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IN THIS ISSUE

Heat Stress Causes and Prevention

James B Beard

There is a lack of understanding concerning plant stress resulting from super-optimal temperatures. Thus, the thrust of this article is to provide an understanding of the heat stress kill mechanism and heat stress resistance, plus the cultural approaches for minimizing heat stress.

HEAT STRESS CAUSES

Heat stress is most commonly a problem with C_3, cool-season turfgrasses, especially when attempts are made to extend their use into the warm climatic regions. **Heat stress typically is most severe on turfgrasses under conditions characterized by extraordinarily high temperatures and high humidities that are sustained for several months.** Periods with an absence of wind movement further accentuate the stratification of high temperature and humidity levels near the surface of the turfgrass. Early summer high air temperatures with cool soil temperatures are not nearly as stressful as late summer periods when both the air and soil temperatures are at heat stress levels. This is because **a high soil temperature is the most critical heat pool affecting the turfgrass plant.** Also, regions with hot days and cool nights sustain cooler soil temperatures and less potential for heat stress.

Lethal heat stress results from the coagulation/destruction of the critical protoplasmic proteins in living cells. **Plant death of cool-season turfgrasses occurs at tissue temperatures of 104°F (40°C) and higher, depending on the particular species and cultivar.** The heat stress injury may be direct and acute, or indirect and more chronic in nature. Visual signs of injury from acute heat stress are first observed via cross sections of grass shoots as a darkened area at the junction of the leaf blade and leaf sheath of the second and third youngest leaves. A progression of plant stresses occur during chronic heat stress as follows:

Chronology of Progressive Chronic Heat Stress on Turfgrasses

- Increased rate of root maturation.
- Death of the roots.
- Decline in shoot growth.
- Cessation of new root growth.
- Reduced leaf length and width.
- Decreased rate of new leaf appearance.
- Leaves turn dark-green to blue-green.
- Death of leaves and shoots.
- Death of nodes on crowns/lateral stems.

HEAT STRESS RESISTANCE

Heat resistance is the ability to survive an externally imposed high temperature stress. When assessing research reports of heat stress resistance of turfgrass cultivars, it is important to understand that there are two types of heat resistance: (a) heat avoidance and (b) heat tolerance. **Heat avoidance** is the ability to sustain internal tissue temperatures below lethal heat stress levels via transpirational cooling. The higher the evapotranspiration rate of a cultivar, the greater the heat avoidance, assuming adequate rooting can be sustained for water uptake. In contrast, **heat toler-**

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ance is the internal physiological ability of the plant to survive high internal tissue temperatures, which is attributed to better thermal stability of heat sensitive enzymes and membrane integrity.

Turfgrass cultivars that exhibit improved heat resistance in low humidity environments, such as Arizona, California, or Kansas, may fail to exhibit comparable heat resistance in humid areas, such as Mississippi, Georgia, and New Jersey, if the resistance is only of a heat avoidance type. In contrast, turfgrass cultivars with good internal heat tolerance will exhibit this trait in both humid and arid climatic regions. This is an important distinction to understand in interpreting comparative heat resistance data among cultivars.

MANAGING HEAT STRESS

The approaches to **minimizing** the adverse effects of heat stress on turfgrasses are multi-dimensional. Note that if soil temperatures rise too high then turf stress and loss are inevitable. The first principle in any stress environment is to select those cultural practices that produce the most healthy plant shoot and root systems possible. Key cultural approaches to heat stress moderation include the following:

High-Sand Root Zone. Water has the highest heat accumulation ability of any material. Wet or water-saturated soils require more energy to warm up and a longer time to cool down. Thus, the construction of high-sand root zones to USGA Method specifications ensures maximum drainage of excess water and also **reduces the level of soil heat accumulation,** when compared to poorly drained, clayey root zones. Also, a high-sand root zone of the proper particle size distribution is sufficiently aerated to **allow deeper, more extensive root growth, thus allowing greater water uptake to support the high rates of evapotranspiration needed to sustain heat avoidance.**

Heat Tolerant Species and Cultivars. The C_4, warm-season turfgrasses are physiologically adapted for optimum growth at temperatures of 80 to 95°F (27–35°C). In contrast, the C_3, cool-season turfgrasses are physiologically adapted to optimum growth at temperatures of 60 to 75°F (16–24°C). The use of cool-season grasses beyond their adaptation zone may exceed their limit for season-long survival.

The heat resistance among cultivars within a species is quite variable for many turfgrasses. Certain turfgrass cultivars are promoted as heat tolerant when they are only heat avoiding in terms of their heat resistance mechanism. It is important when selecting heat tolerant turfgrass cultivars, especially for humid climatic regions, to obtain independent replicated research data under similar humid conditions in order to ascertain that the cultivar has demonstrated true heat tolerance rather than only heat avoidance.

High Potassium Level. Potassium (K) enhances rooting, which contributes to improved heat avoidance and also improves physiological heat tolerance of grass tissues. Chemical tests will provide the basis for selecting the appropriate potassium levels needed in the leaf tissue and the soil. When chemical soil tests show the potassium level to be in the high range, then apply potassium at 80 to 100% of the nitrogen rate being applied.

Modest to Minimal Nitrogen Level. Sufficient tissue nitrogen (N) levels should be maintained to ensure a healthy turfgrass plant, but it is advisable to avoid excessive nitrogen levels that force leaf growth and cause internal physiological reductions in heat tolerance.

Minimal Thatch or Mat. Preventive thatch and mat depth control encourages deeper rooting, thereby facilitating water uptake from a greater portion of the root-zone profile which in turn supports heat avoidance. The thatch control aspects may include vertical cutting, core cultivation, and/or topdressing.

Raised Cutting Height. A slight cutting height elevation, especially on putting greens, during severe heat stress periods may prove beneficial and has minimal effect on putting speed as the grass growth has been slowed. For

Relative Heat Hardiness of Nine Cool-Season Turfgrasses

Heat Hardiness Ranking	Turfgrass Common Name	Scientific Name
good	tall fescue	*Festuca arundinacea*
medium	colonial bentgrass	*Agrostis capillaris*
	creeping bentgrass	*Agrostis stolonifera*
	perennial ryegrass	*Lolium perenne*
	Kentucky bluegrass	*Poa pratensis*
fair	Chewings fescue	*Festuca rubra* var. *commutata*
	red fescue	*Festuca rubra*
poor	annual bluegrass	*Poa annua*
	Italian ryegrass	*Lolium multiflorum*
very poor	rough bluegrass	*Poa trivialis*

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FEATURE ARTICLE

There are Two Types of Anthracnose: Basal Rot and Foliar Blight

Peter H. Dernoeden

Anthracnose is caused by the fungus *Colletotrichum graminicola,* but some scientists believe that there may be more than one causal agent. The aforementioned fungus is a common saprophyte found colonizing thatch or dying plant tissues. Under conditions that remain unclear, however, *C. graminicola* behaves as a pathogen. Anthracnose is primarily a serious problem of annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) turf grown on golf courses. Anthracnose also has been reported to attack creeping red fescue (*Festuca rubra*), perennial ryegrass (*Lolium perenne*), and Kentucky bluegrass (*Poa pratensis*). The latter species, however, are seldom damaged severely. The fungus may cause either a foliar blight or a basal rot. Foliar blighting generally occurs during periods of high temperature and drought stress. Foliar blight is a distinct type or phase of anthracnose, which may or may not progress into basal rot. Plants affected by anthracnose also may be invaded by other disease agents, including those causing leaf spot, summer patch, or *Leptosphaerulina* blight.

The foliar blight phase of anthracnose which occurs during high temperature periods in summer, causes a yellowing or a reddish-brown discoloration and eventually a loss of shoot density. The distinctive fruiting bodies (i.e., acervuli) with protruding black hairs (i.e., setae) can be observed on green and discolored leaf blade or sheath tissue. The presence of large numbers of acervuli on dead tissue in thatch does not always indicate that healthy plants also are infected. Therefore, **it is important to carefully look on green or discolored tissue of living plants for the distinctive fruiting bodies**. For a positive diagnosis, send samples to a lab that specializes in turfgrass diseases. Most land grant universities provide good diagnostic services. The foliar blighting phase is easier to control, and perhaps is less common than basal rot in some regions.

Basal rot anthracnose can be extremely destructive to putting greens. Basal rot has become more commonplace in recent years, and now ranks as one of the most important diseases of greens. The increased occurrence of basal rot in creeping bentgrass can be attributed to the common practice of mowing extremely low, maintaining low nitrogen fertility, and imposing abrasive cultural practices (such as frequent topdressing, brushing, vertical cutting, etc.) in the summer to increase green speed. The disease occurs at varying times of the year and may produce different symptoms on different hosts. **Basal rot in annual bluegrass occurs during both cool periods in the spring, and during warm to hot periods of summer**. Anthracnose can remain active in annual bluegrass throughout mild winters. **Basal rot generally does not appear in bentgrass before mid-June**. The pathogen is much more invasive if it enters stem tissue through wounds. The disease often is associated with close mowing, soil compaction, intense traffic, and low nitrogen fertility. Prolonged periods of overcast and/or rainy weather can trigger or intensify the disease. Shaded and wet sites are particularly vulnerable.

In late winter or spring, infected annual bluegrass turf may appear as orange or yellow spots about the size of a dime (18 mm). Individual plants may have both green, healthy appearing tillers, and yellow-orange infected tillers. The central, or youngest, leaf is the last to show the yellow-orange color change. Removal of all sheath tissue to expose the stem base reveals a water-soaked, black rot of crown tissues where roots and new buds are produced. By May, the dime-spot symptom is less common, and infected annual bluegrass plants coalesce into large, nonuniformly affected areas, which appear yellow or reddish-brown. Huge areas may thin or die-out completely. The disease at this point may be confused with *Helminthosporium* melting-out or red leaf spot. Basal rot is extremely difficult to suppress where it becomes a chronic, spring problem on annual bluegrass greens.

In the summer, affected turf initially develops a reddish-brown color and thins out in irregularly shaped patterns several feet or more in size. Occasionally, circular, gray-brown patches can appear on putting greens. Annual bluegrass plants often turn a brilliant yellow before dying, and this symptom can be confused with summer patch. **When discoloration or thinning is first observed, managers are advised to carefully look on stem bases for the infection mats**, which during the early stages of the disease appear as small (pinhead-sized), black "fly specks." This will involve removing the leaf sheaths to expose the whitish inner sheath tissues or stem areas. **There will be no tell-tale signs of the pathogen on leaf blade or sheath tissue during the early stages of basal rot**. In advanced stages, black aggregates of fungal mycelium often are present on infected stolons or stem bases of creeping bentgrass and annual bluegrass. The spore-bearing acer-

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FEATURE ARTICLE

Managing Wasps, Hornets, and Yellowjackets in Turfgrass Settings

Daniel A. Potter

Wasps, hornets, and yellowjackets are a common nuisance and hazard on golf courses and in outdoor landscapes. Numerous people die each year from an allergic response to their painful stings. These insects are far more dangerous and unpredictable than honeybees. **Worker wasps foraging away from the nest usually are not aggressive, but the process of eliminating nests should be undertaken with great care and in a specific manner.**

General Biology and Habits. Wasps, hornets, and yellowjackets are social insects that live in nests or colonies. Mated queens overwinter under bark or in other sheltered locations. They emerge in the spring and begin constructing a small nest in which the first eggs are laid. The nest is made of paper-like material consisting of chewed wood fibers and salivary secretions. The first brood of wasps matures in about a month, emerging as nonreproductive females called workers. The workers assume all nest activities except egg-laying. Thereafter, the nest is enlarged and the colony grows rapidly, reaching maximum size by summer's end. Males and new queens are produced in the early autumn. After mating, the young queens seek out overwintering sites and the main colony dies off.

These insects generally are beneficial because they prey on other insects, including pests. There usually is no need to control a hornet nest located high in a shade tree or a paper wasp nest on a remote eave of a clubhouse. If the nest doesn't pose an immediate hazard, the best option usually is to leave it alone. The colony will die off naturally once the weather turns cold, and the paper nest disintegrates during the winter. Nests are not reused the following season. Control may be warranted, however, when the nest is located near areas of human activity.

Medical Importance. Wasps, especially hornets and yellowjackets, will sting if the nest is disturbed. Attacking wasps release a chemical "alarm pheromone" that causes nest mates to swarm to the defense. Unlike honeybees, the stinger is barbless so that each wasp can inflict multiple stings. In most people, stings result in localized redness and swelling. Treatment involves washing the wound to prevent infection, using an ice pack and/or oral pain relievers to reduce pain, and taking oral antihistamines. In the case of large, local reactions, elevation of the affected limb and rest also may be needed.

Some people are hypersensitive to wasp and bee venom, so that stings can be life-threatening. **People who have been stung and who experience a general allergic reaction (e.g., hives or rash) away from the site of the sting, dizziness, or difficulty breathing or swallowing should seek immediate medical attention.** Such persons may be in danger should they receive additional stings, regardless of whether these occur weeks, months, or even years later. Sting-allergic persons should ask their doctor about prescribing a kit containing syringes with epinephrine. In the case of a sting, they can give themselves an injection that may well save their life. Allergic persons also should consider immunotherapy, a series of injections to increase their tolerance to insect venom.

Paper Wasps. Paper wasps typically build their umbrella-shaped nests under eaves and ledges of buildings, or sometimes in shrubs or hedges. Adults are narrow-bodied, brownish with yellow or reddish markings, and about 5/8 to 3/4 in. (15–20 mm) long. **Paper wasps are less aggressive than hornets or yellowjackets. They're fairly easy to eliminate with the wasp and hornet sprays sold at grocery or hardware stores.** These products often can be sprayed from as far away as 20 ft (6 m). Although it is safest to treat all wasps at night, paper wasps can be controlled during the daytime *provided that you do not stand directly under the nest during treatment.* Most wasp sprays cause the insects to drop instantly, so standing under the nest increases the chance of being stung. Wait a few days after treatment to ensure that the wasps have been killed, then scrape or knock down the nest.

Hornets. Hornets are far more dangerous and difficult to eliminate than paper wasps. Baldfaced hornets, the most common species, are 5/8 to 3/4 in. (15–20 mm) long and black, with white markings on the face, thorax, and end of the abdomen. Hornet nests are made of gray, paper-like material and resemble a large bloated football. Nests are typically built in trees or shrubs, on overhangs, or attached to the outside of sheds or other structures. Hornet nests may contain thousands of wasps which become highly aggressive when disturbed. The nests are often located out of reach. **When deemed necessary, their removal is best accomplished by a professional pest control firm.**

Hornet nests should be treated *only at night* when most hornets are inside the nest and the colony is less

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active. Wear a full wasp suit, secured at the wrists, ankles and collar. Hornet nests have a single opening, usually at the bottom of the nest, through which the wasps enter and exit. Apply an aerosol-type wasp and hornet spray, or a dust formulation of carbaryl (Sevin®) or bendiocarb (Turcam®) directly into the nest opening. An extension pole that allows application of the dust or aerosol from the ground or from some distance away gives added safety to the applicator. **Only background lighting should be used (do not shine a flashlight into the nest opening during treatment).** Be especially careful not to break the nest, as this will cause the angry wasps to scatter in all directions. Following treatment, wait several days to ensure that all of the wasps are dead before removing the nest. If active hornets are still observed, the application may need to be repeated.

Yellowjackets. These are likely the most dangerous stinging insects in turf and landscape settings**.** The common name is based on their distinctive black and yellow color pattern. Like hornets, yellowjackets become extremely aggressive when their nest is disturbed. Nests often are located underground in old rodent burrows or beneath rocks or landscape timbers. Yellowjackets also build nests in rock walls, or in walls, attics, crawlspaces, garages, sheds, or other structures. **If the nest can be located, the colony usually can be eliminated by applying an aerosol wasp spray into the nest opening.** Dust formulations (e.g., carbaryl or bendiocarb) also are effective provided that a hand duster or similar-type applicator is used to puff the insecticide into the nest opening. A dry, empty detergent bottle filled no more than halfway with dust, and shaken before dispensing works well. A few pebbles can be added to the bottom of the container to prevent caking.

Elimination of colonies should be done only at night, when most of the yellowjackets are in the nest and less active. Locate the nest opening during daylight so that you'll know where to direct the treatment after dark. **As with hornets, a full protective wasp suit should be worn.** Approach the nest carefully, using indirect light. Do not shine your flashlight into the nest opening as this will startle the wasps. If possible, place the light on the ground, to one side, rather than holding it because the angry wasps tend to fly toward light. A long string attached to the handle is helpful for recovering the flashlight when the job is done. If access to the nest is difficult, it's usually best to call an experienced pest control operator.

Yellowjackets' tendency to scavenge for food causes them to become pests around outdoor food concessions, picnic sites, and similar areas. Contact with humans peaks in late summer and autumn, when the colonies are nearing maturity and thousands of workers are out foraging for food for the developing queens. At that time, feeding preferences shift in favor of sugary foods which include fruits, beer, soft drinks, and other sweets. Golf superintendents and grounds managers can take steps to reduce hazards of people being stung.

The best way to reduce problems with foraging yellowjackets is to limit their access to attractive food sources. Equip trash cans with a tight-fitting (preferably self-closing) lid, fitted with a plastic liner, and empty and clean them often. Dumpsters and trash cans should be located away from concession and picnic areas to the extent that it is practical. Clean up spills and leftovers promptly. Maintaining good sanitation earlier in the summer will make areas less attractive to foraging yellowjackets later on. A dilute solution of ammonia—6 oz of ammonia per gallon of water (50 mL per liter)—sprayed in and around trash cans, and sponged onto outdoor tables and food preparation surfaces may help to repel yellowjackets from these areas. Use household ammonia, not bleach.

People eating outdoors should keep food and beverage containers covered. Yellowjackets foraging away from the nest usually are not aggressive and will seldom sting unless provoked. People should resist the urge to swat at the wasps—and be careful when drinking from beverage cans that may contain a foraging wasp. Diet drinks seem to be less attractive to wasps than drinks with sugar.

Cicada Killers and Sand Wasps. Cicada killers are very large wasps, up to 1-5/8 in. (40 mm) long, that resemble gigantic hornets or yellowjackets. They have a rusty red head, amber-yellow wings, and a black abdomen with pale yellow stripes. **These wasps attract attention because of their menacing appearance, burrowing habits, and buzzing flights that alarm golfers and homeowners.** Fortunately, they rarely sting unless handled, stepped upon with bare feet, or otherwise provoked.

Cicada killers prefer to nest in areas of full sun, scant vegetation, and coarse-textured, sandy, well-drained soils. The female wasp digs numerous burrows about 1/2 in. (12.5 mm) across, 6–9 in. (15–23 cm) deep, and vertical or slightly angled, with several secondary tunnels, each ending in a brood chamber. Excess soil is pushed out of the burrow, forming a U-shaped mound around the entrance. Each female excavates numerous burrows which are provisioned with cicadas that she hunts down and incapacitates with her sting. She drags the paralyzed cicada into the burrow, lays an egg on it, backs out, and seals the cell.

Cicada killers may form aggregations with numerous individuals nesting in the same area. However, each female digs and provisions her own burrows. Males usually emerge first and patrol the nesting area, awaiting emergence of virgin females and driving away any rival males. They buzz-bomb any intruder, sometimes hovering about

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Heat Stress...

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example, raise the height to from 5/32 to 3/16 in. (4.0–4.8 mm), being sure to lower the cutting height to the original level once the heat stress has subsided.

Mower Selection. On putting greens, switch to a walking greensmower from a triplex unit during the severe heat stress period and/or change to a solid roller to lessen wear stress when shoot growth recovery is impaired by heat stress.

Syringing for Heat Stress Avoidance. Syringing is the application of a very light amount of water in which only the leaves are wetted and few water droplets move off the leaves. It can be **used for the purpose of cooling the turf canopy.** It has the potential of reducing temperatures in the order of 10°F (5.5°C), if applied 1.5 to 2 hours before maximum mid-day temperatures, which typically occur around 2:00 p.m. A low atmospheric humidity adjacent to the turf canopy maximizes the evapotranspirational cooling. In hot, arid regions, such as Arizona, syringing during mid-day heat stress has been used to maximize heat avoidance through high evapotranspiration rates. Unfortunately, this method of heat avoidance may be of limited benefit in humid climatic regions during periods of high humidity. **Syringing also is used to correct a developing tissue water deficit,** thereby avoiding stomatal closure and subsequent elevation of tissue temperatures to lethal levels.

Enhanced Air Movement. Air stagnation on putting green sites, especially when surrounded by trees in the direction of the prevailing wind, accentuates the stratification of higher temperatures and higher humidities near the turf canopy. This in turn accentuates heat build-up in both the turfgrass canopy and root zone, plus the environment for certain disease pathogens is more favorable.

If a tree-shrub barrier is the primary problem, then **cutting an opening in the direction of the prevailing wind usually proves beneficial.** Air stagnation also can be significantly reduced through the mixing action achieved by mechanical fans, especially in hotter climates. This author conducted the first research in the late 1950s demonstrating the value of fans in reducing heat levels on bentgrass putting green turfs. A 14°F (7.8°C) cooler turf temperature was achieved by the use of a fan that produced a 4 mph (6.4 km hr^{-1}) air movement.

Fans may be used around selected putting greens where the surrounding trees and shrubs and/or low site placement with higher surrounding hills cause serious restrictions in air movement. The development of the best possible mechanical fan design is still evolving. Some criteria to consider in selecting fans include:

- Noise level generated—a 54-in. (137 cm) diameter fan is 50% more quiet than a 48-in. (122 cm) unit, due to a lower blade velocity.
- Effective distance—a longer effective distance allows placement of the fans from 40 to 50 ft (12–15 m) away from the perimeter of the putting green.
- Effective pattern—the wider and longer the better, up to an associated air velocity of 4.5 mph (7.2 km hr^{-1}).
- Relative obtrusiveness—color, distance from green, height above turf, and bulk size all influence just how harmoniously fans blend with the surrounding environment.

Fans also will become more frequently used in sport stadia constructed with an erect, tall, fully enclosed seating design.

...Wasps, Hornets...

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or flying into a person's head or back. Fortunately, males cannot sting, and the females are quite docile and do not defend their burrows. **However, the mounds themselves are unsightly and can smother patches of grass.**

Sand wasps are similar to cicada killers, but smaller. These fast-flying wasps are about 13/16 to 1 in. (20–25 mm) long and dark-colored, often with pale-green markings. Sand wasps nest in sandy areas, usually in colonies, and stock their nests with various kinds of insect prey. Unlike cicada killers, their brood burrows are not completely provisioned before egg-laying, and the young are fed as they grow. Although the wasps aren't aggressive, they're quite a distraction when they nest in golf course bunkers, playground sand boxes, sand-based volleyball courts, and similar sites.

Like most wasps and bees, cicada killers and sand wasps are highly susceptible to carbamate insecticides. Small infestations can be controlled by dusting the burrow openings with carbaryl or bendiocarb to kill the females as they engage in nesting activities. Broadcast applications are effective when many nests are present. Cruising males can be whacked with a tennis racket, which may suffice to end complaints by golfers.

Daniel A. Potter is Professor of Turf and Landscape Entomology at the University of Kentucky. This article is adapted from a section of his new book, "Destructive Turfgrass Insects: Biology, Diagnosis, and Control," *which is available from Ann Arbor Press.*

...Anthracnose...

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vuli with short, black hairs and the black mycelial aggregates can be seen on stem bases and stolons without a hand lens. **Once acervuli develop on leaf sheath or blade tissue, the basal rot phase is advanced and plants generally die**. For mysterious reasons, the disease seldom attacks both annual bluegrass and creeping bentgrass on the same green or even on the same golf course.

MANAGEMENT

Basal rot is very difficult to control once the turf shows signs of thinning. This is especially true when annual bluegrass develops the disease in April or May. To alleviate basal rot, use walk-behind greensmowers and increase the height of cut immediately. Divert traffic away from affected areas by moving holes frequently. When the disease is active avoid topdressing, rolling, double mowing, core cultivation, brushing, vertical cutting, and other potentially abrasive practices. This is because **the pathogen often enters plants more easily through wounds**. In the autumn, after symptoms have dissipated, core cultivate and overseed. Water from irrigation should be applied only as needed to prevent wilt. A modest application of nitrogen (0.15 to 0.25 lb N/1000 ft^2 or 0.07–0.13 kg/100 m^2) combined with a fungicide, such as chlorothalonil (Daconil 2787®) tank mixed with either azoxystrobin (Heritage®), fenarimol (Rubigan®), propiconazole (Banner®), thiophanate (CL 3336® or Fungo 50®), or triadimefon (Bayleton®) should help reduce, but not eradicate, the disease. **For curative sprays, always include a high label rate of chlorothalonil in the mixture.** Two or more applications at a 10- to 14-day intervals may be required to arrest the disease.

Where basal rot is a chronic problem on greens, tees, or fairways, fungicides should be used preventively in combination with an improved nitrogen fertility program. Moderate nitrogen levels (3.0 lb N/1000 ft^2/yr or 1.5 kg/100 m^2/yr) are associated with less foliar blighting by anthracnose, especially when fungicides such as azoxystrobin (Heritage®), propiconazole (Banner®), thiophanate (CL 3336®, or Fungo®), or triadimefon (Bayleton®) are used preventively. Affected greens should be spoon-fed with nitrogen (i.e., 0.1 to 0.2 lb N/1000 ft^2 or 0.05–0.1 kg/100 m^2) **every 2 to 3 weeks throughout the summer. In extreme cases, greens that consist mostly of annual bluegrass that are chronically infected may have to be fumigated**. Similarly, for fairways and other large areas that are chronically affected it is best to eliminate annual bluegrass and renovate with less susceptible, regionally adapted grasses such as Kentucky bluegrass, perennial ryegrass, zoysiagrass, or bermudagrass. **Basal rot is less common in bentgrass grown on fairways and tees**. When treated during the early disease stages, bentgrass fairways and tees often recover in a reasonable amount of time. However, if the disease is allowed to progress to the point where stem bases are blackened before an appropriate fungicide(s) is applied it can be just as destructive as on greens.

Summary: It is important to note that there usually is no blighting of leaves during the early development of basal rot. The foliar blight phase can occur with or without progression to basal rot. Hence, there are actually two distinct types of anthracnose. Greens affected with anthracnose often respond favorably to chlorothalonil tank-mixed with one of the aforementioned penetrants. Where foliar blight or basal rot is a chronic problem, the aforementioned fungicides should be applied preventively, nitrogen should be applied at low rates throughout the summer, mowing height should be increased, and grooming practices should be avoided when the disease is active. Because they have no effect on *C. graminicola,* it is best to avoid applications of iprodione (Chipco 26019®), vinclozolin (Curalan®, Touche®, Vorlan®), and flutalonil (ProStar®) whenever anthracnose is active.

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JB COMMENTS

Diagnosing Summerkill

A wide array of environmental, biological, and soil stresses can occur during the summer period which fall under the general descriptive term of summerkill. To impose proper cultural practices that minimize the potential for injury from these various stresses, it is important to properly diagnose the specific stress or stresses most likely to occur during various parts of the summer in a given location. **Unfortunately, there are too many turfgrass managers who attempt to solve summerkill turf problems by simply removing pest protection chemicals from the shelf and applying at intervals as close as two days.** Typically, this is done without having properly diagnosed that a pest problem exists. Evidently these turfgrass managers are having difficulty accepting that summer turf loss can be the result of an environmental stress rather than a turfgrass pest.

In recent years the term bentgrass decline has been popularized. An array of causes have been attributed to this problem, frequently with emphasis on certain diseases. While many of these potential stresses can contribute to a reduction in the amount of root and shoot biomass, they are not necessarily the keys to avoiding summerkill. **In many situations, heat stress is the dominant problem that must be addressed. It should be noted that serious root loss and turf thinning occur in bentgrass (*Agrostis* spp.) at soil temperatures above 86°F (30°C).** This was well researched in the late 1950s.

I frequently get phone calls from around the United States and the world concerning problems being experienced with summerkill. Typically, they are trying to describe symptoms and asking what disease problem it might be. When I ask them for the specific soil temperature on the site where the problem is occurring, the typical situation is silence. In other words, there has been no attempt to monitor soil temperatures. If this has not been done, it becomes very difficult to properly diagnose a summer turf problem. Thus, the lead article on heat stress in this issue is very important, especially during this 1998 summer of extraordinarily high temperatures early in the growing season.

RESEARCH SUMMARY

Leaf Mulching Effects on Turfgrasses

Disposal of fallen tree leaves during the autumn period is an annual problem which requires substantial labor and cost for removal and disposal. It has been estimated that a woodland will drop approximately 3,000 pounds per acre per year (3,360 kg/ha/yr) of tree litter. The objective of the study was to assess the long-term effects of tree leaf mulching into a turf canopy of perennial ryegrass (*Lolium perenne*). Shredded leaves from maple (*Acer* spp.) trees were applied at rates of 0, 2,000, and 4,000 pounds per acre (0, 2,240, and 4,480 kg/ha). The experimental areas received irrigation as needed to prevent visual plant water stress. The experimental assessments included (a) monthly weight of clippings produced, (b) monthly visual turfgrass quality and color ratings, and (c) annual thatch depth, soil pH, and soil nutrient levels.

Following three years of leaf mulch treatments and turf-soil assessments the results of this study are as follows: The tree leaf mulching had no effect on:

- visual turfgrass quality
- visual turfgrass color
- turfgrass growth measured as clippings weight
- thatch/mat depth
- disease incidence
- weed invasion
- soil pH
- soil nutrient levels

Thus, the results after three years indicate there have been no significant negative effects on turfgrass growth. This suggests that mulching tree leaves into a turf canopy is an economical method of disposal. This study will be continued for three more years during which these turfgrass responses will be assessed for any subsequent longer-term effects that may emerge. **By A. Reicher and G. Hardebeck, 1997 Annual Report of Purdue University Turfgrass Science Program, B-771, p. 19.**

ASK DR. BEARD

Q *How can one distinguish between turf loss by heat stress versus water stress?*

A **It is very difficult to distinguish the cause of death in midsummer between heat and water stresses,** even though they are distinctly different in terms of their mechanistic cause. For example, during heat stress, one of the first occurrences is dieback of the root system at temperature above 86°F (30°C) with no new root initiation and replacement. Subsequently, during periods of high evapotranspiration, an internal plant water stress develops because the turf water loss by evapotranspiration is exceeding the rate of water uptake through the root system. Physiologically, one of the first changes as an internal plant water stress develops is closure of the stomata. On hot days the internal leaf temperature can rise to acute lethal levels above 104°F (40°C) within 30 to 60 minutes after stomatal closure. **In this situation the final cause of death was heat stress, but it was induced as a result of an internal plant water deficit.** This indicates that maintaining a positive plant water balance can be important in minimizing certain types of heat stress.

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