Changes in Growth and Yield of *Phaseolus mungo* L. Induced by UV-A and UV-B Enhanced Radiation

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We investigated the effects of UV-A and UV-B enhanced radiation on plants of *Phaseolus mungo*. Low doses caused varying responses in such growth and yield components as shoot and root lengths, leaf area, fresh mass and dry matter, pod numbers, and seed numbers and weights. Compared with the performances of the control plants, supplementation with UV-A radiation promoted overall growth, while UV-B radiation inhibited development. Moreover, both sources of radiation caused reduced yields, although this effect was comparatively less in plants treated with UV-A radiation.

Keywords: GA, growth, IAA, *Phaseolus mungo*, UV-A, UV-B, yield

The ongoing depletion in stratospheric ozone and a concomitant increase in the level of UV-B radiation (285 - 315 nm) reaching the earths surface has prompted much research into the possible effects of this surplus radiation on plant growth (Müller et al., 1997). Sensitivity to UV-B radiation is determined by the relative changes in a plants overall growth, seedling morphology, photosynthesis, and yield (Sisson and Caldwell, 1977; Teramura et al., 1980). Almost 90% of the UV-B radiation that falls on a leaf surface is absorbed by the epicuticular layers before reaching the mesophyll tissues. Recent attention has been focused on this particular source of radiation because its intensity is regulated by the density of atmospheric ozone.

UV-A (315 - 400 nm), a major component of solar radiation, is readily absorbed by pigments and chromophores, and regulates several photomorphogenic processes (Middleton and Teramura, 1994; Lingakumar and Kulandaivelu, 1998). Caldwell et al. (1994) have reported the ameliorating effects of UV-A radiation on the morphology and yield of soybean plants after previous, exposure to UV-B radiation. For example, PS II activity can be recovered by the addition of UV-A to UV-B irradiated chloroplasts (Panagopoulos et al., 1990). However, these regulatory effects of UV-A are still controversial. Hence, the objective of the study presented here was to determine the effect of low doses of UV-A and UV-B irradiation on growth and yield in *Phaseolus mungo* plants.

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MATERIALS AND METHODS

Plant Material and Growth Conditions

Seedlings of *P. mungo* L. (var. T9) were grown in 30- × 40-cm pots containing red soil, clay, and farmyard manure (2:1:1 v:v:v). Plants were watered daily. One week after germination, the seedlings were thinned to one per pot to promote uniform growth. The pots were then placed under outdoor conditions, with day/night temperatures of 29±4°C/26±3°C photoperiod of 10 - 12 h.

UV-A and UV-B Radiation Treatments

Seven- day-old seedlings were exposed to either UV-A or UV-B irradiation sources (0.5 Wm^{-2}) for 30 min daily, between 10.00 am and 10.30 am. Radiation levels were measured with an IL 700A research radiometer (International Light, Inc., USA) and a 5.5 response vacuum photodiode (SEE 400/W). Supplemental UV-A and UV-B radiation was provided by Philips Holland TL 20 W/8 (λ_{max} 365 nm) and TL 20 W/12 (λ_{max} 315 nm) sun lamps, respectively. These lamps were separately suspended above and perpendicular to the rows of pots. Treatment pots were kept in separate places to avoid mixing of two irradiations. The control pots were kept away from the irradiation. The quantity of radiation was controlled by maintaining the height of the lamps at a fixed distance, 2 ft above the tops of the plants, throughout the 70-d experimental period.

Growth Analysis

Growth parameters were assessed at 10-d intervals, from Day 10 after the first radiation treatment through Day 70 (i.e., when wilting symptoms appeared in irradiated plants). Values for shoot and root lengths, leaf area, fresh mass, and dry matters were determined immediately after the sampled plants were uprooted on the appointed days. Leaf area was measured using an ADC Area meter AM 100 (ADC Bioscientific Ltd., England). Samples were then dried at 70°C for 48 h before their weights were recorded.

Crop Yield

Yield parameters, e.g., number of pods/plant, number of seeds/pod, and 100-seed weight were calculated immediately after harvesting on Day 70.

RESULTS AND DISCUSSION

P. mungo seedlings responded differently when grown under supplemental UV-A and UV-B radiation (Table 1). We had already presumed that radiation sources of <280 nm, which account for only 0.04% of total radiation, had negligible effects when seedlings were exposed for 30 min/d under our field conditions. Values for all growth parameters gradually increased between Day 10 and Day 70 in all the experimental treatments. However, those plants exposed to UV-A radiation showed greater shoot growth compared with both the UV-B treated and control plants, a difference that became significant after Day 30. For example, shoot growth was 13% higher for plants supplemented with UV-A than for the controls, while those grown under UV-B radiation had a 17% reduction in shoot length compared with the controls.

This positive effect of UV-A radiation on shoot lengths is strong evidence for its regulatory role in photomorphogenesis. Middleton and Teramura (1994) have also observed that the combination of visible light and UV-A, at a particular ratio, is highly suitable for enhanced seedling development. Overall growth has also been promoted by the supplementation of UV-A in *Cymopsis* seedlings (Lingakumar and Kulandaivelu, 1998). In contrast, enhanced UV-B radiation retard shoot elongation, an indication of its influence on auxin activity. IAA regulates shoot development, a response that is controlled by visible light/UV-A (Kulandaivelu et al., 1989).

Contrary to the effects of radiation seen in the shoots,

Table 1. Effect of UV-A and UV-B enhanced radiation on growth components in *P. mungo* over different treatment periods (Values are mean ± SE; n = 5).

Treatment period (days)	Treatment (cm)	Shoot length (cm)	Root length (cm)	Leaf area (cm^2)	Fresh mass (g)	Dry matter (g)
	Control	17.8 ± 2.0	7.4 ± 1.0	63.6 ± 5.6	2.1 ± 0.3	0.2 ± 0.01
10	+UV-A	18.2 ± 1.5	6.8 ± 0.8	66.5 ± 6.0	2.3 ± 0.2	0.3 ± 0.03
	+UV-B	14.2 ± 1.5	8.5 ± 1.0	40.1 ± 3.9	1.4 ± 0.1	0.1 ± 0.01
	Control	24.4 ± 2.1	8.2 ± 0.9	84.9 ± 7.5	2.7 ± 0.3	0.3 ± 0.02
20	+UV-A	25.6 ± 2.4	7.9 ± 0.8	85.9 ± 7.8	2.8 ± 0.2	0.3 ± 0.03
	+UV-B	21.1 ± 2.0	9.7 ± 1.0	71.5 ± 6.8	2.3 ± 0.3	0.2 ± 0.02
	Control	28.7 ± 2.7	9.1 ± 1.0	113.4 ± 10.3	3.6 ± 0.2	0.3 ± 0.03
30	+UV-A	32.4 ± 3.0	8.6 ± 0.9	118.3 ± 10.8	3.8 ± 0.2	0.4 ± 0.03
	+UV-B	23.8 ± 2.1	10.8 ± 1.1	104.0 ± 08.8	3.3 ± 0.2	0.3 ± 0.03
	Control	32.7 ± 2.9	9.9 ± 1.0	126.3 ± 11.6	6.6 ± 0.4	0.6 ± 0.05
40	+UV-A	35.3 ± 3.4	9.4 ± 0.9	127.0 ± 12.1	7.7 ± 0.6	0.8 ± 0.07
	+UV-B	31.1 ± 2.8	10.8 ± 1.1	123.9 ± 10.9	6.4 ± 0.5	0.6 ± 0.04
	Control	33.7 ± 3.5	11.1 ± 1.0	132.0 ± 12.9	9.0 ± 0.8	0.9 ± 0.07
50	+UV-A	37.5 ± 3.2	09.7 ± 1.0	135.2 ± 12.0	9.2 ± 0.8	1.1 ± 0.09
	+UV-B	32.7 ± 3.0	12.3 ± 1.2	130.0 ± 12.5	8.5 ± 0.9	0.8 ± 0.08
	Control	41.3 ± 3.8	11.3 ± 1.2	165.1 ± 15.4	25.7 ± 2.1	2.9 ± 0.15
60	+UV-A	41.8 ± 3.9	10.9 ± 1.0	170.7 ± 16.7	25.9 ± 2.6	3.1 ± 0.29
	+UV-B	38.0 ± 2.9	12.1 ± 0.9	165.3 ± 15.5	24.2 ± 2.2	2.8 ± 0.15
	Control	42.2 ± 4.1	11.6 ± 1.1	169.2 ± 14.6	26.8 ± 2.1	3.6 ± 0.32
70	+UV-A	42.6 ± 3.5	11.1 ± 1.0	171.2 ± 16.8	28.2 ± 3.1	3.6 ± 0.35
	+UV-B	38.2 ± 3.8	12.1 ± 1.2	168.8 ± 15.9	26.4 ± 2.5	3.4 ± 0.31

Table 2. Effect of UV-A and UV-B enhanced radiation on yield components in *P. mungo*.

Parameter	Control	+UV-A	+UV-B
Pod number/plant	10	8	6
Seed number/pod	6	4	3
100-seed weight (g)	5.6	4.5	3.6

the roots of seedlings grown under UV-A and UV-B sources showed a 6% decrease and a 19% increase in growth, respectively, by Day 30. These longer roots found in plants exposed to UV-B radiation may have been the result of IAA being transported away from leaves whose growth had been retarded by this particular treatment (data not shown).

Fresh masses for the aerial parts of UV-A supplemented plants were 15% higher than for the control plants, while fresh masses were reduced by only 4% in the UV-B exposed plants compared with the controls. Similar trends were seen in the values for dry matter. By Day 30, leaf areas were marginally increased (4%) for seedlings grown under UV-A radiation, while those under the UV-B lamps showed an 8% reduction from that measured in the control plants. UV-B radiation is known to inhibit fresh mass, dry matter, and leaf area, phenomena that can be attributed to both the destruction of endogenous IAA (Kulandaivelu et al., 1989) and the induction of oxidative enzymes associated with growth responses. UV-B radiation can also deter the action of gibberellic acid (GA) (Tevini and Steinmuller, University of Karlsruhe, Germanyunpublished data).

Compared with the control plants, yields were reduced by 20 to 30% for UV-A exposed plants, and by 40 to 50% for those treated with UV-B radiation (Table 2). The huge decline seen with the latter may have been due to the delayed development of flowers and buds, in addition to an overall reduction in the number of flowers (Tevini, 2000).

The results of these experiments demonstrate that enhanced UV-A radiation promotes vegetative growth, possibly via the stimulation of IAA biosynthesis. In contrast, supplemental UV-B radiation inhibits both growth and yield, perhaps because of its inhibitory effect on the action of IAA and GA_3.

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