulted in serious deterioration of crowns. A favorable growing season (presumably adequate moisture) during the second year may have enhanced recovery.

Figure 32.—Saddled prominent caterpillar.

Figure 33.—*Heterocampa biundata,* a close relative of the saddled prominent; see Fig. 32.

Figure 34.—Greenstriped mapleworm.

Mortality and crown dieback of sugar maple in Vermont was significant after a single year of severe defoliation during 1980. The most extensive damage was in stands with predominantly pole-size (5.0 to 12.0 inches (12 to 30 cm) in d.b.h.) to young sawtimber-size (more than 12.0 inches (30 cm) in d.b.h.) sugar maple trees at high elevations. Despite some top kill, sugar maples with no more than 40 to 50 percent of their crown defoliated usually survived.

The principal short-term economic impact of defoliation by saddled prominent occurs in sugarbushes. Sap quantity and sugar content may decline following heavy defoliation. During the 1967-71 outbreak, New York syrup producers who did not spray their sugarbushes were unable to operate during the spring following defoliation.

It often is difficult to predict the immediate and long-term impact of a saddled prominent outbreak because many events determine the outcome. However, sugarbushes that have been stressed recently by thinning, drought, or severe defoliation should be protected.

This relatively large moth has a wingspan of approximately 2.0 inches (50 mm). The mottled forewings are drab greenish or brownish-gray and marked with irregular creamy white splotches. The hindwings are light brown. All four wings usually have a broken dark to black band near the outer margin. Throughout June and early July, adults deposit eggs on leaves, especially of sugar maple, American beech, or yellow birch. Fully grown caterpillars are approximately 1.3 inches (33 mm) long and usually are green with a reddish saddle-like mark in the center of the back (Fig. 32). The head is marked on each side with a series of distinct stripes: one dark brown, two yellow or white, and one pink. Some caterpillars may lack the saddle marking or are entirely reddish-brown.

Greenstriped Mapleworm *(Dryocampa rubicunda)*

The preferred host of this species is red maple, yet it frequently defoliates sugar maple as well. Infestations usually encompass fewer than 50 acres (20 ha), and last for 2 to 3 years. However, there have been exceptions: an Ontario outbreak in the 1940's lasted for 10 years, and during the early 1970's, defoliation in Pennsylvania affected more than 27,000 acres (11,000 ha). Heavy defoliation can significantly reduce sap quality.

The brightly colored moths of this species have a wingspan of 1.5 to 2.0 inches (37 to 50 mm). The woolly body is creamy yellow on top and rose to pink underneath. Forewings are rose-pink at the base and tip, with a center band of yellow. Hindwings usually are pure yellow but may be faintly streaked with rose-pink. Adults, sometimes called rosy maple moths, frequently congregate around lights at night. The color of mature caterpillars varies, but each usually has a series of longitudinal light to dark green stripes along the back and sides (Fig. 34). The most distinctive feature is a pair of black "horns" on the back of the second body segment, immediately behind the cherry-red head.

The caterpillars initially group and feed together; these young larvae have shiny black, not red, heads. As they mature, the insects disperse from their group and become solitary feeders.

Orangehumped Mapleworm *(Symmerista leucitys)*

This is a minor pest in most regions, though it has severely defoliated sugarbushes in Quebec on occasion. Significant tree mortality or crown dieback has not been associated with outbreaks.

Adults have a wingspan of 1.2 to 1.6 inches (30 to 40 mm). The front wings are ash-gray to brownish-gray with a white band along the leading edge. They often have a narrow dark brown, wavy stripe near the tips. The hind wings are whitish to light brown. When resting on tree bark, the moth resembles a bird dropping. The caterpillar is 1.4 to 1.8 inches (35 to 45 mm) long and is marked with a bright orange head and orange hump on top of a rear segment (Fig. 35). The basic body color is yellow-orange with nine longitudinal black stripes. The stripes occur in groups of three (two lateral groups and one along the back) and the body between the stripes in each group is gray. Eggs are deposited in clusters and young caterpillars are gregarious until nearly full grown when they become solitary. Newly emerged caterpillars have shiny black heads (Fig. 36).

Maple Leafcutter *(Paraclemensia acerifoliella)*

Leafcutter infestations have been recorded since the late 19th century. Once a major outbreak begins, defoliation can occur annually for 6 to 8 years. During an extensive outbreak in eastern Ontario in 1981, maple was defoliated throughout 321,000 acres (130,000 ha). In Vermont during the mid-1970's, trees on more than 35,000 acres (14,000 ha) were heavily defoliated. Studies in Vermont indicated that 3 years of complete defoliation by this insect were required to significantly reduce the starch content of maple roots (an indication of physiological stress). Several consecutive years of defoliation may result in crown dieback, though there usually is little mortality, even when trees are defoliated heavily for as many as 7 years. Sugar maple apparently is more resilient to defoliation by the leafcutter than to that of other insects, probably because of its unique feeding behavior and late-season feeding. Repeated, heavy defoliation significantly reduces sap production.

The moths are steel blue with bright orange heads but they are small and rarely noticed. This insect is most readily detected by the appearance of infested foliage. During mid- to late June, caterpillars mine the leaves, creating brown blotches 0.5 to 0.8 inch (12 to 20 mm) long (Fig. 37). Leaf mining stops after 2 to 3 weeks when the caterpillars begin to skeletonize foliage as they feed from a protective circular case that is constructed from two discs of leaf tissue (Fig. 38). The case is portable and must be replaced as the caterpillar grows. Each time a circular disc is "cut" from a leaf, a hole is created. Frequently, a major leaf vein is severed. The end result is foliage that contains several holes. The largest are about 0.75 inch (2.0 cm) in diameter. The leaf is brown

Figure 35.—Full-grown orangehumped mapleworm.

Figure 36.—Young orangehumped mapleworms.

Figure 37.—Leafmining caused by young larvae of the maple leafcutter.

and partially skeletonized but otherwise intact. When feeding is completed in late August or early September, caterpillars descend trees, bringing their cases with them. Observant sugarbush operators often see a bizarre sight of hundreds of pieces of brown foliage walking down tree trunks and across the ground!

Figure 38.—Disc-shaped shelter of leaf tissue made by the maple leafcutter caterpillar.

Other Defoliators

Some defoliators cause damage only occasionally. Yet, due to their prevalence in sugar maple stands, their unique feeding behaviors, or their distinctive appearance, these insects often are noticed by sugarbush operators. Infestations usually are limited to several trees or to relatively small areas.

Maple Trumpet Skeletonizer *(Epinotia aceriella)*

The caterpillar of this small moth begins feeding on the underside of a maple leaf near the junction of two major veins. It skeletonizes the leaf and spins a silk canopy over the feeding site (Fig. 39). Each caterpillar uses silk and feces to construct an elongated, often curved, tubular shelter in which it lives (Fig. 40). As the caterpillar grows, the tube is enlarged. Frequently it takes on the appearance of a horn or trumpet. Eventually, the silk canopy draws the margins of the leaf together around the tube, and the leaf appears crumpled (Fig. 41). The distorted leaf with conspicuous brown, skelentonized areas on its upper surface is readily apparent in late summer and early fall.

Maple Leafblotch Miner *(Cameraria aceriella)*

Caterpillars of this insect burrow between the upper and lower surfaces of the leaf, and feed on the green chlorophyll-bearing tissues to create whitish or light brown translucent patches on the underside of maple foliage. Usually, only an outline of the patch is visible on the leaf's upper surface (Fig. 42). These patches are translucent when held to the light.

Figure 39.—Silk canopy spun by a young caterpillar of the maple trumpet skeletonizer.

Figure 40.—Tubular shelter made by a caterpillar of the maple trumpet skeletonizer.

Figure 41.—Sugar maple leaf folded by maple trumpet skeletonizer. The brown area is caused by skeletonizing within the fold.

Figure 42.—Discolored patch is feeding damage caused by a larva of the maple leafblotch miner.

Maple Petiole Borer *(Caulocampus acericaulis)*

Larvae of this tiny wasp hollow out the stems (petiole) of sugar maple leaves (Fig. 43). The light yellow larva begins feeding at the base of the petiole and gradually mines its way toward the leaf base. Shortly before it finishes feeding, it chews through the petiole a few millimeters from the leaf blade. The blade droops (Fig. 44), eventually breaks away, and falls to the ground.

Maple Leafrollers

Several species of moths roll, fold, or tie foliage in the process of constructing a shelter in which the caterpillar feeds and/or rests. The species most commonly associated with sugar maple rarely cause significant damage. However, their feeding behavior makes even sparse populations conspicuous.

The most thorough documentation of extensive damage associated with members of this group is from observations in Wisconsin during the late 1950's. Foliage contorted by unusually high populations of the maple leafroller *(Sparganothis acerivorana)* (Fig. 45) and the lesser maple leafroller *(Acleris chalybeana)* provided egg-laying sites for the maple webworm *(Tetralopha asperatella)*. Defoliation by the latter was the major factor that predisposed sugar maple to a decline called maple blight. The maple leafroller apparently has caused significant damage in Quebec and Ontario.

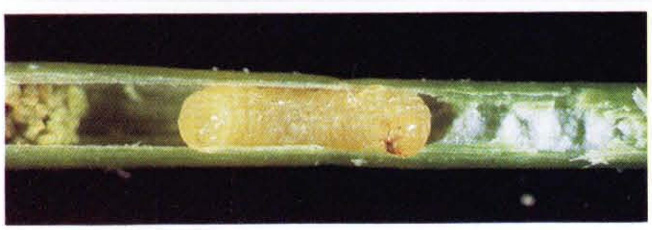

Figure 43.—Larva of the maple petiole borer in the petiole of a sugar maple leaf.

Figure 44.—Drooping sugar maple leaf typical of damage by the maple petiole borer.

Figure 45.—Damage caused by the maple leafroller.

Webworm caterpillars are gregarious and each colony ties several leaves together with silk to form a conspicuous, unkempt nest. Full-grown caterpillars are 0.6 to 0.8 inch (15 to 20 mm) long and range from pale yellow (Fig. 46) through various shades of green to dark brown (Fig. 47).

Linden Looper *(Erannis tiliaria)*

This looper is common in sugarbushes, but outbreaks are rare. Extensive maple defoliation occurred in Quebec during the early 1940's and 1950's and again in the 1960's. Damage was negligible.

Figure 46.—Light-colored phase of the maple webworm.

Figure 47.—Dark phase of the maple webworm.

The female moth has only rudimentary wings and cannot fly. It is 0.4 to 0.5 inch (10 to 12 mm) long and light gray with two distinct rows of black spots along the back. The light brown male has a wingspan of 1.4 to 1.8 inches (35 to 45 mm). Each forewing is marked with two transverse wavy brown bands. Moths emerge in late fall and lay eggs on the trunk of several tree species, including sugar maple.

The mature larva is 1.4 to 1.8 inches (35 to 45 mm) long and has a rusty brown head and bright yellow underside (Fig. 48). The back usually is marked with 10 black wavy lines. Color intensity can vary to the point where some individuals appear uniformly yellow.

Figure 48.—Linden looper.

This damage occurs early in the growing season when leaves begin to unfold. Severely defoliated trees usually produce a second crop of leaves.

Gypsy Moth *(Lymantria dispar)*

Gypsy moth is an introduced pest. Infestations are most frequent in forest stands with abundant oaks and/or gray birch. Apple also is a preferred host. However, gypsy moth feeds readily on a wide range of broad-leaved trees and conifers. Sugarbushes in the vicinity of oak forests, abandoned apple orchards, or sites with abundant gray birch frequently suffer defoliation.

The full-grown caterpillar (Fig. 49) is hairy and 1.5 to 2.5 inches long (35 to 65 mm). The head has yellowish-orange markings. The back has a double row of five pairs of blue spots, followed by a double row of six pairs of red spots. The buff-colored egg masses (Fig. 50) are conspicuous on tree boles and branches, and often are the first indication of a pending gypsy moth infestation.

Figure 49.—Gypsy moth caterpillar.

Figure 50.—Gypsy moth female on her egg mass.

Management Recommendations for Defoliators

Sugarbush operators must learn to recognize insects that are a potential threat to sugar maple. Outbreaks rarely appear within a single year. Typically, insect populations attain damaging levels only after 2 to 3 years of favorable weather, temporary ineffectiveness of natural enemies, and abundant suitable food. Light defoliation and an unusual abundance of caterpillars, or sometimes moths, can be observed for 1 to 2 or more years before damage is significant. An awareness of these early warning signs make it possible to act rather than react. Usually, the operator has time to consult with specialists, evaluate the potential problem, compare management options, and arrange for any necessary action.

Once a threatening problem develops in an area, operators should discuss treatment options with pest management specialists and applicators. Presently, the only way to quickly reduce levels of threatening defoliator populations is to spray with synthetic organic or microbial (bacteriological) insecticides. The latter, which are available under a variety of trade names, all have the bacterium *Bacillus thuringiensis* (Bt) as the active ingredient. Currently, Bt costs slightly more than a chemical insecticide.

Many chemical insecticides act on contact and penetrate the skin of the insect, disrupting the nervous system and killing the pest within a few minutes or hours. To be effective, Bt must be ingested by a caterpillar. Once in the insect's stomach, the microorganism reproduces rapidly and produces a toxic protein. This impairs the functioning and permeability of the stomach wall. This action may be rapid enough to kill the insect within a few hours. Some defoliators are more resistant to the toxin than others and die only after the bacterium has destroyed other tissues. This process may require several days, during which feeding diminishes.

If the correct formulation of a chemical insecticide is mixed properly and applied at the correct time and rate, most defoliator populations can be reduced to acceptable levels consistently and quickly. Bt is more difficult to use and its success is determined especially by weather conditions and insect vigor. However, the efficacy of Bt is continually being improved. In recent years, the effectiveness and cost of this environmentally safe insecticide have approached those of organic chemicals.

Because neither the biological nor the chemical insecticides that are currently registered for use in sugarbushes enter the sap from treated trees, syrup produced from stands treated with these products can still be sold as pure.

Other Insect Pests

Pear Thirps *(Taeniothrips inconsequens)*

The first major outbreak of this small sucking insect on sugar maple was recorded in Pennsylvania in the late 1970's. Since then, widespread damage by pear thrips has occurred on sugar maple in several Northeastern States. In 1988, approximately 1 million acres (400,000 ha) in Pennsylvania, nearly a half million acres (200,000 ha) in Vermont, and several thousand acres in Western Massachusetts were heavily infested. The consequences of this unprecedented outbreak in New England have yet to be determined, but experience in Pennsylvania indicates that even after several years of high thrips populations, sugar maple mortality is rare. During an outbreak, damage may vary substantially from tree to tree. Prolonged infestations may cause crown dieback and reduced sap volume.

This insect spends most of its life in the soil. Most of the damage occurs during a short period in early spring when adults feed within buds. When adult populations are extremely high, there is no leaf development. Larvae also feed throughout the spring as foliage expands. Typical symptoms in light to moderate populations are whitish to yellow blotches on foliage (Fig. 51), puckered, often tattered, abnormally small leaves (Fig. 52), brown, dead areas on edges of the leaves and veins, and early leaf drop. Damage can be severe (Fig. 53) when populations are high and often resembles that caused by a late frost or strong wind. Severe injury sometimes triggers refoliation.

Pear thrips adults (Fig. 54) are extremely small (0.04 to 0.06 inch or 1 to 1.5 mm long), elongate, and dark brown. The head appears swollen, and the wings are narrow and fringed with long hairs. Larvae are yellowish to pale translucent green with conspicuous red eyes.

Figure 51.—Light to moderate feeding by pear thrips results in whitish to yellow blotches or mottling.

Figure 52.—Puckered, tattered, or abnormally small leaves can result from moderate populations of pear thrips (Vermont Dept. of Forests, Parks and Recreation photo).

Figure 53.—Sugar maple severely damaged by pear thrips.

Figure 54.—Pear thrips adult (Pennsylvania Bureau of Forestry photo).

Aphids

These small, delicate, louse-like sucking insects often are found on sugar maple foliage. Their populations may be dense enough for feeding to stunt foliage and cause it to wrinkle and discolor. Foliage may turn brown to nearly black in heavy infestations. Damaged foliage also may drop prematurely. Aphids excrete large amounts of honeydew, a concentrated mixture of sugar and water that is removed from the tree during feeding. This sticky substance often coats foliage and bark (giving a glazed appearance) or even vehicles parked beneath heavily infested trees.

Recently, large numbers of aphids have been noted on sugar maple in New England during spring and early summer. The most common species is closely related to the Norway maple aphid. The earliest stages to appear in the spring are purplish-brown to brown nymphs and wingless adults. At first they infest buds, but later they form colonies on the underside of expanding foliage (Fig. 55). They also infest petioles and green shoots and tend to cluster at the junction of the leaf and petiole. Winged adults are dark brown (nearly black) and slightly less than 0.12 inch (3 mm) long. They first appear in early summer.

Figure 55.—Nymphs and wingless adults of Norway maple aphid (Oregon State University photo).

These aphids are unusual in that they spend most of the summer in a resting stage (or a dimorph). The immobile dimorphs are less than 0.12 inch (3 mm) long, whitish and translucent, and are flattened against the undersurface of the leaves.

Wood Borers

The insects in this group succeed only in stressed or weakened sugar maples, or in damaged portions of otherwise healthy trees. These secondary insects initiate the decomposition process that eventually leads to nutrient recycling. In economic terms, however, wood borers may cause significant losses because of the lumber degrade or reduced crown size that results from their activities.

Sugar maple borer. Damage by the sugar maple borer *(Glycobius speciosus)* varies among forest types and stands within a type. Infestation rates, the proportion of damaged stems per acre or hectare, range from less than 5 to nearly 50 percent. Sugar maples in all stands are susceptible, but the incidence of damage is highest in stands with a high proportion of sugar maple. Rarely does sugar maple borer kill a tree, but it directly affects the main part of the stem, sometimes reducing the available space for tapping. Borer attack is most prevalant on trees of low vigor.

Damage also is important because a successful attack results in the partial girdling of the tree and the possible death of portions of the crown. Silvicultural practices that maintain tree vigor are essential, and early thinnings should include the removal of previously attacked trees.

The adult sugar maple borer (Fig. 56) is a black beetle marked with bright yellow bands of varying width and shape; the most conspicuous is shaped like a W. The borer is 0.8 to 1.0 inch (20 to 25 mm) long and belongs to a group commonly referred to as longhorn beetles, a name evoked by the pest's unusually long antennae.

The sugar maple borer deposits one to several eggs in crevices or holes that it chews through the bark, usually on the lower 20 feet (6 m) of the trunk. Following egg hatch, the small larva enters the tree and feeds beneath the bark. During the second year of its 2-year life cycle, it excavates a shallow transverse or oblique feeding gallery in the outer wood and inner bark. As a result of this girdling (similar to the damage caused by an axe blaze or logging scar), large branches above the gallery may be killed. A large open scar of exposed wood often results (Fig. 57), and a significant portion of the trunk may be rendered unusable for tapping. Large, open wounds are conspicuous, but scars from the sugar maple borer often are difficult to detect as the damage is hidden beneath slightly cracked and loosened bark (Fig. 58). The larval gallery deeply engraved on the surface of the exposed wood distinguishes scars caused by sugar maple borer from those caused by other agents.

During its first year, gallery direction changes from transverse to vertical. Eventually, the off-white, grub-like larva (Fig. 59) excavates an oval overwintering tunnel (Fig. 60) 0.4 to 0.6 inch (10 to 15 mm) in diameter that penetrates the wood to a depth of 2.0 to 4.0 inches (5 to 10 cm).

Horntails. Adult horntails are large wasps with a hardened, spear-like and upcurved projection on the posterior (Fig. 61). Larvae infest wood in trees or parts of trees that are dead or badly weakened. Infested wood deteriorates rapidly. Clusters of larvae and larval tunnels frequently are encountered when dead or old trees are removed from the sugarbush and cut into firewood (Fig. 62).

The species most commonly found in sugar maple and other eastern hardwoods is called the pigeon tremex *(Tremex columba).* The reddish and black adults are 0.75 to 2.0 inches (20 to 50 mm) long and have large wings. The rear half of the female often is marked with yellowish spots and bands, and in addition to the short, up-curved dorsal spine

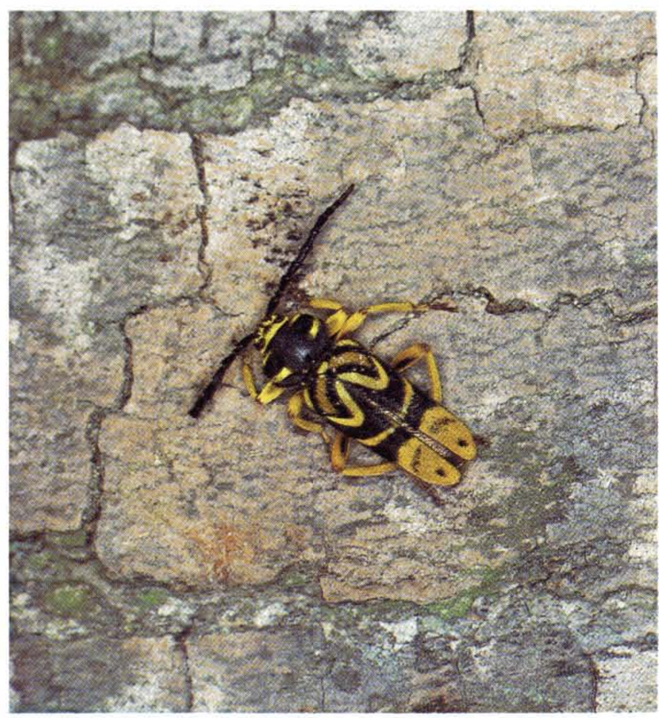

Figure 56.—Sugar maple borer adult.

Figure 57.—Open scar associated with the narrow feeding gallery made by a larva of the sugar maple borer.

Figure 58.—Cracked, loose bark that typically conceals recent damage by the sugar maple borer.

Figure 59.—Sugar maple borer larva.

Figure 60.—Gallery excavated by a larva of the sugar maple borer; the insect overwinters here.

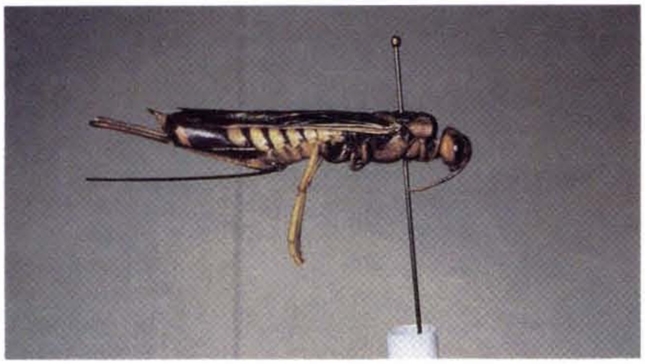

Figure 61.—Female woodwasp or horntail. This species, the pigeon tremex, lays its eggs in the wood of weakened trees. Note the large wings, the long egg-laying device that extends well beyond the posterior, and the short, spear-like, upturned spine immediately above it.

Figure 62.—A decayed piece of sugar maple wood infested with larvae of the pigeon tremex.

the posterior has a long egg-laying device (ovipositor) (Fig. 61). Eggs are deposited in the wood and the white, cylindrical, grub-like larvae tunnel into the wood. The posterior of each larva also has a characteristic short, stiff, and dark-colored spine. Full-grown larvae are approximately the diameter of a pencil and 2.0 inches (5 cm) long.

Ambrosia beetles. Ambrosia beetles are small (usually less than 0.2 inch (5 mm) long), cylindrical, and reddish to dark brown. They bore directly into the wood of recently cut logs or damaged areas of limbs and tree trunks, for example, old tap holes. Ambrosia beetles do not kill trees or prevent them from recovering from stress, but their presence indicates physical damage or severe tree stress.

The adults and white grub-like larvae do not eat wood. Rather, they feed on a fungus ("ambrosia") that grows in the tunnels. Fungus spores are carried by the beetles and introduced into the wood during tunnel construction. As the fungus grows, it discolors or stains the wood immediately adjacent to the tunnel (Fig. 63). In some instances, the wood is stained for several inches (several centimeters) above and below the tunnel.

The most reliable indications of attack are small entrance holes (less than 0.1 inch or 2 mm in diameter) and the presence of fine, light-colored wood dust in bark crevices beneath each hole (Fig. 64). When an infested piece of wood is split open, the simple, branched or compound dark-stained tunnels are obvious (Fig. 63).

One species *(Xyloterinus politus)* frequently associated with declining or wind-thrown sugar maple produces a cylinder of tightly packed boring dust that protrudes up to 1.0 inch (25 mm) from the entrance hole (Fig. 65). Another species, the pitted ambrosia beetle *(Corthylus punctatissimus),* attacks and kills seedlings of sugar maple and other hardwoods. Adults penetrate stems below ground level, tunnel into the outer wood, and eventually girdle the seedlings. There usually is a small pile of white wood chips (Fig. 66) in the soil adjacent to the entrace hole. An infestation is easily detected because seedlings wilt and turn brown during midsummer (Fig. 67). Heavy infestations have been reported in southeastern Canada and North Carolina. Fortunately, sugar maple reproduction is so abundant in most stands that even heavy infestations of the pitted ambrosia beetle are not important.

Figure 63.—Wood discoloration (stain) associated with the branched galleries of an ambrosia beetle that frequently attacks sugar maple.

Figure 64.—White wood dust on sugar maple bark is evidence of attack by ambrosia beetles.

Figure 65.—Protruding "plug" of wood dust that often occurs on sugar maple recently invaded by the ambrosia beetle.

Figure 66.—Wood chips at the base of a sugar maple seedling indicate recent attack by the pitted ambrosia beetle.

Figure 67.—Wilted sugar maple seedling typical of damage caused by the pitted ambrosia beetle.

Conspicuous Insects of Little Consequence

A number of innocuous organisms feed on sugar maple foliage and cause visible damage, but the resulting discoloration or distortion of the leaves rarely affects maple growth or sap quality.

Some insects and mites alter plant growth when they stimulate the host to produce strange-looking growths called galls. These tumor-like abnormalities are derived from cells that grow excessively large or numerous. This unusual development is triggered by growth stimulants introduced into the plant in the saliva of insects and mites. The location, shape, and color of a gall, which provides a source of nutritious and readily available food and shelter for the pest, usually is distinctive enough to identify the gall maker.

Gall Mites

The maple bladdergall mite *(Vasates quadripedes)* and maple spindlegall mite *(V. aceris-crumena)* are found throughout the range of sugar maple. The former is characterized by a globular gall that is 0.05 to 0.1 inch (1 to 3 mm) in diameter. The latter induces an erect, elongate gall approximately 0.2 inch (5 mm) long (Fig. 68). Both of these pouch-like galls are found on the top of the leaf and usually are limited to understory leaves. When first formed (in May), the galls are yellowish-green. They turn rosy pink and eventually may become dark red.

The crimson erineum gall mite (*Aceria regulus*) is responsible for the bright red pile or felt-like patches (erinosis) on the upper surface of maple leaves (Fig. 69). A related species causes a similarly shaped but whitish to green erinosis on the underside of sugar maple leaves.

Figure 68.—Elongate galls induced by spindlegall mites.

Figure 69.—Red patches on the upper surface of sugar maple leaf caused by crimson erineum mites.

Ocellate Gall Midge *(Acericecis ocellaris)*

Injury caused by larvae of this fly resembles that of certain leaf spot fungi. It creates a yellow to greenish-yellow spot with a small dark center surrounded by a red ring (Fig. 70). The circular gall is 0.3 to 0.4 inch (8 to 10 mm) in diameter. It is visible on the upper surface of the leaf from mid-June until the foliage changes color in the fall. The small fly maggot feeds in a depression on the underside of the leaf at the center of the circle (Fig. 70). By the time leaf spots are evident, most maggots have fallen off the leaf.

Gouty Vein Midge *(Dasineura communis)*

This fly creates an elongate, light green to reddish-green pouch gall in major leaf veins. When the fly maggot completes feeding, the gall on the upper surface of the leaf dries and cracks open (Fig. 71). The gall is 0.1 to 0.3 inch (3 to 8 mm) long. Infestations usually become evident in June and galls open sometime during July.

Snout Beetles (Weevils)

Larvae of these small (0.2 to 0.3 inch, 5 to 8 mm long) beetles overwinter in the soil. Adult weevils emerge in late May and early June and feed on buds and expanding foliage of a variety of plants, especially sugar maple. The end result is truncated, frequently tattered, off-color foliage that is especially evident on saplings and seedlings. *Phyllobius oblongus,* one of the two most common species, is shiny, dark brown (Fig. 72), and disappears by midsummer. The other, *Sciaphilus asperatus,* is gray and feeds throughout the summer.

Scales

These strange-looking insects feed on maple sap by inserting fine, thread-like mouthparts (stylets) into cells beneath the bark of twigs and small branches. The cottony maple scale *(Pulvinaria innumerabilis)* is oval, approximately 0.3 inch (8 mm) long, reddish-brown, and convex with a median ridge. The reddish-brown scale and its large, white cottony egg sac resemble a piece of popcorn (Fig. 73). The smaller

Figure 70.—Larva of ocellate gall midge in the center of its red-ringed leaf spot.

Figure 71.—Mature (dried and open) galls of the gouty vein gall midge.

lecanium scale *(Parthenolecanium* sp.) (Fig. 74) varies in size and color but usually is reddish-brown. No cottony sac is produced and eggs are concealed beneath its body. This insect excretes large amounts of sugary honeydew that frequently supports growth of sooty mold fungi which impart unsightly black films on branches and objects beneath heavily infested twigs.

Figure 72.—Mature snout beetle (weevil).

Figure 73.—Cottony maple scale.

Figure 74.—Lecanium scale.

DISEASES

A tree disease can be caused by abiotic factors such as air pollution, mineral imbalances, and climatic extremes; by biotic agents such as tiny viruses, bacteria, mycoplasma-like organisms, and fungi; by nematodes; or by larger parasitic plants such as mistletoe and broomrape. Nearly all diseases of sugar maple incited by biotic agents are caused by fungi. Like insects, fungi can be classed as primary (able to successfully infect and invade healthy vigorous trees) or secondary (able to succeed only on trees altered by stress). Collectively, diseases probably cause more losses to sugar maple than all other destructive agents.

Diseases of sugar maple range from conspicuous, but rarely significant, leaf diseases to inconspicuous, but often lethal, diseases of internal stem wood and roots. The presence of many diseases often goes unnoticed until the damage is significant. And since little can be done to halt their progress, it is important to prevent or reduce the conditions that lead to tree diseases. Nearly all biotically incited diseases of major consequence other than dieback/declines are facilitated by wounds. Wound prevention, especially to roots and lower stems, must be central to an IPM program for sugarbushes.

Dieback/decline diseases epitomize the complex nature of tree diseases for they reflect the interactions of fungal pathogens and various stresses, including defoliating insects, as well as adverse abiotic factors. Their complex etiology also serves to emphasize the need for a holistic approach to managing the sugarbush.

Leaf Diseases

Sugar maple has many leaf diseases, most of which are caused by fungi. Symptoms range from minute dead spots to the death of the entire leaf. Leaf diseases occur throughout the growing season but are more common and important in late spring during wet and cool periods. Defoliation by leaf diseases generally does not cause significant damage. It seldom lowers a tree's ability to produce food energy by more than 25 to 30 percent. However, growth may slow and dieback can occur following serious episodes. Air pollutants also may cause discolored or dead areas on leaves. With the exception of anthracnose, leaf diseases do not cause significant damage.

Anthracnose

Anthracnose, the most important leaf disease of maple, occasionally becomes damaging following several days of wet weather. The first symptoms are scattered, reddish-brown dead areas along leaf veins. These lesions may enlarge rapidly and merge with other spots to cover most or all of the leaf surface (Fig. 75). Dead areas may show irregular zoning and turn gray or black. Severely affected trees may appear scorched. Small, brown fruiting bodies of the causal fungi (the most common one is *Aureobasidium apocryptum,* formerly *Kabatiella apocrypta)* confirm the diagnosis of anthracnose and distinguish it from "leaf scorch" caused by drought and heat injury. Control treatments usually are not recommended against anthracnose in sugarbushes.

Figure 75.—Sugar maple leaf showing extensive area of dead tissue typical of anthracnose disease.

Phloeospora Leaf Spot *(Phloeospora aceris)*

Typically, spots with irregular borders appear soon after a wet period (Fig. 76). A few weeks later, fruiting bodies of the causal fungus appear as small black bodies surrounded by a pinkish zone on the underside of leaves (Fig. 77).

Phyllosticta Leaf Spot *(Phyllosticta minima)*

This fungus causes discrete, small spots 0.25 inch (6 mm) or less in diameter on several species of maple. The spots first appear as brown dots; as they enlarge, their centers become tan. Phyllosticta also is known as "eye spot," or "purple eye spot" disease because the spots have a red or purple border (Fig. 78). With time, black fruiting bodies of the fungus appear on the spots (Fig. 79). Occasionally, adjacent spots coalesce to form irregular dead areas on the leaves.

Tar Spots

Two tar spot diseases affect both sugar and red maple trees. One, the black tar spot caused by *Rhytisma acerinum*, produces large and raised black patches of fungus growth (stroma) on the upper leaf surface (Fig. 80). The other, called speckled tar spot *(R. punctatum)*, is characterized by clusters of individual small black stromata (Fig. 81). Black tar spot is conspicuous because the black, somewhat shiny, stromata are surrounded by yellow-orange zones (Fig. 80). Infection occurs during periods of high humidity shortly after leaves reach full size. Light green and then yellow-green areas appear on the leaf surface. The black stromata form later in the season. The underside of the leaf below a black tar spot turns brown, whereas the underside of a speckled tar spot remains yellow.

Figure 76.—Typical *Phloeospora* leaf spot, with its irregular borders, on a sugar maple leaf.

Figure 77.—Close up of a *Phloeospora* leaf spot on the underside of a sugar maple leaf showing fruiting bodies of the causal fungus.

Figure 78.—Purple eye spot disease on a red maple leaf with characteristic red or purple borders (Quebec Department of Energy and Resources photo).

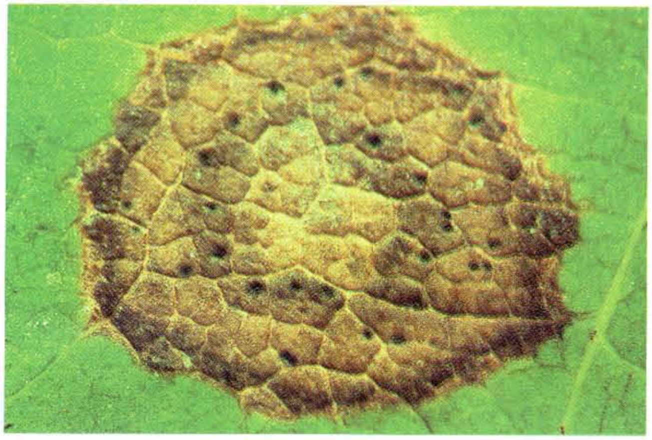

Figure 79.—Purple eye spot disease. Closeup of a spot showing the black fruiting bodies of the causal fungus (Quebec Department of Energy and Resources photo).

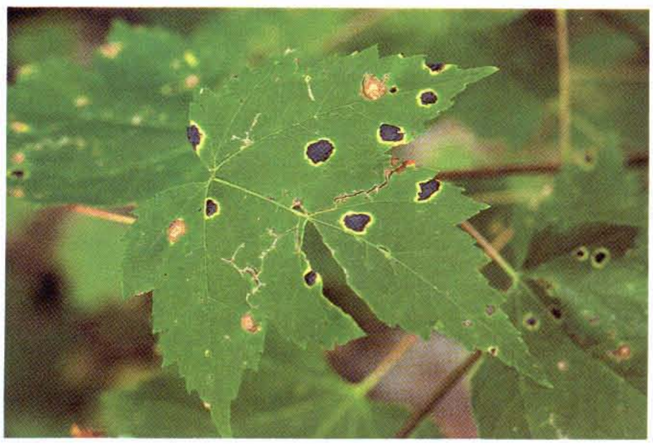

Figure 80.—Tar spot disease on red maple leaf. The characteristic black fungus tissue (stroma) is surrounded by yellow zones (Quebec Department of Energy and Resources photo).

Figure 81.—Speckled tar spot disease on a sugar maple leaf. Each spot is made of clusters of individual small black stroma of the causal fungus.

Cankers and Canker Rots

Cankers

Stem cankers are localized dead areas in the outer and inner bark. They often extend into the wood. They are caused by fungi that infect trees through bark injuries. Some of these fungi repeatedly invade and kill the inner living bark and cambium and cause perennial cankers. In perennial cankers, callus tissues develop around the affected area, producing a stem distortion that may become extensive with time.

Stem cankers are conspicuous tree diseases in that they generally deform the lower tree bole and often render it unsuitable for tapping. Cankers themselves often are points of entry for decay fungi, and create weak points where trees often break. Affected trees should be removed so long as doing so would not create a large opening in the canopy that, as mentioned earlier, would encourage unwanted vegetation or promote excessive soil drying.

Eutypella canker. Young Eutypella cankers *(Eutypella parasitica)* are visible mainly on trees smaller than 6 inches (15 cm) in d.b.h. They appear as depressed or flattened areas with the bark still tightly attached. The outline of callus (new, thickened woody tissue) beneath the bark around the flattened area usually is visible. White to tan "fans" of fungus growth (mycelium) are underneath the callused bark, particularly at the top and bottom of the canker. A branch stub often is present at the canker center. On larger stems, much distortion develops following alternating periods of development by the fungus and callus (Fig. 82). Bark adheres to the canker for several years even when the stem beneath it is well decayed. On large old trees, cankers may be as much as 5 feet (1.5 m) long (Fig. 83).

Five to six years after infection, the fungus produces numerous tiny, black, long-necked, flask-shaped fruiting bodies that protrude through the bark, usually beginning at the center of the canker. These structures release spores that can spread the disease.

Decay fungi often enter the stem through the dead bark of the canker. *Oxyporus populinus* (formerly *Fomes connatus)* causes a major heart rot of sugar maple and is commonly associated with Eutypella canker. The white, fruiting bodies (conks) of this decay fungus often are topped with green moss. They are almost a characteristic feature of old Eutypella cankers (Fig. 83).

Trees 4 inches (10 cm) or less in d.b.h. often are girdled and killed by the canker fungus. On larger trees, the lateral growth rate of the fungus is not rapid enough to girdle the stem, and the canker becomes somewhat permanent. Most cankers are less than 10 feet (3 m) from the ground. Usually, 1 to 4 percent of the trees in a stand are affected, though some stands are damaged more severely. The malformation caused by the canker (and the stem decay that often accompanies it) renders the trunk susceptible to wind breakage and often limits its usefulness for tapping.

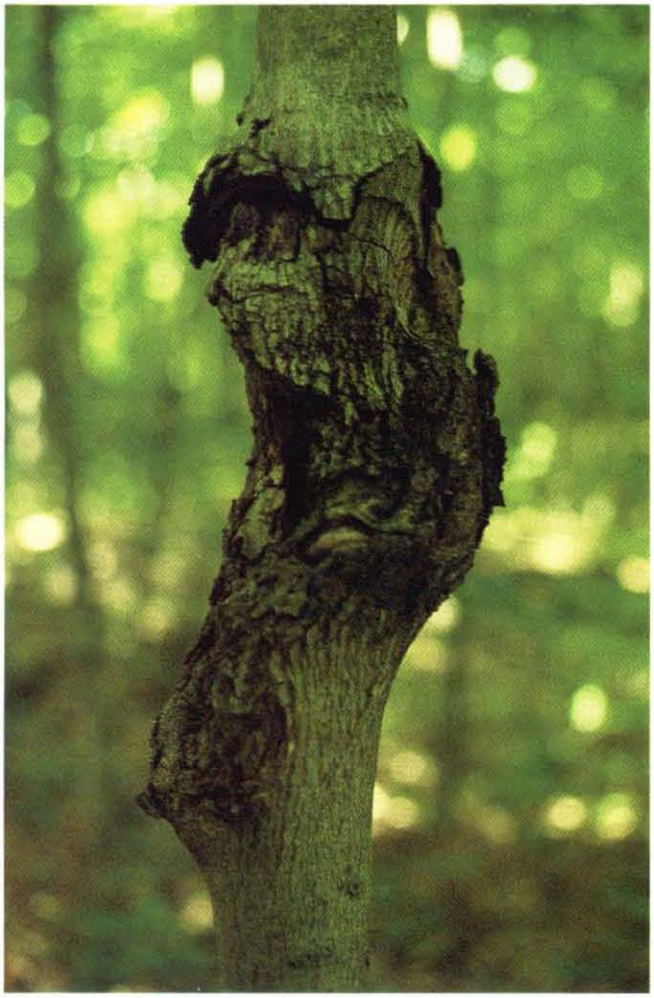

Figure 82.—Eutypella canker on a small sugar maple. Note the severe stem distortion and the numerous black fruiting bodies of the fungus developing on the bark still adhering to the canker.

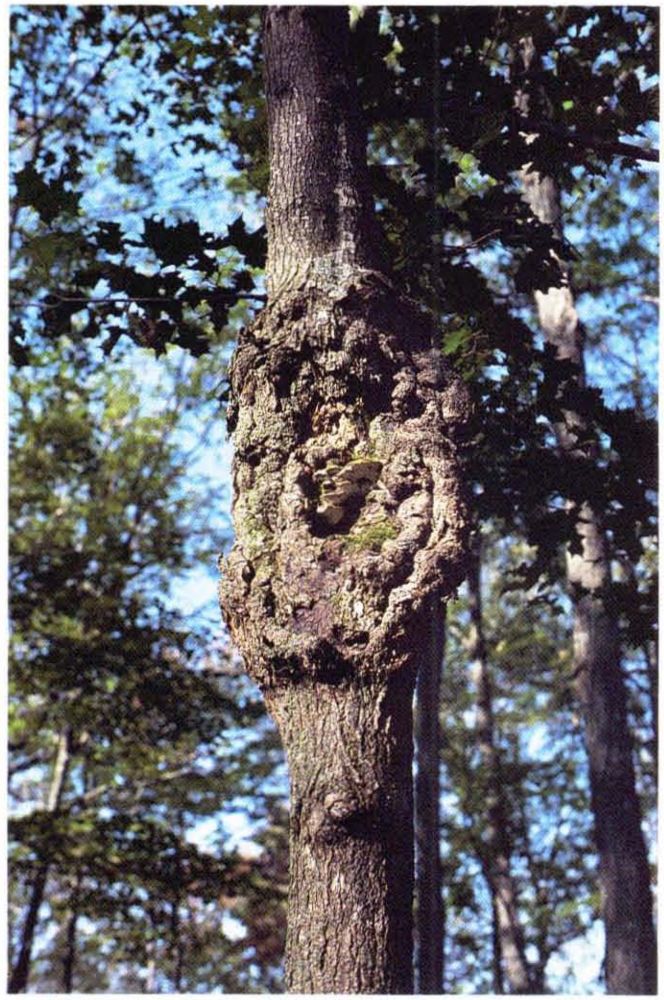

Figure 83.—Typical Eutypella canker on a large sugar maple. Fruiting bodies (topped with green moss) of the decay fungus *Oxyporus populinus* are visible at the center of the canker.

Managing the Eutypella canker is easy. Eliminate trees with cankers because they are sources of infection. Stands treated in this way should remain relatively free of the disease.

Nectria canker. Nectria canker *(Nectria galligena)* is one of the most common diseases of hardwoods in North America. It affects more than 60 species of trees and shrubs. In northern hardwood stands, the species most commonly affected are white and yellow birches, red and sugar maples, oaks, and aspen.

One- or two-year-old cankers appear as dark, flattened or depressed areas on smooth-barked stems or branches. Young cankers may be difficult to detect. Nectria canker differs from Eutypella canker in that the dead bark over it soon falls off to expose concentric ridges of callus tissue. Because these ridges look somewhat like a target, Nectria cankers sometimes are called "target cankers" (Fig. 84). The concentric ridges are formed by the alternating annual extension of the fungus into surrounding healthy bark during the dormant season, and the subsequent production of callus around the newly invaded area by the host tree during the next growing season. Because the canker enlarges slowly, the tree stem is rarely girdled and killed.

Fruiting bodies of the causal fungus generally appear in the fall at the margins of cankers. They are bright red to reddish-orange, spherical, and 0.02 inch (0.5 mm) or less in diameter. Spores that spread the disease are produced in the fruiting bodies. When these occur in large clusters they appear as red spots when viewed with the naked eye. A hand lens is necessary for good observation. Nectria does not decay wood, and the wood behind a canker usually is sound unless it also is invaded by decay fungi.

Although Nectria cankers are more important on birch than on maple, they markedly lower the longevity of any tree by increasing susceptibility to decay. Infection occurs mainly through small wounds on young trees. Removing affected trees during thinning operations will greatly reduce the importance of the disease. Stands on poor sites often are the most severely cankered.

Figure 84.—A target-shaped Nectria canker on a sugar maple stem.

Figure 85.—Numerous pink-orange young fruiting bodies of the coral spot fungus developing on dead bark of Norway maple.

Coral spot canker. Coral spot canker *(Nectria cinnabarina)* is common on sugar maple and other hardwood trees. It usually attacks only dead twigs and branches but also can kill branches and stems of young trees weakened by freezing, drought, or mechanical injury. It is common and highly visible.

The fungus infects dead buds and small branch wounds caused by hail, frost, or insect feeding. It is especially important on trees stressed by drought or other environmental factors. The degree of stress to the host determines how rapidly the fungus develops. It kills the young bark, which soon darkens and produces a flattened or depressed canker on the branch around the infection. The fungus develops mostly when the tree is dormant and produces its distinctive fruiting bodies in late spring or early summer.

Numerous spherical fruiting structures, 0.05 to 0.1 inch (0.5 to 1.5 mm) in diameter and height, develop all over the dead bark (Fig. 85). They range from flesh-colored to pink-orange initially, and later become brown or nearly black. This nonsexual stage of the fungus produces abundant spores. Later during the summer and fall, clusters of small red fruiting bodies also appear among the black forms produced earlier. The red structures are the sexual stage of the fungus. Both stages often are found on the same twig. Spores of both can infect fresh wounds.

Coral spot canker is considered an "annual" disease. The host tree usually regains enough vigor during the growing season to block the later invasion of new tissue. Maintaining good stand vigor should suffice as an effective control in forest stands.

Steganosporium ovatum is another common fungus of dying and dead maple branches (Fig. 86). It produces black fruiting structures on branches of trees stressed previously, especially by defoliation. Steganosporium appears to hasten dieback of stressed branches.

Maple canker. An annual canker that occasionally is found in large numbers on sugar maple, it first appears as a sunken area on stems or branches, with dead cambium underneath. As callus tissue develops around the dead area, the sunken

Figure 86.—Black fruiting structures of *Steganosporium ovatum* on the dead part of a sugar maple branch (Vermont Bureau of Forestry photo).

Figure 87.—Several annual cankers on a sugar maple stem (Pennsylvania State University photo).

bark falls away, exposing the underlying wood. Subsequent callus formation may completely close the lesion, and normal bark may form again during one growing season.

These cankers are lenticular and can be from 0.5 inch (1 cm) to several feet long, and from 0.5 to 8 inches (1 to 20 cm) wide (Fig. 87). They provide openings for secondary decay and stain organisms. Similar-looking cankers have been observed on red maple, black cherry, red oak, and white ash.

Cankers develop between late fall and early spring (during the dormant season). A species of *Fusarium,* probably *F. solani,* is suspected as the causal organism. This fungus is a common inhabitant of soil and of healthy bark of trees, apparently infecting bark wounds that extend to the cambium. Trees stressed by factors such as windstorms, sudden drops of temperature, or insect wounds are affected. Tree growth usually is not impaired and the lesions close over after a good growing season.

Canker Rots

Canker rots are perennial, canker-like distortions of tree stems. They are caused by certain wood-decay fungi that also can kill the inner bark (phloem) and cambium. Most canker-rot fungi enter stems through wounds and produce cankers by killing overlying bark tissues and decaying the wood underneath. After decaying the wood at the original wound, some canker rots form a mass of fungus tissue that spreads slowly through the bark and eventually kills the adjacent cambium and reinfects the wood underneath. These cankers enlarge as this process is repeated.

Inonotus glomeratus. Formerly *Polyporus glomeratus,* this fungus causes a relatively common canker rot on sugar maple. It reportedly is the most important decay fungus of sugar maple in Ontario, accounting for up to 40 percent of volume losses. It also is found on red maple and beech.

Branch stubs and wounds are the primary entry points for infection. Once the decay is advanced in the stem, the fungus produces a sterile, thick mass of tissue that spreads over the wound area or around the branch stub. This soon turns black, crusty, and cracked. The canker is irregularly shaped and generally becomes elongate with raised margins.

Canker rots produce fertile fruiting bodies or conks only after the tree dies. Canker rots cannot be eliminated from the forest, but maintaining healthy and wound-free trees and removing infected ones should reduce the incidence of these diseases.

Decays of Stems and Roots

Internal decays of stems and roots are inconspicuous. They develop slowly in trees for several years before their presence can be detected. Once they become visible it is too late to prevent damage. Sometimes the first signs are conks on stems or roots. Sometimes decays are not noticed until groups of trees begin to die back. When this occurs, decay already is extensive within the stems or roots systems. Once trees are badly decayed, the only remedy is to remove them. Conducting forestry activities in ways that minimize the number and severity of wounds to residual trees is the primary means of preventing stem and root decays.

Stem Decay

Stem-decay fungi infect trees through dead branches, branch stubs, cankers, and other wounds that expose the wood. Spores of decay fungi are common and abundant in the forest. Once a decay fungus has successfully invaded a tree stem, its progress cannot be controlled. However, unless the fungus also attacks the roots, the growth rate of the tree will not be reduced noticeably. Only after the decay becomes extensive within the tree is the damage easily detected.

Decayed trees may break and fall, creating large openings in the stand canopy. Sugaring operations can be adversely affected when good sap-producing trees die prematurely due to stem breakage or extensive decay.

Some Common Decay Fungi

Ganoderma applanatum. Formerly *Fomes applanatus, G. applantum* primarily affects living and dead aspen, basswood, beech, birch, cherry, elm, maple, oak, and poplar. Its common and easily recognized conk is semicircular or bracket-like, and has a woody texture (Fig. 88). A conk can live from 5 to 10 years. Each year it adds a new spore-producing layer over the previous one. The white surface of this layer and the new margin of growth visible on top of the conk contrast sharply with dark brown to gray older parts. When bruised or scratched, the white layer of this fungus immediately turns brown. Because of this, *G. applanatum* is known as the "artist's conk." Some conks may grow more than 3 feet (1 m) wide.

These conks dispense spores profusely from spring to fall. The spores are carried upward by air currents and sometimes form conspicuous brown deposits on or near the upper surfaces of the conks (Fig. 89). The relationship of tree wounds and infection by this fungus is well documented. By the time conks develop, the stem has extensive decay and is prone to break during a wind or ice storm.

Figure 88.—Conk of *Ganoderma applanatum* (artist's conk) on a sugar maple stem.

Figure 89.—The artist conk on a sugar maple log. Note the brown deposits of its spores on its top and on nearby leaves.

Oxyporus populinus. O. populinus, formerly *Fomes connatus,* is another major decayer of red and sugar maples. It is found primarily on ash, aspen, basswood, beech, birch, and elm. Like other decay organisms, infection occurs through wounds deep enough to expose the wood. The resulting decay seldom extends more than 3 feet (1 m) above or below the conks (Fig. 90). The conks often occur in clusters within old wounds, in cracks (Fig. 91), or at the centers of Eutypella (Fig. 83) or Nectria cankers. The irregularly shaped conks are white, spongy, shelf-like, and rarely larger than 6 inches (15 cm) in diameter. Typically, they have green moss growing on the upper surface (Figs 83, 92).

Fomes fomentarius. Fruiting bodies of *Fomes fomentarius,* known as the "tinder conk," can be found on sugar maple, but they are more common on birches and beech. They are perennial, woody, hoof-shaped, about 4 inches (10 cm) wide and relatively thick, and have a gray surface (Fig. 93). They are found on dead trees and on dead portions of living trees. Once the decay within a tree is extensive, the fungus produces conks on the stem in locations that bear no relationship to the presence of stem wounds.

Figure 91.—Fruiting bodies of *Oxyporus populinus* in a crack on a sugar maple stem.

Figure 90.—Split bolt of red maple showing part of a *Oxyporus populinus* conk (on left) with decay caused by this fungus extending above and below it.

Figure 92.—Typical shelf-like conks of *Oxyporus populinus,* covered with green moss, on a sugar maple tree butt.

Figure 93.—"Tinder conks" of *Fomes fomentarius.*

Climacodon septentrionalis. A conspicuous conk occasionally seen on maple, *C. septentrionalis* (formerly *Steccherinum septentrionale)* is a large, fleshy, creamy white fruiting body composed of a cluster of shelf-like projections placed one above the other (Fig. 94). The entire structure may be as much as 1 foot (30 cm) wide and 25 to 30 inches (60 to 75 cm) long. The fungus infects through wounds and cracks and less commonly through dead branches, causing a white spongy rot with characteristic black zone lines in the advanced decay. Decay in the tree is extensive by the time conks appear.

Laetiporus sulfureus. Another conspicuous fruiting body is produced by *L. sulfureus* (formerly *Polyporus sulfureus).* Clusters of shelf-like structures appear on infected trees in summer and early fall (Fig. 95). They are soft, fleshy, and bright sulfur-orange to salmon colored when fresh. Fruiting bodies can be 8 to 12 inches (20 to 30 cm) wide. This fungus causes one of the most important brown rots of maple, ash, beech, cherry, oak, and several other broad-leaved and coniferous trees. *L. sulfureus* decays roots, butts, and stems. It significantly reduces wood strength, rendering infected trees susceptible to breakage and windthrow. Infection sites for this fungus are not known.

Root and Butt Rots

Root and butt rot fungi can substantially reduce the growth of affected trees. The examples discussed here are the most important and common rots that affect sugar maple.

Figure 94.—Large fleshy fruiting body of *Climacodon septentrionalis* on a sugar maple trunk.

Figure 95.—Large, sulfur-orange fruiting body of *Laetiporus sulfureus.*

Armillaria root rot. Armillaria root rot, sometimes called shoestring root rot, is one of the most destructive diseases affecting the roots and butts of most tree species, both conifer and broad leaved. Infection by Armillaria can result in rapid mortality, reduced growth, or increased susceptibility to windthrow. Generally, decay is not extensive in living trees, but it spreads rapidly when the tree dies. Armillaria can infect and establish itself in the nonwounded root systems of stressed trees and widespread death of large trees can occur suddenly following severe stresses such as recurring droughts or severe defoliations. When the stress abates, many trees are able to contain the further spread of the fungus while they recover. Infection is most likely to occur where there are nearby infected hardwood stumps to serve as food bases for the fungus. The fungus spreads from diseased to nearby trees through roots or by means of fungal structures called rhizomorphs which penetrate intact bark of stressed trees. Rhizomorphs are black and cord-like and grow freely in the soil so long as they remain attached to stumps or roots that serve as their food bases. After infection, the fungus spreads in the cambial zone under the bark and produces a white mat of tissue (Fig. 96). When conditions are favorable, the fungus spreads to other roots and up to the root collar where it may girdle the tree. Usually, at this stage there has been little wood decay. Visible growth reduction and crown symptoms (smaller and lighter colored leaves or branch dieback) will appear only after one-half or more of the root system is killed. When a tree dies, the mat of white fungus tissue beneath the bark is rapidly replaced by rhizomorphs (Fig. 97), and the active wood-decay stage sets in. The root system of dead trees or stumps can supply Armillaria with food energy for up to 10 years, enabling it to produce rhizomorphs and infect nearby stress-weakened trees.

Figure 96.—White fungus mat of Armillaria under the bark of a diseased sugar maple tree.

This fungus produces an edible, honey-colored mushroom (Fig. 98). The central stalk is 2 to 4 inches (5 to 10 cm) long and generally has a ring on its upper part. The yellowish brown cap is 1 to 4 inches (3 to 10 cm) in diameter and in late summer occurs in clusters of 5 to 10 on dead stumps. Mushrooms also are found on roots of infected trees or directly on the soil, but they are always attached to an underlying infected root.

Figure 97.—Rhizomorphs (black cord-like structures) of Armillaria under the dead bark of a sugar maple tree.

Figure 98.—"Honey mushrooms" of Armillaria.

Management of Armillaria root rot entails keeping stands as vigorous as possible. Under most circumstances, controlling high populations of insect defoliators is warranted. However, little can be done to combat drought, which seems to be one of the major stress factors that increases susceptibility to infection. Mechanical injury to roots as well as soil compaction should be avoided. Experiments have shown that partially burning or debarking and chipping infected stumps accelerates their decay. This rapidly reduces their potential as food bases for the fungus.

Hypoxylon root and butt rot. The root and butt rot fungus *Hypoxylon deustum* (formerly *Ustulina vulgaris)* infects trees through mechanical wounds on the butt and large roots. It also spreads from parent stumps to sprouts. While causing some root and butt decay in living trees, the fungus becomes most active as a wood-decay organism in dead or downed trees. It forms large masses of tissue near the original wound or on the cut surface of stumps. These masses of fungal tissue are grayish and leathery at first, but soon become black and brittle (Fig. 99). Minute fruiting bodies eventually develop in this tissue. *H. deustum* affects sugar and red maples, ash, basswood, beech, birch, and many oaks.

This fungus is common though not serious in sugarbushes. Minimizing the number of large wounds at the base of trees or on large roots should limit its development in a stand.

Black root rot. Another disease of sugar maple, black root rot *(Xylaria polymorpha)* is sometimes confused with Hypoxylon root rot. Xylaria causes root decay, especially of stressed trees. It is recognized by a black mycelial sheet that develops on decaying roots. In late summer or early fall, clusters of gray to black finger-like to club-shaped fruiting bodies, 1 to 2 inches (3 to 5 cm) tall, develop on large infected roots or butts (Fig. 100). The appearance of these structures has evoked the common name "dead man's fingers." Above ground, symptoms of infection include reduced growth and sparse, chlorotic, and dwarfed foliage. These appear when the infection is severe. A tree may show symptoms only on one side of the crown if only one large root is infected.

Vascular Diseases

Verticillium Wilt *(Verticillium albo-atrum)*

Diseases of the tree's vascular (water-conducting) system generally are not common in the forest or sugarbush. For example, Verticillium wilt damages mainly urban shade trees. The pathogen is a long-lived, soil-borne fungus. Susceptible trees may become infected if they are planted where diseased ones were removed. The fungus also can be transmitted from tree to tree on pruning tools. It is unlikely, therefore, that Verticillium wilt will constitute a significant forest problem. However, in the sugarbush, the pathogen could be carried from diseased to healthy trees during tapping, especially if infected trees near highways or homes are included among those being tapped. Because the organism is present in the soil, there also is the possibility that infection could occur through root and stem wounds.

Foliage of diseased trees may suddenly wilt at any time during the growing season. A few branches, whole sections of the crown (Fig. 101), or the entire crown may show symptoms. Trees with only small portions of crown affected may recover. Those with much or all of their crowns affected probably will die, often rapidly. Stem cross sections show spots or partial to complete circular bands of dark green discoloration involving one or more growth rings (Fig. 102). The discolored streaks may be limited to the trunk or can extend even to the tips of wilting branches.

Figure 99.—Brown to black stromata (hard fungus tissues) of *Hypoxylon deustum* on a sugar maple tree.

Figure 100.—Finger-like fruit bodies of *Xylaria polymorpha.*

Sapstreak Disease *(Ceratocystis coerulescens (C. virescens)*

Sapstreak disease can be a serious problem in the sugarbush. The causal organism is one of the most common stain fungi of northern hardwood logs and bolts. It can enter and kill wounded trees. The primary avenues of infection are root and buttress injuries made by skidding or sap hauling (Fig. 103). Recent observations also suggest that trees can become infected through stumps created when sprout clumps are thinned (Fig. 104). Outbreaks of sapstreak always have been associated with logging or with sugaring. There is no evidence that broken branches, insect injuries, or even tapholes are suitable sites for infection to begin.

A sparse crown usually is the first sign that a sugar maple tree has sapstreak. Leaves often are one-half or less than normal in size (Fig. 105). Sometimes, trees die suddenly. In fact, trees without symptoms during one year may fail to leaf out the next; others may succumb within a year or so. By contrast, some trees may linger for many years, showing progressive dieback before they die. Some may even recover.

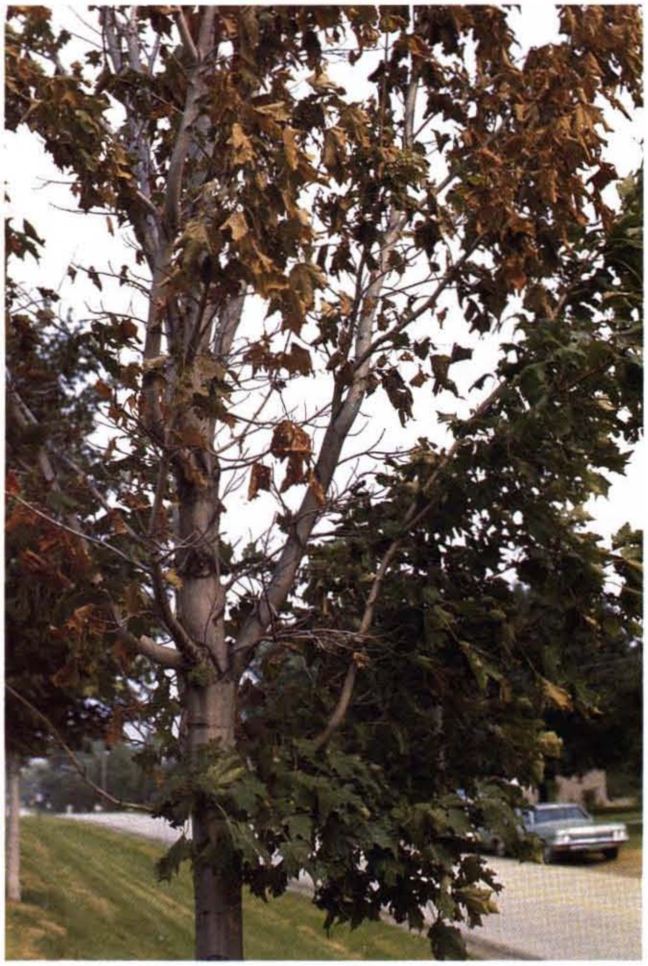

Figure 101.—Verticillium wilt affects urban sugar maples and usually is not serious in sugarbushes. Portions of the affected tree's crown may wilt suddenly and die when the sap-conducting system becomes infected by the soil-borne pathogen (Pennsylvania State University photo).

Figure 102.—Green discolored streaks of sapwood are characteristic of Verticillium wilt (Cornell University photo).

Figure 103.—Injuries made to roots and lower stems during skidding or sap-hauling allow the sapstreak disease fungus to enter the sapstream of the tree.

Figure 104.—Trees can become infected by sapstreak disease through the stump "wound" created when a member of a sprout clump is removed.

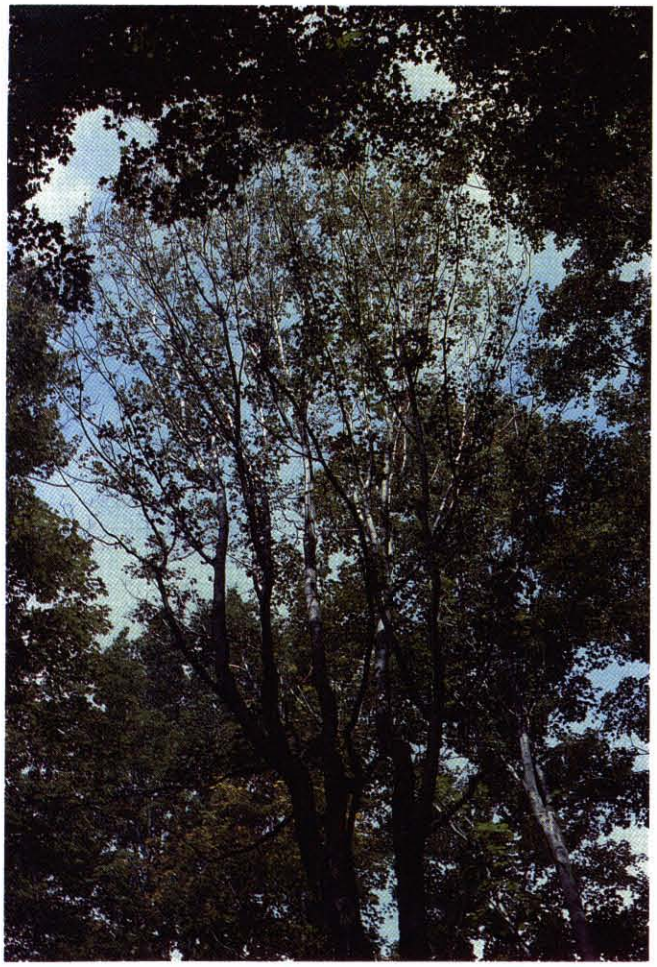

Figure 105.—Early symptoms of sapstreak disease are small leaves that result in a thin crown.

Figure 106.—Sapsteak disease gets its name from the distinctive stain it causes in the wood of roots and lower stems.

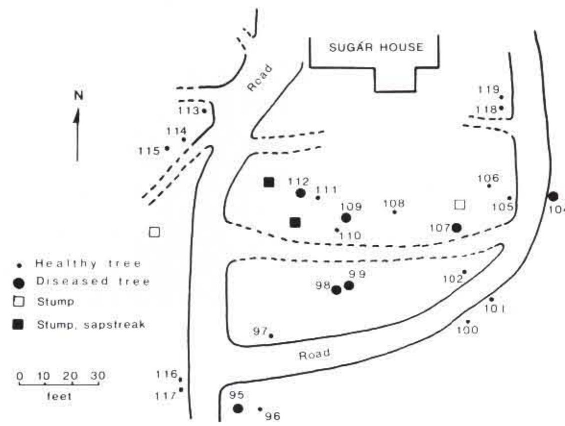

Figure 107.—Sapstreak sometimes affects trees in groups. Within this group near a sugarhouse, many trees were injured repeatedly during sap and wood hauling.

Wood of buttress roots and lower stems has a stain with a unique color and pattern. Freshly exposed stain is moist, and drill shavings from such wood will be "mealy" in consistency and discolored compared to clean, white shavings from healthy wood. The stain is yellowish-green, bordered by a thin dark green margin (Fig. 106). It contains flecks or streaks that are reddish when fresh. Soon after exposure to air, the stain darkens and the red flecks become less distinct. The dark stain then fades to a light brown. In cross sections, the stain appears to radiate outward toward the bark (Fig. 106). Cankers develop where the cambium comes in contact with the spreading stain column.

Most trees affected by sapstreak are located along trails where logs have been skidded or sap has been hauled. The more heavily used the roadway, the more likely it is that adjacent trees will be wounded. More diseased trees have been observed in sugarbushes where buckets are used than where tubing is used. This reflects the greater number of wounds inflicted during the many trips to gather sap.

Sapstreak trees often occur in groups, sometimes close to the sugarhouse (Fig. 107). Such localization could result from the pathogen being carried from diseased to healthy trees by ground-inhabiting organisms (insects, millipedes, etc.), from wounding of groups of trees at specific times, or from interaction with other root pathogens known to attack and kill trees in groups. Nearly all trees killed by sapstreak also are severely attacked by one or more root fungi (Armillaria and/or Xylaria) (Figs. 108, 100).

Because the sapstreak fungus often grows and produces spores on the ends of bolts cut from diseased trees, piling wood from diseased trees near the sugarhouse may serve to build high concentrations of inoculum (spores and other fungus materials that can spread disease). Since such buildups could increase the chances of infection in nearby trees, fuel wood from trees killed by sapstreak should be removed from the sugarbush promptly and used elsewhere.

Figure 108.—White "fan" of Armillaria. Roots of sapstreak-diseased trees frequently are attacked and girdled by this fungus.

Management of these vascular diseases should focus on reducing injuries to roots, buttress roots, and lower stems, and preventing an increase of the vascular pathogens and the commonly associated root pathogens.

For both sapstreak and Verticillium wilt it is of paramount importance to avoid injuring roots and lower stems when gathering sap, hauling wood, or skidding logs. Injuries can be reduced by using the same well-placed trails each year, the smallest machinery possible, and tubing systems rather than buckets. These measures are particularly important on steep, slippery slopes. Because trampling injuries by cows or horses also have been associated with incidents of sapstreak, these animals should not be allowed to graze the sugarbush. And, as mentioned earlier, prompt removal from the sugarbush of wood from sapstreak-infected trees will help reduce the buildup of infectious inoculum.

ANIMAL DAMAGE

Wildlife

Wild animals may cause problems for sugarbush operators as some can injure maple trees or damage equipment, occasionally causing significant losses in time and money. Sugarbush managers frequently are concerned about the impact of deer on sugar maple seedlings and saplings that will make up the future stand, because the buds of such seedlings and saplings can be a major component of a deer's winter diet. Frightened deer running through a sugarbush can destroy tubing but generally they cause little damage to equipment.

Red and gray squirrel, snowshoe hare, cottontail rabbit, porcupine, mice, and a variety of birds sometimes feed on sugar maple stem bark, buds, or twigs. This damage is rarely serious, though significant damage by squirrels stripping bark from buttress roots has been reported. Also, squirrels and chipmunks can cause extensive and costly damage by puncturing and chewing plastic tubing (Fig. 109). It is not known what attracts these animals to tubing. Sweetness of maple sap and the salt that is imparted to the tubing when the plastic is manufactured—especially chlorine salt that is deposited by cleaning solutions—have been implicated. Chlorine salts can be removed by thoroughly rinsing tubing and using low concentrations of the cleaning solution. New tubing produced by a variety of manufacturers (tubing that is salt free and that never has had sap in it) also attracts squirrels. Perhaps squirrels, like most rodents, must contantly use their teeth to prevent them from becoming too long. Curiosity alone may be enough to attract these pests to "foreign objects." Once contact has been made, rodents not only gnaw on tubing but also on spigots, connectors, and couplings.

Rodent damage may vary among regions and from year to year, but once the problem occurs it is difficult to control. Some operators coat tubing and fixtures near the tree with distasteful substances, such as a mixture of cayenne pepper and varnish. Obviously, care must be taken to keep these materials out of the sap. Poison baits also have been used to control rodents. However, because the use of such

Figure 109.—Plastic tubing damaged by squirrels or chipmunks.

materials may be restricted in some states and provinces, sugarbush operators should consult with appropriate pest control agencies or wildlife enforcement officials.

Mice may cause damage in years when their populations are high and competition for food forces them to feed on the thin bark of sugar maple saplings or seedlings. Sugar maple plantations should be protected from this type of damage. Protective metal shields or 0.25-inch (6.0-mm) mesh hardware cloth can be placed around the base of each stem to prevent feeding. Also, approved commercially prepared baits can be distributed throughout areas of concern. Because heavy grass cover provides ideal habitat for mice, cutting grass in fields adjacent to sugarbushes will help reduce mouse populations.

Porcupine subsist on bark in the winter. Sugar maple is not their preferred food, but when their populations are high, porcupine can seriously damage maple by girdling stems and large branches (Fig. 110). This animal usually does not venture far from its den. When damage appears in a sugarbush, the most effective method of control is to locate the den and destroy the animals. The den also should be destroyed or blocked to prevent its re-use by other porcupine. Likely denning sites are large hollow trees, small caves, and the walls of old foundations.

Some States or Provinces permit the use of poisoned baits or hunting to control porcupine. In others, porcupine may be protected. It is important, therefore, to consult local, State, and Provincial officials before using such measures.

Domestic Animals

Sustained moderate to heavy grazing by livestock has reduced sap production and caused the deterioration of sugar maple trees. Grazing of sugarbushes still is common in many regions, and sugarbush operators should realize that grazing can reduce the vigor, longevity, and productivity of a sugarbush. In addition, heavy grazing encourages the growth of nongrazed undesirable species.

Mechanical damage to sugar maple root systems commonly occurs from trampling by grazing animals (Fig. 111). Broken or debarked roots provide infection courts for fungus pathogens. When large roots are damaged severely, major branches located above the root also may die. This reduces crown size and ultimately reduces sap production.

Frequent movement of cattle through a sugarbush can compact the soil (Fig. 111). This can result in water runoff and erosion of the site when water cannot penetrate the compacted soil. Compaction also can damage rootlets and inhibit the uptake of moisture and nutrients.

Figure 110.—Porcupine damage at the base of a sugar maple. The dark area represents old feeding.

Figure 111.—Damaged sugar maple roots and compacted soil caused by cattle trampling.

Figure 112.—Declines of sugar maple occur in the forest (left), in the sugarbush (center), and along highways (right).

DIEBACKS AND DECLINES: STRESS-TRIGGERED COMPLEXES

Sugar maple suffers from a group of stress-initiated diseases known as diebacks and/or declines (Fig. 112). These diseases occur when trees, weakened or altered by adverse environmental factors, are invaded and sometimes killed by secondary-action organisms. The primary stresses range from abiotic factors (such as too much or too little heat and moisture) to biotic factors (such as defoliation by insects or fungi). The organisms that invade and kill stressed sugar maples are common forest fungi that usually hasten the death of weak, suppressed trees and facilitate nutrient cycling.

Roadside trees often bear conspicuous evidence of the cumulative adverse effects of winter road salt (Fig. 113). In addition to the direct damage it causes, salt also is known to intensify the effects of drought on sugar maple. For the most part, however, the stresses that trigger maple decline are ones that interfere in major ways with the manufacture (photosynthesis) and storage of sugars (for example, defoliation by insects, fungi, frost), and with the absorbtion and transport of soil nutrients and moisture (for example, drought, flooding, root freezing). When these occur in concert or in sequence, the effects can be disastrous.

The most important complex of causal agents responsible for maple decline in the sugarbush and forest has been insect defoliation followed by attacks of Armillaria (Figs. 96-98). Significant episodes of decline have followed outbreaks of many insects, especially the forest tent caterpillar and saddled prominent. In some stands, where defoliation occurred during drought years, tree mortality reached 100 percent.

Atmospheric deposition, particularly acid rain, has received much attention as a possible stress factor in maple decline. Reduced growth and sometimes the onset of tree dieback, decline, and mortality in some forests are reportedly correlated with increases in deposition. Many researchers suspect that acidic substances, and perhaps ozone and heavy metals, will change nutrient cycling. Yet few agree on what these changes will be other than that they will be subtle, complex, and variable. Because correlations do not constitute proof of causality, much research is underway to determine the role, if any, of atmospheric deposition in maple decline. A major difficulty facing researchers is determining how to separate the effects of atmospheric deposition from those wrought by the multitude of other natural and anthropogenic (caused by people) disturbances that are common in the sugarbush.

Maples suffering from dieback/decline show a variety of symptoms that generally includes the progressive deterioration of the crown (Fig. 114). This begins with the death of buds and the dieback of twigs starting at the margin of the crown and progressing inward and downward (Fig. 115). Leaves of declining trees are often small, sparse, and off-color (Fig. 116). Frequently, foliage in successive years is borne on sprouts and may appear clumped or tufted (Fig. 117). Leaves may show fall color and drop prematurely (Fig. 118). Terminal and radial growth sometimes slows even before external symptoms appear.

Figure 113.—Along roadsides, trees are stressed by drought, by road paving, and especially by de-icing salt.

Changes also occur inside defoliated trees. Defoliation of about 60 percent or more triggers refoliation and results in the conversion of root starch reserves to simple sugars for use in the manufacture of new leaves and buds. Much

Figure 114.—Aerial view of sugar maples around a sugar house showing the crown symptoms of maple decline ranging from early fall coloration to crown dieback to tree death.

Figure 115.—Dieback of sugar maple begins in the upper crown near the tips of the branches.

Figure 116.—Early symptoms of maple dieback/decline include leaves that are small, sparse, and off-color.

Figure 117.—Clumping or tufting of foliage occurs when foliage is produced on tissues of sprout origin following stresses such as defoliation the previous year.

Figure 118.—Early fall coloration is an indication that trees are under stress.

energy is used in these processes. These energy shifts also seem to enhance the invasion of roots and root collars by the shoestring fungus, Armillaria.

The simple sugars are exceptionally good energy sources for Armillaria and their abundance stimulates the fungus to grow rapidly between the bark and wood and girdle roots and lower stems. The drastic changes in the energy balance of the tree brought about by defoliation also can reduce the quality and quantity of sugar available for making syrup.

Studies of a forest maple decline triggered by insect defoliators revealed that damage was greatest in pure, open sugar maple stands (features of most sugarbushes). Because sun-loving defoliators are favored by such stands, direct control of these insects usually is warranted when their populations reach levels that will result in heavy defoliation of sugarbush trees. Periodic harvests of large trees will leave many large stumps that are good energy sources for Armillaria, a situation that places residual trees in jeopardy should they become stressed. Armillaria probably will be less of a threat in sugarbushes, whose open character can be achieved when trees are young. Small stumps degrade rapidly and soon become unsuitable sources of energy for this fungus.

CONCLUSION

The goal in managing a sugarbush is to produce as much high-quality sap as possible over a sustained period. This is done by providing trees with the best possible growing conditions and protecting them from as many stresses as possible.

Integrated pest (problems) management (IPM) is a sound approach to the overall "health management" of a sugarbush. *In a truly integrated approach, every contemplated activity is weighed carefully to assess possible short- and long-term consequences.*

Early recognition of pests, an understanding of their potential effects, and a knowledge of how and when to deal with them are essential to good health management. Also, many sugarbush problems result directly or indirectly from human activity. Every disturbance, including those resulting from forest management, has significant consequences. Disturbances affect trees and other forest organisms either beneficially or adversely.

As the intensity of management increases, so do pest problems. Some general "rules" or guidelines are:

1. *Learn as much as possible about your sugarbush as a biological community.*

2. *Conduct operations to ensure adequate numbers, distribution, and growth of quality crop trees.*

3. *Understand the consequences of creating a pure stand of sugar maple.*

4. *Avoid wounding roots and stems, and compacting soil.*

5. *Give trees time to recuperate from stress events.*

6. *Ensure that tapping is done properly. Follow carefully guidelines on the number of taps to use for trees of different diameter and on how to place them.*

7. *Do not use paraformaldehyde.*

8. *Remove all spouts soon after sap flow stops.*

9. *Watch for the occurrence of insect and disease pests.*

10. *Learn who the local experts are and contact them before problems become unsolvable.*

ACKNOWLEDGMENT

We gratefully acknowledge the following for their thoughtful reviews of the manuscript: Arch Jones, Macdonald College of McGill University, Ste. Anne de Bellevue; Fred Laing, University of Vermont, Burlington; Ralph Nyland, State University College of Environmental Science and Forestry, Syracuse, New York; Peter Rennie, Forestry Canada, Ottawa; Marcien Roberge, Forestry Canada, Ste. Foy; Lew Staats, Cornell University, Lake Placid, New York; and Brent Teillon, Vermont Department of Forests, Parks and Recreation, Waterbury. We also thank the many people both from within and outside our respective institutions who generously contributed illustrations. Photos contributed by outside institutions are acknowledged on the captions that accompany them.

The authors also wish to acknowledge the support of the North American Sugar Maple Decline Project (NAMP), in particular, the Joint Management Team, Dr. Max McFadden (USDA Forest Service) and Dr. Les Carlson (Forestry Canada). The authors also wish to acknowledge the early leadership of the late Dr. Peter Rennie (Forestry Canada) as Canadian Co-Chair of the Joint Management Team.

NAMP research in the United States is supported in part by funds provided by the Northeastern Forest Experiment Station, Eastern Hardwoods Research Cooperative, within the joint USDA Forest Service-U.S. Environmental Protection Agency Forest Response Program. The Forest Response Program is part of the National Acid Precipitation Assessment Program. This report has not been subject to EPA or Forest Service policy review and should not be construed to represent the policies of either Agency.

NAMP research in Canada is supported by funds provided by Forestry Canada and by cooperating Provinces.

SELECTED REFERENCES

GENERAL

Coons, C. F. 1987. **Sugar bush management for maple syrup producers. (Rev. ed.).** Toronto, ON: Ministry of Natural Resources, Forest Resources Branch. 48 p.

Morselli, M. F.; Whalen, M. L. 1987. **Maple research publications list.** Burlington, VT: Vermont Agricultural Experiment Station and Cooperative Extension Service; Publ. Q-227.

University of Wisconsin-Extension. 1986. **Integrated pest management symposium for northern forests: the proceedings.** 1986 March 24-27; Madison, WI. Madison, WI: University of Wisconsin, Cooperative Extension Service. 333 p.

U.S. Department of Agriculture, Forest Service. 1982. **Sugar maple research: sap production, processing, and marketing of maple syrup.** Gen. Tech. Rep. NE-72. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 109 p.

ABIOTIC DISTURBANCES

Erdmann, G. G.; Metzger, F. T.; Oberg, R. R. 1979. **Macronutrient deficiency symptoms in seedlings of four northern hardwoods.** Gen. Tech. Rep. NC-53. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 36 p.

Skelly, J. M. (and others), eds. 1987. **Diagnosing injury to eastern forest trees.** Atlanta, GA: U.S. Department of Agriculture, Forest Service, University Park, PA: The Pennsylvania State University, College of Agriculture. 122 p.

BIOTIC DISTURBANCES

Allen, D. C. 1987. **Insects, declines and general health of northern hardwoods: issues relevant to good forest management.** In: Nyland, Ralph D., ed. Managing northern hardwoods: a silvicultural symposium; 1986 June 23-25; Syracuse, NY. Fac. of For. Misc. Publ. No. 13 (ESF 87-002): SAF Publ. No. 87-03. Syracuse, NY: State College of New York: 252-285.

Benoit, P.; Lachance, D. 1982. **Insects, maladies, vertebres nuisibles.** Erablierge Agdex. 300/600. Conseil des productions vegetales du Quebec. Ministry Agriculture Pecheries et Alimentation du Quebec. 13 p.

Hepting, G. H. 1971. **Diseases of forest and shade trees of the United States.** Agric. Handb. 386. Washington, DC: U.S. Department of Agriculture. 658 p.

Houston, D. R. 1985. **Sapstreak of sugar maple; how serious is it?** Maple Syrup Digest. 25: 24-27.

Houston, D. R. 1986. **Insects and diseases of northern hardwood ecosystems.** In: Proceedings of the conference on the northern hardwood resouces: management and potential: 1986 August 18-20; Houghton MI, Houghton, MI: Michigan Technological University: 109-138.

Johnson, W. T.; Lyon, H. H. 1988. **Insects that feed on trees and shrubs.** 2nd ed. Ithaca, NY: Cornell University Press.

Martineau, R. 1984. **Insects harmful to forest trees.** For. Tech. Rep. 32. Ottawa, ON: Multiscience Publishers Ltd. and Canadian Forestry Service. 261 p.

Martineau, R. 1985. **Insects nuisibles des forets de l'est du Canada.** Rapp. Tech. for. 32F. Ottawa, ON: Editions Marcel Broquet Inc. et Service Canadien des Forets. 283 p.

Shigo, A. L. 1977. **Compartmentalization of decay in trees.** Agric. Inf. Bull. No. 405. Washington, DC: U.S. Department of Agriculture, Forest Service. 73 p.

Shigo, A.L. 1979. **Tree decay: an expanded concept.** Agric. Inf. Bull. No. 419. Washington, DC: U.S. Department of Agriculture, Forest Service. 73 p.

Sinclair, W. A.; Lyon, H. H.; Johnson, W. T. 1987. **Diseases of trees and shrubs.** Ithaca, NY: Comstock Publishers Association: 574.

U.S. Department of Agriculture, Forest Service. 1985. **Insects of eastern forests.** Misc. Publ. No. 1426. Washington, DC: U.S. Department of Agriculture, Forest Service. 608 p.

DIEBACKS AND DECLINES

Giese, R. L.; Houston, D. R.; Benjamin, D. M.; Kuntz, J.E.; Kapler, J. E.; Skilling, D. D. 1964. **Studies of maple blight.** Res. Bull. 250. Madison, WI: University of Wisconsin. 128 p.

Houston, D. R. 1981. **Stress-triggered tree diseases: the diebacks and declines.** NE-INF-41-81. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 36 p.

Houston, D. R. 1986. **Recognizing and managing diebacks/ declines.** In: Integrated pest management symposium for northern forests: the proceedings. 1986 March 24-27; Madison, WI. Madison, WI: University of Wisconsin, Cooperative Extension Service: 153-166.

Wargo, P. M. 1975. **Estimating starch content in roots of deciduous trees—a visual technique.** Res. Pap. NE-313. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 9 p.

Wargo, P. M. 1978. **Judging vigor of deciduous hardwoods.** Agric. Inf. Bull. 418. Washington, DC: U.S. Department of Agriculture, Forest Service. 15 p.

Wargo, P. M.; Houston, D. R. 1974. **Infection of defoliated sugar maple trees by *Armillaria mellea.*** Phytopathology. 64: 817-822.

TAPPING

Jones, C. H. 1967. **The maple rule of eighty-six (Dec. 1946).** National Maple Syrup Digest. 6: 18-19.

Marvin, J. W.; Morselli, M. F.; Laing, F. M. 1967. **A correlation between sugar concentration and volume yields on sugar maple: an 18-year study.** Forest Science. 13: 346-351.

Shigo, A. L.; Laing, F. M. 1970. **Some effects of paraformaldehyde on wood surrounding tapholes in sugar maple trees.** Res. Pap. NE-161. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 11 p.

Walters, R. S.; Shigo, A. L. 1978. **Discoloration and decay associated with paraformaldehyde-treated tapholes in sugar maple.** Canadian Journal of Forest Research. 8: 54-60.

Walters, R. S.; Shigo, A. L. 1978. **Tapholes in sugar maples: what happens in the tree.** Gen. Tech. Rep. NE-47. Upper Darby, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 12 p.

Wargo, P. M. 1977. **Wound closure in sugar maples: adverse effects of defoliation.** Canadian Journal of Forest Research. 7: 410-414.

SUGARBUSH STRUCTURE AND DEVELOPMENT

Lancaster, K. F., Walters, R. S.; Laing, F. M.; Foulds, R. T. 1974. **A silvicultural guide for developing a sugarbush.** Res. Pap. NE-286. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 11 p.

Ministere des Ressources Naturelles, Nouveau-Brunswick, 1984. **Guide pour l'eclaircie des erablieres 1985.** Service de consultation forestiere. Fredericton, NB: Ministere des Ressources Naturelles, Nouveau-Brunswick. 15 p.

Morrow, R. E. 1976. **Sugar bush management.** Inf. Bull. 110. Ithaca, NY: New York State College of Agriculture and Life Sciences, Cornell University. 19 p.

New Brunswick Ministry of Natural Resources & Energy. 1988. **A guide to sugar bush thinning 1988.** Fredericton, NB: New Brunswick Ministry of Natural Resources & Energy. 15 p.

Robitaille, L.; Roberg, M.; Belanger, M. 1977. **Selection et eclaircie des erables.** Erabliere Agdex 300/25. Conseil des productions vegetales du Quebec. Ministere Agriculture Pecheries et Alimentation du Quebec. 13 p.

Vezina, P. E.; Roberg, M. R. 1981. **Comment amenager nos forets.** Quebec, PQ: Presses de l'Universite Laval. 273 p.

APPENDIX

FIELD TESTING FOR SAP SWEETNESS

Testing for sap sweetness is the second step in crop-tree selection. As a first step, select dominant or codominant maples with good stem and crown forms, and that are free of defects. This is best done in the summer when trees are in leaf. Then mark the crop trees with paint or vinyl ribbons. The painted numbers can be used to help keep sweetness records for each tree.

The percentage of sugar in maple sap varies considerably during each day, from day to day, and during the tapping season, so measurements of sweetness between trees or groups of trees should be made at short intervals, for example, a 2-hour period. Note that measurements taken at any time are only relative values. A tree's sap may read 5 percent in the morning and 2.5 percent in the afternoon. Even so, the sweetest trees among a group of trees always will rank the same.

Using a sugar refractometer (Fig. 3) is the easiest way to test sap for sweetness. The method is fast, and the instrument is relatively easy to use, and requires only one drop of sap per reading. It is easily calibrated in relation to air temperature. After each reading it should be cleaned with distilled water and dried with a clean cloth.

To obtain sap from the trees, use an awl or a small nail to punch a hole through the bark and into the wood. Keep the wound small. Then firmly insert a hypodermic needle or a toothpick. Soon, sap droplets should appear at the end of the sloping needle or toothpick. Let 10 to 20 drops fall before catching one on the refractometer and taking a reading. This helps to make the results more uniform between trees. Testing will be more easily done on a day with good sap flow. Do not test on rainy or windy days. It may be easier to work with a hypodermic needle, but it must be washed after each reading. Toothpicks are simply discarded.

CLASSIFICATION OF INSECT AND DISEASE PESTS

Insects

Early-Season Defoliators

Bruce spanworm *(Operophtera bruceata)*
Fall cankerworm *(Alsophila pometaria)*
Forest tent caterpillar *(Malacosoma disstria)*
Alsophila pometaria (Fall cankerworm)
Malacosoma disstria (Forest tent caterpillar)
Operophtera bruceata (Bruce spanworm)

Late-Season Defoliators

Greenstriped mapleworm *(Dryocampa rubicunda)*
Maple leafcutter *(Paraclemensia acerifoliella)*
Orangehumped mapleworm *(Symmerista leucitys)*
Saddled prominent *(Heterocampa guttivitta*
Whitemarked tussock moth *(Orgyia leucostigma)*
Dryocampa rubicunda (Greenstriped mapleworm)
Heterocampa biundata
Heterocampa guttivitta (Saddled prominent)
Orgyia leucostigma (Whitemarked tussock moth)
Paraclemensia acerifoliella (Maple leafcutter)
Symmerista leucitys (Orangehumped mapleworm)

Other Defoliators

Gypsy moth *(Lymantria dispar)*
Lesser maple leafroller *(Acleris chalybeana)*
Linden looper *(Erannis tiliaria)*
Maple leafblotch miner *(Cameraria aceriella)*
Maple leafroller *(Sparganothesis acerivorana)*
Maple petiole borer *(Caulocampus acericaulis)*
Maple trumpet skeletonizer *(Epinotia aceriella)*
Maple webworm *(Tetralopha asperatella)*
Acleris chalybeana (Lesser maple leafroller)
Cameraria aceriella (Maple leafblotch miner)
Caulocampus acericaulis (Maple petiole borer)
Epinotia aceriella (Maple trumpet skeletonizer)
Erannis tiliaria (Linden looper)
Lymantria dispar (Gypsy moth)
Sparganothesis acerivorana (Maple leafroller)
Tetralopha asperatella (Maple webworm)

Other Insect Pests

Aphids
Pear thrips *(Taeniothrips inconsequens)*
Taeniothrips inconsequens (Pear thrips)

Wood Borers

Ambrosia beetle *(Xyloterinus politus)*
Pigeon tremex *(Tremex columba)*
Pitted ambrosia beetle *(Corthylus punctatissimus)*
Sugar maple borer *(Glycobius speciosus)*
Corythylus punctatissimus (Pitted ambrosia beetle)

Glycobius speciosus (Sugar maple borer)
Tremex columba (Pigeon tremex)
Xyloterinus politus (Ambrosia beetle)

Conspicuous Insects of Little Consequence

Cottony maple scale *(Pulvinaria innumerabilis)*
Crimson erineum gall mite *(Aceris regulus)*
Gouty vein midge *(Dasineura communis)*
Lecanium scale *(Parthenolecanium* sp.)
Maple bladdergall mite *(Vasates quadripedes)*
Maple spindlegall mite *(Vasates aceris-crumena)*
Ocellate gall midge *(Acericecis ocellaris)*
Snout beetles *(Plyllobius oblongus, Sciaphilus asperatus)*
Acericecis ocellaris (Ocellate gall midge)
Dasineura communis (Gouty vein midge)
Aceris regulus (Crimson erineum gall mite)
Parthenolecanium sp. (Lecanium scale)
Phyllobius oblongus (Snout beetle or weevil)
Pulvinaria innumerabilis (Cottony maple scale)
Sciaphilus asperatus (Snout beetle or weevil)
Vasates aceris-crumena (Maple spindlegall mite)
Vasates quadripedes (Maple bladdergall mite)

Diseases

Leaf Diseases

Anthracnose *(Aurobasidium apocryptum* = Kabatiella apocrypta)
Phloeospora leaf spot *(Phloeospora aceris)*
Phyllosticta leaf spot *(Phyllosticta minima)*
Tar spots *(Rhytisma acerinum, R. punctatum)*
Aurobasidium apocryptum = Kabatiella apocrypta (Anthracnose)
Phloeospora aceris (Phloeospora leaf spot)
Phyllosticta minima (Phyllosticta leaf spot)
Rhytisma acerinum (Tar spot)
Rhytisma punctatum (Tar spot)

Cankers

Coral spot canker *(Nectria cinnabarina)*
Eutypella canker *(Eutypella parasitica)*
Maple canker *(Fusarium solani)*
Nectria canker (target canker) *(Nectria galligena)*
Eutypella parasitica (Eutypella canker)
Fusarium solani (Maple canker)
Nectria cinnabarina (Coral spot canker)
Nectria galligena (Nectria canker, target canker)
Steganosporium ovatum

Decays

Artist's conk fungus *(Ganoderma applanatum = Fomes applanatus)*
Black root rot *(Xylaria polymorpha)*
Canker rot *(Inonotus glomeratus = Polyporus glomeratus)*
Dead man's fingers *(Xylaria polymorpha)*
Hypoxylon root and butt rot *(Hypoxylon deustum = Ustilina vulgaris)*
Mossy-top fungus *(Oxyporus populinus = Fomes connatus)*
Shoestring root rot (*Armillaria* sp.)
Sulfur fungus *(Laetiporus sulfureus = Polyporus sulfureus)*
Tinder conk fungus *(Fomes fomentarius)*
Armillaria sp. (Shoestring root rot)
Climacodon septrionalis = Steccherinum septentrionale
Fomes fomentarius (Tinder conk fungus)
Ganoderma applanatum = Fomes applanatus (Artist's conk fungus)
Hypoxylon deustum = Ustilina vulgaris (Hypoxylon root and butt rot)
Inonotus glomeratus = Polyporous glomeratus (Canker rot)
Laetiporus sulfureus = Polyporus sulfureus (Sulfur fungus)
Oxyporus populinus = Fomes connatus (Mossy-top fungus)
Xylaria polymorpha (Black root rot, Dead man's fingers)

Vascular Wilt

Sapstreak disease *(Ceratocystis coerulescens)*
Verticillium wilt *(Verticillium albo-atrum)*
Ceratocystis coerulescens (Sapstreak disease)
Verticillium albo-atrum (Verticillium wilt)

Houston, David R.; Allen, Douglas C.; Lachance, Denis. 1990. **Sugarbush management: a guide to maintaining tree health.** Gen. Tech. Rep. NE-129. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 55 p.

ODC 284.4:710

Keywords: insects, diseases, sugar maple, *Acer saccharum,* air pollution, tapping, maple syrup, northern hardwoods, maple decline, stand management.