Summary of the Invention

Embodiments~~It is an aim~~ of the present invention seek to eliminate at least a part of the problems relating to the art and to provide a new way of facilitating plant growth using LEDs.

Embodiments~~It is a first objective~~ of the invention seek to provide a single light emission source based LED device to which the photosynthesis process responds well.

Embodiments~~It is a second objective~~ of the invention seek to provide a lighting fixture for greenhouse cultivation based on a photosynthesis photon flux (PPF) optimized LED device.

Embodiments~~It is a third objective~~ of the invention seek to achieve an LED device that provides at least two emission peaks in the wavelength range from 300 to 800 nm and at least one of the emission peaks has Full Width of Half Maximum (FWHM) of at least 50 nm or more.

Embodiments~~It is a fourth objective~~ of the invention seek to provide LED based greenhouse cultivation lighting fixture wherein the emission intensity ratio of two emission frequencies, 300–500 nm and 600–800 nm, are reduced with less than 20 % during the 10,000 hours of operation.

Embodiments~~It is a fifth objective~~ of the invention seek to provide a technical solution giving a better PPF value per Watt (i.e. PPFs against used power wattage) than attained by a conventional high pressure sodium lamp normally used in greenhouse cultivation and thus providing an energy efficient light source for greenhouse cultivation process and artificial lighting used therein.

Embodiments~~It is a sixth objective~~ of the invention seek to provide a single light emission source wherein the emission at a wavelength of 300–500 nm is generated by the semiconductor LED chip and the emission at a wavelength of 600–800 nm is generated using a partial wavelength up-conversion of the LED chip radiation power. The inventor has discovered that for example cucumber and lettuce plants reach greater length and/or mass when illuminated with the inventive horticultural light that includes far red light (700-800 nm).

Embodiments~~It is a seventh objective~~ of the invention seek to provide a single light emission source where the emission at wavelength of 300–500 nm is generated by the semiconductor LED chip and the emission at wavelength of 600–800 nm is generated using a partial wavelength up-conversion of the LED chip radiation power. The wavelength up-conversion to produce 600–800 nm radiation is achieved by using one or more wavelength up-conversion materials in proximity with the LED emission source.

In this application "up-conversion" is construed as changing the wavelength of incoming absorbed light to emitted light of longer wavelengths.

Embodiments~~It is an eighth objective~~ of the invention seek to provide 400–500 nm, 600–800 nm or both wavelength ranges partial or complete wavelength up-conversion of semiconductor LED chip radiation, the chip having emission at 300–500 nm range emission range. The wavelength up-conversion is realized by using either organic, inorganic or combination of both types of materials.

Embodiments~~It is a ninth objective~~ of the invention seek to provide the wavelength up-conversion using nano-sized particle material for the up-conversion.

Embodiments~~It is a tenth objective~~ of the invention seek to provide the wavelength up-conversion using molecular like material for the up-conversion.

Embodiments~~It is an eleventh objective~~ of the invention seek to provide the wavelength up-conversion using a polymeric material wherein the up-conversion material is covalently bonded to the polymer matrix providing the wavelength up-conversion.

Embodiments~~It is a twelfth objective~~ of the invention seek to present a LED based lighting fixture where the spectral band 500-600 nm is suppressed. In this suppressed band there is hardly any or no emission at all, or in any case less emission than in either of the adjacent bands 400-500 nm, 600-700 nm. The suppression can be achieved in accordance with the invention by not having any or only a small amount of primary emission in the band 400-500 nm, and by making sure that any up-conversion causes a wavelength shift that shifts the wavelength beyond 600 nm. It is generally known that green plants can not utilize green light (500-600

nm) radiation as well as the radiation in the adjacent bands, as this radiation merely reflects from the plant rather than is being absorbed for photosynthetic conversion.

Embodiments~~It is a thirteenth objective~~ of the invention seek to present a LED based lighting fixture that maximizes anabolic growth of plants by providing desired far-red light, whereas it minimizes green light which from the perspective of plant cultivation is radiation that wastes energy. This~~objective~~ is realized in one embodiment~~aspect~~ of the invention by a blue LED with a wavelength up-conversion device which up-converts part of the emitted blue light (300-500) nm into a broad red spectrum component (600-800nm) which has a far-red component, but omits and/or minimizes the green component (500-600nm).

Embodiments of t~~T~~he present invention seek to provide~~s~~ a light emitting diode and a related light fixture suitable for greenhouse cultivation. According to ~~the invention~~an embodiment, the light emitting diode has a specific emission frequency pattern, viz. it has at least two spectral characteristics; one emission peak with a full width of half maximum of at least 50 nm or more and having a peak wavelength in the range of 600 to 700 nm, and a second spectral characteristics having a peak wavelength below 500 nm range. The emission peaks of the LED match well with a plant photosynthesis response spectrum and is therefore particularly suitable for high efficiency artificial lighting.

A light emitting component suitable for facilitating plant growth, comprises a light emitting compound semiconductor chip; and a light wavelength up-conversion phosphor which is deposited in direct proximity of the LED chip. Such a component is capable of emitting two characteristic light emission peaks.

According to a first aspect, there is provided a horticultural lighting fixture or light emitting component comprising at least one Light Emitting Diode (LED) having a) first spectral characteristics including a peak in the wavelength range from 600 to 700 nm and arranged to exhibit a full width of half maximum of at least 50 nm or more; b) second spectral characteristics with a maximum of 50 nm full width of half maximum and arranged to exhibit a peak wavelength in the range from 440 to 500 nm, and c) all or part of the emission at a wavelength of 600–800 nm is generated using a whole or partial wavelength up-conversion of the LED chip radiation power with at least one up-conversion material in proximity of the LED, and d) the emission at wavelengths of 500–600 nm is arranged to be reduced below the intensity in 400-500 nm band and below the intensity in 600-700 nm band.

According to a second aspect, there is provided a method for enhancing plant growth wherein at least one lighting fixture or light emitting component of the first aspect emits light to at least one plant.

~~More specifically, the light fixture according to the invention is characterized by what is stated in the characterizing part of claim 1 and/or 2.~~

A lighting fixture for facilitating plant growth in accordance with ~~the invention~~an embodiment comprises at least one Light Emitting Diode (LED) having
a) first spectral characteristics including a peak in the wavelength range from 600 to 700 nm and arranged to exhibit a full width of half maximum of at least 50 nm or more; and
b) second spectral characteristics with a maximum of 50 nm full width of half maximum and arranged to exhibit a peak wavelength in the range from 440 to 500 nm.

A horticultural lighting fixture in accordance with ~~the invention~~an embodiment comprises at least one Light Emitting Diode (LED) having

a) first spectral characteristics including a peak in the wavelength range from 600 to 700 nm and arranged to exhibit a full width of half maximum of at least 50 nm or more;

b) second spectral characteristics with a maximum of 50 nm full width of half maximum and arranged to exhibit a peak wavelength in the range from 440 to 500 nm, and

c) all or part of the emission at a wavelength of 600–800 nm is generated using a whole or partial wavelength up-conversion of the LED chip radiation power.

A horticultural lighting fixture in accordance with ~~the invention~~an embodiment comprises at least one Light Emitting Diode (LED) having

a) first spectral characteristics including a peak in the wavelength range from 600 to 700 nm and arranged to exhibit a full width of half maximum of at least 50 nm or more;

b) second spectral characteristics with a maximum of 50 nm full width of half maximum and arranged to exhibit a peak wavelength in the range from 440 to 500 nm, and

c) at least a part or the whole of the emission at wavelengths of 500–600 nm is arranged to be minimized and/or omitted and/or to be reduced below the intensity in 400-500 nm band and below the intensity in 600-700 nm band.

A lighting fixture for facilitating plant growth in accordance with ~~the invention~~an embodiment comprises a luminescent UV LED, optionally with external emission characteristics, said LED arranged to exhibit

a) first phosphorescent spectral characteristics with a peak wavelength in the range of 350 to 550 nm;

b) second optional phosphorescent spectral characteristics with a peak wavelength in the range of 600 to 800 nm;

c) third optional phosphorescent spectral characteristics with a peak wavelength freely adjustable between 350 and 800 nm;

d) the phosphorescent emission intensities of first, optional second and optional third spectral characteristics being adjustable in any ratio.

~~The light emitting component is characterized by what is stated in the characterizing part of claim 16 and/or 17.~~

A light emitting component for facilitating plant growth in accordance with ~~the inventionan~~ embodiment, comprises;

- a light emitting compound semiconductor chip; and
- a light wavelength up-conversion phosphor which is deposited in direct proximity of the LED chip;

said component being capable of emitting two characteristic light emission peaks.

A light emitting component of a horticultural light in accordance with ~~the inventionan~~ embodiment comprises;

- a light emitting compound semiconductor chip; and
- a light wavelength up-conversion phosphor which is deposited in direct proximity of the LED chip;

said component being capable of emitting two characteristic light emission peaks, and all or part of the emission at a wavelength of 600–800 nm is generated using a whole or partial wavelength up-conversion of the LED chip radiation power.

A light emitting component of a horticultural light in accordance with ~~the inventionan~~ embodiment comprises;

- a light emitting compound semiconductor chip; and
- a light wavelength up-conversion phosphor which is deposited in direct proximity of the LED chip;

said component being capable of emitting two characteristic light emission peaks, and at least a part or the whole of the emission at wavelengths of 500–600 nm is arranged to be minimized and/or omitted and/or to be reduced below the intensity in 400-500 nm band and below the intensity in 600-700 nm band.

An embodiment~~The best mode~~ of the invention ~~is considered to~~ involves a plurality of LEDs in the wavelength range of 380-850 nm arranged with emission spectra that is arranged to coincide with the photosynthetic response of a plant to be cultivated with the lighting of the said LEDs. The embodiment~~best mode~~ will feature wavelength up-conversion by phosphor from blue LED emission.