McCree Revisited

First off we would like to pay homage to Dr. Keith McCree and the wonderful detailed work he did in the early 1970s. To his credit no one has really done such a body of work to enhance his findings of over 40 years ago. Dr. McCree was a professor at Texas A&M in the Soils and Crop Sciences department and a physicist by education, which shows we need input from multiple disciplines to get good information. Unfortunately Dr. McCree passed away last year on May 12, 2014 in Eugene OR; his contributions will always be appreciated as his article from 1972 "The action spectrum, absorptance and quantum yield of photosynthesis in crop plants" is the most referenced article on plant lighting.

Why we are conducting our own analysis and summary of this paper

So often we see people refer to the McCree curve and often it seems they do not really understand its actual meaning. We always like to make sure we understand a topic, an analysis, or scientific conclusion to apply it precisely. So we decided to dig deeply into the paper and make sure we understood the steps and conclusions so that we could engage in discussions as to how his work is being used by others today.

What was McCree looking for?

If we look at the title of the paper the 3 topics are:

1. **Action Spectrum**: The relative photosynthesis response as a function of **light energy** to different wavelengths of light.
2. **Absorptance**: The relative amount of light absorbed for different wavelengths.
3. **Quantum yield of photosynthesis**: The relative quantum yield for different wavelengths of light **absorbed**. It's very important to note that this value is based only on light absorbed by the plant **not** the light emitted to the plant.

First to better prepare ourselves let's look at a definition of Quantum: In physics , a **quantum** (plural: **quanta**) is the minimum amount of any physical entity involved in an interaction. Behind this, one finds the fundamental notion that a physical property may be "quantized," referred to as "the hypothesis of quantization. This means that the magnitude can take on only certain discrete values. In plant lighting the quantum concept applies to photosynthesis being driven by discrete photon energy packets, rather than a general light energy level.

How was the study conducted?

1. The values are an average of 22 different **food crops** studied with measurements taken at increments of 25 nm.
2. Photosynthesis rate was determined by placing a leaf section in a controlled chamber and observing changes in CO_2 concentrations as a function of incident light of about 30 to 60 uMole/M^2S for different wavelengths, this is a rather low intensity.
3. Absorptance was measured by putting the leaf section in a light chamber measuring transmitted light with and without the leaf sample for each wavelength of light.
4. Then a lot of calculations. No doubt there are still grad students that to this day have not fully recovered.

What the McCree Curve is and is not

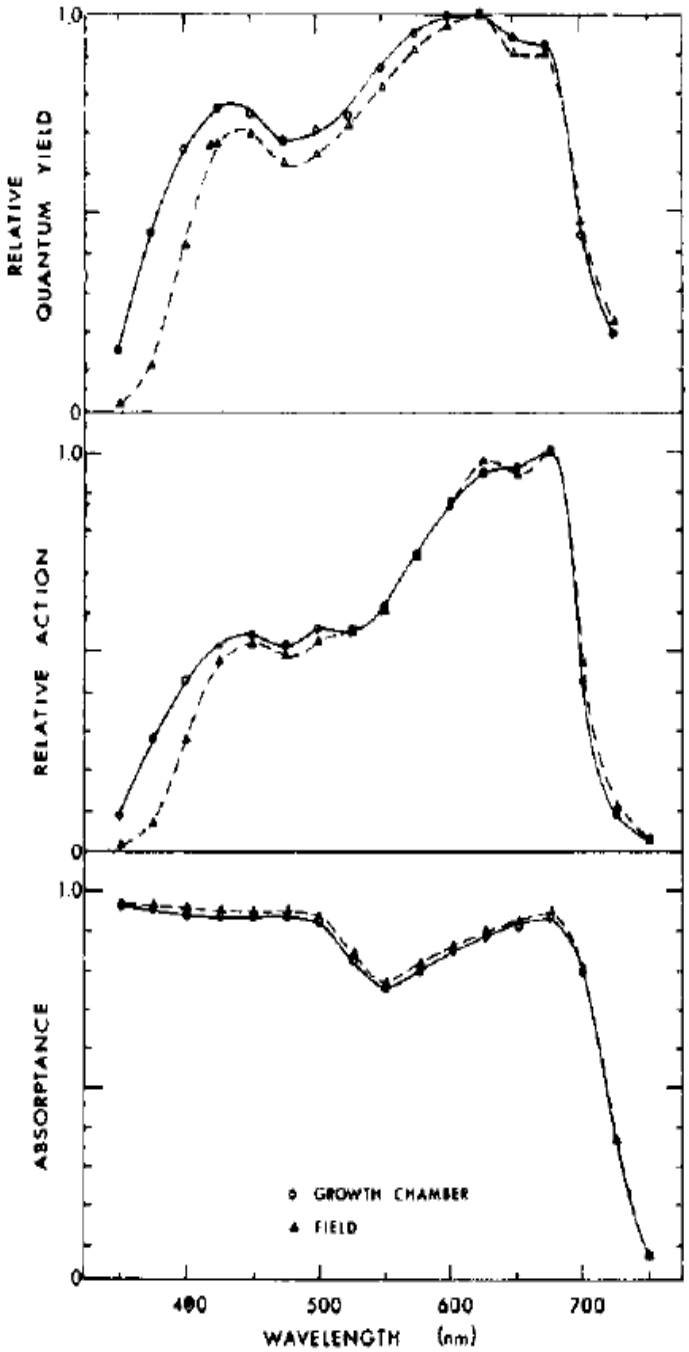
1. First and foremost for how lighting manufacturers like to make comparisons to the McCree Curve they should be using the Relative Action curve not the Relative Quantum Yield curve.
2. The Relative Action curve is a relative weighting of photosynthesis response to light of different wavelengths.
3. The values are relative to each other with the highest value arbitrarily set at 1 (100%). This does **not** mean that the wavelength at the value of 1 (100%) is absorbed and utilized for photosynthesis; only a small fraction of the radiated light is ultimately absorbed and effectively used in photosynthesis, even at the curves peak value.
4. The curve is **not a specific indicator of plant lighting needs**. The study was about photosynthetic response to different light wavelengths, one can make some assumptions about the importance of certain wavelength regions, but nothing precise about the plant's actual light wavelength **requirements**.
5. The McCree Curve indicates **nothing about an ideal plant light profile**. A growth light matching the McCree Curve would not be ideal, it probably is a relatively decent spectrum, but that is just circumstantial. This is a very common misconception about plant lighting which escapes many designers who try to match the McCree curve profile.
6. There was no appropriate quantum weighted graph to make a direct comparison to a quantum weighted light spectral distribution.

Other Interesting observations from the study

1. Absorptance of green light (550 nm) is only 15% less than the average absorptance across the PAR region. The relative action of green light (550 nm) is only 9% less than the average relative action across the PAR region. So let's dispel the myth that green light is reflected wasted energy?
2. Moderate variations CO_2 concentration, temperature, light intensity, and the addition of white light all affected the rate of photosynthesis, but had little effect to the relative rate of photosynthesis as a function of wavelength.
3. The light intensity used was relatively low at 30 to 60 uMole/M^2S. **Normal plant grow intensity can be as much as 30 times higher** than the study intensity, much higher than the variations they studied so at these levels the relative distribution certainly could be different.
4. The results were not drastically varied from species to species, but they were all food crops. While this model is likely a good starting point for other plants, one should not assume it will hold for the great variety of plants and phases of growth.

The Results

The results are most briefly summarized in the 3 graphs below. The graphs are all relative at peak value of 1.0. There are 2 plots on each graph one for crops initially grown in the field and the other for crops grown in a chamber. For purposes of grow light comparisons the chamber grown crop data should be appropriate for indoor grows and the field crop data for greenhouse supplemental lighting.



The Relative Quantum Yield curve has been adjusted for absorptance and represents the yield for light that was actually absorbed so this is not a good comparative model to use for actual light spectrum emitted and should not be used directly for grow light comparisons.

The relative action curve is the photosynthetic response of the plant to different wavelengths of light energy. If comparisons are made to a grow light spectrum the spectrum needs to be energy weighted not quantum weighted.

The relative absorptance was primarily taken to calculate the relative quantum yield of absorbed light. Note that the minimum relative absorptance point in the PAR region is 0.74 at 550 nm.

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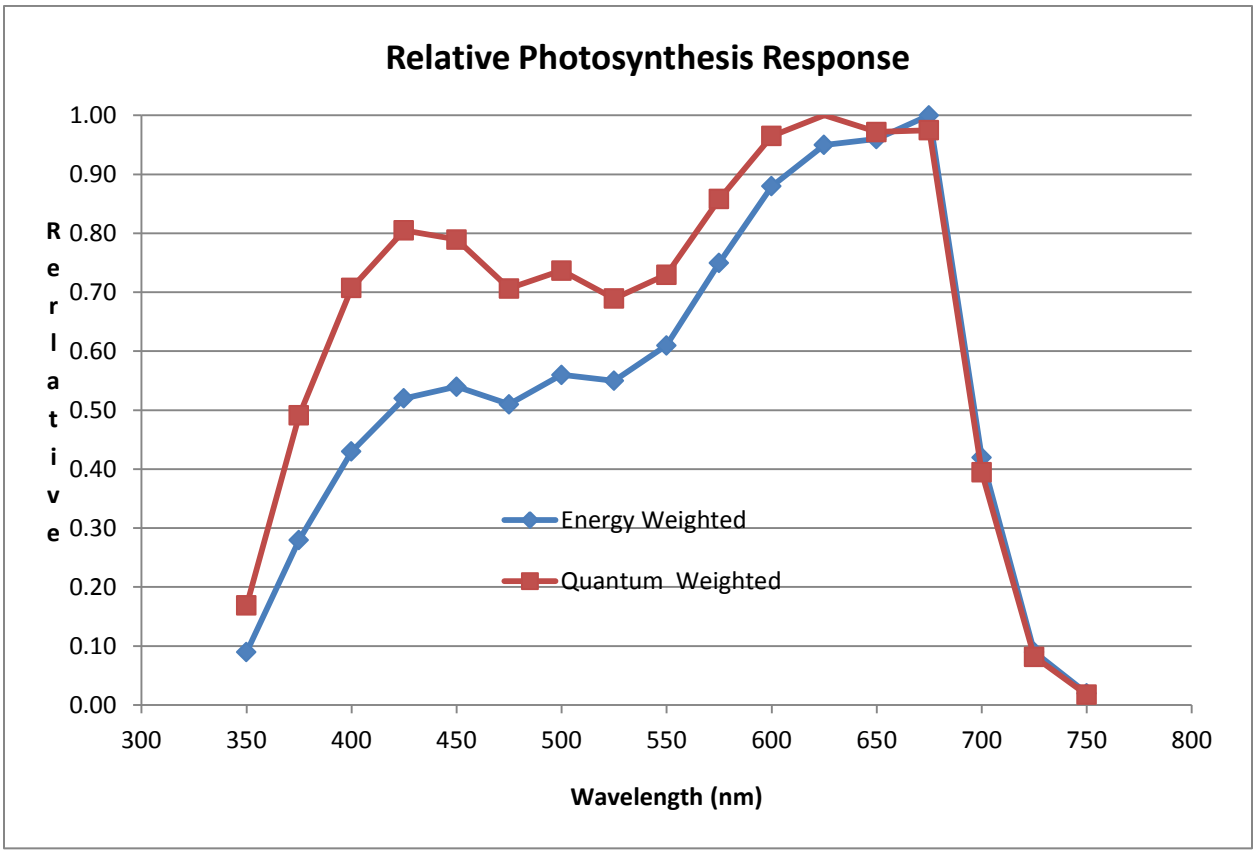
Energy Weighted vs. Photon Weighted

This is important since we know photosynthesis is a quantum process driven by actual photon utilization, but photons of different wavelengths have different energy levels per the Plank Relationship E=hc/λ. So a plot of the relative photosynthesis Response based on photons will be different than that based on energy, as seen below. Lighting manufacturers will often make graphical comparisons of their lights spectral distribution to that of the McCree Curve, it is important that both curves are using the same weighting technique to make a meaningful comparison. The data for the energy weighted curve came directly from the McCree results for chamber grown crops. The quantum weighted curve was calculated from the energy weighted data points by applying the Plank relationship formula E=hc/λ. And once again we would like to point out that a light spectrum comparisons to the McCree curve does not imply an ideal light profile for plants.



References

McCree, Keith J. (1972a). "The action spectrum, absorptance and quantum yield of photosynthesis in crop plants". *Agricultural and Forest Meteorology* 9:191-216.

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