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IPM: What Does It Really Mean?

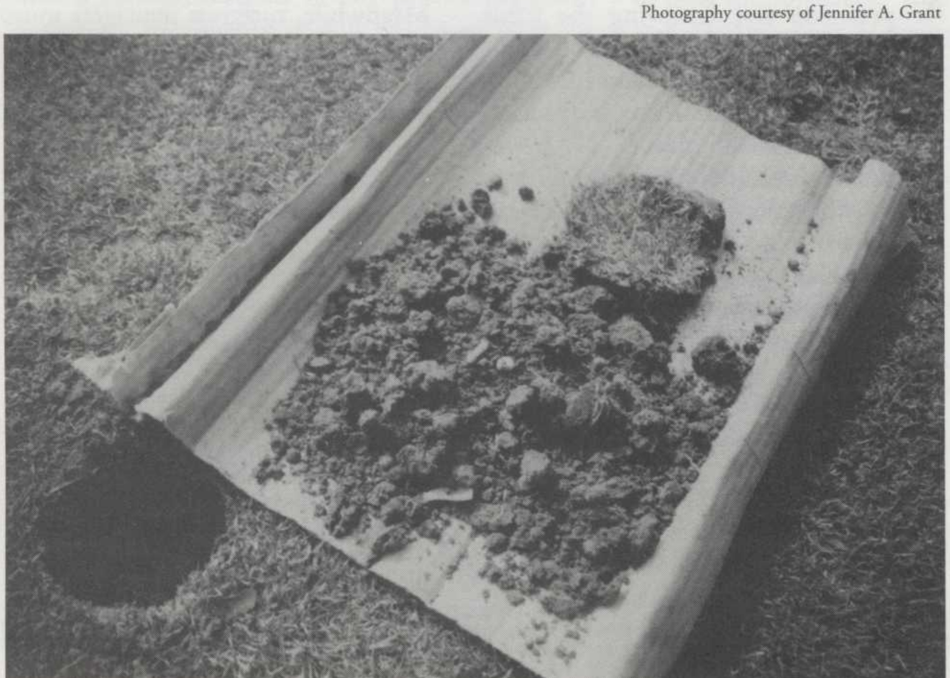
by Jennifer A. Grant

Integrated Pest Management (IPM) is a decision making process that strives to make the best use of all available management tools, including cultural, biological, mechanical, environmental, and chemical methods. IPM is also known as Integrated Turfgrass Management, Best Management Practices, or plain old common sense.

Precise definitions of IPM vary, but most agree on the following as its goals. On the one hand, they are to minimize losses to pests, costs, negative environmental effects, negative effects on human health and pesticide resistance potential. On the other hand, they are to maximize cultural, mechanical and biological pest controls, the effectiveness of chemical pesticides, turf quality and populations of beneficial organisms.

Any decisions based on these criteria involve compromise, and will depend on factors such as pest pressure, weather, quality demands, and intended use of the area. Turfgrass managers therefore select distinct IPM practices in various settings and circumstances. As practitioners you know that IPM is diverse and cannot be applied according to "cookbook" recipes. A weed problem in August will be handled differ-

Photography courtesy of Jennifer A. Grant



IPM involves careful examination of developments in the turf

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ently by a golf course superintendent in Georgia, than by a lawn care professional in Colorado. In fact, neighboring lawns often have unique IPM programs.

Pest monitoring, or "scouting", is considered the backbone of any IPM program. This includes regular inspections of turfgrass health, pest presence and signs of pest damage. Short- and long-term strategies for pest management are based on the information collected. Decisions include the need for control measures, when to take action, and the optimal products and practices to use. Better timing and product selection can greatly improve the performance of pesticides, resulting in higher turfgrass quality. When considering biological control agents and other alternative management strategies, monitoring information is even more critical.

After monitoring and determining where action is needed, there are a variety of pest management methods to choose from. The "I" in IPM aims to create a truly INTEGRATED system by emphasizing cultural, biological, and mechanical pest control practices, and removing the focus from chemicals. Traditional pesticides are still an important IPM tool, but the need for them is reduced, sometimes eliminated, by better timing and diversification of pest control strategies.

IPM can be viewed in two phases. The first phase includes basic techniques such as monitoring, use of thresholds, and the optimal timing and selection of pesticides. This phase is sometimes referred to as "Integrated Pesticide Management." These methods are being implemented throughout the world, and have resulted in pesticide reductions up to 75% on turfgrass as well as many food and fiber crops.

In its second phase, IPM is taken a step further by substituting alternatives for chemical controls. Well-known basics are utilized, such as raising mowing heights, physical removal of weeds, and management of thatch and water to alleviate stress. Recently developed biological methods are also used. Products now or soon to be available for turfgrass insect control include parasitic nematodes and insect-attacking bacteria and fungi. Natural organic fertilizers, composts, and beneficial fungi are also on the market for disease prevention and suppression.

The techniques of the first phase of IPM are available to all turf managers. Many already follow these principles, while others could improve their pest management by monitoring more frequently and by using the information gathered as the basis for pest control decisions. In order to be successful with the alternative strategies of phase two, phase one of IPM must be a routine practice. Unfortunately, a full array of alternative solutions for turfgrass pest problems does not currently exist. Researchers and industry professionals are working to fill the gaps. Meanwhile, turfgrass managers must be content to perfect phase one of IPM, and use appropriate alternatives when available. Most IPM techniques are not new or high tech — just common sense principles being put to use.

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Integrated Pest Management of Insects

by Jennifer A. Grant

At this time of year, turf managers are often forced to think about insects. Scarab grubs have begun their annual feeding cycle in many parts of the country, and the optimal period for mole cricket control is ending in the South. If you are lucky enough to have escaped those pests, perhaps you are battling cutworms, billbugs, or chinch bugs this season. Regardless of your individual insect woes, IPM techniques can help you detect, identify, and manage such pests.

Monitoring is essential

Successful management of most turf insects depends on the detection of pests before they reach damaging levels. This can best be accomplished through frequent turf inspections in search of early signs of insects and their damage.

Monitoring or "scouting" is a systematic method of inspecting turf for pests and cultural problems. It should be the backbone of any pest management program. Its primary goal is to detect, identify, delineate, and rank pest infestations and turfgrass abnormalities. All turf areas should be monitored on a regular basis during the growing season. The scouting interval may vary from one to two days to several months, depending on the location and use of the turf.

Among the more common symptoms of insect-damaged turf are a general thinning of the grass, spongy areas, irregular brown patches, and plants that break away easily at soil level. Substantiating the insect origin of the problem may be difficult, however. Many of the symptoms just described could also have been caused by heat or drought stress, nutritional deficiencies, turf diseases, soil compaction, chemical burns from gasoline, fertilizers, herbicides or insecticides, scalping during mowing operations, or even animal excrement spots. If the problem is insect-related, a close visual inspection of the damaged area should reveal either the insects themselves or indirect evidence of their presence.

Similarly, bird and animal feeding activity often indicates potential insect problems. Starlings, robins, moles, skunks, and raccoons are well-known insectivores. Once again, confirmation of the insect origin of a problem requires close examination of the injured area. Look for signs of skeletonized leaves, clipped grass blades, fecal pellets (excrement), sawdust-like debris, stem tunneling, silken tubes or webbing. Reference books can then be used to identify the insects causing the damage.* If no evidence of insects or their feeding is found, the condition is probably due to another cause.

Insect sampling

In addition to the visual monitoring of turf, insect sampling techniques are useful IPM tools, offering further evidence of the presence and severity of insect problems. Insects are often difficult to find because of their size and covert feeding habits. Some sampling methods can simplify the search process, often by encouraging or forcing insects out of their hiding places. It is not necessary to collect samples on every scouting visit, only when the presence of insects is suspected.

When sampling is indicated, target those areas most likely to be infested first. Divide large plantings into smaller, more-or-less homogeneous areas

***Recommended References:**

Brandenburg, R.L.and M.G. Villani (eds.), Handbook of Turfgrass Insect Pests, Lanham, MD: Entomological Society of America, 1995 [available September, 1995; $30; telephone (301) 731-4535 to order]

Shetlar, D.J., P.R. Heller and P.D. Irish, Turfgrass Insect and Mite Manual, Bellefonte, PA: Pennsylvania Turfgrass Council, 1983; [revised edition available November, 1995; telephone (814) 863-3475 ot write Pennsylvania Turfgrass Council, Landscape Management and Research Center, Orchard Road, University Park, PA, 16802 for information].

Tashiro, H., Turfgrass Insects of the United States and Canada, Ithaca, NY: Comstock Pub. Associates, 1987.

— often referred to as pest management units (PMUs) — so they can be considered individually when making pest management decisions. For example, each tee, green, and fairway on a golf course might be considered a PMU. Likewise, the front and back lawns of residential properties can be considered separate PMUs (homeowners typically have differing aesthetic standards for these areas).

Tips on Sampling

■ *Sample if damage or other visual sign of insect activity is seen.* Example: Off-color turf accompanied by sawdust-like material around the crown of plants indicates billbug presence.

■ *Sample at the appropriate time in the insects' life cycle and the growing season.* Example: Check for scarab grubs in the early stages (1st or 2nd instar), before they cause significant damage.

■ *Sample in "indicator" areas that are highly susceptible or have historically been infested.* Example: A lawn that had chinch bugs last year is likely to have them again. Begin sampling in previously infested areas as soon as the weather turns hot. Once chinch bugs are detected, be alert for activity on properties nearby.

■ *Sample when a post-treatment analysis for efficacy of pesticides or other control measures is desired.* Example: High cutworm populations detected on several golf course greens result in an insecticide application. Sample the greens approximately five days later to be sure the treatment was successful.

Do not assume results will be the same throughout a turfgrass area, because insects are not distributed evenly. Once the need for control actions is assessed, move onto another PMU. Sampling and treatment decisions will depend on the availability of time and labor, and the aesthetic standards for each area. Descriptions of various sampling techniques follow. They are keyed to specific insect pests.

■ **Disclosing (irritant) solution:** Surface-active insects can be flushed from the turf with a disclosing solution. Mix 2–4 tablespoons of liquid dishwashing soap or 1 tablespoon of 1% pyrethrins into 2 gallons of water and pour the mixture over a square yard of turf. Insects irritated by the solution such as webworms, cutworms, armyworms, mole crickets, billbug adults, as well as earthworms, will come to the surface within five to ten minutes. After flushing, they are easily collected, identified, and counted. Treatment thresholds based on this sampling technique have been established for some insects. For example, 14 mole crickets per square yard are likely to cause damage. Because detergents vary in their concentrations and components, they should always be tested to determine the soap-to-water ratio that will irritate the target insects, yet not harm the turfgrass.

■ **Flotation:** Insert a large coffee can with both ends removed 1–2 in. into the soil. Fill the can with water and replace any water that escapes until the turf has been submerged for three to five minutes. Insects will float to the water surface where they can be collected, identified, and counted. Alternatively, remove soil cores with a golf course cup cutter and place them in a bucket of water for a similar period. Several cores can be soaking in the bucket simultaneously. Flotation is ideal for detecting chinch bugs and many of their natural enemies. Consider 20 chinch bugs in a cylinder with an 8–9 in. diameter a damage threshold.

■ **Soil examination (cup cutting and soil digging):** Some soil-inhabiting insects, such as scarab grubs, cannot be sampled by the methods previously discussed. These insects must be sought in the root and thatch zones where they feed. One sampling technique involves cutting three sides of a turf square (1/4 to 1 sq ft in area) with a shovel or knife, and peeling back the sod layer to expose white grubs, billbug larvae, and other soil dwellers. It is important to examine the entire root zone, including both the sod cap and the upper 1–3 in. of soil. Several samples should be taken to determine population levels throughout the area.

An easier method for sampling soil-inhabiting insects utilizes a standard golf course cup-cutter that removes 4-in. soil cores. In fact, these tools are so handy that lawn care professionals and other turf managers should purchase one. Cores can be rapidly inspected for insects as soil is discarded back into the original hole. If the sod cap is then replaced and the area irrigated, damage to the turf will be minimal. Record the number of each insect species found and its predominant life stage (instar) on a data sheet or map.

Inspecting soil samples in a grid pattern across any turf planting will help delineate areas infested by insects. Intervals of 20–30 yds. between samples in large turf areas should be sufficient. Ultimately, the number of samples taken will depend on the time and labor available. Studies in New York have shown that 20–40 samples can be examined per person per hour. Sampling time varies, depending on insect density, soil type, thatch thickness, and other factors.

Knowledge of grub/beetle life cycles will help you get the most out of your sampling effort. Sample when grubs are small: 1st and 2nd instar. For Japanese beetles in the Northeast, this is usually in early- to mid-August. Southern masked chafers in the middle and southeastern states should be sampled in late July or early August. Times vary by grub species and regional and local weather patterns.

Begin sampling a few areas several weeks before you expect grubs, in order to monitor the insects' life cycle. Once the eggs have finished hatching, and the majority of grubs are 1st or 2nd instar, initiate your full sampling plan. A window of 2–3 weeks is usually available to complete sampling.

Damage thresholds have been established for the major grub species.* Use these as guidelines for treatment decisions. Generally speaking, healthy turf with strong roots, adequate moisture, and low stress will tolerate grub infestations above the threshold level. Conversely, stressed turf will be susceptible to damage at threshold levels.

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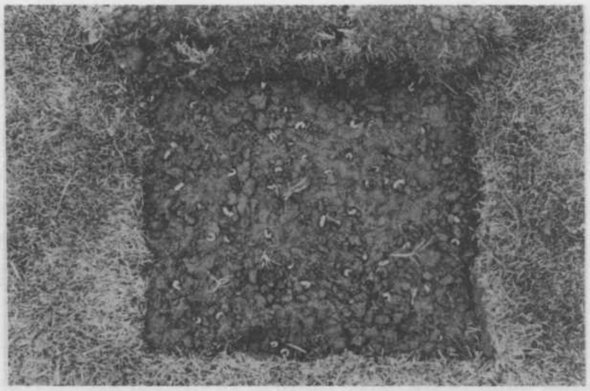
*See the article that follows for a discussion of these thresholds and their use.

■ **Traps:** Insect activity can be monitored using traps of various kinds. Most traps have an attractant (lights, pheromones, food scents) that lure insects. Upon reaching the trap, insects are captured by sticky surfaces or killed with insecticides. Typically, these traps are hung from trees or stakes in or near the turf area. Light traps collect a wide variety of flying insects, including scarab beetles, and cutworm, webworm and armyworm moths. However, it is difficult and time-consuming to sort and identify the large number of diverse insects collected. Pheromone traps, on the other hand, are highly selective and normally capture only one sex (usually males) of a single species of insect. Pitfall traps are placed in the ground so that the top is flush with the turf surface. These traps capture insects as they move along the ground. Arthropods such as mole crickets, billbug adults, ground beetles, and winter grain mites can be monitored using pitfall traps.

Insect traps provide important information confirming the presence and timing of activity of a particular pest in a particular area. For example, peaks in adult activity can be tracked and used to predict when damaging larval activity will occur later in the season.

It is important to fully understand the capabilities and limitations of any trapping method before use. For instance, <u>traps should not be relied on to reduce or eliminate pest infestations</u>. Also remember that to be effective, traps must be checked on a regular basis — sometimes daily!

■ **Visual inspection:** Certain insects are most easily detected by visual inspections. Billbug adults, for example, can be monitored as they stroll on paved areas and sidewalks in hot weather and a treatment threshold of five to ten insects detected in five minutes can be used. Annual bluegrass weevils can be detected by inspecting the clippings from close-cut turf, and chinch bugs can sometimes be found by separating grass plants with the thumb and forefinger and examining the base of the plant. While visual inspection can be used to detect most insects, it is rarely as efficient as other sampling techniques.



Looking under the turf

■ **Other detection methods:** Standard insect sweeping nets are useful for collecting flying insects in turf areas. Mole crickets in flight have been monitored using sound-trapping stations that broadcast recordings of males. Their damage can be assessed by placing a square frame divided into equal sections on a damaged area, then rating the turf by the number of sections containing mounds or tunnels.

Using sampling information

Sampling provides details about insect population densities, species, and developmental stages. High and low population areas can be delineated for possible spot treatments and damage thresholds used as guidelines in making treatment decisions. While sampling, additional information can be gathered about thatch thickness, soil type and moisture, turf health and vigor, and turfgrass species. These facts can be used to decide if control is necessary and what strategy should be employed. If an insecticide is necessary, the site-specific knowledge gained will aid in the selection of the most appropriate product.

If turf damage is evident but no pests are detected, examine the turf for other causes of injury, such as disease, excessive thatch, improper mowing, or heat or moisture stress. When examining turf, be on the lookout for pests' natural enemies, such as lady beetles, big-eyed bugs, lacewings, ground beetles, spiders, and parasitic wasps. A high ratio of natural enemies to pests is usually best left alone—let nature do the work!

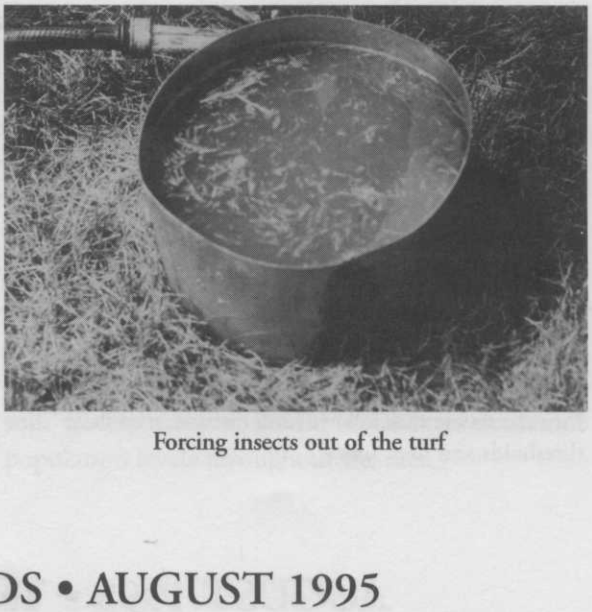
Record keeping and evaluation

Accurate records are essential for the success of a turfgrass pest management program. Keeping the documentation simple will render the process less burdensome.

Sampling and scouting records

During the growing season, day-to-day pest management decisions should be based on scouting information. Effective record-keeping greatly increases the long-term value of this information by providing the turf manager with historical, site-specific knowledge. This information can be used to predict when certain pest problems are likely to occur, both in the current season and in subsequent seasons. In addition, records call attention to patterns and associations that may be overlooked during a pest infestation. Examples include particular turf areas or cultivars that are chronically infested, or insect activity coinciding with drought or disease stress. Pest histories should be reviewed several times each season so that potential problems can be anticipated and initial monitoring efforts focused on historical "hotspots."

Scouting records should be as complete as possible. Note the kinds and numbers of pests present, when and where they were found, and exact locations, and extent of any turf damage or abnormalities observed. Information on the turf species and cultivar development, turf health, and current environmental conditions is also valuable. When recording scouting or



Forcing insects out of the turf

other management information, be as quantitative as possible: record the actual number of insects per unit area; assign numerical ratings to injured turf. Photographs are also an excellent way of documenting and comparing damage.

Control records

Information pertaining to control methods and their results is as vital to a successful IPM program as are scouting records. The combined pest and control information forms the basis for judging efficacy and cost, as well as making future plans. You should already be keeping good records of pesticide use. Compare them with observations of insect activity. Ask yourself: Can your records be enhanced by including sampling and threshold data? Do you follow-up control measures with an assessment of effectiveness? Do you know how much a pesticide application costs (product, labor, environmental effect)? Can you easily access records of other practices and events that affect insects (i.e., fertilization, mowing, temperature, rainfall)?

Assessing the effectiveness of cultural and control practices is an often overlooked but important component of a turfgrass pest management program. In most cases, the same sampling techniques used to detect the original pest infestation can be used to monitor the success or failure of a control strategy. When evaluating the efficacy of a control measure, however, sampling can be limited to only a few previously infested areas. The turfgrass manager can use the evaluation process to differentiate management approaches that were effective from those that need to be modified. At the end of one season, this information can be reviewed in order to plan and prioritize scouting and management activities for the following season.

Pest management options

Sampling and monitoring information can greatly improve your ability to manage insects. The most important benefits are early detection, determining if control measures are needed, and optimal timing of these actions. Pesticide use is often decreased in the process. For example, a turf manager might make successive insecticide applications to control cutworms, reacting every time significant damage is seen. Conversely, forewarned by experience, the same manager might anticipate the problem, sample, then act before injury occurs. Early detection allows treatment of the first infestation of cutworms when they are young and vulnerable, and have yet to cause significant damage. Good control of a parent generation precludes damage from their offspring.

Assessing insect problems before they reach crisis proportions also increases the management options. In the early stages of an infestation, cultural practices such as irrigation, mowing, and fertilization can be manipulated to reduce damage. Additionally, we are entering a new era of pest control, when early detection, proper identification, and proper timing are essential for success of biologically-based solutions. For example, nematodes and microbial products must be applied when insects are young. In addition, various species and strains of these control products must be matched to the exact species of pest insects.

Conclusion

This article contains many practical ideas for fine-tuning your insect management strategies. If you try to implement them all at once, you will be overwhelmed. After all, there's a lot more to growing quality turf than managing insects! Pick out techniques that would have the greatest impact on your most persistant or most severe insect pests. Eventually these practices will become standard, and you will find yourself approaching all pest problems from an IPM point of view. Initial investments of time and labor are paid off in quality improvement, reduced pest management costs, and peace of mind.

Deciding on Control of Scarab Grubs

by Jan P. Nyrop and Dan Dalthorp

Grubs, more properly the larvae of scarab beetles (Japanese beetle, European chafer, and Oriental beetle), feed below the soil surface. When they are abundant, management action must be taken to avert damage to turf.

Deciding whether a grub population warrants application of an insecticide is no simple matter, however. These insects cannot be seen without digging in the soil, and their distribution throughout a planting is rarely uniform. Nonetheless, turf managers need to assess their abundance, and should be making treatment decisions on the basis of those assessments.

This article presents information and techniques that can help managers determine whether a scarab grub population threatens a turf planting, and how best to cope with that threat. The article has three sections. The first gives an overview of pest management decision making and the role in this process of information on pest abundance. The second outlines a method for determining whether a significant scarab grub problem may exist on a site, and describes its use in evaluating residential or other small turf areas. The final section addresses the use of that method in assessing scarab grub densities on larger turf plantings such as golf courses and golf course fairways.

Crop protection decision making

The easiest way to manage an insect pest may be to make a preventative insecticide application whenever the beast is thought to be present. Ordinarily, this is not a good strategy, it is too costly. Applying insecticides to control a pest always incurs costs. Some of these costs, for the purchase and application of the necessary materials, for instance, are easily calculated. Others, such as environmental degradation, health risks or clients' opposition to pesticide use, while difficult to assess concretely, should still be considered. Crop protection decision making entails balancing the costs of insecticide applications with the benefits that result from their use. In most situations, this requires information on the abundance of the pest.

The pertinent concepts in crop protection decision making are best explained by illustration. We refer to the average number of insect pests per unit area (or per sample) as pest density. When pest density exceeds five individuals per square foot of turf, we can assume significant damage will begin to occur, and as it increases in severity its economic consequences will increase accordingly. This relationship is shown in Figure 1.

The point where the cost of insecticide application intersects the value of insect damage is the break-even point for pest control (meaning the value of damage prevented, usually measured in terms of the cost of repair or replacement, is equal to the cost of control). The pest density at which this occurs is called the *economic threshold*. When insecticides are applied to sites with pest densities below the economic threshold, the cost of control exceeds the cost of damage that the insecticide application mitigates, so there is no net benefit. When pest densities exceed the economic threshold, the benefit derived from an insecticide application equals the difference between the anticipated cost of the damage the pests would have caused and the cost of control.

Graphics supplied by the authors

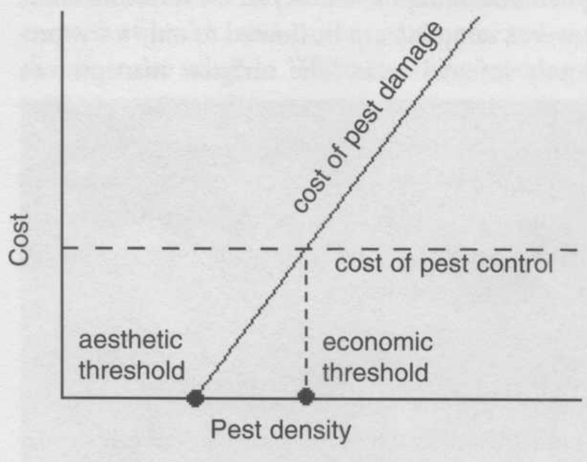


Figure 1. Economic and aesthetice thresholds for crop protection decision making

As mentioned previously, other, often intangible costs should also be considered in pest control decisions. These include aesthetic concerns and adverse reaction to unnecessary pesticide applications.

Clients may not wish any insect-caused damage to be visible. Then, even though the cost of eliminating even minimal damage is rather high, the pest density at which control should be initiated is low — well below the economic threshold. This point is referred to as an *aesthetic threshold* and is also shown on Figure 1.

Other clients might inveigh against all but absolutely necessary pesticide use. In such cases, the pest density at which control should be initiated could be well above the economic threshold.

This illustration has thus far assumed that pest density and the relationships between pest abundance, damage abatement costs and the costs associated with pesticide applications are all known — in other words that the decision maker has perfect information. The costs of acquiring this information have not been factored into this illustration, however. And, obviously, none of these assumptions applies in the real world.

In actuality, the relationship between pest abundance and pest-caused damage is not known with precision. This should not impede using information on pest abundance to decide whether to apply an insecticide, however. Where economic or aesthetic thresholds have not been established, conservative approximations can be used. This can still result in reduced pest control costs.

Estimating pest abundance is of greater concern. Estimation itself incurs costs, and certainty regarding the actual density cannot be achieved. The effect of this uncertainty on pest control decision making can take several forms. On the one hand, a pesticide might not be applied when it is needed; on the other, a pesticide might be applied needlessly. Fortunately, given careful design and execution of sampling methods, the risks inherent in reliance on sample-based estimates of pest density can be controlled.

Collecting sample data to determine whether pest density exceeds a specified threshold, is the most common way information on pest abundance is used in crop protection decision making. This could be an economic threshold, an aesthetic threshold, or an approximation of one or the other. The actual sampling might be as simple as collecting a fixed number of samples, calculating the average number of insects uncovered, and comparing this average to the threshold. More sophisticated statistical procedures can also be used to determine how many sample observations will ensure the risk of incorrect treatment decisions remains acceptable, while minimizing the number of samples required. In general, the more samples taken, the lower the risk of an incorrect decision, but the greater the cost of acquiring samples. Well-designed procedures for assessing pest density balance these risks and costs appropriately.

We have found that the best treatment decisions for scarab grub control are those based on assessments of grub density. It has also been our experience that such assessments carry minimal risk of shaping erroneous decisions, and that, compared with "automatic" prophylactic applications, reliance on such assessments can reduce pesticide use significantly.

Rules for making treatment decisions for scarab grub infestations, and their application to residential turf plantings

As indicated, sample information on pest abundance is usually employed to determine the need for pesticide treatment by comparing pest density to some threshold. The economic threshold for scarab grubs in turfgrass is generally considered to be five to ten individuals per square foot. Given this, devising a procedure for determining grub abundance and the need for pesticide treatment would seem to be straightforward. It would be straightforward if scarab grubs were distributed evenly across a site. They tend not to be.

Scarab grubs are usually found in patches scattered throughout a turf planting, and when the number of larvae exceed densities associated with damage, they often do so only in limited areas of a site. At the same time, the mean density for the entire planting often wili be well below the damage threshold. This situation is illustrated in Figure 2. The area of turf depicted has one large and one small patch of scarab grubs. The density of grubs in the larger patch is high (peaking above 20/sq ft), but the average density for the entire planting is considerably less (4.4 grubs/sq ft). Thus, basing a treatment decision on the mean density for the entire location would lead to a patch that warranted treatment being left untreated.

Because it can fail to detect grubs in high-density patches, mean density over an entire site, by itself, is not a suitable criterion for determining the need for control. While it is certainly possible to sample a site sufficiently to map patches with high grub densities, this is too costly for wide scale use. A third approach is to use data from throughout a site to indicate whether it is likely to harbor patches with high densities, then treat the entire planting accordingly. This has the disadvantage that larger areas are treated when only portions

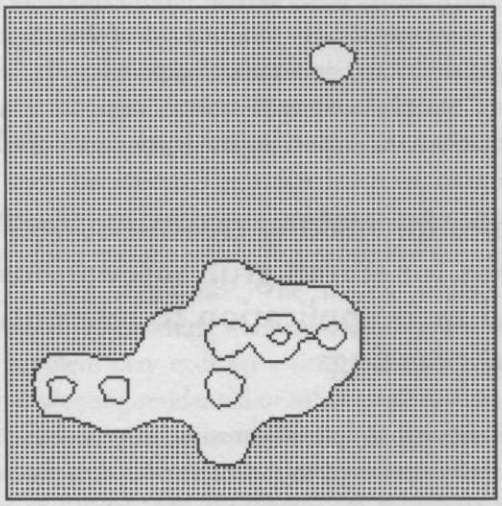


Figure 2. The patchy distribution of scarab grubs in a turf grass planting. Contours enclose areas of equal density in increments of 10 grubs/sq ft. The gray area is devoid of grubs.

of them actually require control. However, provided that only a modest fraction of sites require any control at all, and compared with "automatic" prophylactic treatments, use of this approach to crop protection will still lead to greatly reduced pesticide use.

We recently developed a procedure for determining whether European chafer infesting residential and other small turf sites required control. Based on the data used in elaborating this procedure, its use would eliminate pesticide applications at roughly 65% of the sites receiving prophylaxis.

Preliminary data also indicate there are economic incentives for adopting this approach to pest control decision making. It costs $50 to $100 to treat a lawn for scarab grubs. We have found it requires about one minute to examine a soil sample for larvae. Our proposed procedure uses a minimum of 20 and a maximum of 40 samples per site. Assuming an average of 30 samples per site, a total sampling time, including setup, of one hour, and an hourly cost of $30, the expected net direct saving is $35 per lawn when the treatment cost is $100, and $2.50 when the treatment cost is $50. And this does not consider the environmental and health benefits that may accrue from reduced pesticide use.

The remainder of this section describes this procedure and explains how to use it. While the procedure was developed using only data for European chafer, subsequent work has shown it works equally well with Japanese beetle larvae.

Modeling the size and density of scarab grub patches

We began by mapping European chafer grub densities at over 300 residential sites, counting the grubs found in samples collected at regular intervals throughout each property. These samples consisted of 4-in. diameter plugs cut from the turf. Samples were taken from locations on a 10-ft x 10-ft grid.

European chafer larvae are capable of causing "economic" injury to turf when their density exceeds 10 grubs/sq ft. This equates to roughly one grub per 4-in. plug. When we examined grub density maps derived from the sample data, it was apparent that while there were areas of turf plantings where average density exceeded one grub per plug, the density throughout the property frequently averaged much less than one per plug. From a lawn care perspective, it is important to treat patches of turf in which European chafer grub density exceeds one per 4-in. plug. Based on our experience, we defined a patch necessitating treatment to consist of four or more adjacent sample locations, each showing one or more larvae per plug. And, extending this, we considered properties containing one or more of these patches to contain chafer populations requiring control. The problem was then to devise a way of identifying these properties.

It was our hypothesis that we would find a positive relationship between the size of the largest patch on a property (with patch size measured by the number of adjacent sampling locations showing grubs), the average density of grubs in that patch, and the average density of grubs throughout the property. If such a relationship existed, then average grub density from throughout a property could be used to predict whether there was a patch of grubs somewhere on this property that required control. Reliance on average density throughout a property as a decision criterion would allow the use of well-established sampling techniques. The only alternative was mapping grub presence throughout the property, which seemed impractical.

Figure 3 shows the relationship we established between the average size of patches, the grub density in each patch, and the average grub density over the entire property. Each data point represents a single property. All of the properties examined are separated by a dashed line into those where European chafer required control (plantings having four or more contiguous sample locations producing one or more grubs each) and those where control was not needed. We found that, as the average grub density over the entire property increased, the size of the largest patch and the average grub density in that patch also increased. This demonstrated that average density over an entire property could be used to predict whether it was likely the property contained a patch with a damage threatening density of grubs.

The plot of patch size against property-wide density indicated that the treatment threshold density (the reference value used to judge whether a property harbors at least one patch of grubs requiring control) should lie somewhere between 0.1 and 0.35 grubs per sample. Precisely what the threshold should be was not clear from the data, though. Therefore, we evaluated alternative sampling plans with thresholds set at intervals between 0.1 and 0.35 grubs per sample.

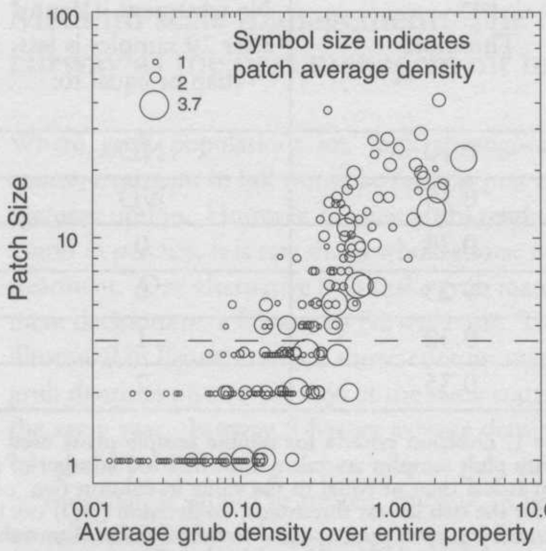


Figure 3. Relationship between patch size (vertical axis), average grub density over an entire property (horizontal axis). The dashed line separates properties that require control from those that do not.

Selecting a treatment threshold and sampling plan

A risk-averse manager might choose a sampling plan based on a low threshold in order to minimize the likelihood that an incorrect decision <u>to not treat</u> would be made. A manager averse to applying pesticides needlessly might choose a sampling plan based on a high threshold. We suggest that the two types of error be balanced, and recommend use of a threshold of 0.25 grubs per sample.

The statistical method used to assess grub density in smaller plantings is known as double sampling. Let us first explain some of the logic behind this procedure, then present specific sampling plans. Whenever an observed density is compared to a threshold, uncertainty increases as the value being compared approaches the threshold value. A simple example can illustrate this. Suppose you are asked to determine whether a coin is "fair," meaning that when flipped it is just as likely to produce a "heads" as a "tails." To make your determination, you flip the coin and record the results. After flipping the coin 10 times you find you have produced six "heads" and

I	II	III	IV
Threshold	No treatment if count after 20 samples is less than or equal to:	Treat if count after 20 samples is greater than or equal to:	Treat if count after 40 samples is greater than or equal to:
0.10	ND	4	4
0.15	ND	6	6
0.20	0	8	8
0.25	0	9	10
0.30	1	11	12
0.35	2	12	14

Table 1. Decision criteria for double sample plans used to classify scarab grub density with respect to a threshold. Twenty plug samples are taken and the total number of grubs found is compared to columns two and three. If the count is less than or equal to the value in column two, no treatment is required and sampling can be stopped. Note that for the two lowest thresholds, no decision (ND) can be made at this point and another 20 samples are needed. If the count is greater than or equal to the value in column three, treatment is needed and no further samples are required. If the total count falls between the values in columns two and three, another twenty samples are taken and the number of grubs found in all forty samples is compared to the value in column four. Treatment is required only if the total equals or exceeds the value in column four.

four "tails." How willing are you to state that the coin is not "fair?" With these results, it is likely that the coin is "fair;" but one cannot be certain because a "fair" coin produces an equal number of heads and tails when flipped an appropriate number of times, and the results achieved are only suggestive of this. The same result could have been obtained if the coin were not "fair" to the extent that "heads" is slightly more likely to appear than "tails." Further flips of the coin should be made to improve the confidence with which a classification of the coin's "fairness" is made.

Double sampling plans for scarab grubs work in a similar way. Grub density at a site is sampled by examining 20 plugs collected throughout the planting. This number was selected because it appeared to be be the minimum needed to obtain a representative result. (If the planting is large — greater than a half acre — the area should be divided and the entire procedure carried out for each subdivision.) Depending on the outcome, a decision is made to treat, not treat, or take another sample. If the estimated density is close to the chosen threshold, a second sample of 20 plugs is taken and then, using all 40 observations, a decision to treat or not treat is made. Table 1 lays out the criteria for making these decisions for each of six alternative thresholds.

Since developing these guidelines, we have evaluated the protocol in two locations. We found the procedure to be very effective, even when Japanese beetles comprised a significant proportion of the scarab grubs at a site.

Rule-based treatment decisions for scarab grub infestations on golf course fairways and other large turf plantings

Golf courses have an abundance of irrigated, well-maintained turfgrass, interspersed with ornamental plants — ideal Japanese beetle habitat. As a consequence, they frequently have potentially damaging grub populations somewhere on the grounds.

Decisions about managing grub populations on golf courses can be made at any of three different scales. At the coarsest scale, the decision is whether to treat the whole course for grubs or not to treat any of the course. At a medium scale, individual fairways are treated on a case by case basis, which requires sampling the soil to determine which fairways harbor grubs. At the finest scale, individual grub patches within fairways are identified and treated.

Each scale has advantages and disadvantages. Each might be appropriate under certain circumstances. Which is appropriate and which is selected should depend on the past experience of grub infestation at the course, the distribution of grubs in the year in question, and on the goals and preferences of the turf manager. In most cases, regardless of the scale selected, acquiring sample information as a basis for treatment decisions is a sound investment.

Coarse scale management: The full course as the pest management unit

The coarsest management scale involves taking the entire golf course as the pest management unit, in which case treatment is all or nothing. For example, when there is a history of grub problems, and their recurrence is anticipated, the whole course is treated. Conversely, when there has never been a problem with grubs, indications of their presence might be met with a decision not to treat the course at all. This approach has the advantage of simplicity. Further, since treatment costs can be high, it could prove to be the most economical.

Grub populations, moreover, are rarely high enough throughout a course to warrant the whole being treated. When the entire complex nonetheless receives treatment, not only is much of the effort wasted but it results in pesticides being introduced needlessly in public areas. Unnecessary applications also contribute to the development of insects' resistance to insecticides, which can render a previously effective treatment ineffective. (Paradoxically, insecticide resistance develops most rapidly against the most effective treatments.)

Medium scale management: The fairway as the pest management unit

Where grub populations are high throughout a course, treatment in full would be the best pest management option. However, because grubs tend to be found in patches, it is rare that a whole course needs treatment. One alternative is to make grub management decisions on a fairway by fairway basis. This is illustrated in Figure 4, which shows contour maps of grub densities on two fairways at the same course in the same year. Fairway 8 has an average density of 13 grubs/sq ft, and patches where the density exceeds that. It should be treated. Fairway 18 has an overall density of only one grub per square foot, and does not require treatment.

Experiments have shown that distinguishing between fairways that do and do not need treatment is relatively easy, and that there is little risk of significant grub populations going untreated. Making these distinctions can often reduce pesticide use by 50–60%, and treatment costs by nearly as much. Such discrimination is not difficult and requires only a minimal amount of soil sampling. Taking a sample involves using a 4-in. cup cutter to remove plugs from the fairway. Each plug is broken apart, and the grubs are counted as the soil is put back in the hole. The sod is replaced, the number of grubs recorded, and the next sample is taken further down the fairway. This process takes about one minute per sample, and does not injure irrigated turf. Depending on the size of the fairway, the sam-

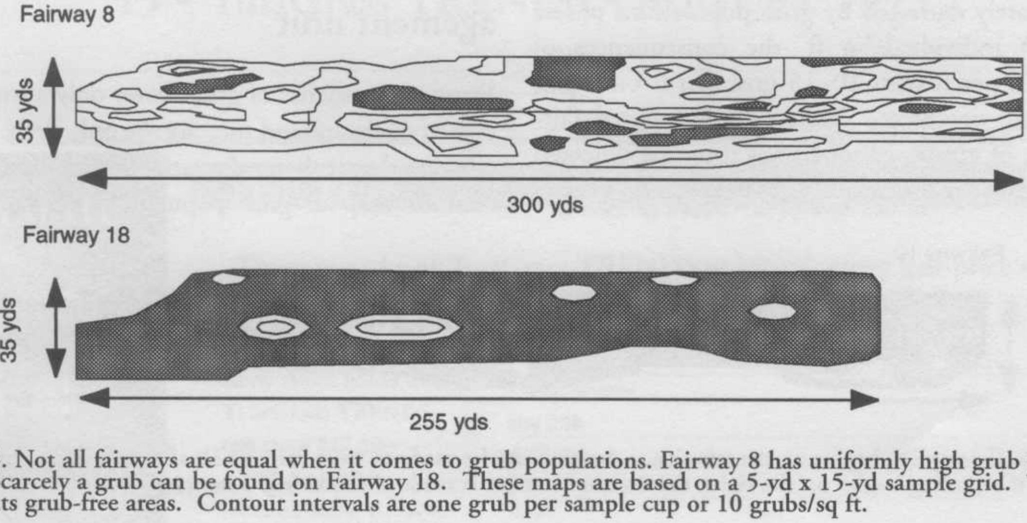


Figure 4. Not all fairways are equal when it comes to grub populations. Fairway 8 has uniformly high grub populations. Scarcely a grub can be found on Fairway 18. These maps are based on a 5-yd x 15-yd sample grid. The grey represents grub-free areas. Contour intervals are one grub per sample cup or 10 grubs/sq ft.

pling interval used (a 10-yd x 30-yd grid is normally sufficient) and the density of grub populations, a maximum of 30–60 samples is required to make a decision whether a fairway needs treatment. Fairways with high grub populations can often be identified after only four to eight samples.

The rules for deciding whether to treat are simple. Fairways with two or more potential patches should be treated. When two adjacent samples each contain grubs, the area is considered a potential patch. A single sample containing two grubs also represents a potential patch. The patterns of grub counts in the samples depicted in Figure 5 illustrate these points.

With two patches on a fairway, it is likely that one of them is a real patch

Two potential patches combine to make one probable patch

Figure 5. Illustrative potential patch configurations

In addition, any sample containing three or more grubs is a strong indication of a problem, so the whole fairway should be treated!

These have shown themselves to be reliable decision rules. They are also conservative, in the sense that treatment is often recommended when it is not actually necessary. Fairways that are only marginally in need of treatment are correctly identified 75–90% of the time. Because high-maintenance turf is rarely damaged by grub populations of less than 15 individuals/sq ft, the consequences of missing a patch with 10–15 grubs/sq ft on a golf course are not great. More heavily-infested fairways are of greater concern, but these are detected with almost 100% certainty. For example, fairways with only one relatively small patch of grubs at densities of 20 and 25 individuals/sq ft are correctly identified as needing treatment 96% and 100% of the time, respectively. Fairways containing moderate to large patches with populations of 10 grubs/sq ft are also flagged for treatment with over 90% certainty.

Therefore, there is very little risk of misclassification of a fairway leading to grub damage. On the contrary, fairways with a population density of one grub per square foot are incorrectly identified as needing treatment 30% of the time. Thus, management errors resulting from use of these decision rules are much more likely to lead to treatment when it is not necessary than failure to treat when it is necessary.

One of the major strengths of using these rules is that detection of heavily infested fairways normally requires taking only a few (four to eight) samples before two potential patches are detected. Under these circumstances, a decision to treat can be reached in short order. Figure 6 illustrates this point.

Taking the individual fairway as a pest management unit can be especially valuable for the course that normally receives full treatment. If most of the fairways are indeed heavily infested, then sampling takes little time. On the other hand, the fairways that do not have high grub populations can be identified with little effort.

Fine scale management: Patches within fairways as the pest management unit

Frequently, patches of grubs cover only a small fraction of a fairway, and they are the only parts of those fairways that truly need treatment. For example, the contour map of grub populations on fairway 17

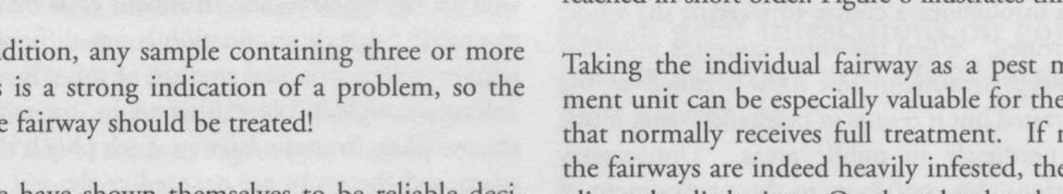


Figure 6. If sampling begins on the left side, a decision can be made to treat Fairway 10 after just one sample is taken. If sampling begins on the right, the decision to treat is made after just eight samples are taken.

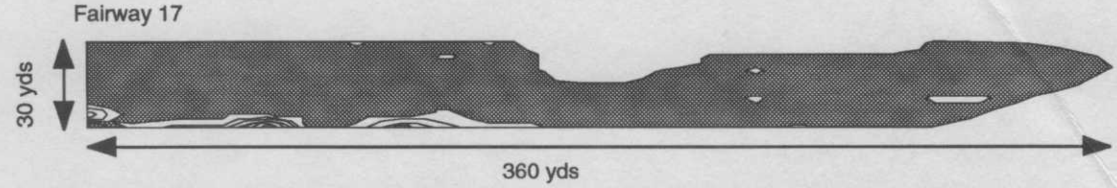


Figure 7. Intense sampling can serve as the basis for clear resolution of patch boundaries. Use of a 5 yd x 15 yd grid is depicted here.

shown in Figure 7 reveals a few dense patches on one side, but almost no grubs in the rest of the fairway. Mapping the boundaries of such patches requires sampling at an intensity of about 5 yards by 15 yards, however. To identify individual patches within fairways therefore requires about four times as many samples as simply identifying infested fairways. The payoff for making this extra effort can be substantial, though, since on some fairways the resulting reductions in pesticide use can exceed 90%.

Such dramatic reductions cannot be expected on every fairway, but a new research program has begun at the New York State Agricultural Experiment Station to determine the economic and environmental costs and benefits of spot treatments based on this kind of heavy sampling. Results will be out within the next few years. At that time, we will be in a position to make recommendations about sampling intensities and decision rules. Also, we should have more detailed estimates of potential cost savings and pesticide reductions.

Dr. Jan P. Nyrop is an Associate Professor in the Department of Entomology at NYSAES/Cornell University. He has degrees in wildlife ecology from the University of Maine and in systems science and entomology from Michigan State University. Dr. Nyrop's field of specialization is the population ecology of arthropod pests of horticultural crops and their natural enemies. He is currently researching the areas of biological control and decision making for integrated pest management. This is his first contribution to *TurfGrass TRENDS.*

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In Future Issues:

- Pesticide Fate in Turfgrass
- Relationships between Insects, Insecticides and Soil
- Nematodes
- Winter Weed Control
- Degree-day Modeling
- Risk-taking and Pest Management
- Rewriting (?) the Rules at EPA

Ask the Expert: Moss in the turf

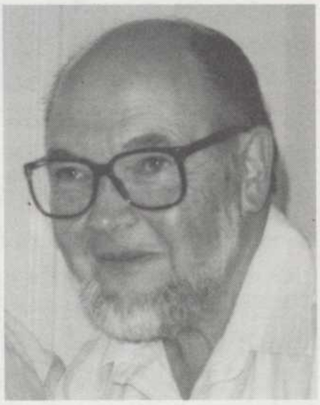
Professor Richard J. Hull, Plant Sciences Department, University of Rhode Island, Kingston, RI

Question: Are there products that will kill moss in turf without lowering soil pH? Don Barry, Weed Free Lawn, 1196 Torbay Rd., Torbay, NF, Canada

Answer: Moss is a serious problem, especially in cool, moist northern regions. The problem is aggravated on golf courses by low cutting heights and the reduction of nitrogen fertility to increase green speed.

Moss becomes a problem when turfgrasses are stressed and the stand thins. Stressed grass cannot resist its encroachment; and once it's established, moss is difficult to control.

The secret to moss management is to alter conditions so grass is favored and moss is not. This involves adding lime to increase soil pH, raising mowing height to make grass more competitive, increasing soil aeration to improve drainage, increasing nitrogen nutrition to stimulate grass growth, and thinning adjacent vegetation to provide more light and ventilation. Use of a high magnesium (dolomitic) limestone is also recommended. Dr. Norman Hummel at Cornell found high moss populations associated with high Cal/Mg ratios in the soil. He also noted that deep spiking or core cultivation followed by sand topdressing significantly reduces moss density by draining the free water moss requires to complete its life cycle.



Dr. Richard J. Hull

Once established, moss may be difficult to remove solely by changing cultural practices. Chemicals can damage it, but they tend not to be as persistent or selective as many herbicides. As a nonvascular plant, with green tissues lacking a well-developed cuticle, moss is susceptible to desiccation. Salts such as ferrous sulfate or ammonium sulfate will consequently burn moss, facilitating grass growth. Salts cause only contact injury to moss, however, so it recovers if turf competitiveness is not enhanced. Hydrated lime applied to moss at 3 to 5 lb/1000 sq ft in early spring will burn it during its growth. And unlike ferrous sulfate, which just adds to soil acidity, hydrated lime neutralizes it.

Herbicides have been used in research trials to suppress moss and allow grasses to become reestablished. No chemical will provide long-term moss control, however. Environmental conditions must be altered to make turfgrasses more competitive.

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