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SHORT TERM EXPOSURE OF UV-B RADIATION ENHANCES SALINITY TOLERANCE IN *VIGNA RADIATA*

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Abstract

Electromagnetic radiation (7%) emitted from the sun is in the UV range (200–400) nm. Several morphological and anatomical changes have been reported from plants grown under long-term UV-B regimes. The effect of UV-B radiation (280-320nm) and salinity alone and in combination were studied. Fifteen days old seedlings of *Vigna radiata* were exposed to UV-B radiation for 10, 20 and 30 minutes and salinity treatment was given to the plants 3 days before the UV-B treatment. UV radiation was artificially provided by Esco Airstream Vertical Laminar Flow Cabinet (AVC-4AI). Significant decrease ($p<0.05$) in root and shoot length, specific leaf area, chlorophyll and carotenoid content of in all UV-B and salinity treatments was observed as compared to control. The reduction was more pronounced in salinity treatment as compared to UV-B alone and combination of UV-B with salinity. It is concluded that the short term exposure of UV-B radiation enhances the salinity tolerance in *Vigna radiata*.

Introduction

The anthropogenic and natural destruction of stratospheric ozone has been correlated to the augmentation in ultraviolet (UV) radiation at the earth's surface (Hofmann *et al.,* 2000). Plants like other living organisms are deleteriously affected by ultraviolet radiation. The increased exposure of UV radiation affects plant growth directly or indirectly by altering various physiological processes (Caldwell, 1971), such as photosynthetic enzymes, metabolic pathways, photosynthetic pigments and stomatal function, thereby decreasing the photosynthetic activity (Tevini, 1993). According to another report, the reduction in photosynthetic pigment, degradation of protein and DNA and elevated oxidative stress are the key damages related to the enhanced ultraviolet radiation (Allen *et al.,* 1998). Photosynthesis is dependent on chlorophyll content UV-B treatments are found to affect also net CO_2 assimilation (Mapelli *et al.,* 2006). The sensitivity of these processes in crop plants to enhanced UV radiation greatly differs among different crop species (Bornman, 1989).

Earlier studies on this subject have mostly focused upon the independent effects of UV-B radiation on plants (Smith *et al.,* 2000). Several plants are more tolerant to UV-B than others because they fabricate a variety of secondary metabolites that successfully absorb UV-B and avoid it from penetrating into mesophyll cells of the leaf (Ravindran *et al.,* 2010). However, the interactions among a number of abiotic factors have now distorted and modified the responses of plants to increased ultraviolet radiation. The interactions among enhanced ultraviolet radiation and other environmental stresses, such as herbicides, high temperature, freezing, drought and mineral deficiency, reduce the ultraviolet damage to plants as contrast to the non-treated control plants (Agrawal *et al.,* 2004). For example, high salinity stress affects plant growth and development by disturbing the osmotic potential (Rajpar *et al.,* 2006). According to an earlier report by Fedina *et al.,* (2003), the accumulation of proline increases in salinity stress which ultimately increases the tolerance of various plants to ultraviolet radiation (Fatima *et al.,* 2010).

The objective of this study was to determine the single and interactive effects of elevated level of ultraviolet radiation and salinity stress on the growth and photosynthetic pigment of mungbean (*Vigna radiata*).

Material and Methods

Healthy seeds of *Vigna radiata* were uncontaminated with 0.1% mercuric chloride solution. A total of 10 seeds were sown in plastic pots having 7cm diameter and 10 cm depth, with drainage holes provided in the bottom. Each pot was filled with 350 g properly processed garden soil. After one week, seedlings were thinned to 4 per pot. The plants were irrigated regularly throughout the experimental period. Fifteen days old seedlings were subjected to UV-B (280 - 320 nm) radiation for 10, 20, and 30 minutes daily upto 4 weeks using Esco Airstream Vertical Laminar Flow Cabinet (AVC-4AI). The plants also received a salinity stress treatment of 50 mM NaCl, three days before the UV-B treatment. Leaf samples from both control and treated plants were collected on weekly basis up to 4 weeks in the early hours of the morning. The samples were stored in the polyethylene bags.

Weekly effect of 10, 20 and 30 minutes UV-B radiation exposure and 50 mM NaCl treatment alone and in combination on root and shoot length were studied. Three plants from all the experimental units were removed carefully and washed with gentle stream of water to ensure least possible damage to roots. The length of roots and shoots of individual plants were recorded. The specific leaf area was estimated by the following formula (Garnier *et al.,* 2001).

$$\text{Specific leaf area} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf dry mass (g)}}$$

The chlorophyll and carotenoids contents were estimated by using the method of Maclachlam & Zalik (1963). To compare the means of root and shoot length, specific leaf area and photosynthetic pigments statistical analysis was performed by using computer software "COSTAT".

Results

Root length: UV-B treatment showed significant ($p<0.05$) effect on root length of mung bean. Decrease in root length of plant was observed in all 3 exposure time to UV-B radiation as compared to the control plants which were grown at ambient UV level (Table 1). The combined effect of UV-B radiation + salinity resulted in an increase in root length as compared to the salinity treatment. The maximum root length was observed at 10 minutes treatment (Table 1).

Shoot length: Statistical analysis showed a significant ($p<0.05$) decrease in shoot length of UV-B radiation, 50 mM NaCl treatment alone and in combination as compared to control and reduction become more prominent as the exposure time increase (Table 2). Maximum reduction was observed in 50 mM NaCl treatment.

Specific leaf area: Results showed significant ($p<0.05$) decrease in specific leaf area in all UV-B and NaCl treatments as compared to control. More reduction was observed as the UV-B exposure time increased (Table 3). Combined UV-B and NaCl treatments showed significant ($p< 0.05$) increase in specific leaf area at 10 minutes and 20 minutes exposure time, however, at 30 minutes decrease was observed (Table 3).

Photosynthetic pigment: Plants treated with different exposure time to UV-B and NaCl showed significant effect on chlorophyll ($p<0.01$) and carotenoid ($p<0.05$) contents of mung bean plant. Reduction in chlorophyll and carotenoid contents was observed in all treatments as compared to control. Reduction in both pigments increased with the increase in exposure time (Tables 4 & 5).

Table 1. Effects of UV-B radiation and salinity individually and in combination on root length (cm) of *Vigna radiata*. Significance level = *P<0.05

Treatment	Exposure time (minutes)	Weeks			
		1st	2nd	3rd	4th
-	control	10.6 ± 0.213	14.7 ±0.613	19.1 ±0.333	22.2 ± 0.381
	10	9.0 ±0.333	13.2 ±0.316	17.9 ±0.322	20.4 ± 0.278
*UV-B	20	8.7 ±0.324	12.6 ±0.187	16.6 ±0.666	20.0 ± 0.476
	30	8.3 ±0.227	12.0 ±0.317	15.8 ±0.636	17.7 ± 1.145
*50mM NaCl	-	7.1 ±0.333	7.8 ±0.268	8.5 ±0.322	9.0 ± 0.255
	10	8.6 ±0.158	12.0 ±0.666	15.7 ±0.277	19.1 ± 0.345
*UV-B+ 50mM NaCl	20	7.7 ±0.458	11.5 ±0.323	14.2 ±0.417	18.2 ± 0.332
	30	7.4 ±0.355	10.6±0.327	13.4 ±0.666	17.3 ± 0.512

*: Each value is mean of three replicate with standard error (Mean ± SD)

Table 2. Effects of UV-B radiation and salinity individually and in combination on shoot length (cm) of *Vigna radiata*. Significance level = *P<0.05

Treatment	Exposure time (minutes)	Weeks			
		1st	2nd	3rd	4th
-	control	9.6 ± 0.333	10.7 ±0.513	11.9 ±0.333	12.9 ±0.603
	10	9.4 ±0.255	10.2 ±0.269	11.5 ±0.182	12.6 ±0.167
*UV-B	20	8.3 ±0.232	9.0±0.217	11.0 ±0.255	11.4 ±0.322
	30	8.4 ±0.217	9.8 ±0.357	10.2 ±0.331	11.1 ±0.217
*50mM NaCl	-	7.6 ±0.217	8.1 ±0.212	9.5 ±0.217	10.2 ±0.255
	10	9.0 ±0.333	10.0 ±0.333	11.4 ±0.267	12.4 ±0.235
*UV-B+ 50mM NaCl	20	7.5 ±0.258	8.1 ±0.333	9.2 ±0.313	10.3 ±0.333
	30	7.2 ±0.235	8.0 ±0.217	8.9 ±0.255	9.6 ±0.427

*: Each value is mean of three replicate with standard error (Mean ± SD)

Table 3. Effects of UV-B radiation and salinity individually and in combination on specific leaf area ($cm^2 . g^{-1}$) of *Vigna radiata*. Significance level = *P<0.05

Treatment	Exposure time (minutes)	Weeks			
		1st	2nd	3rd	4th
-	control	370 ±16.351	395 ±17.513	420 ±13.212	438 ±11.527
	10	367 ±12.309	387 ±12.078	418 ±12.753	437 ±12.511
*UV-B	20	341 ±12.644	352 ±12.644	366 ±12.642	374 ±11.527
	30	303 ±12.511	317 ±10.333	324 ±15.774	334 ±14.666
*50mM NaCl	-	286 ±13.883	300 ±11.121	336 ±10.642	352 ±12.316
	10	355 ±11.282	374 ±12.882	396 ±10.847	410 ±10.847
*UV-B+ 50mM NaCl	20	320 ±12.641	336 ±11.923	357 ±12.935	370 ±10.641
	30	249 ±12.541	262 ±12.733	289 ±13.156	312 ±11.153

*: Each value is mean of three replicate with standard error (Mean ± SD)

Table 4. Effects of UV-B radiation and salinity individually and in combination on total chlorophyll content (mg. g^{-1}) of *Vigna radiata*. Significance level = **P<0.01

Treatment	Exposure time (minutes)	Weeks			
		1st	2nd	3rd	4th
-	control	1.39 ± 0.011	1.50 ± 0.025	1.68 ± 0.023	1.79 ± 0.035
	10	1.37 ± 0.051	1.47 ± 0.016	1.56 ± 0.018	1.67 ± 0.035
*UV-B	20	1.26 ± 0.042	1.38 ± 0.037	1.46 ± 0.025	1.56 ± 0.042
	30	1.15 ± 0.029	1.25 ± 0.015	1.39 ± 0.015	1.44 ± 0.027
*50mM NaCl	-	1.24 ± 0.017	1.31 ± 0.024	1.52 ± 0.012	1.61 ± 0.033
	10	1.27 ± 0.025	1.46 ± 0.015	1.54 ± 0.015	1.61 ± 0.011
*UV-B+ 50mM NaCl	20	1.13 ± 0.015	1.24 ± 0.023	1.41 ± 0.023	1.51 ± 0.021
	30	1.05 ± 0.025	1.17 ± 0.021	1.30 ± 0.031	1.44 ± 0.018

*: Each value is mean of three replicate with standard error (Mean ± SD)

Table 5. Effects of UV-B radiation and salinity individually and in combination on carotenoid content (mg. g^{-1}) of *Vigna radiata*. Significance level = *P<0.05

Treatment	Exposure time (minutes)	Weeks			
		1st	2nd	3rd	4th
-	control	0.38 ± 0.015	0.41 ± 0.02	0.44 ± 0.001	0.47 ± 0.007
	10	0.36 ± 0.005	0.39 ± 0.002	0.42 ± 0.001	0.46 ± 0.001
*UV-B	20	0.34 ± 0.002	0.37 ± 0.002	0.38 ± 0.001	0.41 ± 0.002
	30	0.33 ± 0.003	0.36 ± 0.001	0.37 ± 0.001	0.40 ± 0.001
*50mM NaCl	-	0.32 ± 0.003	0.34 ± 0.001	0.35 ± 0.001	0.36 ± 0.005
	10	0.35 ± 0.001	0.36 ± 0.007	0.38 ± 0.004	0.41 ± 0.004
*UV-B+ 50mM NaCl	20	0.33 ± 0.002	0.34 ± 0.004	0.35 ± 0.004	0.39 ± 0.011
	30	0.29 ± 0.001	0.30 ± 0.001	0.31 ± 0.002	0.32 ± 0.001

*: Each value is mean of three replicate with standard error (Mean ± SD)

Discussion

Reduction in growth is related with change in cell division, cell elongation and synthesis and transport of growth regulator (Tevini, 1994). Our results corroborated with the findings of Balakrishnan *et al.,* (2005) who reported that UV treatment, in *Crotalaria juncea* L resulted in 50% reduction in shoot length. Earlier, Vu *et al.,* (1984) also reported decrease in height of *Pisum sativum* due to UV-B exposure. The UV-B radiation could cause change in membrane integrity due to lipid peroxidation and deterioration on tissues which consequently result in growth reduction (Kramer, 1991). Logemann *et al.,* (1995) reported that the UV radiation may altered cell division via transcriptional repression of the genes encoding for a mitotic cycling and protein kinase. Salinity stress also caused reduction in shoot and root length (Soltani *et al.,* 2002) which might be related either to the inhibitory effect on cell division and enlargement and or to the imbalance of energy between growth and maintenance (Mccue & Hanson, 1990).

Correia *et al.,* (1999) reported decrease in leaf area in wheat plant. Reduction in leaf area gives protection as exposure to the UV radiation minimizes and consequently decreases the damage caused by the UV penetration (Krizek *et al.,* 1997; Khawar *et al*., 2010). It is also reported that the enhanced UV exposure reduces the calmodulin content which is involved in leaf growth (Huang *et al.,* 1997). The UV-B treatment also alters the stomatal opening and closing and the rate of transpiration (Day & Vogelmann, 1995). Salinity causes reduction in leaf area expansion, plant height, leaf area and number (Maggio *et al.,* 2004). This reduction in leaf area could be due to the decreased uptake of water, shrinkage of cell contents and unbalanced nutrition (Ali *et al.,* 2004).

Reduction in pigment fractions have been reported in a number of crop plants following the UV-B exposure (Ali *et al.,* 2004). Day & Vogelmann (1995) observed that the UV-B exposure reduced 30% total chlorophyll of *Pisum sativum.* A reduction in the amount of chlorophyll (20.5%) and carotenoid (15.4%) contents of *Crotalaria juncea* leaves following the UV-B exposure has also been reported (Balakrishnan *et al.,* 2005). Shukla *et al.,* 2008 also reported decrease in chlorophyll a (43%), chlorophyll b (23%), and carotenoid (53%) in *Brassica campestris* seedlings. However, Liu *et al.,* (1995) found no significant differences in level of pigment in barley and other grass species. Correia *et al.,* (1999) observed increase in chlorophyll content on high UV-B treatment. The photosynthetic pigments may also be destroyed by UV exposure, while chlorophyll a is more affected than the chlorophyll b (Strid *et al.,* 1990). UV radiation can lead to dramatic changes of the fine structure of chloroplasts and mitochondria. In the mitochondria, a swelling of the cristae is often observed (Poppe *et al.,* 2003). Salinity causes also reduction in chlorophyll and carotenoid content of plant (Abhishek, 2006). Fadaina *et al.,* (2003) reported decrease in total chlorophyll and an increase in H_2O_2 after combined UV-B radiation and NaCl treatment in barley seedlings. Biosynthesis of chlorophyll may be affected by the accumulation of various salt ions which consequently reduces chlorophyll content of plants (Ali *et al.,* 2004).

Conclusion

The present investigation concluded that the short term exposure of UV-B radiation enhances the salinity tolerance in *Vigna radiata*.

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