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Effects of Ultraviolet-B Radiation on the Photosynthetic Pigments and Protein Content of Strawberry

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Authors' contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The effects of ultraviolet-B (UV-B) radiations were studied on strawberry. The transplanted plants were irradiated with UV-B (280-320 nm) for 30, 60, 90 and 120 minutes on 20th, 40th, and 60th days after transferring. The enhanced UV-B radiation caused a negative effect on photosynthetic pigments and protein content of strawberry. Distinct decreased as a result of UV-B irradiation in contents of chlorophyll *a*, chlorophyll *b*, carotenoids and protein content was observed in strawberry. The impact of increase of duration of UV-B irradiation was also observed and found to be directly proportional.

Keywords: Photosynthetic pigment; protein; UV-B; strawberry (Fragaria ananassa).

1. INTRODUCTION

A decrease (1%) in ozone layer will cause an increase (2%) in UV-B radiation. The intensity of UV radiation reaching the earth's surface depends on many factors, the most important of which are: The time of year and day i.e. the distance of sun from the earth, latitude and

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altitude. UV radiation (UVR) constitutes approximately 5% of the solar radiation that reaches the earth's surface. UVR constitutes UV-A, UV-B, and UV-C. Of the solar UV energy reaching the equator, 95% is UV-A, and 5% is UV-B. No measurable UV-C from solar radiation reaches the earth's surface, because the shortest UV wavelengths are completely absorbed by ozone, molecular oxygen, and water vapour in upper atmosphere. The last two decades have witnessed a decrease in ozone concentration within the stratosphere which has resulted in more UV-B radiations reaching the earth surface. Studies have shown that penetration of harmful UV-B radiations have caused deleterious biochemical as well as physiological effects on plants. These effects are mainly due to the absorption of these radiations by proteins, nucleic acids and lipids, which have resulted in reduced photosynthesis, growth and biomass accumulation in plants [1]. Ever since the appearance of ozone hole over the Antarctic in early 1980s, many studies pertaining to the effect of increased UV-B radiation have been conducted. The studies have shown the alteration in chloroplast and thylakoid membrane [1], reduced ribulose 1,5 bisphosphate carboxylase/oxygenase (RUBISCO) activity, changes in functioning of the photosystem II (PS-II) reaction center and oxygen evolving complex [2] and stomatal closure are important mechanisms through which UV-B radiation led to reduced photosynthesis. Enhanced UV-B radiation causes structural, physiological, bio-chemical and molecular changes in plants. UV-B radiation affects plants in several ways e.g. by impairment of decrease in protein synthesis and lowering of m-RNA levels of photosynthetic genes [3]. UV-B exposure also resulted in regulation of genes involved in the synthesis of phenolic compounds. Since global warming and changing environmental conditions are leading to higher incidence of UV-B radiation on the earth's surface, this will be an important additional stress for the development of cash crops and it may have serious economic implications. Increased UV-B radiation may include detrimental changes to plants' anatomical features, photosynthesis, biomass and flowering, although some of the changes may be taken as positive responses for some plants [4]. It has been reported that photosynthesis and photosynthetic productivity of some higher plants are vulnerable to increased UV-B radiation [5,6]. It has been seen that water oxidizing complex (WOC) is the most sensitive target of UV-B damage in PS-II [7]. It has also been noticed that UV-B impact on RUBISCO results in break down products, 66 Kilo Dalton is the result of tryptophan photolysis under UV-B exposure. Both subunits of RUBISCO contain tryptophan [8]. Thus study is aimed to study the effects of UV-B radiation on the photosynthetic pigments and protein content of strawberry plant.

2. MATERIALS AND METHODS

The experiment was performed at the Department of Biological Sciences of Allahabad Agricultural Institute Deemed University, Allahabad (UP) situated in the eastern Gangetic plains of India at 24°97'N latitude and 82°21' longitudes and 96 m above mean sea level. The variety of strawberry used in this study is *"Sweet charlie"*. Soil and farmyard manure (FYM) was sieved and mixed in 3:1 ratio, respectively. In each pot 4 Kg of this mixture was added and before transplanting, urea, phosphorus and potash were mixed in 1:1:2 ratio. A spray of Dithan M-45 (0.2%) was given to each pot. UV-B exposure was provided artificially by Q panel UV-B 313 fluorescent lamps (Q panel, Cleveland, Ohio, USA) in UV-B chamber. Plants were kept at 30 cm distance from the UV source and irradiated at 20^{th}, 40^{th}, and 60^{th} day after transferring for 30, 60, 90 and 120 minutes to maintain an overall dosage of 20J/square which is optimal for viability.

2.1 Estimation of Chlorophyll

The chlorophyll was estimated following the method of Arnon [9]. Fresh leaves (0.1 g) were homogenized thoroughly in 10 ml of 80% acetone, and centrifuged at 6000 rpm. The supernatant was collected and the absorbance was recorded at 663 and 645 nm. The chlorophyll *a* and *b* were quantified by using the following formula.

$$\text{Chlorophyll } a = 12.7\,(A_{663}) - 2.60\,(A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll } b = 22.9\,(A_{645}) - 4.68\,(A_{663}) \times \frac{V}{1000 \times W}$$

Where,

V= Volume of acetone
W = Fresh Weight of sample
A_{663} = Absorbance at 663nm.
A_{645} = Absorbance at 645nm.

Chlorophyll was expressed as mg/g Fresh Weight.

2.2 Estimation of Carotenoids

The carotenoids were determined according to Duxbuy and Yentshe [10]. Leaves (0.1 g) were homogenized in 10 ml of 80% acetone, and centrifuged at 6000 rpm. The absorbance of clear supernatant was recorded at 480 and 510 nm. Carotenoid was quantified by using following formula:

$$\text{Carotenoid} = \frac{7.6\,(D_{480}) - 1.49\,(D_{510})}{d \times 1000 \times W} \times V$$

Where,

V= Volume of acetone
d = Length of cuvette.
W = Fresh Weight of sample.

The amount of carotenoid is expressed as mg/g fresh weight of leaves.

2.3 Protein

Protein was estimated following the method of Lowry et al. [3].

Extraction of protein: Sample (100 mg) was homogenized with the help of pestle and mortar in 5 to 10 ml of phosphate buffer (pH-7). The sample was harvested by centrifugation and the supernatant was used for protein estimation.

2.4 Statistical Analysis and Presentation of Data

The data were analysed statistically as suggested by Prof. R. A. Fisher [11]. The results were interpreted on the basis of 'F' test and critical difference (at 5% level between means). ANOVA table was used for testing the hypothesis.

3. RESULTS AND DISCUSSION

Chlorophyll *a*, *b* and carotenoid decreased non-significantly in all UV-B irradiated plants compared to controls (Table 1).

Chlorophyll and carotenoids are the central parts of the energy manifestation of virtually every green plant system and any alteration in their levels is likely to cause a marked effect on the entire metabolism of the plant. Earlier reports suggested that UV-B may modify the amount of photosynthetic and accessory pigments. Deleterious UV-B effects may be largely partitioned between damage to plant genome and photosynthetic machinery [12]. Almost every facet of the photosynthetic machinery can be damaged directly by UV-B exposure.

Several studies have demonstrated that PS-II, component of the photosynthetic apparatus is most sensitive to increased UV-B radiation [13] while others suggested that UV-B radiation inhibits photosynthesis without an appreciable effect on PS-II photochemistry [14,15]. Various other reports also suggested decrease in chlorophyll and carotenoids contents in plants when exposed to enhanced UV-B radiation [16-20]. However, there are few reports suggesting increase in the chlorophyll content [21-23]. Reduction in chlorophyll content (Figs. 2, 3) may be due to degradation of chlorophyll and their precursors. Combined effect of UV-B radiation on various parameters of strawberry plant is referred to in Fig. 1.

Table 1. Photosynthetic pigments and protein content of strawberry under enhanced levels of UV-B radiation

UV-B treatments (min)	Chl *a* (mg/g FW)	Chl *b* (mg/g FW)	Carotenoid (mg/g FW)	Protein (mg/g FW)
0	2.83 (±0.09a)	1.82 (±0.07a)	0.565 (±0.08a)	0.804 (±0.05b)
30	2.76 (±0.09a)	1.71 (±0.07a)	0.539 (±0.08a)	0.698 (±0.05b)
60	2.66 (±0.09a)	1.71 (±0.07a)	0.464 (±0.08a)	0.686 (±0.05b)
90	2.66 (±0.09a)	1.65 (±0.07a)	0.461 (±0.08a)	0.624 (±0.05b)
120	2.56 (±0.09a)	1.64 (±0.07a)	0.452 (±0.08a)	0.608 (±0.05b)

Each value is the mean of 4 measurements ± S.E. Mean in each column for each treatment followed by the letter a are not significantly different and letter b are significantly different at P ≤ 0.05 according to Prof. R.A. Fisher [11] 'F' test. FW= Fresh weight

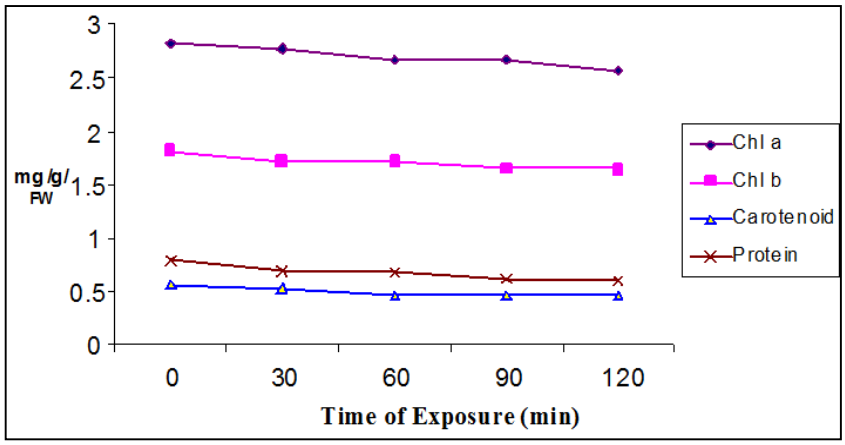

Fig. 1. Contents of strawberry plant as affected by UV-B Radiations (intensity 0.4 w/m^2)

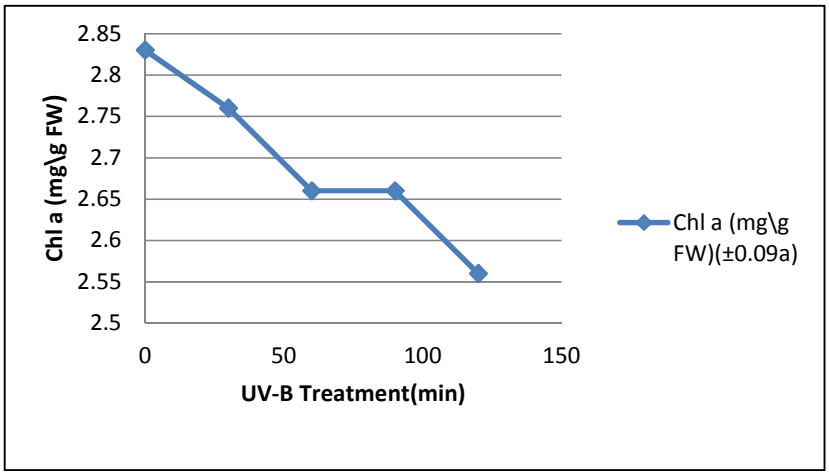

Fig. 2. Graph showing Chl a concentration vs UV treatment

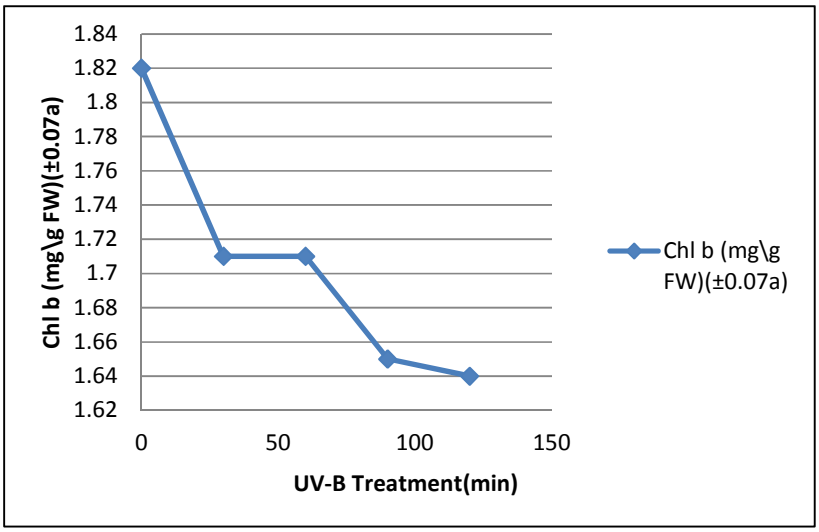

Fig. 3. Graph showing Chl b concentration vs UV treatment

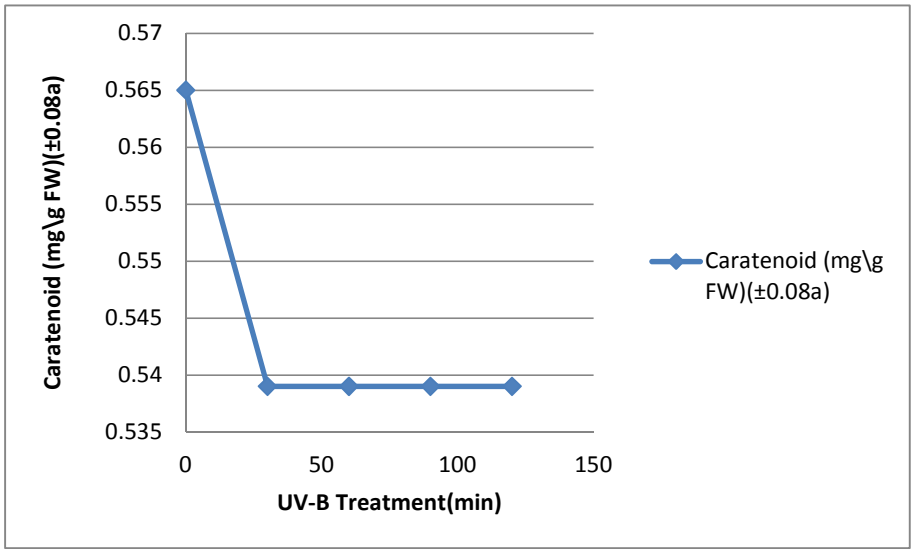

Fig. 4. Graph showing Carotinoid concentration vs UV treatment

Carotenoids protect chlorophyll from photo-oxidative destruction and therefore reduction in carotenoids (Fig. 4) could have serious consequence on chlorophyll pigments.

Reduction in carotenoid content (27%) in *Sorghum vulgare* plants was recorded after 60 days of UV-B exposure [24]. Under high light regime, carotenoids play an important role in protecting the photosynthetic apparatus against oxidative damage. Carotenoids stabilize and protect the lipid phase of the thylakoid membrane and are quenchers of the excited triplet state of chlorophyll and singlet oxygen. It was supported by our findings that plants after UV-B exposure showed reduced carotenoid contents and faced oxidative stress.

Protein content of leaf (Table 1) decreased significantly under UV-B treatments (Fig. 5).

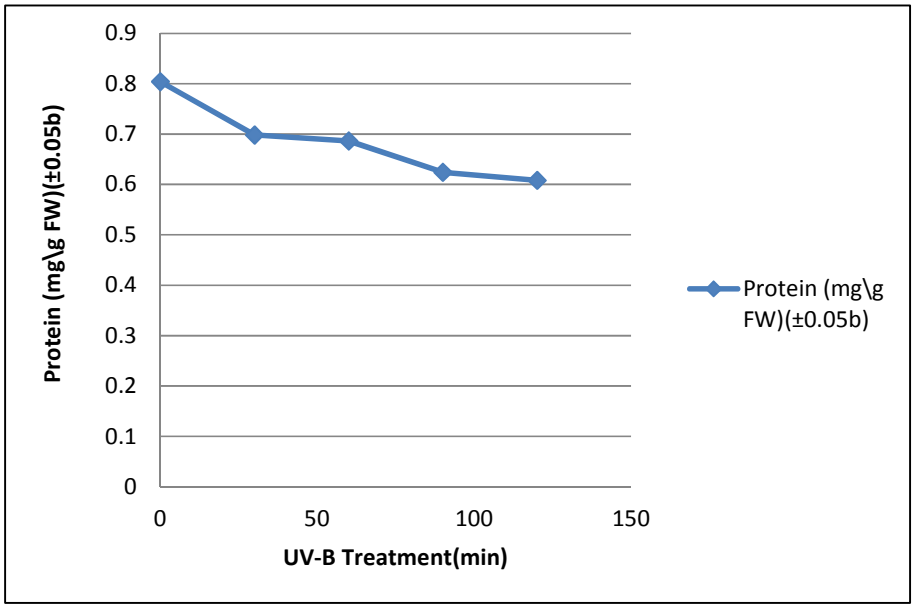

Fig. 5. Graph showing protein content concentration vs UV treatment

Oxidative stress caused by UV-B radiation induced the degradation of a variety of biologically important molecules such as amino acid, nucleic acids, lipids proteins and quinines [25,26]. Leaf soluble protein content was affected in many of the crop species tested for UV-B sensitivity. Ravindran et al. [14] reported 54.7% reduction in protein content of *Suaeda maritimea* seedling due to enhanced UV-B. A significant reduction in total leaf soluble protein also was observed in UV-B exposed leaves of mung bean plants [27].

4. CONCLUSION

UV-B radiations caused severe effects on the physiology of the strawberry plant. The photosynthetic pigments *Chl a, Chl b* and *carotenoids* were distinctly decreased and protein content also suffered a major decrease on account of UV-B radiations. It was further noticed that as the duration of exposure to UV-B radiations was increased, its damaging effects also increased showing that if the current environmental conditions persist and if the induction of UV-B radiations on earth continues, physiology of many plants may be affected in an irreversible manner.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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