ISA Recommendation

General Technical Specification of LED Luminaires for Horticultural Lighting

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International Solid State Lighting Alliance

Technical Committee on Standardization

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CONTENTS

1 Scope

This standard defines the classification, technical requirements and testing methods for horticultural luminaires. This standard includes LED luminaires for horticultural lighting working in normal growing or control environment temperature.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

CIE S 025:2015 Test Method for LED Lamps, LED Luminaires and LED Modules

CISPR 15 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

IEC 60050-845 Electrotechnical terminology – Lighting

IEC 60068-2-1:2007 Environmental testing – Part 2: Test methods - Tests A: Cold

IEC 60068-2-2:2007 Environmental testing – Part 2: Test methods - Tests B: Dry heat

IEC 60068-2-14:2009 Environmental testing – Part 2: Tests methods - Test N: Change of temperature

IEC 60068-2-78 Environmental testing for electric and electronic products - Part 2: Testing method test Cab: Damp heat, Steady state

IEC 60529:2013 Degrees of protection provided by enclosure (IP code)

IEC 60598-1:2014 Luminaires - Part 1: General requirements and tests

IEC 61000-3-2 Electromagnetic compatibility - limits - limits for harmonic current emissions (equipment input current ≤ 16 a per phase)

IEC 61547:2009 Equipment for general lighting purposes - EMC immunity requirements

IEC 62321:2008 Requirements of concentration limits for certain restricted substances in electrical and electronic products

IEC 62471—2006 Photobiological safety of lamps and lamp systems

IECQ QC 080000 Hazardous substances process management

IES LM-80 Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules

IES TM-21 Projecting Long Term Lumen Maintenance of LED Light Sources

ISO 14782:1999 Plastics -- Determination of haze for transparent materials

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845 and the following apply.

3.1 Horticultural supplementary lighting luminaire

A light source to provide additional light energy for plant growth and development when there is insufficient of natural light

3.2 Horticultural lighting luminaire

A light source to provide light energy for plant growth when there is no natural light.

3.3 Plant absorption spectrum

Plant Absorption Spectrum is the light absorption curve by a plant within a certain range of different wavelengths. It contains chlorophyll a absorption spectrum, chlorophyll b absorption spectrum, antenna pigment absorption spectrum, photosynthesis spectrum, total absorption spectrum and others.

3.4 Photon flux efficacy (PFE)

$\mu mol \cdot s^{-1} \cdot W^{-1}$

The number of emitted photons per unit time per unit power is called photon flux efficiency.

3.5 Photon flux density (PFD)

E_P

$\mu mol \cdot m^{-2} \cdot s^{-1}$

The number of photons that reach or pass through a unit area per unit time.

$$E_P = \frac{d\Phi_P}{dA}$$

Where: Φ_p is photon flux in $\mu mol \cdot s^{-1}$ and A is area in m^2.

3.6 Luminous flux maintenance factor

Ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions.

3.7 Lifetime (of plant lighting)

The reduction of LED photon flux to 70% of its initial value or reaching 70% of calibrated LED life expectancy, under the predefined lighting conditions for plant growth.

Unit: hour

3.8 Spatial spectral uniformity

The degree of consistency of the spectral power distribution (SPD) of LED luminaires at various locations in space. In this standard, the ratio of the minimum value to the average value of the red-blue light ratio on the specified plane ($U_{R/B}$) is used for spatial spectral uniformity.

3.9 Haze

Percentage of transmitted light, passing through a specimen, which deviates from the incident light by no more than 0,044 rad (2,5°) by forward scattering.

4 Classification

4.1 Classification according to the application of the luminaire

The luminaires have been classified into plant supplemental lighting luminaire and plant-growth lighting luminaire.

4.2 Classification based on the light control method

According to the control method, the luminaires are classified as either adjustable or non-adjustable.

The control methods could be included as follow:

a) tunable photon flux;

b) tunable duty cycle;

c) tunable spectrum.

5 Technical requirements

5.1 Structure and appearance

5.1.1 Structure

5.1.1.1 The external, internal, installation and light source structure of the luminaire must be robust enough during its normal operation to eliminate safety risks and hazards to the users and the environment.

5.1.1.2 The internal and external surfaces of the luminaire housing should be treated for anti-corrosion and coated with high performance anti-UV adhesive layer.

5.1.2 Appearance

5.1.2.1 The luminaire should not be damaged, deformed, with cracks, stained, rusted or with any other defects. There should not be any burr at the edges, loosening or missing parts, discoloration or serious chromatic aberration. Optical materials should be clear without bubbles and scratches and have good adhesion of coatings. Labels should be clear and durable.

5.1.2.2 The luminaire should be able to meet the environmental requirements of the site, and there should be no apparent change in appearance quality during the service life period.

5.1.2.3 Plastic materials (connectors, wires and etc.) of the luminaire should be anti-UV and have resistance to high temperature, cyclic thermal stresses, chemical and electrochemical corrosion.

5.2 Electrical properties

5.2.1 Power

The measured power of the luminaire should not be more than ±10% of its nominal power.

5.2.2 Power factor

The power factor requirement for the luminaire is shown in Table 1.

Table 1 Power factor requirements for luminaires

Measured power (W)	Power factor(min)
P≤5	0.50
5<P≤25	0.70

P>25	0.90

5.3 Optical properties

5.3.1 Photon flux

The measured photon flux of the luminaire should not be less than 90% of its nominal value.

5.3.2 Iso-photon flux density curve

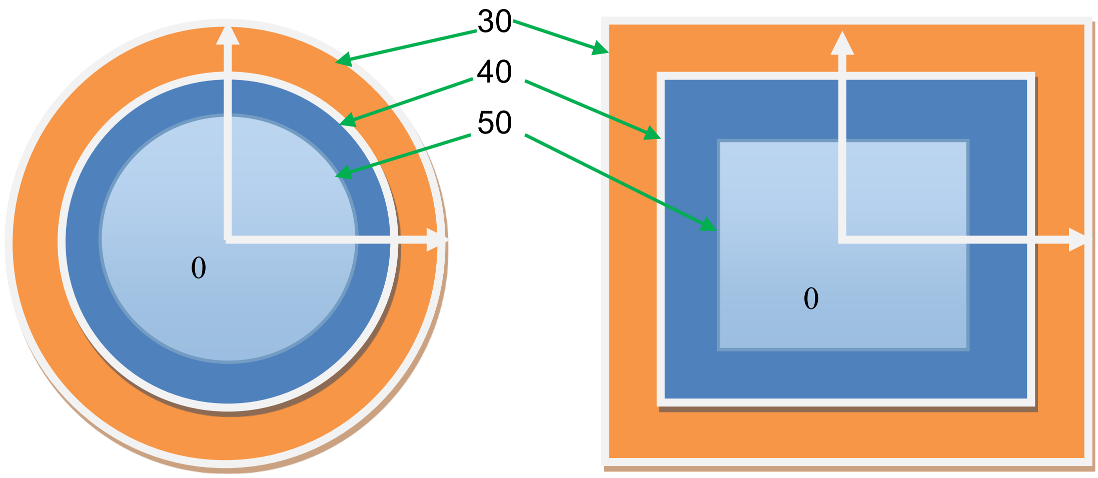
The iso-PFD curve is centered on the projection point of the geometric center of the luminaire on the vertical normal plane, and the PFD curve at center point is measured and recorded as PFD_c. The PFD value of each point on the plane is measured with a step size of not more than 0.1 m; and a curve surrounded by points where the PFD value farthest from the center point is equal to 50% PFD_c, 40% PFD_c, and 30% PFD_c, respectively, is plotted. The iso-PFD curve should include the information as below:

A. The vertical distance between normal plane and luminaire;

B. PFD_c value;

C. The side length or diameter of iso-PFD curve;

Note: For LED plant growth luminaires containing UV light, the PFD curve at the center point between 315 nm ~ 400 nm and 280 nm ~ 315 nm should also be given.



5.3.3 Spatial spectral distribution uniformity

The spatial spectral distribution uniformity on the normal plane above the planting surface with 30cm vertical distance should greater than 80% ($U_{R/B}$≥80%).

5.3.4 Haze

According to the feature of lighting demand, the haze of luminous surface should not be less than 30%.

5.3.5 Spectral distribution

a) The luminaire spectrum is made up of various proportions of red, blue and other colors.

b) The luminaire spectrum is predominantly red and blue with fewer other components.

1) Under the normal condition, the peak wavelength of red band should be in the range of 640nm to 670nm.
2) The peak wavelength of blue band should be in the range of 420nm to 470nm.
3) The photon flux of other color ranges (380 nm～420 nm，470 nm～640 nm，670 nm～780 nm, etc.) should be significantly lower (preferably below 50%).

Typical spectral distribution graph (SDG) can be found in Appendix A.

5.3.6 Photosynthetic photon flux density

For LED luminaires that are used for plant light, the photosynthetic photon flux density of plant growth surface should at least meet the basic requirements for normal growth and development of the irradiated plant.

5.3.7 Photometric distribution and color spatial distribution

Clauses 5.3.2, 5.3.3, 5.3.4, 5.3.5, and 5.3.6 give the light distribution, photometric distribution and color spatial distribution requirements of the luminaire.

5.4 Reliability

5.4.1 Lifetime and luminous flux maintenance factor

a) Luminous flux maintenance factor of the luminaires after ignition for 36000 h should not be less than 90% of its initial value;
b) The luminaires should still be able to work normally after 15000 times of switching on-off test.

5.4.2 Environmental adaptability

5.4.2.1 High and Low Temperature Test

Conduct tests according to the procedures described in Section 6.4.2.1. The test results should meet the requirements shown in Table 2.

Table 2 the requirement of environmental adaptability

Clause	Parameter	Symbol	Range		Unit
			Min	Max	
5.4.2.1.1	Storage temperature	T_{stg}	-25	+55	˚C
5.4.2.1.2	Storage relative humidity	Rh_{stg}	20	90	%
5.4.2.1.3	Working temperature	T_{amb}	-10	+45	˚C
5.4.2.1.4	Working environment relative humidity	Rh_{amb}	20	100	%
Environmental requirements not included in this standard should comply with the related requirement of IEC 60598-1.					

5.4.2.2 Humidity test

Conduct tests according to the procedures described in Section 6.4.2.2. The test results should meet the requirements shown in Table 2.

5.5 Housing protection

5.5.1 Protection requirements

In accordance with the requirements of IEC 60598-1:2014, the luminaire housing structure should comply with IP65 or other ratings based on the customer requirements.

5.5.2 Corrosion resistance

The anti-corrosion grade of indoor and outdoor luminaries should comply with the requirements of IEC 60598-1:2014.

5.6 Hazardous substances limits

The **quantity** ratio of Lead, Mercury, Hexavalent Chromium, Polybrominated Biphenyls and Polybrominated Diphenyl Ethers should less than 0.1%, and that of Cadmium should be less than 0.01% contained in the luminaire.

Note: In normal practices, customer may request compliance with IECQ QC 080000.

5.7 Safety requirements

Safety requirements should comply with the requirements of IEC 60598-1:2014.

When the luminaire reaches stable operating temperature, the temperature fluctuation should be controlled within 1℃/h. The reachable luminaire housing temperature should not exceed 60 ℃.

5.7.1 Photobiological safety

The photobiological safety should comply with the requirements of IEC 62471:2006. The "WARNING" highlight characters should be mentioned on the label for safety precaution.

5.8 EMC requirements

5.8.1 The radio-frequency interference (RFI) from the luminaire should comply with the requirements of CISPR 15.

5.8.2 Any luminaire harmonic currents should comply with the requirements of IEC 61000-3-2.

5.8.3 The electromagnetic compatibility (EMC) of the luminaire should comply with the requirements of IEC 61547:2009.

6 Test methods

6.1 Laboratory requirements for testing

The Laboratory requirements for testing should comply with the chapter 4 of CIE S 025:2015.

6.2 Structure and appearance

Visual inspection method.

6.3 Photoelectric parameters

6.3.1 General test

The tests of photoelectric parameters are only conducted after the luminaire has achieved stable and rated working condition.

6.3.2 Photon flux

The spectral distribution of the luminaire is measured by spectral analysis system (sphere spectroradiometer or gonio-spectroradiometer).

The test method should comply with the procedures in CIE S 025:2015. After obtaining the spectral distribution, apply formula (3) to determine the photon flux (Φp).

$$\Phi_p = dN_p / dt = \int \Phi_{e\lambda} \bullet \lambda / (N_A \bullet hc) d\lambda \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Note: h—Planck constant

c—Speed of light

λ—Light wavelength

N_A—Avogadro number

N_p—Photon number

$\Phi_{e\lambda}$—Spectral density of radiant energy flux

t—time

The integrating sphere spectroradiometer is applicable for the measurement of small size luminaires, whereas the distributed spectroradiometer is applicable to any size luminaires.

6.3.3 Iso-photon flux density curve

According to equivalence map of PFD on the surface which vertical to the normal direction of the luminaire with 15cm and 30cm distance, the diameter or side length of the enclosed area by 50%, 40%, 30% and 20% value of peak PFD could be measured and entered in Table 3.

Table 3 Plane Photon Flux Density distribution

Distance to luminaire	50% PFD area（cm）	40% PFD area（cm）	30% PFD area（cm）	20% PFD area（cm）
15 cm				
30 cm				

6.3.4 Spatial spectral distribution uniformity

a) For a monochromic LED luminaire, it is not necessary to measure the spatial spectral distribution uniformity；

b) For a white or multicolour LED luminaire, the uniformity will be determined on a surface with vertical to the luminaire of 30cm. The spectral irradiance should be measured on a grid not greater than 5cm. The uniformity of the red and blue ratio ($U_{R/B}$) should be calculated using formula (4).

$$U_{R/B} = \frac{X_{min}}{\bar{X}} \qquad (4)$$

Where:

X_{min}-the minmum of red and blue ratio;

$\overline{X}$-the mean value of red and blue ratio;

Note: only the point of more than 10% peak PFD value could be calculated.

The formula of red and blue ratio as shown below：

$$R/B = \frac{\int_{600}^{700} E_e(\lambda,x,y,z)d\lambda}{\int_{400}^{500} E_e(\lambda,x,y,z)d\lambda} \quad (5)$$

Where:

$E_e(\lambda, x, y, z)$-any one point of spectral irradiance in space;

(x,y,z)-spatial coordination, which z=30cm.

6.3.5 Haze

Test method should comply with ISO 14782.

6.4 Reliability

6.4.1 Lifetime and luminous flux maintenance factor

a) Luminous flux maintenance factor

Based on the IES TM-80 test report, luminous flux maintenance factor should be calculated using the IES TM-21 method.

b) Switching times

The luminaire should operate normally after 15000 ON-OFF switching cycles, under the rated working condition. Cycle of the ON-OFF switching test should be set to “ON” for 30 s and “OFF” for another 30 s.

6.4.2 Environmental adaptability

6.4.2.1 High and low temperature test

a) High temperature operation test: according to IEC 60068-2-2:2007 procedures, the luminaire will be stored for 2 h at 55±2 ℃ and then sat a room temperature of 25±2℃ for 2 h. The luminaire will be inspected and it should be able to operate normally.

b) High temperature load test: according to IEC 60068-2-2:2007 procedures, the luminaire will be operated for 16 h at 35±2 ℃ and then at a room temperature of 25±2 ℃ for 2 h. The luminaire will be inspected and it should be able to operate normally.

c) Low temperature storage test: according to GB/T 2423.1 - 2008 procedures, the luminaire will be stored for 2 h at -25±3 ℃ and then at a room temperature of 25±2 ℃ for 2 h. The luminaire will be inspected and it should be able to operate normally.

d) Low temperature operation test: according to IEC 60068-2-1:2007 procedures, the luminaire will be operated for 1 h at 10±3 ℃ and then at a room temperature of 25±2 ℃ for 2 h. The luminaire will be inspected and it should be able to operate normally.

e) High and low temperature thermal shock test: according to IEC 60068-2-14:2009 procedures, the luminaire is placed in its normal working position without packing and power supply, to undergo:

1) Reduce temperature to -10±3 ℃ and maintained for 3 h.
2) Increase temperature to 40±2 ℃ and maintained for 3 h.
3) Reduce temperature to 25±2 ℃ and maintained for 3 h.

Repeat steps 1 to 3 for 10 times and then restore the room temperature to 25±2 ℃ for 2 h. The luminaire should be able to operate normally.

6.4.2.2 Humidity test

According to IEC 60068-2-78 and IEC 60529 procedures, place the luminaire without power supply at temperature and relative humidity of 40±2 ℃ and 93±3%, respectively for 96 h. Then reduce the temperature and relative humidity to 25±2 ℃ and 60±2%, respectively for 4 h. The luminaire will be inspected and it should be able to operate normally.

6.5 Housing protection grade

The protection grade of luminaire housing should be tested according to IEC 60598-1:2014 procedures. The test result should meet the requirements described in Section 5.5.1.

The anti-corrosion grade of luminaire housing should be tested according to IEC 60598-1:2014 procedures. The test result should meet the requirements described in Section 5.5.2.

6.6 Hazardous substances quantities

The quantity of hazardous substances in the luminaire should be measured according to IEC 62321:2008 procedures. The measured result should meet the requirements described in section 5.6.

6.7 Safety performance

The safety hazards of the luminaire should be tested according to IEC 60598-1:2014 procedures. The measured result should meet the requirements described in Section 5.7.

6.8 EMC performance

The electromagnetic compatibility (EMC) of the luminaire should comply with the requirements of CISPR 15, IEC 61000-3-2 and IEC 61547:2009.

Annex A
(Informative Annex)
Absorption spectra of typical plants

A.1 Spectral response of photosynthetic quantum efficiency of green leave s

Leaf photosynthetic pigments play an important role in the absorption and utilization of light during photosynthesis. Chlorophyll has a strong capacity to absorb light. There are two absorption regions with the strongest absorption capacity of chlorophyll: one is in the red-light wavelengths of 600-700 nm, the other is in the blue light wavelengths of 420-470 nm. McCree et al. (1972) have investigated leaf photosynthesis of 22 common plant species under different light conditions in growth chambers and open fields, and analyzed the leaf photosynthesis rate to different spectra, and concluded that the photo quantum efficiency of plant photosynthesis was the highest in the red and blue light regions (Fig.A-1). Therefore, it is widely accepted that red and blue light are the main spectra of plant photosynthesis. At present, different proportions of red and blue light are the main spectra for electric light for plant production.

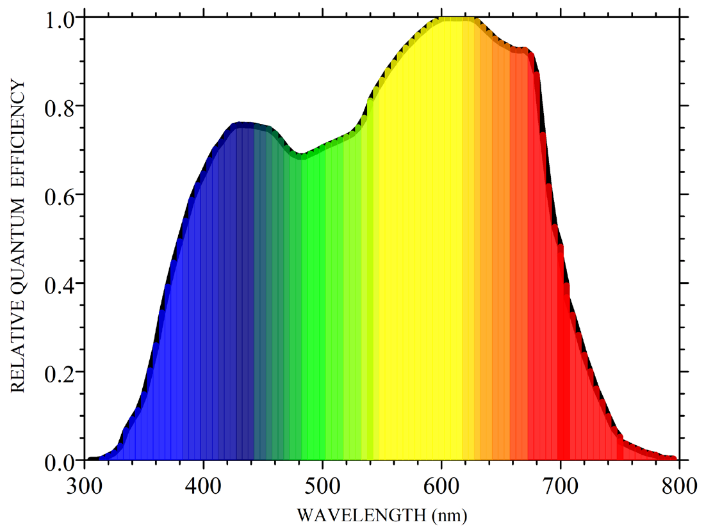


Fig. A-1. Spectral response of photosynthetic quantum efficiency of green leaves.

A.2 Leaf light absorption in the range of visible radiation

In the visible band (400-700 nm), plant leaves have the highest light absorption in the blue and red regions, and the lowest absorption in the green region (as shown in Figure A-2). The average light absorption of leafy vegetables in the visible wavelength is generally about 87-93%, which varies with species and leaf age.

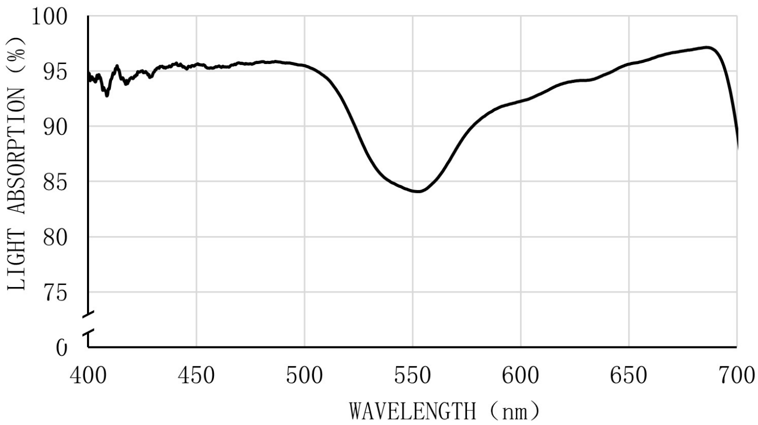


Figure A-2. Leaf light absorption of Lettuce (Lactuca sativa L. cv. *'Tiberius'*) (average light absorption in PAR range is 92%).

A.3 Typical light source spectral structure

Typical spectral structures of LED light sources are shown in Figure A.3.

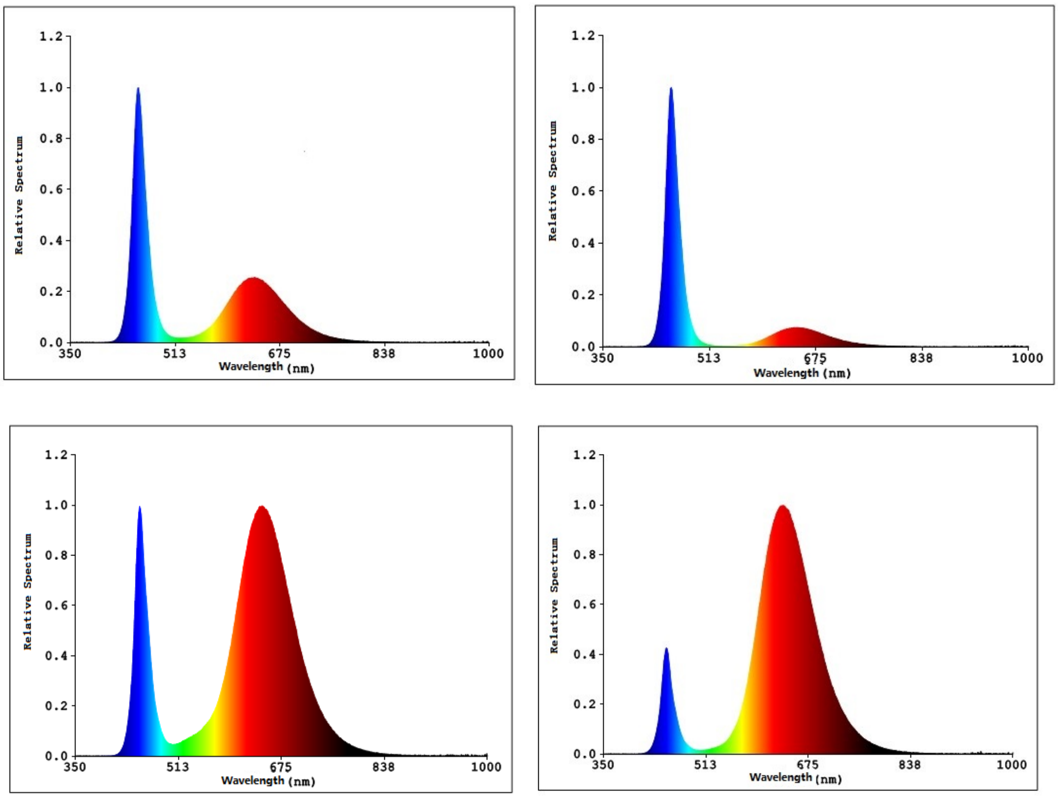


Figure A.3. Several typical spectral structures of light sources

A.4 Leaf photosynthesis photosynthetic photon flux density (PPFD) respon se curve

Leaf photosynthetic rate is the amount of carbon dioxide (CO_2) assimilated per unit photon quantum per second per square metre of leaves. Fig. A.4 is a schematic diagram of the leaf photosynthesis PPFD response for typical leafy vegetables. As shown, the PPFD response curve of leaf photosynthesis has several important points/stages. When PPFD is 0 μmol m^{-2} s^{-1} (i.e. dark, point A), there is no photosynthesis, but only respiration, i.e. consume organic matter and release carbon dioxide. When PPFD increases to a certain value where the amount of photosynthetic assimilation of CO_2 is equal to the amount of CO_2 released by respiration, and the PPFD at this point is the light compensation point (point B). When PPFD higher than the light compensation point, the amount of CO_2 assimilated by photosynthesis is larger than that released by respiration, and the photosynthetic rate increases with the increase of PPFD. At this stage, the photosynthetic rate is linearly related to PPFD (C), and its slope represents the photosynthetic light use efficiency. In the whole photosynthetic PPFD response curve, the light use efficiency in this stage is the largest. When PPFD increases to a certain level, the increases of photosynthetic rate slows down until it remains stable, indicating photosynthesis reaches its maximum value, and this point is called light saturation point (point D), and its corresponding PPFD is called saturated PPFD.

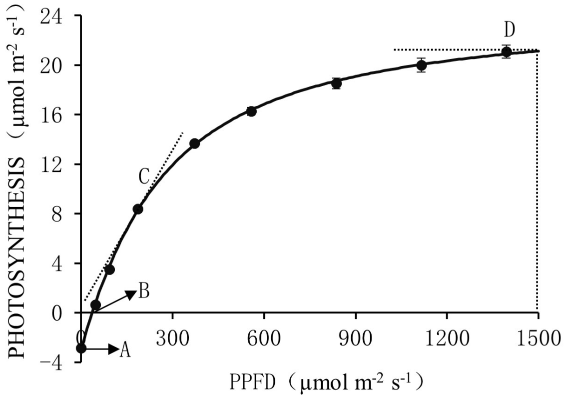


Figure A.4. Leaf photosynthesis PPFD response curve of Lettuce (Lactuca sativa L. cv. *'Tiberius'*) (in the figure, point represent measured data, solid line through data points represent the fit to the non-rectangular hyperbola).

A.5 Typical sole-source lighting spectrum

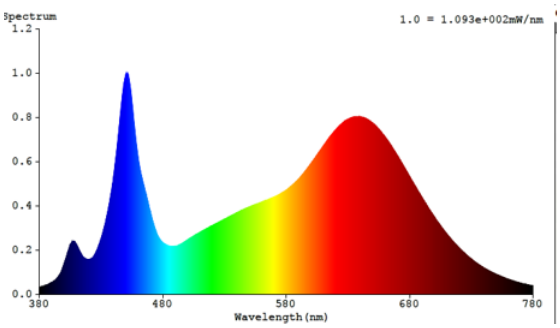


Figure A.5. Typical sole-source light spectrum (380-800nm).