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INSECTS HAVE DEFOLIATED MY TREE— NOW WHAT'S GOING TO HAPPEN?

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Abstract. The effects of defoliation are not dependent on defoliation alone but on a complex interaction of many factors. The major influencing factors of severity, frequency, and timing of defoliation, growing conditions, secondary organisms, and tree vigor are discussed. Some of the adverse effects of defoliation are described and recommendations for preventing or lessening these effects are given.

Defoliation is a household word in the Northeast. In the early 1970s, the elm spanworm (*Ennomos subsignarius* Hbn)) and the gypsy moth (*Lymantria dispar* (L.)) defoliated thousands of acres of hardwoods in the forest and many trees in front lawns and backyards. The gypsy moth infestation has continued in some areas, and many more trees are being or will be defoliated.

What's going to happen to these trees? There are two answers: (1) don't worry, because trees can refoliate and survive, (2) worry, because some trees will die, especially where defoliation is severe enough to cause the trees to refoliate. Unfortunately both answers are correct. Some trees refoliate and survive, while others refoliate and die; often these trees are side by side. The effects of defoliation are not dependent on defoliation alone.

How can an arborist answer the tree owner who asks: What's going to happen? What can I do? What determines whether a defoliated tree survives or dies?

Factors that influence the effects of defoliation

What happens to a tree when it loses its leaves depends upon how much foliage is eaten (severity), the number of successive years of defoliation (frequency), when in the growing season the tree is defoliated (timing), growing conditions (weather), the presence and aggressiveness of pathogens and insects (secondary organisms), and the physiological condition of the tree when it is defoliated (tree vigor). There are probably other factors, but these are the major ones.

These factors must be considered collectively because the effects of one factor may be modified or aggravated by the others. The interaction of these factors determines how much a defoliated tree will be *altered* by reversible and irreversible physical and physiological changes. The boxes in Figure 1 indicate some tree conditions after defoliation and some significant physical and physiological properties of each (Heichel and Turner 1976, Houston 1973, Parker 1970, 1974, Parker and Houston 1971, Parker and Patton 1975, Wargo 1972, 1975, 1977, Wargo and Houston 1974, and Wargo et al. 1972); the circles indicate the points where the interaction of the influencing factors results in a change in tree condition. For example, a defoliated tree that does not refoliate may not be *significantly altered* because it was vigorous, partial defoliation occurred late in the season, and growing conditions were favorable: the direction of flow would be toward *normal healthy tree*. If other factors such as reduced vigor, complete defoliation, and poor growing conditions were dominant, the tree could change to the *significantly altered* tree condition.

Severity of defoliation. The greater the amount of foliage eaten by the insect, the greater are the adverse effects. The less leaf tissue there is, the less food is produced. Apparently a tree can lose up to 50 percent of its foliage in 1 year and not be adversely affected (Wargo et al. 1972, Heichel and Turner 1976). However, when defoliation is severe enough to cause the tree to refoliate in the same growing season, the tree is altered significanlty (Wargo et al. 1972, Wargo 1972). Exactly how much foliage must be removed to trigger complete refoliation is not known because it is difficult to estimate exact percentages of defoliation. Artificial defoliation studies show that when 50 percent of the foliage is removed refoliation will occur sometimes. When 75 to 100 percent of the foliage is removed, refoliation will always occur, unless it is a late-season defoliation.

It is the refoliation process that alters the tree (Wargo et al. 1972). Growth regulators that control the tree's physiology are changed when the leaves are removed. Buds formed originally for next year open in about 3 to 4 weeks and new leaves begin growing. Then new buds are formed within a shortened growing season. The tree metabolizes food reserves (primarily starch in deciduous trees) to maintain its living tissues until the new leaves are formed and produce more food.

A refoliated tree is completely out of phase with the season. Growing conditions in midsummer are not like those in spring: it is usually drier, the days grow shorter after June 21, and it is usually hotter. This "spring again" condition can have drastic effects on a tree by autumn. Not only does the tree have lowered or depleted food reserves, but tree tissues may be chemically and physically immature at the onset of the dormant season and suffer winter damage. The refoliated tree may also be more vulnerable to the effects of additional defoliation next season and to attacks by pathogenic organisms to which it is normally resistant.

Frequency of defoliation. It is usually the weak or unhealthy tree that dies or loses much of its crown from branch dieback after one season of defoliation. If defoliation is repeated for 2 or 3 years in succession, even the healthiest tree can die, especially when defoliation is severe enough to cause refoliation (Campbell and Valentine 1972). A tree that is defoliated and refoliates in the same season will begin the next season with lowered food reserves, less productive leaves (less chlorophyll), and mineral imbalances. Another defoliation will add to these problems. Even a defoliation that does not cause refoliation can alter the tree when it is repeated for several seasons. Crown dieback can occur and tree vigor can change. Good trees can become fair or poor trees, fair trees can become poor trees or die, and poor trees can die (Campbell and Valentine 1972).

Timing of defoliation. The time when defoliation occurs significantly influences the effects of defoliation. When trees are defoliated very early in the growing season, they have a longer time to recover than trees defoliated in midseason. Trees defoliated late in the growing season usually do not refoliate and the impact is less. These trees have also completed much of their growth and stored a major portion of food reserves.

The effects of defoliation seem to be most adverse when the leaves are just about fully expanded. All parts of the tree are growing rapidly and the tree has maximum energy demands and little reserve food. This occurs about 4 to 6 weeks after budbreak, depending on the tree species, climate, and weather.

Another critical time is late in the season just before the buds become dormant. If refoliation takes place and new buds are formed, many are immature and not hardy enough to resist the fall frosts and winter weather conditions. Sometimes late defoliation causes buds to swell but not to refoliate. The swollen buds are susceptible to winter drying and freeze injury, and twig dieback can be heavy (Houston and Kuntz 1964).

However, severe and repeated defoliations that occur even in the less critical parts of the season can alter and kill trees (Nichols 1968, Wargo and Houston 1974).

Weather conditions. In conjunction with timing, weather conditions before defoliation and during and after refoliation, can influence the effects of defoliation. The rate of leaf expansion is regulated especially by temperature (Kozlowski 1971), and cool temperatures can reduce it. Delayed leaf expansion could result in greater damage by early defoliators such as leaf rollers, which feed on the opening bud or very small leaves. Conversely, warm temperatures at this time accelerate leaf ex-

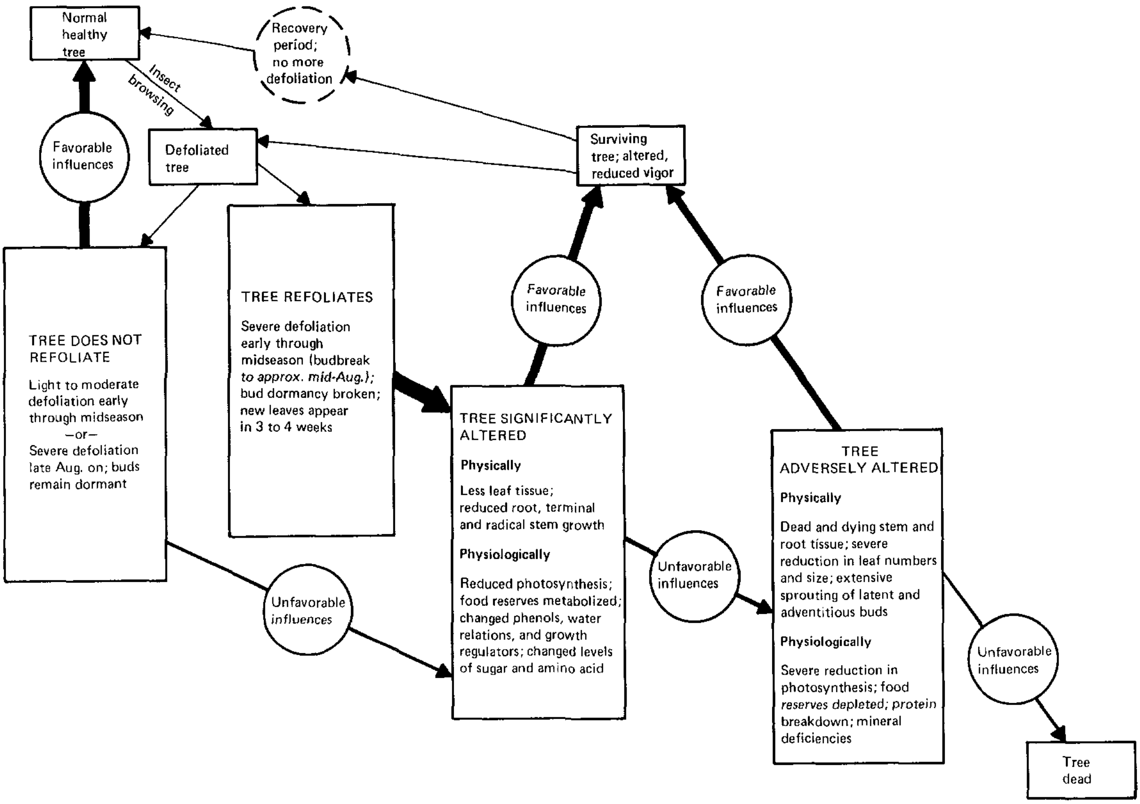

Figure 1. Diagram showing tree conditions and some of their characteristics after defoliation (boxes). Arrows indicate alternative paths of change; the width of the arrows is relative to the dominant direction of change after one defoliation. The actual path of change is determined by the interaction of influencing factors indicated by the circles.

pansion and could reduce the amount of early defoliation. In both situations, the temperature also influences the development and activity of the insects.

During refoliation, excessively moist growing conditions may promote foliage diseases such as anthracnose, which is caused by a fungus (Heichel et al. 1972). Normally this fungus disease is a problem early in the growing season, but tender new leaves on refoliated branches late in the growing season are also susceptible to attack. Excessively dry conditions can be equally bad. Inadequate moisture during refoliation may result in poor leaf expansion, and the small leaves produce less food. If moisture stress continues after leaf expansion, photosynthesis is further impaired and food production and storage are adversely affected. If temperatures are high during moisture stress, additional leaf damage can occur from leaf scorch.

Weather conditions during the previous year determine the physiological condition of a tree at the time of defoliation. A tree that grew under poor conditions the previous year may be more vulnerable to the affects of defoliation, whereas if growing conditions were good in the previous year, the tree will be better able to tolerate the defoliation.

Secondary organisms. There is substantial evidence that suggests that defoliation alone does not kill a tree. Defoliation followed by attacks from secondary or "opportunistic" organisms such as *Armillariella mellea* (Vahl. ex Fr.) Karst., a fungus that attacks the roots of trees, or *Agrilus bilineatus* (Web.), an insect borer, may kill the tree (Staley 1965, Nichols 1968, Kegg 1973, Dunbar and Stephens 1975, and Wargo 1977). In the absence of defoliation, a tree is not susceptible to secondary organisms or it is able to resist or tolerate the attacks that do occur. When a tree is defoliated, it becomes attractive to organisms, its resistance or tolerance is weakened, and attacks are successful. There is some evidence that in the absence or exclusion of these organisms, a tree can tolerate several years of defoliation (Cote 1976).

Tree vigor. The physiological condition of the tree at the time of defoliation must be considered for it will determine to a large extent the influence of all the other factors (Kozlowski 1969). Vigor is defined as the strength or force in the tree's nature or action, which implies the ability to grow fast, strong, and pest-free. It is the expression of the tree's genetic makeup modified by its environment. It is a characteristic sometimes easy to see, but not easy to define, and much more difficult to measure.

There are some general indicators of tree vigor that can be recognized, such as crown class and crown condition. But the attribute that is most important to a tree's ability to survive or tolerate defoliation is not necesarily its general vigor, but its physiological condition at the time of defoliation. Just as vigorous human beings can become run-down from too little sleep or excessive activity, vigorous trees can be weakened by unfavorable growing conditions. For example, trees growing under drought conditions for 1 or 2 years may still look vigorous, but actually be in a weakened or less vigorous condition because of reduced carbohydrate production. Trees recently disturbed by construction could also be more vulnerable. Root disturbance could cause roots to die, or result in reduced food production because of decreased water and mineral uptake. The effects of defoliation would be more severe on these weakened trees than on unstressed trees.

Effects of defoliation

Less leaf tissue. If the tree refoliates in the same growing season, the new leaves are about half the size of the normal ones and fewer in number (Heichel and Turner 1976). Sometimes these leaves have abnormal shapes. In the spring following the season of defoliation, there are also fewer and smaller leaves than normal. There is some evidence that leaf size is affected only by the first defoliation, but the number of leaves decreases with succeeding defoliations (Heichel and Turner 1976). Early in the growing season new leaves may remain yellow or sometimes red-brown longer than is normal. This symptom of a mineral deficiency is less apparent later in the season, but even then the leaves on refoliated trees are a lighter green than those on undefoliated trees.

Twig and branch dieback. The most obvious effect of defoliation is the dieback of twigs and branches noticeable especially in the spring. Terminal buds, twigs, and branches may die from winter injury or starvation from too little food during the dormant months. Twigs and branches may also be killed by pathogenic organisms and insects. When terminal twigs die, many lateral buds begin to grow, which results in clumped or tufted foliage (Houston and Kuntz 1964). When dieback is severe, buds on the larger branches and main stem begin to grow and bole sprouts appear (Figure 2). This effect is objectionable, esthetically. Even in the absence of severe dieback, heavy bole sprouting can detract from the appearance of trees.

Less terminal and radial growth. After one defoliation most buds survive until spring and produce new growth, but the amount of new terminal growth can be significantly reduced. In some instances, twig growth is only 25 percent of that on undefoliated trees. This reduced terminal growth also emphasizes the clumped foliage appearance.

Less radial growth occurs in a defoliated tree (Kulman 1971). This may be a tolerable effect for the shade-tree owner. To the forester it may mean considerable wood loss if a tree is cut on a planned time cycle, or it may mean an extension of the cutting cycle by 5 to 10 years to make up for the reduction in wood production. Either way it represents economic loss. Growth reduction has been shown to be proportional to the percentage of foliage removed and to the number of consecutive years of defoliation (Kulman 1971).

Figure 2. Defoliated tree that has refoliated; sprouting has occurred on the larger branches and main stem.

Retarded rate of wound closure. A defoliated tree may also be more vulnerable to the effects of wounding (Wargo 1977). A wound inflicted on a defoliated tree becomes larger than a similar wound inflicted on a healthy tree because more tissue dies around the original wound. Wound closure depends on the size of the wound and the rate of closure, which is controlled by the amount of radial growth (Neely 1970). Since defoliation reduces radial growth, the closure rate will be slower. Larger wounds plus a slower rate of closure result in an open wound for a longer time and increase the chances of internal defect from discoloration and decay.

Impaired root system. Many small feeder roots needed for mineral and water absorption die after defoliation, probably from lack of food (Staley 1965). This results in poor water and mineral uptake and ultimately in reduced food production in the leaves. The weakening or death of these roots may also create entrance points for fungi such as *A. mellea*, which, in the presence of continued stress, can successfully grow inside the tree and kill additional root tissue. This further reduces the uptake of water and minerals. Eventually the whole root system and lower stem may be colonized by the fungus (Figure 3).

Figure 3. Mycelial fans of Armillariella mellea growing from root collar onto stem in a recently dead oak tree.

In addition, insects such as the two-lined chestnut borer (*A. bilineatus*) can now successfully attack the twigs, branches, and main trunk (Figure 4). Borers tunnel in the newly formed inner bark and wood. These tunnels interfere with the transfer of food down the tree and water and minerals up the tree. The combined actions of the borer in the stem and the fungus in the roots result in rapid death of many defoliated trees.

Figure 4. Galleries of Agrilus bilineatus, the two-lined chestnut borer, on the stem of a recently deak oak tree.

Tree care

What can be done to protect trees from defoliation or to lessen its effects? The best action is to prevent defoliation of trees, especially those of high value, from being severely defoliated. There are several registered pesticides, including at least one microbial pesticide, that can be recommended for use against defoliating insects and are environmentally safe when properly applied. Because insect populations rise and fall, tree owners can be assured that they will not have to spray year after year, but only during years when the pest population is high.

Cared-for trees have better chances of surviving defoliation because they will be healthier. The standard recommendations for maintaining healthy trees apply to potentially defoliated trees. Proper fertilization is essential as well as adequate water, especially during low-moisture periods. The owners can be cautioned about other stresses such as soil compaction, competition from lawn grasses, and restriction of rooting areas by sidewalks and driveways, all of which influence tree health. Also, the recommendations for selecting, planting, and maintaining new trees are all appropriate.

But what should be done if the tree is defoliated and it does refoliate? Tree care during the refoliation period is critical. If rainfall is limited, the tree should be watered. The new leaves are growing at a time when temperatures can be high, and inadequate water at this time could result in leaf scorch or death if drought is severe. Adequate water also promotes leaf development, and larger leaves produce more food. If excessively moist conditions prevail, the foliage may have to be protected from fungi. Early recognition of the symptoms of leaf diseases is important for successful control, so the owner must familiarize himself with these. Trees should be fertilized in the autumn after leaf-fall or in the spring before budbreak to offset the mineral losses caused by defoliation. Fertilization during refoliation or the growing period afterward could be detrimental. It could promote more growth delay hardening off, and lower food reserves stored for winter and early spring use.

Attacks by secondary insects, such as borers, can be prevented by applying an insecticide to the tree stems to kill the penetrating larvae. Dealing with secondary organisms in the soil is another matter. At present there are no acceptable control procedures nor any registered compound for combatting root fungi such as *A. mellea*. There is, however, some effort underway to develop control procedures (Pawsey and Rahman 1976).

Finally, the most important advice is: Don't let the tree be defoliated again next season.

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ABSTRACT

Baumgardt, J.P. 1978. **Soil chemistry and structure as related to water.** Grounds Maintenance 13(3): 24, 26, 30, 32.

Water occurs in soil in several forms. Following a rain considerable free water is found in the spaces between soil particles. But not all soil water coating particles is held loosely. A very thin layer of bound water covers each particle or, in the case of humus matter, the faces of the spongy materials. This water is unavailable to plants, being held by molecular forces to the particles. It pays to know the structure and chemistry of your particular soil. Only by knowing your soil profile can you make the most of an irrigation program. You can also manage an optimum fertilizing program based on plant needs, leaching, and soil retention.