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MONITORING: AN ESSENTIAL FACTOR TO MANAGING PESTS OF LANDSCAPE TREES AND SHRUBS¹

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Abstract. Monitoring is a critical component of pest management programs for trees and shrubs. The regular inspection of plant materials for insect, disease, and cultural problems allows the pest manager to pinpoint control actions. Trapping devices can detect the presence of pests in a location and provide information for the optimal timing of control actions. Environmental monitoring can be used to fine tune controls to local climatic regimes. Incorporating several monitoring techniques into management programs enables landscape plant managers to reduce unnecessary pesticide use. This approach helps create more cost efficient pest control programs and satisfy the growing desire of clients to reduce the risk of pesticide exposure.

The implementation and benefits of integrated pest management (IPM) programs for landscape trees and shrubs have been the topic of several recent reports (2, 3, 4, 9, 10, 11, 14, 24, 28, 29, 30, 31). Among the critical components found in all operational IPM programs is the establishment of a regular system of inspecting the managed landscape for the presence of insects, diseases, weeds, and other environmental factors adversely affecting plant health and beauty. This system of regular inspections, known as monitoring, serves as the focus of this paper. The reasons underlying the need for monitoring will be briefly reviewed. In addition several monitoring techniques and approaches will be described. Finally, some prospects for future advances in monitoring will be discussed.

Reasons for Monitoring

There are several reasons why regular monitoring of pest activity rather than routine application of pesticides (cover or preventive sprays) should

form the basis of a pest management program. First, the occurrence of pests on landscape plants varies from year to year and among locations. For example, in central Maryland Holmes and Davidson (11) found that the most common pest in homeowner landscapes, the azalea lace bug, was present at damaging levels on only one in ten azaleas monitored. At a single location, in California Koehler et al. (13) reported that scale crawler emergence spans an interval up to one month depending on the exposure of branches within the canopy. Also in Maryland, Raupp et al. (30) demonstrated that many common genera of landscape plants varied from one year to the next in their frequency of pest problems. Regular inspection allows the landscape manager to pinpoint which plants have a problem regardless of climatic variation. Accurately identifying infested plants and treating only those with damaging pest levels can greatly reduce unnecessary pesticide use. This approach of monitoring and "spot treating" individual plants reduced the number of trees being sprayed by 93% and 83% in several communities in California and Maryland, respectively (24, 31). In a similar way Holmes and Davidson (11) found that monitoring information could be used to direct sprays toward individual plants thereby reducing the amount of pesticide applied by 94% compared to general cover sprays.

A second advantage of monitoring involves the proper timing of control actions. Most pest managers realize that environmental factors such as temperature and rainfall directly affect the

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growth and development of pests. Control actions are usually most effective against specific developmental stages of pests which may be relatively short lived depending on the biology of the pest and weather conditions that are often unpredictable. Regular monitoring of pest activity provides the critical information that enables the pest manager to time control actions more accurately and obtain better control. For example, traps can be used to monitor the flight activity of several species of clearwing borer moths, such as rhododendron and lilac borer. Egg hatch closely follows the period of flight activity. By regularly observing trap catches, residual insecticides can be applied to the bark in time to kill vulnerable newly hatched borers before they enter the tree. A single well timed insecticide spray can be used to control many pests including several of the clearwing borers (25). Monitoring forms the basis for accurate timing of sprays.

Regular monitoring can be especially important for pests with multiple generations each growing season (11). Under favorable conditions of temperature and humidity pests such as the two spotted spider mite can complete a generation in about 10 days. Each female mite can produce 100 to 200 eggs (17). These two factors permit spider mite populations to build up very rapidly. Frequent monitoring of plants during periods favorable to pest development enables the pest manager to detect incipient pest outbreaks and apply remedial actions before pests reach damaging levels. In comparing the effectiveness of a general cover spray program (3 treatments at monthly intervals) with an IPM program (treatments based on biweekly monitoring information), Holmes (unpublished data) found monthly sprays to be well timed for only 36% of 25 important pests in homeowner landscapes. Regular monitoring greatly increased the effectiveness of spray applications by permitting better timing.

Finally, monitoring allows the pest manager to gain valuable information on the presence and activity of natural enemies of pests. Beneficial insects and mites help to reduce pest outbreaks in a variety of systems (5). At least two cases are known where insecticide sprays contributed to the reduction of beneficial insects and allowed scale populations to reach damaging levels on

street trees (18, 19, 21). Natural enemies such as many lady bird beetles may be conspicuous and their presence can be easily taken into account when making control decisions. However, many beneficial insects are small. Their presence and activity are not easily monitored, although progress has recently been made in this area. Schultz (33) employed an ingenious trapping device to monitor the activity of several small wasps attacking the oak lecanium scale, *Parthenolecanium quercifix*. He suggested that monitoring information be used to better time crawler sprays for a minimum impact on beneficial wasps. This information, provided on a regional basis, would be extremely helpful in implementing integrated pest management programs and reducing adverse effects of insecticides on beneficial insects. However, much basic research remains to be conducted before we fully understand the importance of beneficial insects in landscape settings and how to monitor their activity.

Monitoring Approaches

Numerous techniques and approaches to monitoring pests and their activity have been described in general references on integrated pest management (7, 22). All of these diverse methods will not be discussed here. Instead, several methods currently available to arborists will be described.

Perhaps the most well known and widely used method of monitoring pests and their activity is the visual inspection of plants. Under this approach, plants in a managed landscape are inspected on a routine basis. Its effectiveness has been successfully demonstrated in projects conducted by Extension specialists at the University of Maryland in a variety of landscape settings including detached homes, townhomes and apartments, institutions, and communities (3, 4, 9, 11, 28, 31). Furthermore, at least seven commercial firms in Maryland and New York offer monitoring based IPM service to their clients.

Both pests and their damage are monitored by visual inspections. Large and conspicuous pests can be easily detected. However, small pests like scale insects or mites may require microscopic examination for proper identification. The process of tapping conifer branches on a sheet of white

paper can confirm suspected mite infestations. Some plants may require examination at a diagnostic laboratory to separate causal agents that create similar symptoms. Often pests will be recognized by the damage they cause rather than by observing them directly. For example, the D-shaped exit holes of bronze birch borer adults (Figure 1) are diagnostic as are notched leaf margins caused by the feeding of black vine and two banded Japanese weevil (Figure 2).

Several procedures can facilitate the process of visually inspecting large numbers of landscape plants and increase the prospects for success. First, hire or train personnel who can recognize the most common plants and identify plant damage caused by the major insects, diseases, improper cultural practices and adverse environmental conditions. Many state land grant universities and private colleges offer training in

plant protection disciplines such as Entomology, Plant Pathology, Horticulture, and Agronomy.

To be most effective, monitoring should be done on a regular short term basis. An interval of about two weeks between visits was acceptable in a variety of situations in Maryland (4, 9, 11, 28, 31). This schedule allowed past managers to detect and treat pest problems as they developed throughout the critical period of pest activity of mid-April to early September. For an IPM monitor the relationship between the time spent monitoring, treating plants, and interacting with the client appears to be directly related to the size of the client's property (Figure 3). However, the type and number of plants at each site, condition and size of those plants will also influence the amount of time spent monitoring. Holmes and Davidson (11) estimated that a well trained IPM scout could monitor and treat about 15 clients per day assum-

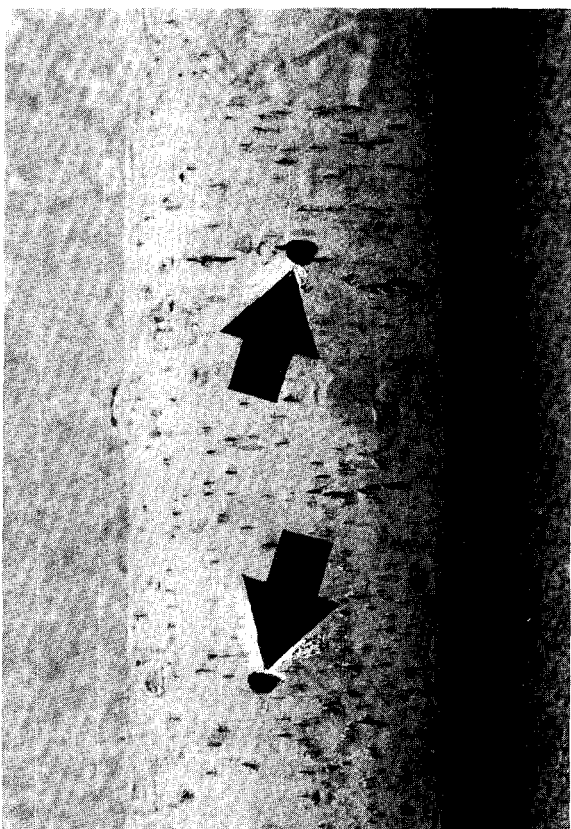


Figure 1. D-shaped emergence holes in the bark of white birch are diagnostic for the bronze birch borer, *Agrilus anxius*. Arrows indicate exit holes.

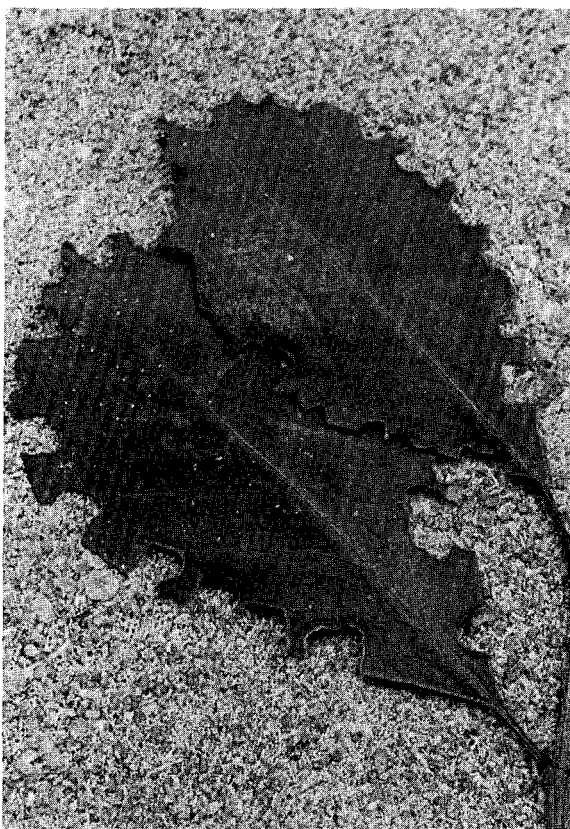


Figure 2. Leaf margins of this euonymus were notched by weevils. Although the weevils were not conspicuous, their damage was.

ing a daily driving distance of 40 miles, 1 acre lots, and similar plant materials. Shorter routes, smaller lots or lots with fewer plants increase the number of clients serviced each day.

Simple, diagnostic landscape maps are extremely valuable tools in monitoring programs (9, 28). Not only do they pinpoint the precise location of plants requiring treatment but regularly updated maps are a permanent record of pest activity and control actions. They help to identify problem prone "key" plants in the landscape. They can be reviewed over several years to reveal trends in pest cycles and control problems. Furthermore, they can be used to develop tree inventories for large scale plantings such as parks and city street trees. Computer generated landscape maps are currently used by at least one commercial arborist.

The diversity of plant materials and associated pests in urban landscapes has been emphasized and appears to impose an obstacle for pest managers (2). However, recent studies have demonstrated that, at least on a regional basis, certain key pests can be identified (9, 11, 28). Insuring that plant monitors know how to identify and control these key pests greatly facilitates the monitoring procedure. Furthermore, certain plants in the landscape are more susceptible than others to insects, diseases, and cultural problems. By learning to identify these problem prone key plants, monitoring activities and control actions can be focused (30). Regional information on key pests and key plants can be obtained from local Cooperative Extension Services or published accounts (9, 11, 12, 23, 28, 30).

A second major category of monitoring techniques involves the use of various types of traps. Baited traps rely on attractant materials to lure the target insect onto a sticky surface or into an enclosure where it is trapped. Regular inspection of the trap allows the pest manager to observe the presence or periods of activity of pests. Many baited traps utilize synthetic insect sex pheromones. These volatile chemicals are released by female insects to attract males for mating. Examples of sex pheromone traps include those for clearwing borers, Nantucket pine tip moth, the gypsy moth, and San Jose scale. Often pheromones are used in combination with

chemical attractants produced by plants. Baited traps for the Japanese beetle, native elm bark beetle, and smaller European elm bark beetle employ this strategy.

Other traps exploit the tendency of pests to be attracted to certain colors or structural features. Many small insect pests such as aphids, whiteflies, leafminers, and thrips are attracted to yellow surfaces where they can be trapped on sticky surfaces and observed (16). As mentioned previously, this technique has been used to monitor beneficial insect activity on street trees (33).

Refuges that trap insects may also be used to monitor pests. At low densities larvae of the gypsy moth feed primarily at night and rest or hide during the day. Older larvae seek refuges on the bole of trees to hide and pupate (6). This behavior can be exploited by placing a band of burlap, plastic, or tar paper around the bole and inspecting it regularly. Banding may be useful in detecting low level gypsy moth populations on individual trees whose canopies are too high to monitor easily. Because bands trap gypsy moths at low populations they should facilitate the early detection of gypsy moths at a precise location.

Other passive trapping devices have been used to directly monitor pests or their activity. Vaseline coated, clear plastic panels hung in apple trees,

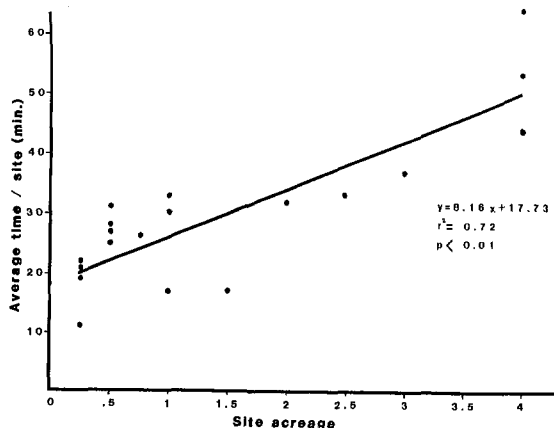


Figure 3. Relationship between the size of a client's property and the amount of time required to monitor and treat plants. Data were gathered from 26 homesites in Maryland over 20 weeks in 1982. Averages are based on 10 visits per site.

were used to observe activity of San Jose scale crawlers (20). In a similar way, bands of masking tape coated with a sticky material have been used to monitor the activity of several types of scale crawlers on oaks (27) and pines (13). While these techniques are not yet commercially operational, they hold promise for many scale insects controlled by well timed crawler sprays. Volney et al. (34) placed sticky cards beneath California live oaks, *Quercus agrifolia*, to trap droppings of the California oakworm. They demonstrated the technique useful in detecting the presence, relative abundance and period of feeding activity for oakworms. Further research could make this a valuable monitoring technique for a variety of leaf eating caterpillars.

Environmental monitoring offers one of the most promising approaches to predicting when pests are active and will be most vulnerable to control actions in a given locality. Insect development is directly related to temperature. Usually, for pests to become active and develop, a critical temperature must be reached. As temperatures increase above this threshold, development also increases up to an upper threshold where development again slows down or stops. When the pest accumulates sufficient heat units, it completes a developmental stage and an important biological event such as emergence or egg hatching occurs.

This dependence of development on temperature can be used to predict pest emergence very accurately. First, the thresholds and relationship between temperature and development must be determined. Then, by measuring local daily minimum and maximum temperatures, daily development can be predicted. When sufficient daily heat units have accumulated, the pest will complete its development and be vulnerable to an appropriate control action. This approach underlies degree-day models currently available for pests such as the lilac borer (26) and bronze birch borer (1). For both of these pests, the environmental monitoring approach predicted treatment dates much more accurately than calendar estimates (1, 26). Recently, pheromone trapping has been used in combination with environmental monitoring to provide accurate control information for San Jose

scale in California (32) and Nantucket pine tip moth in Georgia (8).

Prospects of Advances

Like many operational aspects of IPM for trees and shrubs, monitoring is in its infancy. The identification, synthesis, and formulation of attractants for use in new trapping devices will continue to improve our ability to identify where pests are and when controls should be applied for maximum effect. The development of additional predictive models based on temperature would be of great value especially for pests that are difficult to observe. Although predictive models are available for pests such as lilac and bronze birch borers, local information on temperature accumulations must be collected and made available to the commercial sector for these models to be useful. Furthermore, the key pests and their life histories vary from region to region. Details of this variation must be determined and incorporated into monitoring programs. To make these techniques fully operational will require a commitment from scientists and Extension personnel in different regions of the country.

A strong relationship exists between plant stress and attack by secondary agents. For example, oaks stressed by drought, defoliation, or cold may be more susceptible to attack by the two-lined chesnut borer (15). This cause and effect relationship between stress and susceptibility to pests provides the opportunity to take preemptive management actions if the stressed plant or the environmental factors leading to the stress can be monitored. A better understanding of the complex interactions between environmental factors, plant stress, and susceptibility to pests is greatly needed.

Finally, for the vast majority of our insect pests we must be able to answer the question "How many pests must be present before control is necessary?" For some pests the answer is obvious. One or two dogwood borer larvae may be enough to girdle and kill a small dogwood. However, large street trees may tolerate thousands of scale insects or aphids without noticeable signs of damage. Ideally, we need to know the relationship between the density of a pest and the amount of damage it causes. While

these relationships are well known for several agricultural pests, there are few studies relating densities of tree or shrub pests to the aesthetic damage they cause. A notable exception is the study by Olkowski et al. (24). They found eight California oakmoth larvae/25 shoots of holly oak to cause excessive defoliation. By treating trees only when oakmoth larvae reached this threshold density instead of whenever larvae were seen, pesticide applications were greatly reduced. Until similar decision making guidelines are developed for key pests on a regional basis, pest managers must rely on their own experiences in reaching control decisions.

The prospects for advances in monitoring pests and problems of landscape plants are bright. The current public awareness of problems associated with pesticide use has created a climate favorable toward pest management approaches that can reduce the unnecessary use of pesticides. Monitoring provides the information needed to apply pesticides in the most timely and accurate way. The development and implementation of monitoring techniques and approaches will greatly improve the arborist's ability to provide the best possible plant care. To achieve the greatest benefit from monitoring will require cooperation and commitment from researchers, Extension personnel, and members of the plant care industry.

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CORRECTION

The Editor regrets that the wrong group of graphs was selected for use in Figure 1 on page 304 of the October Journal of Arboriculture in the paper by Geoffrey P. Arron. The graphs for EL-500 and PP-333 also should have been included. They are represented below. Please make a note of this correction in your copy of the Journal.

