Plasma spectrum for use in combination with HPS lighting for the generative phase

Introduction

Many studies have shown that full continuous spectrum with sunlight qualities is the best spectrum for healthy plant development. For this purpose Gavita manufactures a light emitting plasma (LEP) luminaire with a high CRI of 94, the Gavita pro 300 LEP. Though it is lacking some red spectrum it is the best suitable lamp for continuous vegetative development or high intensity sunlight simulations in climate rooms.

A different application for plasma lighting is the quality improvement of HPS light. A combination of LEP and HPS provides a much better spectrum because the HPS is lacking blue spectrum, and generally most spectrum below 560 nm (see fig 1). Additional advantage is the UVA and UVB light that the plasma adds to the spectrum. Blue light and a continuous spectrum is very important in any development phase of the plant, be it vegetative or generative, as the full spectrum contains colors that define photosynthetic rate, morphogenesis and high energy (blue) photons that help maintain the photosynthetic system in the plant during the generative phase.

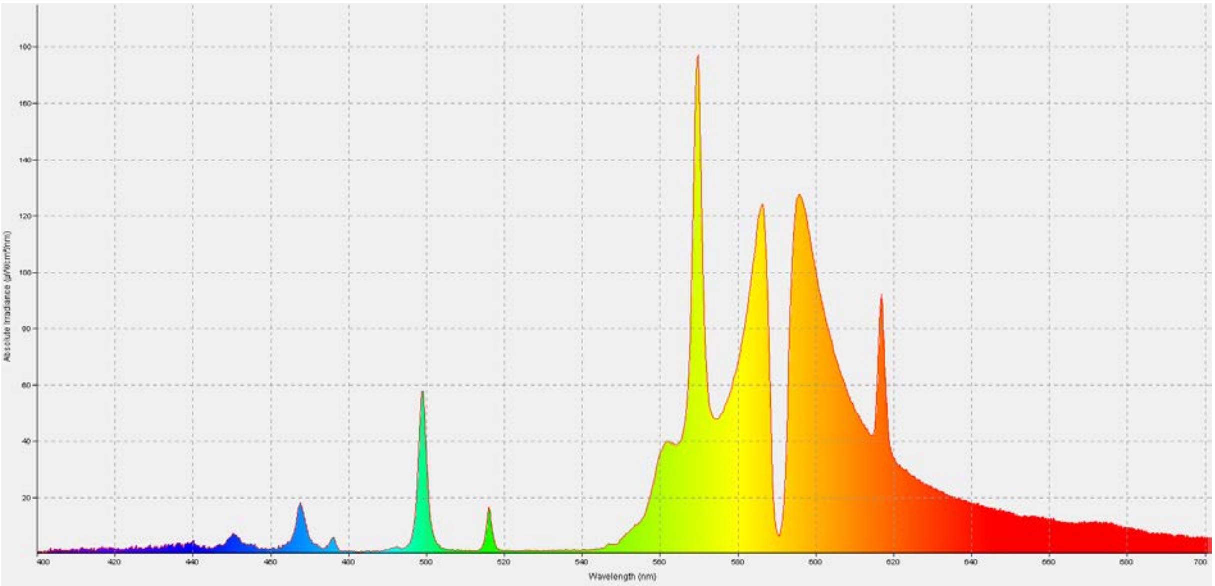

Fig 1: Typical High Pressure Sodium spectral diagram

This paper describes our recommendations for a more efficient plasma spectrum for use in combination with HPS lighting, using an alternative emitter: The STA 41.01.

Efficiency of light

Most plant response curves such as the famous Keith McCree curve (fig 2) show a lower relative photosynthetic efficiency for blue and yellow/green light. This is correct for low PAR levels. Recent studies however have shown that even the green light, which is most abundant in sunlight, is very efficient when used in high intensities. In fact, at high irradiation levels the green light is equally or more efficient than other colors.

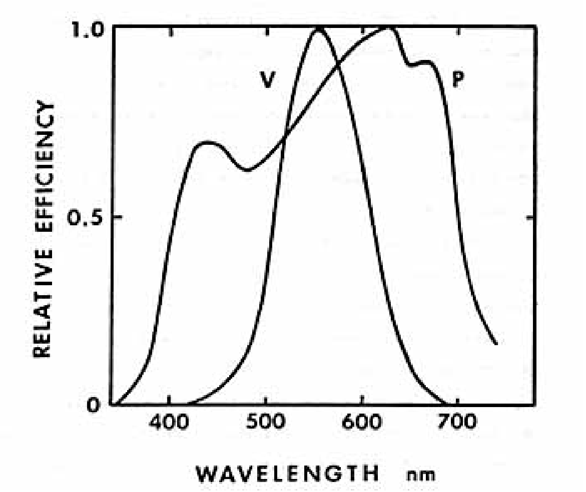

Fig 2: Efficiency of light in the PAR spectrum– McCree '73 – P curve is plant sensitivity curve, V curve is human eye sensitivity http://www.keithmccree.net/Biographical/BioProf/PAR.html

In horticultural greenhouses there is mostly enough quality sunlight available, even in the low light season when HPS assimilation lighting is used. The most efficient technology for creating photons in the PAR region at this moment is High Pressure Sodium light. The disadvantage of the bad quality HPS spectrum is compensated in the greenhouse by the available sunlight. In recent years though we have seen an increase in used HPS PAR levels in the greenhouses, which may be accountable for a less than usual quality in the winter. It is suggested that this is a result of the lacking blue light. In Scandinavia, where the daytime light is even shorter and so the DLI provided by the sunlight is totally inadequate this is compensated by using supplemental Metal Halide lighting.

The effect of blue light

Light spectrum is one of the factors that define how a plant develops. There are many mechanisms in a plant that are responsible for stretching, photosynthetic rate and morphogenesis. One effect of blue light is the development of sun leaves which have higher rate of photosynthesis per unit leaf area. Another very important factor is the morphogenesis: Leafs develop in a better position to intercept the light, which results in a higher photosynthesis and faster vegetative development. It also puts the plant in a favorable position for generative development.

Research indicates a requirement for 7% blue light spectrum as a good balance with the HPS light for quality plant development. The highest measurable increase in quality of added blue light was found within the 0-10% more blue light. Above that level blue light still increases the quality and yield of the crop, but it doesn't increase as much as within the 0-10% range. Below that level plants can suffer from the imbalance in the spectrum, as in a deterioration of their photosynthetic system, more compact growth, vulnerability for disease and fungi and a less efficient morphogenesis.

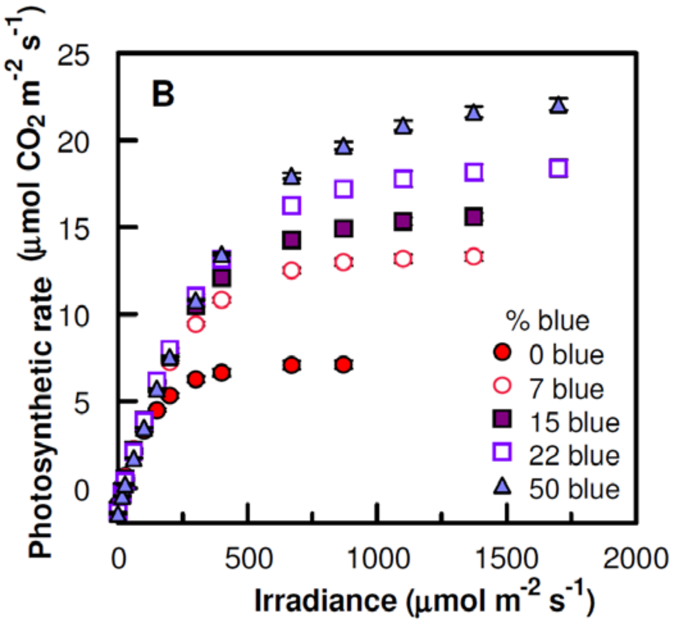

Fig 3: Increase of photosynthetic rate with the addition of blue light (data from Hogewoning et al. 2010)

Another important factor in the applied spectrum is the continuity of the spectrum: Research indicates that plants develop best under a full continuous spectrum. Plasma light provides a continuous spectrum.

Light color and stretching

The phytochrome fotoreceptors are responsible for the stretching of a plant. They have an action spectrum from ~350-800 nm, and the far red color is an important signaling color. Generally a more blue spectrum leads to less stretching, but it is important to take all colors and factors into account, including the leaf positioning and photosynthetic rates. Plasma light will not influence the stretching of the plant much when used in combination with HPS. Other effects, such as light interception of the plant by a better leaf position when plasma is used in the vegetative phase and a higher rate of photosynthesis per unit leaf area have a much bigger influence. The faster development of the plant under just plasma light is only for a small portion due to stretching.

Adding quality spectrum to HPS

Analysis of the HPS spectrum shows a start of the effective spectrum at about 560 nm (yellow to red). Below that wavelength there are a few small spikes, but not a balanced continuous availability and not enough blue spectrum. For that reason Philips recommends to use MH to accompany her GreenPower HPS lamps when used in climate rooms, as these have very low levels blue light. In climate rooms therefore you see many combinations of MH and HPS.

Adding MH however has some disadvantages:

1. The lifetime is very short (6-8 months)
2. MH is not very efficient (much less than HPS)
3. The spectrum is not continuous but has many spikes
4. The color temperature stability is low
5. MH lamps either need a closed fixture or they need to have protection against shattering of the outer bulb in case of a failure. They are very dangerous to look into when they are broken as they provide very high amounts of UVC radiation
6. MH lamps emit a lot of IR radiation (heat)

With the introduction of CMH (Ceramic Metal Halide, arc tube made of ceramic material) better color rendering and longer light maintenance have become available, but only in the low to medium watt ranges, and it still isn't a continuous spectrum and lacks UVA and UVB.

Tests have shown that lacking quality spectrum in HPS lighting in climate rooms can be compensated by LEP, as the sunlight does in the greenhouses. Plants stay greener and healthier, while the available UVA and UVB triggers defense mechanisms in the plant that harden the leafs. UVA and UVB also cause increased levels of flavonoids, essential oils and terpenoids in many different strains. They have a long life (30.000 – 50.000 hours), a stable spectrum with very low levels of infrared and a high CRI of 94. So plasma technology is well suited for this task.

However, some of the spectrum of the plasma lamp overlaps with the HPS lamp which has an abundance of light in wavelengths above 560 nm. HPS technology is currently the most efficient way to generate red photons. So it would be better to have a plasma lamp that supplements the HPS lamp under 560 nm instead of overlapping in the higher bandwidth radiation. The full spectrum version of the plasma lamp is still superior in situations without HPS where you need to only grow vegetative or in sunlight simulations in climate rooms.

Choosing the right emitter

The wide continuous spectrum of a plasma lamp is caused by the emission of molecular light of a specific mixture of chemicals in the plasma cell which is brought into a high temperature plasma state. Changing the combination of the chemicals will change the spectrum. In our first Gavita Pro 300 LEP fixture we use the STA 41.02 emitter, which has the highest quality light output, ideal for simulating sunlight. It is regarded best suited for continuous vegetative growth and sunlight simulation. But there is another emitter available: The STA 41.01 emitter has less red in its spectrum, and shifts more to the spectrum below 590 nm while maintaining the same blue spectrum. (fig 4: plasma spectrum):

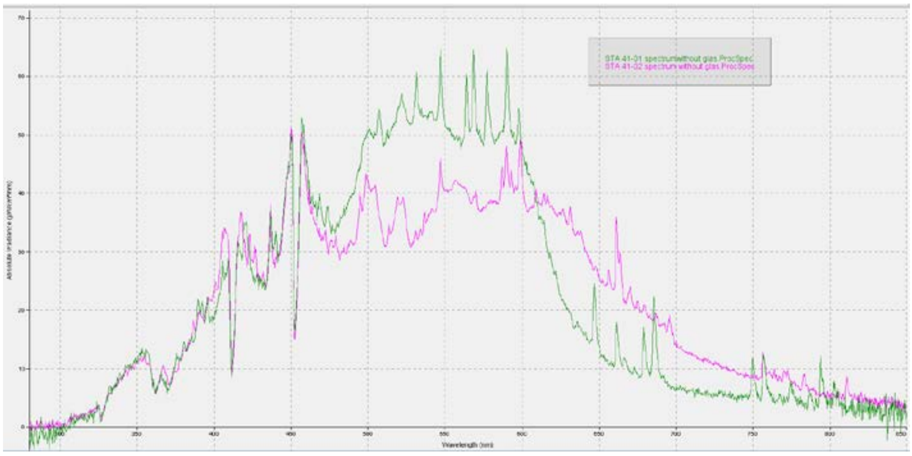

Fig 4: spectrum of the STA 41.01 and STA 41.02 emitter

As you can clearly see the spectrum of the STA 41.01 drops steep as from 590 nm, and it just overlaps for a small bandwidth with the HPS light. Energy is shifted from the red spectrum to a bandwidth below 590 nm. This makes the 41.01 better suitable to *complement HPS light*, as there is more supplemental light and less overlap.

The STA 41.01 module has other generic advantages:

- Increased life time 50.000 hours versus the 30.000 hours for the STA 41.02
- Much better output in lumen, but this is of no significance to the plant
- Slightly higher PAR output (PPF, photons per second)

We have tested the 41.01 lamp for vegetative development as well. Though it does not perform as well as the 41.02 lamp, for a short vegetative phase (<4 weeks) the differences were not significant. Under the 41.01 lamp at very high intensities we see a slight V shape of the top leafs, which disappears when transplanted to a combined HPS/LEP environment or when the leafs move to the lower parts of the plant. Plant development and photosynthesis were not significantly different.

The 41.01 emitter therefore is a better alternative for the 41.02 for situations where it is used in combination with HPS for generative development. For pure vegetative use the 41.02 emitter is still the lamp of choice, and it still is a proven valuable addition to the HPS spectrum as for the blue light.

How much plasma to complement HPS?

Our calculations and research show that for a climate room the combination of one 300W plasma light with 1000-1200W HPS light provides enough blue spectrum (>7%) for a healthy development of the plant. For the HPS light we calculate with the horticultural HPS light, which offer an efficiency of almost 2 µmol W-1.

It can be used in higher intensities to provide a higher blue ratio which will result in a higher photosynthetic rate, but the biggest increase in quality and yield can be obtained with up to 10% blue light. We recommend to use only plasma in the vegetative phase to optimize the photosynthetic rate and harden the plants.

So in conclusion:

- We recommend the 01 version as most efficient to complement HPS light during the generative phase and suitable for short vegetative cycles
- The 02 version is also suitable for a combination with HPS, but has a better quality than the 01 for vegetative development, so it is best utilized in a pure vegetative environment or for sunlight simulations
- Use one Gavita Pro 300 LEP in combination with a maximum of 1200W HPS lighting for a better color spectrum which results in healthier plants, higher quality and a better yielding crop

Gavita Holland bv
Oosteinderweg 127
1432 AH Aalsmeer
The Netherlands

www.gavita-holland.com
info@gavita-holland.com
T +31 297 380450
F +31 - 297 380452