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INTEGRATED PEST MANAGEMENT IN ARBORICULTURE: FROM THEORY TO PRACTICE[1]

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Abstract. Integrated pest management (IPM) has evolved from theory to practice in the arboricultural industry. Enough technical information and experience exist to enable individual arborists to plan and implement biologically rational pest control strategies rather than using pesticidal cover sprays to reduce aesthetic impact of and damage from pests. IPM's most effective usage is in the context of plant health care. Perhaps a better framework for understanding the role of pest control in arboriculture is to define IPM as integrated *PLANT* management. After all, our goal as arborists is ecologically sound resource management. This paper introduces and discusses basic concepts of IPM and suggests establishment of action thresholds for key arthropod pests.

Résumé. La gestion intégrée des insectes et des maladies (IPM) a évolué de la théorie à la pratique au sein de l'industrie arboricole. Il existe assez d'informations techniques et d'expériences pratiques pour permettre aux arboriculteurs de planifier et d'appliquer des stratégies de contrôles biologiques rationnelles plutôt que d'utiliser des applications de pesticides pour réduire les dommages esthétiques causés par les insectes et les maladies. L'usage le plus effectif de la gestion intégrée se situe dans le contexte des soins de santé à l'arbre. Une meilleure manière pour comprendre de rôle d'un contrôle intégré des insectes et des maladies en arboriculture est de définir le concept plutôt comme la gestion intégrée des plantes. En fait, le but des arboriculteurs est d'assurer un porgramme écologique de gestion de la ressource. Cet article présente et discute les concepts de base de la gestion intégrée des insects et des maladies et suggère l'établissement de seuils de tolérance des plantes face à certains arthropodes.

Arborists and other pest control specialists make important decisions that influence environmental quality. This authority carries a responsibility that many practitioners may not have considered. Although the areas in which we live and work seem large and capable of absorbing punishment without impunity, our environment is extremely sensitive to chronic assaults like ambient air pollution, disposal of solid and other waste products of a highly industrial consumer society, and other forms of systematic degradation. Pest control activities associated with production and protection of food and fiber crops and landscape plants can either contribute to the process of environmental enhancement or to degradation, depending upon the approach used. We now know enough about the potential damaging side effects of pesticides to encourage rational decisions about their use in all production and maintenance practices, including arboriculture.

Integrated pest management (IPM) is a comprehensive process that utilizes information about crops, pests, and the environment to plan and implement management tactics in overall strategies to keep pests below levels that cause damage. This process was first introduced, as such, to members of the International Shade Tree Conference in the early 1970's as a concept. Since then, there have been several papers published in the *Journal of Arboriculture* describing the process and its implementation. The process is now part of everyday business practice for some arborists. As we enter the 21st Century, IPM has moved from theory to practice in our profession. Its most effective usage is in the context of plant health care (5). Plant health care professionals who wish to continue to offer pest control services in urban and suburban environments will adopt some form of IPM in the near future.

This paper presents a review of IPM as reported in the *Journal of Arboriculture,* provides practical

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suggestions for operational aspects of the process, and presents a framework for incorporating IPM in the practice of professional arboriculture.

Definition of Terms. According to Webster (1), to *integrate* is to form or blend into a whole, or to incorporate into a larger unit; an *integrator* is one who totalizes variable quantities in a manner comparable to the mathematical integrating or solution of differential equations. A *pest* is a plant or animal detrimental to man; one that pesters or annoys. *Management* is the judicious use of means to accomplish an end.

These standard definitions help us conceptualize *IPM* as *a process that utilizes all available means or tactics, blended together into a whole or strategy that minimizes the impact of pests.* Further, IPM tactics and strategies must be successful without causing adverse side effects. The practitioner is like an integrator, in that he or she analyzes situation variables of plants, pests,and the surrounding environment and makes operational decisions based on expected impacts of all variables, including costs and benefits to the client, their landscape, and the company's reputation and profit/loss statement. Practically, the IPM process requires thoughtful consideration of plant and human health, based on knowledge of plant performance, pest presence and abundance, current status of natural enemies of target pests, and familiarity with pest control procedures and their proper application. The level of expertise required to implement a successful program precludes use of untrained and uncommitted personnel.

People with bachelor, masters, and even doctoral degrees are rapidly joining the Green Industries, including arboriculture. Consultants who analyze properties and write tree health care and pest control protocols are becoming more common. As the liability associated with use of pesticides and management of urban forest resources intensifies, the practice of arboriculture will become more highly regulated, requiring expertise in specialty areas like IPM. The Department of Entomology at The Ohio State University recently established a "Masters in Pest Management" program to provide students with this expertise. As stated by others, "If pest control is to contribute positively to a more productive and aesthetically satisfying environment, more attention must be focused on the management of pest populations with more concern for all organisms in the total environment" (2). After all, our goal as arborists is ecologically sound resource management.

In 1981, J. T. Walker (7) introduced the concept of IPM for arborists in the *Journal of Arboriculture.* "Such a system would consist of identifying those pests which cause economic injury in the absence of control, defining a management unit (large or small), developing reliable monitoring systems, establishing economic thresholds, and developing a strategy through multiple tactics for pest management with the least insult on our environment. In some instances the concept would include the development of models for predicting pest behavior as a management tool. Then, and this perhaps is the most difficult, putting the system together in a workable package or delivery system." At that time, IPM was a high priority within federal and state bureaucracies, and significant dollars were invested in reseach to expedite and facilitate adoption of IPM principles in production agriculture, including commercial forestry. Dr. Walker suggested that government, industry, and academia work together in reseach to provide information necessary to implement IPM in urban forestry. He believed that the public was receptive to environmentally conservative pest control, and that specialists should work to package and deliver operational pest management packages to consumers.

At the 1983 meeting of the Penn-Del Chapter of ISA, W. K. Hock (8) pointed-out that many arborists use techniques of IPM in everyday practice, and that arborists can take advantage of available information to develop, package, and implement their own IPM programs, using techniques developed for other crops. He stated "that an IPM approach to pest management in trees and ornamentals is not only possible, but represents a tree care service that is highly marketable by professional arborists and landscapers." The fledgling urban IPM program for ornamentals at the University of Maryland was given as an example of how this concept could be implemented operationally and gain customer acceptance.

The pilot Maryland project was a cooperative effort between academia and a commercial arborist to compare costs and benefits of an urban landscape IPM program versus conventional cover sprays (9). Pesticide use was reduced by over 90%, while pest control was improved. This model program was further evaluated in other homeowner and institutional landscapes with equal success (10). However, the authors stated that "maximum benefits (of landscape IPM) will not be realized until basic research needs have been fulfilled." Herms et al. (4) discussed the value of considering the landscape as an ecosystem to improve pest management and stated: "By utilizing ecological principles in plant selection and pest management, an increasingly self regulated or low-maintenance landscape can be developed." They, too, suggested that more fundamental research in insect-plant interactions will need to be conducted before the concept can be widely applied in landscape maintenance.

Additional papers published by the Maryland group and others provide standards for a commercial arboricultural IPM program (11), discuss the concept of key plants and defining the management unit (12), and detail the essential process of monitoring (13, 14). Profiles of residential homeowners interested in IPM programs were detailed by Ball (15). These papers provide elements that can become part of a framework for arborists to use when designing and marketing their own IPM program. Operational IPM programs designed and implemented by federal and state personnel (16,17) can be consulted to obtain further details to aid those who wish to develop IPM products for improving landscape maintenance practices.

Action Thresholds and Pest Management

Any discussion of pest management implies a willingness to accept some level of pest population. This principle is especially essential to biological control efforts, since a residual pest population is required to support biological control agents such as parasitic wasps and flies, and predaceous ladybird beetles and lacewings. So, instead of trying to achieve pest control, pest populations are managed at a level below which they cause damage or reduce the aesthetic value of landscape plants.

Acceptance of low-level pest density broaches the question of *action threshold,* the level of pest density at which some form of intervention, either direct (population reduction) or indirect (cultural practices to enhance plant vitality or reduce the quality of the environment for the pest) must occur to prevent unacceptable pest impact. In the following discussion, action thresholds will be considered in the context of direct pest control tactics. Attributes and advantages of total tree health care to minimize pest problems in landscape maintenance have been detailed elsewhere (3,4,5,6).

In crop production, researchers have studied plant growth, pest density, and crop yield to determine the level of infestation that justifies a direct control measure. The terms economic threshold (ET) (the density at which a control measure is applied to prevent unacceptable damage) and economic injury level (EIL), (the density above which a pest causes loss in crop value exceeding the costs of using control measures to reduce its density), are useful in the context of crop production to make decisions about, if, and when pest control activities are warranted. Of course, time of year, stage of plant growth, vitality of the crop, and other factors that influence these assessments are dynamic variables that must be considered when making pest management decisions.

ET and EIL can be considered conceptually in landscape pest management, but little research has been done to define these levels for pests of trees and shrubs. Notable exceptions include papers by Koehler and Moore (18) and Raupp et al. (19).

Woody plants can withstand significant injury from defoliators, gall formers, sucking insects, and many other kinds of pests before their aesthetic value is reduced or damage occurs that might make them more vulnerable to colonization by opportunistic organisms like root rot and canker fungi, bark beetles, and borers. Furthermore, in the landscape we are often concerned more with aesthetic quality than actual damage to plants. So, the value of traditional terms like ET and EIL is limited in landscape management. Instead, we need to consider *action thresholds* (AT) or the *pest population density that signals the need for or justifies intervention activities.* "On the basis of the available fragmentary evidence, it may be concluded that economic threshold levels are almost invariably higher than expected. Too frequently, the visual threshold, the population level at which individuals of the pest species are obvious, is synonymous with the action threshold, and both are equated with the economic threshold. The action threshold is the level of pest population at which action must be taken to prevent the population from rising to the economic threshold where significant damage occurs" (20). thresholds for a given pest or type of pest will be dynamic and influenced by condition of the plant (a vital plant can tolerate pest activity better than a declining tree or shrub), local and seasonal weather (e.g. drought stress would lower the AT), and historical performance of specific pests and their hosts in your service area (e.g. protective sprays may be justified to protect vulnerable trees from attack by bronze birch borer if the insect has been locally common and summer or fall drought has occurred recently).

Few studies have been conducted to measure the aesthetic or physiological impact of a prescribed pest population on landscape plants (20). And, aesthetic damage commonly occurs before the pest population causes measurable plant stress. Although guidelines for establishing AT's have not been developed through rigorous research efforts, specialists who follow development of pest populations and their impact on hosts can make educated estimates that might be useful for initiating this component in landscape IPM programs. Once preliminary AT estimates are selected, practitioners can evaluate their utility under field conditions and make appropriate adjustments. The objective is to become skilled and comfortable with estimating pest density and host quality and how these two variables are related, so that appropriate intervention measures can be taken only when necessary and before aesthetic damage or physiological stress occurs. Arborists can determine usable AT's by keeping careful records during inspections and recording changes in pest density and plant performance through time. Realistically, this is the only way AT's will become an integral part of landscape IPM programs. Their incorporation into the decision making process regarding pesticide usage is essential.

Table 1 is an attempt to provide arborists with guidelines for establishing AT's for selected insect pests. The information should be regarded as preliminary; it is the subjective appraisal of only one specialist. The estimates provided will vary in aforementioned ways and need to be considered only as a starting point for those who wish to use the AT concept in their insect management efforts. Some explanation of the estimates may be helpful.

Table 1. Action thresholds for selected insect pests (a).

Type of insect	*Number of insects/unit area*		
	Spring	**Summer**	**Fall**
Aphids on hardwood leaves	2/leaf	4/leaf	SIN
Soft scales	5 mature females/m branch length		
Pine needle scale (pine)	2/needle+	4/needle+	SIN
Spider mites	1/beat	3/beat	SIN
Spruce gall adelgids	15/2 m tree		
Pine shoot moths	5 laterals/2 m tree		
Defoliators: hardwoods	20% defol.	40% defol.	SIN
conifers	30% uniform defoliation		
Bronze birch borer	1 emergence hole		
Lilac borer: in ash	4 pupal skins/2 m of trunk		
in lilac	1 pupal skin plant		

(a) Action threshold is the pest population density that signals the need for or justifies intervention activities. Values are for vital plants and are estimates based solely on the experience of the author.
SIN: Spray inappropriate now; census population again in spring.
+: Density higher than in previous generation.

Although **aphids** and soft scales imbibe plant fluids and may eventually reduce host vitality, their major impact on residential properties is often through the production of honeydew that falls on automobiles, patios, sidewalks, and elsewhere, thereby creating an annoying nuisance. If many leaves on a maple or oak are colonized by aphids in spring, the population can be expected to increase to noxious levels sometime during the summer, especially during periods of drought. If low levels of aphids are observed during an early inspection, and population increase is not observed during summer, spraying is probably not justified. This decision must be based on location of the tree (e.g. could honeydew from it impact patio or parking activities), presence of natural control agents like parasites and predators, and available soil moisture. Notice that the AT should probably be higher in summer. This is rational because by summer the leaves have already replaced much of the energy that was used for plant growth, and optimal photosynthetic efficiency is no longer required. Furthermore, if only modest aphid populations are present in summer, this may be an indication that conditions have not been and may not be favorable for population increase. In fall, even if relatively high numbers of aphids are present, there is little justification for spraying, since leaves will be shed soon. In fact, spraying could be considered a SIN (spray inappropriate now) in the fall because it would usually be unjustified, both in terms of the aphids' nuisance capability and their impact on tree vitality.

Soft scales (e.g. cottony maple, pine tortoise, tuliptree, Fletcher, and magnolia scales) are much like aphids in their impact on hosts and associated structures in the landscape in that they secrete copious amounts of honeydew. Similar considerations will be made about the nuisance factor associated with their honeydew production when making decisions about the need for direct control tactics. All of the scales mentioned above have only one generation annually, so their population change needs to be measured only once each year. If no more than four or five mature females are present on each meter of branch length inspected and the population density has not increased during the past year, an insecticidal spray is not justified unless honeydew is creating an unacceptable nuisance.

Pine needle scales (there are 2 species that can be determined only by specialists) complete at least two generations annually in much of their range, so their density can increase twice during each growing season. Infestations should be followed carefully in both spring and summer to permit use of a direct control tactic before plant injury occurs. If nearly every needle on a pine, spruce, hemlock, or fir is infested with any kind of arthropod, an insecticidal spray can probably be justified. However, when evaluating a pine needle scale infestation, efforts should be directed toward the most heavily infested part of the tree. Since this scale usually develops first on the bottom third of a tree, this area should be carefully inspected when checking for pine needle scale infestation. When measuring population density in the generally infested part of the tree, one or two scales per needle should not cause undue alarm, but the density should be measured and recorded. If the density doubles from spring to summer generation, the plants should be scheduled for a spring crawler spray the following April or May when all crawlers have hatched but before they molt. Although natural enemies, including parasitic wasps and predaceous beetles commonly occur along with pine needle scale populations, I have not observed them to stabilize pine needle scale density on landscape plants at acceptable levels. Certainly, they never cause dramatic population collapse of these scale insects in the landscape until after the aesthetic value of the tree has been seriously reduced.

Spider mites (e.g. two-spotted and spruce spider mites) cause foliage to assume a bronze color and lose its luster or vibrance. A good way to sample these pests is to place a white sheet or piece of paper beneath foliage and then strike the overhead branch sharply with a rubber-covered stick. If spring counts are less than one mite per beat (based on number of mites landing on a 12 inch square), remedial action is probably not justified. However, spider mites complete a new generation every six to ten days, depending upon temperature, so infested plants should be monitored regularly throughout the spring and summer to prevent unacceptable damage. If a mite infestation is increasing dramatically in spring or summer, miticidal sprays are justified. If the miticide of choice is not ovicidal (=toxic to eggs), two applications must be used at a six to ten day interval (6 days in the South; 10 days in the North).

These examples are provided to explain the logic of the numbers given in Table 1. Generally, if an infestation is not increasing and you are prepared to take appropriate action if and when it does begin to build-up, there is probably no need to spray immediately. In fact, in all cases when an infestation has reached your established action threshold, spraying must not be done until the next time the insect is in a vulnerable stage, even if the client expects tactic implementation sooner. This is where follow-up and educational literature become especially important. Explanations of the seasonal life history of the pest, what it can do to the plant, its potential for creating a nuisance, and how it will be managed must be made to the client. *Follow-up* during the first monitoring after application will permit assessment of its impact and provide information for a complete report to the client.

Concluding Remarks

Integrated Pest Management is no longer theory or a new concept for arborists and other landscape managers. It is a process that many of you are already implementing in your practice. There is enough information and experience within the industry now to provide interested arborists with guidelines to initiate an IPM program.

All such programs will require monitoring of trees, shrubs, and pests. This effort requires personnel who are familiar with both landscape plants and pests. Systematic assessment of plant vitality and pest presence and abundance, computerized information storage and retrieval, pesticide management to reduce environmental assault through targeted application on an *as needed only basis*, equates to IPM, whether it's called integrated pest management or integrated *plant* managment. The incorporation of integrated pest management in an overall plant health care business is an ideal that is now practiced by some of the innovators in our industry. Their attempts have been successful and can serve as models for the rest of us.

Literature Cited

1. Woolf, H. B., editor. 1973. Webster's New Collegiate Dictionary. G. & C. Merriam Company, Springfield, Massachusetts.
2. Rabb, R. L. & F. E. Guthrie, (editors). 1970. Concepts of pest management. Proceedings of a conference at N. C. State University, Raleigh, 1970. N. C. State University.
3. Nielsen, D. G. 1983. *Arborists and insect control: past, present, and future.* J. Arboric. 9: 12-16.
4. Hermes, D. A., R. C. Akers, & D. G. Nielsen. 1984. *The ornamental landscape as an ecosystem: implications for pest management.* J. Arboric. 10: 303-307
5. Nielsen, D. G. 1986. *Planning and implementing a tree health care practice.* J. Arboric. 12: 265-268.
6. Powell, C. C. 1985. *Tree health care from top to bottom.* J. Arboric. 11: 129-131.
7. Walker, J. T. 1981. *A need for urban IPM.* J. Arboric. 7: 204-207.
8. Hock, W. K. 1984. *IPM - is it for the arborist?* J. Arboric. 10: 1-4.
9. Holmes, J. J. & J. A. Davidson. 1984. *Integrated pest management for arborists: implementation of a pilot program.* J. Arboric. 10: 65-70.
10. Raupp, M. J. & R. M. Noland. *Implementing landscape plant management programs in institutional and residential settings.* J. Arboric. 10: 161-169.
11. Koehler, C. S., M. J. Raupp, E. Dutky, & J. A. Davidson. 1985. *Standards for a commerical arboricultural IPM program.* J. Arboric. 11: 293-295.
12. Raupp, M. J., J. A. Davidson, J. J. Holmes, & J. L. Hellman. 1985. *The concept of key plants in integrated pest management for landscapes.* J. Arboric. 11: 317-322.
13. Raupp, M. J. 1985. *Monitoring: an essential factor to managing pest of landscape trees and shrubs.* J. Arboric. 11: 349-355.
14. Ball, J. 1987. *Efficient monitoring for an urban IPM program.* J. Arboric. 13: 174-177.
15. Ball, J. 1986. *Public perception of an integrated pest management program.* J. Arboric. 12: 135-140.
16. Sherald, J. L. & C. L. J. DiSalvo. 1987. *Integrated pest management in the national capital region of the national park service.* J. Arboric. 13: 229-235.
17. Reardon, R., M. McManus, D. Kolodny-Hirsch, R. Tichenor, M. Raupp, C. Schwalbe, R. Webb, & P. Meckley. 1987. *Development and implementation of a gypsy moth integrated pest management program.* J. Arboric. 13: 209-216.
18. Koehler, C. S. & W. S. Moore. 1983. *Resistance of several members of the Cupressaceaeae to the cypress tip miner, Argyresthia cupresella.* J. Environ. Hort 1: 87-88.
19. Raupp, M. J., J. A. Davidson, C. S. Koehler, C. S. Sadof, & K. Reichelderfer. 1988. *Decision-making considerations for aesthetic damage caused by pests.* Bull. Entomol. Soc. Amer. 34: 27-32.
20. Anonymous. 1980. Urban Pest Management. National Academy Press, Washington, D.C.

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