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What's new in turfgrass insect pest management products:

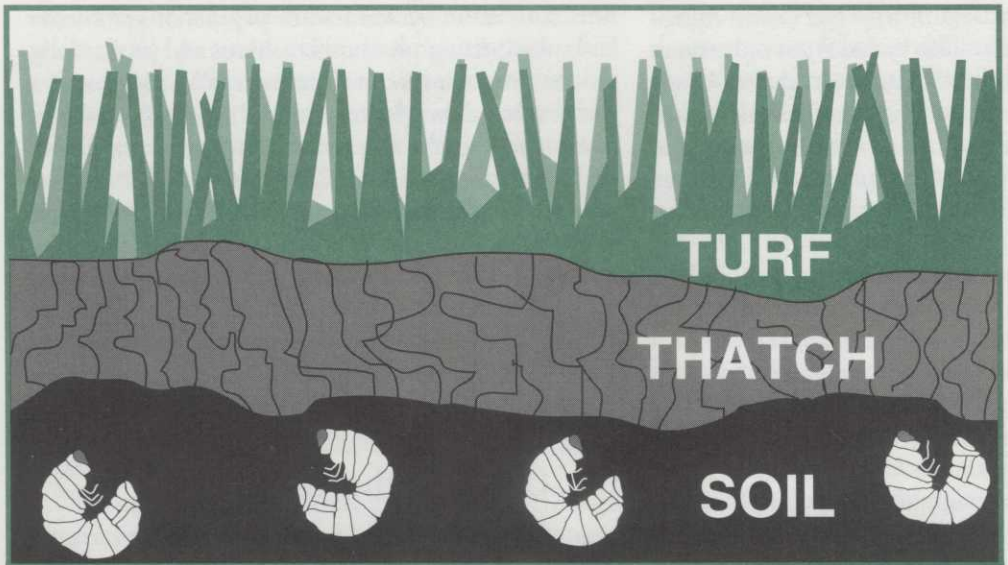
Focus on biological controls

By Michael G. Villani

In years past, the development of pest management products for turf has taken a distant back seat to products that targeted pests of field crops such as corn, soybeans and cotton. Products that were not effective against one or more insect pests on major food or fiber commodities had little chance of being tested against insects particular to turfgrass.

This is no longer true. A minor revolution has occurred over the past ten years as the crop protection industry has focused greater attention on so-called specialty markets like turfgrass. There is a growing appreciation that these specialty markets, although not as large as traditional agricultural markets, provide an important and lucrative product niche. As such, several insect control products targeted at the turfgrass market have been recently registered or are in an advanced stage of development.

The following is a brief review of some of these products, together with the results of representative laboratory and field studies conducted over the last several years by my research team at Cornell. It is important to remember that these studies were conducted under ideal conditions with regard to timing, equipment calibration, quality of control agents, and environmental conditions. Field efficacy may consequently differ.



Grubs Feeding At Thatch/Soil Interface

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Chemical pesticides

Merit

Since organochlorine insecticides such as chlordane and DDT were removed from the market there have been no traditional insecticides labeled for control of scarab grubs that are sufficiently persistent in the field to be applied to turfgrass prior to grub oviposition (usually late spring to early summer for most annual grub species), and continue to provide consistent control of grubs into late summer and fall. For this reason, the most prudent use of soil insecticide for grub control has been to sample for small grubs in late summer (early to mid-August in New York State) and then treat areas showing high grub populations.

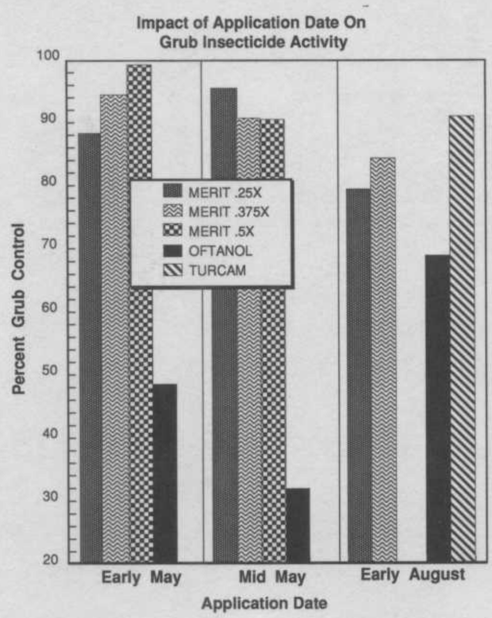


Fig 1. Impact of application date on the activity of Merit insecticide against Japanese beetle grubs on three golf course fairways. Merit insecticide, when applied in early and mid-May, showed no significant loss of residual activity for control of fall Japanese beetle populations. By contrast, May applications of Oftanol did not provide satisfactory reductions in fall grub populations. Appropriately-timed application of Merit shows grub reduction activity comparable to traditional insecticides.

Merit (common name Imidacloprid) is a new-chemistry, broad-spectrum, long residual insecticide, registered by Miles to control soil- and crown-inhabiting insects in turfgrass. This includes not only scarab grubs such as Japanese beetle, European chafer, Asiatic garden beetle, May and June beetles, Oriental beetle, northern and southern masked chafer, green June beetle and black turfgrass Ataenius but also turfgrass inhabiting weevils such as billbugs and the annual bluegrass weevil.

This newly-registered insecticide has shown sufficient residual activity in turfgrass to control the fall brood of annual scarab grubs when applied the previous spring or summer (Figure 1). High levels of grub control can be achieved when applications are made between April 1 and August 15 which is prior to annual scarab grub egg hatch. An application of Merit in spring for billbugs or annual bluegrass weevils will control fall grubs.

There has been considerable debate among turfgrass entomologists about the use of insecticides such as Merit that are designed for application before the size and damage potential of an insect population is known. That is, these products are not only applied before insect eggs are hatched but in many instances several months before the eggs are laid. There is consequently great potential for abuse of this product if turf managers apply it indiscriminately, or without regard to the likelihood of having a damaging population of insects on a treated area some time in the future.

A multi-year study of home lawns in the upstate New York region (see August 1994 TGT) indicated that approximately 80% of those surveyed did not require lawn grub insecticide applications for an acceptable turf stand. The use of pheromone and light traps to assess adult populations can provide some indication of the potential size of a future larval population, but past research has found little correlation between adult populations of beetles and subsequent grub numbers. Merit and similar long residual insecticides can fit into an IPM program if a turf site has a long history of grub damage or shows consistently high grub populations over several years.

Merit carries a CAUTION toxicity signal word on its label, and the label warns of high toxicity to aquatic invertebrates and bees exposed to direct treatment or residues on blooming crops or weeds. As always, appropriate precautions should be taken.

Biological controls

B.t. (Bacillus thuringiensis)

Bacillus thuringiensis is a soil bacterium, common in nature, that was first discovered in Japan in 1901. Since then over 30 subspecies and varieties of B.t. have been identified. This family of bacteria produces a protein crystal that is toxic to a fairly limited number of species or groups.

B.t. products have been used to control insects for many years. Various strains have been identified acting against caterpillars, fly larvae, and beetle larvae. B.t. varieties that are currently being commercialized include B.t. kurstaki and B.t. aizawai (caterpillars), B.t. israelensis (mosquitoes) and B.t. tenbrionis (potato beetles).

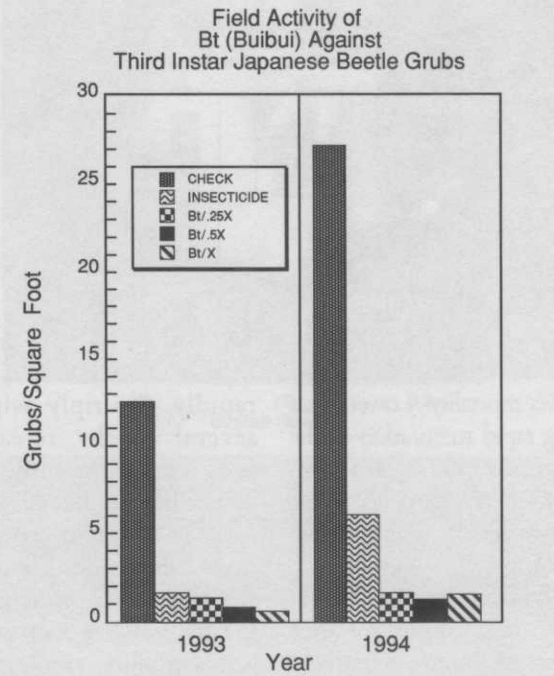


Fig 2. Field evaluation of B.t. Buibui against Japanese beetle grubs in New York State. Three rates of B.t. Buibui, provided by the Mycogen Corp. of San Diego, CA, were field tested during the fall of 1993 and again in 1994 against third instar Japanese beetle grubs on unirrigated golf course roughs containing significant levels of dense thatch. Plots were evaluated six weeks after application. B.t. treated plots had significantly fewer grubs than untreated plots. The B. t. product gave grub reductions equal to or greater than a standard insecticide commonly used against scarab grubs in New York State.

Because B. t. bacteria are environmentally friendly and can be produced in great quantities on artificial media, there is great interest in the commercialization of this bacterium for insect control. Unlike other biological control agents, these bacteria do not normally reproduce in the insect host, persist in the environment, or spread from the treatment site to other areas. As a result, B. t. has typically been used as a microbial insecticide for short-term control.

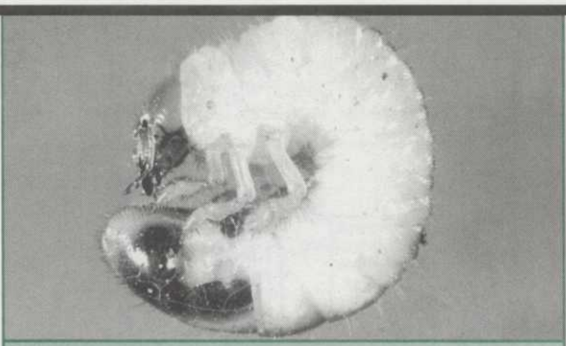
How B. t. kills insects is fairly well understood. First,because it acts as a stomach poison, its protein crystals must be eaten by the insect to be effective. In some cases, additional products produced by the living bacteria must be consumed for maximal activity. If an insect's gut content is of the proper acidity (pH) the crystals will dissolve there. Proteins released from the dissolved crystal bind to a specific site in the gut lining of susceptible insect species, causing rapid paralysis of the gut. The insect stops feeding almost immediately as the gut wall deteriorates.

In most cases a susceptible insect will die 2-7 days after ingestion of the B. t. toxin. The major reasons for the lack of activity of a B. t. strain against an insect species are, first, gut pH that does not allow the toxic protein crystal to dissolve, and second, the inability of the toxic protein to bind to the insect's gut.

Although B.t. products are registered for use against several turf-feeding caterpillars, including cutworms and sod webworms, these products have not been widely recommended or accepted in the turf industry, most probably because of their short residual, slow activity, and inability to kill larger larvae.

Until recently, there were no B.t. varieties known to cause significant mortality in scarab grubs inhabiting turf. In 1991, however, B.t. variety japanensis strain Buibui (B.t. Buibui) was discovered in Japan. Development and commercialization of B.t. Buibui has been undertaken by a biotechnology company, the Mycogen Corporation, of San Diego, CA. They expect registration of this product against certain scarab grubs in 1996. Unlike most B. t. products currently on the market, maximal activity of B.t. Buibui against scarab grubs occurs when formulations include not only the toxic protein crystals but also live spores produced by the bacteria.

In laboratory and field studies, Japanese beetle, Oriental beetle, northern and southern masked chafer and green June beetle grubs have all been shown to be highly susceptible to B.t. Buibui. June beetle, black turfgrass Ataenius beetle and Aphodius beetle grubs appear much less sensitive to this product. Two field studies of the activity of this B. t. against Japanese beetle grubs that were conducted in New York State showed its efficacy to be equal to standard grub insecticides six weeks after application (Figure 2). According to Mycogen, B.t. Buibui is nontoxic to all vertebrates, earthworms, honeybees and plants.



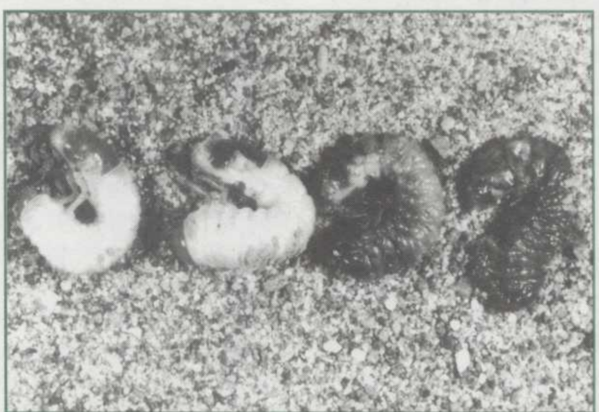
Healthy Grub

Insect growth regulators (IGRs)

Several chemical companies are developing artificial compounds that, by mimicking the action of the natural hormone ecdysone, interfere with the normal insect molting process. High doses of these compounds typically cause rapid insect mortality. Lower doses show sublethal effects, including rapid maturation to the adult stage, larvae showing deformities, and larvae undergoing additional molts instead of changing to pupa. Specific IGR products have shown activity against scarab grubs, cutworms and sod webworms.

Insect growth regulators typically require ingestion for optimum activity, so it is important that they are applied when the target insect is actively feeding. The use of an IGR on scarab grub populations late in the fall, as they prepare to move down into the soil for winter, or its application to grubs in late spring as they prepare to pupate, is liable to prove ineffective.

Laboratory and field studies indicate that early larval stages are susceptible to insect growth regulators. They also suggest that there is wide-ranging activity among closely-related insects, such as different species of scarab grubs (Figure 3). Our studies have pointed to one IGR that shows truly impressive activity against Japanese beetle grubs, but much less dramatic activity against either European chafer or Oriental beetle grubs. The target-specificity of these products demands that, to avoid disappointing results, turfgrass managers determine which insect species is present before application.



Grubs Infected With Nematodes

Entomogenous nematodes

Entomogenous nematodes have recently received attention as alternatives to insecticides for turf insect control. There are many factors that in theory make nematodes the ideal biological control agent: they have a broad host range, will not attack plants or vertebrates, are easy to mass-produce and can be applied with most standard insecticide application equipment. Additionally, nematodes will search out their target hosts and kill them rapidly, multiply within the host, and within several weeks release thousands of mobile progeny, programmed to locate and infect new insect hosts. Because they are considered predators, and not microbial insecticides, entomogenous nematodes are exempt from registration by the U.S. Environmental Protection Agency. This means they are exempt from long-term safety and water quality studies, which greatly reduces the costs and risks associated with bringing a new insecticide to the market.

Entomogenous nematodes enter the target insect through natural openings: most commonly the mouth, less commonly the skin. The nematodes then move through the gut into the blood, where they release a colony of bacteria they carry within their bodies. Once inside the insect, the bacteria multiply and begin to produce toxins that rapidly kill the infected insect.

Nematodes feed and reproduce inside dead insects, each producing several thousand new nematodes. Under ideal conditions, thousands of next-generation nematodes will emerge from a dead insect in as little as ten days and begin to search for new hosts.

There have been many successful field applications of entomogenous nematodes for control of turf insects, although problems with product quality, persistence, and host-specificity have led to unsatisfactory results in some instances. While demonstrating fairly broad host ranges in laboratory studies, different strains and species of nematodes vary in activity against different insect species in the field.

Overall, because they move down in the soil profile and search for insects (Figure 4), the nematodes Heterorhabditis bacteriophora (Hb) and Steinernema glaseri (Sg) are more effective against white grubs than the more commonly marketed Steinernema carpocapsae (Sc). Conversely, Steinernema carpocapsae is effective in control of billbugs and caterpillars such as cutworms, webworms, and armyworms.

Many unsuccessful field applications of entomogenous nematodes for scarab grub control can be traced to improper environmental conditions, either at the time of application or for several weeks after application. Nematodes are extremely sensitive to ultraviolet light, and will last only a matter of minutes when exposed to full sunlight. They are also quite prone to desiccation, requiring high relative humidity and a film of moisture on leaf and soil surfaces to survive and move.

For these reasons, they should be applied early in the morning or late in the day, and be irrigated immediately after application with at least a half inch of water. Nematodes searching for grubs move over soil particles on thin films of water. They will not search efficiently in saturated soils, however. Failure to provide appropriate soil moisture for several weeks after application limits the utility of nematodes in many situations.

One mistake often made by turfgrass managers is to save money by applying nematodes at rates lower than recommended. Extensive field studies on New York golf courses over the past five years confirm that there is a strong positive correlation between the number of nematodes applied and grub mortality.

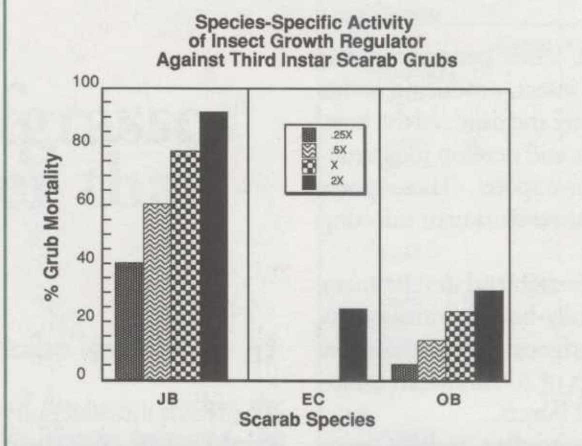


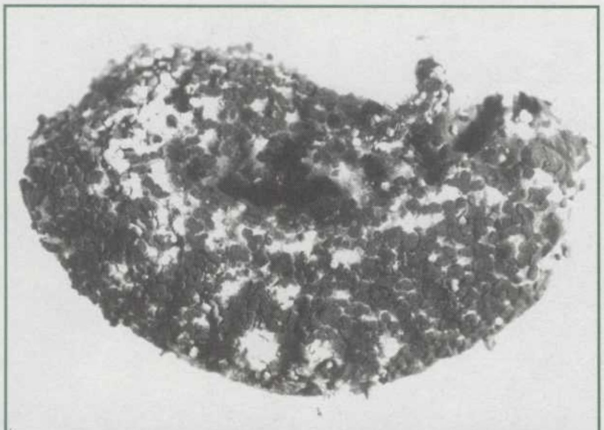
Fig 3. Laboratory evaluation of four rates of an insect growth regulator against third instar Japanese beetle (JB), European chafer (EC) and Oriental beetle (OB) grubs. There was a significant dose response of this product against each species of scarab grub and significant difference in activity of the product among the three grub species.

Although often treated as insecticides, entomogenous nematodes are living organisms, and must be handled with care to be effective. Only nematodes in the best condition will be able to search successfully for an insect host, overcome the defenses of the insect to infect and kill it, and multiply within the dead insect producing progeny to infect new hosts. To maximize the probability of applying healthy nematodes, it is critical that directions regarding storage and application rates are followed carefully.

Fungal pathogens

Virtually every group of turfgrass insect pests, including scarab grubs, chinch bugs, billbugs, annual bluegrass weevils, sod webworms, cutworms and mole crickets, is susceptible to endemic populations of fungal pathogens such as Beauveria bassiana and Metarhizium anisopliae. Commercial interest in fungal pathogens as biological control agents has ebbed and flowed over the last decade as the promising results seen in laboratory and greenhouse research have run up against the hard realities of producing an effective, consistent, price-competitive and safe commercial field product. At present, there are no commercial fungal products available for management of turf pests.

Fungi differ from most other microorganisms because they do not have to be ingested to be effective. Infection is initiated by the adhesion of a fungal spore to the body of an insect. If conditions are correct, the spore will germinate and a tube will grow from the spore into the insect, pen-



Grub Infected With a Fungal Pathogen

etrating its circulatory system. After penetration, the fungus reproduces within the insect, producing toxins that quickly kill the insect. After the death of the host, hyphae emerge from the insect and develop into structures that produce more infective spores. These spores can then be spread through the environment infecting additional insects.

Studies in our long-term research and development program to introduce biologically-based control agents for scarab grub control in turfgrass have focused on evaluating a number of isolates of Metarhizium anisopliae, a fungal pathogen of soil insects.

Fourteen Metarhizium anisopliae isolates were tested against Japanese beetle grubs. Two isolates, MADA and 1020, have generated sufficient interest for commercialization. The other 12 isolates were chosen because they were isolated from scarab grubs obtained around the world. MADA and 1020 performed well at various treatment rates, but other isolates clearly performed consistently better. There were considerable differences in how well several fungal isolates performed under a variety of environmental conditions that are commonly found in northeastern golf courses.

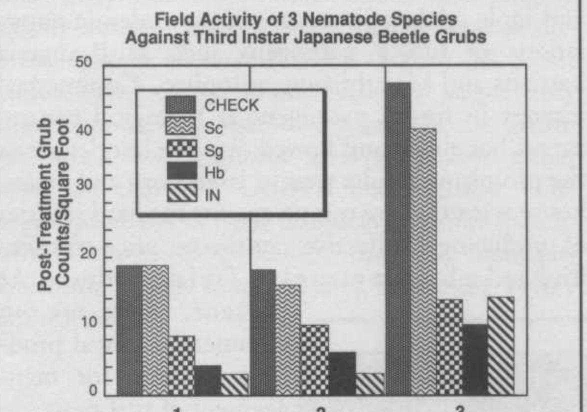


Fig 4. Field evaluation of three species of entomogenous nematodes against Japanese beetle grubs on three golf course fairways in New York State. Overall, the nematodes Heterorhabditis bacteriophora (Hb) and Steinernema glaseri (Sg) were more effective against Japanese beetle grubs six weeks after treatment than the more commonly marketed Steinernema carpocapsae, (Sc) and provided grub reduction equal to or greater than a standard insecticide commonly used against scarab grubs in New York State.

In summary

The recent introduction of new materials for turfgrass insect control, both chemically-based and biologically-based, has increased the number and variety of tools available for turfgrass pest management. At the same time, each of these new developments reinforces an old imperative: before a proper control decision can be made, turfgrass managers must correctly identify the species involved, estimate the size of the population and determine its stage of growth. "Shoot first and ask questions later" is liable to wind up wide of the mark.

Dr. Michael G. Villani is an Associate Professor of Soil Insect Ecology in the Department of Entomology at NYSAES/Cornell University. He has degrees from the State University of New York at Stony Brook and — in entomology — from North Carolina State University. Dr. Villani, who is active in both research and extension work, concentrates on the interrelationships between soil insects, their host plants, and the soil environment. His most recent contribution to *TurfGrass TRENDS* appeared in the August 1994 issue.

Terms to know:

- **Organochlorine** - belonging to the family of chlorinated hydrocarbon pesticides, such as, aldrin, DDT, deldrin, etc.
- **Oviposition** - to lay eggs
- **Scarab** - a family of stout-bodied, mostly brilliantly-colored beetles (including June beetles)
- **Molting** - periodically casting off an outer covering or shell prior to its replacement by new growth
- **Entomogenous** - preying on insects
- **Nypae** - the threadlike structures that make up the asexual reproductive aparatus of a fungus.

Nutrient uptake:

Some turfgrasses do it better than others

By Richard J. Hull and Haibo Liu

There has been a lot of discussion within the turfgrass community about reducing the material inputs required to maintain high quality turf. Environmental concerns, economic realities and shifting priorities in the allocation of scarce resources are all pressing turf managers to do their job more efficiently. It is estimated that as early as the next century, much of the fertilizer, water and pesticide currently used to grow turf will no longer be available.

Responses to the problem of limited resources

The US Golf Association and the Golf Course Superintendents Association of America have invested several million dollars in research intended to reduce by fifty percent the fertilizer, water and pesticides needed to grow turf of high quality. This effort was launched about ten years ago and has involved turfgrass researchers all across the country.

State agricultural experiment stations have been conducting research on integrated pest management (IPM) strategies to reduce pesticide use. They have also been evaluating various organic fertilizer materials in an effort to recycle wastes and minimize nutrient losses.

The National Turfgrass Evaluation Program (NTEP) has been comparing the quality of turfgrasses grown under low maintenance conditions with those grown under more conventional practices (see TGT, September/October 1992 and April 1995). This program is aimed at identifying turfgrass cultivars which are more efficient in their use of resources and will produce good turf with reduced material inputs.

Quality scores*

Cultivar	Rhode Island	All of US
Kentucky bluegrass (1986-90)		
Blacksburg	7.4	6.3
Eclipse	7.2	6.0
Bristol	6.6	5.9
Liberty	6.7	5.7
Kenblue	5.4	5.0
Joy	5.2	5.0
Perennial ryegrass (1987-90)		
Repell	6.8	6.1
Tara	6.5	5.9
Derby	6.2	5.7
J207	6.4	5.2
J208	6.1	5.2
Linn	4.2	3.7
Tall fescue (1988-91)		
Rebel II	6.5	5.9
Apache	5.8	5.8
Jaguar	6.2	5.7
Arid	5.7	5.7
Falcon	5.4	5.5
KY31	4.1	4.7

* Quality scores: 9 = Excellent turf; 1 = Dead turf or bare ground

Table 1. Turfgrasses evaluated and quality scores at Rhode Island and nationally (NTEP data).

FIELD EDITOR'S NOTE

By Christopher Sann
Re: Article by Drs. Hull and Liu on nutrient uptake

I strongly recommend the article on turfgrass nutrient uptake by Drs. Hull and Liu to all of our subscribers. The research that they are reporting to us in this article is revolutionary. For the first time, turfgrass researchers have been able to accurately measure nutrient uptake for multiple cultivars of multiple species of turfgrass and begin to relate these measurements to results in the field.

The implications for future turfgrass managers' ability to tailor their cultivar choices precisely to their site and soil environments, and to manage nutrient and soil chemistry strategies, are spectacular.

So, don't be put off by the apparent technicalities of the discussion. It's very straightforward, and will give you a good look at what the future appears to hold in store for cultivar breeding and cultivar and nutrient management in the field.

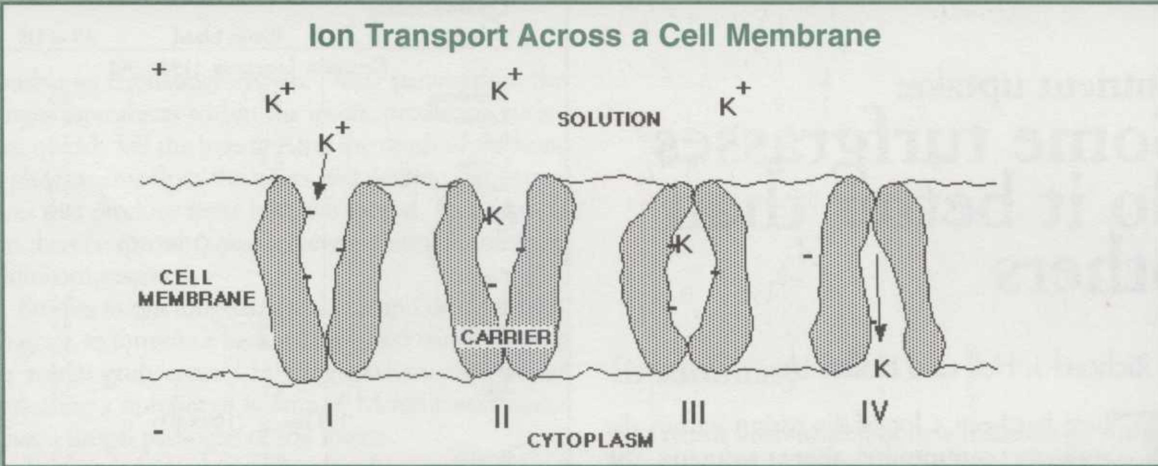


Figure 1. Function of potassium carrier transporting K+ across a cell membrane. I. K+ being attracted by site on carrier protein. II. K+ binding to carrier protein. III. Conformational change in protein enclosing K+ within membrane. IV. Further conformational change and carrier releasing K+ into cytoplasm of cell. The energy driving K+ from the solution into the cell is the electrical gradient spanning the membrane; outside solution positive (+) and inside cytoplasm negative (-). This gradient is produced by a membrane protein which consumes ATP and in the process pumps H+ from the cytoplasm into the external solution (see TGT September 1994). While the potassium carrier shown here provides the channel for K+ transport into the cell, the electrical gradient does the work.

Has all this research resulted in a noticeable decrease in the amount of materials used to maintain turf? An honest answer to that question probably should be "not really."

Many turf managers are actually using fewer materials to grow grass than they did twenty years ago. However, this is more a result of socioeconomic pressures to use less, and pollute less, and because products have been removed from the market without effective replacements being made available at the same (or lower) cost. On top of that, quality standards for general utility turf may be a little lower than they were in the 1950s and 60s. In any event, until now, all this effort to increase the material efficiency of turf management has had little practical impact.

Why is this? In the first place, ten years is not a long time for research to be designed and conducted, the results validated and interpreted, follow-up studies performed, results translated into new management practices or new grass cultivars, and these developments introduced into, and accepted by, the turf profession. Although the close working relationship between university researchers and turf management professionals insures that information transfer is rapid, the process still takes time.

Also, much of this research into turf management efficiency has been conducted at a time of shrinking budgets for university research. Lack of funds has created an atmosphere favoring short-term, externally-funded, practical studies, designed to generate quick answers to immediate problems rather than long-term, basic research on underlying issues like plant efficiency. As a result, our fundamental understanding of what constitutes efficiency in turfgrasses' use of nutrients and water has not advanced very far.

Having said that, we would like to tell you about some research conducted recently at the University of Rhode Island which demonstrates that cultivars of the major cool-season turfgrass species differ in their ability to absorb nutrients from the soil, and suggests why this is so. This information may not be of use to you today, but it is likely to have a profound influence on the development of the turfgrass cultivars you will be using in the not-so-distant future, so you should be aware of it.

Linking turf quality with resource use efficiency

Before describing our research, it is important to understand what efficiency in turfgrass management means. How is efficiency measured? How is quality measured? How are the two linked?

In general, the efficiency of a process can be thought of as the number of units of product made from each unit of a resource invested in its production. For example, the number of bushels of corn harvested per pound of nitrogen fertilizer applied is a measure of the efficiency of the corn's use of nitrogen.

The problem in evaluating turf management efficiently is that its product is not harvested and is therefore not easily measured. The "product" of turf management that most closely resembles a "crop" is turf quality. Quality scores are commonly used to evaluate turf performance in response to experimental treatments. Developing quality scores involves making judgements about characteristics, and combining those judgements into a single value. Needless to say, that involves a lot of subjectivity.

High quality turf has good color and a dense texture, is free of weeds, disease, and insect damage, and is uniform in appearance. Each of those characteristics can be measured individually, but judging turf quality involves integrating all of them into a conclusion about utility and aesthetics. The problem researchers must overcome is finding a way to relate resource use by turf with this illusive property we know as "quality."

One way of making this connection is to measure a particular efficiency characteristic for several different turfgrasses in the laboratory, then relate that characteristic to the quality of turf produced by those grasses when grown in the field under normal management practices. We have several statistical procedures which allow us to quantify the relationship between two properties of the same subject. These procedures give us a measure of how closely, for example, the rate of nutrient uptake is linked with turf quality. As one characteristic increases, how much does the other also increase or decrease?

One word of caution is needed in making correlation analyses like this. We are not measuring cause and effect relationships. We may find that turf quality increases as the rate of nutrient uptake increases, but that does not permit us to say that turf quality results from greater nutrient uptake. Establishing an association between two sets of measurements does not prove that one is the result of the other. Some "third factor" could be at work.

Theory of nutrient uptake

Before starting this research, we had to determine how we were going to measure nutrient utilization by turf. We wanted to use values which would describe the inherent ability of grass roots to absorb a nutrient from solution.

This led us to consider the kinetic description of nutrient uptake first described in the early 1960s by Emanuel Epstein of the University of California at Davis. Epstein recognized that when the rate of nutrient uptake by roots is measured over a range of nutrient concentrations, the resulting curve exhibits what is known as "saturation kinetics." That is, at

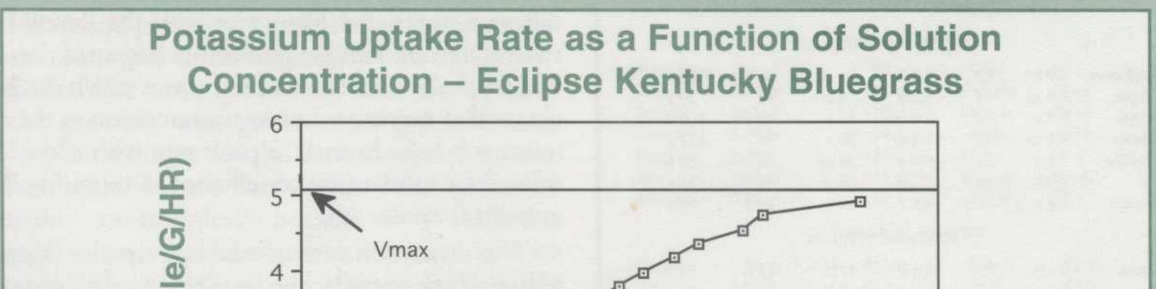


Figure 2. Potassium uptake by concentration curve showing typical saturation kinetics. The kinetic parameters Km and Vmax are identified: Km = 0.14 mM and Vmax = 5.1 µmoles/ gram fresh root/hour. Turfgrass was 'Eclipse' Kentucky bluegrass.

low nutrient concentrations, nutrient uptake increases directly as concentration increases. However, at higher nutrient concentrations, the rate of uptake begins to fall off with further increases in concentration. Eventually, a nutrient concentration is reached where additional increases in nutrient cease to affect the rate of uptake. The uptake process has become saturated.

This sort of saturation response is common in nature and can be described mathematically for the uptake of potassium (K+) by roots with the following equation:

$$V = \frac{Vmax \times [K+]}{Km + [K+]}$$

Where V= the rate or velocity of K+ uptake
Vmax = the rate of K+ uptake at saturating concentrations
[K+] = the concentration of K+ in nutrient solution
Km = the concentration of K+ which produces half the maximum uptake rate

In this equation, Vmax and Km can be considered constants. That makes it possible to calculate the rate of K+ uptake for any concentration of K+ in a nutrient or soil solution.

	Vmax			Km		
Cultivar	NO3-	H2PO4-	K+	NO3-	H2PO4-	K+
	μmole N/gram/hour			μM		
			Kentucky bluegrass			
Blacksburg	4.9 b*	1.3	4.4 bc	36 ab	30	121 a
Eclipse	5.5 ab	1.3	5.5 b	8 b	15	50 c
Bristol	5.9 a	1.2	2.0 cd	71 a	18	160 a
Liberty	5.0 ab	0.9	1.3 d	76 a	18	127 a
Kenblue	5.6 a	1.1	8.0 a	38 ab	16	62 bc
Joy	4.0 b	1.1	2.2 d	26 ab	16	57 c
Average	5.2 z	1.2 y	4.1 z	42 y	19 y	96 x
			Perennial ryegrass			
Saturn	9.0†a	1.1	6.6 b	81†a	15 b	26 ab
Tara	6.2 ab	1.1	7.0 ab	8 b	19 ab	18 b
Derby	4.1 b	1.4	5.2 b	16 b	20 ab	5 b
J207	7.8 a	1.5	4.7 b	26 b	24 a	32 ab
J208	7.0 ab	1.8	7.1 ab	24 b	16 b	21 ab
Linn	9,2 a	1.7	9.2 a	45 ab	24 a	58 a
Average	7.2 y	1.4 y	6.6 y	33 y	20 y	27 z
			Tall fescue			
Rebel II	5.2 ab	1.6	3.5 b	21	12	45 c
Apache	4.2 b	0.9	6.3+a	19	15	15+cd
Jaguar	6.9 a	1.1	6.3 a	64	9	2 d
Arid	5.1 ab	1.1	5.0 ab	21	15	10 cd
Falcon	4.0 b	1.0	6.8 a	9	11	91 b
KY31	7.0 a	1.1	6.3#a	22	12	177#a
Average	5.4 z	1.1 y	5.8 y	26 y	12 z	57 y

* Values in a column for each species followed by the same or no letter are not significantly different.
† Repell perennial ryegrass used in NO3- test.
+ Aquara tall fescue used in K+ test.
# Pst-5AG tall fescue used in K+ test.

Table 2. Kinetic constants for nitrate, phosphate and potassium uptake by three turfgrass species.

Vmax and Km are also the primary values which describe the relationship between K+ concentration and its rate of uptake by roots. If roots of different plants absorb K+ at different rates, the Km and Vmax values for those roots will differ accordingly. Those differences tell us something about the basic relationship between the nutrient ion being absorbed and the cell membrane protein responsible for transporting that nutrient from the soil solution into the root cells.

Ions in a soil solution may or may not enter root cells. Those which are not nutrients for plants, aluminum and silicate for example, are mostly kept out of root cells. Nutrient ions cross the cell membrane because they bind with a protein, imbedded in that membrane, that carries them across the membrane to the cytoplasm inside (Fig. 1). To do this, the nutrient ion must have an attraction or affinity for the carrier protein. This affinity between nutrient ion and carrier protein is represented by Km.

Km also represents the concentration of the nutrient ion which produces half the saturation rate (Vmax) of nutrient uptake. The lower the Km value, the stronger the affinity between nutrient and carrier protein. And the stronger that affinity, the lower the nutrient concentration it will take to begin to saturate the uptake process.

What this means in practical terms is that if we measure Km values for the absorption of a nutrient by different plants, the plant root with the lowest Km value is the one with the greatest binding attraction for that particular nutrient, and is the root which can best obtain that nutrient when its concentration in the soil solution is low. In short, a plant root with a low Km value for a nutrient is very efficient in capturing that nutrient from the soil.

The saturation rate of nutrient uptake (Vmax) tells us how rapidly the carrier protein is transporting the nutrient into a root cell. A high Vmax indicates rapid turnover and consequently a greater potential rate of nutrient uptake. Of course, a large Vmax could also indicate a greater number of carrier proteins in the cell membrane, which would also result in a greater uptake rate.

Nutrient uptake by turfgrasses

Having established the theoretical bases for examining nutrient uptake efficiency, the next step was to measure the Km and Vmax absorption constants for several turfgrasses. This raised the question of which grasses we should examine. We wanted to determine how much difference existed among grasses, so it seemed reasonable to compare grasses that came from diverse places, and which produced turf of differing quality. For this, we turned to the NTEP trials which were underway at Rhode Island and which included many of the turfgrass cultivars available in the United States. We concentrated on three grasses: Kentucky bluegrass, perennial ryegrass and tall fescue. For each of those species, we selected six cultivars that gave us a broad range of turf performance, under both Rhode Island and national conditions (Table 1). We also decided to determine the absorption kinetic constants for three nutrients: nitrate (NO3-), phosphate (H2PO4-) and potassium(K+).

To determine the absorption constants, we measured intact root systems' depletion of nutrients from a solution, taking samples for analysis every 15 minutes over a period of about six hours. Using the nutrient depletion curves derived from those measurements, we constructed nutrient uptake curves over the range of concentrations measured (Fig. 2). These enabled us to calculate the kinetic parameters: Km and Vmax.

The results for the six cultivars of each turfgrass species are presented in Table 2. The most important finding from all those numbers is that, in most cases, there were significant differences among the six cultivars of each turfgrass. The values for phosphate uptake showed little variation, and the differences that were observed were rarely significant; but kinetic constants for nitrate and potassium uptake showed greater variation, and here the differences usually were significant.

Differences among the six cultivars of each species generally were greater than the differences among the averages for the three turfgrass species. In fact, the differences among the three species are probably meaningless, because very different average values would have been obtained had we selected different cultivars. However, these values do appear to support field observations.

Kentucky bluegrass, with its lower Vmax and higher Km values, would be expected to be less able to capture soil nitrate and potassium than perennial ryegrass or tall fescue, which generally exhibited a greater Vmax and lower Km. Most turf managers would agree that it takes more nitrogen to maintain good Kentucky bluegrass than is required for either perennial ryegrass or tall fescue.

Next, we attempted to do what most plant physiologists dread. We tried to see if all our theory and careful laboratory measurements said anything about how these grasses actually perform in the field. To do this, we collected clippings through two growing seasons from the same grasses for which we had measured uptake kinetics. For this, we used the NTEP plots at our turf research farm. Those plots were then in their fourth and fifth seasons, but the turf quality was still reasonably good and they continued to be maintained as they had been for the NTEP program.

Clippings were harvested each week, dried, weighed, and analyzed for total nitrogen, phosphorus and potassium. From those measurements, we calculated average daily clipping production rates and daily nutrient recovery rates (Table 3). We reasoned that these values should reflect differences in basic nutrient uptake kinetics.

Again, significant differences were found among cultivars of Kentucky bluegrass and perennial ryegrass; tall fescue cultivars, on the other hand, showed little difference in anything but potassium recovery. It appears that turfgrass cultivars differ in their ability to absorb nutrients from the soil. This is an encouraging finding because it means there is genetic variability within the major turfgrasses, and this variability can be exploited to select or develop more nutrient-efficient grasses.

		Daily recovery in clippings		
Cultivar	Daily clipping yield	N	P	K
	grams/sq-meter/day	mg/sq-meter/day		
		Kentucky bluegrass		
Blacksburg	1.91 c*	84 c	7.2 c	57 c
Eclipse	2.45 bc	105 bc	10.0 abc	79 ab
Bristol	2.65 ab	118 ab	10.7 ab	80 ab
Liberty	2.20 bc	94 bc	8.4 bc	66 bc
Kenblue	3.24 a	141 a	12.3 a	98 a
Joy	2.67 ab	114 ab	10.2 ab	80 ab
Average	2.52 y	110 y	9.8 yz	77 y
		Perennial ryegrass		
Saturn	2.13 ab (1.89)†	81†ab	9.8 ab	72 ab
Tara	1.50 b	62 b	7.0 b	53 b
Derby	2.02 ab	82 ab	9.7 ab	67 ab
J207	2.24 ab	92 a	10.8 a	76 a
J208	1,93 ab	79 ab	9.0 ab	64 ab
Linn	2.26 a	90 a	10.6 a	76 a
Average	2.01 z	86 z	9.5 z	68 z
		Tall fescue		
Rebel II	2.84	113	10.8	92 ab
Apache	2.76 (2.36)+	100	10.4	72+bc
Jaguar	3.01	121	11.2	97 a
Arid	2.93	115	10.8	93 ab
Falcon	3.05	118	11.3	101 a
KY31	3.11 (1.90)#	113	11.6	61#c
Average	2.95 x	113 y	11.0 y	57 y

* Values in a column for each species followed by the same or no letter are not significantly different.
† Repell perennial ryegrass used in NO_3^- test.
+ Aquara tall fescue used in K^+ test.
# Pst-5AG tall fescue used in K^+ test.

Table 3. Clipping growth rate and nutrient recovery rate from clippings for three turfgrass species grown in field plots.

Completing the story

The final step in our research was to correlate laboratory measurements of nutrient uptake with recovery of those nutrients from turfgrasses growing in the field. Not surprisingly, the results were mixed. In general, there was little relationship between the kinetic parameters of nutrient uptake and turf quality or nutrient recovery in clippings. We say this was not surprising because kinetic constants for phosphateuptake showed little variability across species, and tall fescue cultivars didn't vary in either clipping production rate or nutrient recovery.

This seriously limited our opportunity for observing connections between root properties and field performance for one of the three nutrients and one of the three grass species studied. The most significant relationships observed were for potassium uptake. Km was negatively correlated with the potassium content of clippings in Kentucky bluegrass and tall fescue. This is what we expected, since a low Km should result in more efficient nutrient recovery by roots.

Turf quality of perennial ryegrass also was correlated negatively with Km, but positively with Vmax, as we would have expected. Nitrogen did not provide such predictable relationships between root characteristics and nutrient recovery or turf quality. In tall fescue, clipping yields and daily nitrogen recovery were positively correlated with Vmax. Turf performance was not correlated with Km values, but there was little difference in turf performance within tall fescue cultivars.

We find these results very encouraging. Many initial attempts to relate basic physiological properties with crop performance in the field have come up empty. Something as basic as leaf photosynthesis often does not correlate well with crop yields. While our results were not always comprehensible, they were clear enough to demonstrate that the capacity of turfgrass roots to absorb nutrients is reflected in their performance in the field.

Our field data measured turf quality and nutrient recovery through two growing seasons. We know that turf roots take a beating during the summer, and that grasses lose half of their roots by fall. We also know that high summer temperatures place cool-season grasses under considerable heat and drought stress. It is consequently not surprising that seasonal turf performance may not be predicted by a single physiological property of grasses measured under laboratory conditions. (As noted above in discussing the inability of correlational analysis to capture means-ends relationships, "third factors" can intervene.) When we restricted our correlations to field measurements made in the spring, when grasses were growing well, uptake kinetics demonstrated a closer relationship to field performance.

Given all the problems with this type of research, we were gratified that our basic hypothesis, that turf nutrient recovery from soil can be predicted by the uptake characteristics of roots, was not rejected. We only examined six cultivars of each of three species. The NTEP trials during the 1986-91 period included 65 cultivars each of perennial ryegrass and tall fescue, and 72 cultivars of Kentucky bluegrass. In addition, there are many other genotypes which are not included in these national evaluations. A larger screening of the available turfgrass germplasm may uncover genotypes with nutrient uptake efficiency very much superior to anything we discovered. These could then be developed into commercial cultivars or their superior genes incorporated into established name varieties.

There are other efficiency traits which could be

Terms to know:

- **Absorption kinetics** - The dynamics of nutrients passing through plant tissues from a soil solution.

- **Correlation analysis** - Mathematically-based examination of the nature and strength of the relationship between two sets of measurements.

- **Cytoplasm** - the material enclosed by the plasma membrane of a cell, but exclusive of the large central vacuole in plants (and the nucleus in animals).

- **Saturation response** - Cessation of an absorption process through high concentrations of an input material.

- **Uptake kinetics** - See absorption kinetics.

evaluated in turfgrasses. Crops research has demonstrated that root surface area, root growth rate and photosynthate partitioning to roots are all factors which contribute to greater water and nutrient recovery and overall increased efficiency.

It has long been assumed that the genetic base for many of our turfgrass species is limited, and large differences in basic physiological functions would not be found. Our results indicate this may not be the case, and suggest that future efforts at turfgrass improvement might profitably explore such differences.

For such efforts to be effective, we need to understand the basic biology underlying plant efficiency. We have explored the properties of roots which directly influence nutrient uptake from soil solutions. Once in the plant root, many other processes influence the efficiency of nutrient use. Rate of delivery into the xylem and transport to shoots, rate of incorporation into functional enzymes, turnover rate among metabolites and retention within the plant body are just a few of the factors which contribute to efficiency of nutrient use.

Dr. Richard J. Hull is a professor of Plant Science and Chairman of the Plant Sciences Department at the University of Rhode Island. He has degrees in agronomy and botany from the University of Rhode Island and the University of California at Davis. His research has concentrated on nutrient use efficiency and photosynthate partitioning in turfgrasses and woody ornamental plants. He teaches applied plant physiology and plant nutrition. His most recent contribution to *TurfGrass TRENDS* appeared in the April 1995 issue.

Dr. Haibo Liu is a Postdoctoral Research Associate in Turfgrass Science at the Department of Plant Science, Rutgers University. He has degrees in landscape architecture, horticultural science, and biological science-turf science from Beijing Forestry College, the University of Illinois and the University of Rhode Island. His research focuses on turfgrass management and physiology, emphasizing nutrient use efficiency, stress tolerance and environmental impacts of turfgrass management practices. This is his first contribution to *TurfGrass TRENDS*.

Guest Commentary

The research mill

By Richard J. Hull

My statement in the accompanying article that the ten years of research devoted to increasing the efficiency of turfgrass management has had little practical effect requires some explanation. It does not suggest criticism of the research initiatives undertaken. Quite the contrary. The organizations sponsoring such research are to be commended for their farsightedness, and the researchers involved for their imagination and persistence. It is in the nature of research that practical results are slow to emerge.

I said "ten years is not a long time for research..." I also said "our fundamental understanding of what constitutes efficient nutrient and water use by turfgrasses remains limited."

The turf research enterprise is like a mill. Basic scientific understanding is brought to bear on a practical problem, the two are processed together for a period of time and, with luck, a realistic solution to the problem emerges. The most valuable product of such research often is a deeper understanding of the problem being studied. This greater knowledge and insight makefuture problems easier to handle. The grist for this mill is basic science, without which practical problem solving is difficult if not impossible.

The weakness of basic science related to turfgrasses and their environment is a serious problem for turf researchers. The turf industry has been reluctant to support basic research which offers little prospect of immediately useful information. The federal government has for many years given research on turfgrasses and other ornamental plants a low priority for funding. Universities have not encouraged their faculties to undertake research projects with little opportunity for substantial external support. Most turf research programs are small and only a few universities have enough faculty devoted to turfgrass studies that the luxury of basic research can even be considered. Thus, the basic science grist necessary for sound turf research is often lacking, or at best very thin. This seriously limits the ability of turfgrass research to address fundamental issues like resource use efficiency, tolerance of environmental stresses or long-lasting resistance to diseases and insects.

This problem will be resolved only when turfgrass professionals recognize the importance of maintaining strength in basic research, and insist that their industry leaders commit resources to its support. Deans and other university administrators must be persuaded that basic research on turfgrasses is worth funding, and that it has the support of industry and the professions.

It comes down to investing in the future. Is the turf industry concerned only with solving immediate problems and maximizing profit margins, or does it also recognize the need for taking a broader view and committing resources to strengthening the scientific base on which turfgrass science is built? A sustainable future for the turf industry may very well depend on the answer to that question.

Q&A
Black Turfgrass Ataenius (BTA) control

Question:

"...Last year at the end of August, we started to see a lot of BTA activity on our greens. This year we started to see them again on the 13th of April. The following week we had some very cold mornings and we started finding a lot of dead BTA's. There are still a lot of live ones now but not nearly as many as we saw in the middle of the month. According to the info I have, the best time to treat for overwintering adults is in the first week of May. What I am wondering is, are we too late?..."

Clark Weld, Superintendent
Blue Heron Pines Golf Club, Pomona, NJ

Response:
By Michael Villani

Unlike other scarab species, the adult stages of BTA are purely reproductive. They do not eat and have a limited life span of 7 - 10 days. Because of this, control strategies targeted at adults have a limited window of opportunity. However, like other scarab species, BTA grub stages are usually active from hatch in late spring through the early fall, so turfgrass managers have a better chance of controlling BTA's in this stage than when they are adults.

Answers to your observations and questions:

The early activity that you saw in April indicates that there were a fairly large number of overwintering adults, not unexpected since the East Coast had a mild winter.

The large number of dead adults following the cold spell may have been due to the cold temperatures, or their normally short life span. The uncertainty about the cause of death for the adults leaves two additional questions that should be considered. Were the dead adults males or females? And if they were female, had they already deposited their eggs?

Since female BTAs usually remain in the soil after swarming, most of the dead adults found on the surface are likely to have been males and the apparent high mortality of adult BTAs will probably have little effect on the number of hatched grubs. Further, if dead females were found, they probably had already laid their eggs, so again the high number of dead adults will probably have little effect on later grub populations.

Control strategies for BTA

Control measures for Black Turfgrass Ataenius (BTA) have historically been directed at both the adult and the larval grub stages.

Adults: Early intervention with surface active insecticides such as chlorpyrifos aimed at the adult BTA populations is intended to lower the number of adults by controlling them as they move through the thatch and the upper soil layer. The objective is to reduce the number of adults capable of producing grubs. There are some factors complicating this control strategy that turfgrass mangers should consider, however.

First, BTA adults tend to be attracted to very high organic component soils and thatch. This high level of organic matter tends to bind up traditional surface active insecticides and reduce the efficacy of these treatments.

Second, recent research that was done to correlate observable adult scarab populations with later in-soil grub populations has found no significant relationship between the two. Site conditions, natural predators, egg survival rates, hatch rates, and grub survival rates appear to be the better determinants of later grub populations, so early intervention for adults may not produce significant reductions.

Grubs: Because BTA grubs hatch in late spring, large summertime BTA grub populations can easily be missed if they are not being looked for, and feeding damage can easily be mistaken as a host of similar symptomologies are often present.

If BTA grubs are the only significant scarab grub species that is a pest, then single applications of conventional short-term high-knockdown insecticides, like bendiocarb (Turcam), should be used. If the site is subject to multi-species grub infestations then a long-term insecticide like imidacloprid (Merit) should be applied, so that all of the grub species can be controlled over the several months of their activity.

Bio-controls: Few if any effective bio-controls are currently labeled for control of BTA grubs, although some parasitic nematodes have shown activity.

TGT Advice: As always, to meet federal labeling law requirements make sure that the label of the control product chosen, whether traditional or bio-control, specifically mentions BTA as a susceptible species before making any application.

LETTER FROM THE PUBLISHER

Dear Readers:

To find out how to serve you better, we surveyed a random sample of our readers. (Thanks again to those of you who received and returned the questionnaire.) You had a lot to say. We listened and learned. Here's what we're doing about it.

First and foremost, you wanted us to keep *TurfGrass TRENDS* pointed in the same direction: providing unbiased, in-depth coverage of developments in turfgrass research. We're not going to change that! We are going to make that coverage more readable, however. The content will be the same, but the language will be easier to understand, and the graphics will be more illustrative. You also wanted us to help you put the results of that research to work by providing more field tips. We started doing that in last month's issue.

And you wanted us to provide more coverage of bio-control, integrated pest management (IPM), fertility and soil chemistry, and turf diseases. We will do that.

Finally, you wanted to interact with the experts – more than anything else – to ask questions. Go ahead! If they seem to be of interest to most of our readers, we'll publish the answers. If they're unique, we'll put you in touch with those most able to help.

We'd love to tell you all the positive things readers say about *TurfGrass TRENDS,* but you have better things to do with your time than to read those comments.

Let us know next time you see something you think should be added to *TurfGrass TRENDS,* or subtracted, or kept but presented in a different way. You can call us, put it on the fax, or just send a letter. We'll be listening. To help us serve you better, please fill out and return the form below.

Maria L. Haber, Publisher

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TurfGrass TRENDS would be most helpful to me if future issues covered the following topics in-depth:
(Please rank in order of importance to you)

☐ IPM ☐ Bio-Controls ☐ Fertility and Soil Chemistry ☐ Turf Diseases ☐ Other________________

Please cover the following specific subjects within these groups:

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FUTURE ISSUES:

- The art of diagnosing turfgrass diseases
- Diagnosing root and crown diseases
- Identifying unknown turfgrass pathogens
- Directory of turfgrass disease diagnostic laboratories
- Nutsedge control
- Making treatment decisions for grubs
- IPM scouting for insects on turf

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