

Insects

Insect Structure and Function

Insects are in the scientific classification of a family called Insecta. They are closely related to spiders, ticks, mites, millipedes, crayfish and other animals in the Phylum Arthropoda. While closely related to these other organisms, they share unique characteristics that make them a separate group. Many special characteristics of insects make them a challenge to manage in an effective manner. The better one understands a little about insect biology and ecology, the more likely one will be able to defend the turf from damaging attacks. The structure of an insect is much different than that of a mammal. Two key areas we will discuss are the three main body parts and the skeletal system because these play a role in identification and in development and control. The Exoskeleton: Insects differ from humans in that their skeleton is external rather than internal. Muscles attach to the skeleton internally. Such an arrangement gives the insect considerable strength for its size. This exoskeleton serves as external protection for the insect and its outer waxy coating can actually help protect it from various control agents. Much like snakes, however, insects must shed their exoskeleton or skin to grow larger.

The Body Parts

The insect will always have three basic body parts: the head, thorax and abdomen. Most insects have a pair of compound eyes and maybe one to three simple eyes. The legs and wings are always attached to the thorax or middle section. There are no exceptions to this. Internally the thorax is usually the site of various powerful muscles responsible for locomotion, whether it be the legs or wings. The abdomen contains organs for respiration, excretion, and digestion. In some insects the abdomen contains protective devices such as stingers (fire ants and wasps). Most of the spiracles (breathing holes) are located on the abdomen, but a couple can also be found on the thorax. Legs always are attached to the thorax.

Legs vary greatly in design and function and may be useful for identification. Some legs are for clinging, digging, or jumping. Insects usually have 3 pairs of legs and will never have more than that. Some caterpillars, like cutworms and fall armyworms, may appear to have more legs and there are several sets of legs near the rear of the caterpillar. These are not true legs in that they are not jointed and don't articulate like the legs on the thorax. They are technically referred to as prolegs. Wings also vary quite a bit from hard, shell wings to feathery light, onion skin-like legs. As in the case of legs, wings can be a useful tool for identifying insect pests. Only the adult stage of insects will have wings. Most insects have 2 pair of wings, although flies have only one pair and a few insects have no wings. Many beetles have a hard, shiny first pair of wings that covers the more membranous second pair of wings that do most of the work for flight. Other insects such as moths (the adults of cutworms, armyworms, and sod webworms) have 2 pairs of wings that are quite similar. Wings give the adults an opportunity to escape predators and to move to areas that appear attractive to lay eggs.

Hormones

Hormones and other associated compounds in insects play a critical role in the success of most species. Hormones can control insect development and with today's newer chemistries, understanding insect development and timing insecticide use with the appropriate stage is critical to success. Insect structure is different in that they possess an exoskeleton. In other words their skeleton is on the outside, rather than the inside like ours. In order to grow larger, insects must shed their skin, similar to a snake. Insect may go through several stages of development in which they shed their skin. Some insects go through only a few stages where they shed their skin, but others may go through a number of such stages. The stages of immatures between shedding of the skin (molts) are often referred to as an instar. White grubs typically have three instars while mole crickets may have 10 or more. A hormone called ecdysone is responsible for the shedding of skin and the advance to the next stage. The production of this hormone causes the insect to shed its old skin and develop a new one. Some newer insecticides selectively attack the production of such hormones either by suppressing it or accelerating it.

Nervous Systems

Of all the systems of insects the one that compares in similarity to mammals and humans is that of the nervous system. Despite great differences between insects, and us the mechanism by which the nervous system works is quite similar. The nervous system is made up of axons, which transfer information of signals. Between the axons is a gap called a synapsis. This could be considered similar to a spark plug gap. Rather than a spark jump across the gap, a signal must cross it. This is done by a compound called acetylcholine. The presence of this compound causes a message to be relayed to the next axon by its dendrites. This happens very quickly. Almost as quickly is the disruption of the message. A new compound is introduced called acetylcholinesterase. This compound basically stops the action of the acetylcholine. This is a good thing! Without the action of acetylcholinesterase, the effect of the acetylcholine would continue.

Insect Development and Metamorphosis

Insect development is different from humans. Most insects start as eggs and go through a series of growth stages to become adults. The changes and growth an insect goes through as it develops from an egg to an adult is called metamorphosis. There are four primary categories of metamorphosis or development, but for turfgrass managers only two are of major importance. The two types are gradual metamorphosis and complete metamorphosis. They are unique and have special adaptations.

Gradual Metamorphosis

Gradual metamorphosis begins in the egg stages and goes through a series of immatures or "nymphs". The nymphs look very similar to the adults only they are smaller and do not have wings. The number of nymphal stages or "instars" can vary from just a few to 12 to 15.

Complete Metamorphosis

Complete metamorphosis is characterized by immature stages called larvae that usually are much different than the adult stage. The immature stage must go through a resting period in order for the transformation to the adult stage to occur. The typical stages are the egg, larva, pupa, and adult. The larvae stage goes through a number of stages or instars similar to the nymphs in gradual metamorphosis. They also vary in number, but are still referred to as instars. This instar designation is important particularly in white grub management. As a general rule, the larval or immature stage, is the damaging stage on turfgrass.

Number of Generations

Insects vary in the number of generations per year. Some species, such as cutworms or chinch bugs may have several generations each year, while others such as many of the white grubs and mole crickets have just a single generation per year. Understanding the number of generations per year is very important for effective management.

One-Generation Per Year

An insect that has one generation per year will have a specific time that it is most damaging to the turfgrass. It may also have a very specific time when it is most susceptible to the application of an insecticide. If a turfgrass manager misses that window of opportunity, that time in the insect's life cycle doesn't come around again that year. It's an opportunity missed for excellent control and will usually result in serious turf injury as well as multiple applications of insecticides at higher rates to bring the pest under control. The other component for an insect that has one generation per year is the understanding that if you do the job right the first time, then any problems with that pest are over for that particular year. If you effectively treat the early instar stages of most grub species, then you will not see resurgence or a second generation of grubs that season.

Two or More Generations Per Year

Insects that have two or more generations per year often still have specific targets or window of opportunity to implement control strategies, but in some instances generations may overlap so this becomes less critical. However, in the case of insects like cutworms, it is important to know that multiple generations can occur and that controlling the smaller worms is advisable. The key element to remember for multiple generation pests is that once you've treated, no matter how effectively, the problem can resurface again at a later time.

Synthetic Insecticides Used On Turf

Organophosphates (OPs)

The majority of products registered for turf and landscape industry fall under this category. The most commonly known products in this class are diazinon, trichlorfon (Dylox and Proxol), chlorpyrifos (Dursban), and acephate (Orthene). While most of these products have relatively high mammalian toxicity and are considered the most toxic turfgrass pesticide to humans and other vertebrates there are some within this class that are less toxic like malathion. OPs are nerve poisons,

which kill through ingestion and contact. The mode of action is to interfere with cholinesterase (an enzyme which helps regulate the transmission of nerve impulses in the body). Once the cholinesterase is bound up in the insect's body it causes nerves in the insect's body to become stimulated. This type of stimulation causes tremors, convulsions, paralysis, and ultimately death to the insect. People working with OPs should use cautions since our nervous system reacts in the same manner when exposed to OPs.

Carbamates

Carbamates are similar to the OPs, but there is a slight difference. With carbamates the cholinesterase inhibition is shorter and is also reversible. Carbamates are fast acting and have a short residual control. Some familiar products used are carbaryl (Sevin) and bendiocarb (Turcam, Ficam). Carbaryl is widely used because of its wide range of insect control and low mammalian toxicity. Some carbamates are highly toxic to earthworms, honeybees, and beneficial parasitic wasp.

Pyrethroids have become very popular in the turf and landscape industry. These synthetic compounds imitate the natural botanical pyrethrum. Unlike natural pyrethrum these synthetic compounds have a quick kill and are unlikely to recover. Some products currently on the market are bifenthrin (Talstar), lambda-cyhalothrin (Scimitar), and cyfluthrin (Tempo). Synthetic pyrethroids are cheaper to use than are naturally occurring pyrethrum. Using pyrethroids for insect management will cost you about the same as using carbamates and organophosphates. Another advantage to using pyrethroids is they can be applied at low rates. Typical rates range from 0.05 to 0.2 lb of active ingredient per acre. Pyrethroids are not prone to leaching and have low mammalian toxicity. They are not translocated within plants.

Phenyl Pyrazoles

Phenyl pyrazoles have a unique mode of action, which is they block the passage of chloride ions through the gamma-aminobutyric acid regulated chloride channel, which disrupts the insect's nervous system. An example of this compound currently on the market is fipronil (Chipco Choice). Fipronil works through contact and ingestion and has long residual control when applied to the soil.

Chloronicotinyls

These compounds are synthetic insecticides, which are similar to natural botanical product nicotine. One product currently available is imidacloprid (Merit) which can be applied at low rates and has a broad spectrum of control. Imidacloprid is very effective against white grubs, billbugs, and blue grass weevil. It kills by contact and ingestion. Imidacloprid is a systemic insecticide, which means it is translocated throughout the plant. This is very important when you are treating for sucking insects on ornamentals. The primary mode of action is to disrupt the nervous system, which will ultimately kill the insect. One important fact about using imidacloprid is that it can be used against insect's that may have become resistant to other nervous system disrupters.

Botanicals

Azadirachtin (Neem) is an extract from the neem tree which can be found in India and Burma. Azadirachtin enters through ingestion or contact. Once inside the insect, azadirachtin interferes with the activity of ecdysone (key molting hormone) which will not allow the insect to molt; therefore, the insect will die a few days after being exposed. Azadirachtin has low toxicity when it comes to humans, pets, and wildlife.

Microbial Insecticides

The most widely used product in this class is *Bacillus thuringiensis* (Bt). Bt is a soil bacterium commonly found in nature. Here is how Bt works. The bacteria contain insecticidal proteins, called delta-endotoxins, which form crystals within the sporulating cells. Once ingested, the crystals dissolve and toxins bind to specific receptor sites in the gut lining, which cause paralysis of the gut. Once this occurs, the insect will stop feeding and the gut will deteriorate, which causes death.

This process can take several days depending on the insect's growth stage. There are some caterpillars that are resistant to Bt because their gut pH is too high, which prevents the crystals from dissolving. There are different strains of Bt in nature, but they are specific in what they can control. A milky disease bacterium is another microbial insecticide used to combat insects. This dust formulation contains *Bacillus popilliae* Dutky, the causal agent of milky disease. This product has been on the market for years for control of Japanese beetle grubs. Entomopathogenic nematodes are also used to control soil insects. These microscopic roundworms attack and kill insect larvae and reproduce within the dead host. These nematodes pose no harm to humans, plants, pets, and wildlife and will not contaminate water supplies.

III. TURF INSECT MANAGEMENT:

From Basic Concepts to Best Management Practice

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WHAT IS THE GOAL OF TURF INSECT AND MITE MANAGEMENT?

Home lawns, sports turf, golf courses and sod farms all have different goals for the usage of turf. Therefore, each of these areas would have slightly different needs of pest management. Generally, the goal of insect and mite management is the one of IPM, that is, keep damage to an acceptable aesthetic level while using monitoring and appropriate control tactics.

MONITORING TURF INSECT AND MITE PESTS

Proper detection and identification of insects and mites in turf is the key to using proper controls. Remember that the mere presence of a bug in turf is not a valid reason for taking steps for control. Therefore, you will need a thorough knowledge of the techniques and methods of detecting insect and mite populations and determining whether enough numbers are present to warrant using one of the control tactics. The following techniques are presented as examples of ways in which you may be able to access insect and mite pests. You will have to learn through experience which techniques work best for your particular situations.

Visual Inspection

The old-fashioned technique of looking closely at the turf is probably still the most valuable. Use spot inspection of damaged areas or spots which just don't look right. Proper inspections requires getting down on your hands and knees rather than "curb side" or "truck cab" diagnosis. spread the turf and look at the base of the stems for insects or discoloration. Grab hold of the turf and pull up. If the turf breaks off easily, look for the sawdust of billbugs. If the turf lifts up, cut through and look through the soil for white grubs. If a pest is detected, you will need to know the extent of the problem. The transect method is merely walking in a line across the affected turf counting the number of damage areas observed. Square foot samples are often useful if billbugs or white grubs are suspected. Simply cut back a square foot flap of turf and count the number of grubs visible in the soil. One to five grubs per square foot will not usually result in visible damage to turf, but 10-15 grubs per square foot will definitely need attention.

Disclosing Solutions

Many of the turf insects and mites seem to defy easy detection by simply looking. In other areas, cutting square foot samples will do more damage than good. Therefore, a disclosing solution of pyrethrum or soap will do. A tablespoon or two of household dishwashing detergent in a gallon of water sprinkled over several square feet of turf will cause any cutworms or sod webworms to come to the surface. Occasionally, billbug adults and other insects are also flushed out.

Flotation

Scientists studying chinch bugs often use the technique of flotation. Flotation is merely inserting a large metal cylinder, a one gallon can with the top and bottom cut off is satisfactory, into the turf to the soil level filling it up with water. Chinch bugs and other turf inhabiting insects and mites float to the surface for each counting. Taking flotation counts on home lawns probably would take more time than necessary to determine if an infestation is present.

Trapping

Some of the turf infesting insects are attracted to lights or chemical attractants (pheromones) and can be easily monitored. Most of the cutworms, sod webworms and many of the night flying white grub adults can be collected in a light trap. Pheromone traps have been developed for the Japanese beetle adult and some of the fall armyworms, cutworms and sod webworms. Other insects such as billbugs can be monitored by using simple pitfall traps placed along the side of turf areas.

- A. **Light traps** generally use an ultraviolet (UV) bulb which is more attractive to most night flying insects. By running a trap several nights a week and counting the numbers of cutworms, sod webworms or white grub adults, estimations of when turf damage could occur can be made. As an example, masked chafers can be trapped from mid-June to mid-July. If a chart is constructed which has the numbers collected versus the day of the month, the peak emergence can be determined. We know that masked chafer eggs take about three weeks to hatch and another week or so for the grubs to arrive at the soil-thatch level. Therefore, a grub insecticide would be ideally applied about four weeks after the peak masked chafer captures. Golf course superintendents can do the same with black cutworms. The adults are easily captured in a light trap and larvae can be expected on greens and tees about two weeks after peak adult catches.
- B. **Pheromone traps** are even more precise than light traps because single species can be monitored. Pheromones exist for black cutworms, the cranberry girdler (a sod webworm) and the larger sod webworm as well as a number of cutworms and armyworms.. The pheromones used in the Japanese beetle trap are generally useful in monitoring low populations of beetles. Most places infested with Japanese beetles have such large populations of this pest that the traps may cause more problems than they solve. Recently, a pheromone has become available for the Oriental beetle. This trapping has more value because the adult Oriental beetles, unlike the Japanese beetles, are much less noticeable and can be laying eggs in turfgrass and their presence not noticed. They appear to be present a up to three weeks earlier than Japanese beetles so knowledge of their presence is important for insecticide timing. Many researchers have looked at the used of various pheromones for monitoring and predicting the cutworms and armyworms and found little correlation with trap catches and subsequent pest outbreaks.
- C. **Pitfall traps** can be used for monitoring billbugs in a 16-oz. cup buried in or next to turf with its rim level with the soil. Billbug adults fall into the trap and can be counted to monitor when activity begins in the spring. After two weeks of steady captures, it is time to make adult control applications.

Environmental Monitoring

Turfgrass scientists are always attempting to find better ways of predicting pest activity. Since most pest activity is regulated by weather conditions, several methods have been developed which use weather monitoring to predict pest development. These methods (or models) suggest when activity will occur but not how much activity. In other words, you will still have to look to see if pests are actually in sufficient numbers to cause damage to the turf.

Degree-Day Models

Degree-days are a method of measuring the amount of development than an organism has been exposed to by weather conditions. Its basis rests on the ideal that insects and mites develop more rapidly as they get warmer. It also assumes that below a certain temperature, called the threshold temperature, no development takes place. A full discussion of how to calculate degree-days and what they mean is beyond the scope of this manual. However, you should know that degree-day models can very accurately predict when pest insects and mites of turf will reach certain stages of their life cycles. Knowledge of this can greatly improve your proper timing of

monitoring or controls. Degrees day model have been used for research purposes for black turfgrass atenius, sod webworms, various adults of white grubs, billbugs, and black cutworms but have not been used on any large scale in practical application on golf courses. Many of these have never been validated in the field for their application across a wide area. Below is a brief synopsis on degree days and the application to turfgrass insect management.

What are degree days? Degree days are basically measurements of how hot or cold it has been. This information is useful because insects are cold-blooded and their development is more rapid under warmer conditions.

What purpose can degree days serve? Since insect development is driven by temperature, you can gain a better understanding and possibly even insight into when a pest problem may occur. Most of us know that certain pests show up later in a cool spring and earlier in a warm spring. Degree days help us add a little more precision to this understanding.

Exactly what is a degree day? A degree day is a measurement of warmth as it relates to growth or development. There is a basic lower developmental threshold or base temperature below which no development occurs. The typical base threshold for most insects is 50° F or 10° C. At temperatures below this level, little or no development or growth typically occurs. To figure the growing degree days you can simply take the days maximum temperature and the minimum temperature, add them together and divide by two to get the average temperature for the day. Then subtract the base temperature of 50 to obtain the degree days accumulated for that day. Example: The maximum temperature for the day was 72° F and the minimum was 48. The sum of these two numbers is 120. We then find the average by dividing by two and obtain the figure of 60. We then subtract the base threshold of 50 and determine that 10 degree days were accumulated on that particular day. While this approach is generally accurate enough for our purposes some error does occur. For example it might be cool most of the day, but the sun comes out for an hour and warms things up about 10 degrees fro just that hour. The average temperature you would obtain for the day would be a little misleading A more accurate method is the sine curve method which makes periodic recordings of the temperature (usually every fifteen minutes or every hour) and figures the actual amount of warmth for the day. This is the approach often programed into various computerized weather stations. The table below lists some degree day accumulations that have been determined for several turfgrass insect pests. In the South, these are generally measured from January 1 of that year. We also know the number of degree days it might take for some insects to go from one generation to the next. This might, for example, be useful with some caterpillar pests, if you could determine when the next generation would occur. Unfortunately, in the case of cutworms for example, the generations often get so mixed and we treat the greens quickly once we see an infestation, its difficult to get a good handle on the stage of any one generation in order to predict the next.

Approximate degree day accumulations (base 50 F)

	1 st adults	900
Southern Masked Chafer	90% adult flight	1375-1575
Japanese Beetles	1 st adults	1050-1175

Black Cutworms

Egg to complete larval development

730

While only a limited number of actual models are available, each superintendent can develop his/her own set of forecast using degree days. By recording degree days from January 1, either manually or automatically, one can relate this information to the occurrence of various pests. A good scouting program is important as well as good record keeping of the first occurrence of each pest. After a period of years one can look for trends in the occurrence of certain pests in association with a range of accumulated degree days. It is important to note that most forecasts do include a range as other factors will influence insect development. **B. Plant Phenology Models** - Plant phenology models are essentially nature's degree-day models. Since plant development is also dependent on temperature, associating plant activity with insect activity can improve timing of controls. An example is: spring egg laying by the black turfgrass atenioides is at the same time as horse chestnut is in full bloom.

Economic (Aesthetic) Thresholds

Development of economic thresholds in field crops attempts to relate pest populations with the amount of damage caused. This relationship can then be used to decide if the cost of applying a control will actually result in more money being made from the crop. Obviously, turfgrass is mainly used for its ornamental value and is not harvested like a field crop. This ornamental value varies according to the turf use and in some cases can not even be determined. Therefore, the traditional use of "economic" threshold should probably be changed to aesthetic threshold. Again, this is a value judgement because each person would value turf in a different way. Some people would not mind a few dandelions or brown spots in their lawn while others demand flawless turf. Turf specialists have attempted to study the relationship of turf insects to damage observed and, unfortunately, don't seem to be able to come to any set rules. In the past, controls were recommended for annual grubs when populations reached 6-10 per square foot. We now know that skunks or raccoons may consider this number good enough reason to rip up the turf. On the other hand, with good irrigation and fertilizer over 20 grubs per square foot may not be noticeable. In summary, insect thresholds may be recommended in some of the turfgrass manuals and pamphlets. Be aware that these thresholds are only targets and there are many other factors which will influence the quality of the turf. On the other hand, remember that in order to follow good pest management practices, the mere presence of a pest is no justification to apply a control product. You must determine whether there are enough of the pests to actually cause unacceptable damage to the turf.

INSECT AND MITE CONTROL IN TURFGRASS

As with all types of pests, we now prefer to use the term - pest management. This suggests that some potential pests will always be present but hopefully below damaging levels. Pest management usually is broken down into the three major tactics: biological control, cultural (and mechanical) control, and chemical control. These tactics are discussed more fully in other sections along with the unifying technique of integrated pest management (IPM). In this section, we will discuss these control tactics as they relate to insects and mites in turf.

USING THE BIOLOGICAL CONTROL TACTIC IN TURFGRASS

The turfgrass environment is actually quite complex and usually contains a large number of beneficial insects, mites and spiders. If these organisms are not destroyed by insecticides or other harsh chemicals, they can often control the insects and mites which damage the turf. In some cases, these beneficial insects look like the pests and inexperienced managers may actually apply a pesticide. Therefore, it is important that you learn to identify the "good" bugs from the "bad" bugs. There are also a few diseases (pathogens) of turf insects which are useful. Remember that these biological controls often take longer to do the job and may provide a reduced level of control. This should be perfectly acceptable because of the reduction in the use of pesticides and lack of harm to non target insects.

A. Common Predators and Parasites

These insects actively seek out their prey and attack them. Predators such as bigeyed bugs, earwigs, lacewings, ground beetles, lady beetles and rove beetles are constantly feeding on insect and mite eggs, caterpillars, chinch bugs and greenbugs. There are several wasps which dig after white grubs in order to paralyze them, lay an egg and have feed for their larva. Unfortunately, most of these predators are very susceptible to most of the commonly used insecticides. Therefore, use caution when applying turf insecticides as "preventive" treatments. These treatments probably will kill most of the predators and may cause outbreaks of other pests.

1. **Bigeyed Bugs** These small bugs look much like chinch bugs but have their head wider than the width of their body. They are active runners which seek open areas of the turf in order to chase down their prey, often chinch bugs. Be careful not to think that these are causing the open areas of the turf. The open areas may actually be caused by billbugs, drought dormancy or disease.
2. **Earwigs** Earwigs are occasionally found in the turf and most feed on plant material as well as other insects. Earwig nymphs and adults may attack sod webworms and cutworms as well as a variety of other soft bodied insects. Earwigs are often a nuisance problem when they decide to invade homes in search of a cool, moist place to hide.
3. **Green Lacewings** These lacy green insects with their lizard-like larvae are more common on trees and shrubs where they attack mites and aphids. They occasionally will inhabit turf which is being attacked by greenbugs. Releasing lacewing eggs into turf will probably not be of much use as the larvae have a hard time attacking chinch bugs, billbugs, or white grubs.
4. **Ground Beetles and Rove Beetles** These voracious predators feed on any egg or insect which they can subdue. Both the adults and larvae are predators and are probably the most common natural control for turf attacking caterpillars. There is some evidence that some species may also be able to reduce grub eggs and larvae.
5. **Lady Beetles** Lady beetles, like green lacewings, are more common on trees and shrubs. They occasionally are found feeding on aphids in turf. Releasing lady beetles in turf is not recommended because they do not prefer turf pests as food.
6. **White Grub Wasps** These large, often hairy; and brightly colored wasps are commonly called "digger wasps" because of their habits of digging into the turf. The adults are simply looking for white grubs on which they plan to lay an egg. There are several native

species which attack the masked chafers and May/June beetles. A black species has been imported for control of the Japanese beetle but it is more common in the Carolinas. Though these wasps have the ability to sting, they rarely do so unless captured or disturbed.

B. Common Pathogens

Most turf insect pests have natural diseases which periodically control their populations. A few of these pathogens have been developed and are available for use against turf pests.

Unfortunately, most of the pathogens require some special handling or application technique in order to be fully effective. Be sure to read the instructions for their use carefully.

1. **Milky Disease of White Grubs** There are several bacterial diseases which attack white grubs, causing their blood fluids to turn a milky color. The most famous of these is the Japanese milky disease, *Bacillus popilliae*, which is commercially available. Milky disease strains are known for most of the other white grubs but they are not currently marketed. At present, Japanese beetle milky disease is applied to the turf as tablespoons of powder or as a granule. The bacterial spores work their way into the turf and when a Japanese beetle grub ingests it, they become infected. The grubs turn milky over several weeks or months before enough bacterial spores are in the soil to adequately protect against grub damage. The good part of this control technique is that the spores seem to last indefinitely, once established. If this material is used, remember that only Japanese beetles are affected and other grubs such as the masked chafer may attack the turf once the Japanese beetles are under control.
2. **Insect Parasitic Nematodes** Tiny microscopic nematodes which attack white grubs have been known since the 1930's. However, no one could figure an easy way to raise these parasites or apply them until recently. The nematodes are now being produced in large quantities and several strains have been identified which will kill sod webworms and cutworms, billbugs, and the white grubs. These nematodes search out insects and enter their bodies through natural openings or by drilling through the cuticle. Once inside the body, the nematodes release a bacterium which kills the pest within hours. The nematodes then complete their development and produce new infective juvenile nematodes. Remember that these biological control agents are only infective to insects and will not harm the turf or other larger animals, including humans. As with all biological controls, some care must be exercised to get the best results with parasitic nematodes. The active juveniles are very susceptible to drying and sunlight. Therefore, they should be applied to the turf with considerable water, preferably in the morning or evening and should be irrigated immediately. You also must be sure to obtain the correct strains which are most active against the turf caterpillars, billbugs or white grubs.
3. ***Bacillus thuringiensis*** Bacterium *Bacillus thuringiensis* or B.t. is a common bacterium which has activity against many caterpillars. Certain strains have recently been developed which also have activity against mosquito larvae and leaf beetles. Though there are several products registered for sod webworm control, little efficacy data is available to indicate its usefulness. The soil dwelling cutworms in turf are apparently not affected by the Bt's. If you decide to use B.t. against sod webworms, apply the product when the larvae are under 3/8- inch long. Larger larvae do not seem to be affected. More recent

Bt's have been shown to have activity against scarab larvae (white grubs). Products containing these B.t. strains are under development.

4. **Beauveria Fungus**This fungus disease has many strains which attack a variety of insects. *Beauveria* infections have been recovered from chinch bugs, turf caterpillars and billbugs. Unfortunately, no commercial strains are currently available though some may be on the market in the near future. As with most fungal diseases of insects, considerable moisture and shade are needed for best development.

USING THE CULTURAL CONTROL TACTICS IN TURFGRASS

The cultural control tactic involves modifying the environment so that it is less suitable for pests, using mechanical destruction of pests or using resistant grasses. Most of these concepts are easily forgotten since making an application of a pesticide or releasing a biological control "feels" like something more useful.

- A. **Good Turf Maintenance and the Influence of Thatch**Turf with good horticultural maintenance can withstand much greater pest pressure than weak turf. Turf develops better root structure with proper fertilization, water and mowing. This will help resist the ravages of chinch bugs, billbugs and white grubs. Probably the major factor which helps insect pests and hinders controls is the accumulation of thatch. Thatch provides a good overwintering site for many pests. It helps make a more uniform humidity zone for sod webworms, cutworms and chinch bugs. It is partially used as food by billbug larvae and white grubs. It hinders the movement of pesticides or biological controls applied to control white grubs. Therefore, using those maintenance techniques which reduce thatch or keep it from developing will reduce pest damage, pest survival, and increase pesticide efficacy.
- B. **Turfgrass Resistance**Certain species and cultivars of turfgrasses appear to have natural resistance or tolerance to insect and mite pests. Other turfgrasses seem to be especially attractive to pests or may react badly when pests attack. Though you may not be able to use turf resistance in existing turf areas, knowing that you have a sensitive variety can help you make future control decisions. On the other hand, there is no excuse for not utilizing the most resistant types when establishing new turf or during renovation. Some of the more interesting developments in this area has been the discovery that some of the perennial ryegrasses and tall fescues contain a fungal symbiont. This fungus, called an endophyte, does not seem to harm the turf but gets some of its nutrition from the turf. In return, the endophyte produces toxins which may kill chinch bugs, billbugs and turf caterpillars. When establishing, renovating or overseeding turf, consider using more resistant or tolerant grasses. Most states have lists of turfgrass performances and ability to resist insects and diseases. Most of the current research on insect resistance is from the University of Georgia and Texas A & M University. The July 2001 Golf Course Management has an article on bermudagrass hybrids and mole cricket resistance. In the trials in Georgia TifSport had the least mole cricket injury followed by TifEagle, then Tifdwarf, and last was Tifgreen. This summary does not mean there arent others that rank higher or lower, it is simply a comparison of bermudagrasses many of us are familiar with. The study in georgia has closely examined more than 100 bermudagrass selections for resistance many which have shown some level of resistance. The single biggest

challenge is to determine the true value of the resistance when the insect cant make a choice among small plots.

"Cavalier" zoysiagrass has shown promise for resistance to a number of insect pests including mole crickets

Cultivar	Mole Cricket Resistance (lower no. is better)
Tifgreen	6.3
TifSport	2.3
Tifdwarf	6.0
TifEagle	4.0
70 Experimental hybrids	2.0