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FINAL REPORT

BIOLOGICAL EFFECTS OF ULTRAVIOLET RADIATION ON PLANT
GROWTH AND DEVELOPMENT IN FLORIST AND NURSERY CROPS

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Biological Effects of Ultraviolet Radiation on Plant
Growth and Development in Florist and Nursery Crops

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Abstract. Under simulated UV-B enhancement conditions, florist and nursery plants were irradiated in a glass greenhouse using Westinghouse FS-40^{2/} fluorescent sunlamps filtered with 5 mil cellulose acetate filters for 6 hours (10:00 a.m.-4:00 p.m.) each day for 2-12 weeks. A simulated sun curve and a computer-generated action spectrum were used to determine biologically effective dosage to provide a wide range of UV-B irradiances from 50-400% increase in biologically effective UV (4-13 weighted mWm^{-2}). Visible injury was noted in only 8 of 74 florist and nursery species. Leaves of 'C-I-White' and 'C-I-Red' poinsettia showed distortion, glazing and abnormal leaf curvature. Of all 16 Coleus cultivars, 'Glory of Luxemburg' was the most sensitive and 'Pineapple' the most resistant to 50% or greater increase in biologically effective UV exposure for 2 weeks. Breakdown in anthocyanin content was observed in 15 of the 16 cultivars, with leaf extracts and fresh leaves of 'Red Rainbow' showing a large increase in absorbance at 285 nm. Aster, Hollyhock, Impatiens and Vinca plants irradiated for 4 weeks developed slight chlorosis (degradation of chlorophyll). Stress response was noted in all 6 Browallia species and cultivars. None of the 12 shrub or 6 tree species irradiated showed any sign of stress response to 12 weeks of UV-B.

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Biological effects of UV-A (320-400 nm) and UV-C (less than 280 nm) radiation in plants are well documented (2, 5, 6). A great variety of physiological and morphological plant responses to UV radiation has been demonstrated over the past 75 years. However, most of these experiments have employed ultraviolet lamps which emit radiation unlike the radiation present in the normal terrestrial solar spectrum (3, 4).

The effects of UV-B (280-320 nm) radiation on man have been studied extensively but relatively little is known of the effects of UV-B radiation on growth and development of plants (1, 2, 6). The impact of low levels of UV-B radiation on plant growth and development is largely unknown since most UV-B studies were conducted with lamps that emitted both UV-B and UV-C.

Previous biological studies in the UV-B region were greatly limited by a lack of suitable monitoring equipment and inadequate narrow and broadband radiation sources. Under the auspices of the Environmental Protection Agency (EPA) interagency program on Biological and Climatic Effects Research (BACER), the USDA Agricultural Equipment Laboratory (8) and the Instrumentation Research Laboratory of Beltsville developed improved experimental facilities for irradiating, measuring and monitoring UV-B radiation. My objective was to identify, through a screening program, species and cultivars of economically important florist and nursery plants that are sensitive or resistant to UV-B radiation under glass greenhouse conditions, utilizing standardized techniques and improved instrumentation.

Observations were made on the extent of visual injury, change in pigmentation, leaf abscission, glazing, bronzing, chlorosis and other plant stress responses.

Materials and Methods

Experimental facilities for UV-B irradiation were developed in cooperation with the Beltsville Agricultural Equipment Laboratory and the Instrumentation Research Laboratory. The former developed the lamp configuration, weighting functions and irradiance levels at selected locations; the latter developed the instrumentation (spectroradiometer) for measuring and monitoring UV-B radiation.

Westinghouse FS-40 fluorescent sunlamps were used in conjunction with appropriate plastic filters to provide increased levels of UV-B irradiation. Under simulated UV-B enhancement conditions, florist and nursery plants were irradiated in the greenhouse under 5 mil cellulose acetate (UV-A & B) or 5 mil Mylar (UV-A only) for 6 hours continuously each day for 2-12 weeks about solar noon (10:00 a.m.-4:00 p.m.). Minimum night temperature was kept about 17° C and day temperatures did not exceed 24°.

The standard protocol established was for FS-40 sunlamps to be aged 100 hours before use; cellulose acetate (CA) filters presolarized for 6 hours; filters changed twice weekly; and lamp height adjusted with each filter change to maintain UV levels. Plants were irradiated under 4 fixtures, each containing 2 FS-40 sunlamps spaced 30 cm apart and 82 cm above plants. A simulated sun curve and a computer-generated action spectrum were used to determine biologically effective UV-B dosage. Experimental plants were placed in selected locations to provide a wide range of UV-B irradiances from 50-400% increase in biologically effective UV (4-13 weighted mWm^{-2}). Irradiance levels were verified at the beginning and end of experiments by measuring with an Optronic Laboratories Inc., Model 725 UV-B Radiometer^{2/}.

Results and Discussion

A list of plants tested for the relative sensitivity or resistance to enhanced UV-B radiation in glass greenhouse is shown in Table 1. Visible injury was noted in only 8 of 74 florist and nursery species (Table 2). The remaining 66 species examined were found to tolerate an increase in biologically effective levels of UV from 50-400%. The most common plant response to high levels of UV-B irradiation (100% or greater increase in biologically effective UV under FS-40 sunlamps filtered with 5 mil CA) was breakdown of anthocyanins and chlorophyll, or more commonly, a glazing and bronzing of the tissue which is generally attributed to the presence of oxidized, polymerized, phenolic compounds. This bronzing or darkening phenomenon serves as a convenient indicator of UV absorption and damage. Visible lesions, loss of chlorophyll and reduction or increase in pigmentation were not immediate but rather appeared slowly as reflections of disturbance in the basic metabolic process. The stress responses did not develop until 3-4 days after beginning UV exposure.

'C-I-White' and 'C-I-Red' poinsettia plants were particularly sensitive to UV-B radiation and showed glazing, distortion and abnormal leaf curvature that increased in severity with increased UV-B levels. Under high levels of UV-B irradiation (100% or greater increase in biologically effective UV), leaves of 'Supreme Annette Hegg' poinsettia formed purplish-red anthocyanins, a typical stress response. It is possible that 'Supreme Annette Hegg' has the capacity to prevent damage to sensitive tissue from UV-B radiation by producing materials in epidermal cells that absorb the radiation. Flavonoids have been shown to absorb effectively in the UV-B

radiation region (7). Since anthocyanins were identified in the epidermal cells of poinsettias, it seems likely that these compounds serve to protect the inner cells of the leaves against further ultraviolet damage.

'Pineapple' was the only one of 16 *Coleus* cultivars that showed no visible pigment changes when exposed to artificially enhanced UV-B irradiation.

Of the 16 cultivars, 'Glory of Luxemburg' was the most sensitive. It was the only one that showed a slight loss of anthocyanin pigmentation at 50% increase in biologically effective UV.

The remaining 14 cultivars of *Coleus* required at least 100% increase in biologically effective UV before showing visible pigment breakdown.

Exposure of *Coleus blumei* 'Red Rainbow' for 2 weeks to enhanced UV-B radiation at ca 100% in biologically effective UV produced no significant effect on dry matter accumulation, fresh weight, leaf area, or plant height; however, the red pigment in young leaves was greatly reduced. A small change in degradation of the anthocyanin pigment was evident after 6 hours of exposure. This change was intensified with increased exposure up to 24 hours (4-6 hr UV-B radiation). Both leaf extracts and fresh leaves showed a large increase in absorbance at 285 nm.

Visible breakdown in anthocyanin content was also observed in 13 of the other 14 cultivars exposed to 50% or greater increase in biologically effective UV for 2 weeks. This decrease in the anthocyanin content of *Coleus* leaves suggests the usefulness of these plants as indicators of UV-B damage.

Aster, Hollyhock, Impatiens and Vinca plants irradiated for 4 weeks showed only a subtle UV stress response that was characterized by chlorosis (degradation of chlorophyll). The injurious effects of UV-B radiation were soon masked by the growth of new leaves which emerged from the terminal and lateral buds following the cessation of UV exposure. The length of time necessary for this regrowth was dependent upon the degree of injury.

Fatsia japonica was the only one of the 19 tender perennial species in which plant growth was slightly inhibited by 100% or greater biologically effective UV. None of the 12 shrubs or 6 tree species irradiated showed any sign of stress response to ultraviolet radiation after 12 weeks of exposure.

Stress response to enhanced UV-B was noted in all 6 Browallia species and cultivars after 4 weeks of irradiation. Leaves of Browallia 'Vanja', 'Ultra', 'Panama', 'Blue Bells Improved', and 'Blue Troll' were smaller, twisted and distorted. The only sign of stress in Browallia viscosa 'Sapphire' was the formation of purplish pigment in normally young green flower buds.

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Table 1. Relative sensitivity and type of injury of selected species and cultivars of florist and nursery plants in response to enhanced UV-B irradiance.

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	<u>Type of Plant</u> ^{1/}	<u>UV-B Sensitivity</u> ^{2/}	<u>Type of Injury</u> ^{3/}
African Violet	<u>Saintpaulia ionantha</u> Wendl.			
Blue Fairy Tale		TP	IS	
Ballet		TP	IS	
Ageratum	<u>Ageratum</u> <u>houstonianum</u> Mill.			
Biscaya		A	IS	
North Star		A	IS	
Blue Blazer		A	IS	
Atlantic		A	IS	
Aglaonema	<u>Aglaonema commutatum</u> Schott	TP	IS	
Althaea	<u>Hibiscus syriacus</u> L.	A	IS	
Alyssum	<u>Lobularia maritima</u> (L.) Desv.			
Carpet of Snow		A	IS	
Amaranthus	<u>Amaranthus</u> <u>tricolor</u> L.			
Molten Fire		A	IS	
Red Leaf		A	IS	
Aphelandra	<u>Aphelandra</u> <u>squarrosa</u> Nees	TP	IS	
Aster	<u>Aster alpinus</u> L.			
Totem Pole		A	S-1	C

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- ^{2/} tivity ^{2/}	Type of Injury ^{3/}
Arborvitae	<u>Thuja occidentalis</u> L.			
Globosa		S	IS	
Pensa		S	IS	
Pyramide		S	IS	
Rheindiana		S	IS	
Balsam Fir	<u>Abies balsamea</u> (L.) Mill.	T	IS	
Basil Red Leaf	<u>Ocimum basilicum</u> L.	TP	IS	
Begonia, tuberous rooted	<u>Begonia x tuberhybrida</u> Voss	TP	IS	
double-mix		TP	IS	
Begonia Roulette	<u>Begonia rex</u> Putz.	TP	IS	
Browallia	<u>Browallia viscosa</u> HBK			
Sapphire		A	S-1	PE
Browallia	<u>Browallia speciosa</u> Hook.			
Blue Bells		TP	S-1	D, T
Blue Troll		TP	S-1	D, T
Ultra		TP	S-1	D, T
Vanja		TP	S-1	D, T
Panama		TP	S-1	D, T
Boxwood	<u>Buxus microphylla</u> Siebold & Zucc.			
Jap. Green Beauty		S	IS	
Mic. Green Velvet		S	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- tivity ^{2/}	Type of Injury ^{3/}
Caladium candidum	<u>Caladium</u> x <u>hortulanum</u> Birdsey	TP	IS	
Calendula Fiesta	<u>Calendula</u> <u>officin-</u> <u>alis</u> L.	A	IS	
Camellia sasanqua	<u>Camellia</u> <u>sasanqua</u> Thunb.	S	IS	
Showa		S	IS	
Camellia Showa	<u>Camellia</u> <u>japonica</u> L.	S	IS	
Canna Ambassador	<u>Canna</u> x <u>generalis</u> L. H. Bailey	TP	IS	
Chinese Chestnut	<u>Castanea</u> <u>mollissima</u> Blume	T	IS	
Christmas Pepper	<u>Capsicum</u> <u>annuum</u> L.	A	IS	
Chrysanthemum	<u>Chrysanthemum</u> <u>mori-</u> <u>folium</u> Ramat.	P	IS	
Classic		P	IS	
Elegant		P	IS	
Fred Shoemith		P	IS	
Flaming Sun		P	IS	
Goldtone		P	IS	
Iceberg		P	IS	
Imp. Ind. White		P	IS	
Jackpot		P	IS	
Minn. Autumn		P	IS	
Pancho		P	IS	
Penguin		P	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- tivity ^{2/}	Type of Injury ^{3/}
Shoesmith		P	IS	
Sunburst		P	IS	
Superchief		P	IS	
Tinkerbelle		P	IS	
Coleus	<u>Coleus blumei</u> Benth.			
Pink Rainbow		A	S-1	PL, D, T
Red Rainbow		A	S-1	PL, D, T
Aetna		A	S-1	PL, D
Campfire		A	S-1	PL, D
Carefree Red		A	S-1	PL, D
Freckles		A	S-1	PL, D
Fredericci		A	S-1	PL, D
Glory of Luxemburg		A	S-2	PL, D
Harlequin		A	S-1	PL, D
Marty		A	S-1	PL, D
Pineapple		A	IS	
Saber Jade		A	S-1	PL, D
Saber Golden		A	S-1	PL, D
Saber Pink Dragon		A	S-1	PL, D
Saber Velvet		A	S-1	PL, D
Saber Jade Pastel		A	S-1	PL, D
Col. Blue Spruce	<u>Picea pungens</u> Engelm.	T	IS	
Cone Flower	<u>Rudbeckia hirta</u> L.	A	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- ^{2/} tivity ⁻	Type of Injury ^{3/}
Grape Myrtle	<u>Lagerstroemia</u> <u>indica</u> L.	S	IS	
Dusty Miller	<u>Centaurea</u> <u>maritima</u> Dufour	A	IS	
Exacum Affine	<u>Exacum</u> <u>affine</u> Balf. f.			
Richly Frag.		A	IS	
Blythe Spirit		A	IS	
Midget		A	IS	
False Aralia	<u>Dizygotheca</u> <u>elegantis-</u> <u>sima</u> (Hort. Veitch) R. Vig. & Guillaum.	TP	IS	
False Cypress	<u>Chamaecyparis</u> <u>pisi-</u> <u>fera</u> (Siebold & Zucc.) Endl. ' <u>Cyanoviridis</u> '	S	IS	
Fatsia	<u>Fatsia</u> <u>japonica</u> (Thunb.) Decne. & Planch.	TP	S-1	G
Geranium	<u>Pelargonium</u> x <u>hortorum</u> L. H. Bailey			
Carefree White		A	IS	
Scarlet Sprinter		A	IS	
Glory Bush	<u>Tibouchina</u> <u>urvilleana</u> (DC.) Cogn.	TP	IS	
Glory Lilly	<u>Gloriosa</u> <u>roths-</u> <u>childiana</u> O'Brien	TP	IS	
Gloxinia Emperor Wilhelm	<u>Sinningia</u> <u>speciosa</u> (Lodd.) Hiern	TP	IS	
Hens & Chickens	<u>Sempervivum</u> <u>tectorum</u> L.	P	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- tivity ^{2/}	Type of Injury ^{3/}
Heliotrope Marine	<u>Valeriana officinalis</u> L.	P	IS	
Holly	<u>Ilex crenata</u> Thunb.			
Glory		S	IS	
Golden Gem		S	IS	
Hollyhock	<u>Alcea rosea</u> L.	A	IS	
Majorette		A	IS	
Powderpuffs		A	S-1	C
Impatiens	<u>Impatiens wallerana</u> Hook. f.			
Aflame		A	IS	
Aloha		A	IS	
Futura Coral		A	IS	
Futura Pink		A	IS	
Futura Red		A	IS	
Futura White		A	IS	
HUC		A	IS	
White Imp		P	S-1	C
Juniper	<u>Juniperus chinensis</u> L.			
Glanca		S	IS	
Gold		S	IS	
Old Gold		S	IS	
Pftizer		S	IS	
Skyrocket		S	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- tivity ^{2/}	Type of Injury ^{3/}
Lantana	<u>Lantana montevidensis</u> (K. Spreng.) Briq.	TP	IS	
Larkspur Dk. Blue Supreme	<u>Delphinium exaltatum</u> Ait.	A	IS	
Leucothoe	<u>Leucothoe axillaris</u> (Lam.) D. Don	S	IS	
Marigold Bolero	<u>Tagetes patula</u> L.	A	IS	
Cracker Jack	<u>Tagetes erecta</u> L.	A	IS	
Dwarf French Dlb.	<u>Tagetes patula</u> L.	A	IS	
Early Gigantic	<u>Tagetes erecta</u> L.	A	IS	
First Lady	<u>Tagetes erecta</u> L.	A	IS	
Gold Rush	<u>Tagetes erecta</u> L.	A	IS	
Hawaii	<u>Tagetes erecta</u> L.	A	IS	
Honeybee	<u>Tagetes patula</u> L.	A	IS	
Orange Sherbet	<u>Tagetes patula</u> L.	A	IS	
Petite Gold	<u>Tagetes patula</u> L.	A	IS	
Petite Yellow	<u>Tagetes patula</u> L.	A	IS	
Spun Gold	<u>Tagetes patula</u> L.	A	IS	
Norway Spruce	<u>Picea albies</u> (L.) Karst.	T	IS	
Pansy Goldsmith Grant	<u>Viola x wittrockiana</u> Gams	A	IS	
Peperomia	<u>Peperomia obtusifolia</u> (L.) A. Dietr.	TP	IS	
Periwinkle	<u>Vinca minor</u> L.	P	S-1	C

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	<u>Type of Plant</u> ^{1/}	<u>UV-B Sensitivity</u> ^{2/}	<u>Type of Injury</u> ^{3/}
Petunia	<u>Petunia x hybrida</u> Vilm.			
All Star		A	IS	
Commanche		A	IS	
Pink Cascade		A	IS	
Pink Magic		A	IS	
Plum Pink		A	IS	
Silver Magic		A	IS	
Sugar Daddy		A	IS	
Sugar Plum		A	IS	
Pieris	<u>Pieris japonica</u> (Thunb.) D. Don ex G. Don	S	IS	
Plantain Lily	<u>Hosta sieboldii</u> (Paxt.) J. Ingram	P	IS	
Poinsettia	<u>Euphorbia pulcherrima</u> Willd ex Klotzsch			
Annette Hegg		TP	IS	
C-I-Red		TP	S-2	D, G
C-I-White		TP	S-2	D, G
Prof. Laurie		TP	IS	
Super Star		TP	IS	
Supreme Annette Hegg		TP	S-1	PE
V-10 (Amy)		TP	IS	
White Annette Hegg		TP	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	Type of Plant ^{1/}	UV-B Sensi- tivity ^{2/}	Type of Injury ^{3/}
Portulaca, yellow	<u>Portulaca grandiflora</u> Hook.	A	IS	
Primrose	<u>Primula obconica</u> Hance	P	IS	
Red Improved Rose	<u>Rosa x hybrida</u>	S	IS	
Red Scarlet Maple	<u>Acer rubrum</u> L.	T	IS	
Rex Begonia	<u>Begonia x rex-cultorum</u> L. H. Bailey	TP	IS	
Salpiglossis Emperor	<u>Salpiglossis sinuata</u> Ruiz & Pav.	A	IS	
Salvia	<u>Salvia splendens</u> Sello ex R. & S.			
Rodeo		A	IS	
St. John's Fire		A	IS	
Schefflera compacta	<u>Brassaia actinophylla</u> Endl.	TP	IS	
Snapdragon	<u>Antirrhinum majus</u> L.			
Biocolor Majus Tet		A	IS	
Potomac White		A	IS	
Rocket White		A	IS	
Rose Pixie		A	IS	
Spider Flower	<u>Cleome speciosa</u> Raf.	A	IS	
Stokes Aster	<u>Stokesia laevis</u> (J. Hill) Greene	P	IS	
Taxus	<u>Taxus cuspidata</u> Siebold & Zucc.	S	IS	
Densa		S	IS	

<u>Common Name and Cultivar</u>	<u>Genus and Species</u>	<u>Type of Plant</u> ^{1/}	<u>UV-B Sensitivity</u> ^{2/}	<u>Type of Injury</u> ^{3/}
Intermedia		S	IS	
Media Brownii		S	IS	
Media Kelsey		S	IS	
Torenia	<u>Torenia fournieri</u> Linden ex E. Fowin.	A	IS	
Verbena Springtime	<u>Verbena</u> x <u>hybrida</u> Voss	A	IS	
Veronica	<u>Hebe buxifolia</u> (Benth.) Cockayne & Allan	P	IS	
Vinca Trailing Variegata	<u>Vinca major</u> L.	P	IS	
Zinnia	<u>Zinnia elegans</u> Jacq.			
Carved Ivory		A	IS	
Goddess		A	IS	
Isabelina		A	IS	
Peter Pan Pink		A	IS	
White Dogwood	<u>Cornus florida</u> L.	T	IS	

^{1/} A = annual; P = perennial; TP = tender perennial; S = shrub; T = tree.

^{2/} As indicated by plant expression: S = sensitive to either 100% (S-1) or 50% (S-2) increase in biologically effective UV; IS = insensitive.

^{3/} Visual injury to leaf: C = chlorosis; D = distortion; G = glazing; PL = pigment loss; PE = pigment enhancement; T = twisted.

Table 2. Relative sensitivity of 74 species of florist and nursery plants in response to enhanced UV-B irradiance.

	<u>Annuals</u>	<u>Perennials</u>	<u>Shrubs</u>	<u>Trees</u>
<u>Number Irradiated</u>	27 ^{1/}	29 ^{1/}	12	6
<u>Sensitive Plants</u>	Asters - S-1	Impatiens - S-1	None	None
	Browallia - S-1	Poinsettia - S-1, 2		
	Coleus - S-1, 2	Fatsia - S-1		
	Hollyhock - S-1	Vinca - S-1

^{1/}
S-1 = Sensitive to 100% or greater increase in biologically effective UV.

S-2 = Sensitive to 50% or greater increase in biologically effective UV.

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