BY CHRIS HARTWIGER

Made in the shade or mud in the shade?

Sunlight assessment is a key to success with ultradwarf Bermudagrasses.

Trees and turfgrass are like brothers. Give them ample space to grow and they get along just fine. Put them together in a small bedroom and the bigger one is going to dominate. Just like finding a proper distance between brothers is a key to harmony, trees and turf must have adequate space, too. If they are too close together, the trees will out compete turfgrass for growth-related resources like sunlight, water, and nutrients. Spaced appropriately, trees and turf will get along just fine, too. Ultimately, finding the proper distance to allow both trees and turf to flourish is an agronomic challenge on many golf courses.


Planting trees too close to a putting green can result, years later, in levels of shade that hinder turfgrass growth, particularly ultradwarf Bermudagrasses.

In the Southeast Region, most golf courses have identified and corrected shade problems through trial and error. This could be called "after the fact" or "reactive" shade management. It typically works this way. Certain putting greens on a given course develop poor turf quality over a period of years. Shade is identified as a limiting factor. Protests about protecting the trees ensue. The protesters eventually capitulate under the weight of factual evidence and the desire to have acceptable turf quality on the putting greens. Trees are removed, and turf quality on the putting greens improves. All in all, this model has worked well, and today many golf courses have dealt with their shade issues.

The recent trend in the Southeast to replace creeping bentgrass on putting greens with an ultradwarf Bermudagrass does not lend itself to an "after the fact" or "reactive" shade management program because ultradwarfs do not tolerate shade well. A "before the fact" or "proactive" shade management program is desired because officials at courses want to know if their putting greens receive enough sunlight to sustain an ultradwarf Bermudagrass.

This article will help golf courses assess shade levels on their putting greens prior to a conversion from bentgrass to an ultradwarf. Golf courses with an ultradwarf presently will be able to use this information in case there is a need to address existing shade problems. In this article, some basics of plant physiology are reviewed, and important terms that will be used during site assessment are defined. Practical tips for proactively addressing shade will be presented.

HOW PLANTS GROW. Plant growth is a highly complex and ordered process. Plant growth requires energy, and the source of that energy is the sun. Light is the mechanism for energy transfer from the sun to the plant. The term irradiance (radiant energy) refers to the energy received on a specified surface, or, in our case, on the plant's leaf (Beard, 2002). Turfgrass plants receive the sun's energy via tiny particles called photons. The plant converts the radiant energy it receives into chemical energy through the process of photosynthesis.

Turfgrass plants are selective about the type of light (solar radiation) they require for plant growth. They absorb the bulk of their energy in the visible light range (400 to 700 nm) of the electromagnetic spectrum. This range is referred to as photosynthetically active radiation (PAR). Plant pigments such as chlorophyll molecules each have optimum absorption ranges. PAR in the ranges of 400-500 nm (blue light) and 600-700 nm (red light) is the most important for plant growth. PAR in the range of 500-600 nm (green light) is basically inactive for plant growth (Bell, Danneberger, and McMahon, 2000). The human eye detects light best at about 550 nm. Therefore, the light the human eye is good at detecting is the light that has no value for plant growth. For a graphical look at ranges of light absorption for plants, refer to Figure 1.

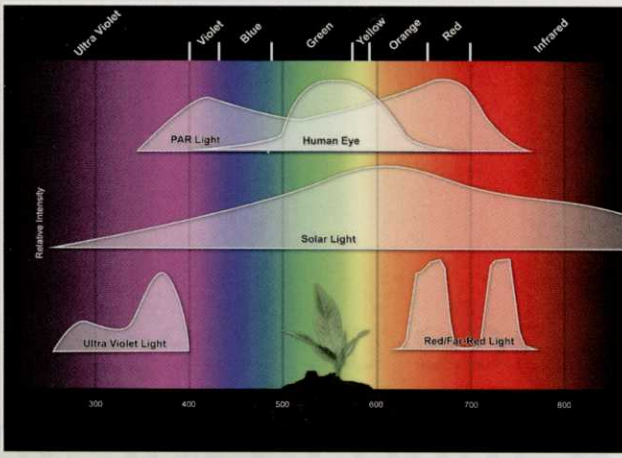

Figure 1: Ranges of light absorption for photosynthesis in plants. Note that the area where visible light for humans is greatest, it is of least value to plants. Therefore, light levels detected by the eye are not a good predictor of light levels used by plants for photosynthesis.

LIGHT QUALITY. Light particles (photons) have different energy levels as determined by their individual wavelengths. Light quality refers to the spectral distribution of light, or the relative number of photons in each portion of the light spectrum (visible and invisible) emitted from a light source.

Outside, the different shade sources have different effects on light quality in terms of plant growth. Shade from clouds and shade cloths in research are considered to be spectrum-neutral. They filter out all wavelengths of light equally. Shade from trees is not spectrum-neutral, and it changes the ratio of blue light to red light, which can affect plant growth. There have been conflicting research data regarding differences to turfgrass growth between deciduous and conifer induced shade, but research on turfgrass at Ohio State University showed no difference in spectrum response between deciduous and coniferous trees (Bell, Danneberger, and McMahon, 2000). This article will not resolve this conflict, so for the purpose of this article, no distinction is made between different types of trees and their impact on light quality.

LIGHT QUANTITY. Given that trees are the most common means of shade on golf courses, the quantity of light becomes the most pressing question. It would be nice if shade could be evaluated strictly in terms of the number of hours of direct sunlight needed, but that would assume that in terms of plant growth, the PAR for one hour of sunlight is constant throughout the day. Practically speaking, this would imply that one hour of sunlight between 7 and 8 a.m. is equivalent to an hour between 12 and 1 p.m. Unfortunately, one hour of direct sun between 7 and 8 a.m. has much less PAR than an hour of sun between 12 and 1 p.m. Therefore, a method

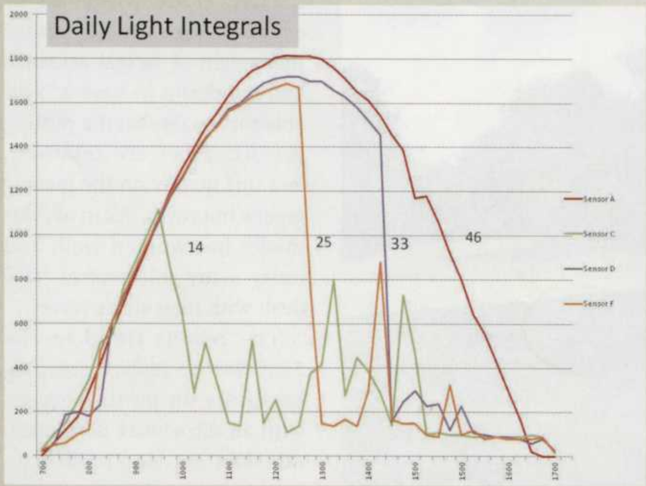

Figure 2: A DLI (daily light integral) is a measure of the total amount of photosynthetically active radiation (PAR) a given area receives in a single day. This graph shows the DLI measure by four different sensors. Note how each DLI curve changes throughout the day, with the highest levels achieved at solar noon. Sharp drop-offs or changes in the curve are caused by shade from trees.

Shade from trees surrounding a putting green vary throughout the year due to the changing angle of the sun. The quantity of light for plant growth not only changes based upon shade, but on the time of day.

to measure PAR over the course of an entire day is needed rather than a method to measure PAR at any given moment.

Scientists measure PAR as the number of photons striking a square meter every second. This measurement is sometimes referred to as the Photosynthetic Photon Flux Density, and the units to express the intensity of PAR light are micromoles per square meter per second. For the purposes of measuring the total amount of PAR an area receives in a 24-hour period, scientists use the term Daily Light Integral (DLI). The DLI is expressed as the number of moles of PAR per square meter per day. Figure 2 shows an example of DLI for a clear summer day with no shade. Note how PAR peaks in the early afternoon and is substantially lower in the hours just after sunrise and just before sunset. PAR will peak at your location at solar noon, which is defined as the time when the sun reaches its highest point and crosses the meridian. Depending on the time of year, solar noon can occur before or after 12 noon. More details on solar noon can be found at http://www.sundials.co.uk/equation.htm.

Dr. Todd Bunnell and Dr. Bert McCarty identified in a research project at Clemson University that a Daily Light Integral of 32.6 was needed for TifEagle Bermudagrass to provide an acceptable level of quality. Practically speaking, Bunnell and McCarty recommend eight to ten hours of sunlight for TifEagle Bermudagrass in Clemson, S.C. (Bunnell and McCarty, 2004a). Four of those hours should be between approximately 11 am to 3 pm, when PAR levels are highest. This is excellent information to know when assessing sunlight levels.

Bunnell and McCarty continued shade-related research and examined the effect of the plant growth regulator Primo, mowing height, and nitrogen rate on TifEagle Bermudagrass grown under varying levels of shade. They found that plots with four hours of sun (12 noon to 4 pm), applications of Primo, and a 3/16" height of cut, produced acceptable turf quality at a DLI of 22.1. These researchers concluded, "Therefore, applying a plant growth regulator that inhibits gibberellic acid and raising mowing heights will improve the growth, quality, and performance of ultradwarf Bermudagrass greens in shade (Bunnell and McCarty, 2004b)."

MEASURING DAILY LIGHT INTEGRALS. With a solid background now established in light terminology and more confidence in how much light an ultradwarf needs, attention can shift to measuring sunlight levels on a golf putting green.

Equipment Needed. The first step in assessing shade levels is to identify the Daily Light Integral on the area in question. This can be done through the acquisition of both a light sensor and a meter to read the light sensor. A popular sensor model contains a row of three to six sensors and comes with detailed instructions for use. Based on 2011 prices, the cost is approximately \$600 - \$650. Other less-expensive light sensors can be purchased for several hundred dollars, but these meters may only express DLI within a range, not as a specific number. Spectrum Technologies (Plainfield, Ill.) is a company with many available choices that would work well in determining the DLI on a putting green.

WHEN TO TAKE MEASUREMENTS. Summer: The Clemson studies were conducted over two years, and data were collected between late June and mid-August. During this time of year, Bermudagrass is producing the greatest quantity of vegetative growth, so it makes sense to assess shade levels for the purpose of growing acceptable ultradwarf turf. Use the light sensor to take measurements sometime between mid June and early August. Because the light sensor will need to be at a given location all day long, Affordable technologies are available for in-field use to more effectively observe the path of the sun and identify trees that block sunlight. When only a few trees may be an issue, a superintendent using the Sun Seeker can identify the trees that block sunlight to a putting green and the approximate length of time these trees cause shade.

there may be interference with play, even though the actual sensor is less than 18 inches long. Make plans to communicate where the sensor is, and make a local rule to deal with any interference.

Spring and Fall: Consider taking measurements in spring and fall, also. These are times of the year when metabolic changes are occurring within the plant in response to day length and temperature. Although plant physiologists have quantified that changes do occur in the plant at these times of year, there is minimal research that quantifies minimum levels of sunlight necessary for adequate long-term growth. We do know that as day-length decreases and temperatures decrease, the plant begins to store carbohydrates that ultimately will be used during greenup the following spring. Therefore, shade in the fall may have an effect on winter survival and spring green-up.

Conversely, sunlight levels in the spring will have an impact on soil temperature and spring green-up, too. It stands to reason that areas receiving less sunlight may be slower to greenup in the spring months. Superintendents have aided the green-up process by increasing canopy temperature through the application of turf paints or dyes and green or black topdressing.

Taking a few measurements during fall and spring will help identify shaded areas. Because we do not have a recommended minimum DLI for the fall, determining acceptable shade levels in the fall will be a judgment call.

WHERE TO TAKE MEASUREMENTS. A golf course superintendent can identify the putting greens that historically have battled issues caused by shade. It is common on some greens that there is only a small corner or area that may receive more shade than other parts of the green. It is a good idea to take two or three measurements on a putting green to assess both the highest and lowest levels of shade on a putting green.

If someone is interested in determining the percent shade that a putting green receives, it will be necessary to also take a DLI reading on any area in full sun. To determine the percentage of shade, use the following equation.

$$\%\ \text{Sun} = \frac{\text{DLI of Shady Location}}{\text{DLI of Sunny Location}} \times 100$$

$$\%\ \text{Shade} = 100 - \%\ \text{Sun}$$

A word of caution is in order – when determining the percentage shade, be sure to take the DLI measurements for both areas on the same day. Try to pick a day with full sun and minimal clouds. Cloud cover can and does impact DLI, so if data were taken on two different days, results could be skewed.

How many measurements to take? This is a judgment call on the part of the end user. The Clemson study took data for almost two months and had the ability to take an average of all those days. At the local level, it would be a good idea to record data on several days that one would consider to be sunny or a typical summer day. A typical summer day in the Southeast would be one with clear skies in the morning and some isolated clouds in the afternoon. Please note that in the Bunnell and McCarty study the two year DLI for plots in full sun was 41.6, with a maximum DLI reading of 52.1.

Is it necessary to measure every putting green? Probably not. Start first with the putting greens most influenced by shade. Generally, there are two or three greens that cause the most concern. Measure them first and make a determination if other less-shaded greens need to be measured. If the shaded greens have DLIs more than 33, it won't be necessary to evaluate less-shaded greens. Also, look for corners of greens that may have shade issues and measure them. The edge of the green with the cleanup lap has more mower traffic and turning, therefore solve the shade issues on the edges and the rest of the green should be okay.

DATA INTERPRETATION. After taking the Clemson studies into account, a superintendent or course official has solid information in hand to make an educated assessment to determine whether adequate sunlight for growing an ultradwarf exists or if additional action is warranted. Please note that the target of 32.6 is an indicator, not an absolute, and does not take into account additional stress factors, such as traffic, water quality, soil-borne pests, etc. Added stress will require higher DLI.

The initial measurements described above will yield several different outcomes.

• Summer DLI comfortably above 32.6; no action needed. Sunlight is adequate for an ultradwarf. There may be some minor tree issues to deal with, but even if no trees were removed, the ultradwarf will have enough sunlight to grow sustainably.

• Summer DLI at mid 20s-33; potential action needed. Are there trees that can be removed, or is the course able to manage this green differently? Primo use will be essential. A putting green in this scenario is going to require closer attention. Assess the percentage of the putting green that has a DLI below 32.6. A secondary issue for putting greens in this range is to look at DLI levels in the fall and spring, too. The lower a summer DLI level is, the more important it will be to have as much sun in the fall and spring as possible.

• Summer sunlight below DLI of 22-30; action needed or green will be deemed unsuitable for an ultradwarf. In this case, removing trees or moving the green is necessary

INCREASING SUNLIGHT LEVELS. On a shaded putting green, it may not be difficult to agree that trees need to be removed, but there may be disagreement on which ones need to be removed. The trees that need to be removed are the ones that will provide the greatest increase in DLI. Fortunately, there are several tools that are available to assist in this process

• Commercial Services – Companies such as ArborCom Technologies use computer modeling technology to determine the shade impact of individual trees on a given putting green. Shade patterns on a putting green can be modeled for any day of the year and any time period during the day. Within the model, an almost unlimited number of scenarios can be run, examining the impact of the removal of a given tree or multiple trees on sunlight levels. This is a highly precise process.

• Applications on Handheld Devices (i.e., apps) – An app developed for the real estate industry has found a niche in shade management. This app is called SunSeeker and is available on iTunes for a nominal fee for owners of an iPhone or an iPad2. With the app running and the device in camera mode and facing the object(s) potentially causing shade, the user will see several lines across the screen. A blue line traces the path of the sun on the winter solstice, December 21. A red line traces the path of the sun on the summer solstice. A third line traces the path of the sun on the day of the user's choice, with the

During the summer months, this app is quite helpful in identifying trees that block sunlight and determining the duration of time that they block sunlight. This app is a good tool to assist in identifying the fewest trees to remove to achieve the largest increase in direct sunlight.

A WORD ABOUT WINTER SHADE. The angle of the sun decreases by about 36% over the course of a year, and, as a result, shade levels may increase dramatically during the winter months if there are trees along the western, southern, and eastern sides of a putting green. Questions involving whether to measure winter shade are common. A warm-season species, such as Bermudagrass, moves from periods of rapid vegetative growth in the warmer summer months to periods of slower to no growth in winter months. The times and rates of growth change are dependent on upon temperature and day length.

In the fall and winter, changes in temperature and light intensity trigger changes in a Bermudagrass plant. Dr. James Beard explains it this way,

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Meters with multiple sensors are now financially affordable and can be used as a tool in assessing the quantity of photosynthetically active radiation (PAR) for turfgrass plants.

"High light intensities and low temperatures interact to cause winter discoloration of Bermudagrass leaves. High light intensities cause degradation of the existing chlorophyll, while low temperatures impair clorophyll synthesis. The result is typical winter discoloration since the chlorophyll degradation rate exceeds the rate of synthesis" (Beard, 1973).

The implication for the topic in this article is that sunlight levels in the winter do not contribute much to plant growth. Therefore, the key issue with winter shade relates to direct or indirect low temperature injury. Shaded putting greens or shaded areas on a putting green are going to have lower soil temperatures because they receive less solar radiation. The focus for superintendents then switches to monitoring air and soil temperatures and turfgrass covers as needed.

CONCLUSION. Trees and turf are an everyday occurrence on golf courses. The desire of all superintendents is to find the proper balance between the locations of trees in relation to areas of turf, particularly the putting greens. As new grasses are being used in the Southeast, the need for assessing unlight levels has started anew. Fortunately, important research and a variety of tools are now available to every superintendent. Applied appropriately, these resources provide the most accurate measurement and assessment of shade on your golf course, setting the stage for sustainable turfgrass for many years. **GCI**

Chris Hartwiger, USGA senior agronomist, enjoys his time in the shade during the hot summer months in the Southeast Region.

Editor's Note

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