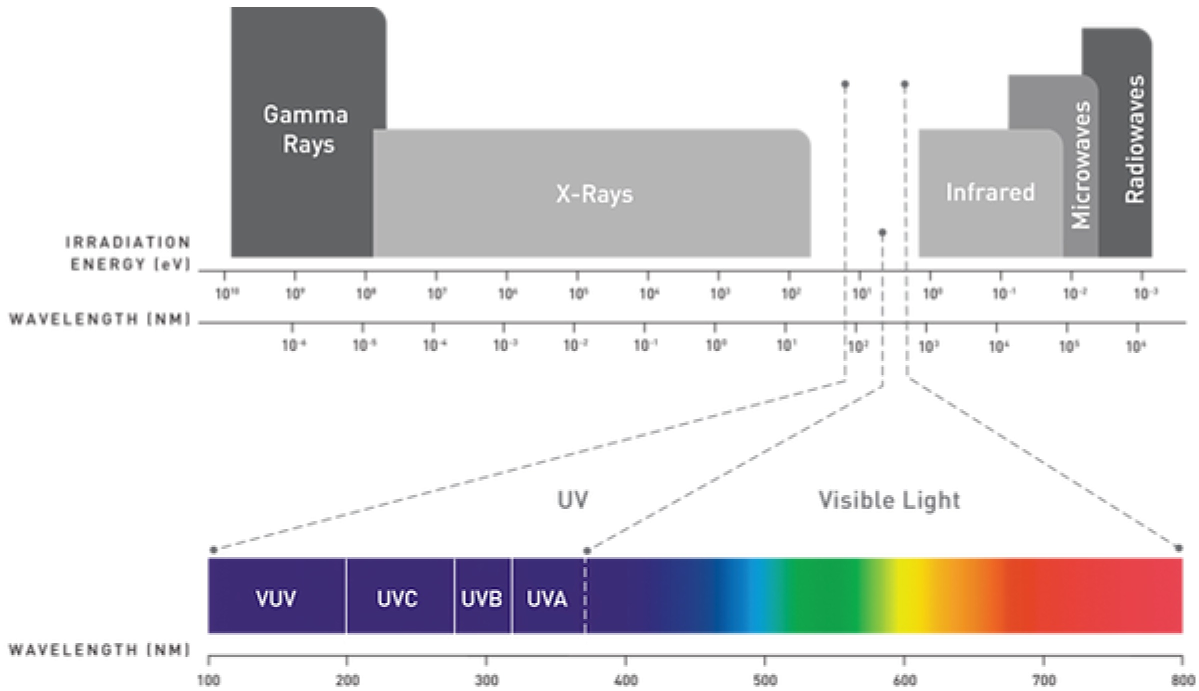
White Paper – UV in Plant Photobiology

Introduction

Before we start, it is imperative to understand that all measurements need to be made with a suitable spectrometer or spectroradiometer. One cannot and should not rely on manufacturers' specs. It is important to look at the spectral power distribution (SPD) which tells you much more about light quality than any single parameter. Measurements should be taken at the canopy. Software or smart device apps are critical in analyzing data for decision making. In all our visible tests we use the Asensetek Lighting Passport spectrometer (www.lighting passport.com) together with their Spectrum Genius Agricultural Lighting app (SGAL). For UV measurements we use the SRI2000-UV from Allied Scientific Pro (www.alliedscientificpro.com).



Plants grown outdoors get a fair amount of UV-A and UV-B, typically in a ratio that is around 5% UV-B and 95% UV-A. Plants have evolved over millennia to adapt to this and survive.

Sunlight includes infrared, visible, and ultraviolet (UV) light. We are familiar with the fact that UV causes sunburn in humans, but how does it affect plants? UV radiation can be both beneficial and harmful to plants as modern research has shown. There are conflicting theories regarding the role of UV in plant photobiology and much more serious research is required.

UV radiation can be broken down into three bands:

- UV-A (320-380 nm)
- UV-B (290-320 nm)
- UV-C (10-200 nm and 200-290 nm)

UV-C radiation within the band from 10-200 nm may be referred to as vacuum or extreme UV. Only UV-A and UV-B rays penetrate the earth’s atmosphere and reach the earth’s surface.

Leaves of outdoor crops are exposed to sunlight which is the energy source for photosynthesis and other photobiological processes. The UV portion causes stress resulting in chemical processes much like sunblock to prevent harmful effects. This process is known as photomorphogenesis.

Photoreceptors like phytochromes mediate many aspects of vegetative and reproductive development and are responsible for absorbing UV, blue, red and far-red light. Cryptochromes, phototropins, and Zeitlupe (ZTL) are the three primary photoreceptors that mediate the effects of UV-A. UV-B light is primarily mediated by the UV-R8 monomer.

Much more research needs to be done on ultraviolet radiation and current research can be controversial and inconclusive. It has been postulated that UV light influences photomorphogenic responses including gene regulation, flavonoid biosynthesis, leaf and epidermal cell expansion, stomatal density, stress and increased photosynthetic efficiency. But it is important to remember that UV radiation can damage membranes, DNA, and proteins. Dose, wavelengths and photoperiod need to be optimized for each plant species as their photoreceptors process UV radiation differently. A wide range of studies have indicated that ultraviolet light is essential for the production of human phytonutrients in plants. Other studies show little or no benefit. UV can trigger plants to undergo photomorphogenic changes which increase the synthesis of phenolic compounds such as flavonoids that absorb solar UV radiation and protect plants from UV damage by removing damaging oxidants and free radicals. Increased phenolics may further retard the systemic growth of microorganisms. UV may also induce the synthesis of specific proteins involved in resistance to microbial attack (Charles et al., 2010). It is interesting to note that these flavonoids are said to improve taste without increasing nutritional value. If we use UV radiation correctly, we can enjoy the delicious benefits of plant sunscreen. This means your flowers will smell better, your fruit will taste superior, and your herbs will have a higher potency.

Although the study of UV’s effects on plants is a fairly recent field of botanical science, there are reports of dramatic increases in essential oil production by flowering crops grown under light sources with higher UV output. High UV Light sources are generally recommended for use in the last two weeks of a flowering cycle once the generative development is completely established. This allows for a crop to continually develop in size and growth vigor while also protecting the flowers and canopy with increased resin production.

Like all aspects of horticulture, balance is the key to effective UV use. Too much or incorrect ratios of VIS/UV-A/UV-B will not help, but the correct amounts could encourage some incredibly useful results.

Timing is also an important part of UV application. When given UV-B throughout the entire growth cycle, sensitive plants such as leafy greens often display reduced growth (plant height, dry weight, leaf area, etc.) and photosynthetic activity.

Generally, the effectiveness of UV-B also varies both among species and among individual strains or genetics of a given species. If you're looking to utilize UV in your indoor/greenhouse grow, it's worth discussing with a professional horticulturalist about the best approach for your chosen plant species whilst catering to your specific plant's physiological requirements.

Post-harvest food treatment with UV may maintain phytonutrient preservation in vegetables and fruits that have already been harvested and stored at low temperature. Some contend that UV treatment after harvest can boost nutritional values but more research is needed to substantiate this claim.

Most of the work on produce preservation has been with the UV-C waveband using germicidal lamps that can kill deleterious microorganisms on or near the surface of plants thereby prolonging freshness. Increased phenolics may then retard the systemic growth of microorganisms and may also induce the synthesis of specific proteins involved in resistance to microbial attack (Charles et al., 2010).

UV-A pre-exposure was found to impede UV-B-induced accumulation of some flavonoids. The photobiological nature of these UV-A mediated effects on flavonoid accumulation implies complex interactions between UV-A and UV-B responses.

Some studies have indicated a 24% increase in net photosynthesis when reducing the UV-B irradiance in certain species which indicates a clear UV-B avoidance response. Such species are affected negatively by ambient UV-B levels.

Tomatoes:
Following UV-A treatments, tomato seedlings became more compact, growth of plant organs was balanced, leaf area was increased, and the total plant fresh and dry weights were enhanced. Our findings suggested that the 376 nm UV-A from LEDs had a beneficial effect on the growth and development of tomato seedlings. Similar results were observed using blue light. This begs the question if UV-A is necessary or if blue light is sufficient.
Tomatoes grown out-of-season in greenhouses did not receive adequate ultraviolet light. Tomatoes supplemented with UV-A and UV-B light were not rated as well as those supplemented with UV-A light alone. The molecular reasons for this are unclear, but it is likely that UV-A and UV-B radiation trigger different kinds of metabolic pathways.

Disappointingly, there was no evidence that UV light supplementation enhanced nutritional value of greenhouse tomatoes. But at least they taste better!

Strawberries:
UV-C treatment after harvesting is effective in killing pathogens and molds in strawberries when followed by a dark period. Mold growth in UV-treated berries was retarded even on surfaces not directly exposed to UV-C suggesting UV may have induced systemic increases in resistance in strawberry tissue. Effects were observed not only with treatment close to the maximum UV-C for microbial killing, but also using UV-B as supplemental lighting.

Peas and Wheat
Plants grown under ambient UV-B radiation were compared with those grown without UV-B. The results indicate increased shoot length, leaf area, dry matter accumulation, leaf area ratio and specific leaf weight in plants of both the crops grown without UV-B compared with those grown under ambient UV-B. The effect of UV-B exclusion was clearer in pea compared with that in wheat. Similarly, the rate of photosynthesis (measured as CO_2 exchange rate), chlorophyll content, nitrate reductase (NR) enzyme activity and sugar content were significantly higher in pea plants grown without UV-B radiation, while changes in wheat plants were marginal and insignificant. We conclude that monocot species may be less sensitive to increased solar UV-B due to ozone depletion compared with dicots.
Tests showed that increasing UV-B radiation dose and exposure, led to decreased pigment.

Shoot height, shoot dry mass and leaf area decreased after exposure to UV-B radiation. There were no observable or measured benefits associated with UB-B supplementation, whereas adverse effects were patently evident.

Cannabis
When we talk about ultraviolet radiation and increased potency in cannabis, we are singularly talking about THC (Tetrahydrocannabinol) production. The effect of UV on the other 84+ cannabinoids isn't fully known, nor has it been studied in detail. One would assume that if you increase the amount of THC, you are probably lowering the amount of other cannabinoids (in particular, CBD or Cannabidiol), but this is just conjecture and the anecdotal evidence is conflicting. Growers who are trying to produce marijuana that is moderate or low in THC but high in CBD would actually want to avoid ultraviolet, which explains why it is usually grown in greenhouses (whose glass filters out all of the UV-B and most of the UV-A). Most growers, however, are wanting to grow cannabis that is high in THC, whether it is for medicinal or recreational use.
THC has very high UV-B absorption rate which protects the plant from dangerous radiation from the sun, much like sunblock, and ensures life for future generations. UV exposure two weeks before harvest causes the plant to produce more THC.

When growing cannabis indoors or in greenhouses we did remove many dangers such as excessive wind, soaking rains, animals, pests, most insects and more, but we also limited the plant’s exposure to UV radiation. Yields increased significantly. Plants grow well, are large, thick, robust and more potent, but they are far below their potential for THC production because of the lack of UV. Without the stress of UV, they have no need to shift resources into producing higher levels of THC.

When the proper spectrum of UV is introduced to the plant it is forced to shift its resources into protecting itself by spending a little less time growing sun leaves, sugar leaves and even buds may be more dense and just a hair smaller, but it will produce a lot more THC. Since THC is the ultimate goal, the market potential is significantly higher for plants grown with proper UV.

Using proper UV most cannabis cultivators are able to get increases of 10% or 20% in THC. Some more experienced growers may see THC yields increase by over 30%.

The key is giving indoor/greenhouse grown marijuana plants a balanced dose of UV in the right wavelengths. This means UV light on each and every bud, at least every other day. Typically, you would run the UV lights for around 12 hours a day as soon as the plants enter flowering mode.

The major impact seems to come from UV-B radiation between 280-315nm which induces stress in cannabis and leads to significantly greater quantities of THC being produced. UV-A appears to be additionally beneficial. While UV-A does not stimulate THC production, it penetrates more deeply than UV-B and may stimulate trichome production which facilitates the production of THC.

Some researchers posit that increased THC due to UV-B exposure is neither myth nor magic but rather a natural reproductive response. Their view is that there is no need to expose plants through vedge or even all the way through bloom. Instead exposure of medical marijuana plants to UV-A and B during the last 2 weeks before harvest at 12 hours continuous per day is the optimal regimen. Others are of the opinion that UV strengthens seedlings and clones and should be applied throughout the growth cycle.

How does this work? THC is the best natural sunblock for UV radiation. Cannabis produces more and more THC to protect itself from UV exposure and damage. So to compensate for high UV-A/UV-B light spectrum exposure, the marijuana plant produces more THC.

Powdery mildew is caused by poor air quality control and is usually contracted through aerial contamination. It is critical that outside air is filtered. When growing in organic soil it is possible to contract any number of pests, diseases or viruses. Many of them are present at all times on plants and in grow media just like many bacteria, molds, fungi and viruses exist in the human body but never manifest in full blown diseases. Poor air quality control provides the circumstances for powdery mildew to flourish, and once it starts it is nigh impossible to eliminate. UV radiation can be used in air handlers to eliminate powdery mildew.

Pate (1983) reported that cannabis exposed to high levels of UV-B resulted in little or no increase in cannabidiol (CBD) but high levels of A'-tetrahydrocannabinol (Ay-THC), while the opposite was true for low UV-B exposure. Their research showed cannabis is physiologically and morphologically insensitive to UV-B radiation during vegetative growth and should not be applied until two weeks before harvest.

Take the guesswork out of horticultural grow lights and UV supplemental lighting by using a functional spectrometer like the Asensetek Lighting Passport for conventional agricultural lighting and the Allied Scientific Pro SRI2000-UV for ultraviolet horticultural radiation. The simple graphic user interface (GUI) makes both instruments user friendly and absolutely necessary for serious lighting professionals.

References

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