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The Rutgers Turfgrass Proceedings is published yearly by the Rutgers Center for Turfgrass Science, Rutgers Cooperative Extension, and the New Jersey Agricultural Experiment Station, Cook College, Rutgers University in cooperation with the New Jersey Turfgrass Association. The purpose of this document is to provide a forum for the dissemination of information and the exchange of ideas and knowledge. The proceedings provide turfgrass managers, research scientists, extension specialists, and industry personnel with opportunities to communicate with co-workers. It also allows these professionals to reach a more general audience, which includes the public. Articles appearing in these proceedings are divided into two sections.

The first section includes lecture notes of papers presented at the 1995 New Jersey Turfgrass Expo. Publication of the New Jersey Turfgrass Expo Notes provides a readily available source of information covering a wide range of topics. The Expo Notes include technical and popular presentations of importance to the turfgrass industry.

The second section includes technical research papers containing original research findings and reviews covering selected subjects in turfgrass science. The primary objective of these papers is to facilitate the timely dissemination of original turfgrass research for use by the turfgrass industry.

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Dr. Ann B. Gould, Editor
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DIAGNOSIS AND MANAGEMENT STRATEGIES FOR FOUR KEY INSECT PESTS OF TREES AND SHRUBS

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This paper is a brief summary of a presentation given for members of the New Jersey Turfgrass Association at their annual meeting in Atlantic City in December of 1995. The objective of the presentation was to discuss some recent research findings that would help landscape managers deal more effectively with a few key landscape pests. To accomplish this, we presented information to assist in the recognition of three major categories of damage caused by insect pests of woody landscape plants. Next, for each damage category, we reviewed examples of causal agents associated with the specific type of damage. We discussed information on life cycles, monitoring approaches, and management strategies for each type of pest. Particular emphasis was given to non-chemical approaches, such as the use of plant culture, landscape design, and biological control.

Defoliation

The first group of insects discussed were defoliators. Defoliators have chewing mouthparts and injure plant leaves by removing tissue as they feed. If the jaws are relatively large and powerful or if the leaves are tender, portions or sometimes the entire leaf disappears. If the jaws are small or the leaves are tough, sometimes only the tissue between the veins of the leaf disappears. We call this *skeletonization*.

An example of a well known defoliator is the gypsy moth. Larvae or caterpillars of this insect pest are among the most common and damaging in the northeastern region of the United States. Young gypsy moth larvae take small bites of leaves and create a type of damage known as "shot holes." As caterpillars age they remove larger portions of leaves and eventually will consume all of the leaf except the toughest leaf veins. High populations of these insects may defoliate entire trees and forest stands. Defoliation may weaken trees and make them more susceptible to other serious pests, including flat-headed borers or the shoe string fungus, that may ultimately cause tree death.

The gypsy moth spends the winter as eggs in a buff colored egg mass on the bark of its host tree or on surrounding structures such as stones and buildings. In the spring when temperatures are favorable, these eggs hatch and hairy, black caterpillars emerge. These caterpillars are less than 1/4 inch in length and they climb to the tops of trees and other structures. This is not the best time for arborists or landscape managers to treat gypsy moths from the ground. Many of the small caterpillars will spin a thread of silk and migrate to other trees nearby. After the migratory behavior is complete, most will settle and begin to feed. They will soon molt to the second instar larvae. This is an excellent time to initiate control. There are many conventional materials labeled for control of the gypsy moth, and these will work well. In addition to synthetic

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insecticides, there is a bacterium known as *Bacillus thuringiensis* which is very effective against young caterpillars. We are currently investigating an innovative way to control gypsy moth caterpillars using nematodes. Nematode roundworms normally inhabit soil where they attack and kill insect larvae. However, nematodes have been formulated for use in landscapes, nurseries, and greenhouses where they have been used to control a wide variety of insect pests. We found that nematodes applied to leaves and bark of trees produced high levels of mortality in both young and the pesticide resistant older larvae. The results of these preliminary studies are encouraging, and with further refinement, this approach could replace more toxic insecticides currently used for gypsy moth control.

Landscape managers should also be aware that two other pathogens contribute significantly to mortality of gypsy moth caterpillars throughout the Northeast. It has long been known that the nucleopolyhedrosis virus (NPV) is responsible for dramatic reductions in gypsy moth populations when population outbreaks occur. More recently, a fungal pathogen, *Entomophaga maimaiga*, has been identified as a major contributor to gypsy moth population decline throughout the east, including New Jersey.

Another defoliator that appears to be on the increase in the past year is the bagworm. Like the gypsy moth, this insect has a very broad host range. Although it feeds on many species of deciduous trees and shrubs, its major impact is on conifers, particularly pines, junipers, and arborvitae. It can defoliate these trees completely, which may result in tree death. The early instars remove green tissues from needles of conifers and leave behind discolored brown foliage. As larvae mature, they consume entire needles and small branchlets, leaving large sections of plants stripped of foliage. The bagworm is often overlooked as a pest due to its cryptic habit of constructing a bag of leaf matter bound together by strands of silk.

The bagworm spends the winter months as an egg resting inside the bag constructed by its mother the previous year. In the latter part of spring, these eggs complete their development and the larvae emerge from the bag. Like the gypsy moth, many larvae will spin a thread of silk and balloon away from their host in search of another plant. Others will settle down, begin to feed, and will soon construct their protective bag. During the course of the summer, bagworms will grow and consume large amounts of foliage. In late summer, larvae will pupate and adults will be produced. The female bagworm never emerges from the bag. Instead, she releases a chemical odor that the male bagworm moth can detect. The male bagworm uses this odor, called a pheromone, to find the female and mate with her. The female will then lay eggs inside the bag. In the mid-Atlantic region these eggs will not hatch until the next spring.

Management of the bagworm is most effective if infestations are detected before populations have attained high levels. If populations are small and the trees to be protected are relatively short, it is easy to remove the bagworm with clippers and dispose of them. Hand removal of bags to destroy eggs is most effective after October and prior to May while eggs are still in the bags. Once the eggs have hatched it is difficult to find and remove numerous small larvae. Many insecticides are labeled for control of the bagworm. Our colleague at the University of Maryland, Stanton Gill (1), has recently demonstrated that entomopathogenic nematodes show some promise as an alternative to conventional pesticides for bagworm control.

Dieback

A second type of injury associated with insect pests of landscape plants is dieback. Dieback can occur in shoots and branches and is indicative of problems with the vascular

transport of nutrients and water. Other symptoms associated with dieback include the wilting of foliage, the cracking and splitting of bark resulting in resin or sap flow, and the production of water sprouts in some plants. Clearwing borers represent a major group of insect pests responsible for dieback in woody landscape plants. These borers belong to a family of moths whose adults closely resemble wasps. Some of the most common clearwing borers in landscapes are the dogwood borer, peach tree borer, lesser peach tree borer, rhododendron borer, lilac borer, and banded ash clearwing.

The life cycle of a clearwing borer begins when the female moth deposits an egg on the bark surface of a plant. The egg will hatch and a small larvae will emerge and enter the bark, often through an existing wound. Once inside, the larvae will feed beneath the bark on vascular tissues. In some species of clearwings, larvae bore into the heartwood of the plant. When populations are high or if infestations have been ongoing for prolonged periods, branches or entire trees may be girdled with resultant dieback or plant death. In the case of the banded ash clearwing, the integrity of branches may be compromised due to the boring and tree tops may be blown out by winds. After feeding beneath the bark, larvae turn in to pupa, and shortly thereafter, adult moths emerge. As with the bagworm and gypsy moth, the female clearwing borer releases a pheromone to attract males. After mating, the female borer deposits an egg on the bark of the tree and the life cycle is complete. Some species such as the banded ash clearwing have only a single generation each year, while others such as the lesser peach tree borer have two. Most clearwing borers spend the winter as larvae beneath the bark of the tree.

Clearwing borer management is multifaceted. First, it is important to keep trees from being wounded by maintenance equipment such as lawn mowers or weed whackers. A properly mulched tree should be less prone to this type of mechanical injury. Cultivar selection is another good way to reduce borer attack. For example, in Maryland, the Kousa dogwood is attacked far less frequently by dogwood borer than is our native *Cornus florida*. When a tree is under attack by clearwing borers, insecticides with prolonged residual activity are often applied to the bark to kill newly hatched larvae as they attempt to enter the tree. If this approach is used, then the timing of these residual insecticides becomes critical. If applied too early, materials will weather off the bark before the eggs hatch. If applied too late, larvae will have entered the plant before they ingest or are contacted by the insecticide. Fortunately, a number of clearwing borer moth pheromones are commercially available and may be used in conjunction with sticky traps to assist in the timing of insecticide treatments. Sticky traps containing pheromone lures should be hung well in advance of the emergence of adult clearwings. When adult male moths begin to appear in traps, the deposition of eggs is imminent and residual insecticides should be applied. Landscape managers should recognize that pheromone traps usually capture more than one species of clearwing borer moth (2). To assist in the identification of species caught in pheromone traps, we recommend the use of the pictorial reference by Taft et al. (3).

In addition to the use of residual bark pesticides, researchers have recently shown that entomopathogenic nematodes can also give very acceptable levels of control of clearwing borer moth larvae. Nematodes are applied directly to the bark of the tree at a time when larvae are present beneath the bark. Stanton Gill, John Davidson, Wanda MacLachlin, and Will Potts demonstrated in a series of studies that nematodes could significantly reduce clearwing borer populations in dogwood (4), cherry laurel (5), and green ash (6). The use of nematodes has potential for managing several other species of clearwing borers, including the rhododendron borer, lilac borer, and viburnum borer.

Leaf discoloration

Leaf discoloration can occur for a number of reasons on landscape plants. One of the most common ways insect pests discolor leaves is through their feeding activities. Many of our most important insect pests have sucking mouthparts. Examples include aphids, scale insects, and bugs such as the azalea lace bug. Insects with sucking mouth parts insert fine stylets into plant tissues and remove the contents of cells or vascular tissues. Some insects like leaf hoppers or lace bugs rupture mesophyll cells and remove the cell contents. The loss of green chlorophyll from ruptured cells creates small white spots on the leaf. These small white spots are called stipples. Pests such as spider mites have very small mouth parts and create very minute, fine stipples. Insects such as lace bugs and leaf hoppers have larger mouthparts and their feeding results in large, coarse stipples. Often, when pests such as mites or lace bugs are abundant, almost all green cells on a leaf may be emptied and the entire leaf surface appears white, yellow, or silver. These leaves may ultimately turn brown and appear scorched. They often abscise from the plant prematurely.

Lace bugs, such as the azalea lace bug, are among the most common of all insect pests in the landscape. This occurs because azaleas are so widely planted throughout the region. Azalea lace bugs spend the winter as eggs inserted into the tissue of a plant leaf. In spring, usually in April or May, the eggs complete their development and hatch. The immature stage of the lace bug is called a nymph and it feeds on the leaf surface and creates the stippling injury described above. The lace bug nymphs molt five times before reaching the adult stage. Lace bug adults have delicate multi-veined wings that gives them the appearance of being covered with lace, hence their name. Adult lace bugs also have piercing mouthparts that create stippling injury to leaves. After feeding for a period of several days, lace bugs mate and deposit eggs into the surface of the leaf. There is more than one generation of lace bug each year in Maryland.

Short term management of lace bugs is relatively straightforward and consists of treating newly emerged lace bugs with insecticides. Many are labeled for use against lace bugs. Insecticidal soaps and horticultural spray oils work well but must contact the bugs if they are to be effective. This means that sprays must be directed to the undersurface of leaves where lace bugs feed and rest. Materials such as soaps and oil have the distinct advantage over some residual materials in that they do not remain on plant surfaces as toxicants for long periods of time. This reduces negative impacts on beneficial insects that frequent plants soon after the application of insecticides. Systemic insecticides applied to the leaves or through the soil may also work well and have the advantage of not directly affecting beneficial insects such as predators that may be on the surface of the plant.

A more sustainable approach to managing lace bugs and many pests of landscape plants is through sustainable landscape design. Studies by Trumbule et al. (7) revealed that azaleas in sunny locations were much more commonly infested and severely damaged than those in shade. It was initially believed that azaleas in sunny habitats were more frequently infested and severely damaged because they were planted in sites for which they were not well adapted. Azaleas are typically denizens of shaded woodlands with rich acidic soils. However, research by Trumbule et al. (7) found that shaded azaleas were actually a better resource for lace bugs than those grown in sunny conditions. Our recent research demonstrates that natural enemies, such as spiders, are far more abundant in shady, diverse landscapes. These natural enemies feed on plant pests and greatly reduce pest numbers in diverse shaded habitats. By diversifying landscapes, homeowners can enhance biological control, thereby reducing pest populations and the use of pesticides.

A second type of leaf discoloration occurs due to a highly specialized life cycle of a group of insect pests known as leaf miners. Leaf miners are present in several families of insects and share the trait of feeding between the epidermal surfaces of leaves. They consume mesophyll tissues and, in some cases, parenchymal cells. Depending on how they move through the leaf tissue, they create galleries that are linear, serpentine, or blotchy.

In Maryland, boxwoods in residential landscapes are frequently attacked by the boxwood leafminer. Each year, 25% of boxwoods require treatment for control of leafminer. Cultivars of American boxwood, *Buxus sempervirens*, are severely damaged by this insect, which causes damage in its larval stage by mining and galling the parenchyma tissue of boxwood leaves. Mined leaves have an ugly, discolored, blistered appearance that destroys the aesthetic quality of the plant. In heavy infestations, leaves senesce and drop prematurely, rendering the canopy thin and unsightly. Heavily infested plants are more susceptible to cold injury and winter kill.

The boxwood leaf miner spends the winter months as a partially grown larva in the tissue of the leaf. In the late winter and early spring, the larvae complete development and cut a small window in the surface of the leaf. It is from this window that the pupa and ultimately the adult fly will emerge. Emergence of the adult boxwood leafminer coincides with the production of tender new leaves on the shoots of boxwood. These tiny orange flies swarm about the plant, mate, and the female midge lands on the undersurface of the boxwood leaf where she deposits several eggs into the leaf tissue. After several days, these eggs hatch into small legless larvae that begin to mine the leaf and in so doing induce the production of a leaf gall. Leaf miner larvae spend the spring, summer, and fall feeding and developing within the leaf.

Management of the boxwood leaf miner has traditionally relied on the application of pesticides to the leaf surface to coincide with the flight activities of the adult flies. We are currently developing a reliable method for timing the application of insecticide treatments based on the degree day or heat accumulation method of prediction. Heat unit accumulations have been measured at Longwood Gardens, PA, The University of Maryland, College Park, MD, and the U.S. National Arboretum during the spring and summer of 1995 and 1996. Using a 50°F base temperature, a March 1 start date, and the averaging method, daily heat unit accumulations were made for the key life history events of adult emergence and flight, oviposition, egg hatch, and larval development. These events will be correlated with heat unit accumulations to construct a predictive model. This project will be completed during the spring and summer of 1996.

In addition to generating a reliable system for predicting key life cycle events, we are evaluating the efficacies of three systemic insecticides (Orthene, Avid, and Merit) and one biological control agent (the nematode *Steinernema carpocapsae*) for the control of the boxwood leaf miner. All materials will be tested against three life stages of the leafminer (pupae, adults, and larvae) to determine which material provides the greatest efficacy and to determine which life stage is the most vulnerable to pesticides. Preliminary studies were completed in 1995 and showed good control from both Avid and Merit on the adult/early larval stage. This data will be coupled with the degree day model to provide a reliable, highly efficacious procedure for leafminer control. This allows landscape managers to plan their control strategies and to be prepared when the proper time for application of a control method is appropriate. A more durable approach to the management of the boxwood leaf miner involves the use of resistant plant materials. Previous researchers have observed variation in the susceptibility of various species and cultivars of boxwood to leafminer attack. However, most of these studies lack quantitative data regarding the levels of susceptibility. We have developed methods for quantifying egg laying behaviors of the boxwood leafminer and tracking the development of leafminer larvae. Our preliminary studies

indicate that much of the resistance observed in boxwoods is due to plant related mortality of developing larvae rather than avoidance of the plants by adult flies. This has important implications for breeding resistant lines of boxwoods. We found the cultivars Handsworthiensis and Vardar Valley are both highly resistant to boxwood leaf miner while others are susceptible. *Arborescens* (the American Box) is the most common boxwood in Maryland and shows the highest susceptibility.

There are many important and interesting insect pests of woody landscape plants for which we have just begun to scratch the surface with respect to understanding their biology and management options. We hope that this short discussion gives you some new insights into the management of defoliators such as gypsy moth and bagworm, leaf stipplers such as lace bugs, and leaf miners such as the boxwood leaf miner. When our research results are more complete, we hope to return and share our findings with you.

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