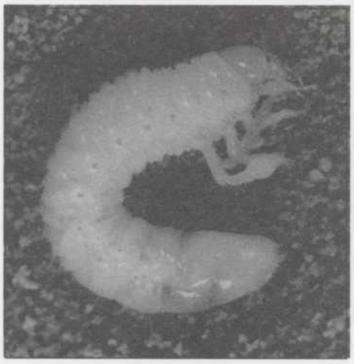
Effects of Milky Spore infection. The grub on the bottom is healthy and the one on top is infected with Milky Spore disease, a bacterial infection that turns the grub's normally clear blood to a milky color before killing them. Sold commercially, the bacteria is one of a number of potential natural controls.



Grub control
Old standbys and new directions

by Christopher Sann

IF THERE IS ONE UNIFYING THEME to the tumult in grub control strategies over the past five to six years, it is that all of the approaches—traditional chemical control, biological (animal, bacterial and fungal based) controls and management strategies—are being closely examined. At this point the main question for turf managers is: how do these approaches mesh with new biologically specific information about grubs and beetles?

New information offers hope of better control

BIOLOGICALLY SPECIFIC INFORMATION about Japanese beetles and other grub forming beetle species has begun to flow from research labs and field tests. In a society that increasingly questions the use of pesticides, turfgrass managers are eager for more accurate information, since it offers a fine-tuned control approach.

New information on the feeding and egg-laying habits of adult beetles, their longevity, and the condition of the reproductive systems of newly emerged female beetles has enhanced the timing factor in traditional chemical control strategies.

There is a considerable amount of new information on the natural occurrence of larval (grub) predators. Surprising levels of natural control have been seen at some test sites. There is new information from initial tests of these naturally occurring predators. The results are hit or miss, but suggest several possible avenues for further study

Management strategies have benefited from the biologically specific information on insect growth, degree day modeling, and information about mortality and endophyte-containing grasses.

Recent past, a confusing era

THE LAST FIVE OR SIX YEARS in the field of traditional chemical grub control have been a mixed bag for turf managers for whom grub control is a significant issue. The introduction early in the 1980's of isofenphos, which is sold under the brand name of Oftanol, offered the chance for season-long grub control for the first time since the removal of chlordane from the turf manager's arsenal of controls.

Early studies, such as tests done at Ohio State University in the mid-1980's, showed that, although isofenphos did not provide the season-long control as was originally claimed, it did provide excellent control over a shorter period of time. Those test results showed exceptional 92% control of over-wintering Japanese beetle larva from April applications; however, the control from these April applications, did not extend into the newly hatched generation in August.

As more turf managers used the isofenphos, reports of control failures began to filter in. Tests of soil from four Ohio golf courses that had previously reported control failures after applications of isofenphos confirmed significant degradation of the compound.

Samples of thatch and soil were dissolved in water and introduced into a microbe supporting nutrient solution that contained 10% isofenphos. The degradation was very high after only three days, ranging from 91% to 99%. Subsequent field tests of as many as five formulations of isophenphos—in different soil types and for three different grub species—showed variable levels of control effectiveness.

The use of the formulations was generally successful in upstate New York and throughout Pennsylvania, while applications on Long Island, New York, showed reduced effectiveness for all formulations. These field results were confirmed with laboratory tests. Isofenphos was proving to be a material that could provide excellent control, but under variable circumstances.

Meanwhile, the old stand-by grub control, diazinon, was having its share of problems. After an unfortunate poisoning of geese at a Long Island golf course, the EPA—in a compromise decision made under pressure from environmental groups—canceled the registration of diazinon for applications on golf courses and sod farms. The EPA also reduced the amount of active ingredient that could be legally applied per

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thousand square feet. A follow-up series of control efficiency test results put diazinon's percent of control—at the reduced level of active ingredient—only in the 60% range. This series of events put the use of diazinon for grub control under a cloud.

During this same period two new materials, Triumph and Dylox, became available: Triumph produces effective control levels—in the 90% range, but so far it is only available in liquid formulations that have a high LD50, causing it to be designated as a Restricted Use Pesticide. This designation has caused some problems for both applicators and potential formulation manufacturers. The applicators have stricter safe handling requirements to meet, in addition to questions about the use of the material on home lawns or in populated areas. Because of concerns about the high toxicity of the product, a major formulator shelved the introduction of a granular formulation of Triumph, although it was showing highly effective control levels.

Dylox shows excellent high knock down of even large, mature grubs, but, because it penetrates rapidly into the soil, it remains in the grub-containing zone for a relatively short time. These characteristics make the precise timing of Dylox applications very important.

Uncertainty leads to look at alternatives

WITH ALL THE UNCERTAINTY INVOLVED in the use of traditional chemical controls, there has been an increasing look at alternative, "natural" materials. These alternative materials include the well-known Milky Spore disease, as well as pathogenic protozoas, fungi, and nematodes.

A Connecticut survey studied the occurrences of natural predators on seven larval stages of various beetle species with some surprising results. Grubs were harvested from 49 locations and checked for the occurrence of natural predators. The parasitic

Common insecticides used for grub control

Trade name	Active ingredient
Oftanol	Isofenphos
Dursban	Chlorphryfos
(name varies)	Diazinon
Sevin	Carbaryl
Dylox	Trichlorfon
Proxol	Trichlorfon
RESTRICTED USE PESTICIDES	
Turfcam	Bendiocarb
Triumph	Isazophos
Mocap	Ethoprop

This table does not include application rates or prices due to the variability of the available formulated products. Follow labeled instructions when making applications.

infection levels varied widely, according to the species of the larva recovered and the type of parasitic organism involved. The infection levels were as low as 1%–2% for some species of larva and parasites, but were in the teens for others. One microsordium had an overall average infection rate of about 25%, even though it was only present at 70% of the recovery sites. Some sites had infection levels that were as high as 80–90%. The fact that the vast majority of the larva that were harvested were actually introduced to the sites showed that the levels of naturally occurring parasites was quite varied and higher than anticipated.

Promising parasites have produced inconsistent results

ADDITIONAL TESTS HAVE BEEN RUN to try to find out which of these naturally occurring predators showed the highest levels of control in the field, as well as the most

Nematode. Nematodes are parasitic worms. Several varieties are being tested for potential use as natural controls on Japanese beetle grubs.

> **Isofenphos is still a viable control material, when some precautions are taken. It still can be used for longer-term grub control, 6–8 weeks, on sites where grubs are an ongoing problem and where there has been no history of control failures.**

effective methods of application.

One test studied the relationship between two promising pathogenic nematodes and application water levels. The results showed that these two species showed maximum control levels when applied with .25 inches of water, and reached control levels of 53% and 73%—a level that is comparable to some traditional chemical controls.

Unfortunately, as further tests were conducted on promising species of parasites, the results have been variable —as illustrated by the test of a parasitic nematode as control for mole crickets. The promising nematode was tested under varying conditions of soil moisture, exposure time, application density and temperature. The researchers even looked at the age of the nematodes to see if that variable had an effect. The low infection efficiency did not change significantly under any of these laboratory conditions. The nematode had showed promise in the field, but it failed to produce confirming results in laboratory testing.

A recent study, which summarized the results of 380 applications of parasitic nematodes to 82 test sites, found that most of the test failures might be explained by the use of unsuitable strains of nematode or poor environmental conditions. More research may yet identify the right combination of biological ingredients and environmental conditions that produce a "natural control" with a broad potential for usage, but tests even of highly promising parasites have shown maximum control rates only under very narrow environmental conditions.

One strain of bacteria was shown to be highly effective at infecting Japanese beetle grubs:

- IF APPLIED IN THE FALL,
- WITH SOIL TEMPERATURES greater than 68°F (20°C),
- ON SILTY CLAY SOIL,
- WITH 1-4 DAY IRRIGATION FREQUENCY
- AND WITH LESS THAN 3/8 INCH OF THATCH.

The obvious limitations of these optimum conditions means that widespread use of this biological control is also not likely anytime soon.

Biologically specific information has helped

A CONSIDERABLE AMOUNT OF INFORMATION on the biology of a number of turf-damaging beetles has become available in the past few years. This information can be used to fine tune management practices.

A test of June beetle eating and egg-laying habits found that when the adults had a chance to feed their longevity increased by 54% (23 vs. 15 days) and they laid 89% more eggs (51 vs. 27 eggs). A test of the reproductive systems of newly emerged female Japanese beetle adults found that the systems were not fully developed and, though they developed rapidly, most of the beetles did not reach maturity until late in the adult emergence cycle.

Other turf-damaging insects have been studied to see if their life cycles lend themselves to Degree Day modeling *(see page 7 "Terms to Know")*. The life cycles of other turf-damaging insects, such as fruit flies, were found to be predictable using Degree Day modeling, and some of the sixteen different species of sod web worms were also found to be subject to degree day modeling. Although Degree Day models for the many species of turf-damaging beetles have yet to be developed, the fact that other species of turf-damaging insect life cycles lend themselves to this modeling technique gives hope that specific models will also become available.

A study in New Jersey of the feeding habits of billbugs on both high-endophyte tall fescue varieties and on endophyte-free tall fescue varieties found that there was little difference in the feeding between the varieties. There was however significantly higher mortality rates on billbugs feeding on high-endophyte varieties. The results of this test show that the effects of high-endophyte turfgrass varieties on the feeding of turf-damaging insects is after the turf damage has been done.

What affect does this information have on field practices?

NOW THAT THE EVENTS IN THE FIELD of chemical control have quieted, turfgrass managers are left with a reduced set of control options. The use of the currently available chemical control materials has been tightened and the when and where of their use has come into clearer focus.

Isofenphos is still a viable control material, when some precautions are taken. It still can be used for longer-term grub control, 6–8 weeks, on sites where grubs are an ongoing problem and where there has been no history of control failures. As a precaution, researchers who have studied isophenphos degradation are recommending that it not be applied at a site for more than 2–3 consecutive years. Alternating isophenphos with other materials may well forestall the development of high populations of degrading parasites and allow its use into the foreseeable future. So far this degradation has not been confirmed for other materials, although the possibility does exist.

The other available chemical control materials—such as diazinon, Triumph, and Dylox—continue to have their places in grub control strategies. Diazinon, though not a material for sites with heavy infestations, can be effectively used at low to moderate infection level sites. It is particularly useful at sites that need a second, late season control application for surface active insects. Triumph seems to be a material better suited to larger sites with available irrigation, although it probably would find wider use by the lawn care industry if it were available in a granular formulation. The use of Dylox should be restricted to curative applications, for it is very effective at high density infestations and the control of mature grubs.

The "natural" alternatives research is in a consolidation phase

THE INITIAL FLUSH OF EXCITEMENT about natural alternative control measures has subsided as the slow research process gets into high gear. There is more than enough survey information on the prevalence of naturally occurring predators to move the examination of these materials into the nuts and bolts phase.

Which materials can be confirmed as promising controls, under what circumstances are these materials effective, do these circumstances translate into materials that can be effective in the field, are these materials mass producible or applicable and can it all be done in a cost effective manner? These questions must be answered before these materials can be marketed as effective alternatives. The recent failure of the "Milky Spore Disease" produced by the Ringer Corporation illustrates how problematic the production of known alternative materials can be—let alone the finding, production and marketing of new materials. Industry sources estimate that the mass introduction of alternative materials at 10 to 15 years—if at all.

Managing sites and strategies has come into tighter focus

BIOLOGICALLY SPECIFIC INFORMATION helps turf managers to make more accurate decisions about whether to apply control materials preventively or whether to wait and apply materials only when needed.

Information about high-endophyte grass varieties has shown they will help reduce populations of feeding insects, but their use will not alleviate the need to monitor the amount of damage done—particularly to highly maintained sites. Information on feeding, egg-laying and longevity of adult beetles helps managers of marginally infected sites to fine tune the applications to the end of the adult emergence cycle. Monitoring adult populations and beetle species in marginally infected sites can eliminate the need for chemical applications.

The potential Degree Day modeling of turf-damaging beetles offers the greatest hope to turf managers for fine tuning control applications, be they alternative or chemical. As this management practice is explored for grubs and other turf-damaging insects, precision applications, or the promotion of alternative environments, may become the norm.

Turfgrass managers will have to bide their time

FOR NOW GRUB CONTROL means chemical control. Whether the future holds viable natural alternatives is still very much in question. Turfgrass managers must bide their time until that point and continue to refine their strategies for control of the complete spectrum of sub-surface and surface active turf-damaging insects. ■

TERMS TO KNOW

chlordane .... A banned insecticide formerly used to control soil grubs and termites in and around structures.

Degree Day modeling ... A way of calculating emergence times, using the total number of degree days, which is expressed as a range. A degree day is the difference between the average daily temperature and a base starting temperature, which is usually chosen because it represents a theshold of activity above minimal levels.

endophyte .... A bacteria that is present in plant in a symbiotic, or mutually beneficial, relationship. The waste products of this bacteria have proven to be powerful naturally occuring insecticide. In some cases, they have demonstrated some degree of disease control. They are present in some varieties of grass and not present in others.

isofenphos .... The active ingredient in the insecticide Oftanol.

LD50 .... The amount, in parts per million, of a material required to kill 50% of a representative population. LD literally stands for lethal dose. It is the numerical representation of a material's potential toxicity.

microspordium .... A small asexually produced, parasidic spore.

Milky Spore disease ...... A disease of grubs caused by a specific bacteria.

mole crickets .... A species of cricket that lives by burrowing in turf.

nematodes .... Small worms, some of which are parasitic, that are being studied as potential grub controls.

oviposition .... Egglaying.

protozoas .... Single cell animals.