Evaluating The Morphological Responses of *Ricinus Communis* to Enhanced UV-B Radiation

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Abstract: UV-B radiation (280-320 nm) is an important environmental stress to plants which poses detrimental impact on their growth and development. The present investigation studied the impact of enhanced UV-B on castor oil plant (*Ricinus communis* L.). The present study was carried out for a time of 20 weeks in the premises of H.N.B. Garhwal University (S.R.T. campus), Tehri Garhwal, Uttarakhand. The plant samples were grown in two different setups *i.e.*, ambient solar radiation and enhanced UV-B. The authors have weekly examined 9 different plant growth parameters, *viz.* shoot length, stem base circumference, no. of branches, no. of nodes, internodal length, no. of leaves, no. of veins, leaf mid-vein length and inflorescence development in 5 random samples in both experiments. Compared to the ambient solar set-up, plants exposed to elevated UV-B showed decrease in plant height and average internodal length, whereas increase in no. of nodes, no. of branches, no. of leaves, leaf mid-vein length and stem base circumference. The inflorescence development was delayed but the development of veins was seen earlier in the enhanced UV-B experiment.

Keywords: Castor • Medicinal plant • Ozone depletion • Stress • UV radiation • UV-B

Introduction

The world has observed an increase in solar ultraviolet (UV) radiation entering the Earth's surface because of depletion of stratospheric ozone envelope. UV-B (280-320 nm) radiation coming from the Sun is an important type of abiotic stress which has potential to influence the morphology, physiology and biochemistry of plant. Though the wavelength range represents only 1.5% of the electromagnetic spectrum, it significantly causes negative impact on plants as well as animals. UV-B exposure leads to slower plant growth, damages the photosynthetic pigments, lowers carbon assimilation etc., altering the biomass allocation ultimately results in reduction of biomass and productivity (Tevini and Teramura, 1989). Plants usually show photoprotective properties against UV-B damage (Vernhes *et al.*, 2013). Researchers have done many studies on the effect of this radiation on selective plants. These experiments include exposure to enhanced UV-B radiation using UV-B lamps and UV-B exclusion experiments using thin polyester filter.

Effect of enhanced UV-B radiation on the morphological development has been studied in many plants, e.g., in wheat (*Triticum aestivum*), soybean (*Glycine max*), poplar (*Populus cathayana* and *P. deltoids*), *Lolium perenne*, mulberry (*Morus alba*), cotton (*Gossypium* sp.) etc. (Bassman *et al.*, 2001; Zhao *et al.*, 2003; Yang *et al.*, 2005; Xu *et al.*, 2010; Comont *et al.*, 2013; Liu *et al.*, 2013). UV-B has long been considered an abiotic stress for plants leading to reduced biomass accumulation, DNA-damage, photosynthetic impairment, damage to the photosystem I (PS

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I) and photosystem II (PS II) proteins and lipid peroxidation (Tevini & Teramura, 1989; Jansen *et al.*, 1998; Kakani *et al.*, 2003; Ballaré *et al.*, 2011), but at lower levels it has also been reported to have some desirable effects on various crops, like grapevine, enhancing secondary metabolism, reducing vegetative growth and decreasing pathogen incidence (Rusjan, 2012; Martínez-Lüscher *et al*., 2014). Elevated UV-B radiation can delay flowering time in several different crops (Kakani *et al*., 2003a; Singh *et al*., 2008a). In regard to exposure to UV-B radiation, the majority of crop species (60%) show a reduction in dry matter production, a moderate 24% show no change, and only 8% of crop species show an increase in dry matter production (Kakani *et al*., 2003a). In most plant species, leaves exposed to UV-B radiation initially develop irregular patches. With continued exposure to UV-B radiation, these chlorotic patches become brown necrotic spots and die (Singh *et al*., 2008a). The appearance of chlorotic and necrotic patches is generally attributed to decreases in leaf chlorophyll content (Zhao *et al*., 2003).

Ricinus is a monotypic genus in the family comprising of only one species, *Ricinus communis* L. It comes under the subfamily Acalyphoideae. The species is widely distributed in the tropical and sub-tropical regions around the world, and is probably indigenous to the SW Mediterranean Basin, Eastern Africa and India (Qiu *et al.*, 2010). This plant is commonly known as 'Arandi' or 'Castor bean plant'. It is found almost throughout India in wild, waste land and in cultivation, from tropics to higher sub-montane region upto 2000 m a.s.l. Castor is one of the oldest cultivated oilseed crops, dating back even before 2000 B.C., with important applications in industry, pharmaceutical and agricultural sectors (Kodjo *et al*., 2011). Its oil is unique among vegetable oils because the oil is the only commercial source of hydroxylated fatty acid *i.e.*, ricinoleic acid (Ogunniyi, 2006). Stem, seeds, leaves, fruit and bark of this plant are used in different traditional therapeutic practices by local practitioners.

R. communis plant extract is found to have UV-protective effect on Plasmid pBR^{322} DNA (Abbas *et al.*, 2018). The oil extracted from the castor seeds showed potential in UV-protection property (Azevedo *et al.*, 2013; Klöcking *et al.*, 2013; Uniyal and Dangwal, 2020). Though being a plant of interest due to its medicinal and potential UV-screening properties, the studies on the effects of UV-B exposure on the development of *R. communis* plant has not been approached yet. The present experiment was designed to examine the effect of enhanced UV-B radiation on different morphological traits of the vegetative phase of the life cycle of castor oil plant. The development of the plant was studied from the seedling stage to the onset of flowering. Plants are grown in an outdoor setting to obtain more realistic and balanced ratios of UV radiation/PAR.

Experimental site

The present study was carried out for a time period of 20 weeks in the premises of H.N.B. Garhwal University (S.R.T. campus), Badshahithaul, Tehri Garhwal, Uttarakhand. The campus is located in the temperate zone at an elevation of approximately 5600 ft. a.s.l. The region has relatively drier and colder climate, and receives higher levels of solar UV radiation.

Methodology

Plants were grown in two separate open plots – one grown under ambient solar radiation and other received ambient + elevated UV-B radiation. Enhanced UV-B was artificially supplied by UV-B fluorescent lamps (Philips UV-B narrowband tubelight, 40 W) held over the plant canopy at a distance of 40 ± 5 cm. These UV-B tubes were covered with cellulose diacetate filter (changed every week) to filter out lower wavelength (less than 280 nm) radiation. Plants were irradiated for 4 hrs. per day between 11:00 a.m. to 3:00 p.m. Intensity of UV radiation were measured with UV radiometer. Five plant samples were selected randomly and their plant growth analysis was done taking into consideration these 9 parameters: plant height, stem base circumference, no. of nodes on main stem, no. of branches on main stem, average internodal length of 3 random internodes on main stem, no. of leaves, average no. of veins on three larger leaves, average mid-vein length of 3 larger leaves and inflorescence length. The readings were taken from the seedling stage till the onset of flowering investigating the vegetative growth of the plant for a period of 20 weeks (28 June 2021 – 8 November 2021) on a weekly basis.

Results

We had investigated nine different morphological aspects of plant growth and development under ambient light condition and elevated UV-B exposure for a time period of 20 weeks. The effects of the enhanced UV-B in castor oil plants were morphologically observable within 3 to 5 weeks of exposure. Changes in the studied morphological parameters are described below:

1. Plant Height

Decrease in plant height was observed in case of supplemental UV-B exposure [Fig. 1(A)]. A significant decrease in plant height was observed from 12th week onwards. This might be due to the inhibitory effect of UV-B stress on apical meristem activity, negatively affecting the rate of cell division. The maximum height attained by the plant in ambient light condition was 388.7 cm while the plant under high UV-B radiation attained a maximum height of 315.8 cm. The average plant height on the 20th week was 380.4 ± 8.89 cm and 310.26 ± 4.93 cm in the ambient and enhanced UV-B treatments respectively.

2. Stem base circumference

We observed a small increase in the stem base circumference in the samples grown under the elevated UV-B stress [Fig. 1(B)]. The change was not very notable compared to the ambient light treatment. The maximum circumference obtained by the plant under elevated UV-B was 17.4 cm and the plant under ambient light was 16.8 cm. The average stem base circumference on the last week was 17.08 ± 0.22 cm for the enhanced UV-B condition and 16.4 ± 0.38 cm for the ambient light condition.

3. No. of nodes on main stem

Under enhanced UV-B, no. of nodes was increased [Fig. 1(C)]. No. of nodes on the main stem had shown notable incline from the 8th week of high UV-B exposure. The maximum no. of nodes found in plants under enhanced UV-B condition was 62 and the maximum nodes found in plants under grown in ambient light condition was 61. The average value was 60.4 ± 1.14 for elevated UV-B treatment and 58.2 ± 3.11 for the ambient light treatment.

4. Internodal length

Average internodal length of random three internodes from the main stem from each sample was recorded on a weekly basis. Enhanced UV-B resulted in slower stem extension rates and thus decrease in average internodal length [Fig. 1(D)]. Average internodal length seemed to decrease from the 2nd week of higher UV-B exposure. The maximum internodal length was 9.7 cm and 7.7 cm for the ambient solar radiation and enhanced UV-B respectively. The average value for the internodal length for the ambient light treatment was 8 ± 1.34 cm and for the enhanced UV-B treatment was 6.08 ± 1.27 cm.

5. No. of branches on main stem

An increase in the no. of branches on the main stem of plants under high UV-B stress was seen [Fig. 1(E)]. Elevated UV-B exposure led to increase in the lateral growth of the plant. The no. of branches increased crucially from the 7th week of higher UV-B irradiation. In the ambient light treatment, the maximum no. of branches attained was 65 and the average value was 55.2 ± 8.53. In elevated UV-B treatment, the maximum no. of branches attained was 71 and the average value on the 20th week was 68.2 ± 2.95.

6. No. of leaves

Total no. of leaves was counted weekly and the result showed notable increase in the no. of leaves from 10th week of enhanced UV-B irradiation [Fig. 1(F)]. In the ambient solar radiation, the maximum no. of leaves observed was 129 and the average value was 118.8 ± 9.71. In the elevated UV-B treatment, the maximum no. of leaves recorded was 144 and the average value was 122.4 ± 18.64. Also, the leaves exposed to higher level of UV-B had several chlorotic spots showing the stressful nature of the radiation.

6. No. of veins

Average no. of veins of random three larger leaves from each sample was observed. No. of veins in leaves were comparatively developed faster in the enhanced UV-B set-up [Fig. 1(G)]. The development of veins in leaves under higher UV-B stress, though being earlier in comparison to the one in the ambient light conditions, was not a significant change.

7. Mid-vein length

Average mid-vein length of randomly selected three larger leaves from each sample was measured. The average mid-vein length of the leaves was increased in enhanced UV-B set-up [Fig. 1(H)]. The comparatively significant change in the mid-vein length was seen from the 6th week of higher UV-B irradiation. In the ambient light condition, the maximum value was 51 cm and the average value was 44.62 ± 5.05 cm. In the enhanced UV-B condition, the maximum value was 59 cm and the average value was 56.72 ± 2.31cm.

8. Inflorescence length

We have also explored the first few weeks of development of inflorescences in both the set-ups – ambient light condition and enhanced UV-B exposure. We found decrease in the rate of inflorescence development under enhanced UV-B stress [Fig. 1(I)]. The incident of first inflorescence in the ambient light condition was on 11th week while in the elevated UV-B set-up was 13th week. Also, the length of inflorescences was comparatively more in the ambient light condition than in the enhanced UV-B experiment.

Discussion

In *Ricinus communis* L., elevated UV-B irradiation seemed to inhibit the apical growth of the plant resulting from slowing down the rate of cell division in apical meristem. On the other hand, the lateral growth was increased making a comparatively wider plant canopy than in ambient solar radiation. This may be indicative of failure of the UV-B stress to attenuate the activity of axillary meristem. The photosynthetic efficiency was negatively influenced as observable through development of leaf chlorotic spots and leaf curling. This is attributed to damage to chloroplasts present in leaves by the penetrating UV-B radiation. There are also chances of further DNA and/or protein damage in the plant cells. But, though being under such high UV-B stress, the plant had the ability to cope with the stress by increasing the no. of branches, no. of leaves and leaf length in its vegetative phase of life cycle. This was probably done to increase the deteriorating photosynthetic activity of the plant. As a result, since most of the energy produced was being employed in increasing the photosynthetic activity and DNA and protein damage-repairing mechanisms, we observed delayed development of inflorescence in the plants under enhanced UV-B stress. Further the flowering and post maturation stages of the plant will be studied for the complete understanding of the impact of the elevated UV-B stress on the morphological traits of *Ricinus communis* L.

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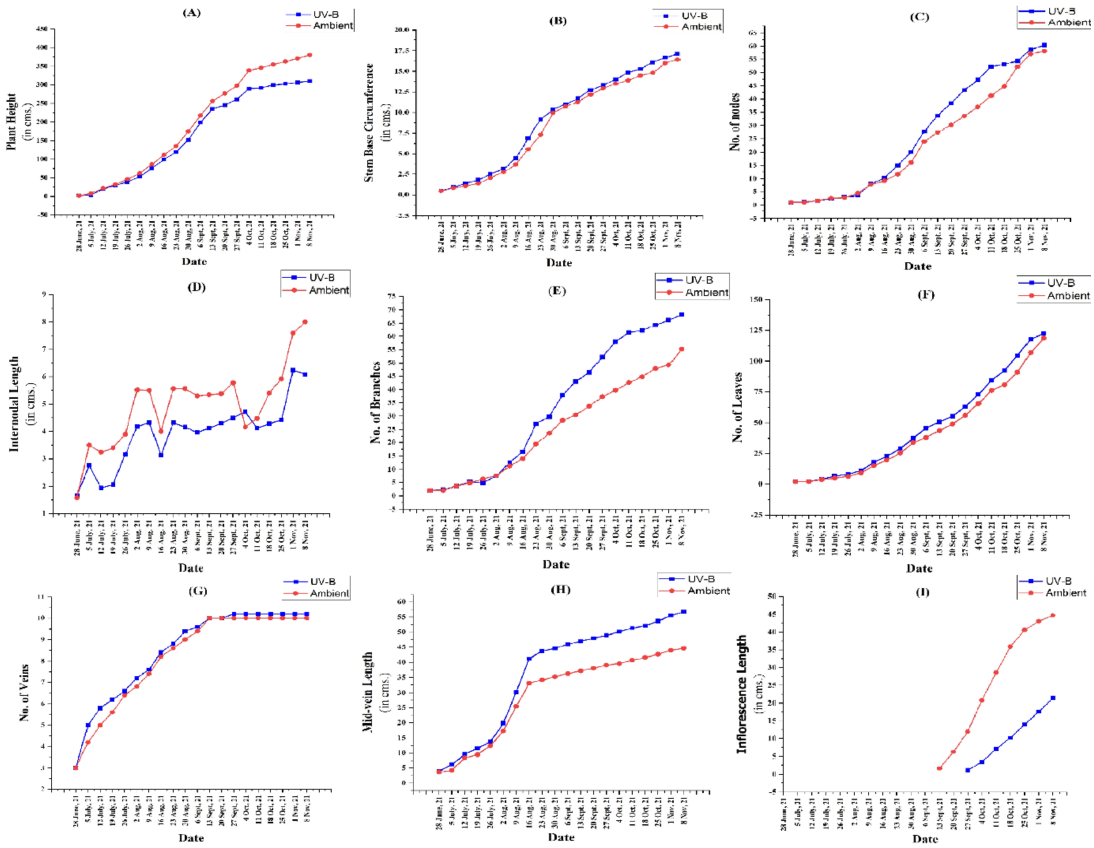

Fig. 1: Graphs showing comparative morphological difference between plants grown under ambient solar condition and that grown under enhanced UV-B radiation

The UV-B stress suppressed the apical growth of the plant which is in turn compensated with the promotion of lateral growth instead. Supplemental UV-B lead to increase in the lateral growth of the plant by increasing stem base circumference, and the no. of nodes, branches and leaves. This was mainly for increasing the photosynthetic efficiency of the plant. This might all be due to the plant focusing on increasing the photosynthetic efficiency, which was deteriorated because of photosystem damage or chloroplast destruction. Most of the energy is lost in enhancing the photosynthetic factors and repair mechanisms, leading to delayed inflorescence development in the higher UV-B exposed plants. Overall, these morphological changes resulted in shorter plants but comparatively larger plant canopy. Larger plant canopy is in contrast to the general response of different plants from other enhanced UV-B studies. The possible reason for this is that the plant was able to adapt and modify its morphological traits so as to increase the photosynthetic efficiency to survive.

Conclusion

UV-B radiation is an important environmental stress that significantly influences that plant growth and development. *Ricinus communis* L. seemed to be stress-tolerant towards higher UV-B irradiation. Increased UV-B dose have resulted in lateral development of plant, while suppressing the apical growth. Most of the energy is lost in enhancing the photosynthetic factors and repair mechanisms, leading to delayed inflorescence development. Though higher UV-B had resulted in shorter plants, delayed inflorescence development and chlorosis in leaves, the plants were able to cope with the damage by increasing the branching, no. of nodes and leaves, leaf length and faster development of leaf veins. Further investigations on physiological and biochemical effects of enhanced UV-B are needed for better understanding of the impact of elevated UV-B on *Ricinus communis* L. Authors also suggest to examine the effect of UV-B exclusion experiment in the plant for the complete profile of the effects of UV-B stress on castor oil plant. These studies will be useful for enhancing agricultural yields in the upcoming changes in global UV-B levels. Future changes in UV radiation in combination with other global change factors, including increased atmospheric carbon dioxide, temperature, drought and nitrogen deposition will be another important challenge of the future, which influence the protective and repair systems under conditions of present-day and predicted UV-B levels. Further investigations are needed to realize these possibilities.

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