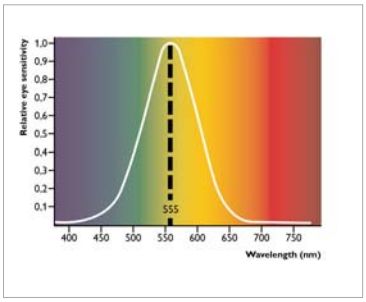
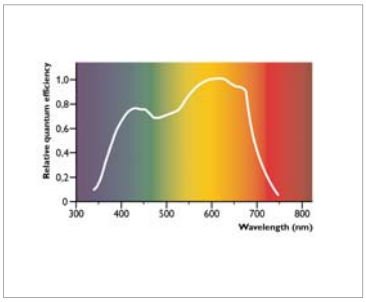
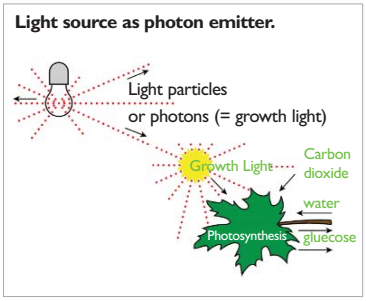
The role of light in the growth and development of plants



Light sensitivity curve of the human eye



Light sensitivity curve of plants



Photosynthesis process

For the human eye, light is the visible part of electromagnetic radiation. Most lighting products are developed for human application. For these purposes, the intensity of visible light is expressed in lux. Lux is a photometric unit and is based on the average sensitivity of the human eye.

The sensitivity is maximised at green/yellow (555nm) and declines towards longer (red) and shorter (blue) wavelengths. A lux meter is corrected for this specific eye sensitivity.

For horticulture, natural daylight (global radiation) is in most cases measured in terms of energy (J or W) with a solar meter. This meter is generally positioned on top of the greenhouse. The value of global radiation is important for climate and humidity control in the greenhouse.

Growth Light

Plants have a completely different sensitivity for colours of light than the human eye. For plant growth, it is important to define light as small light particles, also called photons or quantum. The energy content of photons is different depending on wavelength (colour of light). For one W of energy, almost twice as many red photons can be produced compared to blue. In addition to this, plants are most efficient using the red part of the light and less efficient using the green and blue part. In fact, we are dealing with a plant sensitivity curve for growth light.

Plant growth (Photosynthesis) is not then determined by lux or energy, but by the photons from blue to red (400-700 nm) part of the spectrum. This is called growth light!

Micromole and PPF

Research, both at universities and applied research stations, has demonstrated that the rate of photosynthesis is determined by the amount of photons between 400 - 700 nm. In scientific terms, this growth light is called 'Photosynthetic Photon Flux (PPF) and is the only reliable measure to clarify if a light source is suitable for photosynthesis. The higher the PPF value per Watt, the more efficient the light source for plant growth. This is the reason why Philips specifies the PPF value in micromoles per second (µmol/s) for all its light sources for horticultural use. The Philips MASTER GreenPower is specially developed for maximum growth light and for this reason, is the most efficient light source available for horticulture.

PHILIPS

High pressure sodium	Lamp base	Colour temp.	Light Output	PPF*
Green Power series				
MASTER SON-T PIA Green Power 400W/230V	E40	2000K	58.500 Lm	745 µmol/s^{-1}
MASTER SON-T PIA Green Power 600W/230V	E40	2000K	90.000 Lm (in fitting)	1100 µmol/s^{-1}
MASTER SON-T PIA Green Power 600W/400V	E40	2000K	88.000 Lm (90.000 in fitting)	1150 µmol/s^{-1}
Agro				
MASTER SON-T PIA Agro 400W	E40	2050K	55.000 Lm	660 µmol/s^{-1}

Metal-halogen	Lamp base	Colour temp.	Light Output	PPF*
MASTER HPI-T Plus 400W on SON gear	E40	4.000K	38.000 Lm	532 µmol/s^{-1}
MASTER HPI-T Plus 400W on HPL gear	E40	4.500K	35.000 Lm	490 µmol/s^{-1}

Fluorescent	Lamp base	Colour temp.	Light Output	PPF*
Reflex				
MASTER TL-D Reflex 36W/830	G13	3000K	3.350 Lm	47 µmol/s^{-1}
MASTER TL-D Reflex 36W/840	G13	4000K	3.350 Lm	47 µmol/s^{-1}
MASTER TL-D Reflex 58W/830	G13	3000K	5.200 Lm	73 µmol/s^{-1}
MASTER TL-D Reflex 58W/840	G13	4000K	5.200 Lm	73 µmol/s^{-1}
Secura				
MASTER TL-D Secura 36W/830	G13	3000K	3.200 Lm	45 µmol/s^{-1}
MASTER TL-D Secura 36W/840	G13	4000K	3.200 Lm	45 µmol/s^{-1}
MASTER TL-D Secura 58W/830	G13	3000K	5.000 Lm	70 µmol/s^{-1}
MASTER TL-D Secura 58W/840	G13	4000K	5.000 Lm	70 µmol/s^{-1}
HF				
MASTER TL-D Secura 50W/840 HF	G13	4000K	5.000 Lm	70µmol/s^{-1}

* These are calculated PPF values, the exact measured values will be published when available and may vary from the values given here.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Adiantum	potplants	40	HID	winter	16-18 hrs	Improving vegetative growth.
Alstroemeria	cut-flowers	1,5	inc.	mid Jan.-Febr.	10 min. per half hr	Flower advancement.
Alstroemeria	cut-flowers	40 - 50	HID	Jan.-March	14 hrs	Flower advancement, better quality, increased production.
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	Raising seedlings in growing rooms.
Aphelandra	young plants	5	TL	winter	14-16 hrs	Improving vegetative growth and flower advancement.
Aster	young plants	40 - 50	HID	Jan.-March	16 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	potplants	40	HID	winter	16-18 hrs	Improving vegetative growth, shorter culture time.

Plant species		**Required PPFD** µmol $m^{-2}s^{-1}$	**Lamp type**	**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 in greenhouses and growing rooms.
Begonia:	stockplants	45 - 55	HID	winter	16 hrs	Improving vegetative growth.
elatior	cuttings and	1,5	TL	winter	16 hrs	Flower deferment.
Lorraine	potplants	45 - 55	HID	winter	16 hrs	Improving vegetative growth, shorter culture time.
rex						
rieger						
Bromelia: Achmea Guzmania Neoregelia Vriesia	seedlings and young plants	40 - 45	HID	Sept.-April	16-18 hrs	Raising seedlings, improving vegetative growth, shorter culture time.
Bulbs: Tulipa Hyacinthus Narcissus (daffodil) Crocus bulbs	bollen	25 - 40	TL/HID	Dec.-Febr.	12 hrs without daylight	Flower forcing.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Cactaceae	seedlings and young plants	85 110	HID	Sept.-April	16-18 hrs	Raising seedlings, improving vegetative growth, shorter culture time.
Calceolaria hybriden	potplants	4	TL	mid Nov.-mid March	16-24 hrs	Flower advancement.
Calceolaria hybriden	potplants	40 50	HID	mid Nov.-mid March	16-18 hrs	Flower advancement, quality improvement.
Carmellia japonica	young plants	45 55	HID	Sept.-April	16 hrs	Improving quality, flower advancement.
Campanula isophylla	potplants	40 50	TL/HID	Jan.-March	16 hrs	Flower advancement, better quality.
Chrysant	stockplants	40	HID	Sept.-April	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth for good quality cuttings.
Chrysant	cuttings	40 45	HID	Sept.-April	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth for good quality cuttings.
Chrysant	cut-flowers	40 50	HID	year round	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth, flower advancement, improving quality.
Chrysant	potplants	40 45	HID	Sept.-April	18-20 hrs (incl. photoperiodic lighting)	Improving vegetative growth, shorter culture time.
Cineraria	potplants	6	TL	from mid. Jan.	18 hrs	After bud formation a flower advancement of 2-4 weeks is obtained.
Coleus hybriden	potplants	40	HID	winter	16 hrs	Improving vegetative growth.
Columnea	potplants	25 40	HID	winter	16-18 hrs	Improving vegetative growth, more and earlier flowering.
Cordyline	potplants	40 50	HID	winter	18 hrs	Improving vegetative growth, good colour quality.
Croton	potplants	40 50	HID	winter	16-18 hrs	Improving vegetative growth, good colour quality.
Cyclamen persicum	seedlings and potplants	40 55	HID	Nov.-Febr.	18 hrs	Raising seedlings and improving vegetative growth.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	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)	stockplants	40 - 50	HID	Sept.-April	14 hrs	Improving vegetative growth for good quality cuttings
	cuttings	40	HID	Sept.-April	14 hrs	Improving vegetative growth and shorter culture time, rooting of cuttings.
	cut-flowers	1,5 - 2	inc.	Sept.-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)	potplants	1,5	inc.	Oct. during 2-3 weeks	2-3 hrs during night	Deferring bud formation till Christmas.
milli (=splendens)	potplants	5	TL	Oct.-April	16 hrs	Improving vegetative growth, year round culture.
Ficus	potplants	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	potplants	6	TL	Sept.-Oct.	4 hrs during night	Flower advancement.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	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.-Febr.	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	HID	winter	16-20 hrs	Improving vegetative growth, flower advancement.
Gypsophylia	cut-flowers	1,5	inc.	winter	16-20 hrs	Improving vegetative growth, flower advancement.
Hedera	potplants, stockplants, cuttings	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth.
Hydrangea macrophyla (hortensia)	potplants	40 - 55	HID	from Dec.	16-18 hrs	Improving vegetative growth.
Hypoestes taeniata	potplants	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	stockplants and cuttings, potplants	40 - 50	TL/HID	Jan.-March	18-20 hrs	Deferring bud formation, improving vegetative growth, shorter culture time.
Kalanchoë blossfeldiana	potplants	35 - 50	HID	winter	18-20 hrs	Improving vegetative growth, shorter culture time.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	Annual irradiance period	Irradiance time per 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		1,5	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	potplants, stockplants	35 - 45	HID	winter	16-18 hrs	Improving vegetative growth.
Orchis: Cattleya Cymbidium Cyperidium Odontoglossum Paphiopedilum Phalaenopsis	seedlings and young plants	45 - 60	HID	Sept.-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 µmol $m^{-2}s^{-1}$	Lamp type	Annual irradiance period	Irradiance time per day (incl. daylight)	Purpose and method
Pelargonium	stockplants	45 - 60	HID	winter	16-18 hrs	Improving vegetative growth.
Pelargonium	cuttings	60	HID	winter	16-18 hrs	Rooting of cuttings, better quality of young plants, shorter culture time.
Rosa hybrida	potplants	45 - 60	HID	winter	18-20 hrs	High yields, improvement vegetative growth, stronger plants.
Rosa hybrida	cut-flowers	60 - 100	HID	winter	18-20 hrs	High yields of good quality flowers.
Saintpaulia ionantha	stockplants, cuttings and	40 - 50	HID	winter	16-18 hrs	Improving vegetative growth for production of high quality cuttings, flower advancement, shorter culture time.
	potplants	30 - 40	HID		16-18 hrs	
Saxifraga Cotyledon pyramidalis	potplants	2	inc.	3 weeks from mid Febr.	3-4 hrs (night-break)	Flower advancement, 3-4 weeks.
Sinningia (gloxinia)	seedlings and young plants	45 - 55	HID	Nov.-Febr.	16 hrs	Raising seedlings, improving vegetative growth, flower advancement.
Spathyphyllium	potplants	40	HID	winter	16 hrs	Improving vegetative growth, earlier flowering.
Succulenten	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.

Plant species		Required PPFD µmol $m^{-2}s^{-1}$	Lamp type	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.-Febr.	16 hrs	Improving vegetative growth, harvest advancement, more production.
Beet (various)	seedlings and young plants	65 -100	HID	Sept.-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.
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 productions	1,5 - 2	inc.	Jan.-Febr.	15 min. per hr 2 µmol $m^{-2}s^{-1}$ or 8 hrs per night continuously 1,5 µmol $m^{-2}s^{-1}$	Flower advancement, more and better fruit production.
Tomatoes	young plants	45 - 55	HID	Oct.-Febr.	14 16 hrs	Improving vegetative growth, shorter culture time (2 weeks), more and better fruit production.
	fruit productions	150	HID	Winter	14 16 hrs	
Tomatoes	seedlings and young plants	300 - 380	HID/TL	Winter	16 hrs (without daylight)	Production in growing rooms.