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Researchers at the University of Kentucky are investigating the effectiveness of parasitic wasps to be used in a biological control strategy against white grubs .

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 215 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Biological Control of White Grubs by Parasitic Wasps

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SUMMARY

Researchers at the University of Kentucky investigated how effective two wasp species can be as a biological control of white grubs. Their findings include:

- *Tiphia pygidialis* and *Tiphia vernalis* were found to be abundant on Kentucky golf courses.
- Pan traps and dilute sugar sprays were used to monitor seasonal flight periods of both wasp species.
- Sugar sprays applied to tree foliage was ineffective for monitoring *T. pygidialis*, but sugar water sprayed directly on the turf attracted large numbers of that species.
- Parasitism rates ranged from 15-50% at the study sites.
- Each wasp species can discriminate between body odor trails and frass from host and non-host grubs to find their specific target grubs.
- Once parasitized, grubs cease feeding on turfgrass roots and move deeper into the soil.
- Wildflower gardens planted near the turf sites were ineffective in attracting *Tiphia* wasps.
- Field and lab studies suggested that applications of imiacloprid (Merit) insecticide adversely affected the wasps' ability to locate grubs.

White grubs, the root-feeding larvae of various native and introduced scarab beetles, are the most widespread and destructive insect pests of lawns and golf courses in the United States. Collectively they account for hundreds of millions of dollars in damage and control costs every year (1).

White grubs traditionally have been controlled with soil insecticides. However, pesticide usage in suburban areas is increasingly restricted due to perceived hazards and environmental concerns such as ground water contamination. These issues, and the 1996 Food Quality Protection Act, have led to cancellation of nearly all of the organophosphate and carbamate insecticides that previously were mainstays for curative grub control. While the older chemistry has given way to more selective, preventive products such as imidacloprid (Merit) and halofenozide (Mach 2), many superintendents still seek ways to reduce their reliance on insecticides, treating only as necessary and integrating pesticides with non-chemical controls.

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Natural enemies can be important in buffering turf habitats against pest outbreaks (2), yet beneficial insects received little attention in the past decades of reliance on chemical controls. The research summarized here focused on wasps in the genus *Tiphia*, which are the predominant parasitic insects that attack white grubs in the soil. Little was known about these beneficial wasps before our studies revealed details of their life history and behavior, and some ways that their benefits on golf courses can be conserved.

We found two species of *Tiphia* to be abundant on Kentucky golf courses, taking a surprisingly heavy toll on the grub population at some sites. *Tiphia pygidialis* is a native species that attacks grubs of northern and southern masked chafers. *Tiphia vernalis*, a native of Japan, was introduced into the eastern United States during the 1920s for biological control of the Japanese beetle. We studied their life history,

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Tiphia pygidialis attacking its host chafer grub in the soil.

time of year that they are active, how wasps locate and parasitize their victims, and the extent of natural grub control that they provide. We also investigated ways that superintendents might conserve their populations on golf courses.

Tiphia Wasp Biology

Tiphia are dark-colored solitary wasps, typically less than ½ inch (12.5 mm) long, that spend most of their lives below ground. They are inconspicuous and pose no threat to humans. The females fly over turf, land, and burrow into the soil where grubs are present. Unlike the much larger cicada killer wasps, burrowing by *Tiphia* does not cause mounding or other turf damage.

Once a suitable host is located, the wasp stings the grub in its ventral nerve cord to temporarily paralyze it. Then she lays a single egg on the immobilized grub in a species-specific location. Eggs of *Tiphia vernalis* are attached to the underside of Japanese beetle grubs, whereas *Tiphia pygidialis* glues its eggs on the back of masked chafers. The paralyzed grub soon recovers from the sting, but when the *Tiphia* egg hatches in about three days, the tiny wasp larva bites through the grub's skin and begins feeding on its body fluids.

The larval *Tiphia* feeds, vampire-like, slowly draining juices from the still-living victim. It molts several times over the next 14-21 days, increasing in size. By the time the parasite reaches the 5th (final) instar, the host grub has become flaccid and deflated. The *Tiphia* larva then devours all the remaining soft body tissue of its host and spins a small, fuzzy brown football-shaped cocoon. The *Tiphia* pupates and overwinters within this cocoon, emerging as an adult wasp the following year.

Flight Period and Parasitism Rates

We monitored the seasonal flight periods of both species of *Tiphia* wasps on central Kentucky golf courses. Two sampling methods were used. Pan traps, yellow plastic bowls filled with soapy water, were placed in roughs, one day per week, to monitor the spring-active *Tiphia vernalis*. We also sprayed dilute (10%) sugar water on foliage of adjacent trees and noted activity of wasps that came to the residues to feed.

Deploying these methods for three consecutive years, we determined that, *T. vernalis* wasps are active in Kentucky from late-April through the first week of June. They seek out and parasitize third-instar Japanese beetle grubs that have resumed feeding in the rootzone after overwintering. The wasp flight is largely over by the time non-parasitized grubs are pupating, two weeks or so before adult Japanese beetles begin to emerge.

Our pan traps failed to attract the fall-active *T. pygidialis* wasps. Sugar sprays applied to tree foliage also were ineffective for monitoring the flight of that species. Instead, we found that sugar water sprayed directly on the turf readily attracted large numbers of *T. pygidialis*. The difference in the two species' response to sugar sprays is likely due to a difference in their mating behavior. *Tiphia vernalis* mate on the foliage of trees and low-growing plants surrounding turf

Masked chafer grub bearing a newly laid *Tiphia* egg.

sites, whereas *T. pygidialis* mate directly on the turf. Monitoring also determined that *T. pygidialis* wasps are active from mid-August through the end of September, parasitizing third-instar masked chafer grubs.

The extent of natural control provided by each *Tiphia* species was estimated near the end of the wasps' flight period by sampling the grub population in the rough along the edge of fairways at several golf courses. We sampled Japanese beetle grubs in early June and masked chafers in September. Ten one-square-foot sections of turf about a foot deep, were sampled at each site. Based on the number of non-parasitized grubs, parasitized grubs, and *Tiphia* cocoons found in each sample, grub parasitism rates ranged from 15-50% at our study sites. Parasitism rates tended to be highest in patches of turf where grubs were abundant, suggesting that *Tiphia* wasps focus on such areas.

How Do Wasps Locate Grubs Below Ground?

Each *Tiphia* species parasitizes only one or a few closely-related grub species. Given that several unrelated grub species (e.g., Japanese beetles and masked chafers) often occur in the same turf, how do these wasps locate the "right" grubs and avoid those that are non-hosts?

We used a soil-filled glass observation chamber to observe and videotape the wasps' underground behavior including their response to cues from host and non-host grubs. In the observation chamber, a Y-shaped trail was made in the soil. Each arm of the Y-trail was provided with cues that included grub body odor trails, grub frass (feces) or combinations thereof. A female wasp was introduced at the base of the Y and allowed to choose between the two trails containing different cues. Each comparison was repeated 30 times with different wasps, and response to cues from both host and non-host grubs were tested.

The wasps, especially *T. pygidialis*, could be attracted to patches of turf by spraying the grass with sugar water.

Half-grown wasp larva feeding on back of grub.

We determined that each species of *Tiphia* wasp can discriminate between body odor trails and frass from host and non-host grubs (3). Like a bloodhound, they follow these trails to locate their hosts in the soil. Females of *Tiphia vernalis* followed trails containing body odor and frass from Japanese beetle grubs, their normal prey, whereas *Tiphia pygidialis* followed similar cues from masked chafers. Neither wasp responded to cues from non-host grubs.

Parasitism Affects Grub Behavior

Grub damage usually is diagnosed by pulling back patches of damaged turf which exposes grubs at the soil surface. We tried to survey for parasitized grubs by this method, but surprising few were found. Excavating such patches with a shovel revealed that the parasitized grubs and *Tiphia* cocoons were deeper down than grubs normally feed. These observations suggest that parasitism causes grubs to cease feeding and move deeper in the soil.

We tested this hypothesis by placing newly parasitized or normal grubs into observation chambers resembling an "ant farm" through which we could observe their movements in the soil. Observations confirmed that parasitized grubs cease feeding and move deeper in the soil. This burrowing response is induced by venom injected by the adult wasp, and sustained feeding of the developing *Tiphia* larva. Field tests with grubs implanted into turf plots showed the same response- white grubs bearing a *Tiphia* larva moved downward over 2-3 weeks until they were 8-10 inches deep in the soil. Likewise, *Tiphia* cocoons will be found relatively deep in the soil. This phenomenon likely is why the impact of *Tiphia* wasps on grub populations was underestimated, or even overlooked, in the past.

Conserving *Tiphia* Wasp Populations

Since *Tiphia* wasps occur naturally on many golf courses, we investigated tactics that superintendents might use to encourage or conserve their populations. One approach might be to provide supplemental food such as plantings of nectar-producing perennial wildflowers to attract or sustain the wasps in particular areas, resulting in increased parasitism rates.

To test this idea, we established gardens with several dozen species of spring- or fall-blooming perennial wildflowers and monitored them to determine which flowers *Tiphia* wasps might use as a food source. While the gardens attracted many other species of parasitic wasps, as well as pollinators, almost no *Tiphia* wasps visited the wildflower gardens. Instead, we mainly found them feeding on the sugary excrement, or honeydew, left by aphids and scale insects on leaves of nearby trees. We did, however, find that the wasps, especially *T. pygidialis*, could be attracted to patches of turf by spraying the grass with sugar water. Further work is needed to determine if this approach results in any real practical benefit.

We also examined the compatibility of spring insecticide application with the natural control provided by *Tiphia* wasps. Lawn care companies and homeowners sometimes apply preventive insecticides, typically imidacloprid (Merit®) or halofenozide (Mach 2®) as early as late April or May, counting on their relatively long-lived residues to last until egg hatch of annual grub species in July or August. Golf superintendents may make such applications in May when multiple-targeting black turfgrass ataenius and annual grub species. Such treatments coincide with the period when *T. vernalis* wasps are active, parasitizing Japanese beetle grubs.

Field and lab studies were done to examine the effects of imidacloprid (Merit) on the health of *Tiphia* wasps and their ability to parasitize grubs in treated soil. Turf plots on a golf course where *T. vernalis* are abundant were treated with the label rate for grub control at the beginning of May, while others were untreated. Thirty, third-instar Japanese beetle grubs were implanted into each plot. After three weeks, the plots were excavated to compare parasitism rates. The difference was striking: less than 10% of the grubs were parasitized in the treated plots, as compared to 45% in the controls. A similar experiment in pots of turf showed an even greater reduction in parasitism. We determined that exposure to the freshly-treated soil did not kill the *Tiphia* wasps, nor did they avoid treated turf areas. Rather, the exposed wasps became intoxicated to the extent that their ability to locate and parasitize grubs was impaired.

These results show that even with modern insecticides, proper timing can be important to conserve natural enemies. Unless the superintendent is simultaneously targeting the earlier-hatching black turfgrass ataenius, the optimal window for preventive control of Japanese beetles, masked chafers, and other major grub pests on golf courses is mid-June to late July. That timing ensures that fresh residues are in the soil during egg hatch,

Dilute sugar sprays applied on tree foliage was effective in attracting *Tiphia vernalis* to the study site while conserving the spring *Tiphia* wasp populations that help to suppress Japanese beetle grubs in non-treated areas. While no one natural enemy alone is likely to bring about complete control of white grubs, conserving natural enemies, when possible, makes good agronomic sense.

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