Phymea systems

QPAR User Manual

Revision v1.0 October 2021

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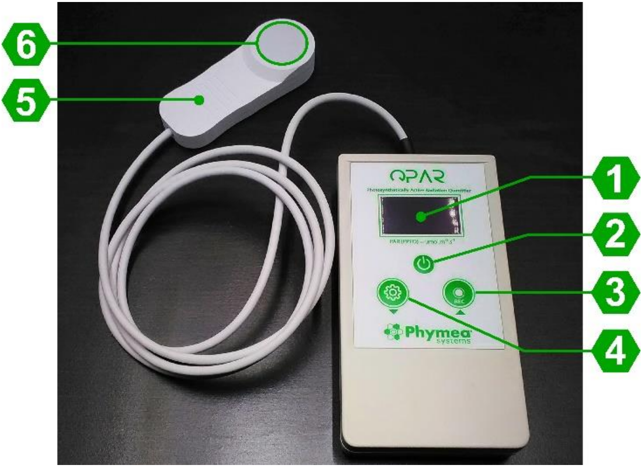
GENERAL VIEW



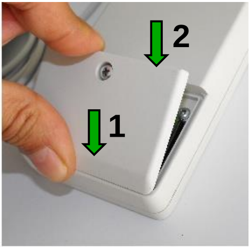
1 : OLED screen
2 : ON/OFF button
3 : Record button
4 : Parameter button

5 : Sensor
6 : Diffuser

SYSTEM START-UP

1. INSERT/CHANGE THE 9V BATTERY

- Open the **battery cover under the device**.
- Insert a **9V battery type PP3** while paying attention to the polarity.
- Close the battery cover, starting by inserting the side opposite the screw.

2. TURN THE DEVICE ON / OFF

- **Press the ON/OFF button** (see GENERAL VIEW, p.3) to turn on the power (ON).
- Re-press the ON/OFF button to turn off the power (OFF).
- **If the device does not detect any activity on your part (button press) over a period of 10min, it will automatically turn off.**

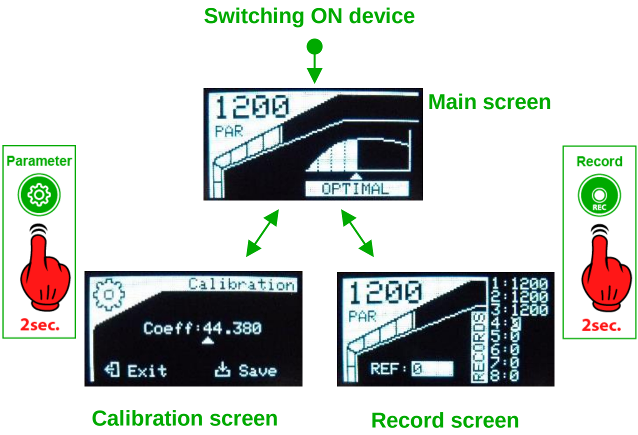
3. Check the state of the sensor diffuser

- Check the diffuser (see GENERAL VIEW, p.3). It must be perfectly clean for the device to work correctly.
- If needed, clean the diffuser with a soft cloth (ex: microfiber) moistened with a mild soap or glass cleaner solution.

4. Battery status

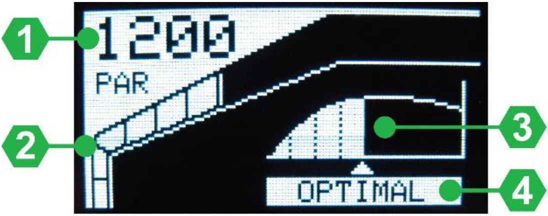
- When the battery level reaches a low voltage (~6V), the icon  appears below the PAR.
- Depending on the battery (brand/model), the unit may then encounter operating problems (incorrect measurement, unstable display, low screen brightness, etc.).
- To avoid operating problems, it is best to recharge/change the battery.

1. Screen arborescence



2. MAIN SCREEN

After switching the power ON, the system boots and shows the Phymea logo. When the device is ready, the main screen is displayed



1 : PAR measurement
2 : PAR gauge
3 : Photosynthesis gauge (response curve)
4 : Indicator (LOW, GOOD, OPTIMAL, HIGH,CAUTION)

The main screen displays 2 important information:

- The measured PAR (PPFD) in µmol.m^{-2}.s^{-1},
- and its effect on photosynthesis.

The measured PAR is represented by the number displayed in **(1)** and in the PAR gauge **(2)**.
The effect of PAR is displayed on the photosynthesis gauge **(3)**.
This gauge is what biologist call a ***response curve***: the response curve of photosynthesis to light (PAR). We defined it by synthetizing multiple data from scientific articles including measurements on **tomato, maize, cannabis, and Arabidopsis Thaliana**. It is therefore applicable to all those species and many others (excluding

ombrophilous species such as orchids). It represents the response of photosynthesis to light at 25°C and 400ppm of CO_2.
To help you apprehend the effect of PAR, we have added an indicator that tells you what PAR level the sensor is measuring **(4)**:

- LOW: the PAR level is too low to guarantee the good development of your plants (0-300 µmol.m^{-2}.s^{-1})

- GOOD: the level of PAR is sufficient for the development and survival of the plant. **(Optimal level for Ombrophilous species, Orchid type)**. (300-900 µmol.m^{-2}.s^{-1})

- OPTIMAL: the PAR level is adapted for optimal production, where yield is the objective. (900-1600 µmol.m^{-2}.s^{-1})

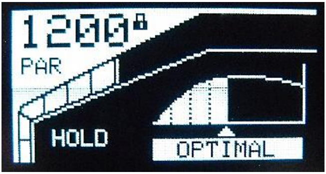
- HIGH: the PAR level is too high. This level may become deleterious due to excess light or temperature, potentially leading to yield loss. (1600-2100 µmol.m^{-2}.s^{-1})

- **CAUTION: the PAR level is abnormally high.** At this level, the sensor is too close to the light source. There is a risk of fire. **Do not hold anything at this level, especially the sensor or plants.**

The effect of temperature and CO2 will modify the intensity of photosynthesis, but the shape of the curve with respect to light (PAR) will remain mostly the same. For more information, the effects of PAR and temperature are detailed in paragraphs p.17 and p.19.

To hold the screen:

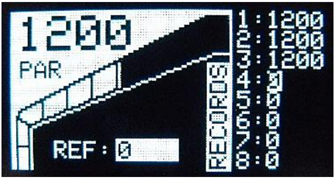
The screen can be put on hold with a **short press** (<1sec) on the **« Parameter »** or **« Record »** button.



3. Record screen

To display the record screen:

From the main screen, press the **« Record »** button with a **long press** (press >2sec.) **to record or display the measurements saved in the device.**



The system then displays the « **RECORD** » screen, which allows you to record 8 different measurements. These measurements remain saved even when the device is turned off or when the battery is changed.

To facilitate the comparison of light measurements over time, it is possible to define 1 of the 8 measurements as a **reference measurement** and save it outside of the measurement fields.

To record a measurement:

Push the « Record » button with a short press (<1sec.). After recording, the selection area (highlighted value) automatically moves to the next value.

To repeat a measurement / move between values:

Push the « Parameter/▼ » button with a short press (<1sec.). The selection area (highlighted value) automatically moves to the precedent value.

To define and record a reference value:

Select the recording by moving through the measurements (see above). **Push the « Parameter » button with a long press** (>2sec.). The selected measurement then appears in the reference box (**PAR ref**).

To go back to the main screen:

Push the « Record » button with a long press (>2sec.).

4. CALIBRATION SCREEN

This screen is useful if you replace your sensor, after damaging it or to replace it with another model.

You can insert the calibration coefficient of your sensor. The coefficient to be declared is in µmol.m^{-2}.s^{-1}.mV^{-1}, the instrument measures by default mV over a measuring range from 0 to 250mV with a resolution of 0.0078125mV.

To display the calibration screen:

From the main screen, push the **« Parameter »** button with a long press (>2sec.) **to modify or display the calibration coefficient of the PAR sensor.**

To select of modify the numbers of the coefficient:

Push the « Parameter/▼ » button with a short press (<1sec.). The selection (highlighted value) switches to the previous digit.

Push the « Record/▲ » button with a short press (<1sec.) to modify the select digit until the right value is reached.

To return to the main screen without saving:

Push the « Parameter/▼ » button with a short press (<1sec.) **until "Exit" is selected** (highlighted)**.**

When **« Exit »** is selected**, push the « Record » button with a short press** (<1sec.) to return to the main screen.

To save the coefficient:

Push the « Parameter/▼ » button with a short press (<1sec.) **until « Save » is selected** (highlighted).

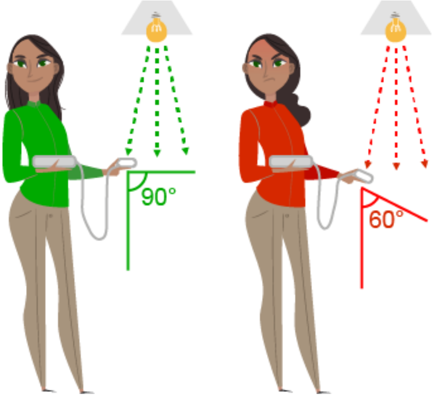
When **« Save »** is selected, **push the « Record/▲ » button with a long press** (<2sec.) to save the coefficient and return to the main screen.

INSTRUCTIONS FOR USE

1. Measuring PAR

The PAR is a delicate measure that requires rigour to be compared and repeated. The measurement is sensitive to the angle between the sensor and the light source. **If the inclination is less than ±5°, the effect remains negligible.**

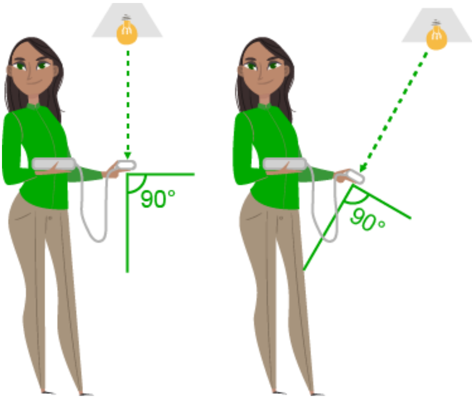
In theory: A PAR measurement in a scientific context is performed with a sensor parallel with the ground plane. This allows "fixing" the angle of the sensor with the light source, and therefore allows a measurement independent of this angle.



Theoretically correct measurement

Theoretically incorrect measurement

In Practice: The theoretical method, above, is a useful and necessary method to compare a light source (light bulb) over time and see if it is changing significantly. However, in practice to quantify the light perceived by plants, it is more relevant to position the sensor in front of the light source (sensor diffuser at 90° from the light source). The referential here is the light source (lamp), unlike the previous method where the ground was the referential.



2. Understanding the photosynthesis

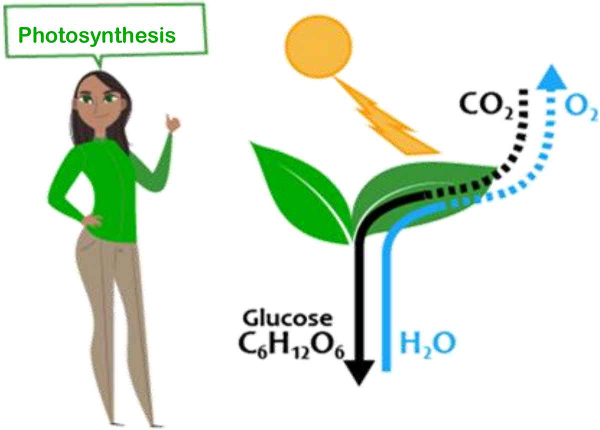
The photosynthesis response curve provided (photosynthesis gauge) by the device is based on a modeling of the photosynthesis of several plant species sufficiently documented in the scientific literature **(tomato, corn, cannabis, and Arabidopsis thaliana)**. This results in mathematical equations that reflect the potential photosynthesis of each plant species under different environmental conditions (PAR, CO2, Temperature, VPD). This approach has allowed us to produce a synthetic response curve that can be understood by all. **Our goal is to synthesize scientific knowledge so that it is accessible to all.**

NOTE*: The photosynthesis provided by the device is a simulation and not a measurement. This means that it is not directly the photosynthesis of your plants.*

a. What is photosynthesis?

Photosynthesis is the process by which the plant fixes atmospheric Carbon (CO_2) through light energy. The chemical reaction requires CO2 and water (H_2O) to produce Glucose ($C_6H_{12}O_6$) and Oxygen (O_2).

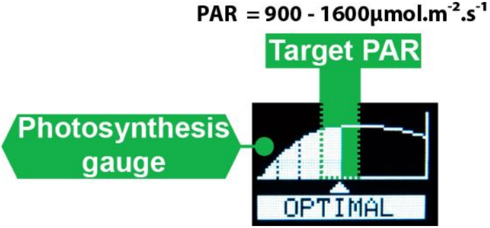
$$6\ CO_2 + 6\ H_2O \Rightarrow C_6H_{12}O_6 + 6\ O_2$$

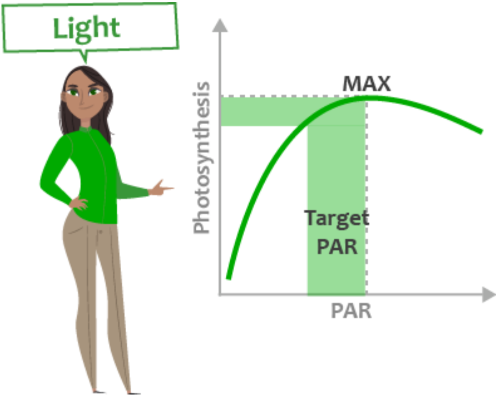


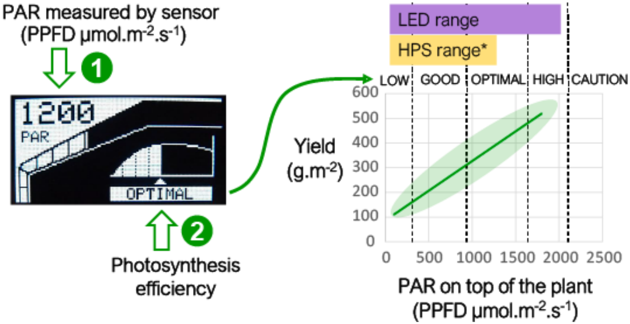
It produces the bricks of plant matter and the sugars essential to the plant's physiology (cellular energy, osmoregulation, etc.). Optimal plant production is therefore dependent on maximized photosynthesis, which depends directly on light, temperature, and CO_2 concentration. These three parameters interact with each other in such a way that it becomes difficult to reason about certain practices such as CO_2 enrichment.

b. The light effect

Photosynthesis depends directly on light, and more precisely on the energy of the photons which activates the photosynthesis reaction. Therefore, PAR (Photosynthetically Active Radiation) measures the number of photons (µmol) per unit area (m²) and time (second), whose wavelengths activate photosynthesis.
The greater the light intensity, the greater the photosynthesis. However in natural conditions, the PAR reaches maximum values around 2200µmol.m^{-2}.s^{-1} over a period of a few hours when the sun is close to the zenith. In this context, plants are generally not adapted to high and constant radiations (>2000), which can become harmful if they are maintained over several hours or the whole photoperiod. **The PAR value to aim for is therefore slightly before the PAR generating maximum photosynthesis.**





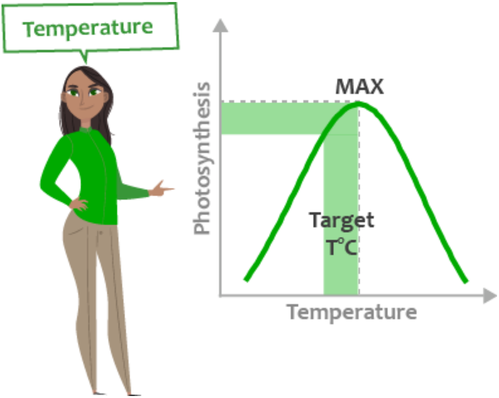


Source: Cannabis yield, potency, and leaf photosynthesis respond to differently to increasing light levels in an indoor environment. Rodriguez-Morrison et al., 2021. Frontiers in Plant Science.

***With HPS (High Pressure Sodium) systems it is often not possible to reach the OPTIMAL level because the bulb emits too much heat. We recommend to use the GOOD level with non-ventilated HPS lighting.**

c. The temperature effect

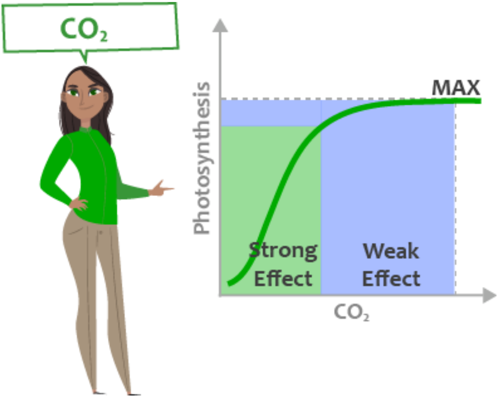
Temperature directly modifies the efficiency of photosynthesis. Temperatures that are too low or too high reduce the efficiency of photosynthesis. The optimum is generally between 24-27°C for the air temperature, which can vary depending on the plant species. The leaf temperature is generally a little warmer or a little colder (±2-3°C), depending on the light radiation perceived by the leaf and its water status.



d. The CO_2 effect

The higher the CO2 concentration, the more Photosynthesis is important. Under natural conditions the atmospheric concentration generally varies between 390 and 450ppm. Plants are adapted to these concentrations but can grow in ranges between 200ppm and 1200ppm. However, information on the long-term effect of CO2 is poorly documented, and it is difficult to advise a target range for CO2. **In the long term, concentrations that are too low or too high can disturb the plant's physiology and thus harm its growth and development.** In this context, only the user's experience can allow him to really quantify the effect of CO2 enrichment on his production. **Based on the information available to date, we can only recommend targeting CO2 concentrations in reasonable ranges where CO2 has a strong effect on photosynthesis.**

NOTE*: The concentration of atmospheric CO2 generally varies between 390 and 450ppm. It is particularly influenced by the surrounding vegetation and the time of day (day/night). Thus, it will be low in a forest during the day, while it will be higher in the city at night.*



e. *The grower effect*

Cultivation practices can directly influence photosynthesis positively or negatively. The device cannot take these practices into account. The photosynthesis curve provided is therefore a potential photosynthesis, equivalent to a perfectly watered plant, without nutritional deficiency and cultivated in an adapted environment.

To find oneself in these conditions, it is necessary to respect some good practices, with the objective of optimizing the leaf temperature to maximize photosynthesis.

GOOD PRACTICES:

Adapting PAR level to plant development

The needs of the plant vary according to its development. At the juvenile stage or when it has passed its production stage (or its development cycle), its needs are less important than during the flowering period, for example. Thus, during flowering the levels of PAR "OPTIMAL" are recommended, while at earlier or later stages, levels of PAR "GOOD" are generally satisfactory.

Air temperature regulation

Maintain an air temperature appropriate to the crop species; generally, between 24°-27°C (see The Effect of Temperature, p.19).

NOTE*: To measure the air temperature, a temperature sensor must be used under ventilated cover, so that the sensor measurement is not influenced by the heating of the artificial lighting. At the very least, the temperature sensor should be shaded and, if possible, placed in a slight draught to avoid the formation of microclimate in the vicinity of the sensor.*

NOTE: *To measure leaf temperature we recommend using a non-contact infrared temperature sensor.*

Plant / Light distance:

Maintain a distance between the lamp and the plant according to the compromise between the heat released by the lamp and the light energy (PAR) received by the plant.

If the plant is too close to the lamp, photosynthesis can be reduced because of the heat of the lamp which heats the leaves. So even if the air is at 25°C, the leaves can be at 40°C and more.

Plant watering and nutrition

Watering your plants well is essential! Water, among countless functions (turgidity, growth, thermal regulation, etc.), is one of the reagents of photosynthesis. It also regulates the temperature of the leaves. **The evaporation of water allows the leaves to regulate their temperature to maintain optimal photosynthetic efficiency.**

Plant nutrition is also an essential factor for photosynthesis. Chlorophylls are the pigments (molecules) that give plants their green color and transform light energy into chemical energy. Chlorophylls are strongly composed of Nitrogen and are therefore dependent on the plant's nutrition, which is essentially provided by a correctly dosed nutrient solution.

3. MEASURE LIGHT BULB AGEING

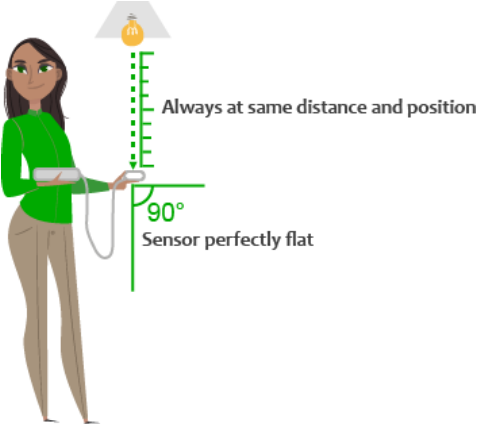
To measure the ageing of a bulb or LED system, PAR measurements need to be performed (see Measure PAR, p.14) regularly (every 3 to 6 months) under the lamp to be characterized, positioning the sensor at each measurement strictly at the same position with respect to the lamp (same distance, etc.). It is also especially important to carry out all measurements in the same environment. Plant development or modifications of the reflector, for example, can influence the perceptible radiation of a lamp and therefore bias the comparison.

We recommend making these measurements when the growing area is empty (without plants) at the beginning or end of the cycle, for example. The next step is as follows:

- **Locate a point relative to the lamp that you can easily find during future measurements** for a reliable comparison. Choose a relevant position relative to the lamp, at a PAR close to the desired one when the lamp is new. You can use a leaded wire or a tape measure to memorize this distance and then accurately reproduce it.
- **Do a reference measurement** (see. Record screen, p.9) as soon as possible after the installation of the new lamp.
- **Do measurements for the comparison** (see Record screen, p.9) regularly, for example at the beginning and end of each cycle.
- **Compare the last measurement made with the reference measurement to assess the current lamp performance.**
  Ex: 820/900=0.91. 91% of initial PAR and a yield loss of 9%, potentially an equivalent loss of production.

NOTE: *It is recommended to measure a lamp at the same time after start-up, respecting a minimum heating time of 20 minutes.*

NOTE: *If you want to track multiple lamps, you will need to note the reference values of each lamp outside the device on the medium of your choice.*


Always at same distance and position
90°
Sensor perfectly flat

TECHNICAL SPECIFICATIONS

Spectral response: 400 – 750nm

Recommended PAR range: 1-2500µmol of PAR

Precision: 1µmol.m^{-2}.s^{-1}

Error: typic <3%, maximum = 5%

Signal type: Voltage reading (mV), resolution = 0.0078125mV

Power supply: 9V battery PP3

Use and conservation environment: 15°C-40°C. Sensitive to water and dust: IP51

Maintenance: Clean the device with a soft cloth moistened with soapy water. Avoid solvents and other chemicals.

AFTER-SALE

Phymea products are guaranteed for 2 years: parts and labour, according to our general terms and conditions of sale.

If you have a problem with a device that seems defective to you or a question about how it works, do not hesitate to contact us! Our team will do its best to answer you and find solutions.

AFTER-SALES CONTACT: aftersale@phymea-systems.com

Any intervention or disassembly of the device by anyone other than Phymea staff, as well as any use outside the scope defined in the user manual, voids any warranty.

PHYMEA

Phymea systems is a young company from the South of France (Montpellier), founded by academics from public research in plant biology and ecophysiology on one hand, and signal processing engineering on the other.

From environmental measurements to plant characterisation, we design and develop innovative products combining scientific knowledge and technology into practical and learning tools for plant research and production.