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ISSN No: 2319-5886

International Journal of Medical Research & Health Sciences, 2021, 10(6): 94-102

Effect of Ultraviolet Radiation on Growth, Structure, and Bio-contents of *Foeniculum vulgare*

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ABSTRACT

Morphological traits such as growth, shape, and weight, internal structure like order and position of chemical compound and bio-contents such as enzymes, vitamins, and antioxidant activity for normal and irradiated Foeniculum vulgare were studied. The growth of Foeniculum vulgare is affected by exposure to UVC. The volumetrical shape of the Foeniculum vulgare also decreased by exposure to UVC. Continuous increase in enzyme activity, tocopherol content, vitamin C, total phenol content, and antioxidant activity for the Foeniculum vulgare by increased the exposure time to UVC up to 3 hours then declined in the fourth hour.

Keywords: *Foeniculum vulgare,* UVC, Molecular structure, Antioxidant activity, Phenol, Vitamins

INTRODUCTION

Foeniculum vulgare is a flowering plant species in the carrot family. *F. vulgare* has been reported to contain 6.3% of moisture, 9.5% protein, 10% fat, 13.4% minerals, 18.5% fiber, and 42.3% carbohydrates. Ultraviolet (UV) constituted approximately 8%-9% of total solar radiation and considers a part of non-ionizing rays of the electromagnetic spectrum region [1,2]. Plants sensitive to UV may also respond by accumulating UV absorbing compounds in their outer tissue layers, which presumably protect sensitive targets from UV damage. The key enzymes in the biosynthetic pathways of these compounds are specifically induced by UV irradiation *via.* gene activation [3]. UV radiation above ambient may inhibit plant growth, development, and reproduction and depress photosynthesis [4,5]. UV in the range 2800 Å-4000 Å as a small fraction of the solar radiation reaching the terrestrial ecosystems is an important modulator of plant physiology [6]. The physiological, biochemical processes, leaf chlorophyll, protein content, and peroxidase enzyme activity in plants can be affected by ultraviolet C radiation [7,8]. The effect of UVC on the germination percentage, germination rate, radicle length, and plumule length of maize and sugar beet seeds has been reported [9]. Also, UVC radiation was shown to increase the germination percentage of the groundnut [10]. Nonetheless that UVC radiation did not significantly affect the germination percentage of *Acacia* ampliceps seeds [11]. The influence of UVC on growth behavior, internal structure, enzymes, and free radical of *Nigella sativa* has been studied [12]. Also, the UVC radiation effect on the morphological and secondary metabolites content of garden cress is studied and analyzed [13]. Different organic compounds, antioxidant activity and vitamins content of *Ammi majus* changed after exposure to UVC radiation for different times and dissimilar distances [14]. This research aims to study the effect of ultraviolet C on morphological and internal structure and bio-contents such as enzymes, vitamins, and antioxidant activity for *Foeniculum vulgare*.

MATERIAL AND METHODS

The pure seeds of *Foeniculum vulgare* are received from the Egyptian ministry of agriculture. The irradiated used system consists of a fluorescent lamp (Type-C with λ from 2000 Å-2800 Å), its power equal to 15 watts. Also, the system was covered totally with aluminum foil to illuminate the sample from all sides. The internal structure of *Foeniculum vulgare* was studied by PANalytical X`Pert PRO XRD device, using Cu K_{α} target with secondary monochromatic (where λ=1.540 Å, the tube operated at 45 kV-40 mA (Holland), the Bragg's angle (2θ) in the range

of 5°-80°). The molecular structure of *Foeniculum vulgare* was studied using Nicolet™ iS™ 10 FT-IR Spectrometer from the USA. Absorption of extracted *Foeniculum vulgare* is measured by UV-2100 Spectrophotometer.

Preparation of Plant Extracts

Sample (1 g) of *Foeniculum vulgare* is extracted in different solvents with 80% ethanol, 80% methanol, 80% acetone, ethyl acetate, and distilled water with a ratio of 1:10. The mixture was then centrifuged at 5000 rpm for 20 min and the supernatant was decanted into a 15 ml vial. The pellet was extracted under identical conditions. The supernatants are combined and used for meaning the antioxidant compounds and antioxidant activity. Vitamin C (ascorbate) content is determined by the method of Hodges, et al. [15]. The absorbance was measured at 525 nm. The content of α-tocopherol (Vitamin E) is estimated according to Hira, et al. [16]. The absorbance was measured spectrophotometrically at 460 nm. Total Phenolic Content (TPC) in leaf extracts is determined by the method of Singleton and Rossi using the Folin-Ciocalteu colorimetric method and the absorbance was taken at 500 nm spectrophotometrically [17]. SOD activity is measured according to Dhindsa, et al. [18]. The absorbance was measured at 560 nm. APX activity is determined following the method of Nakano and Asada, depending on measuring the rate of ascorbate oxidation at 290 nm [19]. GR is assayed according to the method of Goldberg and Spooner [20]. The GR activity in the sample is directly proportional to the change in the absorbance at 340 nm.

RESULTS AND DISCUSSION

X-ray Analysis

X-ray diffraction patterns of *Foeniculum vulgare* seeds before and after exposure to UVC for different times at 5 cm distance are shown in Figure 1. The analysis listed in Table 1 shows, started baseline and area under the peak is changed after exposure to UVC for 1 h, 2 h, 3 h, and 4 h at a 5 cm distance. That is meant, an internal structure such as ordered and linked molecules of *Foeniculum vulgare* changed by exposure to UV radiation. These molecules absorb energy from UV caused vibrated or break bonds linked it. Also, these results agree with our previous studies [12-14].

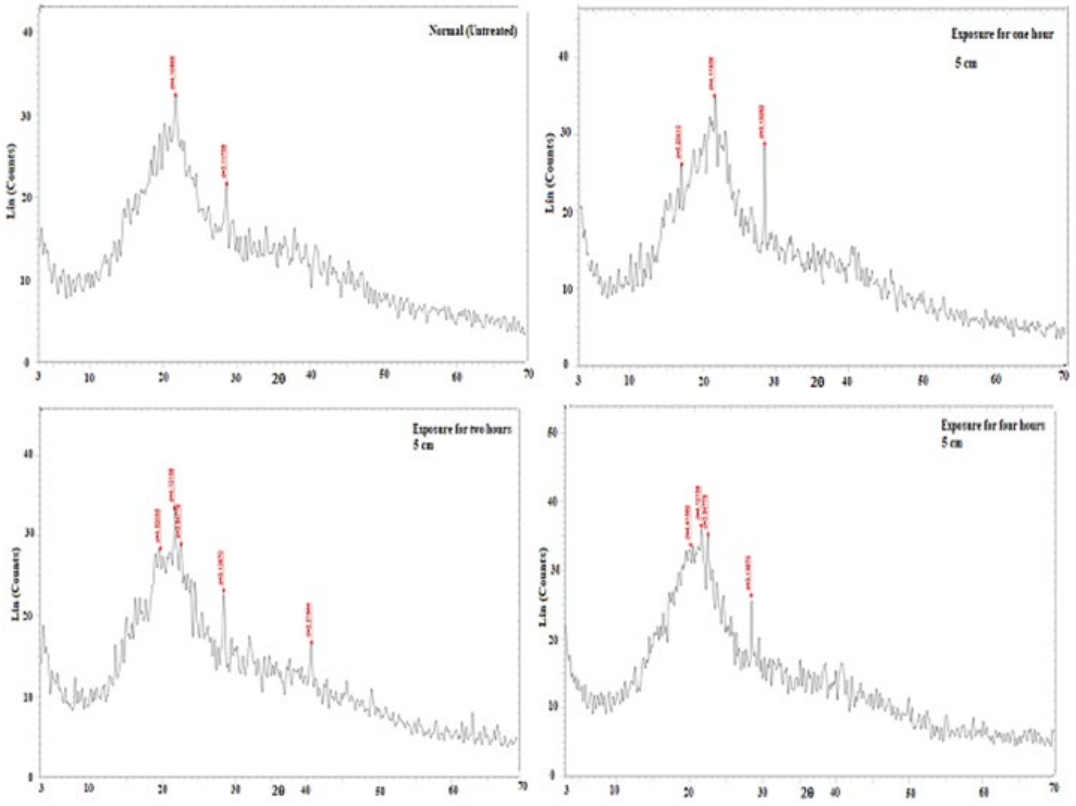

Figure 1 X-ray diffraction patterns for *Foeniculum vulgare*

Table 1 X-ray data for normal and irradiated *Foeniculum vulgare*

	d Å	2 θ	Int. counts	Area	FWHM
Normal	4.10865	21.612	32.1	6.1	0.572
	3.11758	28.61	21.3	4.9	0.414
One hour 5 cm	4.11939	21.555	34.7	356.8	11.21
	3.13292	28.467	28.5	2.4	0.187
Two hours 5 cm	4.12158	21.543	33.2	125.8	6.45
	3.1397	28.404	22.8	2.62	0.29
Four hours 5 cm	4.12158	21.543	36.1	193.95	8.196
	3.1397	28.404	25.9	4.3	0.24

IR Analysis

Figure 2 shows the relation between wavenumber (X-axis) and % transmittance (Y-axis) for normal and irradiated *Foeniculum vulgare* for one, two, three, and four hours at a 5 cm distance. IR spectrum analysis for *Foeniculum vulgare* from device shows that % transmittance at position 1040 cm^{-1}, 1649 cm^{-1}, 2924 cm^{-1}, and 3421 cm^{-1} changed after exposure to UVC. That is means, a molecular structure such as C-C bond at 1649 cm^{-1}, C-H bond at 2924 cm^{-1}, and O-H bond at ~3421 cm^{-1} bonded of *Foeniculum vulgare* changed after exposure to UVC. These results revealed that these molecules absorb energy from UV which caused vibrated or break bonds linked it, produced its position, intensity and broadness change. Also, these results agree with our previous studies [12-14].

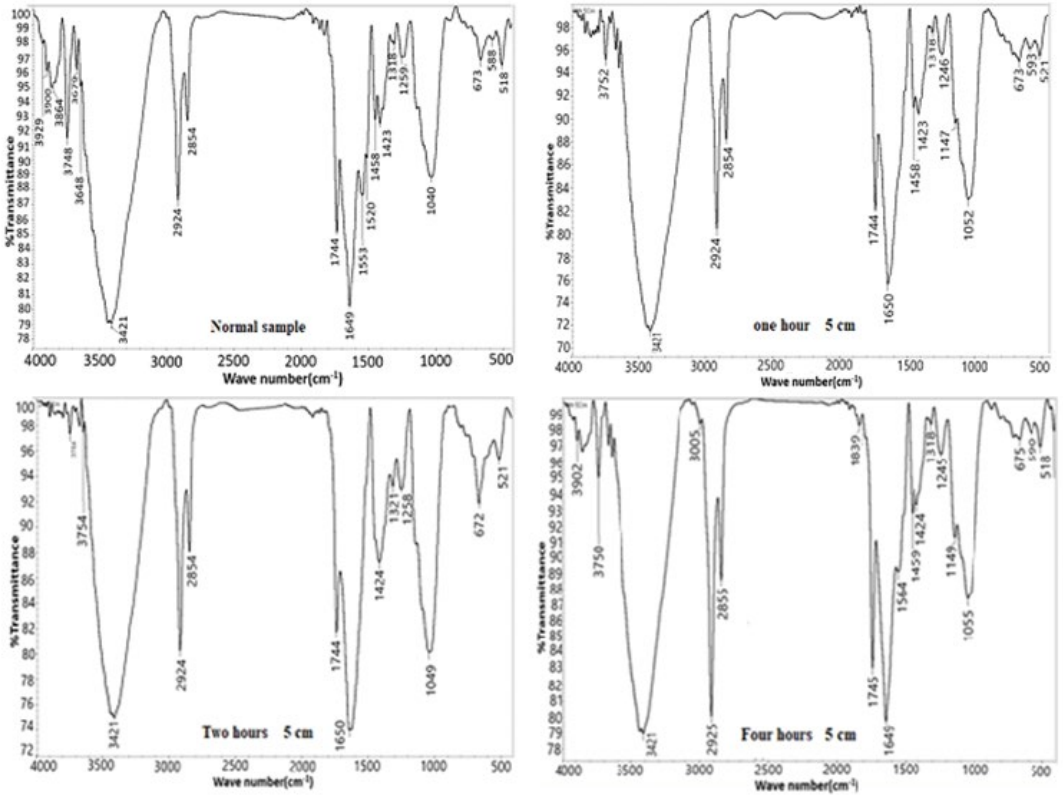

Figure 2 IR spectra of *Foeniculum vulgare* before and after exposure to UVC

Antioxidant Activity of Methanol Extract from *Foeniculum vulgare*

Foeniculum vulgare is exposed to UVC and the antioxidant activity is determined using DPPH assay. Therefore,

extracts are prepared in methanol, ethanol, ethyl acetate, and acetone solvents. The antioxidant activity of different extracts from *Foeniculum vulgare* exposed to UVC at 5 cm for 1 h, 2 h, 3 h, and 4 h is shown in Figure 3. The results indicate, continuous increase in the antioxidant activity throughout the four hours of exposure at each concentration of (20, 40, 60, 80, and 100) µg/ml. Also, the increase in the antioxidant activity was continuous until 3h, then decreased after the fourth hour.

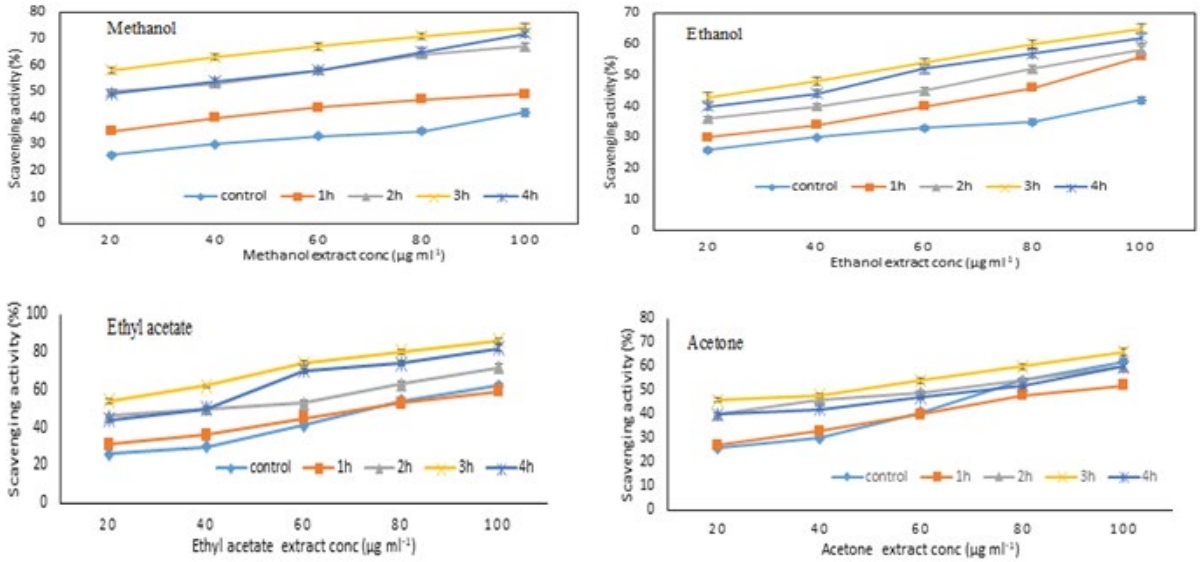

Figure 3 Antioxidant activity of methanol, ethanol, ethyl acetate, and acetone extract from *Foeniculum vulgare*

Total Phenol Content of Methanol Extract from *Foeniculum vulgare*

The results in Figure 4 show the continuous increase in total phenol content in the methanol, ethanol, ethyl acetate and acetone extract throughout the first three hours for 5 cm and 20 cm distances exposure respectively. However, after the fourth hour, the total phenol content declined. It should be stressed the fact that the total phenol content in *Foeniculum vulgare* is higher after exposure to UVC at 5 cm than that at 20 cm distances. This phenomenon was repeated throughout the exposure periods.

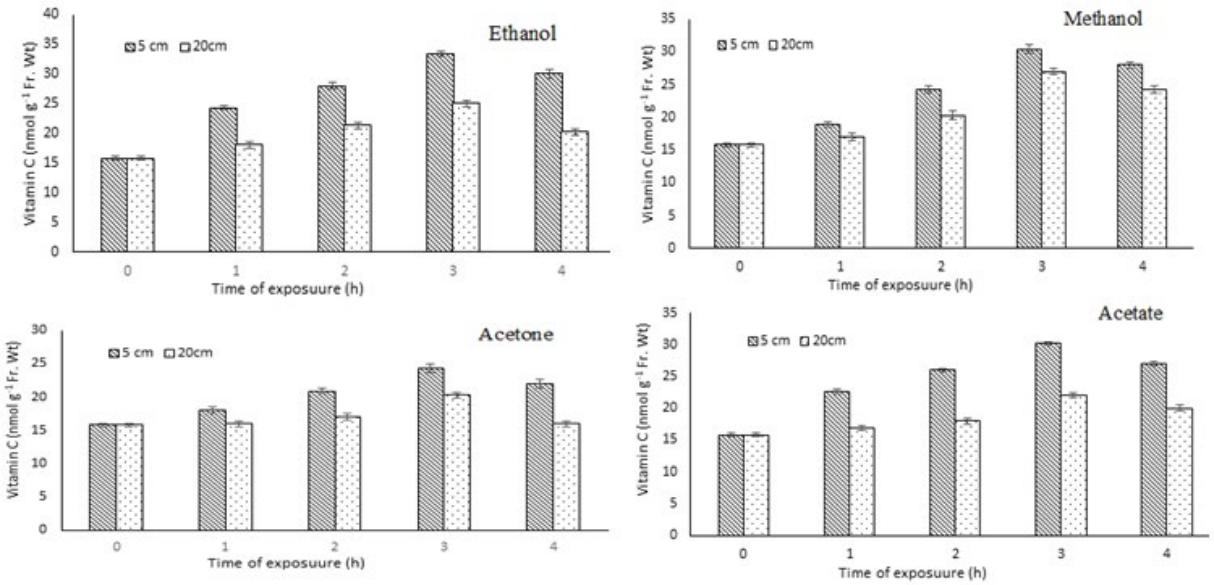

Figure 4 Total phenol content of methanol, ethanol, ethyl acetate, and acetone extract from *Foeniculum vulgare*

Vitamin C Content of Methanol Extract from *Foeniculum vulgare*

Vitamin C content of methanol, ethanol, ethyl acetate, and acetone extract from *Foeniculum vulgare* exposed to UVC at 5 cm and 20 cm recorded in Figure 5 indicate continuous increase after exposure to UVC for 1 h, 2 h, and 3 h but the fourth hour the Vitamin C content decreased. Such phenomenon also is repeated for Vitamin C content after exposure at 20 cm distance. However, the level of Vitamin C in plants exposed from 20 cm was lower compared to those exposed from a 5 cm distance.

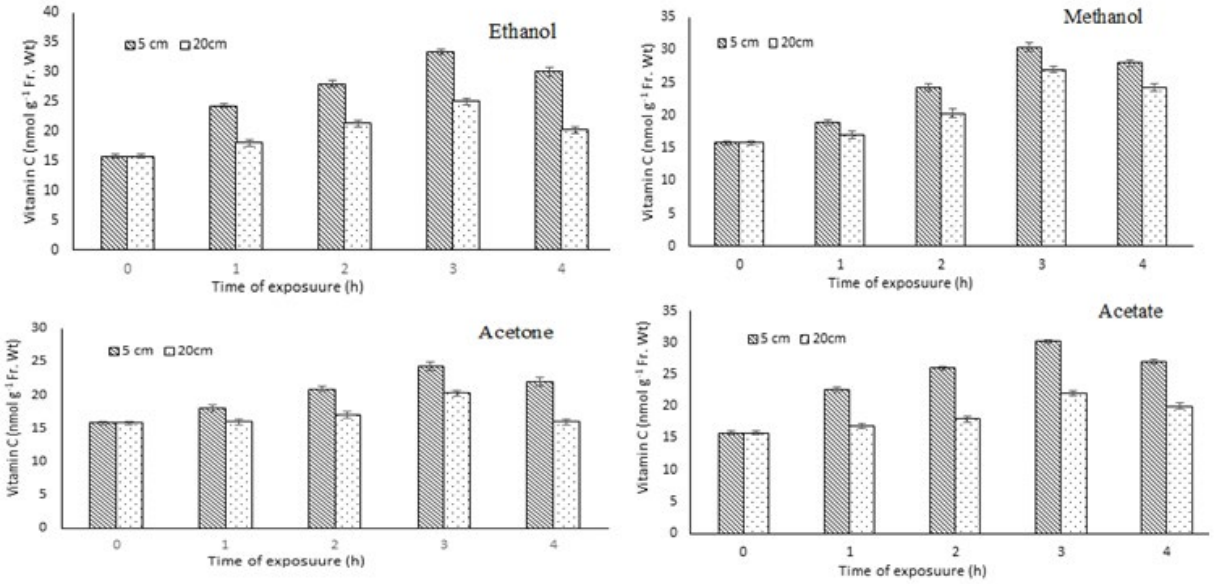

Figure 5 Vitamin C content of different extracts from *Foeniculum vulgare*

Tocopherol Content of Methanol Extract from *Foeniculum vulgare*

Figure 6 shows the tocopherol content in methanol, ethanol, acetate, and acetone extracts from *Foeniculum vulgare* after exposed to UVC from 5 cm and 20 cm distances which indicate the higher content of tocopherol is for 5 cm than that for 20 cm and the exposure intervals (1h, 2h, and 3h) were inductive whereas exposure for 4 h resulted in a reduction of tocopherol.

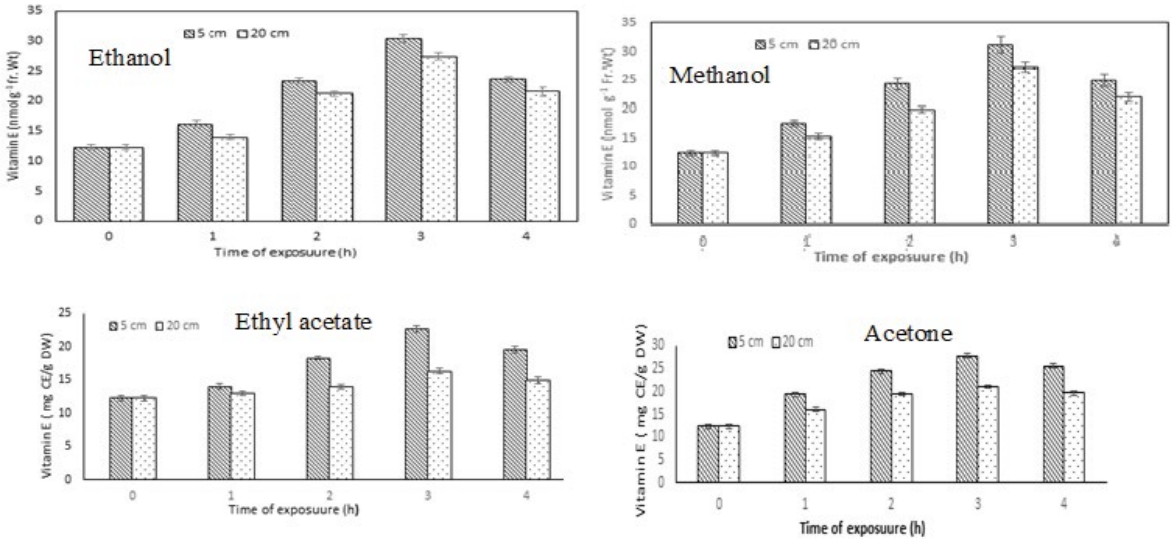

Figure 6 Vitamin E content of different extracts from *Foeniculum vulgare*

Antioxidant Enzymes in *Foeniculum vulgare*

Superoxide Dismutase (SOD): The activity of SOD is estimated in an extract prepared from *Foeniculum vulgare* and the results shown in Figure 7 indicate a continuous increase in the enzyme activities after exposure to UVC for 1hour, 2 hours, and 3 hours after which it declined by exposure for 4 hours.

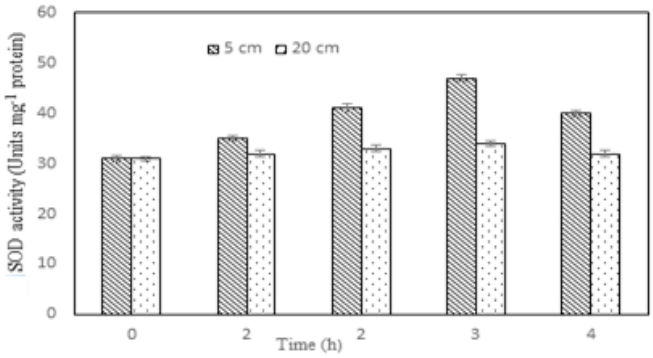

Figure 7: SOD activity in *Foeniculum vulgare*

Ascorbate Peroxidase (APX): The APX of activity is measured in *Foeniculum vulgare* after exposure to UVC for 1 hour, 2 hours, 3 hours, and 4 hours and the results in Figure 8 revealed an increase in the enzyme activity after exposure to UVC until 3 hours. But during the fourth hour, the activity was declined.

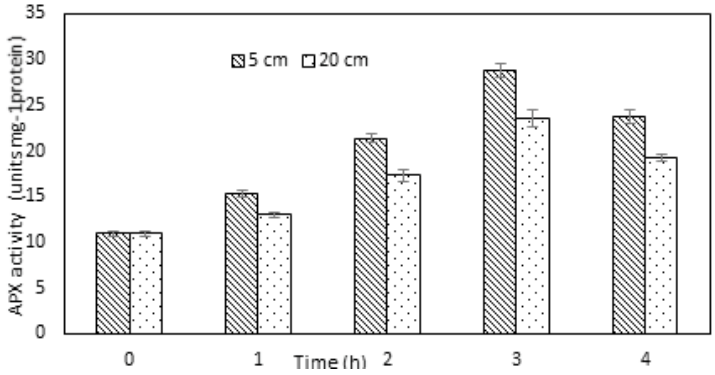

Figure 8 APX activity in *Foeniculum vulgare*

Glutathione Reductase (GR): The activity of glutathione reductase in an extract prepared from *Foeniculum vulgare* measured and shown in Figure 9. The result indicates a continuous increase in the enzyme activity by increasing the exposure time to 3 hours then declined during the fourth hour.

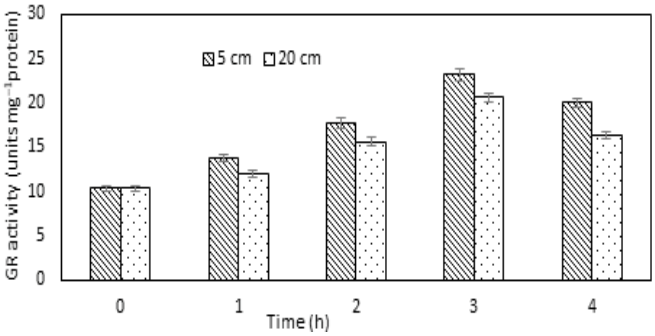

Figure 9 GR activity in *Foeniculum vulgare*

The level of antioxidant enzymes increased for the response to environmental stresses such as UVC because both biotic and abiotic stresses are responsible for the productions and that is agreed with the previous results [21,22]. Also, the increase in enzyme activities could be attributed to the ability of plants to improve the scavenging system [23].

Seeds Growth (Morphological Structure)

Figure 10 shows *Foeniculum vulgare* seeds' growth before and after exposure to UVC for different interval times (1 hour, 2 hours, 3 hours, and 4 hours) at a 5 cm distance. The results show growth (shape, straightness of branch growth, greenness, and the number of seeds grown) of seeds is affected after exposure to UVC. That is means, UVC radiation is affected the internal structure of seeds as proved before in X-ray and IR analysis.

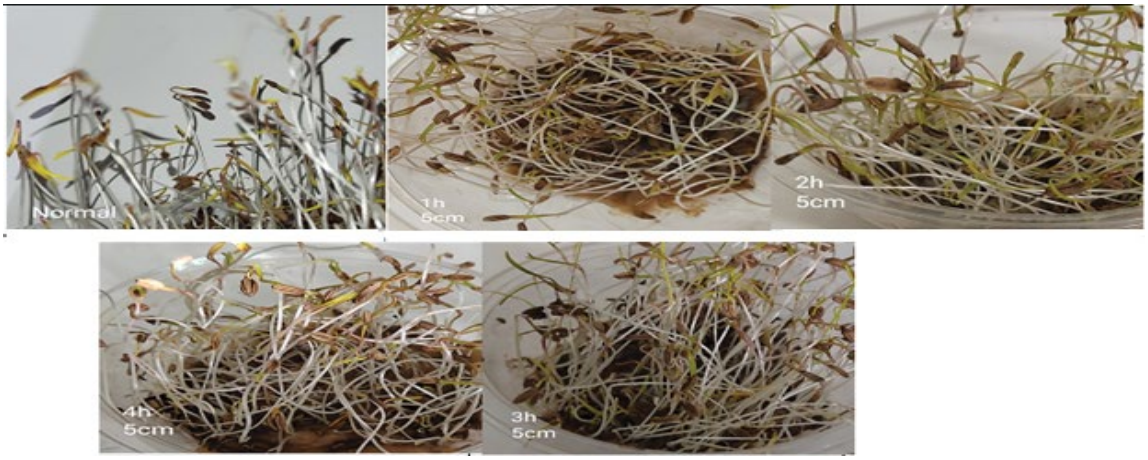

Figure 10 *Foeniculum vulgare* seeds growth before and after exposure to UVC

Seeds Weight (Volumetrically Change)

The weight of normal *Foeniculum vulgare* seeds and after exposure to UVC for 1 hour, 2 hours, 3 hours, and 4 hours at distances 5 cm was listed in Table 2. The results revealed that the weight of seeds is decreased after exposure to UVC. That is the mean the geometrical structure of seeds is affected by exposure to UVC.

Table 2 *Foeniculum vulgare* seeds weight (W g) before and after exposure to UVC

Time	(W g) 5 cm distance
Normal	5
1h	4.85
2h	4.84
3h	4.79
4h	4.77

CONCLUSION

1. The growth of *Foeniculum vulgare* seeds (shape, straightness of branch growth, greenness, and the number of seeds grown) affected after exposure to UVC. That is means that the internal structure of seeds changed after exposed to UVC as proved before in x-ray and IR analysis.
2. The *Foeniculum vulgare* seeds' weight decreased after exposure to UVC. That means UVC radiation affect the geometrical structure of seeds.
3. *Foeniculum vulgare* enzyme activity, tocopherol content, vitamin C, total phenol content, and antioxidant activity values increased by exposure to UVC up to 3 hours then declined during the fourth hour. Also continuous increase of the antioxidant activity with increasing the extract concentration.

DECLARATIONS

Conflicts of Interest

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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