Pest Index: A New Approach to Establishing Thresholds for Pest Management in Woody Landscape Plants[1]

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Abstract

Pest index, a new approach to categorizing the threat posed by an organism to woody plants, is proposed to assist plant managers in establishing treatment thresholds for pests of woody plants. The need for such a tool is based on the incredible diversity of pests of woody plants and the lack of experimental data establishing such thresholds. The pest index is computed using information about the detectability, damage potential, and ease of control of various pest groups. Values of the pest index are proposed for a variety of pest groups, but can be readily adapted to other groups not considered (or modified for particular pests that differ significantly from others in the broad groupings listed here). Using the pest index should allow plant managers to deal effectively with pests that are likely to pose serious threats to trees and shrubs instead of simply applying pesticides whenever a pest is detected. Thus, the pest index should foster the adoption of integrated pest management (IPM) in ornamental settings.

Index words: pest thresholds, integrated pest management.

Significance to the Nursery Industry

A new approach is proposed for prioritizing management of pests of woody plants in landscapes. A *pest index*, which is calculated by considering the detectability, damage potential, and the ease with which pests can be controlled, is proposed as a measure of the threat posed by a number of groups of insect and mite pests to trees and shrubs. The pest index can be used to assist in making decisions about pests that are encountered, whether to ignore them, have zero tolerance for them, or tolerate them up to critical threshold values. Using this approach should enable managers of woody plants in landscapes to effectively limit damage from arthropod pests while minimizing the unnecessary usage of pesticides, thereby fostering the adoption of integrated pest management.

Introduction

Management of arthropod pests of woody plants in the landscape is challenging because of the huge diversity of pests and potential host plants in these settings. As pest management in landscapes has moved to incorporate elements of integrated pest management (IPM), the result of greater concern about pesticides and stricter environmental regulations, an increasing number of landscape management firms are shifting away from the use of cover sprays and a zero-tolerance mentality toward arthropod pests. This approach, by definition, requires that one is willing to accept the presence of pests at some level. A fundamental question to address is: How many pests are too many? How many pests can be tolerated before intervention is required to keep the pest population from causing excessive damage? Further, what level of damage is excessive?

The answers to these questions depend on many factors. Because landscape plants are grown primarily for aesthetic purposes, it is more difficult to quantify damage than for, say, a crop plant, where damage thresholds can be readily quantified. In addition, tolerance for plant damage varies greatly with the property owner and the setting; some people prefer to see pest-free trees and shrubs, and less damage is tolerated in high-visibility locations than in back yards. If property owners truly wish to use less pesticide in managing the arthropod pests of their trees and shrubs, however, they will clearly need to become tolerant of some level of pest damage (changing attitudes such as this may require substantial educational effort, which is not the focus of this paper). For the purposes of discussion, I am assuming that the property owner has been convinced of the need to accept some level of aesthetic damage; for the rest of this paper, I focus on developing pest management thresholds that are designed to prevent damage to the health of woody plants, not aesthetic damage.

Ball and Marsan (1) nicely developed the concept of treatment thresholds for a landscape IPM program. They point out that landscape firms using a See-And-Spray approach to pest management (i.e. a zero-tolerance approach) use a *visual threshold* to make decisions about pesticide application; if a pest is seen on a landscape plant, regardless of the number of pests or the damage, a pesticide application is made. One step above this is the *damage boundary* approach, which results in pesticide application whenever damage from a pest is apparent. Both of these approaches suffer from the fact that woody plants are able to tolerate significant amounts of feeding damage, anywhere from 25 to 50%, in the case of defoliators (3, 5, 10); thus, unneeded pesticide is applied using these approaches.

A more sophisticated type of treatment threshold, as Ball and Marsan (1) point out, is the *economic threshold*. This level is the level at which intervention prevents a pest population from exceeding the economic injury level (the level of damage at which damage from the pest equals the cost of controlling the pest). Because this type of threshold requires

[1]Received for publication March 23, 2007; in revised form September 7, 2007. This research was supported in part by **The Horticultural Research Institute, 1000 Vermont Ave., NW Suite 300, Washington, DC 20005**.

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exact quantification of the value of the plant, it is more suitable for use in agronomic settings (such as nurseries), where plants are grown for sale. Quantifying the aesthetic damage is much trickier, but has been elegantly approached by Raupp et al. (15). As pointed out earlier, though, this paper will not focus on aesthetic damage but rather on damage threatening to the health of the plant.

A more neutral type of threshold is the *action threshold* (2, 11), defined as the pest population level at which action must be taken to prevent unacceptable damage. The level of damage is generally agreed upon at the start of a growing season, and if the level of damage approaches the threshold, intervention is generally required (although declining pest population levels would dictate that pesticide application be deferred).

A number of researchers have attempted to establish action thresholds for landscape pests, but unfortunately, the number of pests for which treatment thresholds exist is disappointingly small considering the large number of plant/pest combinations. The earliest attempt to establish thresholds for landscape pests was by Pinnock and Milstead (13, 14), who determined the damage threshold to California live oak by California oakworm. A limited number of thresholds have been determined for other pest/woody plant combinations: Olkowski et al. (12) presented thresholds for California oakworm on holly oak and blue spruce aphid on *Picea* spp.; Koehler and Moore (9) established relationships between density of cypress tipminer and aesthetic damage to cypress; and Raupp et al. (15) developed aesthetic injury levels by bagworm on arborvitae. Other pests for which aesthetic damage thresholds have been established include azalea lace bug (7, 8), orangestriped oakworm (3, 4), twospotted spider mite (16), Japanese beetle (18), and western flower thrips (18). Given the large number of arthropod pests of woody plants and the variety of host plants and settings in which they are found, however, this represents a trivial proportion of the pests that are faced by managers of woody plants.

Other investigators have attempted to broaden the range of treatment thresholds for woody plant pests by suggesting values based on reasoning as opposed to experimentation (11, 17), and I am convinced that such an approach needs to be expanded because of the overwhelming number of pest/host/setting combinations and the logistical and financial limitations facing researchers who might attempt to determine such thresholds experimentally. Consider the number of plant/pest combinations: there are over 300 species of woody plants found in landscapes in North America, and over 300 species of pests. Not all pests occur on all species of plants, of course, but the number of plant and pest combinations is staggering nonetheless. Other factors influence the tolerance for pests as well: time of year, soil conditions, weather, the starting health of the plant (or previous infestation history), location (e.g. back yard vs. high profile landscape), and the tolerance level of the property owner/manager. These factors all need to be considered when deciding what level of pest damage is acceptable.

To establish treatment thresholds rigorously for even the most significant pests out of the multitude that infest trees and shrubs would be a tremendous amount of work. It would take many researchers many years to measure the impact of each pest at a variety of densities on each of their host plants. Then, the impact of the moderating variables mentioned (soil and weather conditions, time of year, location, etc.) would need to be assessed with additional years of effort. The likelihood of this type of research being conducted is increasingly unlikely because funding for ornamentals research is far below what it should be for a sector of the agricultural economy that is as vibrant and growing as the Green Industry. Further, the number of researchers available to conduct the needed work is becoming limiting as well.

Given the impracticality of trying to experimentally establish treatment thresholds for the myriad of arthropod pests of woody plants, I took a more theoretical approach to the problem. The objective was to derive a measure of the threat posed by pests to the woody plants they attack based on several factors that determine pest potential, a measure I have termed the *pest index*.

Materials and Methods

To narrow down the plethora of pest/plant combinations to a more manageable set of pests for which thresholds can be established, I lumped pests into groups based on similarity in their feeding habits. For example, leaf feeders, sucking insects, and trunk borers have very different life history traits and exposure on plants, so need to be considered separately. In addition, certain pests are different enough from others feeding on the same part of the plant that they need to be treated separately. For example, insects feeding on the same plant tissues may vary widely with respect to their damage potential and ease of control; thus, taxonomic groupings were established for these pests to reflect these differences. As a concrete example, I have separated lepidopteran, coleopteran, and hymenopteran leaf-feeding larvae (i.e. caterpillars, beetle larvae, and sawflies, respectively) because of differential susceptibility of these groups to pesticides (e.g. caterpillars and beetle larvae are sensitive to *Bt*, unlike sawflies, and beetle larvae and sawflies are more readily controlled by imidacloprid than caterpillars). Using these criteria, I have broken pests of woody plants into 17 categories (Table 1). These groups can be further subdivided, even to the point of listing individual species separately, if there are significant differences among the three dimensions of pest potential listed below.

The next step was to classify each of these groups according to three dimensions that go into determining the overall pest potential of each group. The first dimension is *detectability*. This is merely the ease or difficulty of detecting these arthropods when they are present on a plant. Thus, leaf-feeding larvae as a rule are quite easily seen, so they would be classified as high on the detectability scale. In contrast, borers are generally not seen until feeding damage is rather extensive, so they rate low on the detectability dimension.

The second dimension is *damage potential*. This is a rough assessment of the damage the arthropod is capable of inflicting on the host plant if nothing is done to protect the plant. Thus, leaf feeding larvae rate from moderate to high, whereas borers rate high on damage potential. I have rated bark beetles low in terms of damage potential because they primarily infest trees that are dead or dying, although species of bark beetles that may attack and kill trees under stress that otherwise would have survived should be classified differently, perhaps lumping them with borers.

The final dimension is *ease of control*. This is a rough assessment of how easy or difficult the pest is to control, especially with reduced risk pesticides (e.g. *Bt*). Ease of control is determined by several factors, the main ones being how

Table 1. Classification of woody plant pests by ecological niche and taxonomic affiliation, where necessary. Values of detectability, damage potential, and ease of control were assigned subjectively, and pest index was calculated as described in the text.

Pest group	Detectability	Damage potential	Ease of control	Pest index
Beetle leaf chewers	High	Moderate/High	Easy	Low
Caterpillars	High	Moderate/High	Easy	Low
Sawflies	High	Low/Moderate	Easy	Low
Plant bugs/ lace bugs	High/Medium	Low/Moderate	Easy	Low/Moderate
Leafminers	Medium	Low/Moderate	Moderate	Moderate
Aphids	High/Medium	Low/Moderate	Easy	Low
Leafhoppers	High/Medium	Moderate	Moderate	Moderate
Scales	High/Medium	Moderate	Easy/Moderate	Moderate
Spider mites	High/Medium	Low/Moderate	Easy/Moderate	Moderate
Thrips	Medium	Low/Moderate	Moderate	Moderate
Bud mites	Low/Medium	Low/Moderate	Moderate/Difficult	Moderate
Twig/shoot feeders	Medium	Low/Moderate	Moderate/Difficult	Moderate
Borers	Low	High	Difficult	High
Bark beetles	Medium	Low	Moderate/Difficult	Low/Moderate
Tree crickets	Medium	Moderate	Moderate	Moderate
Twig gallers	Medium	Moderate	Moderate/Difficult	Moderate
Root weevils	Low	Moderate/High	Moderate	Moderate

exposed the pest is (e.g. internal vs. external feeders) and how readily it is killed by pesticides. Pests that feed externally and can be easily managed with pesticides would thus rate high on the ease-of-control scale, whereas internal feeders (e.g. borers) or those that are not easily impacted by pesticides would rate low. Other groups of pests fall somewhere between these two extremes.

The *pest index* is a combined function of the three dimensions just described: detectability, damage potential, and ease of control. I assigned numerical values to the ratings for each dimension, with 1 being assigned to ‘low’ or ‘easy’ and 3 being assigned to ‘high’ or ‘difficult’ for each dimension. If a pest was classified as intermediate between two rankings, the average was used (e.g. the average of a moderate/high rating would be 2.5). Then I multiplied the three values for each pest group, resulting in a numerical value ranging from 1 (= 1 × 1 × 1) to 27 (= 3 × 3 × 3). Because the pest index is the product of three factors, the relationship between its numerical value and a qualitative rating is not linear, and is biased toward low values. For example, a pest that rates ‘moderate’ on all three dimensions would have a pest index of 8 (= 2 × 2 × 2), whereas one that rates ‘high’ on all three would have a pest index of 27. Thus, cutoffs for ‘low, ’ ‘moderate, ’ and ‘high’ pest index were determined as the cube of the intermediate value for low to moderate and moderate to high for each dimension [i.e. 1.5^3 (= 3.4) and 2.5^3 (= 15.6), respectively].

Results and Discussion

The pest index represents a relative measure of the threat posed by a pest to a woody plant. It differs from damage potential, which is a measure of how much damage a pest is capable of inflicting on the plant if left uncontrolled, because it takes into consideration other factors that impact our ability to control the pest. Thus, a pest that is easily controlled but is difficult to detect will naturally have a greater likelihood of causing damage than an insect that is easily detected, and thus will have a greater value for its pest index. In addition, the pest index does not reflect differences in likelihood of encountering pests in a given landscape. Just because a pest has a high pest index (that is, poses a serious threat to a plant if encountered) does not mean that it is likely to cause damage to the woody plants in that landscape; the threat exists only if the pest is encountered. Given the unpredictability of occurrence of many of our landscape pests, it seems prudent to consider the potential threat posed by arthropods known to infest woody plants in a region, and be prepared to deal with them should they surface in a given year.

Calculating the pest index for the groups of pests in Table 1 results in most of the pests falling into the low and moderate categories, with the only member of the high category being borers. It is not surprising that borers would surface as the pests with the greatest pest potential; borers are one of the more serious groups of pests because of their damage potential, their inaccessibility to pesticides, and their difficult detection. As a result, the tolerance for this group should be near zero; they should be vigorously battled in the landscape, and prevented from becoming established, whenever possible. Using detection traps would be appropriate for these pests, and fortunately, there are traps available for a number of borers (mainly clearwing borers). Unfortunately, there are many borers for which traps are not available (e.g. most coleopteran borers, including roundheaded and flatheaded borers as well as ambrosia beetles); prophylactic application of pesticides, normally considered counter to the principles of IPM, are justified for settings where these insects can be expected to occur based on prior history or their presence in nearby locations.

The pest groups with low to moderate pest index values and low damage potential can probably be safely ignored — using the values listed, that covers lace bugs/plant bugs, aphids, and bark beetles. (Again, those species of pests within these groups that pose more serious threats to plant health should be treated separately, and have a pest index computed that reflects their greater damage potential. For example, lace bugs are often unimportant pests in more northern reaches of the United States, but can be serious pests in many southern locations; for these pests, a pest index should be adjusted to reflect this difference in damage potential.) Those pests with moderate to high damage potential should be treated as they are encountered at any level in the damaging life stage(s). This grouping includes primarily leaf-feeding coleopteran and lepidopteran larvae as well as root feeders with high damage potential (e.g. black vine weevil in the vicinity of newly transplanted host plants). Those pests with low to moderate damage potential that can increase rapidly in numbers (e.g.

Table 2. **Suggested treatment thresholds for pest groups with low to moderate pest potential and moderate to high damage potential.**

Pest group	Treatment threshold
Sawflies	25% of branches infested
Leafminers	50% of leaves infested
Scales	5 mature females/m branch length
Twig/shoot feeders	25% of branches infested
Tree crickets	25% of tree damaged
Twig gallers	15% of branches infested

spider mites, thrips, and bud mites) should also be treated when found if conditions for population growth are favorable, especially if monitoring frequency is expected to be low because of unavailability of labor.

The remaining insects — sawfly larvae, leafminers, leafhoppers, scales, twig/shoot feeders, tree crickets, and twig gallers — are ones for which thresholds should be employed when making treatment decisions. No published thresholds exist for these pests, however, so thresholds based on logic will have to suffice for the moment. I have suggested thresholds for these pests in Table 2. The values there are based on the notion that defoliation from 25 to 50% can be tolerated before damage is done to a woody plant (3, 5, 10), but I have used the more conservative end of this range for most of these pests. For leafminers, I increased this threshold to 50% because the damage these insects cause to leaves is only partial. For scales, I used the value proposed by Nielsen (11) of 5 mature females per meter of branch length, and for twig gallers, I dropped the infestation rate to 15% of branches infested because loss of branches is much more harmful to woody plants than loss of leaves. These thresholds are merely suggested starting values, and should be modified based on experience with these pest groups and the damage they cause, similar to the approach proposed by Ball and Marsan (2) for establishing action thresholds. Ideally, action thresholds will be the focus of researchers aiming to develop IPM programs for landscape pests.

How do these values compare with those used in practice by companies employing IPM principles? In an effort to answer this question, I interviewed a pest control coordinator for one of the few landscape maintenance firms in western NY that follows IPM principles, and found that a number of pest control guidelines were similar to my suggestions, but differed significantly in several cases (Table 3). In most cases where we differ, they took a more aggressive approach to pest management. This is probably due in part to the logistic and economic challenges of keeping up with a particular landscape on a commercial basis: it is simply not economically viable to scout plants and track pests in a commercially-managed landscape closely enough to follow idealized pest thresholds.

One important aspect of the pest management thresholds that I am proposing is that they were chosen to preserve plant health, and not necessarily minimize aesthetic damage to woody plants. While aesthetic injury levels aim to keep damage from arthropods below levels that are noticeable by humans, I am suggesting that looser thresholds be followed that, while they may result in plant damage that is unappealing to the human eye, will not seriously impact the health of the tree or shrub. This involves modification of human tolerance for damage, and will not be acceptable in certain high-exposure landscapes, but as pesticide regulations become stricter and fewer products available for use in landscapes, it may be inevitable that managers and users of landscapes will need to tolerate more pest damage. Nursery managers are likely to follow stricter thresholds because appearance of plants is critical for maximizing their market value, but for deciduous trees and shrubs grown for several years in a nursery, it may be possible to follow the looser guidelines while preserving plant health when plants are young, and then tighten up the thresholds as the plants reach marketable size.

So where do we stand with treatment thresholds for pests of woody plants? First, I think it would be very instructive to survey a spectrum of pest management firms striving to employ IPM, and find what is being used in the field and how it is working. Recent surveys of landscape pest management firms have been conducted (6, 19) and found that IPM practices, especially scouting, are becoming common practice for many landscape firms, but pest-management decisions are most often based on the extent of pest damage (19), without regard to other factors (time of year, pest population trends, etc.). This suggests that there is abundant opportunity for educational efforts regarding the decision-making process by landscape management firms. It is also clear that attitudes

Table 3. **Comparison of pest management decisions for major groups of woody plant pests between the Pest Index approach and a landscape firm that practices IPM.**

Pest group	Pest Index approach	IPM landscape firm
Beetle leaf chewers	treat if found and damage potential is high	try mechanical control 1st, then spray if larvae found
Caterpillars	treat if found and damage potential is high	try mechanical control 1st, then spray if larvae found
Sawflies	treat if > threshold	ignore
Plant bugs/ lace bugs	ignore	treat if found
Leafminers	treat if > threshold	birch leaf miner: treat others: only if heavy
Aphids	ignore	don't treat, but follow up
Leafhoppers	treat if > threshold	ignore
Scales	treat if > threshold	treat if found
Spider mites	treat if found	treat if found
Thrips	treat if found	ignore
Bud mites	treat if found	ignore
Twig/shoot feeders	treat if > threshold	ignore
Borers	treat prophylactically	treat prophylactically if history of particular borers
Bark beetles	ignore	ignore
Tree crickets	treat if > threshold	ignore
Twig gallers	treat if > threshold	treat if found
Root weevils	treat if found	treat rhododendrons and azaleas if chlorotic; rarely treat *Taxus*

and perceptions of landscape appearance will need to be changed if the amount of pesticides used to manage pests is to be decreased, as pointed out by Hubbell et al. (6).

It is important to realize that my classification of pests by pest group is arbitrary to some extent, and this breakdown and the subsequent calculation of the pest index should be modified as necessary to make sure that important pests that differ from others with which they might be lumped are not overlooked. For example, those pests that vector diseases have not been explicitly considered in my classification scheme; such pests may need to be considered separately from others with which they are currently combined. In addition, insects that cause problems unrelated to the damage they do to their woody plant hosts (e.g. dripping of honeydew by sucking insects onto valued objects below) would require action thresholds designed to limit property damage, and not thresholds designed to prevent damage to plant health. In situations where the property owner is more concerned about the appearance of their plants rather than following an approach that will reduce pesticide use while ensuring the health of their plants, treatment guidelines such as these are meaningless because the treatment threshold would be determined solely by aesthetic considerations. However, a number of factors are forcing managers of woody plants to look at pest management differently. Following an IPM approach requires increasing our tolerance of pests and pest damage, but only to levels at which they do not seriously damage the aesthetic value or pose a threat to the health of the plant.

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