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isms called microbes feed on the insecticide, reducing the amount of active ingredient available to kill the target pest. A classic example of this is when Oftanol failures in the 1980s were linked to accelerated microbial degradation.

▶ **Volatilization** — This involves the loss of insecticide from the grass or soil surface through evaporation. This could reduce application effectiveness, as well as increase the potential of human exposure. High air temperatures and windy conditions increase insecticides' volatility, so make sure to apply on cool, cloudy and calm days.

▶ **Insect resistance** — Much is said about resistance, but, in actuality, there have been few documented cases in turf and landscape settings. Resistance is the greatest concern in situations where applications of the same insecticide are repeated over an extended time period. For example, two-spotted spider mites can have many generations each year in a typical landscape. If several generations are sprayed with the same miticide, the possibility of resistance can increase. Certain chlorinated hydrocarbons, carbamates, organophosphates and synthetic pyrethroids seem especially vulnerable to insect resistance.

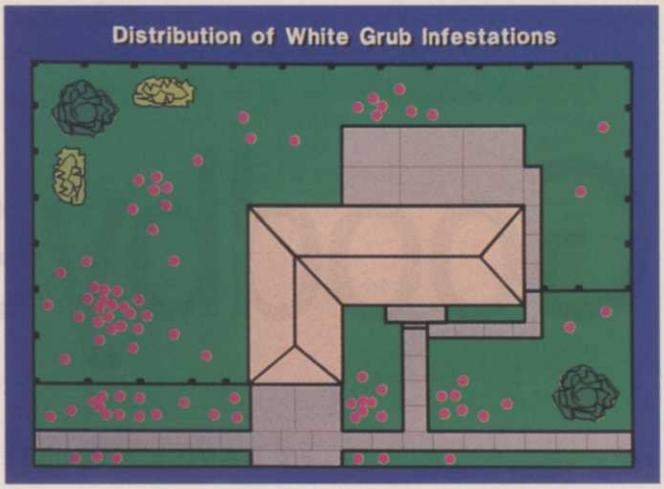
Several practices can reduce the likelihood of developing insecticide resistance. These include:

1. *Spot treating rather than using total cover sprays of the entire lawn or landscape*
2. *Using shorter residual insecticides*
3. *Alternating between classes of insecticides*
4. *Planting turfgrasses and landscape plants with genetic resistance to insect pests*
5. *Selecting non-chemical methods of insect control*

▶ **Application errors** — The most common errors involve equipment misuse. Clogged nozzles, gaps in coverage and so on are likely to be the culprit. Make sure to calibrate your sprayers and spreaders before each application. It's amazing how often nozzles don't deliver the proper amount of formulated material. Remember to use spray marker indicators to reduce coverage errors.

▶ **Selecting the wrong insecticide** — Many insecticides work better for certain insects and not at all on others. Check with your local cooperative extension office for the latest control recommendations for specific turf and landscape pests in your state. Resist selecting a certain pesticide that your supplier offers at a reduced price. It may work well for insect A, but not for insect B.

▶ **Improper timing** — Each pest has a "stage of vulnerability" when it's most susceptible to an insecticide application. Once certain insects grow out of that vulnerable stage, they can be impossible to control. For example, if a contact insecticide is applied to the egg or early larval stages of the bluegrass billbug, satisfactory control is unlikely. However, if the same insecticide is properly applied at the adult stage, is much more likely to produce acceptable results.



Turf managers often map properties to better predict where insect problems are most likely to occur and areas that should be watched.

▶ **Inadequate irrigation (related to a "failure to penetrate the thatch" factor)** — This problem is most serious in the case of insecticides applied for control of soil dwelling insects such as white grubs. Liquid formulations can dry on leaf blades, and the active ingredient in both liquid and granular formulations tends to be tied up by thatch before it can move down into the insect's feeding zone. Reduce this factor by selecting granular formulations for soil insects, informing the customer about the importance of adequate pre- and post-treatment irrigation, and consider core aeration to assist with the chemical's downward movement.

▶ **Using the wrong rate or formulation** — Thoroughly read and follow label directions. Be sure to use the correct rate for the target pest. Use liquid formulations for blade and leaf feeding insects where a surface residual is necessary for effective control.

▶ **High water pH** — This is perhaps the most overlooked reason for insecticide failures. The pesticide label shows the desired pH range of the water in the spray tank. In many parts of the country, the water pH is highly alkaline, sometimes in the range of 9 to 10. An insecticide that performs well at a pH of 5.5 can have its residual activity reduced from several days to several hours in alkaline water. Test your water if you suspect this is a problem.

Regardless of the insecticide used or the pest controlled, a successful application is directly related to accurately identifying the target pest, understanding the insect's life cycle and habits, determining the best time to apply the insecticide, using the appropriate formulation at the correct rate and ensuring the insecticide reaches the target pest's feeding zone. An accomplished turf manager will strive to do this with every application.

John Fech and Fred Baxendale are with the University of Nebraska.

Goodbye, grubs

Use the new generation of reduced-risk insecticides properly and you'll get excellent control of turf-damaging grubs

BY DANIEL A. POTTER

Root-feeding white grubs can cause headaches for lawn care managers. A decade ago, your only practical line of defense was a short residual organophosphate or carbamate insecticide for curative control. But with the advent of longer lived, reduced-risk insecticides such as imidacloprid (Bayer's Merit) and halofenozide (RohMid's Mach 2), you now have preventive control options as well. To understand the best way to use these insecticides, you need to review white grub biology.

Grubs made easy

White grubs are the immature, or larval, stage of a group of stout-bodied beetles. Most of the important species, including Japanese beetles, masked chafers, European chafers, green June beetles, Oriental beetles and Asiatic garden beetles have one-year life cycles. Adult beetles are active from June to August, mating and laying eggs 1- to 2-in. deep in moist soil of turf or pastures. Eggs hatch in two weeks, and the young grubs, each the size of a bluegrass seed, feed on roots and organic matter.

The grubs grow quickly, shed their skin twice and are nearly full size by autumn. At first frost, they hibernate, returning to the root zone to resume feeding in early spring. When nearly mature (typically in May or early June, depending on species and geographic location), the grubs form an earthen cell and transform into pupae, the transitional stage between larva and adult. The beetles emerge a few weeks later.

Grub damage is most severe in late summer when the larvae are vigorously feeding and the turf is otherwise stressed. With severe infestations, there may be 50 or more grubs per sq. ft., and they may completely consume the roots. Without roots to extract water and anchor the turf, the grass dies and the sod lifts from the soil. Skunks, raccoons, blackbirds, moles and other varmints may dig in the turf to feast on the grubs. Grub damage is less noticeable during spring.

In late summer, grubs can completely consume roots. Grass dies, and sod easily lifts from the soil.

Looking for a cure

Organophosphate (OP) insecticides such as trichlorfon (Bayer=Dylox) or diazinon (Novartis=Diazinon), or carbamates such as carbaryl (Chipco=Sevin), have traditionally been used for curative control of grubs. These insecticides have fairly short residual toxicity (usually two weeks or less), so there's a relatively narrow treatment window. If you apply them too early, the residues may degrade before the eggs hatch. Conversely, if you make late applications or "rescue" treatments, grubs will be large and harder to control, and severe turf damage may already have occurred.

The list of OPs and carbamates for curative grub control has been reduced in the past five years due to the EPA's cancellation of their registrations, but there are still some choices left. Although more often applied preventively, Mach 2 can also be used for early curative control (one to three weeks after egg hatch) as

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RISE

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long as the target grubs are still less than half their full size.

Perform curative treatments right after eggs hatch The window is late July to mid-August in the transition zone, or one to three weeks later in the northern Great Plains, Great Lakes region and Northeast. Optimum timing can vary by several weeks, however, depending on grub species and soil temperatures in a given year. Beginning in late July, sample soil with a spade or golf cup-cutter when eggs have hatched to help you judge whether treatment is needed. Concentrate on probable hot spots such as sites that were irrigated during beetle flights and areas with a history of grub problems. Healthy turf will often tolerate at least six to eight grubs per sq. ft. before it shows any visible damage.

The larger grubs get, the harder it is to control them.

Granular and sprayable formulations provide comparable control if you irrigate right after application to leach residues into the root zone. However, granules are more forgiving if you delay post-treatment irrigation. Without any irrigation or rain, you won't get grub control. Control thatch, too, since too much stops infiltration of soil insecticides.

Grub infestations sometimes go undetected until brown patches appear in September or the skunks and raccoons start to dig. By then, the grubs are full-sized, weighing 40 to 60 times as much as newly-hatched grubs, and harder to control. Mow the turf and collect clippings to increase infiltration of the insecticide. Also, irrigate beforehand to bring the grubs close to the surface. Dylox is the fastest-acting product for rescue situations. Be sure to water it into the soil. Fall treatments will be ineffective once grubs have begun to dig down.

The green June beetle (GJB) is a problem on sports fields in the transition zone and southern United States. GJB grubs feed on decomposing organic matter rather than on living roots, and they dislodge the grass by tunneling and pushing up mounds of soil. Curative treatments applied after the mounding appears may result in many GJB grubs dying on the turf surface. You are likely to find thousands of rotting grubs littering the turf on the morning after application. If GJB grubs are a concern, it's better to target them preventively with imidacloprid during the beetles' flight period, or to use an early curative treatment when larvae are small.

Curative treatments are sometimes applied in spring after overwintered grubs have returned to the root zone. There are several reasons why spring is generally not the best time for curative control:

- Post-overwintering grubs are large and hard to kill.
- Weather conditions are moderate, turf is vigorous and the grass usually outgrows whatever damage the grubs may do before pupating.
- Use of a short-residual insecticide in the spring affords no protection against reinfestation by egg-laying beetles flying in mid-summer.

An ounce of prevention

With the preventive approach to grub control, you apply the insecticide before a grub problem develops. Preventive control doesn't require sampling to pinpoint proper timing. In addition, you avoid potential damage. The downside is that you must decide to treat before you know the extent of the infestation. Because grubs tend to be localized and sporadic, you may be unnecessarily treating areas that would not otherwise have damaging infestations.

Recent registration of imidacloprid (Merit) and halofenozide (Mach 2) opened a new era of preventive grub control. Both of these insecticides are more persistent in thatch and soil than others. You can apply them weeks or even as much as two to three months before grubs hatch. Both products have low label rates, exhibit low toxicity to humans and other non-insect organisms and pose little hazard to the environment.

Imidacloprid belongs to a new class of synthetic insecticides called chloronicotinyls which have selective activity on insects' nervous systems. It's effective against young grubs, but is much more active against large grubs. Thus, you must apply it before you see symptoms of grub damage. Also, it translocates within plants, so it also controls stem-tunneling larvae of billbugs and annual bluegrass weevils. It is not, however, effective against caterpillars such as sod webworms, cutworms and armyworms.

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Halofenozide belongs to another new class of synthetic insecticides called molt accelerating compounds (the trade name, Mach 2, is an acronym for Molt Accelerating Compound - Halofenozide). It works by mimicking the action of ecdysone, a hormone that regulates insect molting. Ingestion of even a tiny amount of halofenozide forces susceptible insects to initiate a premature and ultimately lethal molt.

Like imidacloprid, halofenozide is most active against newly hatched grubs. It also works against turf-infesting caterpillars. Halofenozide will control mid-sized and large grubs, but not as quickly as organophosphates such as Dylox.

Although large grubs stop feeding soon after ingesting halofenozide, they may not die for several weeks. You may find thatwhen you curatively apply halofenozide after damage appears, it may not control large grubs quickly enough to discourage skunks and raccoons from digging.

Damage like this comes from green june beetles that push up mounds of soil by tunneling.

Both imidacloprid and halofenozide will provide residual control of white grubs in turf for two to three months, which provides you with more flexibility in timing applications.

However, if your main target is the major annual grub species such as Japanese beetles or masked chafers, it makes no biological sense to apply preventive insecticides in April or May (several months before egg hatch.) You may experience poor control if you apply too early because the residues "run out of gas" before the young grubs appear in late July or early August. The optimum window for preventive control of annual grubs is from about four to six weeks before egg hatch until the first newly hatched grubs are present. This interval extends from early June to mid-July in the cool-season and transition zones.

Regardless of whether you use a curative or

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preventive approach, the current pesticide climate demands that you make every effort to reduce unnecessary insecticide use. This means using selective treatments rather than routine, fence-to-fence applications. Good recordkeeping is a must.

Keep a close watch on areas that had grub problems in the past since those sites are likely to be reinfested. Learn to recognize adults of the main grub species in your area. Sites with abundant beetles are more likely to have a grub problem in late summer. Preventive treatments can be selective if they're targeted at high-risk sites or where perennial infestations have occurred. LM

— Daniel A. Potter is Professor of Entomology at the University of Kentucky, where he has taught and conducted research on turfgrass insects for 22 years. His practical book, "Destructive Turfgrass Insects: Biology, Diagnosis, and Control," is available from GCSAA or PLCAA bookstores, or from Ann Arbor Press (800/858-5299).

Comparing how two preventive insecticides work

When applied before egg hatch, both halofenozide and imidacloprid provide excellent control of newly hatched grubs. Both products require water to move into the root zone, but provide more leeway than traditional insecticides in this regard. They are effective even if you delay irrigation for up to a week. Neither product is effective for curative control of large grubs. Once the damage appears, you'll get better results with a fast-acting, short-residual insecticide.

Halofenozide is more active against sod webworms, cutworms and armyworms than imidacloprid, which is not labeled for these pests. Imidacloprid, on the other hand, seems to be effective against a wider range of grub species. When you apply them before egg hatch, both products provide excellent control of masked chafers and Japanese beetle grubs. Halofenozide, however, seems to be less effective against European chafers and Asiatic garden beetles, two non-native species that occur mainly in the northeastern states, and GJB grubs.

Imidacloprid and halofenozide are already paving the way for other insecticides that pose minimal hazard to humans or the environment. For example, thiamethoxam (Novartis=Meridian), a new thianicotinyl insecticide that provides excellent preventive grub control, is expected to be registered in 2001. Although we'll probably see even greater federal restrictions on OPs and carbamates, new, reduced-risk chemistry will likely fill the void. Even with preventive products, fast-acting, curative insecticides will always have a role in spot treatments and the elimination of skunks and other predators' food supply.

— Daniel A. Potter