Long-Term Effects of Short-Term Ultraviolet Light Exposure On Greenhouse Seedlings

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INTRODUCTION

Only about 6% of radiation from the sun is in the ultraviolet (UV) range. In greenhouse production, UV-B is eliminated and UV-A (315-400 nm waveband) is reduced. UV light in the 280-315 nm waveband (UV-B) is a documented stressor of plants. UV stress response includes darker, thicker leaves, increased secondary metabolite production, and plant stunting. We sought to determine if short-term doses of UV-A + UV-B on seedlings have a predictable long-term response in altering plant growth and form. Based on these results, we believe brief intense doses of UV-A + UV-B lead to immediate changes in plant growth and function, but the effects are largely reversible after several weeks which may have potential in modifying plant growth in greenhouse production.

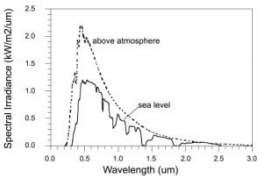

Figure 1. Radiation from the sun above and below the earth's atmosphere (adapted from Wikipedia). Only ~6% of the surface radiation is in the ultraviolet (UV) range, with most of that in the less damaging UV-A range (0.315 to 0.4 µm).

MATERIALS AND METHODS

Plant Material: Lettuce 'Galactic', Pansy 'Mammoth Deep Blue Dazzle', radish 'Cherry Belle', and spinach 'Baby's Leaf Hybrid' were seeded into soilless plug trays and germinated in growth chambers.

UV Treatments: When seedlings had 2-3 true leaves, they were subjected to broadband UV treatments (peak wavelengths between 290 and 330 nm). Treatments consisted of three distances (0, 5 and 10 cm away from the top of the meristem to the broadband UV light source) and four durations of light exposure (0, 30, and 60 and 120 min), to create seven total UV doses (0.0, 40.8, 47.6, 81.6, 95.2, 163.2 and 190.5 kJ), each with four replications. The light source consisted of two short compact broadband UV fluorescent light bulbs (Philips PL-L36W/12, Royal Philips Electronics, Amsterdam, the Netherlands) in a hand-held home eczema device (Solarc/SolRx 100 Series, Solarc Systems Inc, Minesing, Ontario, Canada). Between the lights and the plants was a layer of acrylic (3 mm thickness). In the UV treatments, the acrylic was OP-4 (Acrylite, Evonik Cryo LLC., Parsippany, NJ, USA) which transmits UV wavelengths down to 275 nm. Plain acrylic (Optix by Plaskolite, Inc., Columbus, OH, USA), which does not transmit wavelengths below 370 nm, was used as a control. Light was quantified using a spectroradiometer (PS-200 Apogee Instruments Inc., Logan, UT, USA).

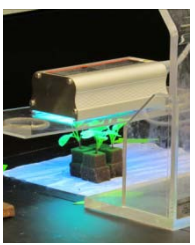

Figure 2. Broad-spectrum ultraviolet (UV) lamp providing radiation treatment to radish seedlings. About half the radiation from this lamp is in the UV-A range (0.315 to 0.4 µm), with the other half in the UV-B range. During treatments, lamp was supported by a UV-transmitting plastic to maintain distance from the seedlings. Up to four seedlings were treated at once.

Growth Conditions: Directly after exposure to UV, seedlings were maintained in a greenhouse. Canopy cover and photosynthetic efficiency measurements were taken throughout the growth of the transplants to characterize growth rates and photosynthetic damage between treatments. Efficiency of photosynthetic electron transport of photosystem II (Fv'/Fm') was measured using a portable fluorometer (OS1-FL Portable Modulated Chlorophyll Fluorometer, Opti-Sciences Hudson, NH, USA). Plant dry weights were taken at the termination of the experiment.

Statistical Analysis: ANOVA and Tukey's HSD analyses were performed using JMP 8 (SAS Institute Inc., Cary, NC, USA) with UV dose as the dependent variable and dry weight, canopy cover and leaf fluorescence as independent variables.

RESULTS

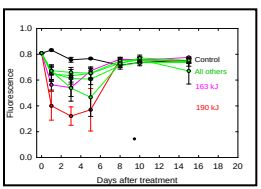

Figure 3. Efficiency of photosynthetic electron transport of photosystem II was measured immediately before (day 0) and immediately after ("day 1") ultraviolet (UV) treatment. In this example, radish plants immediately exhibited evidence of stress at higher dosage rates. After 1 week, photosynthetic potential completely recovered to control, unexposed levels.

Figure 4. Radish plants 3 weeks after exposure to ultraviolet (UV) radiation. In spite of evidence of photosynthetic recovery per leaf area (Fig. 3), leaf expansion was reduced as radiation doses increased. The smaller plants had smaller leaves, some of which were malformed or discolored (Fig. 5). There was greater variability in plant response as dosage increased. Other species (lettuce, pansy, and spinach) had similar patterns of leaf expansion, but different levels of sensitivity to the UV treatments.

Figure 5. A radish seedling a few days after ultraviolet (UV) exposure exhibits some leaf malformation and discoloration or bronzing in spots. These leaves had low fluorescence measurements (Fig. 3) for up to a week after exposure to UV, and never fully recovered compared to untreated leaves. Other species responded similarly.

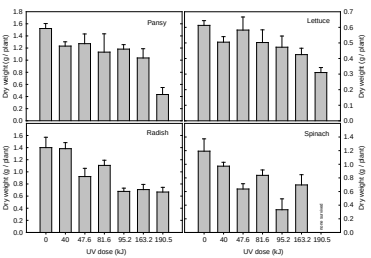

Figure 6. Final dry weights of pansy, lettuce, radish, and spinach 3 to 4 weeks after ultraviolet (UV) exposure. Generally, higher doses of UV resulted in smaller plants. Spinach was the most sensitive while lettuce was the least.

CONCLUSIONS

- General pattern similar across species, with rapid loss of Pn, stunting of leaves, leaf bronzing and smaller plants as UV dosage increased.
- Some differences in sensitivity to UV between species; lettuce was least sensitive and spinach was most sensitive.
- With high UV rates, there was more inconsistency and plant death.
- Some promise in UV as a growth regulator.
- Several, smaller doses vs. single larger dose may result in more controlled growth regulation.

ACKNOWLEDGEMENTS

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