

How Much do Clouds Affect Photosynthetic Irradiance? Measures of Light at Thailand, Hong Kong, Vietnam, and Japan

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ABSTRACT

The main factors influencing turfgrass growth are nitrogen, water, temperature, and light. Turfgrass managers are able to modify the nitrogen and water supply to the grass, but are limited in the amount of change they can make to the temperature and the light. Light, more specifically the instantaneous photosynthetic irradiance, was measured at multiple locations in East and Southeast Asia during July, August, and September of 2012. Because of typical cloud cover in these regions during this season, the average photosynthetic irradiance at midday was 30% lower than in full sun, with photosynthetic irradiance reduced by 50 to 75% on cloudy days. A daily light integral was calculated based on these measurements. In 3 days of measurements at Hong Kong, 17 days at Thailand, 2 days at Vietnam, and 33 days in Japan, the average daily light integral (DLI) was $38.4 \text{ mol m}^{-2} \text{ d}^{-1}$ at Hong Kong, 35 at Thailand, 38 in the Ryukyu Islands, 48.1 in Central and West Japan, and 22.4 in Vietnam. This report provides details of these measurements and gives suggestions on how these meters can have practical use for turfgrass managers.

The importance of light in determining which turfgrass species grow well and how they can best be managed cannot be overstated. This report discusses data on photosynthetic irradiance collected at Thailand, Hong Kong, Vietnam, and Japan, with the locations of data collection shown in Figure 1.

The light that is available for plants to use is termed photosynthetic irradiance and is expressed on an instantaneous basis in units of micromoles of photons per square meter per second ($\mu\text{mol m}^{-2} \text{ s}^{-1}$) or on a daily basis as a daily light integral (DLI) which is in units of moles of photons per square meter per day ($\text{mol m}^{-2} \text{ d}^{-1}$). Another broad term for photosynthetic irradiance is *photosynthetically active radiation*, or PAR. And the photosynthetic irradiance, specifically that measurement of the photons per square meter per unit of time, is also called *photosynthetic photon flux density*, or

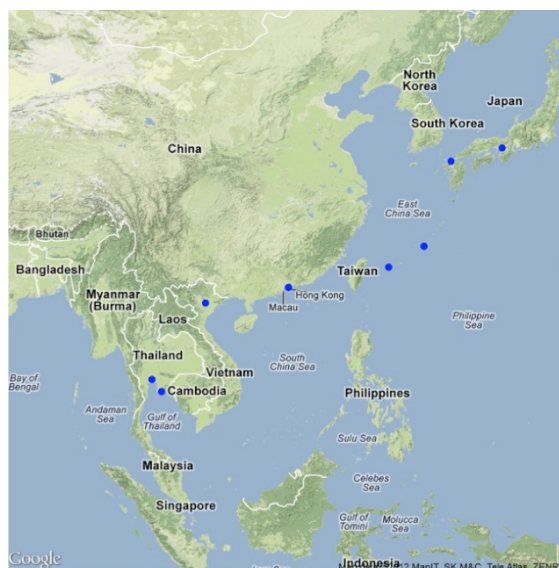


Figure 1: This map shows the locations, in blue, where irradiance measurements were made at Thailand, Hong Kong, Vietnam, and Japan

PPFD. In this article, I'll generally use the terms photosynthetic irradiance and daily light integral rather than PAR and PPFD.

Temperature data are readily available and the response of turfgrasses to variations in temperature are well-established. The response of turfgrass to shade is also well-established, but irradiance data are less readily available. Recent review articles on shade discuss reduced light environments related to trees, shrubs, and buildings, but do not consider the reduction in photosynthetic irradiance caused by clouds (Beard, 1997; Stier and Gardner, 2008; Dudeck and Peacock, 1992). Wiecko (2000) noted the effect of clouds on turfgrass performance and explained how bermudagrass did not perform well in Guam and other parts of tropical Asia due to restricted light from clouds.

Based on the relative performance of *Cynodon* and *Zoysia* species in Asia, specifically in reference to their performance as a regularly-mown turfgrass in areas unaffected by tree, shrub, or building shade,¹ there is widespread empirical evidence

¹All the measurements of irradiance reported in this document have been in what we would term "full sun", meaning that there was no building or tree shade blocking the light. Any reduction in midday irradiance in the data presented here is the

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Figure 2: Shown here near Naha, Japan, the quantum light meter from Spectrum Technologies was used to make hundreds of measures of instantaneous photosynthetic irradiance

that shade from clouds has a profound effect on turfgrass performance in Asia.

Normal Ranges of Irradiance

On a sunny day, in the middle of the day, the instantaneous photosynthetic irradiance will be about $2000 \mu\text{mol m}^{-2} \text{s}^{-1}$. Irradiance sensors (Figure 2) are available that measure just the photosynthetic irradiance, and in this project the Field Scout Quantum Light Meter from Spectrum Technologies² was used to collect the irradiance data.

When the sun is high in the sky, the photosynthetic irradiance is at its maximum; at night the photosynthetic irradiance will be 0; when the sun is low in the sky, the irradiance will be at a value more than 0 and less than $2000 \mu\text{mol m}^{-2} \text{s}^{-1}$. In measurements made approximately hourly during the day for more than two months at Thailand, Hong Kong, Vietnam, and Japan, the time at which maximum irradiance occurs is from about 09:00 to 15:00.

Measured Irradiance and the Cloud Effect

Figure 3 shows the instantaneous photosynthetic irradiance measured on 4 August 2012 at Ishigaki,

result of cloud shade.

²Spectrum Technologies, Inc., Plainfield, IL, USA, <http://www.specmeters.com>, Field Scout Quantum Meter Item # 3415F

Japan. It was a mostly sunny day with brief rain showers in the morning and in the afternoon. The photosynthetic irradiance dropped by more than half during those rain events because of the associated clouds that blocked much of the irradiance.

On many days, however, there is not bright sunshine, and the clouds block a portion of the irradiance throughout the day. Figure 4 shows the average photosynthetic irradiance measured over 17 days at Thailand. Figure 5 shows the average photosynthetic irradiance measured over 3 days at Hong Kong, Figure 7 shows the average photosynthetic irradiance for 2 days at Hanoi, and Figure 6 shows the average photosynthetic irradiance measured over 33 days in Japan. The blue line on each chart traces the average value of photosynthetic irradiance by time of day based on data collected at that location.

At each location, midday cloud cover reduced photosynthetic irradiance by 50 to 75%. This is a meaningful amount of shade, enough to cause a decrease in turfgrass performance, especially for species with a high light requirement such as bermudagrass. Bunnell et al. (2005) demonstrated a continuous decline in Tifeagle bermudagrass quality as the daily light integral went from 42 down to $22 \text{ mol m}^{-2} \text{ d}^{-1}$. A 55% reduction in irradiance, similar to the effect of clouds, resulted in unacceptable quality of Champion bermudagrass (Baldwin and Liu, 2010). And after eight continuous weeks of a 65% reduction in irradiance, Baldwin and Liu (2008) found that only Diamond

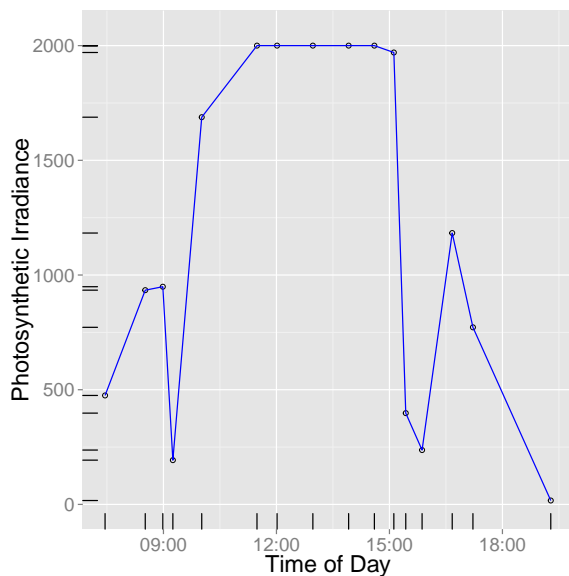


Figure 3: Photosynthetic irradiance on a relatively sunny day at Ishigaki, Japan; drops in irradiance at about 9:00 and just after 15:00 were during brief rain showers

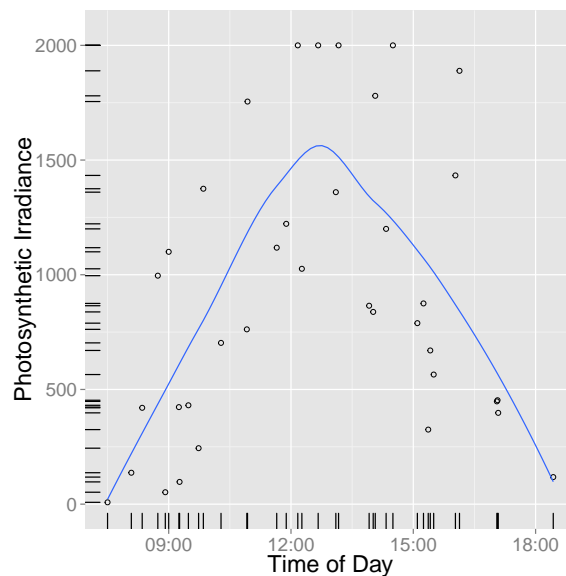


Figure 5: Photosynthetic irradiance measured at Hong Kong

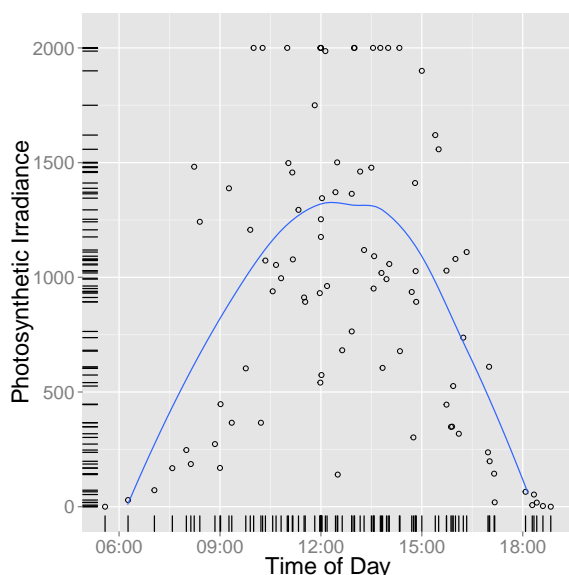


Figure 4: Photosynthetic irradiance measured at Thailand

zoysiagrass³ maintained acceptable turfgrass quality; Sea Isle 2000 seashore paspalum and Celebration and Tifway 419 bermudagrass did not maintain acceptable quality with such a reduction in irradiance.

Implications of Reduced Irradiance

The data⁴ shown in Figures 3 to 7 demonstrate that cloud cover at midday can reduce the photosynthetic irradiance by more than 75%. These results also show that when averaged across multiple days of varying cloudiness, the midday irradiance, in areas not affected by tree or building shade, was only about 70% of full irradiance, due to the affect of clouds. This varies throughout the year, obviously, by location, so during cloudier times the reduction may be more, and during sunnier times – January in Bangkok comes to mind – there is expected to be almost full irradiance at midday, every day.

There are a number of steps that can be taken to improve turfgrass performance under conditions of reduced irradiance.

1. Choose a grass that is tolerant of reduced irradiance (Figure 8). In Southeast Asia, manilagrass (*Zoysia matrella*) and broadleaf carpetgrass (*Axonopus compressus*) are the most tolerant of reduced irradiance. At low mowing heights of 5 mm or less, such as found on

³Diamond is a type of *Zoysia matrella* (manilagrass), similar to the types found in tropical Southeast Asia.

⁴This report was prepared on September 17, 2012. The data in this report are updated as more observations are made; the first version of this report was generated on August 16, 2012. This report was written in RStudio (<http://www.rstudio.org/>) and used the knitr package (Xie, 2012) to compile the final version which was typeset in X_YLA_TE_X. Charts were made using the ggplot2 (Wickham, 2009) package in R (R Development Core Team, 2012).

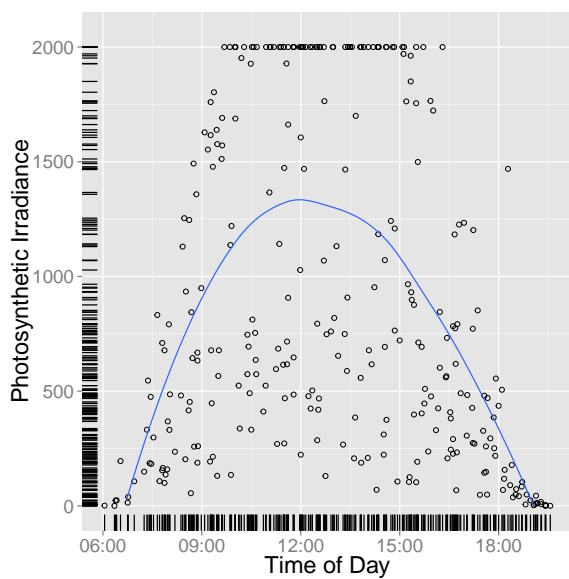


Figure 6: Photosynthetic irradiance measured in Japan

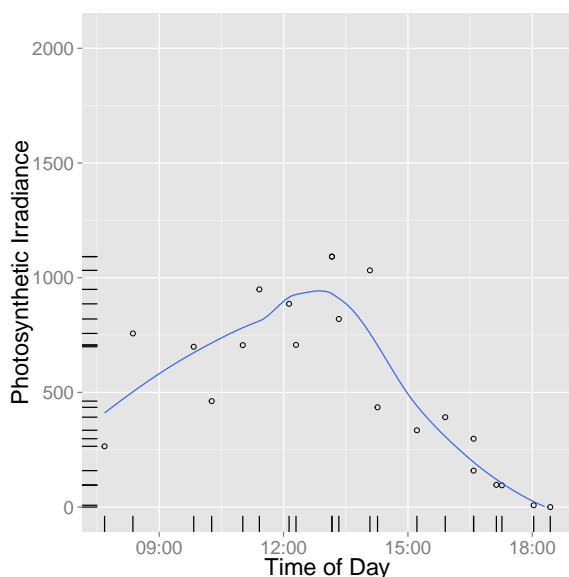


Figure 7: Photosynthetic irradiance measured at Hanoi on two cloudy days in mid-September 2012

golf course putting greens, seashore paspalum (*Paspalum vaginatum*) also shows excellent tolerance of reduced photosynthetic irradiance.

2. Most types of bermudagrass perform worse than do the previously-mentioned grasses under reduced irradiance.
3. To improve the tolerance of bermudagrass or other species to reduced irradiance, the mowing height should be increased, trinexapacethyl should be applied, and the nitrogen application rate should be reduced.

How Can This Information be Used?

Photosynthetic irradiance sounds complicated, but it is really quite simple. At midday, in full sun, the instantaneous photosynthetic irradiance will be $2000 \mu\text{mol m}^{-2} \text{s}^{-1}$. If you go under a tree this value may be reduced to about $200 \mu\text{mol m}^{-2} \text{s}^{-1}$. If there are low clouds, the irradiance may be about $500 \mu\text{mol m}^{-2} \text{s}^{-1}$. So we might measure a 75% reduction in irradiance from clouds, and we might measure a 90% reduction in irradiance from a tree. Any reduction in irradiance will cause a decline in turfgrass quality, especially for bermudagrass.

Being able to quantify that reduction in light allows a turfgrass manager to take proactive steps to minimize turfgrass problems. That may involve removing the tree or structure that is causing the shade, choosing a grass species (or variety) for the shaded area that is more tolerant of reduced irradiance, and determining when to make changes in mowing height and nitrogen rate and trinexapacethyl application as a result of reduced irradiance.

Just as digital soil moisture meters are becoming an essential tool in turfgrass management, helping to minimize water use while at the same time reducing drought stress and improving surface consistency, light meters that measure the photosynthetic irradiance will come to be a regularly-used tool by turfgrass managers. The four main factors influencing turfgrass growth are nitrogen, water, temperature, and light. Turfgrass managers know exactly how much nitrogen they apply. Turfgrass managers know how much it rains, how much water is applied through the irrigation system, and with a soil moisture meter can determine exactly how much plant-available water is in the soil. And when it comes to temperature, turfgrass managers almost always know the day's high, and low, and the soil temperature, and sometimes even the leaf surface temperature.

Adding irradiance data gives the turfgrass manager a complete picture, expressed in data that can be compared with benchmarks, tracked through the season and from year to year, identifying the areas on a course that require special attention because of reduced irradiance, and quantifying the effect of clouds on the light available for plant growth.



Figure 8: There are three species of grass here, grown under reduced irradiance and mown at putting green height in Southeast Asia during the sunniest time of the year; a) is seashore paspalum; b) is manilagrass; c) and d) are hybrid bermudagrass

In the absence of irradiance data, the Asian Turfgrass Climate Charts website⁵ provides a number of charts that show daily or monthly sunshine hours, with links to the data sources for those who wish to explore this in more detail. As a general rule, for warm season grasses, when there are less than six daily sunshine hours, or less than 180 monthly sunshine hours, the photosynthetic irradiance can be considered reduced, and the mowing, nitrogen, and trinexapac-ethyl shade management strategies should be implemented.

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⁵<http://climate.asianturfgrass.com/>