A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

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IN THIS ISSUE

Heat Stress and Decline of Creeping Bentgrass

by Leon T. Lucas
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Heat stress is a major factor in the decline of bentgrass during the summer months. Bentgrass grows best during the spring and fall in hotter regions of the country where this grass is used. Under natural conditions, where the grass is allowed to grow tall and flower, it would go dormant during hot-dry weather. When irrigated, mowed and stimulated to grow throughout the summer, bentgrasses are under severe stress from heat and diseases. Factors involved in this summer stress are discussed below.

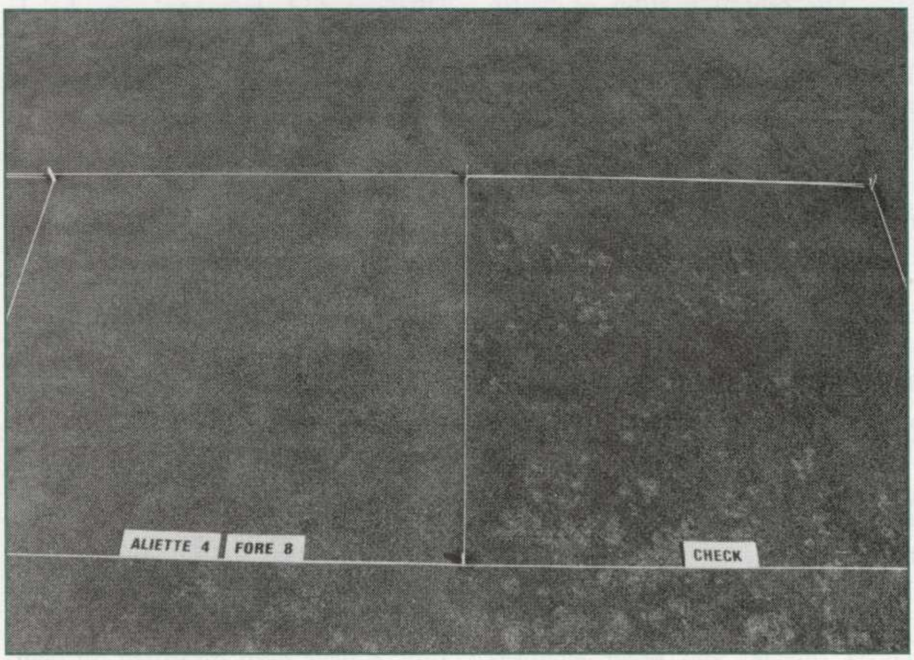

Fig. 1. Comparison of bentgrass treated with and without fungicides

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North Carolina -- Similar to other regions in the U.S.

To make this article relevant to most regions of the country, I should indicate my experience with bentgrass under the wide range of environmental conditions that occur in North Carolina. In the northwestern portion of the state, bentgrass is grown under cool conditions where diseases are the major summer problem with heat stress being a problem only occasionally. These conditions are similar to those in the northern portions of the United States where bentgrass is grown on greens, fairways and tees of many courses. Golf courses in this region usually close in November and open for play again in March. Conditions in the southeastern portion of the state, where bentgrass is grown on many golf greens, are similar to conditions throughout the humid southern United States. Heat stress is a major problem throughout this region every year. The central portion of North Carolina is in the transition zone along with much of the Midwest, where long periods of hot weather occur in most years. Problems occur on bentgrass in some areas of North Carolina that are similar to all regions of the country except the dry Southwest.

Summer decline and temperature

I have used the term summer decline to describe the problem that develops on bentgrass turf during hot and humid conditions. This problem involves diseases and other environmental stresses that cause the quality of bentgrass turf to decline during the summer. Bentgrass does not grow well under these conditions and root systems become shallow due to physiological and pathological problems.

Why does bentgrass grow poorly during hot and humid weather? Research reports indicate the optimum air temperature for shoot growth of cool-season grasses is 60° to 75° F and that optimum soil temperature for root growth is 50° to 65° F. Shoot growth ceases when air temperature is above 90° F and root growth ceases when soil temperature is above 77° F. Bentgrass was killed when exposed to 122° F for 144° minutes (Wallner, 1982). Injury from heat is often closely associated with water stress (DiPaola, 1992).

These temperatures are often exceeded on bentgrass turf throughout the summer in the southern region where this grass is grown. To measure canopy temperatures on bentgrass turf I use a hand-held infrared thermometer purchased from Omega in Stamford, CT (1-800-826-6342) for about $300. During mid-afternoon on bright sunny days, the canopy temperature of "healthy looking" bentgrass is usually 2° to 4° F higher than the air temperature. For example, when the air temperature was 92° F at 2 p.m., the canopy temperature was usually 94° to 96° F. Temperatures usually were 100° to 105° F when wilt symptoms such as foot printing started to appear. When blue wilt symptoms became evident, canopy temperatures were usually 110° to 115° F. The temperature of the turf increases because the plants cannot take up enough water to maintain cooling through transpiration because of shallow roots or lack of moisture in the soil. Temperatures as high as 126° F have been measured on bentgrass during advanced stages of wilt on hot-sunny days in North Carolina.

During mid afternoon in the summer soil temperatures measured at a 2 inch depth have been close to the air temperature, about 92° F for a typical day on a bentgrass golf green. Soil temperatures at a 4 inch depth were lower than at the 2 inch depth. The morning following a hot day, soil temperatures at a 2 inch depth have been observed to be above 80° F even when the night air temperatures remained in the 70's. Therefore, considering the temperatures under which shoot and root growth ceases for cool season grasses, long periods of time can occur throughout the hot, humid regions when temperatures exceed conditions favorable for the growth of bentgrass. Available water and air movement are related to cooling of bentgrass leaves and that will be discussed under management of heat stress.

Heat affects energy and plant growth

Bentgrass turf growing on golf courses captures light energy and uses it to maintain and produce new leaves, stolons and roots. Photosynthesis is the process used by plants to capture light energy and assimilate CO_2 into carbohydrates. Under high temperatures, this process is less efficient in cool-season grasses than in warm-season grasses. The pentose phosphate cycle, or C - 3 pathway, that occurs in cool-season grasses, is accompanied during high temperatures by photorespiration that uses oxygen and liberates CO_2 at the same time. The efficiency of energy capture and therefore CO_2 fixation, decreases during high temperatures and the maintenance and growth of bentgrass turf declines. The warm-season grasses have a C - 4 pathway for CO_2 assimilation which is not accompanied by photorespiration and is more efficient in warmer weather (Hull, 1992). The difference in efficiency of energy utilization between C - 3 and C - 4 type grasses can be seen in the rapid growth of crabgrass or the invasion of bermudagrass (both C - 4 grasses) on bentgrass golf greens during the summer (Hull, 1992). This less efficient photosynthesis during high temperatures contributes to heat stress on bentgrass by causing poor growth and the inability to recover from other stresses such as diseases and traffic damage during the summer.

Soil conditions and heat stress

Soil conditions, management practices and microclimatic conditions have also been associated with the summer decline problem by increasing the damage from heat stress. Poor soil drainage due to layers in the soil cause poor root growth and encourage root diseases. Heavy soils that hold too much water and are low in oxygen are known to contribute to damage from diseases and heat stress in bentgrass turf. High sand-content greens often develop layers of different types of soil and thatch, which interfere with the movement of water through the soil. High sand-content greens based on USGA construction specifications usually develop a layer of thatch and soil top topdressing ½ to 1 inch thick at the surface. This layer is usually needed to stabilize the soil surface and to provide the desirable ball holding properties when a golf ball lands on the green. This finer layer of material over a course sand prevents normal drainage and water does not move into the sand below until the layer is saturated. This layer holds an excessive amount of water around the stolons, crowns and roots of the plants, creates conditions favorable for disease causing fungi, and can cause a deficiency of oxygen in the thatch layer and in the soil mixture below.

The lack of oxygen causes an anaerobic condition around the roots and roots can "drown" in a short time during hot weather. Live and actively growing white roots are usually limited to the top ½ to 1 inch of the soil mixture during late summer. The severity of the anaerobic condition that can develop in thatch layers was observed in the fall of 1994 in North Carolina on a golf green growing on native soil that was not properly drained. The superintendent called and described raised areas on his greens following heavy rains. The areas were raised about 1 inch and were from 6 inches to 1 foot in diameter. When the raised areas were cut with a knife, air came rushing out and the turf could be pressed down level with the surrounding surface. The air in the soil was displaced by the large amounts of water and was trapped under the air-tight layer of sod. This condition had developed within 2 months after aerification with ½ inch hollow tines. This would probably not occur on a USGA type green because of the good drainage, however, the anaerobic condition can occur in the thatch layer at the surface if frequent aerification is not used.

The black layer conditions that have frequently been described on greens are caused by anaerobic conditions in the soil. The lack of oxygen and toxic chemicals that result can kill roots or cause very poor root growth. The black layer becomes visible when sulfur is reduced under anaerobic conditions; whereas, sulfur does not appear black under aerobic conditions when sufficient oxygen is present. This condition can develop on some high-sand-content greens due to water retention in organic layers over sand or where water collects in low areas of greens. Moisture levels as high as 50% have been measured on these greens where water collects until enough hydraulic pressure develops to force the water into the sand layer below.

High soluble salts have frequently been associated with bentgrass decline during heat stress. The salts can be from excess fertilizer or from irrigation water containing high salts. Symptoms of decline during hot weather often occur as yellowing strips every 12 to 15 feet across a green. This pattern is due to overlapping fertilizer applications from a rotary spreader. The water is bound more tightly to the salt and produces physiological drought stress or the salt draws water from plant cells and "burns" the roots. The damaged roots are more susceptible to root rot fungi and some Pythium species are encouraged by high salt levels. The top ½ inch of sod and soil from a cup cutter plug can be used to analyze for soluble salts. Increased root rot and decline in turf quality have been observed in samples containing over 500 ppm of salts in this top layer. The salt level is higher in the top ½ inch than in the soil or sand below. This is due to the accumulation of salt at the surface when water evaporates and the thatch layer appears to hold salt more tightly than soil below. This level of salt is lower than that reported as damaging to bentgrass, however, those reports were not based on soil but on a water solution. The damage to roots from the salt and Pythium root rot increase turf injury from heat stress because the poor root system is less able to absorb sufficient water.

Disease and heat stress

Diseases have a major role in the summer heat stress complex. Pythium species are usually isolated from bentgrass plants that are declining during the summer. We have identified 33 species of Pythium from bentgrasses in North Carolina and other researchers have identified many of the same species in other regions of the country. Pythium species can be isolated from roots during all times of the year, even in the fall, winter and spring when bentgrass does not show symptoms of root rot or stress. Recent research has shown that in laboratory tests many of these species do not cause disease on bentgrass seedlings (Abad, 1995). Some of these species that do not cause disease appear to help protect the plants from some of the more pathogenic species. Therefore, the presence of a Pythium species does not mean that Pythium root rot is the primary cause of bentgrass decline. The species present must be identified, which is often difficult to do, before we can say that Pythium root rot is the primary problem.

Rhizoctonia brown patch also is often associated with heat stress problems. During the summer brown patch may weaken the bentgrass plants and increase the susceptibility to heat stress. Some fungicide evaluations, discussed later, indicate that Rhizoctonia diseases in combination with Pythium diseases may be involved in the summer decline of bentgrass.

Micro-climate and heat stress

Micro-environmental conditions on golf courses can contribute to heat stress problems. Golf greens that are surrounded by trees usually have more summer stress problems. Shade in early morning has been associated with weaker bentgrass. However, some shade on the west side during the summer after 3 p.m. appears to help reduce heat stress. Trees on the southwest side of a green can block the wind, which is usually from this direction during very hot periods, and contribute to heat stress. Wind does not blow over the surface of these greens during the summer to cool and dry the turf. The wind breaks up the humid boundary layer of air on the surface of the green resulting in increased evapotranspiration which causes more cooling and less disease. Bentgrass often grows better in western regions of the country where low relative humidity even with high day time temperatures promote increased evaporative cooling. In dry climates, night temperatures are also cooler.

The removal of trees that shade the green in the morning or block the wind from the southwest will help to reduce summer stress problems. It is often difficult to obtain approval to remove trees to help the grass. In cases where the trees are crowding one another, their removal has been approved to improve the growing conditions and health of the remaining trees. Fans have been installed around greens where wind movement is restricted with excellent results in improved turf quality. Research projects at N. C. State University have shown that fans can reduce the canopy temperature of bentgrass greens several degrees during the afternoon. Soil moisture levels were also reduced which would provide better conditions for root growth during high temperatures. Wind speeds greater than 2 mph 1 inch above the turf canopy gave the best results (Taylor, 1995). Fans should be run 24 hours a day throughout the summer for maximum benefit. Less morning dew and disease were observed on bentgrass in experimental areas where fans were run continuously.

Management practices to help bentgrass tolerate high temperature stress should deal with many of the problems discussed above. Practices to encourage root growth during the summer and to reduce drought stress should be used. This involves utilizing good soil mixtures, aerification, proper irrigation, fertilization and fungicides. Aerification of bentgrass in the spring, early summer and fall with hollow tines will improve oxygen relations in the soil and help root systems to grow. Aerification throughout the summer with solid tines has helped to reduce summer stresses in North Carolina. Open holes in the thatch layer help to avoid the anaerobic conditions that can kill roots and inhibit their growth during periods of high temperature. Also, the temperature in open holes and the soil surrounding them should be lower at night than in a sod without aerification holes. Lower temperatures in aerification holes may explain how new roots can grow in these holes even when soil temperatures remain above the maximum for the growth of bentgrass roots. Night time temperatures usually are below 75°F in regions where bentgrass is grown on greens.

Irrigation and summer decline

Modification of irrigation practices during the summer will help bentgrass tolerate heat stress. Infrequent but deep irrigation should be used during the spring and fall when bentgrass grows well. When root systems are declining and are shallow during the summer, light-frequent irrigation should be applied as needed. In the Southeast during the summer the active roots on bentgrass plants are not more than 2 to 3 inches deep. Hand syringing should be used on days when the bentgrass shows symptoms of heat stress. An infrared thermometer would be useful to measure the canopy temperature and determine where and when light irrigation is needed. Recent research at N. C. State University has shown that sufficient water should be applied as often as needed to wet the crowns of the plants.

Bentgrass plants can continue to take up water and water deficits are less when crowns are wet than when just enough water is applied to wet the leaves (Bennett, 1996). Water should be applied as needed to bentgrass turf and avoid "making the bentgrass tough" during periods of high temperature. Superintendents have been taught to keep the bentgrass as dry as possible to help avoid diseases. I think you should apply more water if needed to keep the plants alive and avoid the very high temperatures that can occur in bentgrass plants during advanced stages of wilt in the summer. A simple statement of this principle is that "it is better to have wet live bentgrass plants that can get disease rather than dry dead plants."

Fertilizer management and stress

Applications of small amounts of fertilizer throughout the summer have been observed to increase summer survival. To encourage some growth during the summer, superintendents are applying $\frac{1}{8}$ to $\frac{1}{10}$ pound of N, P, and K per 1,000 square feet about every 10 to 14 days on high-sand-content greens. This method insures that nutrients are present in the top $\frac{1}{2}$ inch of thatch and soil where new roots are growing during the summer. Soil tests may indicate that sufficient nutrients are present in the soil, but these nutrients may not be available in the high organic thatch layer where the short live roots are growing. Tissue analysis may provide more useful information about nutrient requirements during heat stress than soil tests. The rapid analytical techniques that are now available can tell you in a few hours if the turf needs certain nutrients.

Fungicides can reduce summer decline

Disease management is important to help reduce high temperature stress in bentgrass turf. Normal fungicide applications in the spring will help the bentgrass go into the summer in a healthy condition. The use of the group of DMI (demethylation inhibitors), or sterol inhibitor, type fungicides during the summer should be monitored carefully. This group of fungicides used at high rates can cause additional stress and reduce the quality of bentgrass during the summer.

Applications of fungicides to control Pythium species on a bentgrass green may not result in the improvement of turf quality during the summer. In 1992, it was discovered that the combination of *Aliette*® plus *Fore*® fungicides increased summer survival and improved the quality of bentgrass on a poorly drained soil (Figure 1; cover). The effectiveness of the fungicides was based on turf quality, which may indicate Pythium root rot control, percent brown patch reduction and temperature moderation of the turf. This treatment resulted in improved turf quality over other fungicide applications and the bentgrass was darker green and growing during the summer stress period. The canopy temperature of the plots with good turf

EVALUATION OF FUNGICIDES FOR *PYTHIUM* - 1992

Treatments	oz /1000 ft²	Turf Quality	Turf Temp.	Disease Control (%)
Aliette 80WP + Fore 80WP	4 + 8	8.0 a	98.1	100 a
Fore 80WP	8	5.5 b	100.1	61.5 ab
Aliette 80WP	4	5.5 b	100.3	43.8 bc
Aliette 80WP + Koban 30WP	4 + 3	4.8 bc	100.0	55.2 ab
Fore 80WP + Subdue 2EC	8 + 2	4.5 bc	101.3	70.8 ab
Koban 30WP + Subdue 2EC	3 + 2	4.3 bc	102.8	40.6 bc
Koban 30WP	3	3.8 c	100.6	25.0 bc
Check	--	4.0 c	102.8	0.0 c

Table 1. Evaluation of fungicides for Pythium root rot control in 1992. Turf quality is rated from 1 to 9 with 9 being excellent turf quality. Turf quality is an indication of Pythium root rot and brown patch control. Disease Control (%) is the control of brown patch by the fungicides.

quality was 3° to 4° F lower than turf treated with other fungicides on very hot days. This lower temperature indicates that the bentgrass probably had a deeper root systems and could take up more water during heat stress (table 1).

Recent research has shown that the *Aliette*® plus *Fore*® fungicides in addition to controlling Pythium and brown patch, also provide nutrients to the bentgrass. Phosphorus, sulfur, manganese, zinc and copper are in this combination and levels of these nutrients were higher in leaves of bentgrass from treated plots during the summer. A systemic source of P is provided by *Aliette*® and the other nutrients are present in the *Fore*®. Statistical correlations indicated that P is the major nutrient associated with improved turf quality and growth during hot weather (Dorer, 1995). The best results were obtained with this fungicide combination when applications of 4 ounces of *Aliette*® and 8 ounces of Fore were started about June 15 and applied every 2 weeks throughout the summer. The fungicides were applied in 2.5 gallons of water per 1000 square feet and were not watered into the soil. Other mancozeb fungicides that did not contain the blue pigment present in *Fore*® also did not improve turf quality as much as *Fore*® when used in the combination. More recent results have shown similar improvements in turf quality when combinations of *Aliette*® and *Daconil*® are used (table 2).

In summary, heat stress is the major factor that causes summer decline of bentgrass in hot and humid regions of the country. Many factors can be involved in heat stress. Some factors that contribute to damage, such as shallow roots, may occur many days or months before the decline or damage to turf from heat stress becomes evident. A management program that encourages root growth (Hull, 1996) and avoids drought stress will help to reduce the damage to bentgrass from heat stress.

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SUMMER DECLINE FUNGICIDE EVALUATION - 1993

Treatments	oz /1000 ft²	% Brown Patch	Turf Quality
Aliette 80WDG + Fore 80WP	4 + 8	1.3 d	8.8 a
Aliette 80WDG + Daconil 80WDG	4 + 6	0.0 d	8.0 ab
Aliette 80WDG + Chipco26019 50WDG	4 + 2	0.0 d	7.3 bcd
Fluazinam 4.17FL	1	0.0 d	7.3 bcd
Daconil 90WDG	6	1.3 d	7.0 cde
Fore 80WP	8	0.0 d	7.0 cde
Aliette 80WDG + Prostar 50WP	4 + 4	1.3 d	6.8 de
Eagle 40WG	1.2	1.3 d	6.8 de
Aliette 80WDG	4	12.5 bc	6.5 de
Eagle 40WG	0.6	13.8 b	6.3 e
Prostar 50WP	4	0.0 d	6.3 e
Check	---	30.0 a	5.3 f

Table 2. Summer decline fungicide evaluation in 1993. Additional fungicides were tested showing significantly better turf quality with *Aliette*®plus *Fore*® and *Aliette*® plus *Daconil*® than with other fungicides tested. Other fungicides gave good control of brown patch but not as good turf quality.

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Managing Turf in the Shade

Toby D. Bost
NCCES, Forsyth County Center

Growing quality turf is "shady business" for some turfgrass managers!

In the late 80's Federal monies were appropriated for planting shade trees in urban centers, and promoting efforts to affect Global Warming.

Additionally, residents' appreciation for wooded landscapes is at an all-time high, as trees can significantly enhance the real estate values in communities, bringing a premium to developers. According to one estimate, one-fourth of the turfgrass in the United States grows in shade.

Growing turf in the shade is a challenge for turf managers. Keeping density up and disease down is no easy feat in the transition zone of North Carolina.

Like all plants, turfgrasses require sufficient light to grow. They grow poorly on sites getting less than four hours of full sun each day. Food reserves of plants growing in dense shade are drained, resulting in weak plants and shallow root systems.

Besides sunlight, turfgrass must compete with trees for water and nutrients. Evergreens and shallow-rooted trees, such as maples, dogwoods and birches, create an especially competitive environment for grasses, as do trees with dense canopies.

Air movement across turf is frequently impeded by shade, or screening hedges which thwart wind circulation, increasing the threat of disease in the summer.

If an area gets less than 50 percent open sunlight each day, consider making some changes in the landscape. Some possible solutions include:

- removal of selected trees that will not detract from the landscape;
- if removal is not an option, then limb up trees and thin others;
- consider the use of ground covers or mulching in lieu of turf;
- tree rings of mulch improve the health of trees and reduce maintenance time;
- use shade-tolerant cultivars of turfgrass, i.e. hard fescue;
- mow turf at the top of it's recommended mowing height;
- irrigate turf deeply and infrequently;
- follow soil test recommendations to keep the turf thriving;
- keep an eye out for diseases and treat per label instructions.

The Oriental Beetle

by Steven R. Alm
University of Rhode Island

The Japanese beetle is still the single most important insect damaging to turfgrasses in most of the U. S., however, the oriental beetle is fast becoming an important pest of turfgrasses in many areas on the East Coast from North Carolina to Massachusetts (Fig. 1). The oriental beetle was recently classified as *Exomala orientalis* (Waterhouse) by Baraud (1991). In the American literature, the beetle was classified as Anomala orientalis, while in the Japanese literature it was known as *Blitopertha orientalis.* The oriental beetle was introduced into Connecticut around 1920, probably from Japan in balled nursery stock.

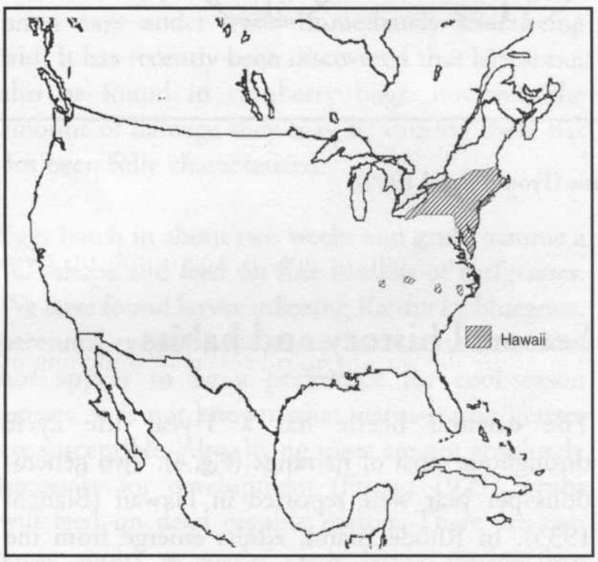

Fig. 1. Distribution of the oriental beetle. Courtesy of the Entomological Society of America

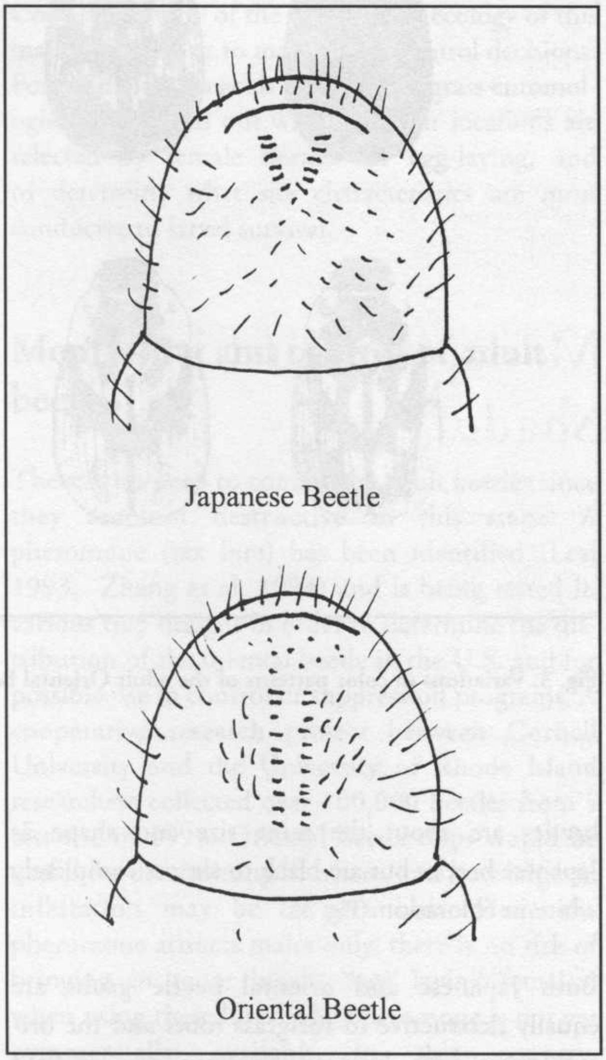

Fig. 2. Rastral patterns of two of the major turf infesting grubs. Courtesy of Dr. Steven R. Alm.

It has since spread to Delaware, Maryland, Massachusetts, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island and there are some data to suggest it can be found in New Hampshire, Tennessee and West Virginia. The larvae of the oriental beetle look exactly like the larvae of Japanese beetles except for a series of spines on the raster that are visible only with a hand lens or microscope. The spines on Japanese beetle grubs are arranged in a "V" shape (Fig. 2). On the oriental beetle, the spines are arranged in two parallel rows (Fig. 2). The anal slit, which is a smooth curve, is also important in distinguishing these grubs from other white grub species. Adult oriental

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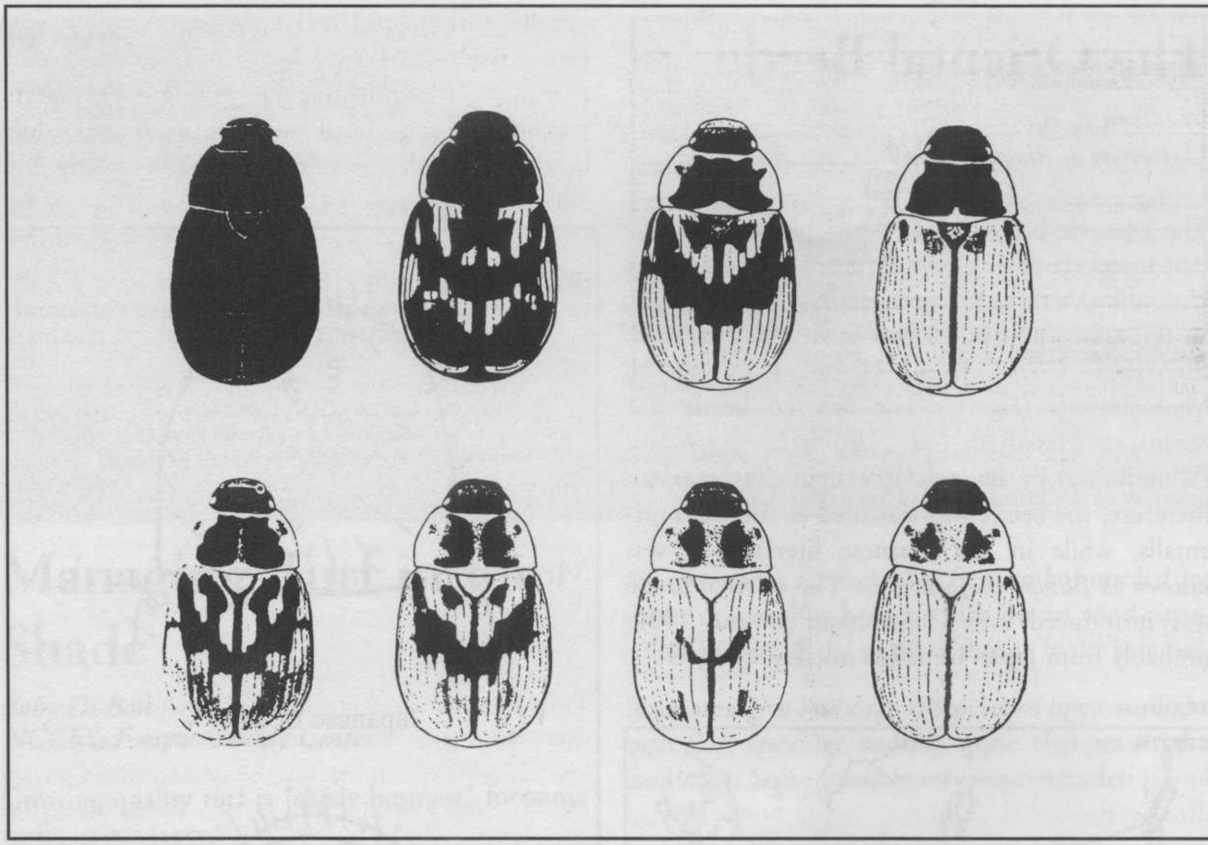

Fig. 3. Variations in color patterns of the adult Oriental beetle (From Friend 1929).

beetles are about the same size and shape as Japanese beetles but are black to almost completely white in coloration (Fig. 3).

Both Japanese and oriental beetle grubs are equally destructive to turfgrass roots and the oriental beetle has become a serious pest of field grown nursery stock (e.g. Canada hemlock) on Long Island, NY. The peak flight activity of the oriental beetle is between 7 and 11 PM with a maximum at 9 PM (Facundo, personal communication). Adults feed at night on roses, hollyhock, phlox, petunias and dahlias but this is not considered serious as oriental beetles are <u>not</u> the voracious ornamental feeders Japanese beetles are. Since adult beetles are rarely noticed by the turf manager, they are often surprised at the extent of larval infestations that can develop.

Seasonal history and habits

The oriental beetle has a 1-year life cycle throughout most of its range (Fig. 4). Two generations per year were reported in Hawaii (Bianchi 1935). In Rhode Island, adults emerge from the soil in mid-to-late June, just a short time before Japanese beetles are seen. Adults emerge one to two weeks earlier further south. They feed and mate after emergence. After mating, adult females burrow into the soil to a depth of 2-4 inches and deposit eggs. A female may enter the soil several times and deposit several eggs per entry. Females prefer to enter the soil and lay eggs in well watered turf, however, dryer sites are also infested. Friend (1929) stated that moisture seems absolutely essential to the development of the embryo, since a lack of moisture retards development, and exposure to

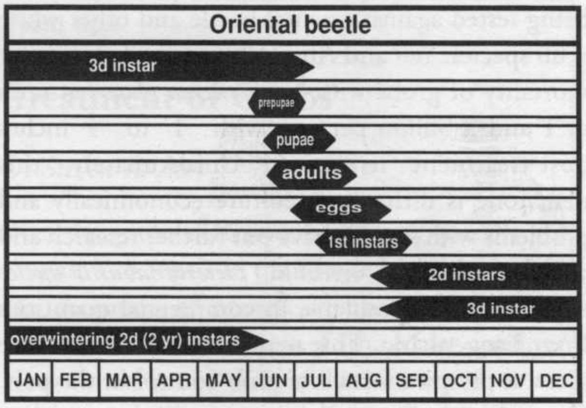

Fig. 4. Life cycle and stages of the oriental beetle. Courtesy of the Entomological Society of America

air-dry conditions for the first ten days after oviposition is fatal. Submergence of eggs in water also retards development, but eggs can survive at least seven days under water immediately after being laid. It has recently been discovered that larvae can also be found in cranberry bogs, however, the amount of damage they may be causing there has not been fully characterized.

Eggs hatch in about two weeks and grubs assume a "C"-shape and feed on fine rootlets of turfgrasses. We have found larvae infesting Kentucky bluegrass, perennial ryegrass, and sheep fescue, so, there does not appear to be a preference for cool-season grasses. It is not known what warm-season grasses are susceptible. Also, living roots are not absolutely necessary for development (Friend 1929), grubs will feed on dead organic matter. There are two more molts as grubs grow larger during late summer and fall, each molt producing a slightly larger C-shaped grub. During this time the grubs are within the top two inches of soil.

Grubs continue to feed on roots in the fall until the soil temperatures reach about 59° F. At that temperature, grubs will begin to move downward and continue to do so until soil temperatures reach 50° F. Grubs become inactive at that temperature and will remain at their hibernation level (8-17 inches) throughout the winter. As temperatures warm in the spring, grubs will migrate upwards usually during April in Rhode Island. Grubs will feed actively for 4-5 weeks, then move downward to transform into the pupal or resting stage. Insects stay in that stage until transformation into adult beetles is complete in mid-to-late June or early July when adults emerge and repeat the cycle. Continued study of the biology and ecology of this insect will help us to make better control decisions. For example, two goals of many turfgrass entomologists are to find out why particular locations are selected by female beetles for egg-laying, and to determine what site characteristics are most conducive to larval survival.

Monitoring and control of adult beetles

There is no need to control the adult beetles since they are not destructive in this stage. A pheromone (sex lure) has been identified (Leal 1993, Zhang et al. 1994) and is being tested in various trap designs in order to determine the distribution of the oriental beetle in the U.S. and for possible use in control or suppression programs. A cooperative research project between Cornell University and the University of Rhode Island researchers collected over 100,000 beetles from a test site in 1993. Oriental beetle traps would be useful for determining if, where, and how large an infestation may be in your area. Since the pheromone attracts males only, there is no risk of bringing in more insects (egg laying females) when using these lures. The pheromone is not yet commercially available in this country. Pheromone lures and traps can be obtained from Fuji Flavor Co., Ltd., 3-5-8 Midorigaoka, Hamura-Shi, Tokyo 205, Japan.

Traps used for Japanese beetle monitoring can also be used for oriental beetles. We have found that traps with the funnel rim placed at ground level capture significantly more beetles than traps with funnel rims above ground level. We used a standard cup changer to make a hole for the collection container, and a turf mender (6" diameter) to allow the funnel rim to be placed at ground level.

Natural enemies

Like all other insects, the oriental beetle is attacked by a large number of microorganisms, parasites and predators. Grubs are beset by various microorganisms including bacteria, rickettsiae, fungi, protozoa, and nematodes. Other predators such as skunks and raccoons digging in turf are a dead giveaway that a grub population has developed. Holes in turf and soil caused by starlings, grackles, or robins also indicate the presence of grubs.

Larval control (biological)

Microbial Control: Grubs are susceptible to a milky disease, however the exact causal organism is not known. Dunbar and Beard (1975) and Hanula and Andreadis (1988) reported a low incidence of milky disease in Connecticut white grub populations. In 1992, a population of oriental beetles in Norwich, Conn. was found with nearly 50% milky grubs (Alm, unpublished data). The activity of the commercial formulation of milky disease against oriental beetle grubs is unknown. Hanula and Andreadis (1988) also reported a protozoan (Gregarinidae) from *E. orientalis* in a survey of scarabs collected in Connecticut.

A novel isolate of *Bacillus thuringiensis,* designated var. *japonensis* strain Buibui, obtained from a soil sample collected in the vicinity of Tokushima, Japan was found to be highly toxic to oriental beetle grubs in field experiments (Alm, unpublished data). A commercial formulation is scheduled to be released by the Mycogen, Corp. in 1997.

Parasites: *Scolia manilae* Ashmead, a wasp, has been successfully introduced into Hawaii and has been so effective in parasitizing oriental beetle grubs that they are no longer a serious problem in sugar cane fields there. This parasite may prove effective against the southern populations of oriental beetles where climate is more in line with its native habitat. Entomopathogenic nematodes are being tested against oriental beetle and other white grub species. Yeh and Alm (1995) found significant mortality of grubs with *Steinernema glaseri* at rates of 1 and 2 billion per acre with $\frac{1}{4}$ to $\frac{1}{2}$ inches post-treatment irrigation. Unfortunately, this nematode is difficult to culture economically and problems with storage have put further research and commercialization on hold. *Heterorhabditis bacteriophora* will be available in commercial quantities from Ecogen, Inc. This nematode has shown the greatest promise for white grub control in the past. Control with nematodes is generally better when soil temperatures are between 70° and 86° F (Georgis and Gaugler 1991), $\frac{1}{4}$ to $\frac{1}{2}$ inches of irrigation are applied after treatment, and applications are timed to coincide with early instar grubs.

Larval control (cultural)

There are no data on soil pH and its' effect on oriental beetle populations at this time but there have been surveys that reported average annual Japanese beetle grub populations ranging from 2.2 to 6.0 per square foot in soils with a pH less than 5.0 and from 0 to 0.6 grubs per square foot in neutral and alkaline soils. Adjusting soil pH between 6.5 and 6.8 will at least assist agronomically in growing a dense stand of turf and may help the turf withstand a grub infestation.

Larval control (chemical)

Larval control should be considered if sampling reveals eight or more grubs per square foot. More detailed information on monitoring grubs and making control decisions can be found in the August 1995 issue of *TurfGrass TRENDS.* Egg hatch may occur as late as mid-September in the Northeast; so continued monitoring throughout this period is necessary. Villani et al. (1988) found differential susceptibility of oriental beetle, Japanese beetle, and European chafer larvae to five soil insecticides, which

Field tips

Treatment of Grubs

by Steven R. Alm

Treat for grubs with insecticides anywhere from August 1 to Sept 7 in the Rhode Island area with the exception of *Merit*®, which can be applied from April 1st to August 15th. Make applications when grubs are at densities equal to or greater than 8 per square foot. *Triumph*® is a good choice for tees, greens, and aprons. However, *Triumph*® is extremely toxic to fish, so, make certain there is no chance to contaminate streams, lakes or ponds. Pay particular attention to the label irrigation requirements, since most labels require materials be watered in with $\frac{1}{4}$ to $\frac{1}{2}$ inch of water. Do not expect the chemical to control grubs in two to three days; you may not see significant mortality until 14-21 days after treatment. Since there is only one generation of beetles per year, a single fall application (or one spring - fall application with *Merit*®) is all that should be required.

indicates a need to develop species-specific insecticide recommendations for the white grub complex. In a laboratory soil bioassay, Diazinon provided good control of oriental beetle and European chafer grubs but very poor control of Japanese beetles. Chlorpyrifos (*Dursban*®) provided good control of Japanese and oriental beetles but very poor control of European chafers in the laboratory.

We know that chlorpyrifos binds to thatch and soil and is generally considered a better insecticide for surface feeding pests but is not as good on grubs as some other insecticides. Isofenphos (*Oftanol*®) provided a relatively low level of control against all grub species, while bendiocarb (*Turcam*®) provided intermediate control. Ethoprop (*Mocap*®) was effective against all three grub species. Field experiments in 1993 also demonstrated a high degree of control with Mocap®. Isazofos (*Triumph*®) and *Merit*® (imidachloprid) have been the most effective materials for oriental beetle grub control in our experiments in the Northeast. Trichlorfon (*Dylox*®, *Proxol*®) have also worked well in most experiments.

Dr. Steven R. Alm, is an Associate Professor of Entomology in the Department of Plant Sciences at the University of Rhode Island. He has degrees in entomology from the State University of New York, College of Environmental Science and Forestry, Syracuse University, and The Ohio State University. Dr. Alm's research program includes work with entomopathogenic nematodes, and other pathogens for use against turf and ornamental insect and nematode pests. This is his first contribution to *TurfGrass TRENDS.*

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Deciding on Control of Scarab Grubs

by Jan P. Nyrop and Dan Dalthorp

Grubs, more properly the larvae of scarab beetles (Japanese beetle, European chafer and Oriental beetle), feed below the soil surface. When they are abundant, management action must be taken to avert damage to turf.

Deciding on whether a grub population warrants application of an insecticide is no simple matter, however. These insects cannot be seen without digging in the soil, and their distribution throughout a planting is rarely uniform. Nonetheless, turf managers need to assess their abundance, and should be making treatment decisions on the basis of those assessments.

Rule-based treatment decisions for scarab grub infestations on golf course fairways and other large turf plantings

Golf courses have an abundance of irrigated, well-maintained turfgrass, interspersed with ornamental plants - an ideal beetle habitat. As a consequence, they frequently have potentially damaging grub populations somewhere on the grounds.

Decisions about managing grub populations on golf courses can be made at any of three different scales. At the coarsest scale, the decision is whether to treat the whole course for grubs or not to treat any of the course. At a medium scale, individual fairways are treated on a case by case basis, which requires sampling the soil to determine which fairways harbor grubs. At the finest scale, individual grub patches within fairways are identified and treated.

Each scale has advantages and disadvantages. Each might be appropriate under certain circumstances. Which is appropriate and which is selected should depend on the past experience of grub infestation at the course, the distribution of grubs in the year in question, and on the goals and preferences of the turf manager. In most cases, regardless of the scale selected, acquiring sample information as a basis for treatment decisions is a sound investment.

Information and techniques that can help managers determine whether a scarab grub population threatens a turf planting, and how best to cope with that threat appeared in an extensive, three section article in the August 1995 issue of *TurfGrass TRENDS.* The first section gives an overview of pest management decision making and the role in this process of information on pest abundance. The second section outlines a method for determining whether a significant scarab grub problem may exist on a site, and describes it's use in evaluating residential or other small turf areas. The final section addresses the use of that method in assessing scarab grub densities on larger turf plantings such as golf courses and golf course fairways.

Dr. Jan P. Nyrop is an Associate Professor in the Department of Entomology at NYSAES / Cornell University. He has degrees in wildlife ecology from the University of Maine and in systems science and entomology from Michigan State University. Dr. Nyrop's field of specialization is the population ecology of arthropod pests of horticultural crops and their natural enemies. He is currently researching the areas of biological control and decision making for integrated pest management.

Dan Dalthorp is a Ph.D. Student at the Department of Entomology at NYSAES / Cornell University. He has degrees in mathematics from Brown University and the University of Oregon, and has studied environmental systems at Humboldt State University (Arcata, CA). Mr. Dalthorp has been active in agricultural research and education in China and Guatemala.

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