

Measurement Protocol

Light Measurement in Horticulture

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1 Introduction

The purchase of a lighting installation by horticultural companies usually starts with a proposal/specifications drafted by the supplier, stating the specifications the installation has to meet. Generally speaking, these suppliers are electrical contractors. Light measurements are usually conducted to assess if the installation meets the light related specifications. Due to the diversity of aspects influencing the installation/light measurement, both client and supplier will benefit from a clearly defined measurement protocol.

Light measurements conducted in accordance with this protocol will lead to an objective and comparable assessment of the lighting installation.

This protocol has been drafted together with the following parties:

DLV Adviesgroep in Aalsmeer

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PPO in Aalsmeer

Raymax b.v. in Monster

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Lighting quality standards

Light intensity measurements should be conducted in a representative measuring field in the greenhouse in question. During the execution of these measurements, ensure that all light sources contributing to the lighting of the location can reach the photocell (no obstructions).



2. Light and Light Intensity Measurement in Practice

Growers commission continuity tests of lighting installations in order to determine if the installation functions according to specifications. Measurements are conducted shortly after completion, to verify if the installation has been delivered in accordance with the order or later on, to verify if the installation still meets the stated requirements. In older installations, this concerns the decline of the light intensity through lamp ageing and dirty reflectors, or the uniformity of the light intensity as a result of ageing or alterations of the original installation. Measurements should be conducted in at least two measuring fields, selected to be representative for the installation as a whole.

This measurement protocol has been specifically drafted to be used when testing the installation immediately after delivery.

2.1 Representative measuring field

The measuring field should consist of a representative section of the lighted greenhouse, over the full width of one roof. In principle, the measuring field covers two consecutive lamps, or when lamps are densely spaced, (<2 meters) three consecutive lamps. Furthermore, the field should enable comparison with the theoretic calculation as stated in the supplier light plan. If this is not feasible for practical reasons, a new theoretical calculation will have to be made. All edge effects should be prevented. As a rule, at least three strings of burning fixtures should be located to the left and right of the measuring field, and at least four burning lamps should be located in the string in front of and behind the measuring field. If this is not possible, this should be recorded. A measuring grid is applied over the measuring field. The measuring grid is a collection of points defined as the crossing of gridlines spread evenly over the measuring field (see figure appendix 3; representative measuring field). The number of gridlines distributed over the roof is determined by the number of paths under the roof, also allowing measurements to be taken in the middle of beds.

Depending on the geometry of the measuring field, the following recommendations apply: The grid has to be selected in such a way that crossings are located immediately below the different fixtures. This also applies to the central positions between 2 fixtures and 2 strings of fixtures. Therefore, the grid has to consist of an odd number of lines in linear direction of the roof, and an odd number of lines widthwise.

- width of 9.6 meters: 9 x 5 points
- width of 8.0 meters: 7 x 5 points
- width of 6.4 meters: 7 x 5 points
- width of 4.0 meters: 5 x 5 points

A representative measuring field should incorporate at least 25 measurement points.

3. Assessment of Lighting Installation

The following aspects should be taken into account in the assessment of the technical light quality in a greenhouse:

1. Geometry
2. Light related technical characteristics of the installation
3. Power supply and power consumption
4. Surrounding factors at the time of the measurement

3.1 Geometry

Geometric parameters refer to the greenhouse, the installation, and its surroundings.

The following parameters should be taken into consideration:

- roof width
- mounting method of the fixtures (on truss or in strings to a cable duct)
- position of the strings per bay
- distance between underside fixture and measurement height/sensor
- position of the bays to be assessed in the greenhouse

3.2 Light related technical characteristics of the installation

- make and type number of the fixture
- nominal supply voltage for which the fixture is fit
- make and type number of the source of bulb
- mutual distance of the fixtures within a string; is this constant
- mutual distance of the fixtures between strings; is this constant
- have the fixtures been leveled in horizontal direction
- completion date of installation
- number of burning hours of the source of the bulbs
- mains/generator supply

3.3 Power supply and power consumption

Data concerning the power supply are important; because of dependency of the light output of the light sources on the electric potential, and also because of the energetic output of the installation. Low voltages or high THD-distortion have a negative effect on the light output.

Parameters to be measured in this context are:

- electric potential in the supply panel (all phases + zero)
- the percentage of THD-distortion (Total Harmonic Distortion*) in the voltage

*) Total harmonic distortion of the mains voltage expressed as a percentage.

The light output of the high-pressure sodium lamp can be assumed to be directly proportional to the capacity measured within the work area, specified by the lamp manufacturer. Any statements on the effects of either voltage or voltage quality on the light output, should preferably be based upon an assessment of the power consumption per fixture.

3.4 Surrounding factors

These may influence the measurement results, or even preclude them altogether. In some cases, correction of the measurements results is required. The recording has to include an assessment of the following parameters:

- Intensity of light in the vicinity (external light should not exceed 1% of the light intensity measured inside)
- Is there any spray/mist inside the greenhouse? If this is the case, measurements should not be conducted
- Are there any interfering elements between the fixtures and the crop, such as heating pipes, sprinklers etc.? If this is the case, determine the position of shade spots in the measuring field and avoid the inclusion of measurement points in such locations
- Reflection surface by f.i. white floor cloth without crop
- Closed screen in combination with empty greenhouse (concrete floor)



4. Conditions for Light Intensity Measurements

4.1 Preconditions

In order to perform valid measurements, the installation should be switched on well before, to allow the light intensity to stabilize. In general, this will occur approximately 30 minutes after the system has been switched on.

Effects of surrounding factors (see chapter 3.4 Surrounding Factors) have to be avoided or have to be expressly included in the report.

4.2 Measuring light intensity

Light intensity measurements have to be conducted in the unit as defined in the proposal/specifications. Light intensity should be measured with a cosine corrected sensor. Use of a quantum-sensor (PAR-sensor*) for the measurement of the number of photons between 400 – 700 nm is preferable, simply because this will allow you to compare the measurement data of the different light sources to one another (lux sensors are also permissible). The use of a separate measurement cell, connected to the indicating instrument via a 2 meter cable, is recommended. Neutral clothes should be worn to prevent reflection (no whites). The measurement cell has to be placed at the same height for each measurement point. It is advisable to use a tripod with holder.

*) Photo synthetically Active Radiation, expressed in $\mu\text{Mol}/\text{m}^2.\text{s}$ or PPF.

4.3 Preconditions light measurement

See surrounding factors described in chapter 3 “Assessment of Lighting Installation”. Any such conditions will influence the light measurement and will therefore have to be assessed using a checklist. See also appendix 3: “Form for Recording Light Measurement Data”.

4.4 Preconditions concerning fixtures and lamps

Control measurements in new assimilation lighting installations (also growlight installations) with high-pressure sodium lamps have to be conducted after the lamps have burned at least for 100 hours, but not more than 500 hours.

The luminous flux of the lamps between these burning hours should be assumed to scarcely differ from the luminous flux used in the light calculation.

Beyond 500 burning hours, the decline is no longer fractional (see specifications of lamp manufacturer for further details).

4.5 Additional measurements

The mains voltage has to be determined immediately before and immediately after termination of the measurement. The voltage should be measured at the supply panel of the fixtures in question.

All three phase voltages are measured, including the THD-distortion share of the voltage (percentage).

5. Measurements in Practice

Introduction

Measurement assignments should at least include the technical light variables or measurements are required, and should include the scope of the measurements.

5.1 Completion measurement of new installation

Measurements in an appropriate grid pattern to realize the most accurate possible approximation of the value of the variable to be measured, in particular the measured light intensity and light distribution (min./max. in %).

PLEASE NOTE:

- . These measurements aim to assess if the installation meets its requirements.
- . Installation in conformity with plan/proposal.
- . The installation assessment meets the outcome of the technical calculations of the fixture manufacturer.
- . At least 2 complete measuring fields have to be measured.
- . In case of variance > 5%, execute third measurement.

6. Measuring Instruments

6.1 Measuring instruments and tools

For light specific measurements, the following measurement instruments and tools are required.

The measurement instruments used should be calibrated upon receipt, and subsequently in accordance with supplier specifications (usually annually). Variances have to be recorded in a calibration report, which has to be kept together with the measurement instrument.

6.2 Personnel and organization requirements

The electrical measurements conducted at the time of the light measurements, have to be executed in accordance with NEN 3140 standards for the execution of risk-bearing measurements. Any persons conducting such measurements in practice are deemed to have knowledge of and to be fully qualified to conduct such measurements in accordance with applicable guidelines.

6.3 Measuring instruments for light intensity in lux

The luxmeter used has to meet the requirements regarding the maximum permissible specific error margin and the maximum permissible total error margin, as stated in appendix 1.

Appendix 1 of the NEN-EN 1838 issued in 1999 states the following:

- All photometers should be cosine $V(\lambda)$ -corrected
(= measurement correction for slanting incidence of light + spectral sensitivity of the human eye)
- The permissible fault-tolerance of the apparatus is 5% (see appendix)

6.4 Measuring instrument for PAR

The requirements that apply to luxmeters, are also applicable to PAR-meters. They only differ in the sense that the spectral sensitivity has been adjusted to accommodate for plant growth. The preferred type of PAR-meter is the quantum meter (see appendix 2).

6.5 Voltage quality meter

To measure the mains voltage, a class 0.5 or higher voltmeter should be used in accordance with NEN 10051-2 (or equal class of digital meter), which should read the TRUE-RMS-value of the voltage. Furthermore, the instrument should be suitable for determining the THD-value of the supply voltage.

PLEASE NOTE

The instruments should not be subjected to extreme temperatures and/or relative humidity during use, storage, or transportation, nor should they be subjected to shocks or strong vibrations. Ensure that the meters are free of condensation during the measurement and are at least at room temperature.

Appendix

Photometer requirements

| Characteristic | Symbol | Max. admissible specific error margin |
|-----------------------------------------------------------------------|--------|---------------------------------------|
| Adjustment to the relative spectral visual sensitivity (V-adjustment) | FI | 3 |
| UV-sensitivity | U | 1 |
| IR-sensitivity | R | 1 |
| Correction for slanting incidence of light (cosine correction) | F2 | 1.5 |
| Linearity deviation | F3 | 1 |
| Measurement of instrument deviation | F4 | 3 |
| Temperature coefficient | A | 0.2/K |
| Fatigue | F5 | 0.5 |
| Frequency dependency of the light fluctuation | F7 | 0.2 |
| Adjusting error | F11 | 0.5 |
| Maximum admissible total error margin for the luxmeter | Ft | 5*) |

*) ft is the sum of the specific error margins

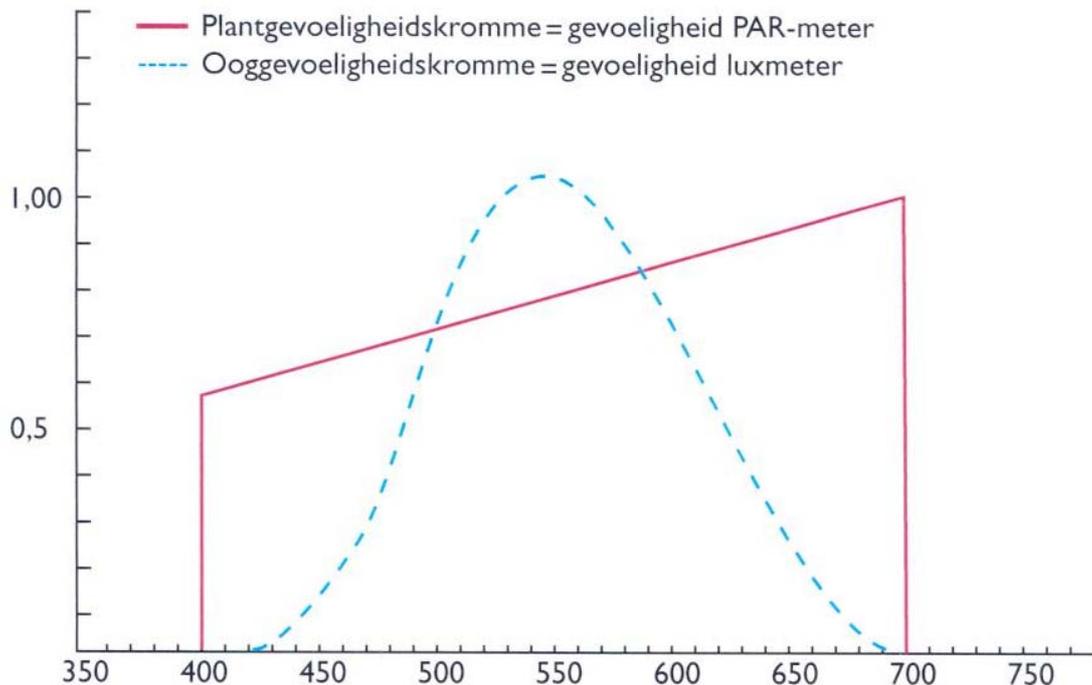
Appendix 2.

Spectral response luxmeter

The spectral response of the visual system (human eye) can be graphically represented. As far as cones in the human eye are concerned, this is the so-called λ -curve. In this curve the sensitivity of the visual system has been plotted out in a relative scale against the wave length of the light. V indicates the sensitivity, which varies according to wave length (see figure). This curve is a representation of the results of measurements conducted with different observers, and is applied by the international standards organization (ISO). The response of the luxmeter is equal to this eye sensitivity curve (dotted curve in figure below).

Spectral response PAR-meter

PAR is the spectrum between 400 – 700 nm (Photosynthetic Active Radiation). The photosynthesis is determined by the absorbed photons (quanta) between 400 – 700 nm, rather than it being the sum of energetic contents of these photons. The number of photons is the most suitable measure to express the amount of light in a photochemical process. A quantum sensor (cosine-corrected and only sensitive to the PAR-part of the spectrum) measures the number of photons in $\mu\text{Mol}/\text{m}^2\text{s}$. Light intensity measured in lux can be roughly converted to a certain number of photons in $\mu\text{Mol}/\text{m}^2\text{s}$. However, this conversion factor will depend upon the type of light source/burning hours at which measurements were performed. The response of the PAR-meter can be seen in the figure below.



Appendix 3.

Sample Form for Recording Light Measurement Data

Client : _____

Aim of the measurement: control measurement / completion measurement*

Name : _____

Address : _____

City : _____

Tel./ Fax. : _____

Location measurement in greenhouse: Roof no. ___ Left /right* from the centrepath Fixture nr. ___/___

Location measurement in greenhouse: Roof no. ___ Left /right* from the centrepath Fixture nr. ___/___

Location measurement in greenhouse: Roof no. ___ Left /right* from the centrepath Fixture nr. ___/___

Fixture specifications

Manufacturer : _____

Arm suitable for : 220/230/240 volt

Type reflector : _____

Brand/wattage lamp : _____

Installation specifications

Length/width/mounting height : _____ meters

Height lamp/measurement height : _____ meters

Installation date: month /year

Number of burning hours lamps : _____ hours

Number of burning hours fixtures : _____ hours

Power supply

TE Parallel/ Island Mains supply*

Voltage L1 _____ L2 _____ L3 _____

Quality supply voltage L1 _____ L2 _____ L3 _____

Measured at supply panel/fixture/ _____

Quality supply voltage

Equipment used + calibration date:

Photometer : _____

Voltmeter : _____

*) Delete where not applicable.

Continuation of appendix 3

Sample Form for Recording Light Measurement Data

Field measurements conducted in lux/PAR*

Size measuring field: ___ x ___ x ___ (lxwxh)

Measurement data field 1

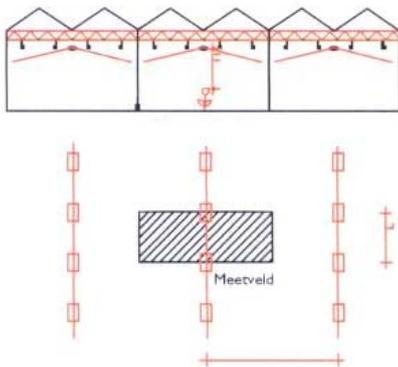
NB: Please circle the fixtures in the measuring field

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

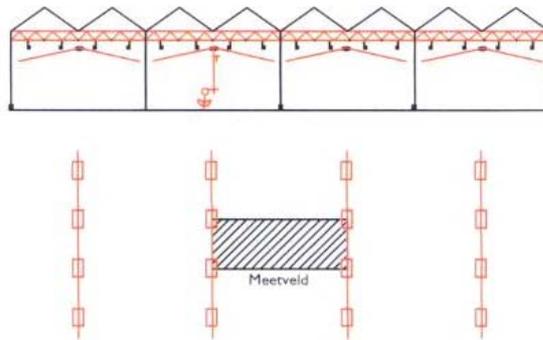
Measurement data field 2

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

Calculation field in 1 bay



calculation field between 2 rows of fixtures



L = distance between the fixtures in a row W = distance between the rows H = height from lamp to crop

Where possible execute measuring field in conformity with the proposal/lighting plan
(see representative measuring field)

Remarks: _____

Measurement date : _____
 Measured by : _____