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ANSI/ASABE S640 JUL2017
Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)

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Approved July 2017 as an American National Standard

Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)

Developed by the ES-311, Electromagnetic Radiation Application for Plants Committee; approved as an ASABE standard July 2017; approved by ANSI July 2017.

Keywords: Metrics, Radiation, Plant Growth, Horticulture.

0 Introduction

The conventional radiation metric for plant growth applications is photosynthetically active radiation (PAR), as introduced by McCree [1]. It is based on field and growth chamber measurements of photosynthesis in 22 common plant species, and represents the CO_2 assimilation per mole of incident photons at specific wavelengths between 400 nm and 700 nm.

PAR is expressed in terms of the photosynthetic photon flux (PPF) and photosynthetic photon flux density, (PPFD). These metrics can be measured with a suitably calibrated quantum sensor or derived from spectroradiometer measurements. PPF is the amount of radiation emitted from a source. PPFD indicates the amount of radiation that is incident upon a unit of surface area.

Plant growth, architecture, and flowering, however, involve more than just photosynthesis. Plants have numerous photoreceptors that absorb and are activated or deactivated by specific spectral regions from UVB to far-red. Ultraviolet radiation, for example, may induce changes in leaf and plant morphology [2]. As another example, the far-red isoform of phytochrome, which is responsible for many plant functions including seed germination, flower induction, plant height, and leaf expansion, has a spectral absorptance peak at 730 nm [3].

These phenomena have previously been of interest mostly to plant biologists, as the electromagnetic radiation sources available for plant growth applications were limited to incandescent, fluorescent, and high-intensity discharge (e.g. high-pressure sodium and metal halide) lamps. The light sources customarily used by horticulturalists were often designed for human perception or general illumination purposes, rather than optimized for plant applications. Thus, simplifying incident light intensity to PPFD measurements provided adequate precision with a useful degree of standardization.

This has all changed with the introduction of solid-state lighting for horticultural applications. Horticulturists quickly realized that light-emitting diodes (LEDs) appeared adequate for the photosynthetic needs of many plants, as their spectral output can coincide with the spectral absorptance of leaves and the action spectrum of photosynthesis. Furthermore, the range from ultraviolet to far-red LEDs has become available for horticultural radiation applications. Commercial growers and horticultural researchers alike now have the ability to “tune” the spectral output to complement the action spectra of any plant pigment or species or pursue specific photomorphological responses.

This ability is important not only for the inclusion of ultraviolet and far-red radiation in horticultural lighting, but also because the spectral power distribution (SPD) of plant growth radiation is important. Green radiation in particular, while not highly absorbed by isolated chlorophyll A and B, nevertheless has significant impact on both photosynthesis and photomorphogenesis of the leaf and whole plant (for example, Reference 4 and Reference 5). Unlike traditional electric lighting for horticulture, the use of LED technology allows for the inclusion of many different wavelengths of radiation as well as their proportions to each other.

Solid-state lighting has further emphasized the need for horticultural radiation metrics beyond that of PAR and PPFD. The availability of solid-state lighting has contributed to a significant increase in the understanding of plant photobiological responses, and it offers the potential to specifically trigger these with more control. This document

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presents equivalent metrics and associated definitions for ultraviolet and far-red radiation, as well as spectral power distribution. In addition to establishing the appropriate definition of metrics for plant growth, this document also presents equivalent metrics for defining UV and FR radiation often associated with photomorphological effects in plants.

1 Scope

This document provides definitions and descriptions of metrics used for radiation measurements for plant (photosynthetic organisms) growth and development. This document does not cover display aspects and human visualization.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASAE EP402, *Radiation Quantities and Units.*

ANSI/ASAE EP411, *Guidelines for Measuring and Reporting Environmental Parameters for Plant Experiments in Growth Chambers.*

ANSI/IES RP-16-10, *Nomenclature and Definitions for Illuminating Engineering*, New York, NY: Illuminating Engineering Society.

IES TM-27-14, *IES Standard Format for the Electronic Transfer of Spectral Data*, New York, NY: Illuminating Engineering Society.

CIE Lighting Vocabulary, http://eilv.cie.co.at/termlist.

ISO Standard 21348:2007, *Space environment (natural and artificial) — Process for determining solar irradiances*. Geneva, Switzerland: International Organization for Standardization.

3 Definitions

3.1 Daily Light Integral (DLI): Photosynthetic photon flux density integrated over a 24-hour period typically coinciding with the 24 hours of a calendar day).

3.2 Far-red radiation: For horticultural applications, far-red radiation is defined as electromagnetic radiation with wavelengths between 700 nm and 800 nm.

3.3 Irradiance: Irradiance is radiant flux per unit area incident upon a point on a surface.

3.4 Photobiology: Photobiology is broadly defined as the study of all biological phenomena involving electromagnetic radiation. It is recognized that photobiological responses are the result of chemical and/or physical changes induced in biological systems by non-ionizing radiation.

3.5 Photochemistry: Photochemistry is the underlying mechanism for all photobiology.

3.6 Photomorphogenesis: Photomorphogenesis is defined as any change in the morphology (shape) or composition (e.g., flowering induction, secondary metabolite production) of a plant or plant part that occurs in response to exposure to electromagnetic radiation.

3.7 Photon: A photon is a quantum (smallest quantity) of electromagnetic radiation.

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