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Analysis of ultraviolet-B (UV-B) radiation on ecophysiological parameter

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Abstract

The role of visible light in the growth and development of a plant is well established. The Sun is the source of light energy. The rays of light reach us in the form of electromagnetic radiations. The spectrum of this radiation consists of gamma rays, x rays, ultraviolet rays, visible rays, infrared rays, microwaves and radio waves etc. Ultraviolet radiation is the part of the electromagnetic spectrum between x rays and visible light with wavelength 100 nm to 400 nm. Ultraviolet spectrum accounts for 5 % of all solar radiation reaching the earth. The energy of radiation increases as the wavelength gets shorter. UV radiation therefore has much higher energy than visible light, enough to cause severe injury to plants.

Keywords: Ultraviolet radiation, electromagnetic radiations

1. Introduction

(T. Matthew, 2014) reappraised the effects of UV-B radiation on plant morphology in the light of improved mechanistic understanding of UV-B effects, particularly elucidation of the UV RESISTANCE LOCUS 8 (UVR8) photoreceptor. He reviewed responses at cell and organismal levels and explored their underlying regulatory mechanisms, function in UV protection and consequences for plant fitness. UV-induced morphological changes included thicker leaves, shorter petioles, shorter stems, increased axillary branching and altered root: shoot ratios. At the cellular level, UV-B morphogenesis comprised changes in cell division, elongation and/or differentiation. However, lack of substantial new knowledge of molecular, cellular and organismal UV-B responses, there remains a wide gap in our understanding of the interactions between these organizational levels, and how they control plant architecture. Furthermore, despite a broad consensus that UV-B induces relatively compact architecture, substantial diversity in reported phenotypes has been noted. This may relate to UV-induced morphological changes being underpinned by different mechanisms at high and low UV-B doses. It remains unproven whether UV-induced morphological changes have a protective function involving shading and decreased leaf penetration of UV-B, counterbalancing trade-offs such as decreased photosynthetic light capture and plant-competitive abilities. Future research will be needed to disentangle seemingly contradictory interactions occurring at the threshold UV dose where regulation and stress-induced morphogenesis overlap.

2. Review of literature

(Dai *et al*., 1997) **[1]** Conducted an intensive and extensive series of field experiments, using irrigated rice cultivars under tropical conditions to address the response of rice (*Oryza sativa* L.) to UV-B radiation. This multi season study indicated that supplemental UV-B radiation had no significant effects on rice (*Oryza sativa* L.) grain yield and growth parameters. The absence of UV-B effects was consistent across seasonal environment (4 dry and 3 wet seasons), cultivars and types of exposure system. Thus yields were likely to be affected by increases in UV-B under realistic field conditions.

(Karousou *et al*., 1998) [2] Studied that due to the decreasing trends in stratospheric ozone concentration, UV-B radiation has increased at the surface of the earth, which has led to much research on the effects of enhanced UV-B radiation on some changes in *Mentha spicata* plants. (Yue *et al*., 1998) [3] reported a higher reduction in the biomass of leaves than that of stem or spikes in *Triticum aestivum* L. due to enhanced ultraviolet-B (UV-B) radiation. (Jansen *et al*., 1998) observed that UV-B radiation above ambient levels may inhibit plant growth, development, reproduction and depress photosynthesis. (Ambasht and Agrawal, 1998) [4] Observed that over 275 percent increase in the anthocyanin content in maize (*Zea mays* L.). Anthocyanins have very weak absorption in the UV-B regions and are regarded as UV screens only at very high concentration.

(Golaszewska *et al*., 2003) [5] Conducted an experiment in green house under different doses of supplemental UV-B radiation in two species *Avenafatua* and *Setariaviridis*. They observed a decrease of plant height, fresh mass of leaves, shoots and roots as well as leaf area and leaf curling in both of the species. The significant differences between *Avenafatua* and *Setariaviridis* in the studied traits were mainly due to the tillering ability of the species. The content of chlorophyll varied considerably. Supplemental UV-B radiation did not reduce leaf weight ratio, shoot dry matter, shoot to root ratio and leaf area ratio.

(Hong *et al*., 2008) [6] Observed that enhanced supplemental UV-B radiation did not affect seed germination of common alpine grass species and the order affecting seed germination. (Chang *et al*., 2009)**[7]** observed that supplemental ultraviolet-B (UV-B) radiation significantly reduced plant height but increased the number of shoots and plant dry matter in *Ocimum basilicum* L. (Ravindran, 2005) [8] investigated that peroxidase activity was also an important component of antioxidant defense system for scavenging H_2O_2. The peroxidise activity in *Phyllanthus amarus* was increased with increasing treatment period of supplemental UV-B radiation.

(Hongmei *et al*., 2010) [9] Systematically studied the response of 16 day old rice (*Oryza sativa* L.) seedlings to UV (0.67 Wm-2) biologically effective UVB and 0.28Wm-2 UV-A exposure for 6, 12 and 24 hrs. Supplemental ultraviolet exposure resulted in the appearance of light brown patches on leaves, a decrease in the net photosynthetic rate, lipid per oxidation, accumulation of UV-absorbing compounds (including flavonoids and other phenolic pigments) and differential expression of 22 proteins. Both physiological and molecular responses became stronger with increasing supplemental UV exposure time, indicating the effects of UV accumulation on plants.

3. Observations

3.1 Plant height

The height of the plant was measured from the soil surface up to the tip of the main stem with the help of a meter scale. The first reading was recorded just before the onset of the treatment. The second reading was recorded after 30 days of treatment.

The control plants of *Ocimum basilicum* (Table 1) had an initial height of 23.71 cm which reached 28.54 cm after 30 days. Thus an increase of 20.37% in height was attained. This percent increase in UV-B treatment was only 3.79%. When UV-B exposure was given in combination with 100 ppm ascorbic acid, the increase in plant height was 1.59%, with 200 ppm ascorbic acid, the increase in height was 17.92%. Maximum height was 29.51 cm in UV-B + 500 ppm ascorbic acid treated plants. The percentage increase was 21.46%.

The control plants of *Mentha piperata* (Table 2) were having an average initial height of 13.82 cm which reached 15.06 cm after 30 days. The percentage growth in control plants was 8.97%. The percentage growth in UV-B treatment was larger than in control plants i.e. 32.90%. UV-B radiation given in combination with 200 ppm and 500 ppm concentrations of ascorbic acid showed percentage growth 37.48% and 12.15% respectively. Maximum height was recorded in UV-B + 100 ppm ascorbic acid treated plants i.e. 61.90%.

3.2 Number of nodes

The control plants of *Ocimum basilicum* (Table 1) had 10 nodes after 30 days of treatment. Here the smallest plants were UV-B exposed plants and these had an average of 9 nodes. No. of nodes per plant were 9.33, 10.0 and 10.5 in UV-B + 100 ppm, UV-B + 200 ppm and UV-B + 500 ppm ascorbic acid treatments respectively.

The control plants of *Mentha piperata* (Table 2) had 7.4 nodes after 30 days of treatment. This number increased in UV-B exposed plants. The no. of nodes were 11.8, 12 and 10.4 in UV-B, UV-B + 200 ppm and UV-B + 500 ppm ascorbic acid treated plants. The maximum number of nodes was observed in UV-B + 100 ppm ascorbic acid treated plants i.e., 12.6.

Table 1: Effect of UV-B radiation singly and with various concentrations of Ascorbic Acid on ecophysiological parameters of *Ocimum basilicum*

Treatment	Plant height (cm)		% Growth in 30 days		No. of nodes			Length of internode after 30 days (cm)	Leaf area (cm^2)	% Increase or decrease in leaf area over control
	Before treatment	After 30 days of treatment	% Growth	% Increase or decrease Over control	Before treatment	After 30 days of treatment	% Increase or decrease over control			
Control	23.71 ± 0.847	28.54 ± 0.313	20.37	-	7.33 ± 1.153	10.00 ± 0.812	-	2.89 ± 0.260	5.45 ± 0.946	-
UV–B	23.71 ± 0.847	24.61 ± 2.279	3.79	-13.77	7.33 ± 1.153	9.00 ± 0.707	-10.00	2.68 ± 0.064	4.00 ± 0.595	-26.6
UV–B+100 ppm AA	23.71 ± 0.847	24.80 ± 2.444	4.59	-13.10	7.33 ± 1.153	9.33 ± 1.244	-6.70	2.80 ± 0.064	4.63 ± 0.739	-15
UV–B+200 ppm AA	23.71 ± 0.847	27.96 ± 2.692	17.92	-2.03	7.33 ± 1.153	10.00 ± 2.080	0	2.83 ± 0.200	4.89 ± 0.755	-10.27
UV–B+500 ppm AA	23.71 ± 0.847	29.51 ± 2.828	24.46	+3.39	7.33 ± 1.153	10.50 ± 0.707	+5.00	3.06 ± 0.250	5.85 ± 0.611	+7.33

Table 2: Effect of UV-B radiation singly and with various concentrations of Ascorbic Acid on ecophysiological parameters of *Mentha piperata*.

Treatment	Plant height (cm)		% Growth in 30 days		No. of nodes			Length of internode after 30 days of treatment	Leaf area (cm^2)	% Increase or decrease in leaf area over control
	Before treatment	After 30 days of treatment	% Growth	% Increase or decrease over control	Before treatment	After 30 days of treatment	% Increase or decrease over control			
Control	13.82 ± 1.948	15.06 ± 2.181	8.97	-	5.60 ± 1.356	7.40 ± 1.201	-	1.51 ± 0.238	6.34 ± 1.248	-
UV–B	13.82 ± 1.948	18.38 ± 2.880	32.90	+22.04	5.60 ± 1.356	11.80 ± 1.939	+59.40	1.55 ± 0.179	4.38 ± 0.961	-30.14
UV–B+100 ppm AA	13.82 ± 1.948	22.80 ± 1.040	64.90	+51.31	5.60 ± 1.356	12.60 ± 1.489	+97.20	1.79 ± 0.738	4.85 ± 0.771	-23.50
UV–B+200 ppm AA	13.82 ± 1.948	19.00 ± 3.473	37.48	+26.23	5.60 ± 1.356	12.00 ± 2.607	+62.10	1.48 ± 0.273	4.60 ± 0.754	-27.4
UV–B+500 ppm AA	13.82 ± 1.948	15.51 ± 2.081	12.15	+2.92	5.60 ± 1.356	10.40 ± 2.154	+40.50	1.51 ± 0.238	6.64 ± 1.053	+4.73

4. Result and discussion

UV-B induced reduction in plant height was observed in *Ocimum basilicum*, where UV-B exposed plants showed only 3.79 % growth in 30 days, against control plants which showed 20.37 % growth. The reduced elongation of the main stem of basil plants altered the phenology to compact plants; possibly it was due to changes in the phytohormones, especially IAA that has been shown to play a role in the stem elongation. (Wang *et al.*, 2008) [10] Found reduction in *Cerastium glomeratum* Thuill in plant height by enhanced UV-B radiation. Similarly (Bal Krishnan *et al*., 2005) [11] found out 50 % reduction in plant height in UV-B treated *Crotalaria juncea* plants. According to (Biggs *et al*., 1994) reduction in plant height has often been used as an index to assess the degree of UV-B sensitivity. It is possible that the physiological basis for growth, reduction in stem elongation under UV-B radiation, may involve changes in membrane integrity due to lipid peroxidation caused by free radicals (Kramer *et al.*, 1991) [12] and also to a disruption in the synthesis and transport of plant hormones such as IAA and gibberelic acid (Tevini, 1994) [13].

However in *Mentha piperata* plants, UV-B exposed plants showed a drastic change in plant height. UV-B treated and UV-B + 100 ppm ascorbic acid treated plants showed a great increase in plant height. UV-B + 100 ppm ascorbic acid treated plants showed 51.3 % growth in plant height in 30 days over control.

UV-B treated plants of *Ocimum basilicum* showed a smaller height with low no. of nodes and smaller internodes. (Kakani *et al*., 2003) [14] Observed smaller cotton plants with shortened internode but without any significant differences in main stem node number. This reduction in plant height has also been explained by (Ros and Tevini, 1995) [15]. They reported the destruction of IAA as well as formation of growth inhibiting IAA photoproducts in sunflower due to UV-B exposure.

In *Ocimum basilicum,* UV-B radiation slowed processes of growth as well as development resulting in smaller and fewer internodes. This is also evident from the present findings that the tolerance of plants to oxidative stress of UV-B radiation is correlated with the increasing amount of ascorbic acid. It acts as an antioxidant and increases the activity of free radicals scavenging enzymes. Therefore, a progressive increase in plant height as well as internodal length was recorded with increasing concentrations of ascorbic acid. Exposure of plants to UV-B radiation showed different results in both studied genera *Ocimum basilicum*and *Mentha piperata*.

The root length of *Ocimum basilicum* UV-B treated plants was drastically reduced by 46.78 percent. Earlier (Pal *et al*., 1995) [16] also recorded inhibition of elongation in roots of *Vignaradiata*on exposure of UV-B radiation. (Ros, 1990) [17] attributed the inhibition of elongation in UV-B irradiated sun flower roots due to the UV-B mediated action of peroxidase, acting as IAA oxidase causing reduction in cell wall extensibility. In the present investigation the negative impact of UV-B on root length was countered by the spray of ascorbic acid. Root length was almost equal to that of control in UV-B + 200 ppm ascorbic acid treatment and even exceeded in UV-B + 500 ppm ascorbic acid concentration. These findings indicate that the action of peroxidase causing reduction in cell wall extensibility is masked by ascorbic acid.

However *Mentha piperata* proved to be an enigmatic plant species for UV-B impact on root length. A significant increase of 29.85 percent in root length owing to UV-B exposure is a surprising observation. It contradicts all earlier reports of different scientists and needs new explanations. Here the normal root length is reversed by ascorbic acid spray treatment. The positive impact of UV-B on *Mentha* root length was totally antagonized by 500 ppm ascorbic treatment.

On exposure of UV-B radiation a drastic reduction in leaf area of leaves in both the studied genera was observed. This reduction was accompanied by a reduction in leaf dry weight too. Such a reduction in leaf area on UV-B exposure is also reported in *Lycopersicum esculentum*var. New Yorker (Hao *et al.,* 2000) [18] and in cotton (Reddy *et al.,* 2003) [19]. The reduction in leaf area has been suggested to occur due to reduction in calmodulin content, which is most likely involved in leaf growth. According to (Hoffmaan *et al*., 2001) [20] decrease in leaf area was the result of a reduction in cell division rather than slower cell expansion.

According to (Krizek *et al*., 1997) [21] reduction in leaf area could be an adaptive mechanism to minimize the exposure damage of UV-B radiation. However, UV-B mediated decrease in leaf area was antagonized by ascorbic acid. The 500 ppm concentration of ascorbic acid not only negated the impact of UV-B but also increased the leaf area.

Leaf dry weight also showed a decline. There was reduction in leaf dry weight per gram fresh weight in both genera in UV-B exposed plants. Earlier reduction in leaf dry weight was reported in pea (Pal *et al.,* 1998) [22] and in soybean (Vue *et al.,* 1982) [23] due to exposure of UV-B. Ascorbic acid showed a progressive increase in leaf dry weight of UV-B exposed plants of *Ocimum* and *Mentha* with increase in concentration.

The present results with ascorbic acid evince that though it has an antagonistic effect for UV-B exposure on variances like plant height, intermodal and root lengths, leaf area, dry weight of leaf etc. on both the studied genera, the optimum concentration varies from genus to genus. The UV-B mediated negative impact was totally countered by ascorbic acid application. The 500 ppm concentration of ascorbic acid proved to be stimulatory for these variances in *Ocimum basilicum*.

However, in *Mentha piperata* UV-B + 100 ppm ascorbic acid treated plants showed maximum plant height and maximum length of internode. Here the higher concentrations of ascorbic acid were effect less. Thus the findings go in favour of the indirect theory of (Phillips, 1975) [24] which emphasizes that a chemical may be inhibitory both at sub-optimal level and supra-optimal level.

Changes in chlorophyll content due to UV-B radiation are well documented. Several studies have indicated that changes in m-RNA turnover of the Chlorophyll a/b binding protein are responsible for reduction in total chlorophyll content (Strid and Porra, 1992) [25]. Chlorophyll content in *Ocimum basilicum* appears to be sensitive to UV-B radiation. Total chlorophyll content was found reduced in UV-B mediated plants.

The reduction in total chlorophyll by UV-B radiation in *Ocimum* may be the result of photo degradation of existing chlorophyll (He *et al*., 1994) [26] or may be due to lower chlorophyll synthesis as UV-B can reduce the level of m-RNA transcripts of proteins involved in chlorophyll production. Lower chlorophyll content causes reduction in photosynthesis rate as well as in yield. Ascorbic acid given to UV-B exposed plants of *Ocimum* increases total chlorophyll.

(Battaglia and Brenann, 2000) [27] also found that concentration of both Chlorophyll a and Chlorophyll b was unchanged in response to UV-B treatment in cucumber

(Cumissativus). (Maffei and Scannerini, 2000) also did not find significant differences in chlorophyll content in *Mentha piperata*. An enhancement in chlorophyll content has also been recorded in cucumber and cotton plants by exclusion of UV-A and UV-B radiation by (Solanki *et al.*, 2006) [28].

Yield (vegetative) which was measured in terms of total number of intact leaves per plant at the end of the experiment was badly affected in both genera by UV-B radiation. The UV-B treated plants showed drastic reduction in yield in both genera. The negative influence of UV-B was totally countered by simultaneous treatment with ascorbic acid. (Varalakshmi *et al.*, 2003) [29] Observed that exclusion of UV-B radiation from solar radiation enhanced the total number of pods formed by about 64 %. (Agarwal *et al.*, 2004) [30] also recorded reduced yield in wheat. Table 3 for leaf area, total chlorophyll content, leaf dry weight and yield illustrate the effect of UV-B, used singly and in combination with ascorbic acid on both studied genera. Seed viability of the seeds of *Ocimum basilicum* from control and treated plants was tested by tetrazolium chloride method. UV-B treated plants showed negative effect. The negative effect of UV-B was countered by the spray of ascorbic acid. Seed viability was almost equal to that of control in UV-B+500 ppm ascorbic acid treated plants in *Ocimum*.

Table 3: Percentage change in leaf area, chlorophyll content, leaf dry weight, number of vegetative leaves in *Ocimum basilicum* and *Mentha piperata.*

Treatment	***Ocimum basilicum***				***Mentha piperata***			
	Leaf area	**Total chlorophyl content**	**Leaf dry weight**	**No. of Vegetative leaves (yield/plant)**	**Leaf area**	**Total chlorophyl content**	**Leaf dry weight**	**No. of Vegetative leaves (yield/plant)**
Control	-	-	-	-	-	-	-	-
UV–B	-26.6	-16.91	-29.4	-53.29	-30.14	-6.08	-6.58	-69.62
UV–B+100 ppm AA	-15	-11.97	-5.68	-40.35	-23.50	-6.17	+3.61	-65.27
UV–B+200 ppm AA	-10.27	-5.81	+5.11	-3.17	-27.40	-1.24	+36.9	-53.55
UV–B+500 ppm AA	+7.33	+7.52	+13.63	-1.17	+4.73	+10.64	+53.07	-37.23

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