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PROPERTIES OF LIGHT

ENERGY TRANSFER - light is one of the ways in which energy is transferred.

1) conduction - molecule to molecule

2) convection - mass movement

3) radiation - radiant energy transferred as electromagnetic waves

light - light is the layman's term for visible radiant energy in the 400 to 700 nm wavelength region of the spectrum. In other words, it is the form of radiant energy (i.e. radiation) that animals can see. It is also the wavelengths of radiant energy that plants use in photosynthesis and for most other reactions that require light.

LIGHT HAS FOUR PROPERTIES

1) quantity - the intensity or amount of light

2) quality - the wavelength or color of light

3) duration - determines the total amount of light energy received
total amount of light energy = quantity x # hours of light

4) photoperiod- the day length, or length of light in a 24 hour cycle, regardless of quantity.

LIGHT CAN BE AFFECTED AS FOLLOWS

1) absorbed - when radiant energy (such as light) is absorbed it is converted primarily to heat energy.
re-radiation - heat energy is converted to radiant energy as long wavelengths in the infrared (IR) region of the spectrum.

2) transmitted - when radiant energy (such as light) passes through an object unaffected, such as glass.

3) reflected or scattered - when radiant energy (such as light) is "bounced off" an object, such as a solid colored surface.

The color of an object is the color (as determined by wavelength) of light that is transmitted or reflected. In other words, your eyes see the color that is not absorbed.

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MEASUREMENT OF LIGHT INTENSITY

1) photometer or common light meter (cheapest) - measures amount of luminance

Expressed as:

a) foot-candle (**ft-c**) - 1 lumen per square foot

b) lux - 1 lumen per square meter

1 foot-candle = 10.76 lux

2) quantum sensor - measures actual light intensity or light energy in the 400-700 nm wavelength band.

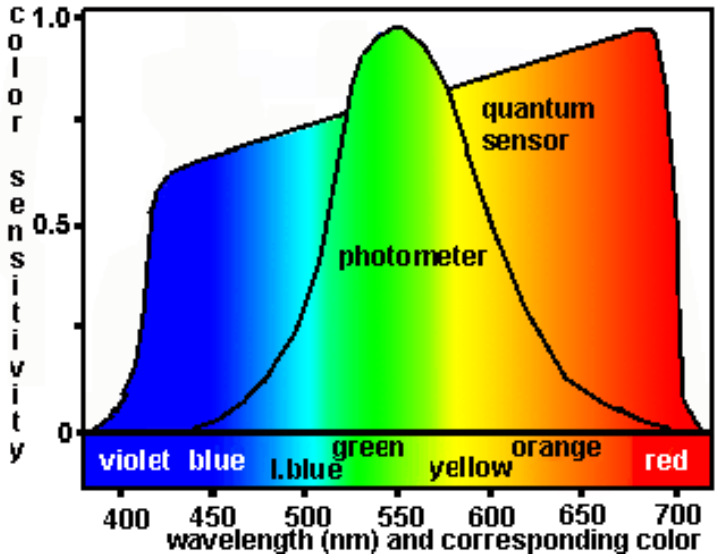
photosynthetically active radiation (**PAR**) **-** light intensity in the 400-700 nm wavelength band that is used by plants in photosynthesis.

Expressed as

a) microEinstein per second per square meter - $\mu Es^{-1}m^{-2}$ (400-700 nm)

b) watts per square meter - Wm^{-2}(400-700 nm)

Color Sensitivity of a Photometer vs. a Quantum Sensor



3) **radiometer** - measures radiant energy received at all wavelengths, i.e. total solar radiation.
4) **spectral radiometer** **-** measures the intensity at each wavelength (i.e. color spectrum of a light).

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EFFECT OF LIGHT QUANTITY ON PLANTS

1) **phototropism** - response of plants to light
  a) plants bend towards areas of higher light intensity.
2) **photosynthesis**
  a) light reaction - increases with increasing light intensity
  b) stomata - C3 and C4 plants: open in light; close in dark
  c) stomata **-** CAM plants: open in dark; close in light
3) **temperature** **-** high light intensity increases temperature due to:
  a) absorption of radiation, especially IR; greater with darker colors
  b) greenhouse effect
4) **transpiration** **-** greater in high light intensity due to heat buildup, but transpiration may decrease if it gets too bright then too hot, which will cause the stomata to close.
5) **sun versus shade plants**

a) **leaf structure**

sun grown leaf
- thicker, due to thicker palisade parenchyma layer

shade grown leaf
- thinner, due to thinner palisade parenchyma layer
- therefore, higher proportion of spongy mesophyll
- larger size
- softer and more pliable

b) **optimum light intensity**

shade plants: have a low optimum light intensity
sun plants: have a high optimum light intensity

6) **photooxidation** - destruction of chlorophyll by high light intensity.
7) **etiolation** - elongated, pale green to yellowish growth due to low light intensity.
8) **blanching** - lack of color development due to exclusion of light;

- used on cauliflower, asparagus and celery.

9) **light acclimatization** - conditioning of plants to low light intensity interior environments.

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INDOOR PERFORMANCE OF SHADE VERSUS SUN FOLIAGE PLANTS

	Number of Months of Attractive Live At Various Indoor Light Intensities			
Plant Name	**15-25 ft-c**	**25-50 ft-c**	**50-75 ft-c**	**75-100 ft-c**
Shade Plants (lowest light tolerant)				
Chinese Evergreen	12	36	36	-
Cast Iron Plant	12	-	-	-
Aucuba	12	-	36	36
Dumbcane	12	-	26	38
Janet Craig Dracaena	30	36	36	38
Sander's Dracaena	12	-	-	-
Heart-Leaf Philodendron	12	24	-	-
Mother-in-Law's Tongue	12	-	-	-
Syngonium, Arrowhead Ivy	12	-	--	38
Shade Plants (moderate light tolerant)				
Norfolk Island Pine	-	36	36	38
Schefflera, Umbrella Plant	-	30	36	38
Anthurium	-	12	-	-
Spider Plant	-	30	-	36
Kentia Palm	-	12	-	-
Boston Fern	-	12	-	-
Peperomia	-	12	-	-
Aluminum Plant	-	12	-	-
Variegated Dumbcanes	-	12	-	-
Sun Plants				
Weeping Fig	-	-	-	12
Rubber Plant	-	-	-	12
Grape Ivy	-	-	-	12
English Ivy	-	-	-	12
Fatshedera	-	-	-	12

(from: G. Thames and M.R. Harrison. 1966. Foliage Plants for Interiors. Bulletin 327-A, Rutgers University, New Brunswick, NJ)

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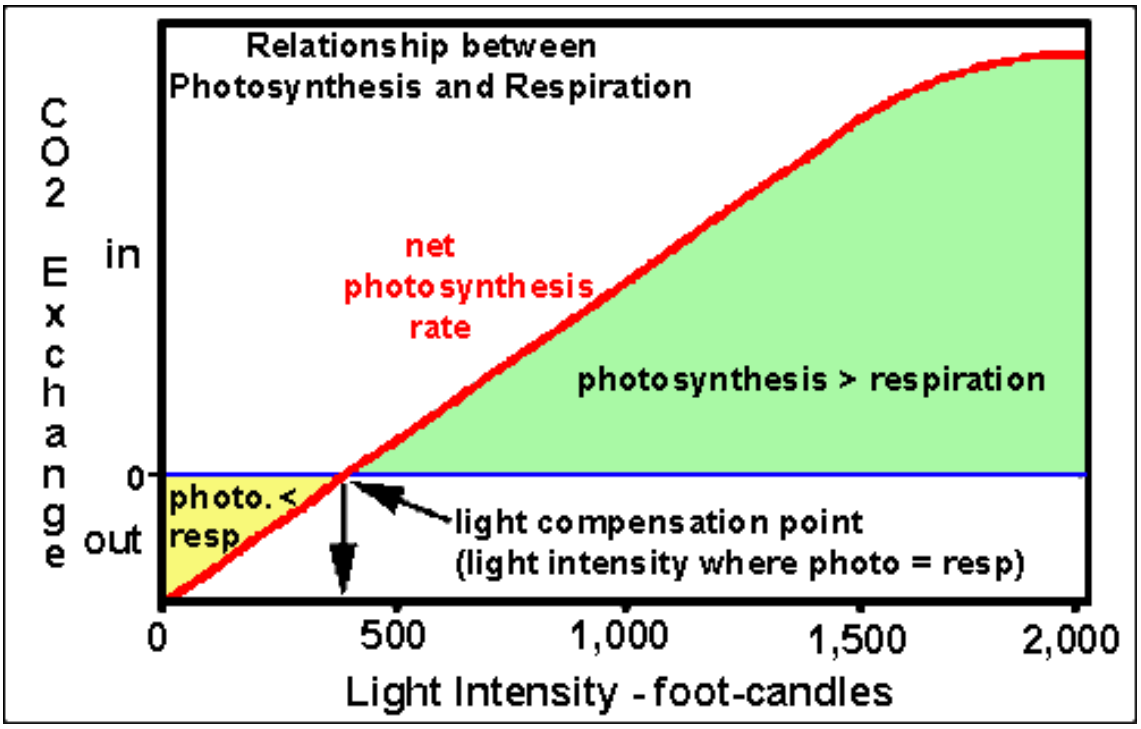
EFFECT OF LIGHT INTENSITY ON PHOTOSYNTHESIS/RESPIRATION RELATIONS OF SUN VERSUS SHADE PLANTS

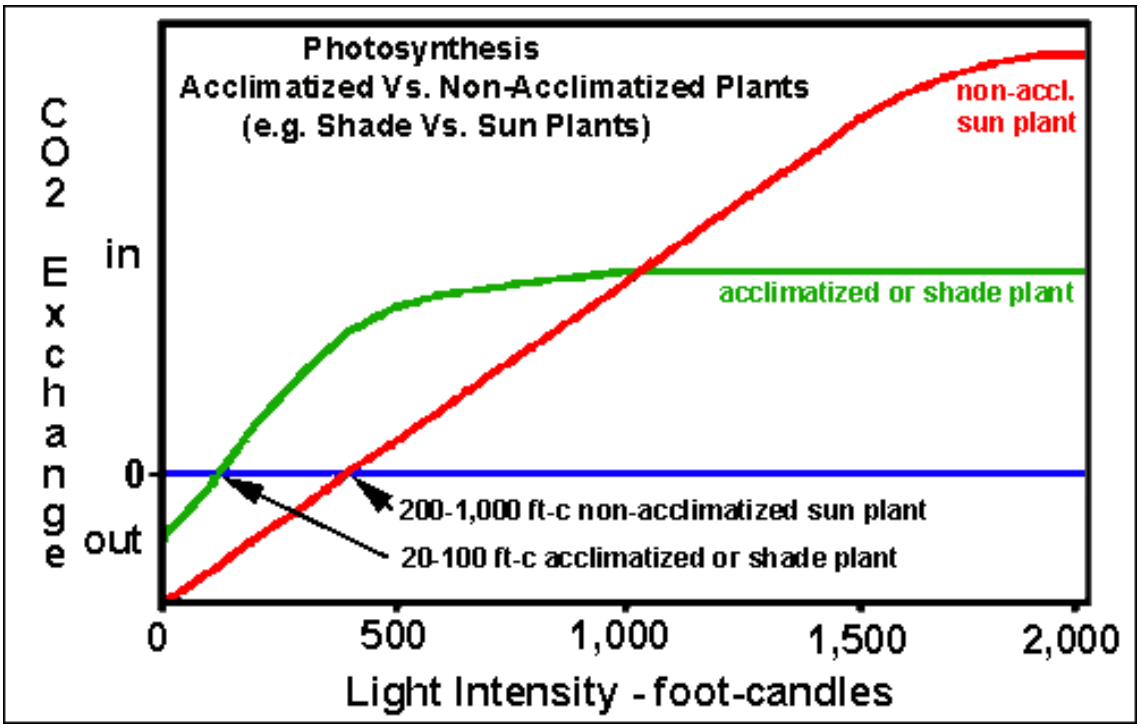
Relationship between Photosynthesis, Respiration and Light Intensity

Photosynthesis makes fixed carbon compounds and respiration burns fixed carbon compounds. At light intensities above the photosynthesis **light saturation range** (1,200-2,000 ft-c), the rate of photosynthesis is much higher than the rate of respiration, up to 10-times higher. Thus, plants produce a great excess of fixed carbon. But, as the light intensity decreases the rate of photosynthesis goes down. Eventually, a light intensity is reached where the rates of photosynthesis and respiration are equal; this is called the **light compensation point**. At light intensities below the light compensation, the plant is starved because its rate of photosynthesis is less than its rate of respiration.



Why do Shade or Acclimatized Plants Grow Well At Low Light Intensities

The relationships discussed in the figure above apply to sun plants, which are plants that grow best at very high light intensities. Shade plants grow best at lower light intensities, such as would be found on a forest/jungle floor. Notice in the figure below, the shade plants have a: **a)** **lower maximum photosynthesis rate**, **b)** **lower light saturation range**, but most importantly **c)** **lower light compensation point**. Thus, shade plants are adapted to grow best at lower light intensities, which is why they make good indoor plants. An acclimatized plant is a sun plant that is "conditioned" to behave like a shade plant.



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METHODS OF LIGHT ACCLIMATIZATION

METHOD 1. GROW PLANTS UNDER REDUCED LIGHT INTENSITY FOR THE ENTIRE PRODUCTION TIME (most common method used)

Common Name	Scientific Name	Suggested Light Intensity (ft-c)	% Shade (in summer)
Zebra Plant	*Aphelandra squarrosa*	1000-2000	80-90%
Chinese Evergreen	*Aglaonema* spp.	2000-2500	80%
Prayer Plant	*Maranta* spp.	"	"
Stromanthe	*Stromanthe amabilis*	"	"
Pilea	*Pilea* spp.	2000-3500	73-80%
Spathiphyllum	*Spathiphyllum clevelandii*	"	"
Peacock Plant	*Calathea* spp.	3000-3500	73%
Parlor Palm	*Chamaedorea elegans*	"	"
Ferns	*Nephrolepis exaltata cv,*	"	"
Peperomia	*Peperomia* spp.	"	"
Philodendron	*Philodendron* spp.	"	"
Christmas cactus	*Zygocactus truncatus*	"	"
Dumbcane	*Dieffenbachia spp.*	3000-4500	63-73%
Dracaena	*Dracaena deremensis*	"	"
Fragrant Dracaena	*Dracaena fragrans*	"	"
Arrowhead Ivy	*Syngonium podophyllum*	"	"
Asparagus Ferns	*Asparagus* spp.	3500-4500	63%
Ti plant	*Cordyline terminalis*	"	"
Weeping Fig	*Ficus benjamina*	"	"
Indian Laurel Fig	*Ficus nitida*	"	"
Splitleaf Philodendron	*Monstera deliciosa*	"	"
Snake Plant	*Sansevieria* spp.	"	"
Pothos	*Epipremnum* spp.	"	"
Norfolk Island Pine	*Araucaria heterophylla*	5000-6000	55%
Schefflera	*Brassaia actinophylla*	"	"
Madagascar Palm	*Chrysalidocarpus lutescens*	"	"
False Aralia	*Dizygotheca elegantessima*	"	"
Corn Plant	*Dracaena marginata*	"	"
Fiddle Leaf Fig	*Ficus lyrata*	"	"
Lg Leaf Philodendron	*Philodendron selloum*	"	"
Rubber Plant	*Ficus elastica*	5000-8000	30-55%
Croton	*Codiaeum variegatum*	7000-8000	30%

Recommendation:
Greenhouses are covered with shade cloth to yield the desired % shade. In the Rio Grand Valley of south Texas, the greenhouses commonly are covered with 63-73% shade. The plants are grown the entire time under these shaded conditions. The production time is a bit longer than growing in higher light. The plants are typically a bit taller with larger, deeper green leaves. They can be used immediately indoors and in interiorscapes.

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METHODS OF ACCLIMATIZATION

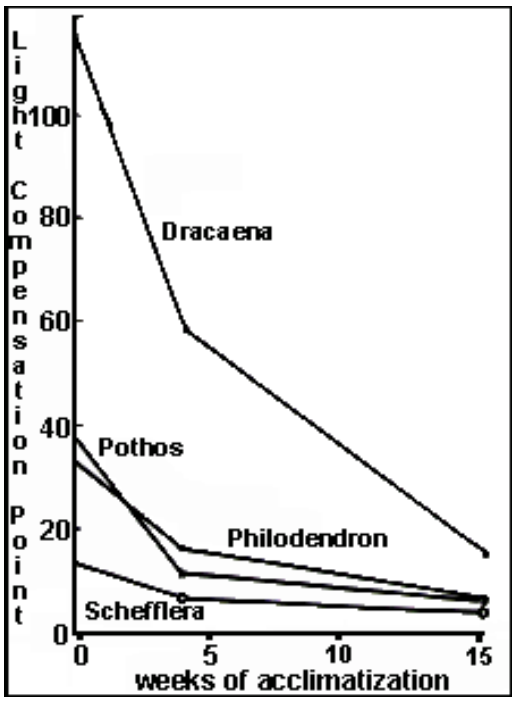
METHOD 2. GIVE FINAL PERIOD OF GREATLY REDUCED LIGHT INTENSITY

In this method the plants are grown in a greenhouse at very bright light intensity, often full sun. The plants grow fast, are short and compact with lighter green leaves. If placed directly indoors or in an interiorscape.

a) growth stops
b) leaves turn yellow, especially the older leaves, and
c) leaves fall off, especially the older leaves

So to acclimatize the plants, they are placed in a very heavily shaded greenhouse or a lighted warehouse in order to acclimatize them to low light intensities.

Notice on the graph below that each plant started out with a certain light compensation point. For example, Dracaena was the highest at about 120 ft-c and Schefflera was the lowest at about 15 ft-c. Over time in the acclimatization treatment, each plant's light compensation point decreased. This is showing their rate of acclimatization. Notice that all the species acclimatized, i.e. even very shade tolerant plants acclimatized to even lower light intensities. After about 4 to 6 weeks, the light compensation point does not decrease much more, so the light acclimatization process is virtually complete.



(From: W.C. Fonteno and E.L. McWilliams
J. Amer. Soc. Hort. Sci. 103(1):52-56, 1976)

Recommendation:
Grow plants at high light intensities. Acclimatize plants for 4-6 weeks at very low light intensities (about 150-500 ft-c) in a heavily shaded greenhouse or lighted warehouse**.**

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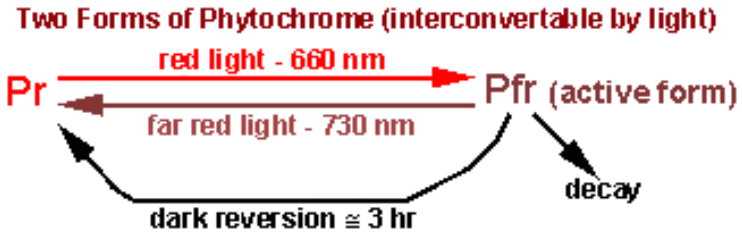
EFFECT OF LIGHT QUALITY ON PLANTS

1) photosynthesis
- **a)** chlorophyll absorbs predominately blue and orange-red light
- **b)** green-yellow is transmitted and reflected

2) growth responses - due to effect on photosynthesis
- **a) colored coverings**
  - **1)** plant canopy - shade rich in green-yellow & far red, poor in blue & orange-red light
  - **2)** fiberglass -
  - **3)** tinted/shaded glass
  - **4)** shade cloth or saran
- **b) artificial light sources**
  - **1)** tungsten - rich in red and far red
  - **2)** fluorescent - rich in blue and yellow-orange
  - **3)** HID - varies

3) pigments
- **a) anthocyanins** - blue, red and purple in color
- **b) carotenoids** - orange and yellow in color; absorb 450-500 nm (blue and green); carotenoids can pass energy to chlorophyll to assist in photosynthesis
- **c) phytochrome** - absorbs red (660 nm) and far red (730 nm) light; involved in photomorphogenic and photoperiodic responses



4) seed germination in light requiring seeds

Some seeds will only germinate in the light, therefore sow on surface to see sunlight.
- **a)** sunlight and any white or red light causes germination; (causes Pfr form to be present)
- **b)** far red light inhibits germination (causes Pr form to be present)

CONCEPT OF THE "ATMOSPHERIC WINDOW"

The 400 to 700 nm wavelength band of radiation (visible light) from the sun passes through the atmosphere relatively unaffected before reaching the earth's surface, whereas other wavelengths (especially UV and IR) are absorbed, reflected or scattered by the atmosphere.

- **ultraviolet light** - absorbed by ozone
- **visible light** - not selectively affected
- **infrared light** - absorbed by carbon dioxide and water vapor

Thus, the atmosphere acts as a window allowing visible light through relatively unaffected. Plants and animals are adapted to utilize this relatively stable source of radiation in their photosynthesis, photomorphogenic responses, sight, etc.

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RESPONSE OF PLANTS TO PHOTOPERIOD

PLANT TYPES BASED ON RESPONSE TO PHOTOPERIOD

short-day plant (SDP) - plants that exhibit their photoperiodic response when the photoperiod is shorter than a critical photoperiod.

long-day plant (LDP) - plants that exhibit their photoperiodic response when the photoperiod is longer than a critical photoperiod.

day-neutral plant (DNP) - plants that are not affected by photoperiod.

	Examples of Plants Based on Response to Photoperiod		
Response	**Short-Day Plants**	**Long-Day Plants**	**Day-Neutral Plants**
Flowering	chrysanthemum poinsettia kalanchoe strawberry soybean	sedum tuberous begonia carnation radish spinach	bean tomato squash rose corn
Bulbs and Tubers	Jerusalem artichoke tuberous begonia	onion	tulip crocus
Plantlets	none	bryophyllum spider plant	piggy-back plant
Runners	none	strawberry	grasses
Color Development	maple sumac	none	coleus foliage plants
Dormancy	dogwood birch	none	many trees
Cold Acclimatization	dogwood birch	none	many trees
Elongation of Stems	-	most plants	-

civil twilight - reflected sky light that occurs approximately 1/2 hour before sunrise and 1/2 hour after sunset.

Plants can detect civil twilight, so it must be taken into account when determining the photoperiod that plants perceive. Plants cannot detect moonlight, so it does not effect the photoperiod plants perceive.

photoperiod - the day length a plant perceives, which will be the absolute day length (time from sunrise to sunset) plus 1 hour of civil twilight.

critical photoperiod - the photoperiod (absolute day length + civil twilight) above or below which the photoperiodic response is turned-on or turned-off.
-each species has its own unique critical photoperiod that it "looks" for.

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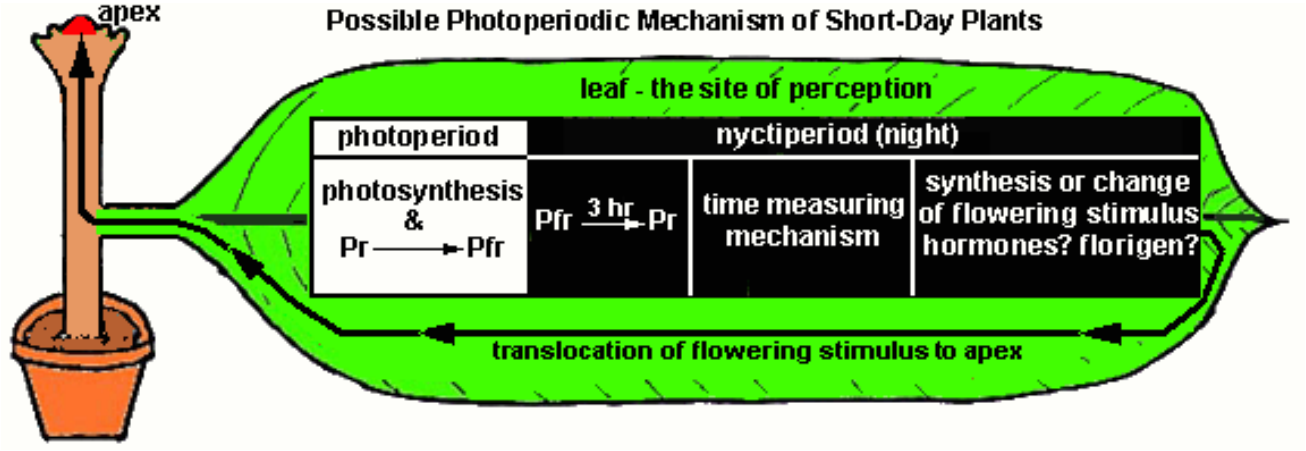
MECHANISM OF PHOTOPERIODIC RESPONSES

LIGHT PERCEPTION, TIMING AND FLORAL INDUCTION IN SHORT-DAY PLANTS

All the critical events happen at night, therefore plants are not photoperiodic but rather are nyctiperiodic. Short-day plants really are long-night plants.



RESPONSE OF PHOTOPERIODIC PLANTS TO DIFFERENT PHOTOPERIODS

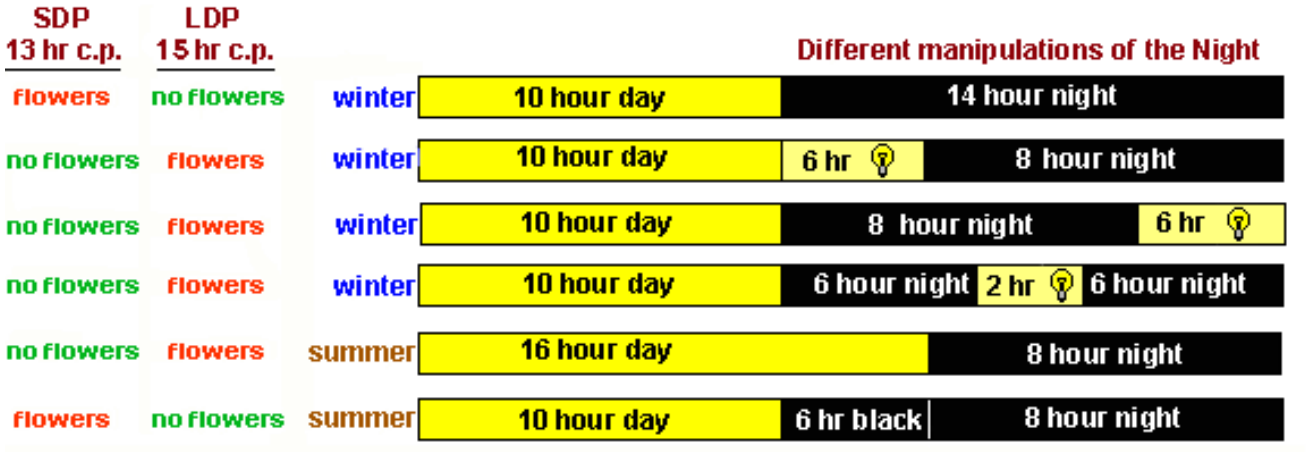
It is the trend in response to photoperiod that is important, not the absolute day length. In the table below, the SDPs flower at all photoperiods below their particular critical photoperiod, and the LDPs flower at all photoperiods above their particular critical photoperiod.

	Plant Type*	
Photoperiod	**SDP (ex. Chrysanthemum) 14.5 hr critical photoperiod**	**LDP (ex. Henbane) 11 hr critical photoperiod**
4 hour	flowers	no flowers
8 hour	flowers	no flowers
12 hour	flowers	flowers
16 hour	no flowers	flowers
20 hour	no flowers	flowers
24 hour	no flowers	flowers

*day-neutral plants would flower at all day lengths

MANIPULATING FLOWERING OF PHOTOPERIOD PLANTS

Horticulturist manipulate the light and dark periods to which plants are exposed in order to trigger photoperiodic plants to flower during any season of the year. That is why you can purchase a chrysanthemum year round.



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