Quantum Light meter

Instruction manuals

STEP Systems GmbH
Soil Testing Equipment - Professional Systems

Quantum meter

BASIC QUANTUM METER

Quantum sensors measure light energy at the specific wavelengths plants actually use for photosynthesis. Research indicates that older lux and foot-candle meters could have error rates up to 45% when used to estimate light quantum available for plant growth. Start taking more meaningful light level measurements yourself with a low-cost quantum meter.

All quantum meters here measure Photosynthetic Photon Flux (PPF) as µmol m^{-2} s^{-1} for Photosynthetically Active Radiation (PAR) in the range of 400 to 700 nm. Quantum meters can be used in the field, laboratory, above or below plants, in growth rooms and green-houses. The meter approximates radiation between 400 and 700 nanometers (PAR) as µmol m^{-2} s^{-1}.

TAKING A MEASUREMENT:

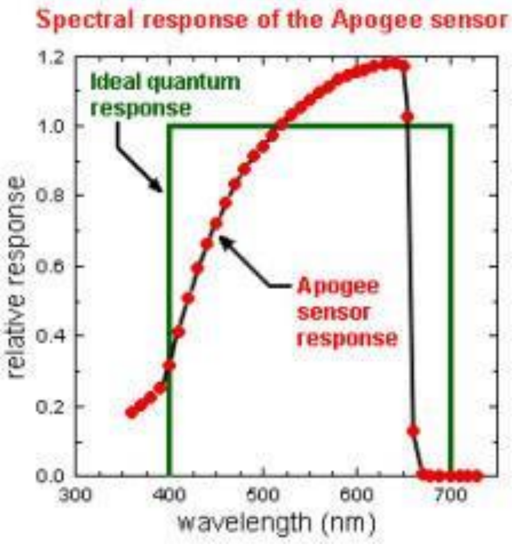
Our quantum meters offer good accuracy at a low cost, but the user should be aware of potential sources of error. The biggest error is often caused by small changes in the position of the meter. The sensor on the top of the meter must be exactly horizontal for the most accurate measurement. The correct position for making a measurement is shown at right.

USING THE INSTRUMENT:

1. Turn the dial to the "ON" position.
2. Hold the meter so that the sensor surface on the top is horizontal.
3. Hold the meter at eye level to avoid shading the sensor with your head.
4. The number in the display is the PPF with units of µmol m^{-2} s^{-1} .
5. Turn the meter ,,OFF" after use to conserve battery power.

SPECTRAL RESPONSE

An ideal quantum sensor would give equal emphasis to all photons between 400 and 700 nm and would exclude photons above and below these wavelengths. The spectral response of the sensor used in Quantum Meter and the Quantum Sensor is shown at right. As the figure indicates, the sensor underestimates the 400 to 500 nm wavelengths (blue light), overestimates the 550-650 wavelengths (yellow and orange light), and has little sensitivity above 650 nm (red light). Fortunately, *common light sources are mixtures of colors and the spectral errors offset each othe*r. The sensor measures green light (500-550 nm) accurately, so it can be used to measure the radiation inside and at the bottom of plant canopies.



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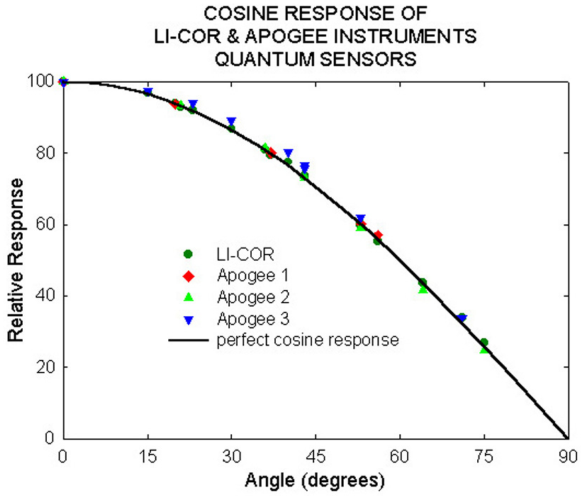

COSINE RESPONSE

The term “cosine response” means that the sensor properly responds radiation coming from all angles. A sensor without a proper cosine response would accurately measure radiation when it was pointed directly at the sun, but it could have a significant error (up to 50%) on cloudy days, when there is no direct sunlight. A cosine corrected sensor is accurate on both sunny and cloudy days; accurate at solar noon as well as at low sun angles; and accurate on both the summer and the winter solstice, when the sun angle at solar noon varies by 47 degrees. A flat sensor surface (without cosine correction) reflects radiation at low angles and under-weights low angle radiation. A sensor with a raised white diffusion disk over-weights low angle radiation. The traditional approach to achieving a good cosine response is to build a sensor with a raised, white disk, and then add a raised wall around the perimeter to block low angle radiation (this is called the castle design). This is an effective design, but it traps water and dust, which block light and result in low readings. The Apogee meter with integral sensor uses a domed top to repel water and dust. This makes the sensor self cleaning. Accurate cosine response is achieved by having just the right amount of curvature on the dome, as well as using an appropriately opaque diffuser. The Apogee sensor is cosine corrected to 80 degrees. Our long term tests indicate that the cosine errors between completely sunny and heavily over-cast days are less than 0.5 %. Cosine errors between the summer and the winter solstice are also less than 0.5%.

LONG-TERM STABILITY

The output of all radiation sensors tends to decrease over time as the detector ages. Our experience indicates that the average decrease of the sensor in this meter is about 1% to 2 % per year.

TEMPERATURE RESPONSE

Increasing temperature decreases the output of most silicon photodiodes. This meter was calibrated at 20°C. It reads 0.6% low at 10°C and 0.8% high at 30°C. This temperature error is insignificant for most applications.

ERRORS DUE TO LAMP TYPE

Because the spectral response of the sensor and the spectral output of electric lamps is constant, the errors under different lamp types can be calculated. This meter is calibrated for either sunlight or electric lamps. The errors under other light sources are shown below.

ELECTRIC LAMP CALIBRATION		SUNLIGHT CALIBRATION	
LAMP TYPE	ERROR	LAMP TYPE	ERROR
cool white fluorescent	2 %	cool white fluorescent	10 % high
metal halide	2 % low	metal halide	8 % high
high pressure sodium	2 % high	high pressure sodium	12 % high
sunlight	10 % low	sunlight	2 %

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SPECIFICATIONS

Measuring range: 0 to 1999 µmol m^{-2} s^{-1}
Accuracy: ± 2 % µmol m^{-2} s^{-1}
Output voltage: 0,1 mV per 10 µmol m^{-2} s^{-1}
Display: 3-1/2 digit, 1.2 cm height
Dimension: 125 x 70 x 25 mm
Weight: 140 g
Operating environment: 0 to 50 °C
Power: Standard 9 Volt battery
Battery life is typically 100 hours with the carbon-zinc battery (included) and 200 hours with an alkaline battery. The letters "BAT" appear in the display when the battery needs to be replaced. To replace the battery, remove the 2 screws in the back of the case and carefully lift off the back. Observe polarity of the battery contacts.
Warranty: 1 year parts and labor

Quantum sensor
This line of products use a sensor that approximates the radiation between 400 and 700 nm, which are the most important wavelengths for plant growth. Photosynthesis is largely driven by the number of photons between these wavelengths, so this radiation is called the Photosynthetic Photon Flux (PPF) and is measured in µmol m^{-2}s^{-1} (micromoles of photons per square meter second). A quantum is the energy carried by a photon so this is a quantum sensor.

Optimal values for plants

Plants	µmol m^{-2}s^{-1} PAR	W / m² PAR	Lux
Room-plants	30 – 200	6 - 44	1700 – 12.000
Salad	200 – 400	44 -90	12.000 – 24 000
Tomatoes	400 – 1000	90 - 220	24.000 – 56.000
<u>to compare:</u> Full sunlight/summer/12 o´clock	ca. 2.000	ca. 440	ca. 112.000
Full sunlight/winter/ 12 o´clock	ca. 1.200	ca. 260	ca. 67.000

Notes about PAR units and conversion

1 Lux = 1 lumen/m^2 (0,929 lm/m^2)
µmol m^2 s = µE
µE = 6,02 x 10^{17} photon pro m^2 in sec
µE (m^{2}s) = W/m^2 x 4,6
5 µE = 1 footcandle (fc)
10,45 Einstein/day = 1 Langley/day

Note: Einstein is not an official SI unit of measure.
Langley= unit sometimes used in climatology

PPF (µmol m^{-2}s^{-1}) to lux		Lux to PPF (µmol m^{-2}s^{-1})	
Sunlight	54	Sunlight	0,0185
Cool white fluorescent lamps	74	Cool white fluorescent lamps	0,0135
High pressure sodium lamps	82	High pressure sodium lamps	0,0122
High pressure metal halide lamps	71	High pressure metal halide lamps	0,0141

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General recommendations for light levels for supplemental lighting of cut flowers/pot plants and vegetable production

Cut flowers and pot plants

Plant species		Required PPFD µMol $m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Adiantum	pot plants	40	HID	winter	16-18 hrs	Improving vegetative growth.
Alstroemeria	cut-flowers	1 - 1,5	inc.	mid Jan.-Feb	10 min. per half hour	Flower advancement.
		40 - 50	HID	Jan.-March	14 hrs	Flower advancement, better quality, increased production.
Anthurium	cut-flowers pot plants	45 - 55	HID	winter	10-12 hrs	Improving vegetative growth and flower advancement,
Anthirrhinum	seedlings	25 - 40	HID	winter	14-16 hrs	Improving vegetative growth and flower advancement, approx. 4 weeks.
Aphelandra	seedlings	100	TL	winter	18-20 hrs	Improving vegetative growth and flower advancement.
	young plants	5	TL	winter	14-16 hrs	
Aster (Chinese aster)	young plants	40 - 50	HID	Jan.-March	6 hrs, followed by short days	Improving vegetative growth and flower advancement. Short days after buds become visible.
Aster	cut-flowers	40 - 50	HID	winter	16 hrs	Improving vegetative growth, earlier flowering.
Aspleniumnidus	pot plants	40	HID	winter	16-18 hrs	Improving vegetative growth, shorter culture time.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Bedding plants	seedlings and young plants	40 - 65	HID	Jan.-March	16 hrs	Raising seedlings, improving vegetative growth and flower advancement greenhouses and growing rooms.
Begonia:	stock plants	45 - 55	HID	winter	16 hrs	Improving vegetative growth.
elatior	cuttings	1 - 1.5	TL	winter	16 hrs	Flower deferment.
lorraine rex rieger	pot plants	45 - 55	HID	winter	16 hrs	Improving vegetative growth, shorter culture time.
Bromelia: Achmea Guzmania Neoregelia Vriesia	seedlings and young plants	40 - 45	HID	Sep.-April	16 - 18 hrs	Raising seedlings, improving vegetative growth, shorter culture time.
Bulbs: Tulipa Hyacinthus Narcissus (daffodil) Crocus	bulbs	25 - 40	TL/HID	Dec.-Feb.	12 hrs without daylight	Flower forcing.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Cactaceae	seedlings and young plants	85 - 100	HID	Sep.-April	16-18 hrs	Raising seedlings, improving vegetative growth, shorter culture time.
Calceolaria hybriden	pot plants	4	TL	mid-Nov.-mid-March	16-24 hrs	Flower advancement.
		40 - 50	HID	mid-Nov.-mid-March	16-18 hrs	
Carmellia japonica	young plants	45 - 55	HID	Sep.-April	16 hrs	Improving quality, flower advancement.
Campanula isophylla	pot plants	40 - 50	TL/HID	Jan.-March	16 hrs	Flower advancement, better quality.
Chrysanthemum	stock plants	40	HID	Sep.-April	18-20 hrs (incl. photoperiodic lighting)	Good quality cuttings.
	cuttings	40 - 45	HID	Sep.-April	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth, for good quality cuttings.
	cut-flowers	40 - 50	HID	year round	18-20 hrs, later 12 hrs (photoperiodic lightning)	Improving vegetative growth, flower advancement, improving quality.
	pot plants	40 - 45	HID	Sep.-April	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth, shorter culture time.
Cineraria	pot plants	6	TL	from mid Jan.	18 hrs	After bud formation a flower advancement of 2-4 weeks is obtained.
Coleus hybriden	pot plants	40	HID	winter	16 hrs	Improving vegetative growth.
Columnea	pot plants	25 - 40	HID	winter	16-18 hrs	Improving vegetative growth, more and earlier flowering.
Cordyline	pot plants	40 - 50	HID	winter	18 hrs	Improving vegetative growth, good color quality.
Croton	pot plants	40 - 50	HID	winter	16-18 hrs	Flower advancement.
Cyclamen persicum	seedlings and pot plants	40 - 55	HID	Nov.-Feb.	18 hrs	Raising seedlings and improving vegetative growth.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Dahlia	cut-flowers	1,5	TL	winter	2 hrs during night	Flower advancement
Dianthus (carnation)	stock plants	40 - 50	HID	Sep.-April	14 hrs	Improving vegetative growth for good quality cuttings.
	cuttings	40	HID	Sep.-April	14 hrs	Improving vegetative growth and shorter culture time, rooting of cuttings.
	cut-flowers	1 - 2	inc.	Sep.-April	16-24 hrs	Flower advancement.
Dianthus barbatus	cut-flowers	40 - 50	HID	winter	16 hrs	Improving vegetative growth, flower advancement.
Euphorbia: fulgens	cut-flowers	1,5	inc.	Aug.-Jan.	3 hrs during night	Improving vegetative growth, year round culture.
Pulcherrima (Poinsettia)	pot plants	1,5	inc.	Oct, during 2-3 weeks	2-3 hrs during night	Deferring bud formation till Christmas.
Milli (=splendens)	pot plants	5	TL	Oct.-April	16 hrs	Improving vegetative growth, year round culture.
Ficus	pot plants	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth.
Forestry products (shrubs...	seedlings and cuttings	55	HID	Aug.-March	16-20 hrs	Raising seedlings and rooting of cuttings, speeding up growth
... and trees)	young trees	65-100	HID	Aug.-March	16-20 hrs	Prevention of dormancy, speeding up growth.
Freesia	cut-flowers	40 - 50	HID	winter	16-20 hrs	Improving vegetative growth, flower advancement, more and better quality flowers.
Fuchsia hybrida	pot plants	6	TL	Sept.-Oct.	4 hrs during night	Flower advancement.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Gerbera	young plants	55	HID	winter	16 hrs	Rooting of young plants, improving vegetative growth, shorter culture time.
Gesnera	seedlings	40 - 50	HID	Nov.-Feb.	18-20 hrs	Raising seedlings, improving vegetative growth.
Gladiolus	cut-flowers	50 - 65	HID	Jan.-March	16 hrs	Flower advancement, improving vegetative growth.
Gypsophylia	cut-flowers	55 - 75 1,5	HID Inc.	winter	16-20 hrs 16-20 hrs	Improving vegetative growth, flower advancement.
Hedera	pot plants, stock plants, cuttings	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth.
Hydrangea macrophyla (hortensia)	pot plants	40 - 55	HID	from Dec.	16-18 hrs	Improving vegetative growth.
Hypoestes taeniata	pot plants	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth, good colour quality.
Ixia	cut-flowers	40 - 50	HID	winter	16 hrs	Improving vegetative growth, flower advancement.
Kalanchoë blossfeldiana	stock plants and cuttings, pot plants	40 - 50	TL/HID	Jan.-March	18-20 hrs	Deferring bud formation, improving vegetative growth, shorter culture time.
Kalanchoë blossfeldiana	pot plants	35 - 50	HID	winter	18-20 hrs	Improving vegetative growth, shorter culture time.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance timeper day (incl. daylight)	Purpose and method
Liatris	cut-flowers	40 - 55	HID	winter	16 hrs	Improving vegetative growth, flower advancement.
Lilium longiflorum	cut-flowers	35 - 45	HID	winter	16-24 hrs	Prevention of bud abscission, improving vegetative growth.
Lilium M.C. hybriden 'Enchantment'	cut-flowers	50 - 65	HID	after 6 weeks, continuous lighting during 4 weeks	24 hrs during 4 weeks	After bud formation, continuous flowering and vegetative growth are improved. Shorter culture time.
Lisianthus	cut-flowers	50 - 60	HID	winter	16-18 hrs	Improving vegetative growth, shorter culture time, flower advancement.
Lilium speciosum	cut-flowers	1,5 - 2,5	inc.	winter	16 hrs	Flower advancement.
Oriental		1 - 1,5	PL			Flower advancement.
Matthiola incana (stock)	cut-flowers	40 - 50	HID	winter	16-24 hrs	Improving vegetative growth, flower advancement, shorter culture time.
Matricaria	cut-flowers	40 - 50	HID	winter	16 hrs	Improving vegetative growth, flower advancement.
Nephrolepis	pot plants, stock plants	35 - 45	HID	winter	16-18 hrs	Improving vegetative growth
Orchis: Cattleya Cymbidium Cyperidium Odontoglossum Paphiopedilum Phalaenopsis	seedlings and young plants	45 - 60	HID	Sep.-April	16 hrs	Improving vegetative growth, flower advancement, high-quality flowers.
Ornamental green plants	cuttings and young plants	40 - 55	HID	winter	16-18 hrs	Rooting of cuttings, improving vegetative growth.

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Pelargonium	stock plants	45 - 60	HID	winter	16-18 hrs	Improving vegetative growth.
	cuttings	60	HID	winter	16-18 hrs	Rooting of cuttings, better quality of young plants, shorter culture time.
Rosa hybrida	pot plants	45 - 60	HID	winter	18-20 hrs	High yields, improvement vegetative growth, stronger plants.
	cut-flowers	100 - 180	HID	winter	18-20 hrs	High yields of good quality flowers.
Saintpaulia ionantha	stock plants, cuttings	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth for production of high quality cuttings, flower advancement, shorter culture time.
	pot plants	30 - 40	HID	winter	16-18 hrs	
Saxifraga Cotyledon pyramidalis	pot plants	2	inc.	3 weeks from mid Feb.	16 hrs	Flower advancement, 3-4 weeks.
Sinningia (gloxinia)	seedlings and young plants	45 - 55	HID	Nov.-Feb.	16 hrs	Raising seedlings, improving vegetative growth, flower advancement.
Spathyphyllium	pot plants	40	HID	winter	16 hrs	Improving vegetative growth, earlier flowering.
Succulents	seedlings and young plants	55 - 80	HID	winter	16-18 hrs	Raising seedlings, improving vegetative growth.
Trachelium	cut-flowers	45 - 60	HID	winter	16-18 hrs	Improving vegetative growth, shorter culture time and flower advancement.

Fruit and vegetables

Plant species		Required PPFD $\mu Mol\ m^{-2}s^{-1}$	Type of lamp	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Aubergines	seedlings	80 - 160	TL	year round	16-18 hrs (without daylight)	Seedling production in growing rooms.
	young plants	40 - 50	HID	winter	14-16 hrs	Improving vegetative growth, harvest advancement.
Beans (French)	young plants	55	HID	Oct.-Feb.	16 hrs	Improving vegetative growth, harvest advancement, more production.
Beet (various)	seedlings and young plants	65 - 100	HID	Sep.-April	16 hrs	Improving vegetative growth, shorter culture time.
Cucumbers	seedlings and young plants	25 - 40	HID	Oct.-March	16 hrs	Improving vegetative growth, shorter culture time.
	production fruits	150 - 200	HID	winter	16 - 18 hrs	Increase production, better fruit quality
Lettuce	seed production	280 - 380	HID	winter	16 hrs	Speeding up of culture times, 4-5 times.
	seedlings and young plants	150	HID/TL	winter	16 hrs (growing rooms)	Improving vegetative growth, shorter culture time.
	crop production	45 - 60	HID	winter	16 hrs (greenhouses)	Improving vegetative growth, shorter culture time.
Strawberries	fruit production	1 - 2	inc.	Jan.-Feb.	15 min. per hr 2 $\mu mol\ m^{-2}s^{-1}$ or 8 hrs per night continuously 1 $\mu mol\ m^{-2}s^{-1}$	Flower advancement, more and better fruit production.
Sweet pepper	fruit production	80 - 150	HID	winter	14 - 16 hrs	Earlier fruit production and enhancement, reduction abortion.
Tomatoes	young plants	45 - 55	HID	Oct.-Feb.	14 -16 hrs	Improving vegetative growth, shorter culture time (2 weeks), more and better fruit production.
	fruit production	150 - 200	HID	winter	14 - 16 hrs	
Tomatoes	seedlings and young plants	300 - 380	HID/TL	winter	16 hrs (without daylight)	Production in growing rooms.

Light sum

Although growth light irradiance is very important for the photosynthesis rate, the SUM of growth light is the most important factor for plant growth. Based on his own experience, the Norwegian Professor Moe has created a plant classification, depending on their light sum needs for optimal growth.

- Shade-plants
  For example Saintpaulia and Lorraine-begonia and some green pot plants prefer low light conditions (5 -10 $mol.m^{-2}$ per day). In fact these plants are easily damaged by full sunlight.

- Medium tolerance plants
  Most flowering pot plants have a medium tolerance in light sum (10 - 20 $mol.m^{-2}$ per day). Examples are Kalanchoë, Poinsettia, pot-Chrysanthemum and Elatior-begonia.

- Tolerant plants
  Plants with a very high need for light (> 20 $mol.m^{-2}$) are for example Roses, Tomato and Cucumber.

The sum of growth light is calculated as:
irradiance ($\mu mol.m^{-2}.s$-1) x duration (sec.)

For example:
100 $\mu mol.m^{-2}.s$-1 during 16 hours gives a light sum of:
100 * (16 * 3600) / 1000000 = 5,76 $mol.m^2$

The sum of growth light is a combination of natural daylight and artificial light. The tool below (see CD-ROM) can be used to determine how much supplemental growth light is needed for the required sum of growth light.