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IN THIS ISSUE

Heat Stress Causes and Prevention

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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

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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*

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.

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