It's Too Darn Hot! High Temperature Stress and Turf Health

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The National Climatic Data Center recently reported that July, 1998 was the hottest recorded month on earth ever, and that this July was the seventh month in a row that was hotter than the previous year (San Diego Union Tribune, August 11, 1998). The enclosed insert will give you an idea of how hot the summers have been in several California locations over the past six years.

Why the concern over hot summers? The answer, of course is that cool season greens become stressed and ultimately die when turf canopy temperatures get too hot. In this issue of *PACE Insights*, we will describe the factors that lead to turf heat stress, and some strategies to help prevent it.

Heat Kills: For each turf variety, there is a range of temperatures in which optimum growth occurs. As temperatures increase above this range, however, the turf gradually becomes stressed, and if temperatures keep climbing, the plant will die. When temperatures first begin to go above the optimum range, root growth rates decrease, leading to a slow down in turf growth. Eventually, if temperatures get high enough, plant growth will completely stop. As a result, turf begins to thin, and frequently turn a darker color. As temperatures increase even further, large patches of turf begin to turn brown or white as the turf -- shoots, roots and crowns -- gradually dies. The cause of death resides within the cells of the turf plants, where proteins (known as enzymes) that are critical to the plant's survival become destroyed by heat in a process known as denaturation -- the same process that occurs when an egg is fried.

Turf Canopy Temperatures: Why Are They So Important? The turf canopy refers to the small area defined by the verdure (turf foliage) above the thatch area. It is the temperature in this area which makes the difference between life and death for turf. Unfortunately, there is little agreement in the scientific literature on which canopy temperatures will result in death of each turf variety. Based on our field research and observations, however, we have been able to come up with some rough estimates. For *Poa annua*, canopy temperatures of 115°F for two hours or more will result in death, while bentgrass is a bit more heat tolerant, with a canopy temperature of 120°F for two hours its **thermal death point**. We suspect that lower canopy temperatures for longer periods of time can also cause irreversible plant damage. In other words, four hours at a canopy temperature of 110°F might cause the same damage as two hours at 115°F would cause. It therefore seems obvious that preventive cooling strategies that lower the temperatures in the turf canopy -- must be taken **before** these critical temperatures are reached. Based on our observations, preventive actions (discussed below) should be taken when air temperatures reach about 90°F, or when turf canopy temperatures reach 100°F or 105°F for *Poa annua* or bentgrass, respectively (see Figure 1). These are rough numbers, empirically developed, and need much refinement, but should help provide some guidelines until more data is available.

Factors That Influence Turf Canopy Temperatures: We frequently assume that air temperature is a good indicator of turf canopy temperature, but this is not always the case. While turf canopy temperatures generally run 10-15°F higher than the air temperature during the peak heat of summer, this rule of thumb can be very misleading. This is because other factors such as relative humidity, soil moisture, wind speed, and even compaction can affect turf canopy temperature (Table 1). It is for this reason that on any given golf course, some greens will fail during hot weather, while others will not. For example, turf canopy temperatures may reach the plant's thermal death point on greens that are surrounded by trees, or are situated in a low spot where air movement is low, while on other greens with better air movement (wind speeds that sometimes go above 4 mph) the turf will look fine, despite high air temperatures.

Table 1. Factors which can increase turf canopy temperatures (DiPaola and Beard, 1992).

Factor	Effect on turf canopy temperature
air temperature	As air temperature increases, canopy temperature increases
humidity	As humidity increases, canopy cooling efficiency is reduced
soil moisture	If plants are drought stressed, canopy cooling efficiency is reduced
wind speed	Canopy temperatures increase if air movement is restricted
compaction	Highly compacted areas have higher canopy temperatures

There are therefore risks to using air temperature as your only indicator of turf canopy temperature. Most importantly, greens with poor air movement, that are stressed due to drought or other factors (high salts, low fertility, etc.) or that are compacted may fail even when air temperatures are only in the low 90s. This is because these other factors have the effect of raising turf canopy temperatures significantly -- more than the 10-15°F rule of thumb guide given above. In these situations, using air temperature as the only indicator of turf canopy temperature would convince us that turf

canopy temperatures were low enough, and that everything was fine -- even when it wasn't. The result? Dead greens.

Measuring soil temperatures as an indicator of turf canopy temperature can likewise be misleading. This is because soil temperatures tend to increase very slowly, while turf canopy temperatures can change quite rapidly. Therefore, relying on soil temperatures would likely give you a rosier picture (more stable, lower temperatures) than actually exists within the turf canopy.

Monitoring Turf Canopy Temperatures: Equipment

Regular monitoring and recording of air and soil temperatures is already hopefully part of your turf management program. If you have suffered from heat related stress problems in the past, we strongly suggest that you enhance your management program by including a monitoring program for turf canopy temperatures and wind speeds during the summer months. These are relatively easy procedures that require a minimal financial investment ($200-$300), and can provide gratifying returns. The equipment that you'll need is described below.

Bead thermocouple: The small size of this thermocouple allows more accurate readings of actual turf canopy temperatures. Larger probes which are good for measuring soil or air temperatures may change the temperature in the small area you want to measure and/or measure temperature in the wrong spot. Two pieces of equipment are required: a thermometer (Thermometer mini-K, Grainger part # 1M934: $79) and a bead thermocouple (Grainger part # 1T322: $13.20). Grainger's can be reached via their web page (www.grainger.com) or by obtaining their local warehouse number from your phone company information service.

Turbometer: This piece of equipment (available from Ben Meadows [800-241-6401] part 110958, $123.95) is used to measure wind speed. Use it to identify or confirm those greens with the poorest air movement by measuring wind speeds at one or more specified times of day during the course of the summer.

Bound notebook and ball-point pen: Maybe this goes without saying, but the benefits of monitoring are only as good as your ability to read and understand your measurements months, and even years later. When it doubt, write it down!

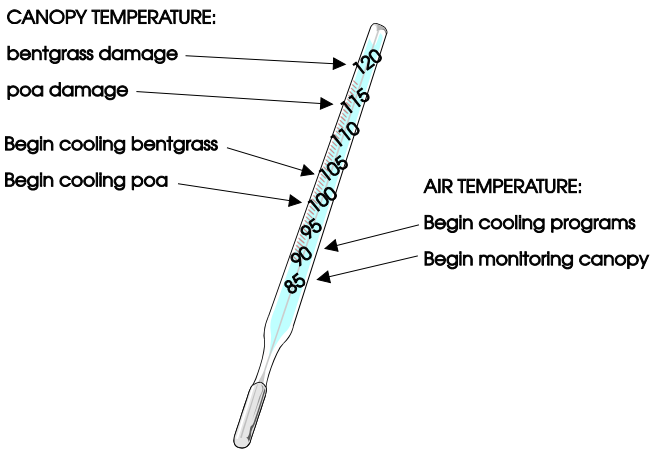
A Temperature Monitoring Program for Your Golf Course

1. If you aren't already monitoring air temperatures, now is a good time to begin, either via your weather station, or by taking daily readings, at the same time (the hottest time of day is best) and same place each day (an area out of direct sunlight is best).
2. Select a minimum of three greens where you will do the bulk of your turf canopy monitoring. Your best bet is usually to choose those greens that have failed in the past during hot weather.

Begin turf canopy temperature monitoring when maximum air temperatures for the day reach 85°F. Monitor and record turf canopy temperatures every day that the maximum air temperatures reaches 85°F or higher. The hottest time of day (about 2:00pm) is best.

3. To measure turf canopy temperatures, make measurements during the hottest part of the day (usually around 2:00 pm in most areas). Place the bead in the area between the base of the foliage and the top of the thatch layer. Allow a few moments for the thermometer to equilibrate, and for the reading to remain stable. Record the readings in a hard bound notebook, with a ball-point pen, so that your records remain legible for years to come.
4. Begin preventive cooling programs (see below) when turf canopy temperatures reach 100°F or 105°F for poa and bentgrass, respectively (Fig. 1).
5. If you are unable to regularly monitor turf canopy temperatures, monitoring air temperatures is a distant second choice, but still much better than not monitoring at all. Preventive cooling programs should be initiated when air temperatures reach 90°F in most cases, but you need to remain aware of the weaknesses of relying completely on air temperature, as described above.
6. A quick test for turf canopy temperatures, in the event the bead thermocouple isn't available, is to place the flat of the palm of your hand on the turf surface. If the surface feels warm, the canopy temperature is probably above 98°F (your body temperature) and therefore close to, or within the danger zone of 100°F - 105°F.

Figure 1. Critical air and turf canopy temperatures (°F) for managing heat stress to cool season turf.



Preventive Cooling Programs: When turf canopy temperatures reach 100°F (for poa greens) or 105°F (for bentgrass greens), one or more of the preventive actions below should be taken until canopy temperatures drop below these trigger points.

Fans and blowers: In hot weather areas of the country such as Palm Springs, fans are relatively common and reliable tools for reducing turf canopy temperatures, but elsewhere in California they are relatively unknown. They are particularly useful on greens with low air movement and/or greens that don't drain well. In these situations, fans have been observed to decrease turf canopy temperatures by 10°F or more when they are situated correctly (two to four fans are usually required per green, depending on the size, conformation and surrounding areas of the green). Although fans are a large investment, they should be considered for golf courses where heat stress has resulted in greens failures on a regular basis. A variety of commonly used fans are available from Patterson Fan (Blythewood, SC 800-768-3985) and other suppliers. If you are located in an area where temperatures get into the dangerous zone only occasionally, or if your greens are not wired for electricity, or if you budget simply won't withstand the purchase of fans, you may want to consider the use of leaf blowers, or tractor mounted blowers as a stopgap measure. While these measures are not practical (from a time and labor efficiency standpoint) when used on a regular basis, they can simulate the effects of fans in hot spots on the golf course during the occasional hot spell.

Syringing: Frequent irrigation of greens for short periods of time can produce significant (a decrease of 10°F or more) cooling of the canopy, especially when there is sufficient (4 mph) air movement, either from wind or fans (Duff and Beard, 1966). The amount and frequency of syringing will vary from course to course depending on your irrigation system, weather patterns and drainage. To determine how frequently syringing is needed at your location, select a green with high canopy temperatures, and use the bead thermocouple to determine canopy temperatures before and after a single syringe cycle. Check the canopy temperature every 10 or 15 minutes after this initial syringe to determine how long it takes for the canopy temperature to climb back to the 100-105°F danger level. This period of time then becomes your syringing frequency. For example, if it takes 1 hour for turf canopy temperatures to rise again to 100-105°F, then your syringe cycles should be 1 hour apart.

While the benefits of syringing as a preventive action are clear, there is also a risk -- of enhanced plant disease due to increased moisture on the surface of the green. For this reason, a strict preventive fungicide program needs to be in place before any syringing program begins, with a particular emphasis on pythium and algae control. In addition, aerification using 1/4 inch solid tines will increase the benefits of syringing by providing gas exchange, and therefore preventing the anaerobic conditions that can otherwise develop as the result of syringing.

The Role of Nitrogen Fertilization in Heat Stress

There is an old adage that heat stress can be avoided by keeping greens "lean and mean" -- in other words, by maintaining low soil nitrogen levels. However, there is little or no evidence to support this claim. Instead, we now know that turf health, and therefore turf response to heat stress, is enhanced by the proper balance and the proper composition of nitrogen in the soil. Both too little nitrogen or too much nitrogen can spell trouble. And the presence of high levels of ammonium may make matters even worse (see October, 1997 *PACE Insights*, "Nitrate Fertilization for Improved Root Health"). The guidelines below should help you promote turf health as well as avoid the anaerobic conditions and high ammonium concentrations than may cause root damage during the hot summer months.

- Increase oxygen levels in the soil with spring aerifications (core aerification with 5/8" tines, vertidraining, sand topdressing) In addition, conduct monthly aerations with small (1/4" - 3/8") hollow core or solid tines.
- Obtain regular soil analyses, particularly on problem greens. For optimum turf health, maintain total soil nitrogen levels at less than 20 parts per million (ppm). Nitrate levels should range between 3 - 20 ppm, and ammonium levels should be less than 7 ppm. There should be at least three times as much nitrate as ammonium in the soil.
- To fertilize greens in the hot summer months, spray applications of low rates of nitrogen is the safest bet (not more than 1/4 lb N/10000 sq ft per week).
- Application of nitrate nitrogen (as opposed to ammonium or urea based nitrogen products) during the peak heat of the summer will lessen the possibility of ammonia damage.

Experiments to Conduct on the Golf Course

Using the equipment described above, we have designed some experiments that you can conduct and that will demonstrate the effect of air movement, solar radiation, turf health and syringing on turf canopy temperatures. These experiments can be easily conducted, and in addition to adding to your store of knowledge about the conditions on your course, can be used to illustrate the impact of heat on turf health to Greens Committee members and the like.

The effect of air movement on turf canopy temperatures: Select a green and a day when wind speeds vary from 0 - 4 or more mph, and turf canopy temperatures are 90°F or more. Leaving the bead

thermocouple in one area of healthy turf, record the turf canopy temperature when wind speeds are 0 mph (as determined using the Turbometer described above) and when wind speeds are 4 mph or higher. What effect did wind have on your turf canopy temperatures? We usually expect to see roughly a 10°F drop in turf canopy temperatures when wind speeds go from 0 mph to 4 or more mph. This demonstration may convince you and your management of the utility of fans, particularly on greens with poor air movement.

The effect of syringing on turf canopy temperatures: As described below, periodic syringing of greens during the hottest time of day can reduce turf canopy by several degrees. To investigate this, select a healthy area of turf that has not been recently irrigated, and where canopy temperatures are 90°F or more. Measure turf canopy temperatures before and after you apply a small volume of water to the area. Try to take temperatures when wind speeds are moderate (2 - 4 mph). How much of a drop in canopy temperature did you observe following syringing?

The effect of turf health on turf canopy temperatures: Locate three different areas on the green: regions of stressed (wilting, thinning or browning), but still living turf; regions of dead turf; and regions of healthy turf. Measure the turf canopy temperature in each of these three areas. This experiment should demonstrate the importance of healthy turf in regulating canopy temperatures. As turf becomes more and more stressed, it loses its ability to transpire -- the plant's way of regulating temperature. By the time the turf finally dies, canopy temperatures can get so high that re-seeding efforts are inhibited, simply because the soil and thatch are too hot for germination and growth to take place.

The effect of solar radiation on turf canopy temperatures: Select a warm, sunny day with little or no cloud cover, and when turf canopy temperatures are over 90°F for this experiment. Place the bead thermocouple in a healthy area of turf, and record the temperature when the turf is unshaded. Now, place yourself or another object in the path of the sun so that the turf becomes shaded in the area where you placed the thermocouple. How many degrees does the turf canopy temperature drop when there is no direct solar radiation? This type of cooling mechanism explains why areas of a green that receive afternoon shade frequently have the healthiest turf during the summer months.

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