A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

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Use of Pheromones in Turfgrass IPM Programs

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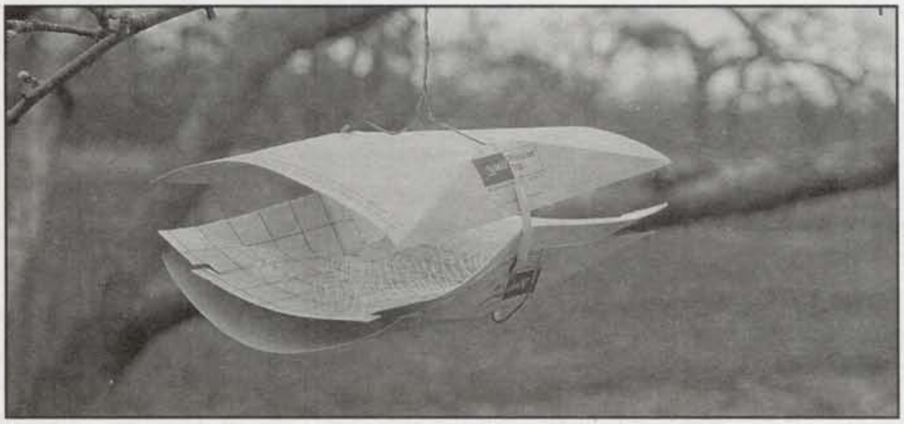
There is hardly a turfgrass manager in a state east of the Mississippi River who has not seen a Japanese beetle pheromone trap hanging from a tree or post in mid-summer. These traps are often overflowing with adult Japanese beetles, and for this reason turf managers, landscapers and homeowners are often convinced that these traps helped to reduce feeding damage of the adult beetles on their ornamental plantings and also help to reduce the number of Japanese beetle grubs that will invade and damage their lawns in the fall of the year. Is this a reasonable assumption? My goal in this article is to address this question. I will describe what pheromones are and why they are important to the insects that produce them, next I will outline possible uses (and misuses) of pheromones in turfgrass pest management programs, and finally, I will review the steps required to develop a synthetic pheromone for commercialization.

What Are Pheromones?

Pheromones are chemical signals that are released by one individual of a species and stimulate a reaction in other individuals of the same species. Insects of the same species can communicate with one another by emitting



Wing trap used for many moth species, including black cutworm adults.

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small quantities of chemical substances from their bodies into the air. While in some cases pheromones are single compounds, in many instances an insect pheromone will be a blend of two or more compounds that are produced and released in a specific ratio by the insect. An alteration in either the structure of the individual compounds or the relative amount of any compound in the blend will cause the pheromone to become inactive.

The released compound (or compounds) travel through the air until it is intercepted by sensory organs that sit on the antenna (or possible other body part) of other members of the same species.

Information transmitted through pheromones may include:

• *the presence of a willing individual* (usually a female) advertising her (or his) presence and location to distant members of the opposite sex (usually a male). Pheromones of this type are known as sex pheromones, and are the type most commonly used in pest management programs to monitor or manage pest populations. Japanese beetle traps usually contain the chemical, (R, Z,)-5-(1-decenyl) dihydro-2(3H)-furonone, that mimics the female sex pheromone of this species. Sex pheromones, by definition, attract members of only one sex; standard Japanese beetle traps incorporate two chemical lures the first containing the sex pheromone mimic attracting only male beetles, and the second, a floral lure composed of a mixture of phenethyl propionate, eugenol, and geraniol (3:7:3 ratio), that serves as a feeding lure attracting both male and female beetles.

• *the presence of high quality food or a valuable area to mate or take shelter.* These pheromones, known as aggregation pheromones, are often produced by members of both sexes of a species and will often attract members of both species. Japanese beetle and Green June beetle adults are thought to produce aggregation pheromones at feeding sites but this has not yet been confirmed. Interestingly, there are some species (none described in turf) that produce pheromones, known as anti-aggregation pheromones, that that repel individuals of the same sexes. Anti-aggregation pheromones may reduce the chance that too many insects will feed or lay eggs on the same tree or shrub thereby resulting in a localized food shortage.

• *the presence of danger such as predators or parasites or other unwanted intruders in the area.* These pheromones, known as alarm pheromones, are usually produced by social insects such as bees, wasps, and ants to warn their neighbors that danger is near. This alarm pheromone often causes these insects to mass and attack the intruder in protection of their nest or hive. Aphids such as the greenbug are also thought to produce an alarm pheromone that alerts their nearby relatives to flee from predators such as ladybird beetles.

Uses of Pheromones in Turf Pest Management

Pheromones have been used in a number of programs for managing turfgrass pests. Most often, they aid in the detection of exotic (foreign and introduced) or endemic (native and established) pests; there is also great interest in using pheromones to manage rather than monitor pests by trapping a large portion of the pest population or flooding the landscape with synthetic pheromone to confuse or disrupt the normal mating behavior of a pest population.

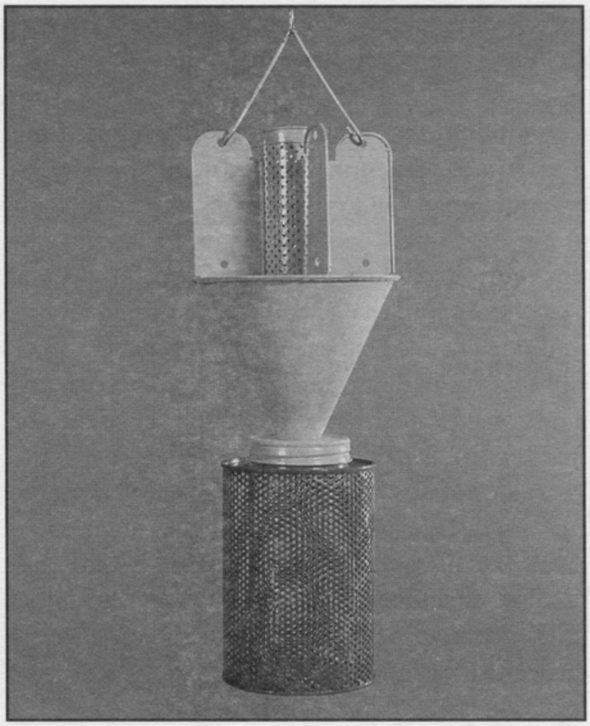
Monitoring - Pest detection requires a sensitive trapping method that provides qualitative information about presence or absence. Pheromone traps provide the most sensitive monitoring system known; they are usually species specific, need no power or maintenance, are not labor intensive, and can be operated by the public. Pheromone traps are a great aid in detecting low numbers of adult insects over considerable distances.

Because pheromones tend to be fairly species specific, they can be used to identify one pest species found in low numbers against a background of high numbers of other insects in the area; for this reason they can be much more use than more general trapping tools such as blacklights in monitoring insects. Such factors as temperature, rainfall, and trap location can affect the effectiveness of a pheromone trap, therefore it is unwise to rely on a single trap or a single trapping date for making management decisions.

Several uses of pheromone traps when used in monitoring programs include confirmation, pinpointing infestation sources, estimating populations, and timing controls.

Confirmation of the presence or absence of insects: Because pheromones will attract individual insects from great distances they are important tools in discovering potential insect pests invading from other areas, foreign or domestic, before they become established and build to sufficient numbers to cause economic damage.

A good example of the use of pheromones for determination of the geographic distribution of an introduced pest species involves the exotic pest, the oriental beetle. Oriental beetles were first collected on the US mainland in 1920 (New Haven CT) having presumably been imported directly from Japan in infested balled nursery stock. Oriental beetles do little if any adult feeding, spending most of their time hiding in the grass and thatch. The absence of readily apparent adult feeding damage greatly reduces the chance that a casual observer will notice a sizable beetle population before significant numbers of eggs are laid in turf and nursery soil.



Pheromone trap used for Scarab, Japanese, and Oriental beetles.

A comprehensive geographic survey for the presence of oriental beetle adult populations through the use of pheromone-baited traps similar to commercial Japanese beetle traps in selected nurseries was undertaken by Dr. Steve Alm and myself in 1994 and completed in 1996.

Ten to twenty-five traps baited with 100 micrograms per septa were used in each state and were monitored at least twice at each location traps from May 1 through August 1. States with positive trap catch at least one year of survey included: Maryland, Massachusetts, New York, Rhode Island, Ohio, New Hampshire, Delaware, Connecticut, New Jersey, Tennessee (probably not established), West Virginia (probably not established),Virginia, and North Carolina. States with negative trap catch included: Georgia, Kansas, Kentucky, South Carolina, Maine, Alabama, and California. Although the establishment of oriental beetles was well known in several of the states with positive trap catches, for several states the survey provided the first indications that the oriental beetle had arrived. This information has important consequences for the sale of nursery stock out of those infested areas, and may also allow local eradication of local populations before they become established and spread to surrounding areas.

Pinpointing the source of insect infestations: Introduced pests often arrive in a new site by hitchhiking on the roots or leaves of plants. Many of our exotic pet species arrive in this country by this route (including the Japanese beetle, oriental beetle, European chafer, and Asiatic garden beetle). Additionally, insects hitchhiking on nursery stock and transplanted into residential, commercial, and public landscapes, are often responsible for the spread of these pests over wide geographic regions. Pheromone traps placed in ports of entry, nurseries and newly established landscapes will often document the presences of pest species before they become established and spread from the initial introduction sites. Such introductions are easily managed if documented early.

Estimating the magnitude of insect populations: There is a great temptation to use the number of insects caught in pheromone traps to help predict the size of the developing pest population and the need to treat.

While low trap counts may accurately reflect a year with low pest pressure, the alternative is not true. Because a number of environmental factors are involved in translating high adult populations into economically damaging larval population, pheromone trap counts have never been shown to be a good indication of larva population levels or potential feeding damage.

Improved timing of insecticide application: Pheromone traps can be useful in determining when an insecticide treatment should be made for controlling a damaging pest population by establishing important milestones in the development of a pest population. One good example of this use of pheromones is the trapping of black cutworm moths in the Northeast. In typical years, black cutworms do not survive the cold northeastern winters, instead they migrate to the north from southern states in each spring. Wing traps baited with black cutworm pheromone can help pinpoint when the wave of black cutworm moths arrive in a specific location. Since insecticides are most effective when applied to newly hatched caterpillars, knowing when moths arrive in a location (factoring in the lag time required for eggs to be laid and then hatch) improves insecticide efficacy.

Direct Control of Insect Pests

Direct control of insects with pheromones centers around mass trapping and disruption of mating.

Mass Trapping - Anyone who has seen Japanese beetle traps overflowing with insects might believe that this trapping will translate into less adult feeding damage to ornamental plants in the area, and few Japanese beetle grubs infesting the surrounding turf the following fall. Although the pheromone/floral lure baits will attract large numbers of beetles, many beetles drawn to the trap will be intercepted by attractive host plants in the landscape leading to higher beetle numbers. Mass trapping may be a useful control tactic for an established pest species if large geographic regions are targeted and if a great number of highly efficient traps are used. Mass trapping may also be useful if an introduced pest that has not had a chance to establish in an area is targeted (for example the mass trapping of oriental beetle adults in a nursery or interiorscape in an area with no established beetle population).

Mating Disruption - This approach involves the saturation of the environment with massive amounts of synthetic pheromones so that males and females cannot locate each other to mate. Mating disruption have the best chance for success when the initial pest population is small, there is little chance for immigration of individuals into the target site, the synthetic lure will out compete calling females, and males emerge before calling females thereby reducing the synthetic lure's competition with calling females. These factors are in our favor if we attempt to reduce introduced pests in isolated nursery blocks or greenhouses.

Pheromone Research: Discovery To Commercialization

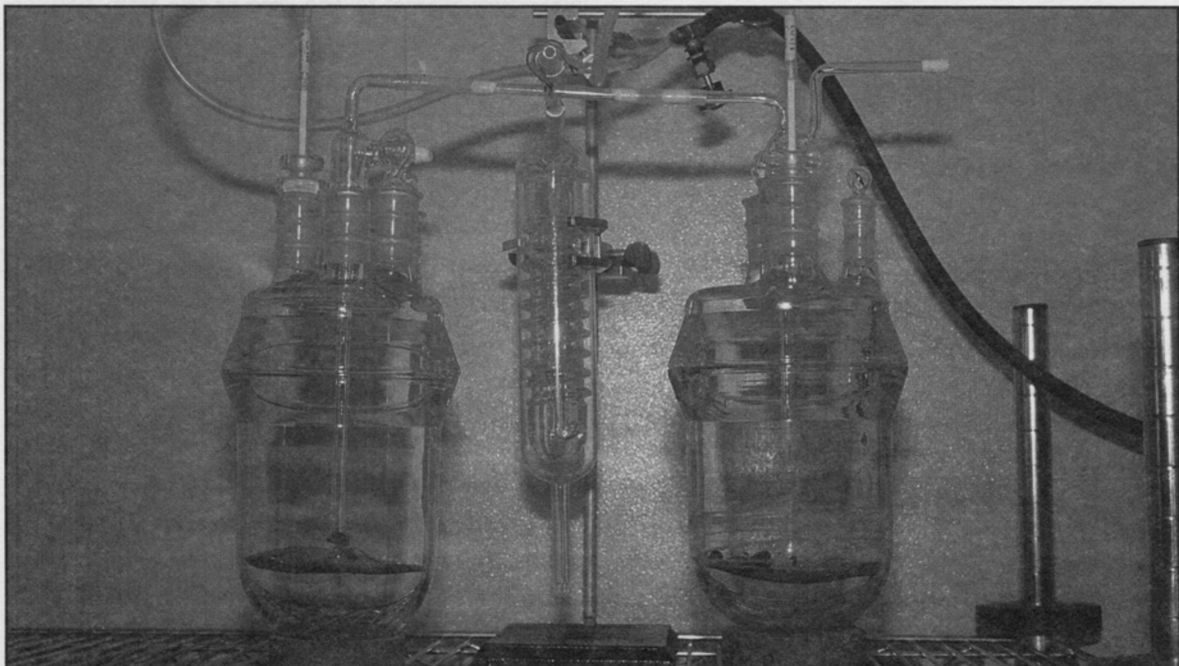
Studies have confirmed the presence of a sex pheromone in a number of turfgrass insect pests besides the Japanese beetle. These species include: oriental beetles, southern and northern masked chafers, many May and June beetle species, Green June beetles, fall armyworms, black cutworms, true armyworms, and a sod webworm species also known as the cranberry girdler.

Other turfgrass insects are suspected of producing sex pheromones but this has yet to be confirmed by researchers. Although we know that many insect species employ sex pheromones to attract mates, the presence of a sex pheromone is just the first in a long series of steps needed before a synthetic pheromone can be used in a practical pest management program.

These steps include the verification of the pheromone's presence, isolation, identification, synthesis of compounds, determining proper blend ratios in the lab, testing of release rates in the field, optimization of trap placement and design in the field, and finally incorporation of the pheromone into an established turfgrass pest management program. Consider the steps taken in the discovery and commercialization of the oriental beetle pheromone in the northeastern U.S.

Discovery - The discovery of a pheromone usually begins with the study of insect behavior in the field. Insects that appear to be flying in a systematic or controlled manner over turfgrass or around trees and shrubs may be attempting to locate a mate who is releasing a sex pheromone into the air. Searching males often show a distinctive search pattern that includes flying into the wind in a casting pattern as it moves into and then out of the pheromone plume. When close to a calling female, male insects will often fly in a straight line to the female and begin to mate. Calling females (females releasing pheromone) will often have distinctive behaviors to improve the release of pheromone into the environment. Jim Hanula (then at the Connecticut Experiment Station) first observed the typical searching behavior of male oriental beetles on golf course fairways early in 1990.

Confirmation - The next step in the path from discovery to commercialization is experimental proof that a pheromone is present. Jim Hanula and Steve Alm caged virgin oriental beetle females on golf courses that had high population of oriental beetle adults. Females in these cages could not be seen by flying males but any compounds released by the



Laboratory device used to collect pheromones from live female insects.

females would spread down wind. Other traps, were similar in every way but contained dead rather than live female beetles (only live insects emit pheromones). The traps containing live females attracted many more male beetles than did those containing dead females confirming the presence of a sex pheromone.

Isolation, Identification, & Synthesis - The first step in the isolation, identification, and synthesis of a pheromone is to collect the pheromone from calling individuals. Researchers at the New York State Agricultural Experiment Station placed virgin female oriental beetles in closed containers and collected the compounds the female released into the air. Gas chromatography coupled with wind-tunnel assays of male beetles identified the pheromone as a mixture of 7-(Z)- and 7-(E)-tetradecen-2-one (89:11 ratio). Oriental beetle pheromone was synthesized and formulated in synthetic lure incorporated plastic pellets (4-5 mm in diameter) made of polyethylene plastic.

Field Testing - The man-made (synthetic) sex pheromone must be at least as attractive as calling females to be useful in pest management. Field studies conducted on golf course fairways during the summer of 1993 showed that traps baited with 100 μg of synthetic pheromone caught significantly more males than did traps baited with three live virgin Oriental beetle females. All baited traps caught significantly more beetles than did unbaited traps.

Optimization - Although a synthetic pheromone may effectively attract insects to the general area of a trap, optimal trap design and placement will maximize the number of attracted insects that end up safely in the trap. Understanding the behavior of the insect species you are trying to catch is critical for successful trapping. Field studies conducted during 1993, 1994 and 1995 suggested that male oriental beetles attracted to calling females or synthetic pheromone usually walked, rather than flew to the female of pheromone lure. This suggested that traps set at ground-level, rather than hung on stakes or in trees would be more effective at catching beetles. Alm confirmed this by placing pheromone-baited traps a several different heights on golf course fairways and counting the number of males trapped at each height. Those traps placed with the collection funnel at ground level consistently trapped more oriental beetles than did traps at any other height. Trap size and color may also significantly affect trap catch.

Commercialization - For a synthetic pheromone lure to be a commercial success it must be relatively inexpensive to produce, have a long shelf life (not lose potency from the time it is manufactured to when it is sold), remain active in the field for the entire time the insects are active, and provide information to the end user that justifies the purchase price. Synthetic oriental beetle pheromone appears to have characteristics that will encourage commercialization and user acceptance.

Conclusions

While pheromone lures are often very effective in attracting insects to the area of the trap, they are usually much less efficient at predicting the size of the population, or significantly reducing either adult or feeding damage. Much like a power mower or a high-pressure spray rig, pheromones are a tool that may be useful in an integrated turf management program, but the misuse of the tool can often result in more harm than good. Any turf manager who has hung a Japanese beetle trap in, or near, a tree or shrub that is a favorite food of adult Japanese beetles will readily attest to this observation.

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Insecticide Series, Part VII: Insect Monitoring Techniques and Setting Thresholds

Dr. Patricia J. Vittum
University of Massachusetts

With the increasing emphasis on Integrated Pest Management (or Best Management Plans or Intelligent Plant Management), most turf managers are well aware of the importance of monitoring insect populations on the turf for which they are responsible. Many turf insects are reasonably straightforward to identify. However, figuring out ways to measure the quantity (or population density) of an insect infestation can seem daunting at times. In fact, there are several fairly simple techniques which can be used to measure insect activity, and most require little in the way of equipment or supplies.

Soil Sample

Several turf insects remain in the lower thatch or the root zone for most of their lives and are difficult to control because of this behavior. In addition, these insects are seldom seen unless active steps are taken to seek them out. Soil samples are such a step.

The simplest way to take a soil sample is to use a small spade or garden trowel to cut three sides of a square, four to six inches wide on each side. The soil should be cut to a depth of four inches or more. Using the uncut side as a pivot point, turn the sample over onto a sheet of plywood. Use the sharp edge of a hand trowel to dislodge the soil from the roots which are now exposed. Any white grubs which are present in the soil will be visible (although tiny grubs which have just hatched from eggs may escape detection by virtue of their small size). Remove the grubs and place them in a cake pan for counting later.

Normally it is easier to transform the counts from "grubs per sample" to "grubs per square foot". One square foot consists of 144 square inches, so if the original sample was six inches on a side (36 square inches), that sample was 0.25 square foot. Therefore, you can multiply the number of grubs you actually found by four, which will give you the number of grubs per square foot. Similarly, if the original sample was four inches on a side (16 square inches), multiply by nine to get the number of grubs per square foot.

An even easier technique for taking a soil sample is to use a cup cutter (4.25 inch diameter), which is the tool golf course superintendents use to prepare the target hole on each putting green. Each sample is almost exactly 0.1 square foot, so ten cores would equal one square foot.

The important point, regardless of the manner in which a sample is taken, is to take several samples from each area. This provides overall information about the grub population, and indicates where the "hot spots" are. One technique which has been developed for use on golf courses, following research conducted at Cornell University, is to have four people walk along a fairway taking samples at specified intervals. Each person uses a cup cutter and starts at the beginning of the fairway (nearest the tee). One person samples within five feet of the edge of the rough on one side of the fairway, another does the same on the other side, and the other two sample at even intervals between the people along the edges. They take a sample every 30 yards as they make their way toward the green. Such a sampling technique provides a grid of numbers which can indicate where grub populations are greatest. This sampling procedure enables a golf course superintendent to determine precisely where curative insecticides are needed and which areas can be left untreated.

The soil sample technique is used most frequently for white grubs, such as Japanese beetles, European chafers, masked chafers, or oriental beetles. It should be conducted after most eggs have been laid and hatched but before grubs have grown to damaging sizes (typically late July through August throughout most of the range of these insects).

Soapy Flush (Irritating Drench)

A soapy flush can be used to irritate insects which are active in the thatch and induce them to come to the surface. The drench is prepared by putting one or two tablespoons of a lemon-scented liquid dish detergent in a bucket and filling the bucket with one or two gallons of water. This solution is then poured over an area which is one or two feet on a side. Any sensitive insects which are in the affected area will wriggle to the surface, often within half a minute.

The technique is particularly effective at bringing mole crickets to the surface. Some of the larger stages will emerge from the turf in half a minute, while some of the smaller stages may take a little longer. Similarly the technique brings cutworm and webworm larvae to the surface relatively quickly (within a minute or two). However, some of the smallest (youngest) caterpillars die or are otherwise immobilized before they get to the surface, so sometimes caterpillar numbers are underestimated by this technique.

Earthworms are also irritated by the detergent and wriggle to the surface quite quickly, trying to escape the irritation. In addition soapy flushes which are used to estimate cutworm populations on putting greens often "bring up" black turfgrass ataenius adults and annual bluegrass weevils.

A soapy flush will not usually provide an "absolute" count of insects. In other words, it will not force every pest insect to the surface. But it is an excellent way to determine what stages predominate. If a turf manager is able to confirm that most of the mole crickets are still quite small, this information can be used to plan an appropriate control strategy. Similarly if most of the cutworms that surface are already late instars (more than an inch long), it may not be prudent to apply an insecticide.

The technique should be conducted when a turf manager has reason to believe that the target insect is present in the thatch. For mole crickets, the technique could be used to confirm the presence of late nymphs and adults in the spring (and to obtain some adults which can then be inspected to determine whether the females contain viable eggs). It is particularly useful when nymphs are hatching (often June or July in the Gulf States and Carolinas). Once "first hatch" has been confirmed, management strategies can be implemented - and most will be markedly more effective against the young nymphs.

The timing for sampling cutworms is even more open ended because cutworm activity depends on latitude, winter conditions in the Southeast, and spring conditions throughout the country. Nevertheless if a turf manager has experienced cutworm damage in the past, the technique should be used throughout the growing season to confirm the presence of cutworm larvae and to determine when the population is most likely to be susceptible to insecticides. (Normally once the typical "ball mark" damage spots become visible, many caterpillars are already in large stages and very difficult to control. The trick is to start conducting soapy flushes BEFORE the caterpillars reach that point.)

A word of caution - the soapy solution can burn turf if the procedure is carried out on a bentgrass putting green on a hot sunny day in the summer. To avoid damage, conduct the sampling early in the day and rinse the soap off the turf. Similar stress can be experienced in the extremely hot conditions which occur in the southern half of the country, so use common sense and do not try the irritating drench when conditions have already put the turf under stress.

Flotation (Flooding)

Some insects can be counted by forcing them to swim to the surface of an artificially flooded area. Text books often suggest driving a large coffee can through the thatch and into the soil, and then filling the can with water. The insects which are trapped in the flooded container float to the surface, where they can be identified and counted. However, in some parts of the country (for example, the Northeast), thatch is dense enough that it is next to impossible to penetrate with a can. An alternative approach is to cut a core of turf (to a depth of one or two inches into the soil), using a cup cutter or a turf knife, and place the core in a bucket. Fill the bucket with water and wait for the insects to surface.

This technique is often recommended for counting chinch bug populations. One predatory insect which often occurs alongside chinch bug infestations is the "big-eyed bug", which closely resembles the chinch bug in appearance. Both bugs will float when flooded - and a turf manager must learn to look closely to determine whether the trapped bugs have bulging big eyes or not.

A variation on the flotation technique is also used to sample hibernation quarters for some insects. For example, the annual bluegrass weevil often overwinters in litter under white pine trees or in clumps of high grass near fairways. Samples from these areas can be placed in dish pans and filled with luke warm water. The insects (in this case adult weevils) float to the surface, where they crawl onto floating debris or attempt to crawl up the wall of the container.

As with other sampling techniques, flotation should be conducted when the pest population is presumed to be present - or is expected in the near future. In the Northeast, the hairy chinch bug becomes active in April and begins laying eggs in May or June, so this technique could be appropriate any time from May through August. Southern chinch bugs are active for even more months of the year.

Area Count

Another technique which can be very useful is to construct a "sampler" which defines a specific area and inspect all of the turf inside the sampler to determine the presence or absence of a pest insect. One such sampler is a grid, developed initially by Dr. Pat Cobb (Auburn University) to measure mole cricket activity. The device consists of a square frame made with one inch diameter PVC pipe and normally is either two feet on a side or three feet on a side. Two eyebolts are inserted on each side of the frame at equal distances from the corners. String is strung between opposing eye bolts, forming nine equal sized squares within the frame. The scout tosses the frame on the ground and then inspects each of the nine squares for evidence of mole cricket activity - burrow entrances or surface tunneling. Any square which has cricket activity is awarded a score of "one", and squares without activity are awarded a score of "zero". The scores for the nine squares are then totalled. A score for the entire frame will vary from 0 (no activity in any of the squares) to 9 (activity in all of the squares).

This "area grid" has proven to be very useful at recording mole cricket activity and comparing activity from one location to another or from one season to another. The same technique could also be used for measuring cutworm activity or other insect pests which leave evidence of their presence (for example, burrow entrances or deposits of frass). The bermudagrass mite often induces bermudagrass to produce "witches' brooms", tufts of elongated grass. This kind of damage is easily measured (how many samples contain tufts OR how many tufts are found in a designated area).

The same concept - defining a specific area and inspecting the turf within the area - can be carried out using different kinds of sampling devices. Turf managers have used techniques ranging from flat rings (almost a foot in diameter) to forming a frame with a coat hanger to constructing simple one foot squares with thin plywood. The actual area of the sampler is not critical as long as it is kept consistent from location to location and season to season.

Area counts should be conducted just before damage is expected, and continued regularly after that. For example, mole cricket area counts should be taken in the spring when adults and late nymphs are active.

Research in Alabama and other southern states has indicated that if turf managers map their turf in the spring and confirm where adults are most active, they can concentrate their summer sampling and management efforts in those same areas and in many cases reduce their overall pesticide load by concentrating on the "trouble spots". Area counts should be conducted regularly beginning shortly after eggs begin to hatch (as determined by soapy flushes and inspecting females).

Area counts for cutworms will provide a great deal of information about the arrival of damaging populations and the timing of development. However, the date when counts should be initiated will depend on the latitude and altitude (i.e., spring and summer temperatures), how mild the winter was in southern states (mild winters allow more cutworms to survive and begin the migration northward earlier in the spring), and spring conditions. Generally area counts will provide valuable information from late June through September in the Northeast and Midwest.

Visual Inspection

Visual inspection simply involves getting down on hands and knees and taking a close look at the turfgrass. Often insects can be found moving along the surface or can be startled into moving by running fingers gently on the surface or prying into the thatch. Chinch bugs are quite active, particularly on warm sunny days in the summer. Bigeyed bugs (chinch bug predators) run even more rapidly, often in search of the nearest chinch bug. Annual bluegrass weevil adults are readily apparent moving on the surface just after they have emerged in late June or early July.

While it is not always easy to "measure" the number of insects observed by visual inspection, such a technique certainly gives indications of the presence - and potential for damage - of a pest population. Some techniques call for watching an area for a specified period of time and recording the number of insects observed during that period. Of course some people will notice more insects than others, so comparisons between individuals may be risky.

Pheromone Traps

Some insects produce "pheromones" (chemicals which are used to communicate within a species). One of the most common such chemicals is a sex pheromone, usually produced by a female to announce to the males of her species that she is fertile and ready to mate. In many cases these pheromones are quite specific, so females attract males of her species but not closely related species.

Through a series of intricate steps, chemists have been able to identify the precise shape of some of these molecules and produce them synthetically. When the pheromones are placed in traps, they often attract large numbers of males to the traps. In many cases these "pheromone traps" do not attract enough insects to reduce populations significantly, but they are excellent tools for monitoring adult activity - for example, date of first emergence or peak flight.

Some commercial traps combine a sex pheromone and another lure, so both sexes are attracted. For example, some of the Japanese beetle traps which are commercially available include the beetle pheromone and a floral scent. These traps can attract impressive numbers of beetles, but normally do not reduce local populations significantly. Japanese beetle adults are strong fliers and can detect the pheromone from several hundred yards away, so they may fly in from relatively long distances. Indeed studies in Kentucky (Dr. Dan Potter) have documented that damage to ornamental plantings can be more severe when traps are placed within 30 feet of popular plants as compared to not putting up any traps.

Pheromone traps are excellent monitoring tools but should not be used to reduce pest populations. Several commercial traps are under development but currently the most common ones used by turf managers target Japanese beetle adults. Other pheromones have been identified for some of the cutworm species, as well as for several insect pests of agricultural crops. Traps should be put in place at least a week before the first flight (or emergence) is anticipated.

Black Light Traps

Several insects are nocturnal (active at night) and are attracted to lights. Some of these insects are particularly attracted to "black light". Traps have been designed which contain a vertical black light fluorescent bulb surrounded by "baffles", or plates of metal. When an insect flies toward the trap, it bumps into the baffle and drops toward the ground but instead is collected in a funnel. The next morning the funnel (or collecting cup) can be emptied and the insects can be identified. Night flying moths will usually predominate, but there are several beetles which fly at night as well.

These traps, like pheromone traps, are excellent monitoring tools and can provide information about the beginning of insect flight activity or notable increases in activity. The current recommendation for cutworm management is to determine when a peak in moth flight occurs (either by collecting regular samples from black light traps or by making observations of moth flight at dusk) and then apply an insecticide (or biological control agent) two or three weeks later. This approach makes sense - the moths begin to lay eggs shortly after they begin flying, but several days pass between the laying of eggs and the emergence of young caterpillars. Eggs are virtually untouchable by insecticides, so applications should be delayed until young larvae emerge.

Black light traps are particularly useful for monitoring activity of cutworms and armyworms. In addition black turfgrass ataenius and annual bluegrass weevils adults are attracted to traps during certain parts of their development (notably in the spring when they are moving from overwintering sites toward fairways). Mole crickets are attracted to lights and can be collected in light traps, as well.

Black light captures seldom correlated with subsequent damage by a pest insect. For example, black light traps have been used to monitor masked chafer adult flights, but often there is no correlation between the number of adults caught and the amount of damage done by grubs (the offspring of the captured adults) that same season. But still the traps can indicate when adults become active and when management strategies should be scheduled.

Berlese Funnel

One technique involves collecting turf samples (usually a core cut to a depth of two or three inches) and placing the cores in a "Berlese funnel". Set up a large funnel (the funnels used to collect motor oil in an auto mechanic shop work well) on a rack with a jar of rubbing alcohol or antifreeze beneath the funnel. Place a large mesh screen in the funnel and put the turf sample on the screen (turf side down). Set up a light bulb (no more than 40 watts, and 25 watts is even better) above the funnel, turf off the lights in the room, and let the system go to work.

The concept is simple - any insects in the turf sample will try to avoid the heat and light, and will crawl down throught the sample to escape. When they reach the bottom of the sample, they fall down through the funnel into the collecting jar. Normally, a Berlese funnel will extract most insects within the first 24 hours (although we run our samples for 48 hours in the laboratory).

We use Berlese funnels to extract a wide range of insects from turf samples, and sometimes will find more than a thousand "springtails" (relatively primitive insects which can jump a surprisingly long distance) in one sample. We also find large numbers of spiders, predatory beetles, aphids, thrips, and predatory mites. The technique gives a relatively accurate assessment of mobile insects, but underestimates less mobile creatures (for example, white grubs may not respond to the heat quickly enough to move all the way through the turf sample).

Using Berlese funnels is an excellent way to sample hibernating quarters for insects which overwinter near turf. For example, annual bluegrass weevils often overwinter in white pine litter near golf courses. A golf course superintendent can collect a few plastic bags of pine litter and spread the litter in a few Berlese funnels. Normally the insects which are present in leaf litter samples will be active almost immediately, and will drop into the collecting jar within the first 24 hours.

Berlese funnels also can be terrific "teaching" tools. A lawn care professional can take a few samples from a representative account and show curious customers the wide variety of insects which can be found in turfgrass. Many of these insects are beneficial, either as active predators of pest insects or as organisms which assist in breaking down organic matter. The technique is also very efficient at extracting chinch bugs, so a lawn care professional can collect samples throughout the growing season and generate some accurate counts of chinch bugs.

Pitfall Traps

Pitfall traps are constructed by removing a core (often the standard cup cutter corer works well) from a turf site, placing a plastic cup inside the cup, and placing a tight fitting plastic funnel so that it fits along the ridge of the cup. The whole apparatus should be placed so the top of the cup is flush with the surface. The cup is filled with an inch or two of anti-freeze (a preservative which will kill and preserve the insect but will not evaporate too quickly).

Many insects and other small arthropods are very active in the turf, foraging through the thatch and upper soil surface. As they move, they encounter the ridge of the cup and tumble over the edge into the anti-freeze. Pitfall traps can be left in place for a week or more, and then the cup can be emptied into a small jar so the insects can be transported back to the office to be identified. The original site of the trap can be used throughout the growing season.

Pitfall traps are used by researchers to measure the populations of a wide range of turf arthropods. Mole crickets are commonly sampled by setting pitfall traps (although sometimes the traps are constructed with a length of pipe and a trench rather than individual cups in the ground). In addition populations of billbugs often are estimated from pitfall trap counts.

A few words of caution about pitfall traps - If the trap is placed in an area where turf is growing actively, grass clippings will fall into the trap. Some of the smaller insects and mites may "stick" to the clippings, so if you are trying to do an accurate count, you must be careful to inspect the grass blades too. If the area receives heavy rain or is irrigated regularly, the cup may fill up with water. In this case it must be changed more frequently, although normally once a week is sufficient.
Pitfall traps involve cutting a hole in the turf and inserting a relatively flimsy cup in the hole. If a person does not notice the trap and steps in the hole, there is a risk of injury. So most pitfall traps are placed in areas away from pedestrian traffic, or are marked with small flags to reduce the risk of accident.

Setting Tolerance Levels

Most turf managers are expected to justify any actions they take to control insect pests. The days of "spray and pray" are gone. Now turf managers often must document the presence of a pest before they use an insecticide or another method to reduce the population. "IPM", or "Integrated Pest Management" is a system which relies on the identification of insect pests and determining the tolerance level - how many insects are too many? Once a tolerance level is exceeded, control is deemed appropriate. (IPM also uses the same concept of setting tolerance levels for weeds, diseases, and other pests.)

Several things must be taken into consideration when establishing tolerance levels for insect pests. First, the manager must identify the species of insect. For example, there are several species of white grubs which attack turfgrass but some are more damaging, "grub for grub", than others. European chafers tend to be more damaging than Japanese beetles of the same age, in part because European chafers are larger and in part because they feed longer throughout the growing season. So just knowing that grubs are present may not be sufficient - if those grubs are European chafers, a turf manager probably will have to take remedial action more quickly than if the grubs are Japanese beetles.

Next, the turf manager must understand the life cycle of the insect. Most insects are susceptible to insecticides at certain times during their development (usually right after they hatch from eggs). Other stages (for example, eggs and pupae) are virtually untouchable. Part of setting thresholds is knowing which stages are vulnerable and knowing when the insects will be in those stages. Not surprisingly, later instars (larger or older individuals) feed more and cause more damage than smaller individuals. So understanding the life cycle and knowing when the larger stages may be present is critical. (The tolerance level will be lower when insects are larger or feeding more actively, because each individual is able to cause more damage than smaller or less aggressive individuals.)

Turf can tolerate two or three stresses but cannot tolerate additional stresses. So if the turfgrass is already under agronomic stress (for example, low mowing height, drought stress, high temperature stress, winter injury), it will be less able to survive additional stress from insect feeding.

One golf course on which we have conducted research has a virtually unlimited water supply, a rather restricted membership, and several areas which are maintained but are out of reach of golfers, so are not subjected to heavy traffic. We have often found more than 30 Japanese beetle grubs per square foot in these areas, and yet the turf shows no visible signs of insect damage. Another golf course puts through 100,000 rounds of golf a year (a large number for New England!), does not have irrigation in the roughs, and has a limited budget so fertility is minimal. This course experiences loss of turf with six to eight Japanese beetle grubs per square foot.

So tolerance levels will depend on stress factors. If the agronomic conditions are optimized (good fertility program, adequate irrigation, no temperature extremes, reasonable mowing heights), the tolerance level for insect activity will be higher - it will take more insects to cause visible damage. Another aspect of stress involves the time of year - if the insect activity occurs at a time when turf is already under stress (for example, the hot summer months for cool season grasses; cool autumn and winter conditions for warm season grasses), the "recuperative potential" for the turf is lower and it will take longer for the turf to recover from insect damage. Therefore, in these conditions the tolerance level will be lower.

The turf purpose plays a major role in determining tolerance levels. Some turfgrass settings involve lower levels of maintenance and can tolerate more insect activity. Other settings (golf putting greens, critical entry points in a commercial landscape) are highly maintained and are expected to be immaculate. Normally very few insects will be tolerated in such a location.

The expectations of the golfing membership or the customer also will determine the tolerance level, at least to some degree. If a customer indicates to you that he or she wants total eradication of an insect problem, you must explain that no material can provide 100% control. However, there are steps which can be taken which will reduce insect populations significantly. Some people think they want total elimination of insects (and may not be concerned about the environmental issues that are associated with insecticide applications). Other people would prefer to see a reduced pesticide load and are willing to tolerate a some insect activity. A turf manager must determine the expectations of the people paying the salary or the maintenance fee, and adjust tolerance levels accordingly.

Finally, the tolerance level (how many grubs is too many grubs?) will depend in part on the availability of curative treatments. If the only effective insecticide is one which must be applied several weeks BEFORE the pest can be monitored accurately, then the tolerance level will be much lower than it might otherwise be. If, on the other hand, there is an insecticide which can be applied AFTER the pest has become active and can provide a rapid knockdown of the population, the tolerance level can be higher. In other words, the turf manager can wait a little longer before making a decision.

In the final analysis, turf managers should be monitoring for insect activity throughout the growing season. They must learn which insects are active at which times of the year, and use the monitoring techniques which are best suited for those insects. Setting tolerance levels is a very individual thing - action thresholds change during the growing season. Thresholds go down as the stress on the turf goes up, they go down as the pest insect grows into larger and more damaging stages.

Often thresholds are very different from one part of an establishment to another. For example, thresholds on golf courses will vary tremendously with little or no insect activity tolerated on putting greens and tees and more activity accepted in roughs. An athletic field complex may have a couple fields which are designated as "primary" fields. These fields are more aggressively maintained and would have lower action thresholds. A commercial landscaping account often has particular areas which have been designated as critical - they may be along the entrance drive or surrounding the central building. Turf in these areas is expected to be highly manicured, while less visible, or less highly trafficked, areas can tolerate more activity.

As with much of the challenge of managing turf, the turf manager usually knows the situation better than anyone else. Use all the information available to monitor insect activity and make wise insect management decisions.

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