All colours in light are equal for photosynthesis

Light is of the most important factors for plant growth but it is often thought that different coloured light has a less or greater effect on photosynthesis. For this process it makes no difference and a balanced light spectrum is good for overall development.

By Harry Stijger

Light is an important factor for photosynthesis but plants have a different sensitivity to light than humans. Only a small part of the radiation spectrum is visible to the human eye and this is the part we call light. The human eye is not equally sensitive to each colour component in light and that can be seen from the eye sensitivity curve (*see Figure 1*). Maximum sensitivity lies around 555nm – (yellow-green light) and drops away by longer (red) and shorter (blue) wavelengths. Plants on the other hand are sensitive to light of different wavelengths, being most sensitive to red light and least sensitive to green (*see Figure 2*). Their maximum sensitivity lies in the radiation spectrum between 400 and 700nm which is the so called PAR area. During daylight around 45% of radiation hitting the earth lies in this region and therefore is called PAR-light. This means that for supplementary lighting to efficiently stimulate growth, lamps should emit as much electrical energy as possible as PAR radiation.

A light source sends out energy particles which are known as quanta or photons. The energy content of a photon is related to its wavelength and that, for example, at 400 nm (blue) is 1.75 times higher than a photon emitted at 700nm (red). But for the purpose of photosynthesis both photons have an equal value. The excess energy in a blue photo is largely converted into heat. Therefore, the rate of photosynthesis is determined by the number of photons between 400 and 700 nm that the plant absorbs and not by the total energy content of these photons. However, it is often thought that the colour of light does influence the rate of photosynthesis.

Chlorophyll

Having said that, plants are not sensitive to all wavelengths within the PAR region. This is due to the specific absorption characteristics of all the pigments in the leaf. Chlorophyll (green leaf pigment) is the best known and due its relative strong reflective characteristics, the leaf uses green light the least effectively. It also explains why leaves appear green to the human eye. The effect of radiation at different wavelengths on plant growth can be seen in the plant sensitivity curve.

But chlorophyll is not the only pigment playing a role in photosynthesis, the most important process for plant growth. Other pigments are also involved. Therefore the differences in efficiency of photosynthesis are less than expected if only the absorption spectrum of chlorophyll is considered.

The different processes in photosynthesis are also independent of colour. Light which is absorbed by chlorophyll and carotenoids in the leaves, generates energy via two photosystems in order to fix water and carbon dioxide in sugar (glucose) and oxygen. This process uses light from the entire visible spectrum so for photosynthesis the colour of light hardly makes a difference.

Balanced light spectrum

Nevertheless some research trials haves shown that photosynthesis is at its most efficient under red orange light. But this is not to say that plants should only be cultivated under this colour light. For good plant development, crop structure and the colour of the leaves it is important that the plant receives a balanced light spectrum.

Blue light (400-500 nm) for

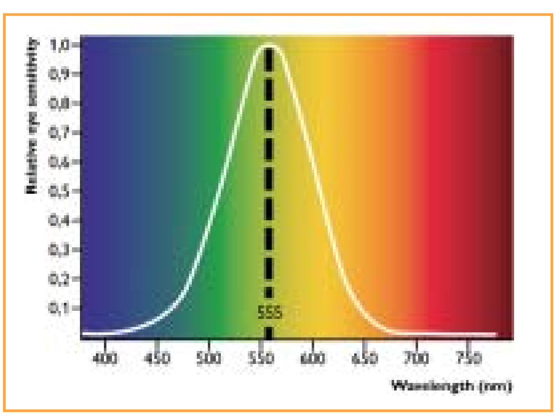

Figure 1: Sensitivity curve to radiation wavelength of the human eye.

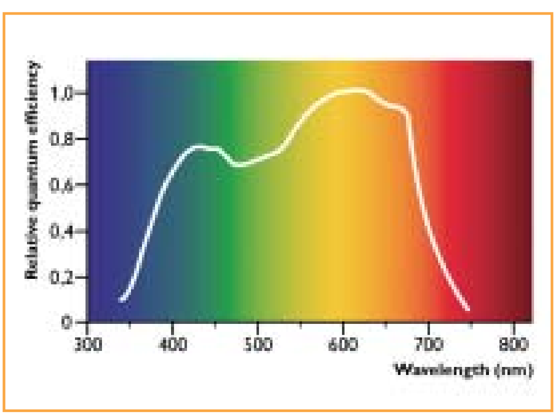

Figure 2: Sensitivity curve of plants to radiation wavelength.

The most used lamps for supplementary growth lighting are high pressure sodium lamps.

example, is important for good plant development and the correct regulation of the stomata. A shortage of blue light and a relatively high proportion of far-red light cause excessive stem growth and sometimes yellowing of the leaves. A ratio of red (655-665nm) to far red (725-735 nm) light between 1 and 1.2 gives normal plant development. This sensitivity may vary according to the plant species.

Measuring light

The intensity of visible light is given in lumen and is based on the average sensitivity of the human eye. The quantity of radiation emitted from a light source and which falls on a particularly area is known as lux (lumen/m^2).

The total number of photons between 400 and 700nm emitted per second is called the Photosynthetic Photon Flux (PPF) expressed in units of µmol/s. This is similar to the concept of lumen but is based on plant sensitivity. The PPF value per Watt is a reliable measurement with which to determine if a lamp is suitable for photosynthesis.

Plant photosynthesis is determined by the number of photons between 400 and 700nm which are absorbed by the leaves. The amount of these photons falling on a certain area per second is called the Photosynthetic Photo Flux Density (PPFD) and is expressed in micromol photons per m2 per second (µmol/m^2/s). PPFD can be compared with lux but again on the basis of plant sensitivity.

Photosynthetic Active Radiation (PAR) is the energy content of light between 400 and 700nm per second per area and is measured in units of W/m^2 (J/s/m^2)

Normal development

The most used supplementary growth lighting in the greenhouse is a high pressure sodium lamp. Philips specifically developed the Master SON-T PIA Green Power bulb to produce light according to the plant sensitivity curve. Therefore this bulb output peaks in the orange-red region of the spectrum (which is the most efficient region of the spectrum for photosynthesis). The amount of far red light emitted from a high pressure sodium bulb is low. Also, the ratio of red:far red is greater than 2.0 but that doesn't lead to shorter plants due to far red light in natural sunlight.

Also, in general blue light is sufficiently available in daylight. Daylight contains a proportion of blue light of around 20% but it is not necessary for an artificial light to emit such a high proportion. For normal development, most plants need just 6% of blue light in the whole PAR spectrum otherwise they experience stem elongation. High pressure lamps do not provide enough blue light.

Nevertheless in most cases, they provide sufficient blue light because enough additional blue light enters the greenhouse in the form of natural daylight. However, at low light intensities it may be necessary to increase the proportion of blue light. For a few sensitive crops which, if not given access to sufficient natural daylight and instead are lit for many hours with supplementary lighting, the availability of blue light from the lamps can be critical if light intensity is under 15,000 lux (195 µmol/m^2/s). Nevertheless, growers are advised to only use lamps which provide more blue light, when the problem of excessive stem growth cannot be solved through other

Plant photosynthesis is determined by the number of photons between 400 and 700nm, in natural light or emitted from artificial lights, which are absorbed by the leaves.

Developing safe and reliable electronic lights

Electronic circuits in the light fittings offer some advantages over conventional types in terms of higher output, slower deterioration of the lamps and more opportunities for intelligent control over the entire light fittings.

In the future, it is possible for example that the lamps can be digitally controlled from a remote position. With such a digital control, aging of the lamp is recorded precisely so it is possible to know exactly when the lamp should be changed. It also seems that with digital lighting it is possible to dim the lamps on a continuous scale rather than just have them on or off. It is not possible to dim traditional greenhouse lighting, only to have some rows on and some off but this doesn't provide optimal lighting for the plant.

Also, by being able to dim lights it is possible to use them at a low setting on cloudy, dull days in summer to maintain production levels.

Electronic light circuits can also use fittings which are light in weight and narrow in design so they produce less shadow. Electronic lamps should also be able to compensate for dips in electricity delivered to the network so that the lamps themselves always receive the correct voltage. Also, while the amount of light emitted from a standard lamp falls away with time, in an electronic circuit, light emitted should always remain the same.

Philips sees plenty of advantages for having good electronic circuits in the future. For example, light can be given to suit the needs of the plant and through monitoring it should be possible to have maximum efficiency for the growth of the plant. The development of electronic circuits is still in the early stages but Garita launched its electronic prototype at the Horti fair last November and is now starting commercial production. Philips anticipates being able to introduce an electronic system sometime next year. Electronic circuits comprise many components and are sensitive to temperature differences and high voltage which needs to be overcome. Also, the lamps should not be sensitive to cuts in power and they should not be the cause of power cuts when used with other electronic system. Research currently being carried out by Philips is designed to ensure that the lamps are safe and reliable. And it still has to be seen if dimming causes changes in the light spectrum, which consequently may affect the amount of light available, and what the plant can effectively use for growth.

cultivation methods such as temperature and use of growth regulators. This is because, in comparison with high pressure sodium lamps, these sorts of lamps give low return in terms of growth.