Effects of Near Ultraviolet and Green Radiations on Plant Growth [1, 2]

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In an earlier paper, Klein (7) reported that the growth of nonphytosynthetic plant tissue cultures was reversibly repressed by near-ultraviolet (near-UV) and green radiations. The present paper reports our studies on the effects of these wavelengths on the growth and respiration of higher plants, on algae, and on a fungus.

Materials and Methods

Test Systems. Tagetes erecta L., Dwarf Pigmy French Marigold (Burpee 4166) was planted in soil in polyethylene boxes; radiation treatments were started immediately. *Impatiens Balsamina* L., Holsti Hybrid (Burpee 4107) and *Lycopersicon esculentum* Mill., Rutgers (Burpee 5061) were similarly grown; radiation treatments were started when the seedlings were 1 cm tall. One week after planting, the seedlings were thinned for uniformity. Day temperatures ranged from 23° to 26° and dark temperatures ranged from 19° to 23°. Experiments were terminated 1 month after planting. Experiments were repeated at least once.

Chlamydomonas reinhardti Dang. was grown in Trainor's I-N medium (19) at 20°, cells were washed 3 to 4 times in water and used to inoculate 10 ml of medium in 50 ml flasks. Five cultures for each variable were incubated on a rotary shaker at 100 cycles per minute for 96 hours at 20°. Cell density was measured in a Klett colorimeter with a green 54 filter.

Euglena gracilis bacillaris Klebs was shaken under white light at 20° as either a nongrowing culture in buffer (1) or as a growing culture in medium (9) and O_2 uptake measured manometrically at 30° in water 1, 2, and 3 days after inoculation. Other cultures were grown in darkness at 20° on a rotary shaker, the cells washed by centrifugation and then incubated in buffer or in medium for up to 72 hours in light. Chlorophylls and carotenoids were determined (18).

Sordaria fimicola Cesati and Notarius was grown in darkness at 25° in petri dishes containing Difco cornmeal agar plus 1 % glucose. Disks of agar and mycelium were removed with a no. 2 corkborer and 1 disk transferred to each racer tube (17) containing the same medium. Linear growth was measured daily for 7 to 9 days. Increase of weight of mycelium was measured in 50 ml of liquid medium (5) in 125 ml flasks inoculated with agar disks of mycelium. Six tubes or flasks were used for each variable.

Radiation Procedures. White light was supplied from banks of cool-white fluorescent and incandescent lamps in a 10:1 w ratio. Marigold plants received 1000 ft-c and the balsam and tomato plants received 500 ft-c, as measured with a Weston cosine-corrected illumination meter. The photoperiod was 15 hours for the higher plants and 24 hours for the microorganisms. Supplementary near-UV radiation was supplied from integral filter black-light fluorescent lamps emitting 70 % of their radiation between 355 and 380 mμ. Supplementary green radiation (530–585 mμ, peak at 565 mμ) was supplied from filtered green fluorescent lamps (8).

Near-UV radiations were completely removed from white light with plastic filter with a low wavelength cut-off at 385 mμ and 95 % transmission above 400 mμ (8). The green component of white light was reduced approximately 50 % with a Cinemoid no. 36 pale lavender plastic filter. Appropriate adjustment of plant to lamp distance was made to equalize total radiant energy in μw/cm^2 received by the plants (fig 1).

Results

Growth of Intact Higher Plants. Removal of all of the near-UV or half of the green radiation from white light increased the fresh and dry weight, height of the plants, and the lengths of the peduncle of marigold plants (fig 2a, table I). Peduncle weight and length were reduced when either near-UV or green wavelengths were filtered but were increased above control levels when both wavelengths were filtered. Tomato plants showed a similar response (fig 2b) as did corn and bean plants. Since marigold, tomato, and corn are semi-tropical, high-light requiring species, identical experiments were performed with *Impatiens,* a temperate zone, semi-shade plant. Selective removal of near-UV and/or green wavelengths from white light caused growth responses similar to those observed in marigold (fig 2c). Thus, monocot and dicot species from widely separated families are responsive to selective removal of these wavelengths.

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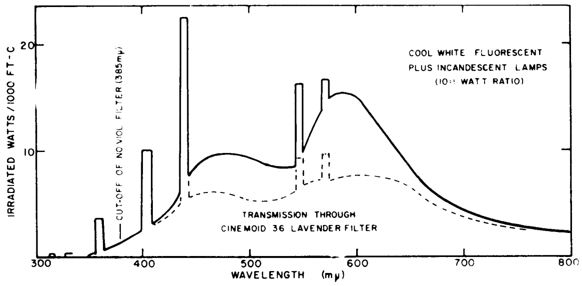

FIG. 1. Spectral energy distribution curves of light bank containing fluorescent and incandescent lamps with (dashed line) and without (solid line) plastic filters.

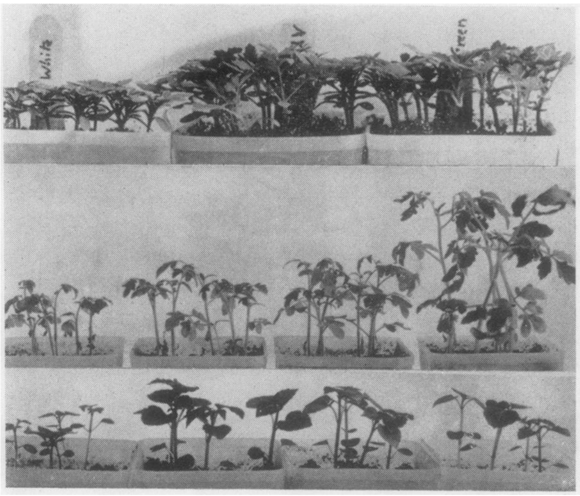

FIG. 2. Effects of selective removal from white light of near-UV and green wavelengths on growth of plants. A, marigold plants 21 days from seed showing (left to right) full white light, white light minus near-UV, and white light minus green component. B, tomato and C, *Impatiens* plants 21 days from seed showing (left to right) full white light, white light minus near-UV, white light minus green, and white light minus both near-UV and green components.

Addition of supplementary near-UV and/or green wavelengths to white light decreased the fresh weight of vegetative and reproductive structures of marigold plants but did not affect the dry weight or height of the plants (table I).

Growth of Chlamydomonas. Cell multiplication in this green alga was increased by selective removal of the near-UV component of 300 and 700 ft-c (but not 1500 ft-c) of white light, but selective reduction in the green component affected cell number only at 300 ft-c of white light (table II). The removal of both near-UV and green wavelengths was without effect.

Table II. *Effect of Removal of Near-UV or Green Wavelengths from White Light on the Growth of Cultures of* Chlamydomonas

Population density was measured with Klett colorimeter after 96 hours at 20°.

Ft-c white	Control	-UV	-G	-UV, -G
1500	190 ± 14	180 ± 16	210 ± 20	190 ± 12
700	313 ± 26	405 ± 30	311 ± 24	311 ± 27
300	150 ± 10	208 ± 16	183 ± 14	166 ± 11

Growth of Sordaria. Like some other fungi (4, 6, 23) *Sordaria* grew more rapidly in the presence than in the absence of white light and the light effect (found to be at nor near 420 mμ) was virtually independent of light intensity. Selective filtration of the near-UV or green wavelengths increased the linear extension of the mycelium but removal of both near-UV and green wavelengths was no more effective than removal of either near-UV or green light (table III). Dry weight of mycelium followed a similar but not identical pattern. In the absence of white light, near-UV and/or green radiations supplied at 100 μw/cm² was without effect on dry weight of liquid cultures, but near-UV plus green light repressed the linear extension of agar cultures.

Metabolic Studies. Although most studies indicate that light has little or no direct effect on respiration (16, 22), green radiations have been reported

Table I. *Effects of Near-UV (UV) and Green (G) Radiations on Growth of Marigold Plants*

Average data per plant of white light control are given as weights or lengths with standard errors; all other values are given as percentages of white light controls.

	White light control	White light minus: UV	White light minus: G	White light minus: UV + G	White light plus: UV	White light plus: G	White light plus: UV + G
Vegetative height (mm)	41.1 ± 3.7	141	156	144	97	80	89
Fr wt (g)	0.648 ± 0.057	142	126	123	73	61	69
Dry wt (g)	0.061	136	130	126	98	73	88
No. flower buds	20.0 ± 2.1	190	135	135	112	100	120
Length peduncle (mm)	13.0 ± 1.2	112	104	121	74	76	48
Fr wt peduncle (g)	0.058 ± 0.006	59	68	78	70	78	52
Dry wt peduncle (g)	0.005	77	52	127	58	64	39

Table III. *Effect of Removal of Near-UV (UV) or Green (G) Radiation from White Light on the Growth of* Sordaria

Linear extension was measured daily for 9 days on agar medium. Mycelial dry weight was determined after 10 days in liquid medium. Dark control linear extension = 12.5 ± 0.2 mm per day; dry weight = 132.9 mg.

Intensity (ft-c)	White	White -UV	White -G	White -UV -G
	Linear extension (mm/day)			
1500	17.7±0.2	21.5±0.4	18.2±0.1	21.5±0.3
700	17.6±0.4	17.7±0.6	18.0±0.4	18.0±0.8
300	16.2±0.4	15.9±0.1	15.8±0.9	15.8±0.5
	Dry wt (mg in 10 days)			
700	163.2	204.7	165.2	216.6

to suppress the respiration of yeast cells (12, 15), the cytochrome oxidase activity and oxidation of organic acids of cauliflower mitochondria (13) and the malonate sensitive respiration of *Euphorbia* bracts (14). The oxidation of marigold leaf tissues from plants grown under white light supplemented with near-UV or green radiations for 21 days did not differ from that from plants grown under white light. Neither filtration or the near-UV or green wavelengths from white lights nor supplementary near-UV or green radiations to white light had any effect on the endogenous O_2 uptake of stationary or growing cultures of *Euglena*. No changes were observed in the cytochrome oxidase activity of cauliflower mitochondria measured spectrophotometrically at 550 mμ when the mitochondria isolated by the method of Laties (11) were carefully washed to remove endogenous reducing compounds. Mitochondria isolated from bean stems, *Rumex* tissue cultures, and cauliflower buds were used for manometric succinoxidase measurements. Light did not cause any diminution in succinoxidase activity of washed mitochondria; reductions in activity were noted only in unwashed preparations (table IV). We conclude that the observed growth changes caused by near-UV and green light are unlikely to be due to alterations in energy metabolism as determined by O_2 uptake.

There was no repression in the rates of synthesis of chlorophylls or carotenoids by *Euglena* cells when the near-UV or green components of the white light were filtered or when the white light was supplemented with these radiations.

Discussion

Near-UV and green wavelengths are capable of suppressing the growth of plants which also receive adequate levels of those wavelengths necessary for photosynthesis and for normal development (10, 20). Vince et al. (21) obtained reductions in leaf number, internode length, and a delay in flower induction of carnation and lettuce when white light was supplemented with green wavelengths. We have also found that the growth of intact higher plants, a green alga, a fungus, and tissue cultures is promoted by selective removal of these wavelengths from white light. Boney and Corner (2, 3) stimulated the growth of sporelings of red algae by removing a fraction of the green component of white light, and similar observations have been made in our laboratory with a bacterium (H. H. Clum, unpublished). Although there is a pattern of similarity in the responses of these test systems, certain differences in detail have been found. In addition, some test systems do not respond to either removal or addition of near-UV or green wavelengths.

Our reported attempts to determine the reason for the observed growth effects are negative. Near-UV or green radiations do not appear to affect chlorophyll or carotenoid synthesis, respiration, or mitochondrial oxidations. Investigations of the mechanisms(s) are in progress.

Summary

Selective removal of near ultraviolet and green wavelengths from white light permitted enhanced growth of marigold, tomato, corn, and *Impatiens* plants, *Chlamydomonas* cells and the mycelium of *Sordaria*. Additions of near ultraviolet and green radiations caused repressions in the growth of marigold and *Sordaria*. These wavelengths do not alter the oxidative mechanisms of mitochondria, intact

Table IV. *Effect of Visible Radiation on the Oxidation of Succinate by Washed Cauliflower Mitochondria*

All radiations were filtered through water and $CuSO_4$ solutions. Phosphate buffer, 0.02 M; succinate, 0.6 M.

Expt	Light source	Spectrum	Total energy (mw/cm²)	O_2 uptake (μl/hr per vessel) Dark	Light
1–2	GE Quartzline	White	15	109	117
3	Quartzline + 550 mμ filter	530–585 mμ	9	148	146
4*	Philips HPL	550, 565	12	142	111
5–6	Philips HPL	550, 565	12	77	77

* Unwashed mitochondria.

algal cells or marigold leaf tissues. The capacity for chlorophyll and carotenoid synthesis by *Euglena* cells was unaffected by these wavelengths.

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