

Effects of UV-B irradiance on biomass and uptake of nutrients in mangrove seedlings of *Rhizophora apiculata* (Rhizophorales: Rhizophoraceae)

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Effect of ultraviolet-B (UV-B) irradiation was studied on hydroponically grown *Rhizophora apiculata* seedlings in terms of biomass and nutrient accumulation. The seedlings were exposed to four levels of UV-B irradiation equivalent to 10, 20, 30 and 40% stratospheric ozone depletion at the study area along the southeast coast of India. There was an increase of biomass in seedlings exposed to low dose of UV-B. The Na/K ratio was lower in leaves, but higher in stem and root of seedlings exposed to UV-B. The degree of nutrient accumulation was in the decreasing order - root > stem > leaves. Translocation of nutrients from root to shoot seemed to be inhibited by UV-B.

Ozone layer shielding the earth absorbs ultraviolet radiation¹ shorter than 315 nm. Depletion of stratospheric ozone layer results in the enhanced flux of solar UV-B on earth². Higher incidence of UV-B radiation is of utmost importance, in terms of its effectivity in injuring or altering plant processes viz., photosynthesis and transpiration³, dark respiration⁴, nutrient accumulation⁵ and biomass allocation⁶. Ambler *et al.*⁷ reported an inhibited uptake of several nutrients in tobacco exposed to UV-B radiation. However, such studies in mangroves have not been made till date. But, nutrient levels of mangroves in response to soil type and salinity⁸, growth habitat⁹ have been already documented. The mangroves play a vital role in metal recycling¹⁰ and pollution monitoring¹¹ in tropical coastal environment, where the incidence of UV-B is higher than that of temperate coast¹². Hence, the present work was made to investigate the influence of UV-B on the levels of macronutrients (Na, K, Mg, Ca) and heavy metals (Fe, Cu, Zn, Mn, and Pb) in hydroponically grown seedlings of mangrove species *Rhizophora apiculata* Blume (Rhizophorales: Rhizophoraceae).

Healthy propagules of *Rhizophora apiculata* were collected from the Pichavaram mangrove forest (lat. 11°27'N; long. 79°47'E). Propagules of

25 ± 2 cm long were placed in one litre containers having 500 ml of Arnon-Hoagland nutrient medium with a salinity of 15 g. l⁻¹. Nutrient medium was replenished once in three days. The propagules after sprouting were exposed to different UV-B radiation.

The UV-B radiation was supplied by Philips sun-lamps (TL 12/20 W; Philips, Gloeilampenfabrieken, the Netherlands). The sun-lamps were preburnt and matched for desired spectral irradiance³ of 300 nm prior to each treatment. Photosynthetically active radiation (400-700 nm) under the lamp was 90%. The radiation was filtered through a 0.13 mm cellulose diacetate (pre-solarised) for transmission below 290 nm for treatment with supplemental UV-B radiation. The UV-B radiation was checked using the generalized plant response action spectrum of Caldwell¹³ normalised at 300 nm. Therefore, the plants kept under UV lamps received supplemental doses of UV-B radiation in addition to ambient solar UV-B. The cumulative radiation (ambient + supplemental) were similar to those which would be received at the study site at Pichavaram mangrove forest with 10, 20, 30 and 40% depletion of stratospheric ozone¹⁴ during a cloudless day on the summer solstice according to Green *et al.*¹⁵. Under such conditions the plants were irradiated for 6 h

daily (10 00 - 16 00 hrs) for 14 days in an open field environment with the temperature at $28 \pm 2^\circ\text{C}$. Different UV-B irradiances were induced by altering the distance between the top of plants and the lamp frame. The required irradiance was monitored and maintained once in 7 days. The plants kept under normal solar radiation, without exposing to any supplemental UV-B, were treated as control.

Plants after 14 days of UV-B treatment were used for analysing biomass (plant parts were dried at 80°C for 72 h), micronutrients¹⁶ present in leaves, stem and root. Plant parts were dried at 105°C for 24 h and ground to a fine powder in a pestle and mortar. Powdered materials (0.5 g) were digested in tri-acid mixture of HNO_3 : H_2SO_4 : HClO_4 in the ratio of 4:10:1 and digests were

filtered through Whatman No 42 filter paper. Elemental determination of Na, K, Ca, Mg, Fe, Cu, Zn, Mn and Pb were done on an atomic absorption spectrophotometer (Perkin-Elmer 5000, USA).

Three replicates of 10 propagules each were analysed for each treatment. Different treatments were statistically analysed by Students' *t* test and least significant difference (LSD) was calculated and defined either at 95 or 99% confidence levels.

Total plant biomass was not influenced at low doses of 10 and 20% UV-B treatments; but the same was reduced to 13 and 21% respectively in seedlings exposed to 30 and 40% UV-B radiation. Root/shoot ratio increased by 78 and 56% at 10 and 20% UV-B treatments (Fig. 1). This increased ratio reflects that linear growth of shoot was affected more than that of root.

Table 1- Levels of nutrients ($\mu\text{g/g}$) in root, stem and leaves of *Rhizophora apiculata* seedlings exposed to UV-B radiation

Nutrients ($\mu\text{g/g dw}$)	Solar enhanced UV-B radiation (%)				
	0%	10%	20%	30%	40%
Root					
Na	144.0	96.0*	116.0	878.0**	666.0**
K	200.0	156.0	164.0	740.0**	980.0**
Ca	67.6	51.0	137.2*	63.6	66.1
Mg	108.6	94.0	80.0	84.0	70.4*
Mn	0.1	0.1	0.1	0.1	0.10
Fe	58.0	57.0	53.2	35.8*	44.8
Zn	1.8	2.5*	2.0	1.36	1.66
Cu	1.6	16.8*	2.6*	0.38*	0.40*
Pb	1.3	1.4	1.4	1.61	1.64*
Stem					
Na	181.0	82.0*	124.0	172.0	188.0
K	276.0	150.0*	206.0	418.4*	696.0**
Ca	53.0	38.2*	52.2	52.3	38.1*
Mg	130.4	129.3	128.4	150.2	142.1
Mn	0.1	0.1	0.1	0.1	0.2
Fe	29.8	34.1	34.0	32.5	34.0
Zn	1.44	2.2*	1.2	1.7	2.3*
Cu	1.26	10.2**	1.4	23.9**	9.2**
Pb	1.23	1.4	1.6*	1.6*	1.6*
Leaves					
Na	268.0	40.0*	57.1*	68.0*	189.0
K	436.0	176.6*	204.0*	288.0*	378.0
Ca	58.8	79.4*	89.7*	140.2*	67.0
Mg	174.4	111.2*	172.5	138.8	140.2
Mn	0.3	0.3	0.3	0.3	0.4
Fe	50.4	65.7	56.5	47.2	56.7
Zn	1.4	1.4	1.9*	1.4	2.3*
Cu	0.7	0.4*	0.4*	1.4*	4.0**
Pb	1.2	1.4	2.0*	1.6	2.6**

* Significant at 5% ; ** Significant at 1%

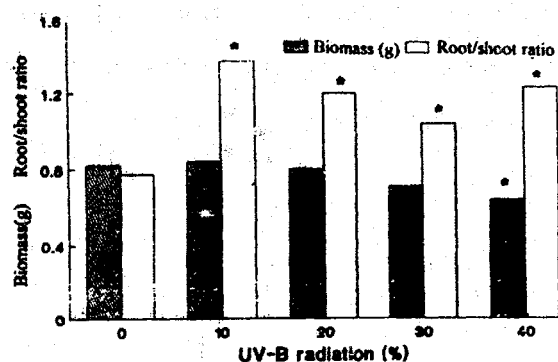


Fig. 1—Effects of UV-B on plant drymass and root/shoot ratio in *Rhizophora apiculata* (*Significant at 5% level)

Levels of Na and K were high in root, remarkably by 362% and 390% respectively in 14 days of 40% UV-B treatment. Magnesium and iron were reduced by 35% and 23% at the same dose of UV-B. However, Mn remained unaltered in stem and root due to UV-B treatment. But, Zn and Cu were enhanced by 38.9% and 950% respectively at 10% of UV-B. Content of lead was also elevated by 26% at 40% irradiance of UV-B (Table 1).

Concentrations of Na and K in stem lowered at 10% UV-B, but increased at 40% dose. Calcium was low in all UV-B treatments. Unlike in root, levels of Mg and Fe were higher in stem, but insignificantly. Levels of Zn, Cu, Pb were higher by 59.7%, 630% and 30% respectively at 40% UV-B dose than those in control (Table 1).

Na and K reduced in leaves as the dose of UV increased. Calcium and iron were enhanced by 35% and 30% respectively at 10% UV-B. Content of Mg declined, similar to root, by 36%. But, high accumulation of about 64%, 471%, 116.6% were recorded for Zn, Cu, and Pb in leaves treated at 40% of UV-B, as compared to ones unexposed to UV-B (Table 1). Na/K ratio in different parts of plants revealed that leaves exhibited low Na/K ratio of 0.3105, which reflects the selective absorption and accumulation of nutrients.

The accumulation of nutrients in response to UV-B might be due to indirect effects of UV-B rather than direct effects of UV-B on uptake and compartmentation of nutrients. This is well supported by this study that UV-B at high

incidence decreased the biomass, especially of shoot (increase root/shoot ratio), as a result of high translocation of photosynthates from shoot to the root, which might also be the possible factor of higher nutrients in root. Content of Pb was higher in UV-B treated plants than in control. Eventhough, there was no source for Pb, it was opined that it could be due to its supply from atmosphere¹¹. The elements - Mg, Fe and Mn, reduced marginally. This is a typical effect of UV-B with a simultaneous increase in potassium. The increased accumulation of nutrients in the present study due to UV-B, is because of more compartmentation of nutrients in root and further inhibition in its translocation to stem and leaves. This finding is in conformity with Brouwer¹⁷ who noted that growth of root ceased only later than that of shoot, because of its proximity to the source of nutrients. It is concluded that UV irradiation has no direct effects on nutrient balance of mangrove plant. However, UV-B irradiation has some pronounced indirect effects on the status of plant nutrients, which alter the growth and physiology of the mangrove plants.

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References

- 1 Caldwell M M, Teramura A H & Tevini M, *Trends Ecol Evol*, 4 (1989) 363.
- 2 Caldwell M M & Flint S D, *Climatic Change*, 28(1994) 375.
- 3 Teramura A H, Biggs R H & Kossuth S, *Plant Physiol*, 65(1980) 4834
- 4 Murali N S & Teramura A H, *Photochem. Photobiol*, 44 (1986) 215.
- 5 Murali N S & Teramura A H, *J Plant Nutr*, 8 (1985) 177.
- 6 Teramura A H, *Physiol Plant*, 48 (1980) 333.
- 7 Ambler J E, Krizek K T & Semeniuk P, *Physiol Plant*, 34 (1975) 177.
- 8 Kathiresan K, Moorthy P & Ravikumar S, *Int Tree Crops J*, 8 (1995) 183.
- 9 Kathiresan K, Moorthy P & Rajendran N, *Indian J Mar Sci*, 23 (1994) 168.
- 10 Harbinson P, *Search*, 12 (1981) 273.
- 11 Lacerda L D de, Pfeiffer W C & Figzman M, *Cien Cult*, 34 (1982) 921.
- 12 Srivastava B N, *Everyman's Sci*, 28 (1992) 69.

- 13 Caldwell M M , in *Photophysiology*, Vol 7 (Academic Press, New York) 1971, 131.
- 14 Moorthy P, *Effects of ultraviolet B radiation on mangrove environment : Physiological responses of Rhizophora apiculata Blume*, Ph.D thesis, Annamalai University, India, 1996.
- 15 Green A E S, Cross K R & Smith L A, *Photochem Photobiol* , 31 (1980) 59.
- 16 Isaac R A & Johnson W C, *J Ass Analyt Chem*, 58 (1975) 436.
- 17 Brouwer R, *Neth J Agric Sci*, 10 (1968) 399.