A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

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IN THIS ISSUE

Managing Mole Crickets: Developing a Strategy for Success

by Rick Brandenburg
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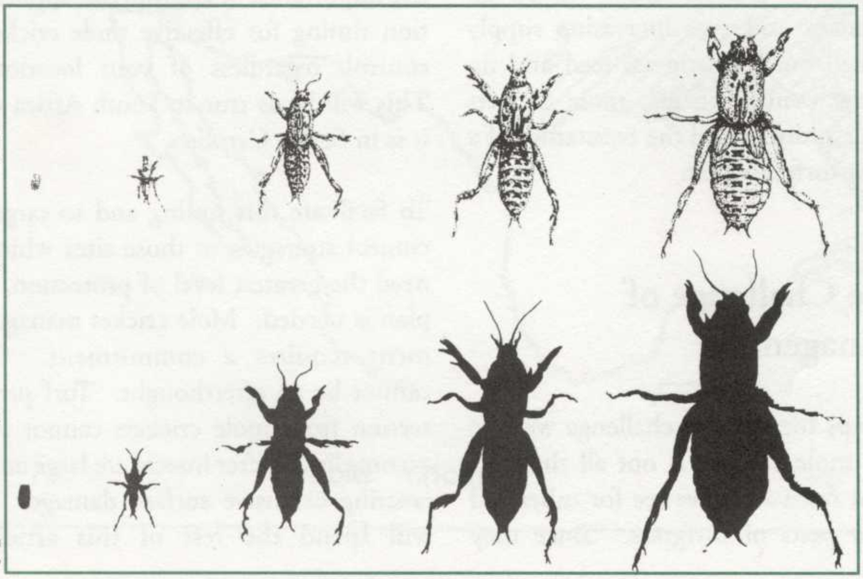
Mole Crickets: The Problem

Mole crickets have firmly established themselves as a major turfgrass pest, not only in the Southeastern United States, but throughout the world. Concerns over the potential damage from this pest range from Spain and Italy in Europe to South Africa and Southeast Asia. While different species are responsible for these infestations, they all-regardless of where they occur-are capable of causing severe damage and are difficult to control.

The consistent themes of serious damage and expensive control measures have moved this pest to the number one status for many turfgrass managers in affected areas. In the United States, the problem extends from eastern Texas across Louisiana, Mississippi, Alabama, Georgia, and Florida and north up the coast through South Carolina and North Carolina. Small pockets of infestation have been reported in other southern states further to the west.



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The predominant species throughout the southeastern United States have been the tawny mole cricket (*Scapteriscus vicinus*) and the southern mole cricket (*Scapteriscus borelli*). In addition, South Florida also has to deal with the short-winged mole cricket. Throughout the rest of the United States, turfgrass managers will on rare occasions have to battle the northern mole cricket (*Neocurtilla hexadactyla*).

The tawny mole cricket feeds primarily on turfgrass roots and is very destructive through its feeding and tunneling activities. Southern mole crickets are more a predator and most of their diet consists of other creatures in the soil. The southern mole cricket is still quite damaging due to its extensive tunneling for food just below the surface.

The fact that the northern mole cricket is native to the U.S. and rarely causes serious turf damage is important. The other mole cricket species are not native to the U.S. They were accidentally introduced approximately 95 years ago. Like other insects introduced to the United States from abroad, they have gained pest status because they had no natural enemies when they arrived here. Given an abundant and ever increasing supply of high quality turfgrass feed and no natural control agents, mole crickets have rapidly earned the reputation of a major turfgrass pest.

The Challenge of Management

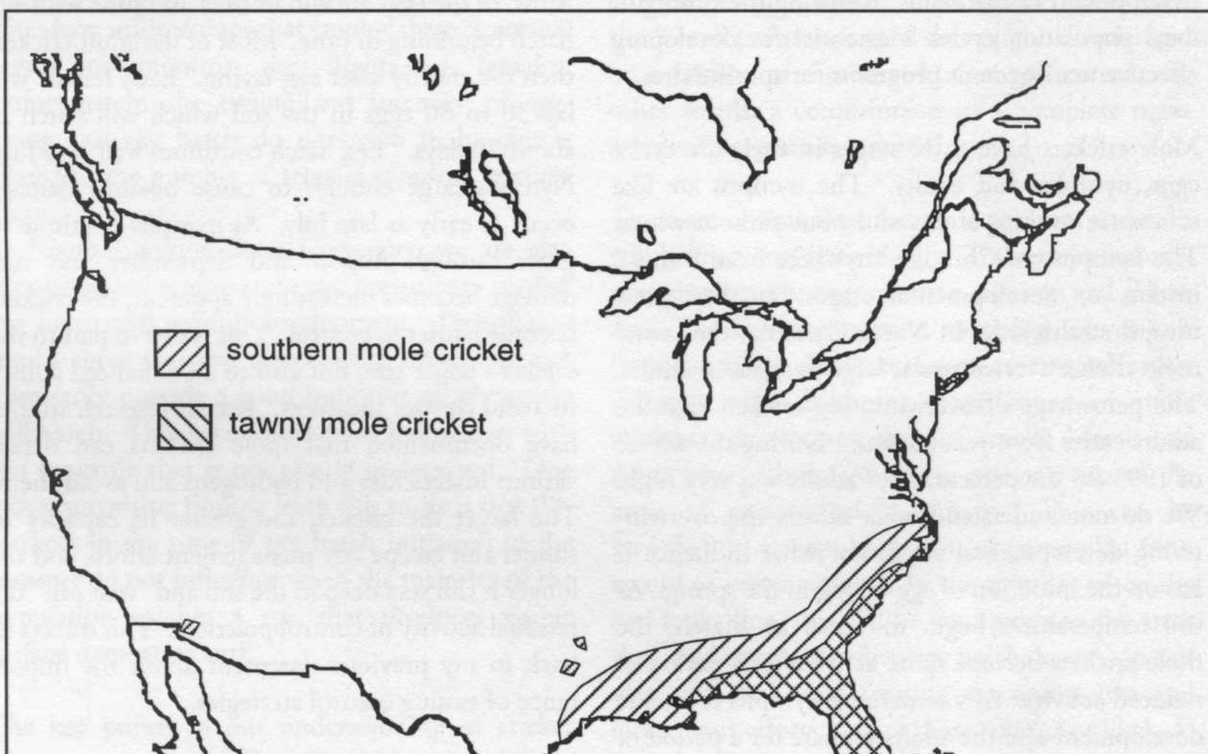
Perhaps the greatest challenge we face with mole crickets is not all that different from what we see for other soil insect pests of turfgrass. Since they reside mostly in the soil, we do not know what they are doing, and it is more difficult to manage control of the pest. This major difference between insect pests that reside in the soil and those that spend much of their time on the foliage means a different approach must be taken for effective management. Since much of a soil insect's activity occurs out of sight, we need to have a solid working knowledge of its biology and ecology. This is true for mole crickets, but is an essential component for the effective management of any turfgrass soil insect pest. By knowing what the pest is doing in the soil, we can apply control strategies at the most susceptible stage of the insect life cycle and maximize our chance of success. This is, of course, what everyone desires. Given the difficulty in obtaining effective mole cricket control, it is essential that we have this understanding.

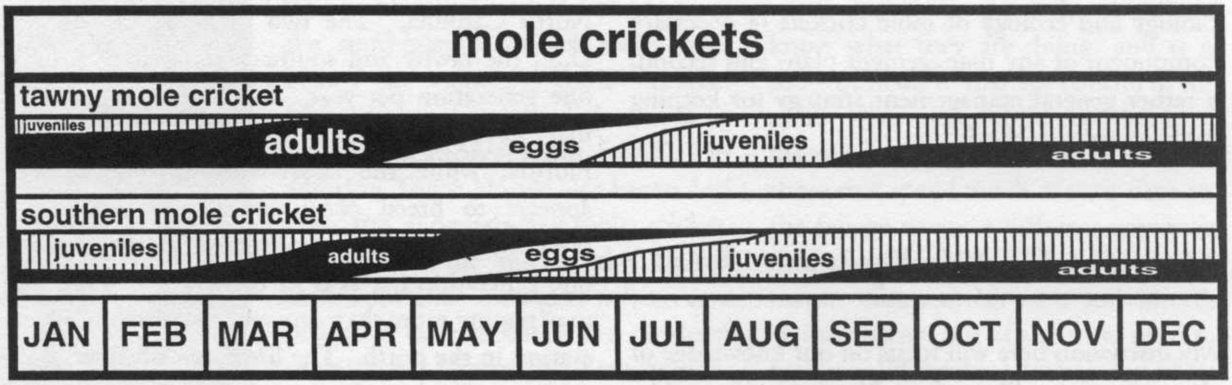
The three most important aspects of mole cricket management are: the timing of application, the timing of application, and the timing of application. While this may sound like a rather silly overstatement of common knowledge, I cannot overemphasize the importance of appropriate application timing for effective mole cricket control, regardless of your location. This will be as true in South Africa as it is in South Carolina.

To facilitate this timing and to target control strategies to those sites which need the greatest level of protection, a plan is needed. Mole cricket management requires a commitment. It cannot be an afterthought. Turf protection from mole crickets cannot be accomplished after insects are large and creating extensive surface damage. I will spend the rest of this article focusing on two areas: first, our knowledge of the biology and ecology of mole crickets (a necessary component of any management plan) and second, a rather general management strategy for keeping mole crickets in check.

Mole Cricket Life Cycle

My discussion here will focus on our knowledge of the mole cricket life cycle in North Carolina. The exact dates of specific stages will vary slightly throughout the southeastern U.S., but the basic life cycle is generally the same. For example, spring flights begin a month earlier in Florida than in North Carolina. The two major species in the U.S., the tawny and southern mole cricket, have one generation per year. Southern mole crickets may have two generations per year in South Florida, while the short-winged mole cricket appears to breed continuously with all stages present at all times. The northern mole cricket has one generation per year in the southern U.S. but may require more than one year to complete a generation in the north. The life cycles of other mole cricket species in various parts of the world are generally not as well understood, especially as relate to their presence in turfgrass and the use of this information to manage their control. However, this





does not mean that they cannot be managed effectively. A simple technique, that will be discussed shortly, allows an individual to monitor cricket development rather easily. Knowing the timing of local population cycles is essential for developing effective management programs for specific sites.

Mole crickets have three stages in their life cycle: eggs, nymphs, and adults. The nymphs are like miniature versions of the adults but without wings. The nymphs pass through anywhere from 7 to 12 instars, or developmental stages, as they grow toward adulthood. In North Carolina, the tawny mole cricket overwinters as large nymphs or adults. The percentage of overwintering crickets that are adults varies from year to year. During the winter of 1995-96 the percentage of adults was very high. We do not understand what affects the overwintering developmental stage, nor what influence it has on the initiation of egg-laying in the spring. As soil temperatures begin to warm in March, the mole crickets become quite active after a period of reduced activity. Any remaining nymphs complete development and the adults prepare for a period of mating and dispersal flights in April. Warm nights in April bring about increased activity. Damage to turf becomes quite noticeable when adult mole crickets begin to build "calling chambers". These funnel or megaphone shaped holes are used by the males to help transmit their mating call to attract flying females. Adult males generally build their chambers in areas with adequate soil moisture. By attracting females, who fly immediately after sunset, to an area of high soil moisture to mate and lay eggs, they probably ensure a better chance of egg and small nymph survival.

Most of the eggs are laid in May and June with egg hatch beginning in June. Most of the adult crickets then die shortly after egg-laying. Each female will lay 30 to 60 eggs in the soil which will hatch in about 20 days. Egg hatch continues well into July. Nymphs large enough to cause obvious damage occur as early as late July. As nymphs continue to grow through August and September and turf damage becomes increasingly apparent, the crickets become harder to control. This is due in part to the cricket's larger size, but also to an enhanced ability to avoid control measures. Recent research studies have documented that mole crickets can detect various insecticides and pathogens and avoid them. The larger the cricket, the greater its capacity to tunnel and escape any management efforts and the longer it can stay deep in the soil and "wait out" the residual activity of control practices. This directs us back to my previous statement about the importance of timing control strategies.

The tawny mole crickets continue development until the soil temperatures begin to cool in November and December when they overwinter in the larger nymph or adult stages. The southern mole cricket has a very similar life cycle-however, the majority of its egg-laying and egg hatch lags slightly behind that of the tawny mole cricket. One interesting aspect of this difference is that the southern mole cricket will devour a tawny mole cricket if it is as large or larger than the tawny.

Since the two species often coexist, this predation could have a significant effect on the abundance of the more damaging tawny mole cricket. However, since the tawny crickets appear to get a head start on their southern cousins, this probably minimizes the impact of such feeding. What it does create is a rather extended period of egg hatch for the combined species which will be considered in our management plan.

Many attempts have been made to forecast or predict the egg hatch and development of mole crickets. In the spring, adult males produce a buzzing mating call that attracts the females. This sound can be produced synthetically to attract females during their spring flight. Studies in several states have utilized traps that employ these electronic callers to monitor the flights of females. Unfortunately, the timing and intensity of egg-laying and egg hatch do not seem to be closely related to the number of females captured in these traps.

At North Carolina State University, we are also measuring soil temperature and moisture to predict egg hatch and nymph development. Preliminary results show that soil temperature alone does not necessarily provide a good indicator of when eggs will hatch. There is an important interaction with soil moisture that is not clearly understood. One rather surprising finding from this study is that differences in the time of egg hatch initiation in the summer do not influence when the majority of the population reaches a size that produces visible surface damage to turf.

The key points in our understanding of cricket management are: small mole crickets are easier to control, specific biological control strategies are available that are effective only on the adults, determining which areas to target for management can be best determined during adult activity in the spring, and the best time to treat is when the turfgrass looks its best and there are no obvious signs of mole cricket activity. With that said, the importance of understanding mole cricket biology should be obvious.

A Mole Cricket Management Plan

When we talk about a mole cricket management program, one should note that it is indeed a program. There are many facets to this program and it is not something you do one time per year. It is also important to realize that in most situations no single control strategy will produce acceptable results. In addition to the difficulty of controlling this pest, one must put the problem in the context of pest abundance. Soon after egg hatch, we have encountered populations as high as 25 mole cricket nymphs per square foot. Assuming a particular control strategy provides 90% control, that would still leave 18 mole crickets per square yard. That number far exceeds the 3 or 4 per square yard that might be tolerated on a fairway of a modest budget golf course. In other words, a commitment to a complete management program is essential.

There are several steps to such a program and each will be discussed individually. These steps include: mapping, monitoring selection, timing, and follow up. The first component, **mapping**, serves two basic functions. Many turf areas are not uniformly infested with damaging populations of mole crickets. By scouting the turf area in March and April when adults are active, one can record the areas of greatest adult activity. This can be recorded on a map, blueprint, or green plan for a record of insect activity. In the summer when the turf looks fine, this will be your guide to the areas that need treatment when egg hatch occurs. In this way, you can avoid treating the entire area and target your efforts toward those sites most likely to be infested. In some years, the adult damage may be so severe that adult control is necessary. Adults are difficult to control, but one approach is to use an entomogenous nematode product such as Vector MC. These often provide 50% control and reduce the number of adults that eventually lay eggs. This product is only for the control of adults. Conventional pesticides can also be used with variable levels of success.

In addition, mapping helps you to be efficient in your **monitoring** of egg hatch. Rather than sampling randomly, you can target those areas where eggs were most likely laid (areas of adult activity in early spring). This monitoring begins in late May in North Carolina. The tool used for monitoring is called the "soapy water flush." This consists of a sprinkling can filled with two gallons of water and two tablespoons of lemon-scented liquid dishwashing detergent. This mixture acts as an irritant to the newly-hatched nymphs and causes them to come to the soil surface where they can be readily observed. The soapy water should be sprinkled over a square yard area and then observed closely for the next several minutes. It is not advisable to leave and return to the site after a few minutes because the small crickets often do not move after emerging and are difficult to detect unless seen actually moving.

The monitoring technique should be used on at least a weekly basis in several locations that were previously mapped. Once small nymphs are observed you should begin preparations for implementing your control program. This means **selection** of the product you want to use. Make this selection based upon your own personal experiences, the experiences of people you trust, and recommendations from your state turf entomologist. A lot of options and products are available, so choose carefully and consider the individual characteristics of each product. Some may not be appropriate for your specific set of environmental concerns. Also, be aware that as soil types and the environment change so does the performance of many products. If you hear a success story about a product with which you are unfamiliar, you may want to proceed with caution and treat only a small area until you become more confident of its performance.

As previously mentioned, **timing** is the critical component in mole cricket management. The most common mistake is to let the mole crickets get ahead of you and then finding yourself in a position of trying to control large crickets while they are causing serious damage. On the other hand, treating too early can result in the residual activity of the insecticide diminishing before all eggs have hatched. In situations where both the tawny and southern mole crickets exist together, this period of egg hatch is even longer. In North Carolina, our general rule-of-thumb is to wait about three weeks from the time the first mole crickets are found using the soapy water flush to initiate control strategies. This avoids the problem of putting out treatments too early, yet still targets the treatments to begin control before any crickets get too large or visual turf damage occurs. It is important to note that insecticides having short residual activity are not the best choice for this initial application. Soil moisture is important for obtaining good mole cricket control. Do not treat if the soil is extremely dry. Preirrigating the areas to be treated the previous evening often proves useful for enhancing insecticide performance.

We have worked extensively with subsurface application equipment for mole cricket control. This equipment is designed by placing the insecticide (either liquid or granular formulations) just below the soil surface. Our trials have shown a general trend for improved mole cricket control, but it is not always significant. You should carefully consider your specific site needs and investigate all the options available before investing in this technology.

Finally, we come to the **follow up** phase of the mole cricket management program. Within two weeks of the initial application, return to the treated areas and determine the level of control by using the soapy water flush technique. If areas of high mole cricket populations are observed, note this on your map. If desired control in these areas is not obtained within three or four weeks, re-treatment should be considered. The presence of crickets in treated areas may not indicate a pesticide failure, but rather as previously mentioned, simply may be a reflection of a very high initial cricket population. The more time you spend identifying those areas that require a follow up treatment, the better you will be able to target and treat only those areas still supporting potentially damaging cricket populations. Total eradication is not a practical goal, but any area that still contains more than 5 or 6 crickets per square yard emerging from a soapy water flush will probably suffer damage if not re-treated.

In the months of August and September, surface damage becomes quite obvious. Examine the turf frequently during these months. Note areas of damage and spot-treat as soon as possible. There is no sense in letting the cricket do more damage and grow larger, only to become more difficult to control. Once we enter October and November, mole cricket control is not quite impossible, but it is getting very close. The bottom line is that a good turfgrass manager who maintains a complete mole cricket management program should never be in the position of having serious mole cricket problems late in the season.

Mole cricket control is difficult. These pests can be effectively managed, but only if one commits to a program similar to the one outlined. Mole crickets in other parts of the world-where a one year life cycle is common-will best be managed by a similar approach. If one can determine when adult activity-mating and flying-is occurring, she can begin with soap flushes a short time later to determine egg hatch. Some refinements may be necessary for local conditions.

The name of the game for mole cricket control is commitment. Develop a game plan and stick with it. Commitment to a plan can help ensure that turfgrass managers everywhere can win the mole cricket battle.

Dr. Rick L. Brandenburg is a Professor of Entomology and Extension Entomologist at North Carolina State University. He has degrees in entomology from Purdue University and North Carolina State University. His research and extension interests include the use of biological control techniques, innovative insecticide application technology, pest forecasting, and public education on pesticides and the environment.

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Five Steps to Effective Mole Cricket Management

1. Mapping: Determine where the adult mole crickets are in the spring. This provides insight into the preferred sites for egg laying and helps you focus your egg hatch monitoring program.

2. Monitoring: This effort requires the use of the soapy water flush technique to obtain information on egg hatch and nymph development during the summer. Such information is critical to time effectively the application of mole cricket control measures.

3. Selection: Pick the appropriate materials for your specific site. Take into account local environmental concerns. Also, consider the products of choice, their particular qualities, (i.e. persistence in the soil) and the timing of use (i.e. Orthene works best when applied in the evening).

4. Timing: Based upon observations from the soapy water flush techniques, time most treatments for application about three weeks after the first major hatch occurs. This ensures that most of the eggs have hatched, yet will prevent the earliest hatching crickets from causing serious damage.

5. Follow up: If mole cricket infestations are severe, few if any products will provide the desired level of control with a single application. About a month after treatment, begin examining the turf for signs of tunneling. Use the soapy flush technique on these areas to confirm the presence of life crickets. Map those areas requiring retreatment (usually the whole area will not need to be retreated, but rather small areas of high density should be targeted). Do not wait to treat if damage is visible and live crickets are present, because crickets become more difficult to control as they grow.

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Call Up 'Mcricket' for Answers

How can you tell the 10 species of mole crickets in the United States apart?

It's much easier to identify the adults than the young (nymphs)to the species level. One way to identify them is to use a computerized knowledge base called Mcricket. This knowledge base not only has graphics that let you identify the mole crickets, but it also has information about their life cycles and behavior. It also has information about control methods, including tutorials. Mcricket was developed by University of Florida entomologists Tom Fasulo, Howard Frank and Don Short with extension agents Harold Jones and LaRue Robinson.

Mcricket: Alternative Methods of Mole Cricket Control including the software (three diskettes, Program 089) and manual (Circular SW-089) can be purchased as a package from: University of Florida, IFAS Software Support, P.O. Box 110340, Gainesville, FL 32611-0340. Phone: (352) 392-7853. Mcricket costs $30 for Florida residents (add sales tax) and educational institutions, $40 for all others. Prepayment by check or Visa/MasterCard is required. Checks should be made out to the University of Florida.

However, if you know how to surf the World Wide Web from your computer, you can access Mcricket free at:

http://gnv.ifas.ufl.edu/~ent1/mcricket/index.html

Reprinted from Landscape Management.

Back to Basics - Insecticide Primer Part Two: Chemical Classes of Turfgrass Insecticides

by Patricia J. Vittum
University of Massachusetts

Introduction

Traditional insecticides are chemicals designed to kill or otherwise control insects. Most of the insecticides which are used widely in turfgrass management are "organic," which simply means that they contain carbon (and usually hydrogen) somewhere in the molecule. This article will attempt to explain some of the structural differences and performance characteristics of the most common chemical classes of insecticides a turf manager can expect to encounter.

Organochlorines

Background

The first class of organic insecticides to be developed commercially was the organochlorines or chlorinated hydrocarbons. A close inspection of the name reveals a great deal about the molecular structure of these compounds. "Organo" indicates there is carbon (and usually hydrogen) in the molecule, and "chlorine" indicates that at least one atom of chlorine is present. "Chlorinated hydrocarbon" is, in fact, another way of saying the exact same thing.

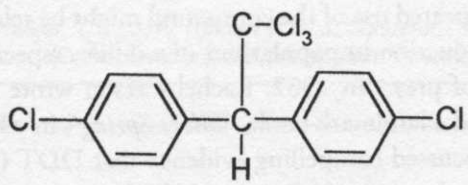
DDT was first synthesized in 1873, by a German graduate student, but he had no way of knowing about the special characteristics of the compound. In 1939, Paul Muller, a Swiss entomologist, accidentally came upon the work of the graduate student and discovered that DDT had long lasting effects against flies and mosquitoes. Several qualities of the material suited it for use in public health settings (for example, mosquito control to reduce the spread of malaria), and it quickly became the mainstay in several public health efforts. Meanwhile DDT was used in various agricultural operations to control several different kinds of insects. Farmers found that the material remained active in the soil for a long period of time (often more than a year), and they looked forward to the day when DDT would solve all of their insect pest problems.

DDT was used in agriculture, forestry, and mosquito control programs for several years. Eventually some people began to suspect that heavy and repeated use of the compound might be related to a reduction in populations of wildlife, especially birds of prey. In 1962, Rachel Carson wrote and released a landmark book, *"Silent Spring"*, in which she discussed compelling evidence that DDT (and some other organic insecticides) almost certainly was building up in the fat tissue of insects and other invertebrates. When a small fish fed on these insects, the DDT was stored in even higher concentrations in the fat tissue of the fish. At each step in the "food chain," DDT accumulated in the fat tissue of the consumer in higher and higher concentrations. Eventually birds of prey, such as eagles and falcons, fed on this highly contaminated prey and accumulated very high concentrations of DDT in their tissue. One side effect of the exposure to this contamination was that female birds produced eggs with very thin shells unable to withstand the weight of the incubating female, so the eggs collapsed or were crushed. Not surprisingly, eagle and hawk populations began to plummet.

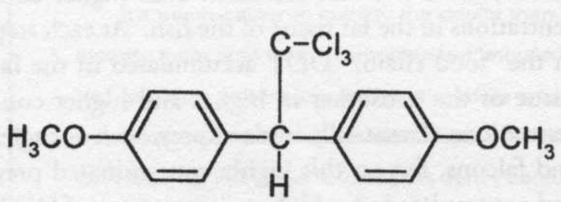
In the 1970s, soon after the Environmental Protection Agency was formed, DDT, chlordane, and several other insecticides in the same chemical class were removed from the market. Their registrations were revoked and their use is now prohibited in the United States. However, there are several other organochlorines which have strikingly different characteristics, and which are used in several agricultural and ornamental settings.

Diphenyl aliphatics

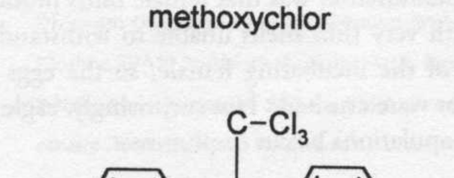
Several compounds have a striking similarity to DDT and are described as diphenyl aliphatics. "Phenyl" is a term used to describe a ring of six carbon atoms, usually represented as a hexagon when sketching a molecule. "Diphenyl" simply means that there are two such rings in the molecule. "Aliphatic" means that the chains of atoms attached to the rings are "straight," with no additional rings or branches. Three examples of diphenyl aliphatics are given here:



DDT



methoxychlor



Dicofol

The chemical structures of each of these compounds look remarkably similar. For example, methoxychlor appears identical to DDT except that the chlorine atoms which are attached to the rings in DDT are replaced by methoxy "OCH3," groups which consist of an oxygen atom attached to a carbon atom which has three hydrogens linked to it. Such a seemingly simple difference results in a tremendous change in physical characteristics. DDT tends to be very persistent in the environment, sometimes remaining active for several years, while methoxychlor is much less persistent, usually remaining active for a few weeks. DDT tends to accumulate in fat tissue of animals as they move through the food chain, while methoxychlor is much less likely to do so.

However, most organochlorine compounds which fall into the "diphenyl aliphatic" class do have certain characteristics in common. They tend to be relatively low in acute toxicity to mammals and other vertebrates. (Note: a subsequent article will discuss acute vs. chronic toxicity in more detail.) In addition, they tend to be less water soluble and mobile than many other insecticides, and so are not as likely to leach into groundwater or run-off into surface water.

Examples: DDT (no longer available), methoxychlor, dicofol (Kelthane™, used as a miticide)

Cyclodienes

Cyclodienes are organochlorine compounds that have a relatively complicated structure which often includes two or more carbon rings interconnected to each other. These compounds were developed in the late 1940's and 1950's and were used as soil insecticides for several years because they were very persistent in the soil. One such compound most familiar to turf managers was chlordane, which was used in turf settings until about 1975 and was a very effective material against termites as well as turf insects. However, because of concerns about the persistence of chlordane in the soil and the development of resistance to chlordane by several insects, its registration was phased out - by 1982, it was no longer legal to use chlordane in the United States.

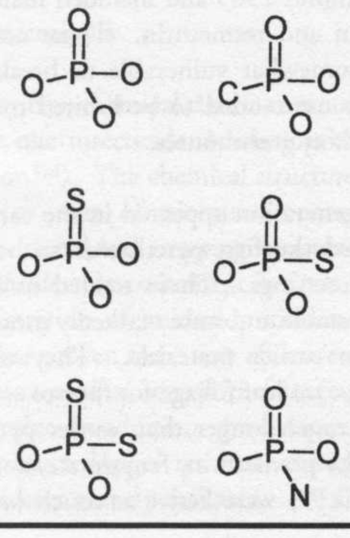
Examples: aldrin, chlordane, dieldrin (none of which is still available)

Organophosphates

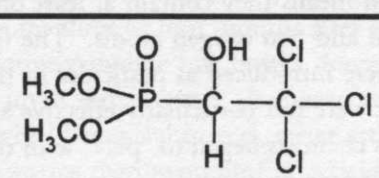
Organophosphates (OPs) contain carbon and hydrogen, but also have at least one atom of phosphorus and either oxygen or sulfur attached to that phosphorus atom. Chemists would say that organophosphates are derived from phosphoric acid. There are six possible variations, each of which is considered a different type of organophosphate (or, more accurately, organophosphorus) compound.

The first organophosphorus insecticides were developed in the late 1940's and early 1950's, in part in response to concerns voiced about the persistence of DDT and other organochlorines. Just as with the organochlorines, there are several different kinds of organophosphates, some are relatively simple and some are very complicated molecules.

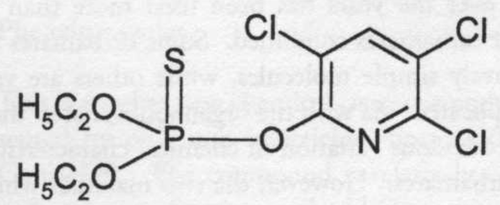
The chemical characteristics depend on the length and shape of the chain of atoms attached to the phosphorus, oxygen, and/or sulfur located at the central part of the molecule. Some OPs have fairly simple chemical structures, while others are quite complex, with long or complicated chains attached to the central structure.



There is tremendous variation in characteristics within the class. For example, some OP insecticides are very persistent, while others break down very quickly. Some OPs are virtually insoluble in water and therefore quite immobile, while others are extremely soluble (and mobile) in water. Some of these materials are extremely toxic to mammals and other vertebrates, while others are much less toxic. It is virtually impossible to generalize about the environmental characteristics of organophosphate insecticides, because there is so much variation within the class.



Trichlorfon



Chlorpyrifos

Most OP insecticides are "broad spectrum," which means that they are effective on many different kinds of insects, and therefore may have harmful effects on beneficial insects and other arthropods. Most OPs do not accumulate in the food chain.

Typical application rates - 1 to 8 pounds active ingredient per acre

Examples: acephate (Orthene™), chlorpyrifos (Dursban™), diazinon (**not on golf courses**), fonofos (Crusade™, Mainstay™), isazofos (Triumph™), isofenphos (Oftanol™), trichlorfon (Proxol™, Dylox™)

Carbamates

Carbamate insecticides are derived from carbamic acid, which means they contain at least one atom of nitrogen and two oxygen atoms. The first carbamates were introduced as pesticides in the early 1950's but were not particularly effective as insecticides. As chemists began to "play" with the molecule, adding some things here and taking away things there, they found ways to improve the effectiveness of these compounds against insects.

Carbaryl (Sevin™) was the first truly successful carbamate insecticide to be introduced, in 1956, and over the years has been used more than all other carbamates combined. Some carbamates are relatively simple molecules, while others are very complicated. As with the organophosphates, there is tremendous variation in chemical characteristics of carbamates. However, the two materials which are currently available for use by turf managers in the United States (carbaryl, or Sevin™, and bendiocarb, or Turcam™) are intermediate in mobility, persistence, and toxicity. Both of these materials are broad spectrum, and tend to be quite toxic to earthworms, honey bees, and certain other non-target arthropods.
Typical application rates - 2 to 8 pounds active ingredient per acre

Examples: bendiocarb (Turcam™), carbaryl (Sevin™, Sevimol™)

Synthetic Pyrethroids

Pyrethrum/Pyrethrin

There are several compounds which occur naturally in plants and have insecticidal properties. One of these is pyrethrum, a compound produced by some kinds of chrysanthemums native to Africa. Pyrethrum refers to the crude flower dust, while pyrethrin refers to six closely related compounds which occur in the blend. Some of these pyrethrins are quite toxic to insects. Pyrethrins act very quickly against target insects and cause a virtually immediate "knockdown" effect, in which the insect is paralyzed. However, many insects are able to metabolize (break down) pyrethrins quite quickly, so some insects survive after a brief period of paralization. Pyrethrins as a group are less acutely toxic to mammals than are several other classes of insecticides, but they usually are quite toxic to fish. Pyrethrins tend to be less stable than several other kinds of insecticides and break down in ultraviolet light quite quickly.

Synthetic Pyrethroids

As with so many other kinds of insecticides, chemists looked at some of the naturally occurring pyrethrins and began to experiment with the structure of the basic molecules. They found that as they added atoms to different parts of the original molecule, they could "improve" the insecticidal properties of the compound. These new pyrethroids are not natural compounds, but they are directly based on the structure of natural compounds. The chemical "tweaking" has resulted in the development of materials which last much longer than the natural pyrethrins (several weeks instead of a few hours or days) and are more toxic to insects.

Pyrethroids have gone through several levels of development. The first generation was developed around 1950 and included materials like allethrin, which essentially was a synthetic duplicate of one of the natural pyrethrins. The second generation appeared around 1965 and included materials like tetramethrin and resmethrin. These compounds were still somewhat vulnerable to breakdown in sunlight, so use tended to be limited to enclosed settings such as greenhouses.

The third generation appeared in the early 1970's and included the first pyrethroids to be used in agricultural settings. These tended to be much more photostable and were markedly more toxic to insects than earlier materials. They tended to remain active on leaf foliage for four to seven days, which was much longer than earlier pyrethroids. Materials like permethrin, fenvalerate, and fluvalinate (Mavrik™) were active at much lower rates than other classes of insecticides, and were applied at 0.1 to 0.2 lb active ingredient per acre.

The fourth, and most recent, generation was first developed in the 1980's and continues to undergo further refinement. These compounds are much more stable in sunlight and can remain active on leaf surfaces for a few weeks. They are applied at even lower rates than third generation pyrethroids, which may become a significant factor for turf managers in years to come. Materials like bifenthrin (Talstar™), lambda-cyhalothrin (Battle™, Scimitar™), and cyfluthrin (Tempo™) are sometimes effective at 0.01 to 0.05 lb active ingredient per acre.

Most of the synthetic pyrethroids which are currently being used on turf are of the fourth generation group. In many cases, the acute toxicity (to mammals and other vertebrates) and environmental characteristics (such as mobility and persistence) depend on the kind of solvent which is used in a given formulation. While most of the pyrethroids tend to be less toxic to vertebrates than other classes of insecticides, there are some exceptions.

Typical application rates - 0.01 to 0.5 pound active ingredient per acre

Examples: bifenthrin (Talstar™), lambda-cyhalothrin (Battle™, Scimitar™), cyfluthrin (Tempo™), fluvalinate (Mavrik™)

Chloronicotinyls

This very new chemical class is currently represented by only one insecticide, imidacloprid (Merit™ or Marathon™). The chemical structure is somewhat related to that of nicotine, containing several nitrogen atoms and two ring structures. There has been considerable excitement in the turf world since the registration of imidacloprid because the compound has proven to be very effective at low rates of application against several turf insects, particularly white grubs. In addition, the compound appears to provide much longer residual activity than other insecticides currently available.

Imidacloprid, the only representative of this chemical class, is relatively low in acute toxicity to mammals and most other vertebrates. It appears to be quite persistent in the soil, sometimes remaining active for three or four months after application. It is relatively mobile but breaks down quickly if it ends up in surface water. It appears to be less toxic to several beneficial insects, other arthropods, and earthworms than many turf insecticides.

Typical application rates - 0.2 to 0.4 pound active ingredient per acre

Example: imidacloprid (Merit™)

Phenylpyrazoles

This is another new chemical class, currently represented by only one insecticide, fipronil (Chipco Choice™). The compound is relatively complex and contains fluorine and chlorine, among the usual atoms. This compound has generated considerable excitement in the turf world because it appears to be very effective against mole crickets at low rates of application. In addition, it appears to provide much longer residual activity against mole crickets than other insecticides currently available.

At this point, fipronil must be applied sub-surface (using high pressure liquid injection or a slicing technique). This is in part because the product is relatively immobile in soil, so even heavy irrigation following an application may not be sufficient to move a surface application of the material through the thatch. While fipronil is moderately toxic to mammals and other vertebrates, it does not appear to be as disruptive to beneficial insects as most other turf insecticides.

Typical application rates: 0.02 to 0.05 pound active ingredient per acre

Example: fipronil (Chipco Choice™)

Resistance Issues

Most insects have the ability to break down, or otherwise detoxify, many of the chemicals with which they come in contact during their daily activity. Some of these chemicals are natural products produced by plants as a form of natural defense, while others are insecticides applied by humans in an effort to suppress an insect population.

Just as no two people are alike, most insect populations have considerable variation, with some individuals being particularly talented at finding new food sources and others being especially able to break down chemicals. If an insecticide is used in such an area, the insects which are already inherently better able to break down chemicals will survive exposure to an insecticide which is applied, while other insects which had other innate abilities but were not as efficient at breaking down chemicals will be more likely to be killed by exposure to the material.

The insects which survive in such a situation are almost certainly the ones which had an inherent ability to break down chemicals. There are several ways by which insects can break down chemicals, so there are many variations which can show up in an insect population. The main point, however, is that the insects which survive the first exposure to an insecticide will pass on their genetic makeup to subsequent generations. The gene which enables an insect to break down an insecticide will be passed on from generation to generation (especially if the insecticide is used at least once during each generation of that insect), because the gene provides a competitive advantage to the insects which

Figure 1. How resistance develops in an insect population. (S = susceptible, R = resistant)

NORMAL POPULATION	S S S R S S S R S S S R
	R S S S R S S S R S S S
	S R S S S R S S S R S S
INSECTICIDE APPLIED	S R R S R
(many susceptible insects die)	R S R R S
	R R S R S
SURVIVORS REPRODUCE	R S R R R S R R R S R S
	S R R R S R R S R R S R
	R R S R S R R R S R R S
INSECTICIDE APPLIED	
(many susceptible insects die)	R R R R R
	R S R R R
	R R R S R

EVENTUALLY MOST SUSCEPTIBLE INDIVIDUALS DIE, AND SURVIVORS ARE RESISTANT possess it. Eventually the gene will become so prevalent in the population that most insects will not be affected by an application of that insecticide. When this happens, scientists say that the population of insects has become resistant to the insecticide.

Figure 1 demonstrates the concept visually. If we start with a population of insects in which most individuals are susceptible to an insecticide ("S" in the diagram) but a few individuals are inherently resistant to that insecticide ("R" in the diagram), and allow those insects to interbreed, the overall percentage of individuals which are susceptible and resistant remains constant in the absence of the insecticide. However, if the insecticide is applied, most of the susceptible individuals will be killed, while the resistant individuals will survive. Over time, the percentage of individuals which are resistant to the insecticide increases, because the resistant ones are the ones which survive and pass on their genes.

As it happens, the mechanisms which an insect uses to detoxify an organophosphate insecticide are often the same, regardless of the OP to which it is exposed. If an insect develops resistance to one organophosphate, it usually becomes resistant to other organophosphates at the same time. The same is true for most other classes of insecticides, as well.

There are several things a turf manager can and should do to reduce the likelihood of resistance developing in an insect population. The most important suggestion is to **avoid using the same insecticide or insecticides in the same chemical class repeatedly in the same location.** If you do use the same material over and over, some insects invariably will develop resistance to that material and pass on their resistant genes to their offspring. Eventually the "normal" insecticide application will have no noticeable effect on the population because most individuals will be unaffected by it.

If possible, **avoid treating "wall to wall"**. Monitor the turf areas and determine which areas are most heavily infested. Concentrate control efforts in those areas and leave other areas, with lower populations (and likely non-damaging) untreated. Any time a turf insecticide is applied, the chance exists that some individuals will already be or will develop resistance to the material. To delay the inevitable, **treat only when absolutely necessary.**

Selecting an Insecticide

If you determine that the insect population on your turf warrants the use of an insecticide, consider several factors before deciding which material to use. There are many kinds of insecticides, with a wide range of characteristics (for example, how quickly they work; how long they last; how mobile they are in surface water or ground water; toxicity to humans, target insects, and beneficial insects; and chemical structure). Take the time to review the information available and determine which ones are best suited to your needs. Note that a good choice in one instance will not necessarily be an appropriate choice in a different set of circumstances. As a guide, consider each of the following items before deciding which inseciticide would be "best."

1. Identify any environmental conditions (nearby ponds or streams, sandy soils, compacted soils) which should be considered. Choose materials which will not leach or run-off in those conditions.
2. Identify any toxicity issues which should be considered. Are you treating athletic fields? Is there a playground nearby - or are children likely to play on the treated area? Will pets or wildlife have access to the area after application? Choose materials which have lower levels of toxicity to humans and other vertebrates.
3. Can you irrigate the area after application? If you are unable to irrigate, you must select materials very carefully. Do not use a material which must be watered in unless you are equipped to do so!
4. Are there any particular beneficial insects which you must be careful to protect? Several insecticides are extremely toxic to honey bees. Follow label instructions carefully and do not use such materials when bees are foraging. There are several other insects which are beneficial but not necessarily

obvious. Avoid using broad spectrum insecticides whenever possible, to reduce the detrimental effects on these beneficial insects.

5. Determine whether you need a fast acting material (are the insects already causing damage?) or whether you can use a slower but longer lasting material. (Sometimes there is considerable variability within a chemical class, but the chemical class often provides a clue to "speed of efficacy" and residual activity.)

6. Do not use insecticides in the same chemical class repeatedly in the same location. Alternate chemical classes so that insect populations are less likely to become resistant to the insecticides being used.

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Terms to Know

Biomagnification- occurs when a material is not metabolized by an animal, but instead is stored in fat tissue. If that animal is consumed by another animal, the material is stored in the fat tissue of the consumer at even higher concentrations than it was present in the original animal.

Inorganic - does not contain carbon.

Metabolize - break down from a complex chemical structure into numerous simpler structures (refers to break down of an insecticide into a usually less toxic form)

Molecule - a collection of atoms which bond together, retaining a particular and specific structure.

Natural - produced by a plant or an animal.

Organic - containing carbon and hydrogen (and usually oxygen).

Organochlorine (Chlorinated Hydrocarbon) - a synthetic insecticide which contains chlorine and carbon, among other things.

Organophosphate (Organophosphorous Compound) - a synthetic insecticide which contains carbon and phosphorus (as well as oxygen and/or sulfur).

Photostable - stable in sunlight

Synthetic - produced by humans (may be organic or inorganic).

Synthetic Pyrethroid - a synthetic insecticide whose complex chemical structure is derived from pyrethrins (naturally occurring compounds found in some chrysanthemums)

Genetic Resistance to Mole Crickets in Turf Bermudagrass

by Wayne Hanna, U.S. Department of Agriculture
Will Hudson, University of Georgia

Mole crickets can quickly ruin beautiful turf if a plan to manage and/or control them is not in place. It seems that this pest is becoming more serious each year. Insect management procedures are usually continuous and must be repeated. Genetic resistance to pests is usually permanent and can greatly reduce and simplify (and possibly eliminate) some management procedures.

Development of turf cultivars with genetically controlled pest resistance is an important objective in the U.S. Department of Agriculture-ARS turf bermudagrass breeding program at the University of Georgia Coastal Plain Experiment Station in Tifton, GA. Pesticides (including insecticides) are rarely applied to the plots with experimental cultivars so that insects will infest the research area and new plant types with resistance to insects can be identified. 1996 has been an exceptionally good year to screen for genetic resistance to the tawny mole cricket (Scapteriscus vicinus) in our research plots.

In 1996, we rated mole cricket activity in 497 experimental turf bermudagrass hybrids growing in 4 x 4 meter plots replicated twice. These were selected for close mowing tolerance from over 27,000 hybrids produced in 1993. Ratings ranged from 1 (no mole cricket activity) to 9 (severe mole cricket activity) indicating at least that the mole crickets preferred some cultivars more than others. Differential feeding by the mole crickets on the experimental hybrids was dramatic. Where the lowest and highest rated plots were adjacent to each other, the crickets would not invade the non-preferred plots. Tift 94, a fine-textured cultivar introduced at Midiron at Tifton, GA, which should be

Interpreting Chemical Structures

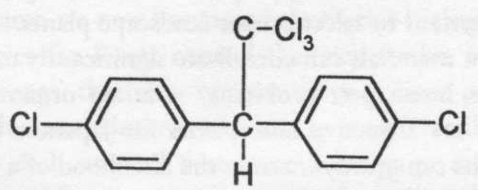
Chemists use a kind of shorthand to sketch the shape of molecules, which are made up of two or more atoms.

Abbreviations:

C = carbon
Cl = chlorine
H = hydrogen
O = oxygen
P = phosphorus
S = sulfur

Bonds:

Many atoms are connected to their neighbors by "single bonds," which are usually relatively stable and are represented by a single dash between the atoms. Sometimes atoms are connected by double bonds, which tend to be less stable and are represented by two dashes between the atoms.



DDT

The center of the molecule is a carbon atom, which is attached to two hexagonal rings. These are rings of carbon connected by alternating single and double bonds (actually it is not quite that simple!). The central carbon also has another carbon atom attached to it (at the top of the sketch), which in turn has three chlorine atoms attached to it. Finally, there is a chlorine atom attached at the "far" end of each of the hexagonal rings.

Chemical Characteristics:

The molecular structure of an insecticide will determine its persistence, solubility in water, acute toxicity (to people or to insects), and other characteristics.

available to certified growers in 1997, continues to show the almost no mole cricket activity, as originally reported in 1993. In addition to mole cricket non-preference, Tift 94 has excellent color, quality, and cold resistance and should be an excellent grass for golf course fairways, sports fields, parks, lawns and landscaping. TW72, a potential new dwarf bermudagrass for golf greens in the future, also continued to show significantly less mole cricket damage than Tifdwarf.

The turf breeding research at Tifton, GA, shows that mole crickets prefer to avoid certain cultivars where a choice of cultivars exists. What would happen if the cultivars showing non-preference were the only ones available? Experiments will be conducted in 1997 in cooperation with Kristine Braman, entomologist at the UGA Georgia Station in Griffin, GA, to determine the level of genetic resistance associated with the non-preference.

Dr. Wayne Hanna is a research geneticist with the U.S. Department of Agriculture at the Coastal Plain Experiment Station in Tiston, Georgia. He has been breeding turf and forage grass for twenty five years.

Dr. Will Hudson is an Associate Professor of Entomology at the University of Georgia. He has been invloved in mole cricket research and extension for fifteen years.

Planning Ahead to Minimize Insecticide Impacts on Golf Courses

by Rick L. Brandenburg
North Carolina State University

The use of insecticides on golf courses has been documented to have the potential for adverse, off-target effects on the environment. The key word is "potential." Insecticide use can and should be directed in such a fashion so as to keep the potential risk to a minimal level. This, of course, involves the use of properly selected pesticides chosen specifically for the pest and site to be treated. It also requires that insecticides are properly applied in an appropriate manner and timed in accordance with the insect's life stage. However, minimizing the potential for adverse risk from insecticide use starts long before the actual pest outbreak.

In theory, environmentally sound pest management should start during golf course design and construction. The installation of catch basins to capture insecticide contaminated runoff has proven effective for several years on many courses. More common considerations for avoiding runoff from areas that may require insecticide use include utilizing the slope of the land to direct runoff into buffer areas and appropriate landscaping. It is important to select proper landscape plants. Some plant materials can contribute significantly to turfgrass insect pest problems. Certain ornamentals that are attractive host plants for Japanese beetle adults can greatly increase the likelihood of a white grub problem. Since Japanese beetles prefer to lay their eggs in moist soil under healthy turf, any plants that attract the adults into the vicinity of the turf are likely to increase the chances of having such a problem.

Other more subtle problems can occur with insects like the two-lined spittlebug. The adults prefer to feed on hollies while the nymphs favor certain grasses. If hollies are used in plantings around buildings, they will attract adults and soon increase the number of nymphs feeding on the turfgrass. The same is true for grubs of the green June beetle and several other common turfgrass pests. Adjustments in landscaping can help avoid insect problems and thus reduce the need for insecticide use.

Areas of special concern over insecticide use (i.e. those immediately adjacent to water) can still provide the aesthetics and challenging ball play desired without the use of highly maintained turfgrass immediately adjacent to the water's edge. In many such sensitive areas where serious insect pests such as mole crickets often are present, control is virtually impossible. Even if this area is not the focal point of a fairway and the insect's presence can be tolerated, they provide a source of infestation for the remainder of the course each year they are not controlled. Reevaluating the need for turf extending directly to the water's edge in light of such concerns may prompt the use of an attractive, low maintenance, playable ground cover that does not feed insects. The use of alternate plant material maintained in an organic mulch may form an excellent buffer to protect surface water bodies. Some mulches such as oyster shells, gravel, or other similar materials may actually enhance the likelihood of runoff into an area of concern. Such landscape modifications can greatly ease the pressure on a superintendent over pesticide use in environmentally sensitive areas.

Of course, we now have some alternative biological strategies for insect control (i.e. nematodes, bacteria, fungi) that offer opportunities to limit pests in such areas. However, the best approach is still to survey each site and determine if design or structural modifications can be made that will reduce the likelihood of pest problems in the area or make the insect's presence more tolerable.

By monitoring insect infestations and spot-treating areas where damage is occurring rather than wholesale broadcast applications, the quantity of insecticide used can be reduced markedly. Perhaps the most logical means of minimizing insecticide impact on the environment is to treat areas only when threatened by insect attack and to select an insecticide based on the site considerations, including choosing less toxic, less mobile, and less persistent materials. However, a persistent insecticide may result in a reduction in the total number of treatments required. Timing of insecticide use may even consider the presence of migratory bird species or modifying application methods through the use of newer technology such as subsurface application equipment. Chemical formulation can also play a factor since some are more susceptible to runoff and surface loss. Indirectly, pesticide formulations can play a role in reducing the quantity applied because you may be better equipped to apply some formulations more accurately and in a more timely fashion than others. Granular formulations are often considered to present greater risk for runoff or ingestion by birds, however, proper irrigation following treatment minimizes this risk and granuals offer less likelihood of drift injury or off site transport.

Remember, each insecticide use decision needs to be site specific. Environmental concerns can vary across a golf course as much as the soil types. Your insecticide use patterns may need to change as well with different locations. Many superintendents like the new synthetic pyrethroids such as lambda-cyhalothrin or fluvalinate because of their low use rates and their relative safety for people, mammals, and birds. However, these products can be very toxic to fish. Proper site selection for the use of such products is critical and these concerns can provide positive off-target benefits when considered prior to choosing an insecticide.

Fortunately, the science of insecticide selection has made great strides in recent years. Various indexes of pesticide leaching potential, toxicity rankings, and other rating systems help one customize insecticide selection and use to the needs of each specific site. This information is available from a number of sources including your state extension service, private consultants and technical publications. A listing of state extension services is attached, and one of the best sources of private consultants is your state or regional turfgrass association. In addition, assistance and information on pest identification is available through a number of turfgrass diagnostic laboratories listed in past issues of *TurfGrass Trends* (October 1996).

In Future Issues

- Advanced Concepts in Turfgrass Nutrition
- Caught in the Web
- Physiology of Winter Injury
- Maximizing Turfgrass Irrigation Efficiency

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