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01/06

Horticultural lighting

Photometry in greenhouse horticulture

Contents

1. Introduction

Before a new horticultural lighting installation is installed, the service-provider (normally the installer) draws up a quotation/specification to forecast the performance of the installation. After installation, photometry is used to show whether the installation meets the forecast performance. Because so many variables affect the installation and therefore photometry, a well-defined measuring protocol is needed, to safeguard the service-provider and satisfy the client.

Light measurements carried out in accordance with this protocol will then produce an assessment of the lighting installation that is as objective as possible and mutually comparable and acceptable.

This protocol was produced in collaboration with the following Dutch parties:

- DLV Adviesgroep in Aalsmeer.
- Hortilux Schréder b.v. in Monster.
- Philips Nederland in Eindhoven.
- PPO in Aalsmeer.
- Raymax b.v. in Monster.
- WLTO Advies in Naaldwijk.

Quality criteria for lighting

When measuring lighting intensities, it is important to choose a representative measuring field in the greenhouse, ensuring that all surrounding sources of lighting for the site being measured can reach the photocell without hindrance.

2. Measuring light and lighting intensity in practice

The performance of a lighting installation is measured to check that it performs to the grower's requirements. Measurements are taken either shortly after delivery, to check whether the installation is performing in accordance with the order or later in the installation's life, to check whether it still satisfies the requirements placed on it. In older installations, a drop in lighting intensity can be caused by ageing lamps and dirty reflectors, and the uniformity of lighting intensity can be affected by ageing or changes made to the installation. The measurements are taken at a minimum of two measuring fields chosen as being representative of the installation as a whole.
This measuring protocol relates specifically to measurements carried out to check the installation immediately after delivery.

2.1 Representative measuring field

The measuring field must be a representative part of the lit greenhouse, over the entire width of a single roof span. In principle, the measuring field should cover two adjacent lamps, or three if the lamps are close together (<2 m). Measurements must also be easily compared with the theoretical calculation as given in the supplier's lighting plan. If practical considerations (for example, the lack of availability of a suitable PAR meter) make this impossible, the service provider will have to produce a new theoretical calculation. Interference from peripheral factors must be avoided. Where possible, there should be at least three rows of burning luminaires either side of the measuring field and at least four burning lamps in the row in front of and behind the measuring field. The tester should record if this is not possible.

A measuring grid is laid over the measuring field in the plan of the greenhouse floor area such that the lines either intersect beneath each luminaire or intersect centrally between two luminaires and two rows of luminaires (see Appendix 3 Page 11-12). The number of grid lines in the measuring field is determined by the number and position of the pathways between growing beds on the floor below.

The grid should consist of an uneven number of lines in the roof and an uneven number of diagonals on the roof.

- width from 9.6 m: 9 x 5 points
- width from 8.0 m: 7 x 5 points
- width from 6.4 m: 7 x 5 points
- width from 4.0 m: 5 x 5 points

Measurements are made at the intersections of the grid lines. To be representative, a measuring field must contain at least 25 measuring points. Measurements may also be taken in the centre of the beds if required.

3. Assessing the lighting installation

The following points are important in assessing the luminous quality of the lighting installation in a greenhouse:

1. geometry,
2. the photometric data of the installation,
3. power supply and energy consumption,
4. environmental factors at the time of measurement.

3.1 Geometry

Geometric parameters concern the greenhouse, the installation and the environment.
The following parameters are important:

- roof width
- installation of the luminaires (on grating or in rows on a cable duct)
- position of the rows with respect to the roof
- distance between underside of luminaire and measuring height/sensor
- position of the growing segments where measurements are to be carried out in relation to the whole greenhouse.

3.2 Luminous properties of the installation

The following data are important for the tests:

- manufacturer and serial number of each luminaire
- nominal supply voltage for which the luminaire is designed
- manufacturer and serial number of the light sources (lamps)
- space between luminaires within a row; is this constant?
- space between rows of luminaires is this constant?
- lamps all suspended at the same height?
- delivery date of installation
- number of burning hours of light sources
- whether supply comes from the mains or from a local generator.

3.3 Power supply and energy consumption

Information about the power supply is important because of the dependence of light output on line voltage and also to maintain the energy efficiency of the installation. An excessively low voltage or an excessively high THD (Total Harmonic Distortion) has an adverse effect on light output.

Parameters to be measured for this are:

- voltage on the power supply panel (all phases + zero)
- THD as a percentage of the voltage

The light output of a high-pressure sodium lamp may be assumed to be directly proportional to the power consumption within the working tolerance specified by the lamp manufacturer. Determining the power consumption per luminaire is therefore a good way of estimating the effect of voltage or voltage quality on light output.

3.4 Environmental factors

These can adversely affect measurements, or even make them impossible. In some cases the measurement results will require correction.

The following parameters should be determined when recording:

- Light level of the surroundings (light from outside not more than 1% of the measured light level inside)
- Is there spray/mist in the greenhouse? If so, measurements cannot be taken
- Are there visual obstacles between the luminaires and the plants, such as heating pipes, water spray installation, etc. If so, determine the position of the shadows in the measuring field and avoid placing measuring points in these areas
- Reflection from ground due to e.g. white groundsheet with no plants
- Sealed protective canvas in combination with an empty greenhouse (concrete floor)

4. Conditions for measuring lighting

4.1 Framework conditions

Before measurements are taken, the installation must have been switched on long enough for the lighting intensity to have stabilised. Normally this is the case around 30 minutes after switching on.

The effects of environmental factors (see chapter 3.4 Environmental factors) must be avoided or explicitly mentioned in the report.

4.2 Measuring lighting intensities

Lighting intensity should be measured in the unit indicated in the quotation/specification. Lighting intensity is measured using a cosine-corrected sensor. A quantum sensor (PAR sensor*) is preferable for measuring the number of photons between 400 - 700 nm, simply because the measuring data from various light sources can then be compared (lux sensors are also permitted). The use of a loose measuring cell, connected to the indicating instrument by a cable at least 2 m long, is recommended. Wear neutral clothing to avoid unwanted reflection (no white). The measuring cell must be carefully placed horizontally and at the same height on each measuring point. It is recommended that a holder on a tripod be used.

*) Photosynthetically Active Radiation, expressed in $\mu Mol/m^2.s$ or PPFD.

4.3 Framework conditions for photometry

The environmental factors referred to in chapter 3 “Assessing the lighting installation”.
will affect the measurement of light and will therefore have to be assessed using a check-list. See also Appendix 3: “Specimen form with photometric data to be noted”.

4.4. Conditions placed on luminaires and lamps

The control measurements for new assimilation lighting installations using high-pressure sodium lamps must be taken after the lamp/luminaire combination has been burning for at least 100 hours and for not more than 500 hours. It can be assumed that the light outputs of the lamps between these specified burning hours vary little from the light output figures used in the original specification. Light loss is negligible after longer burning times (see lamp manufacturers’ specifications for further details).

4.5 Additional measurements

The mains voltage must be recorded immediately before and after light measurement. The voltage is measured on the supply panel of the fittings where the light measurement is taken. All three phase voltages must be measured, including the THD proportion of the voltage (as percentages).

5. Measuring in practice

Introduction

A measurement order should at the least indicate what photometric quantities and measurements are being requested and the extent of these measurements.

5.1 Delivery measurement of new installation

Measure in an appropriate point pattern to obtain as close an approximation as possible to the value of the quantity being measured, in particular the mean luminous intensity and the distribution of light (min./max. in %).

NOTE

- The purpose of these measurements is to show whether the installation satisfies requirements.
- Installation complies with drawings/quotation.
- Testing whether the installation complies with the results of the photometric calculation of the luminaire supplier.
- At least two complete measuring fields must be measured.
- In the case of variations >5% take a third measurement

6. Measuring instruments

The following measuring instruments and aids are required for photometric measurements:

The measuring instruments used must be calibrated on delivery and subsequently in accordance with the manufacturer's instructions (usually annually). Variations must be listed in a calibration report to be stored with the measuring instrument.

6.1 Requirements to be placed on personnel and organisation

The electrical measurements taken at the time of the light measurements must be carried out using NEN 3140 'hazardous measurements' procedures. The people who carry out the measurements must have sufficient knowledge and training to be able to work in accordance with the applicable guidelines.

6.2 Instrument for measuring lighting intensity (lux)

The luxmeter must satisfy the requirements imposed in Appendix 1 for maximum permissible specific margins of error and maximum permissible total margin of error.

According to Appendix 1 of NEN-EN 1838 from 1999:

- All lighting intensity meters must be designed with cosine V(Ì) correction (= measuring correction for oblique light + spectral sensitivity of the human eye)
- The appliance may have a maximum error tolerance of 5% (see Appendix 1)

6.3 Instrument for measuring PAR

The same requirements apply to PAR meters as to luxmeters, except that the spectral sensitivity is adapted for plant growth. Quantum meters are preferred as PAR meters (see Appendix 2).

6.4 Voltage quality meter

A voltmeter of at least class 0.5 to NEN 10051-2 that gives the TRUE RMS value of the voltage must be used to measure mains voltage (or an equivalent class for digital meters). It must also be possible to determine the THD value of the supply voltage.

N.B.

Instruments must not be exposed to external conditions of temperature and/or relative humidity, nor be subjected to shocks or strong vibrations during use, storage or transport. Make sure that the meters are free from condensation during measurement and are at least at room temperature

Appendix 1

Photometers' Specifications

Characteristic	Symbol	Max. permissible specific margin of error %
Adaptation to relative spectral ocular sensitivity (V-adaptation)	F1	3
UV sensitivity	U	1
IR sensitivity	R	1
Correction for non-perpendicular oblique light (cosine correction)	F2	1,5
Variation of linearity	F3	1
Variation of measuring instrument	F4	3
Temperature coefficient	A	0,2/K
Fatigue	F5	0,5
Frequency dependence of light fluctuation	F7	0,2
Adjustment error	F11	0,5
Maximum permissible total margin of error for the luxmeter	Ft	5*)

*) ft is the sum of the specific margins of error

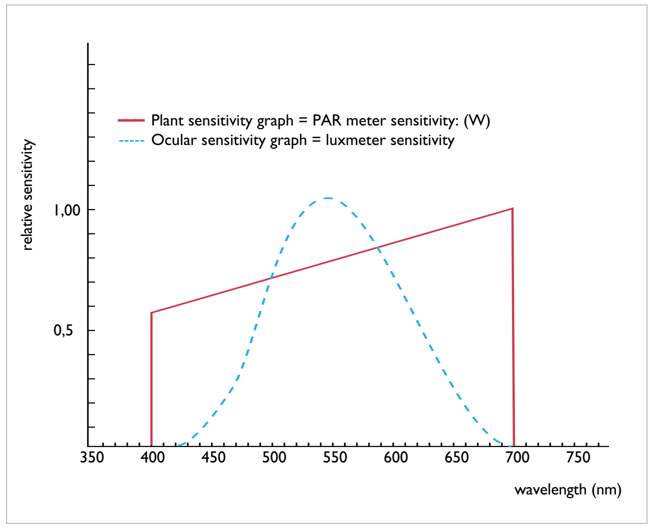
Appendix 2

Spectral response of luxmeter

The spectral response of the human eye can be depicted in graphic form on the so-called Ï-graph. In this graph the sensitivity of the human eye (V) is plotted against the wavelength of the light (see figure). This graph shows the results of measurements taken with a number of people and is used by the International Standards Organisation (ISO). A luxmeter has a response similar to the human eye (blue dotted curve in figure below).

Spectral response of PAR meter

PAR (Photosynthetic Active Radiation) is the spectrum between 400 - 700 nm. Photosynthesis rate is determined by the number of photons (quanta) absorbed between 400 and 700 nm and not by the sum of energy levels of these photons. The number of photons is therefore the most suitable measure in which the amount of light for a photochemical process can be expressed. A quantum sensor (cosine-corrected and only sensitive in the PAR part of the spectrum) measures the number of photons in μmol/m²sup. A measured lighting intensity in lux therefore has to be totally converted to the number of photons in μmol/m²s. Note that this conversion factor is dependent on the type of light source/burning hours at the time of measurement. The spectral response of the PAR Watts is shown by the solid red line in the figure below.



Appendix 3

Specimen form to record photometric data

Client: ____________________

Purpose of the measurement: control measurement/delivery measurement*

Name: ____________________
Address: ____________________
Town: ____________________
Tel./Fax: ____________________

Location of measurement in greenhouse: Roof no ______ Left/right* of the central path Luminaire no ____ / ____
Location of measurement in greenhouse: Roof no ______ Left/right* of the central path Luminaire no ____ / ____
Location of measurement in greenhouse: Roof no ______ Left/right* of the central path Luminaire no ____ / ____

Luminaire details

Manufacturer: ____________________
luminaire suitable for: 220 / 230 / 240 Volt / or else...
Type of reflector: ____________________
Make of lamp/wattage: ____________________

Installation details

Length/width/suspension height: ________ m
Height of lamp/measuring height: ________ m

Installation date: mon/yr Number of burning hours - lamps: ________ hrs
Number of burning hours - luminaires: ________ hrs

Power supply

TE Parallel/Island Utility connection*

Voltage L1 ________ L2 ________ L3 ________
Quality of supply voltage L1 ________ L2 ________ L3 ________
Measured on supply panel / luminaire / ________

Quality of supply voltage

____
____
____

Equipment used + calibration date: photometer ________
voltmeter ________

* Delete wherever not applicable

Appendix 3 (cont.)

Specimen form with photometric data to be noted

Field measurement taken in lux/PAR*

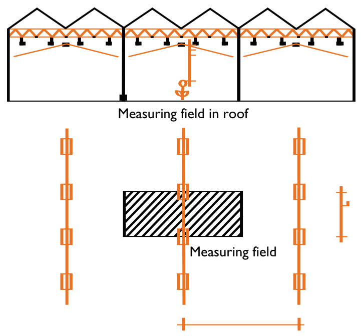
Measuring field dimensions: ________ x ______ x ______ (lxwxh)

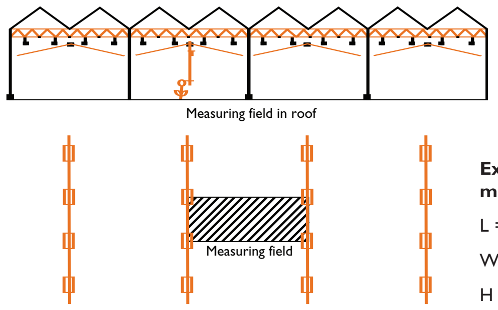
Measuring data for field 1
N.B.: please circle the fittings in the measuring field

	1	2	3	4	5	6	7	8	9
A									
B									
C									
D									
E									

Measuring data for field 2

	1	2	3	4	5	6	7	8	9
A									
B									
C									
D									
E									





Example of representative measuring field

L = distance between fittings in the row

W = distance between rows

H = height between lamp and plants

If possible lay out measuring field in accordance with quotation/lighting plan (see representative measuring field)
Comment:

____

____

____

____

____

Measuring date: ______________________________

Measured by: ______________________________