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The Effect of UV-B Radiation on Morphological, Anatomical and Biochemical Traits of Aptenia cordifolia

Rana Notaraj*, Haniyeh Mohajel Shoja, Elham Mohajel Kazemi

Department of Biology, Faculty of Natural Sciences, Tabriz University, Tabriz, Iran.

***Corresponding Author**

Abstract: *Regarding different ultraviolet radiations (UV), UV-B plays the most effective role on the earth and bio-plant, which needs sunshine. These radiations have a negative effect on plant growth while they mostly affect the processes such as genetic activities, cellular metabolism, plant anatomy and morphology, and ultimately the whole plant growth. The present study investigated the effects of UV-B stress on Aptenia cordifolia which is an ornamental and medicinal plant originated from Aizoaceae family and it is resistant to some stress conditions. In this study the effect of UV-B with the intensity of 40 Lux was examined during germination and vegetative stages randomly with three replications in four intervals; 0, 45, 90,120 min and then the morphological, anatomical and phytochemical traits of the plant were examined. The results showed that when treatment level increaseed, the growth and morphological parameters such as: the percentage and rate of germination, seedling height, fresh and dry weight of root, aerial organ and leaf area decreased. Considering the anatomical traits, an increase was found in the stem thickness of the transverse wall vessel, the number of vascular bundles, the stem diameter of the vascular openings and the stem diameter. Also, in the roots under the root diameter stress, the number of vascular bundles, and diameter of their vascular opening decreased. The results of the biochemical section were consistent with the results in the morphological and anatomical sections, as any increase in the stress level led to the gradual decreases in the amount of phenolic and flavonoid compounds and photosynthetic pigments.*

Keywords: Aptenia cordifolia, UV-B, Morphological traits, Anatomical traits, Biochemical traits

INTRODUCTION

Recently the studies on the synthesis of organic materials have increased dramatically. However, plants have been regarded as the most significant natural resources in the production of drugs and other important compounds (Zhang et al., 2009) which can be attributed to the complexity of the synthesis of chemicals from active compounds or the high cost of their production (Sakalauskaite et al., 2012). Production of secondary metabolites in plants depends not only on genetic regulation but also on environmental factors, which can be used to produce bioactive compounds (Jansen et al., 2008; Ncube et al., 2012). Air pollution and atmospheric pollutant compounds, specially halogenated compounds, have now emerged in developing countries as a result of industrial activities which may

damage the ozone layer and consequently increase the amount of UV radiations on the surface of the biosphere and create problems for living organisms (Balouchi et al.,2009). Inappropriate biological and non-biological conditions which affect the living organisms is called stress, and when this organism is resistant to the environmental stresses, stress resistance appears (Msri et al., 2014). Stress can damage the plant species leading to a reversible inhibitory on metabolism and growth, or an irreversible damage associated with cell death (Blum and Ebercon, 1976). Stress factors which can reduce crop production include dryness, salinity, heat, UV-B radiations and flood irrigation. There is a significant relationship between the direct effect of ultraviolet light and the plant growth and development, and this light affects processes such as genetic activity, cellular metabolism, plant function, anfd ultimately, the whole plant growth. Therefore, the absorption of ultraviolet radiations by the epidermis layer affects the genetic processes, membrane structure and function, photosynthesis and respiration, growth and development, aperture mechanism, anatomical properties of leaves and photosynthesis pigments. It can also increase the production of compounds such as phenolics, flavonoids, flavins, coumarins, lignins Yen and anthocyanins in the epidermis in order to protect against ultraviolet radiation (Hollosy, 2002). Regarding the ultraviolet radiations, UV-B significantly affects the earth since UV-C does not reach the earth surface and UV-A is the lowest-risk group of UV radiations which can be found in the normal sunlight and it is not absorbed by the ozone layer. UV-B radiation is regarded as a stress for the plants and it causes morphological, anatomical and biochemical changes (Jansen et al., 2011).

Flavonoid is one of the most important UV-B absorbent compounds and, like an antistatic agent, it protects plants from the destructive effects of UV-B radiation (Winkel et al., 2002). For example, it prevents the splitting of photocysystem II. These important compounds are highly present in both the epidermis and leaf pilus. Several reports have indicated that the production of flavonoids increased under the UV-B radiations (Kramer et al., 1991). Flavonoids are polyphenolic compounds in plants and they act differently. Increasing the phenylpropanoid metabolism and the amount of phenolic compounds can be observed under environmental factors and stress conditions (Diaz et al., 2001).

Enzymatic and non-enzymatic mechanisms have evolved in the plants and they protect the cells against the mentioned radiations (Hollosy, 2002). The enzymatic mechanisms include the activities done by superoxidase, peroxidase, catalase, glutathione, reductase, etc. (Mittler, 2002). Flavonoids play an important role in reducing the risk of chronic diseases, especially cancer, because they have antioxidant activity which can eliminate free radicals (Holman and Katan, 2000). In recent years, it has been recorded that polyphenols can be used as herbal medicines and complementary therapies for type 2 diabetes due to their biological properties. Based on several in vitro studies on animal and human, plant polyphenols regulate the metabolism of carbohydrates and lipids and prevent hyperglycemia, dyslipidemia and insulin resistance. They can also improve the metabolism of adipose tissue and reduce the oxidative stress and inflammatory process. Also, polyphenolic compounds containing flavonoids can prevent the development of chronic diabetes and related diseases such as cardiovascular disease, neuropathy, nephropathy and retinopathy (Bahadoran et al., 2013). Different types of flavonoids are present in most nutritional plants such as fruits and vegetables, and it has been observed that flavonoids are the largest group of phenolic compounds used in clinical studies (Ren et al., 2003). The most common flavonoids are luteolin, apigenin, baicalein, crisin and glycosides, and they are found mainly in the labiaatae, Astraceae and also in the root of scutellaria baicalensis, Chrysanthemum morifolium inflorescences and Artemisia annua aerial parts (Huang et al ., 2008). Several studies have been conducted over the last 10 years on the phenolic compounds of foods, as well as their bioavailability, metabolism and biological effects.

Several hundred molecules, polyphenolic structures including benzene ring with one or more hydroxyl groups in edible plants have been identified (Manach et al., 2004).

Aptenia cordifolia L. f. Schwantes, originated from the family Aizoaceae, and also known as Mesembryanthemum cordifolium, is a perennial grass that grows rapidly in a smooth mass of the ground and it is highly aggressive and not competitive with local species (cela et al., 2009). This plant is a succulent and shrub-form with green heart-shaped leaves and beautifully red, purple and amethystine flowers, which can grow a lot (Takahashi et al., 2011). Aptenia cordifolia is native to the South African coastal deserts and some other locations such as several different habitats from southern and northern Europe and some parts of the southern United States (eg California, Oregon, and Florida), Australia and Hawaii. This is a popular ornamental plant due to its pretty flowers and its rapid and easy growth (Herppich et al., 1997). Although all species of Aptenia cordifolia live in arid and semi-arid regions, it represents a huge variety of epidermis while two distinct and totally different types of them can be conquered including ; 1- a type in which all normal epidermal cells (with the exception of protective cells and auxiliary and adjuvant cells) are approximately in the same size, this type of epidermis may indicate morphological epidermis which exhibit similar characteristics of drought-tolerant epidermis (Ihlenfeldt and Hartmann, 1982). 2. Another type of epidermis is specified through the formation of a large epidermal cell (idiopoidal) in normal epidermal cells in a less or more different pattern. These ideoblasts are typically higher than normal epidermis cells and are called papilla or bladder cells. (Hagen, 1873; Oberstein, 1910).

The previous studies have shown that this plant exhibits a good resistance to stress conditions as well as drought stress (Fleta et al., 2015). So far, the effect of UV-B pretreatment has not been studied on this plant. Therefore, the present study was carried out to investigate the effect of this stress on morphological, anatomical traits of polyphenolic and chlorophyll components of Aptenia cordifolia.

Materials and Methods

First Aptenia cordifolia seeds (from Aizoacea family) were studied regarding their morphological, taxonomy and assurance. In order to examine the germination process under UV-B stress conditions, an experiment was conducted in a completely randomized design with 4 treatments and 3 replications. Healthy seeds were selected and disinfected. Then, 30 seeds were transferred to Petri's sterilized dishes. The time durations of putting Petri's sterilized dishes under UV exposure were 45, 90, 120 minutes per day for 14 days. After applying the petri dishes treatment, they were placed in a dark environment at 25 ° C to allow germination. Counting the germinated seeds was carried out on a daily basis at a specific time. The germinated seeds were considered to have a root length of at least 2 mm. After 14 days, traits such as germination percentage and germination rate were calculated. Root length, shoot length and internode length were used in order to measure the length of the shoot. The length of the root was measured from the collar to root tip and stem length from the collar to the tip of the sprout. The length of the third and fourth internodes was also measured. Leaf area was measured using leaf drawing method on graph paper and then the numbers of cells were counted. Leaves 3 and 4 were removed from each treatment and replication. To determine the dry weight of plants, they were placed in oven at 70 ° C for 48 hours. Then, dry weight of shoot and root were measured by scaling with the accuracy of 0.001 g. To measure the stomatal densities on the leaf surface and observation of open and closed pores and also the density of epidermal cells, the back of the third and fourth leaves were varnished of each replication and treatment. Then, the varnished layer which actually reflects the back surface of the leaves was separated and placed on the slide,

and a drop of distilled water was added to it and it was placed under a light microscope using a 40 * lens.

For anatomical studies, the samples were first fixed and then stained. For biochemical studies, total phenol, flavonoid measurements and chlorophyll measurements were performed. The total phenol content of the extracts was measured using Folin-Sikhlach reagent (Kaur and Kapoor, 2002). In this stage, gallic acid was used as a standard acid and a standard curve was drawn, too. The phenol content of the extracts was determined using the resulting line equation. Total flavonoids were measured by chromatography of aluminum chloride and the absorbance of the samples at 510 nm was measured in a spectrophotometer (Toor and Savage, 2005). The total flavonoid content of all extracts was evaluated based on Chlorometric chloride (Chang et al., 2002). In order to determine the amount of flavonoids in each of the samples, Quercetin standard curve was used. In order to measure chlorophyll in leaves 3 and 4, it was extracted in 100% acetone and then stored in a refrigerator and dark conditions for 24 hours. For each 100 milligrams of the sample, 5 milliliters of solvent (100% acetone) were used and all extraction steps were performed at 4 ° C in order to prevent degradation

Having used spectrophotometer, chlorophyll adsorption was measured at 662 and 670 nm and absorption of carotenoids was measured at 470 nm. The concentration of chlorophyll was calculated according to the following formulas and was reported based on mg / g.FW (Sukran et al., 1998). 4 ml acetone was used as control. The amount of carotenoids for each extract was calculated using the following formulas:

$Ca = 11/24\ A_{662} - 2/04\ A_{645}$

$Cb = 20/13\ A_{645} - 4/19\ A_{662}$

Where

C_a is a chlorophyll content

C_b: b chlorophyll content

A_{645}: absorption at 645 nm (related to chlorophyll a)

A_{662}: absorption at 662 nm (related to chlorophyll b)

Results

Figure 1 shows the morphological results of this study:

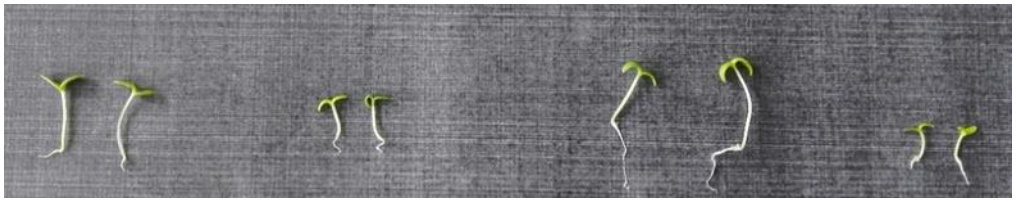

Figure 1: Examination and comparison of the height of seedlings

Germination data showed that the percentage of germination in Aptenia cordifolia under 90-minute treatment increased by 33%, as it was compared to the control treatment. However, the germination rate decreased about 53% under 120-minute treatment when comparing with the control treatment (Fig. 2).

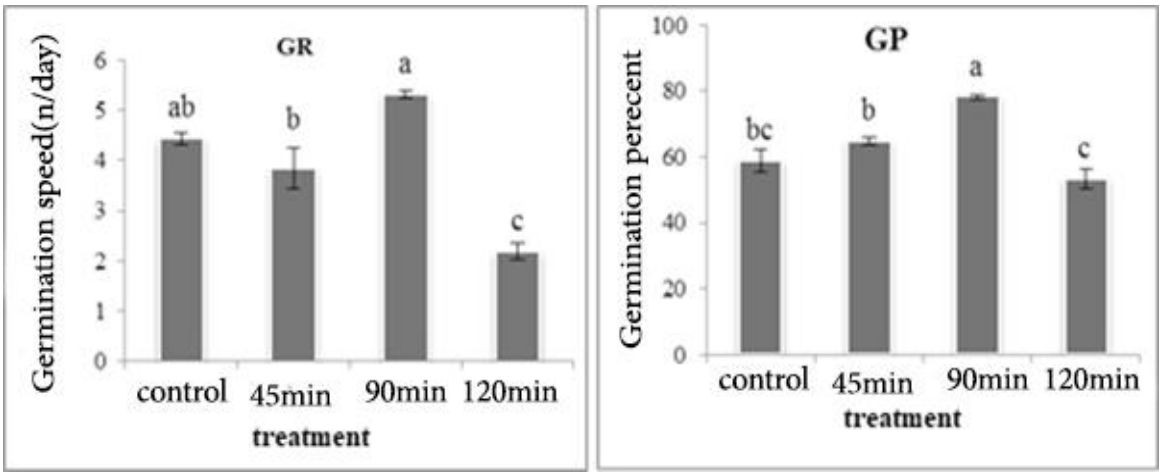

Figure 2: The effect of different germination treatments on the rate and percentage of germination

In the vegetative stage of the target plants (SHL), the length of the fourth internode (NL4) significantly decreased ($P < 0.05$) in 90- and 120-minute UV-B radiation. Figure (3) shows the highest significant decreases in both parameters (aerial and internode length) in 90-minute UV-B radiation. Other parameters such as root length (RL) and third node length (NL3) did not show any significant difference in comparing with the control treatment.

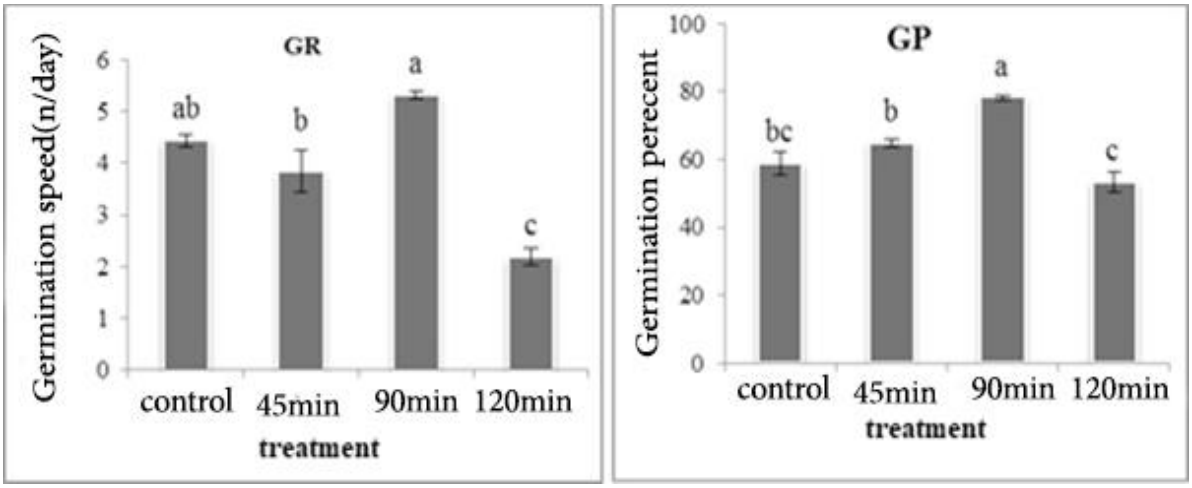

Figure 3: Comparison of shoot length (SHL), root length (RL), third internode length (NL3) and fourth internode length (NL4), different letters indicate a significant difference at the significance level of $P < 0.05$

In the growth stage, shoot fresh weight (SHFW) and dry weight (SHDW) of the aerial organ significantly decreased in the 90-minute treatment group when comparing with the control treatment. Root fresh weights (RFW) and dry weight (RDW) didn't show any significant difference when it was compared with the control treatment (Fig. 4).

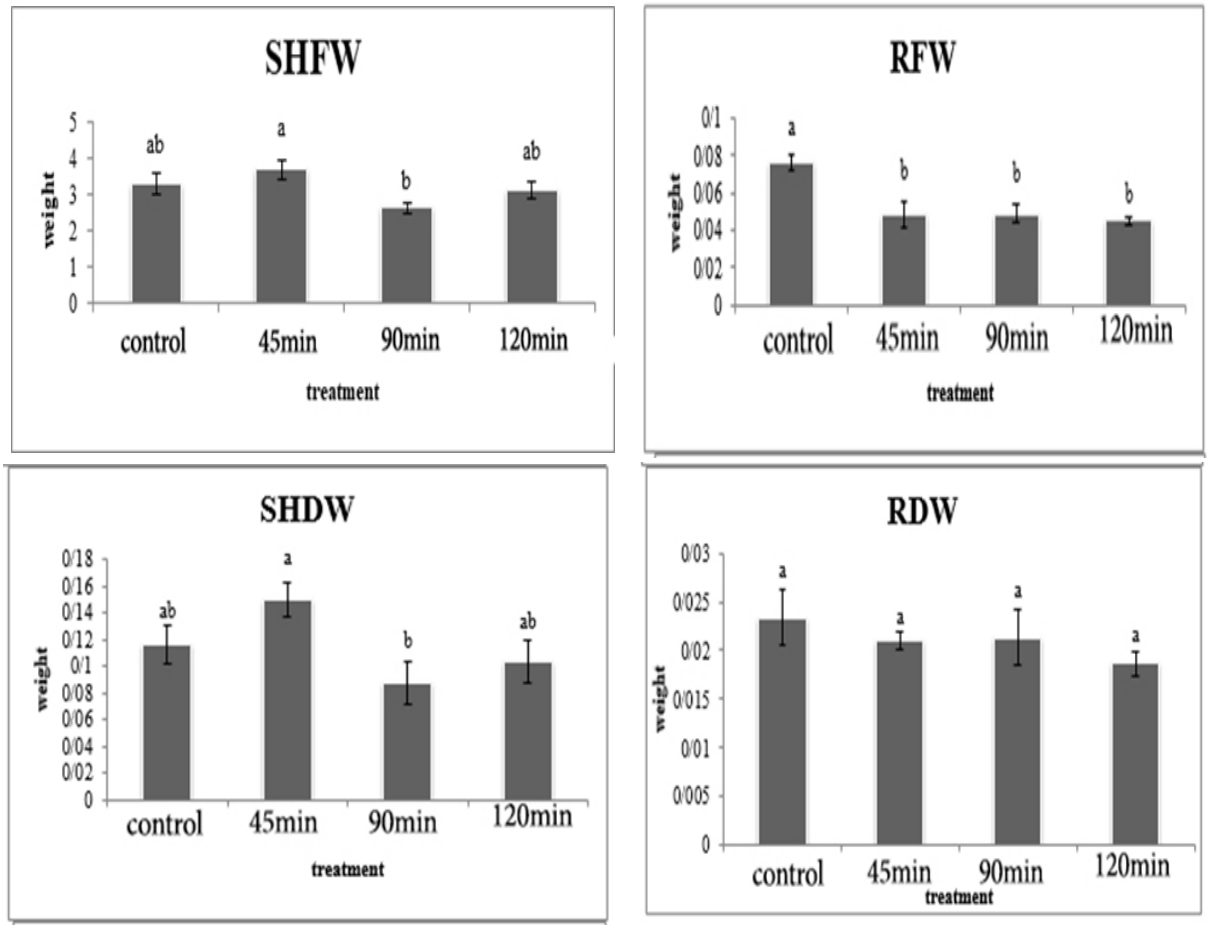

Figure 4: The effect UV-B different treatments on shoot fresh weight (SHFW) and dry weight (SHDW) in the aerial organ, and root fresh weight (RFW) and root dry weight (RDW) in the growth stage.

Different characters indicate a significant difference at significance level of $P < 0.05$.In the growth stage, the third leaf area (L3) and the fourth leaf area (L4) were exposed to UV-B radiation in a 90-minute treatment, as shown in Figure A (5); L3 level significantly reduced by 19% in the 90-minute treatment ($P \leq 0.05$), when it was compared to the control treatment. L4 levels significantly reduced by 47% in the 90-minute treatment ($P \leq 0.05$) when comparing with the value in the control treatment. Stomatal density significantly increased by 30% and 32% in the 90-minute treatment ($P \leq 0.05$) under UV-B, when it was compared to the control treatment (Fig. 5). The density of epidermal cells in L3 showed no significant difference with the control plants, but it increased by about 24% in a 90-minute treatment. Finally, the density of L4 epidermal cells, in a 90 and 120 -minute treatment under UV-B radiation increased significantly when comparing with the control plants. The highest increase was found in minute 120, which was measured to be about 50% (Fig. 5).

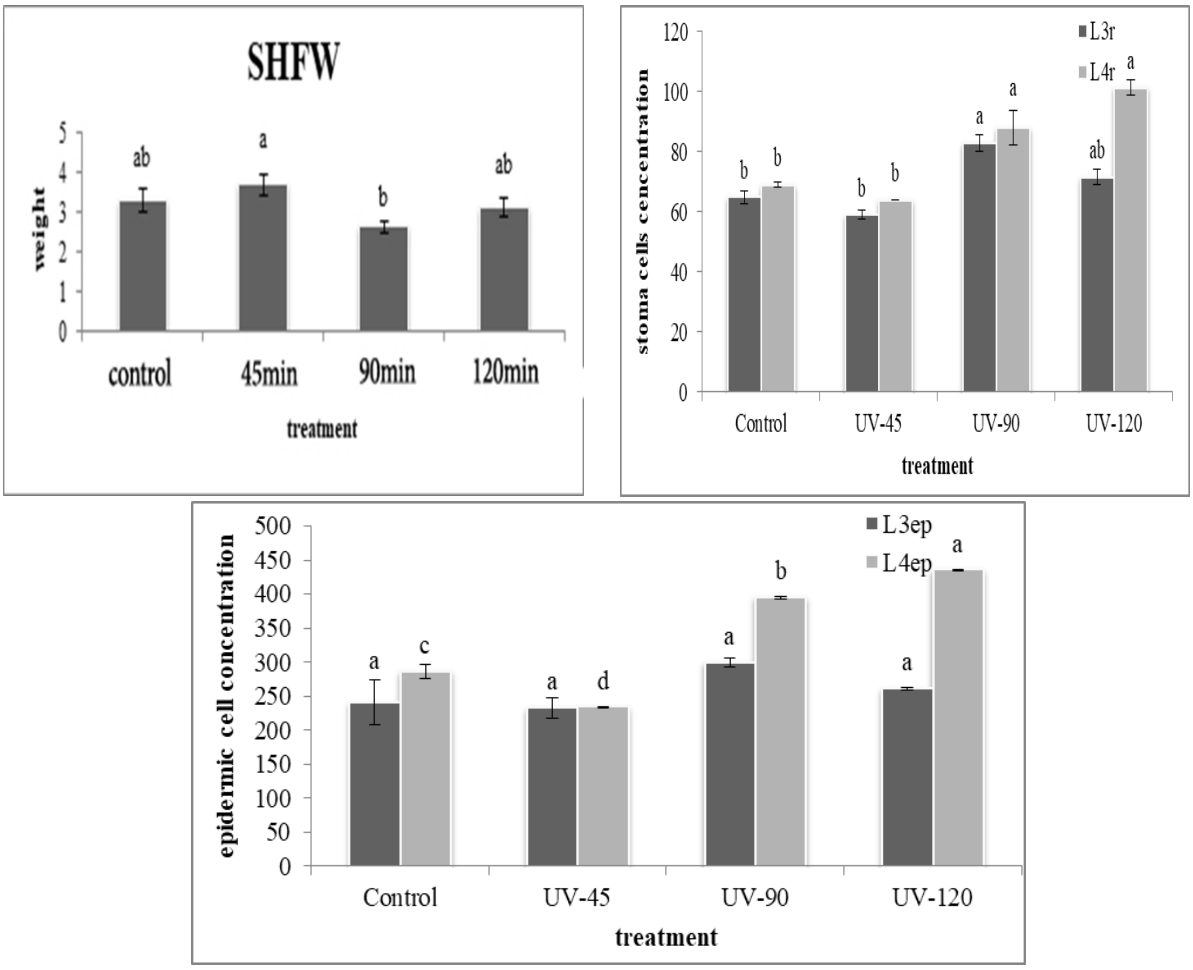

Figure 5: The effect of different levels of ultraviolet radiation on the leaf surface (A), stomatal density (B) and density of epidermis (C) in the soil culture stage, different characters indicated a significant difference at the statistical significance level of $P < 0.05$.

To measure total phenol compounds, 0.1 g of fresh leaves was dissolved in 2 ml of methanol for 2 minutes, and the solution was strained with filter paper. The total phenolic compounds were determined with the Foln-Sicultou reagent. The aluminum chloride colorimetric method was used to determine the amount of flavonoids. The amount of chlorophyll a; Chla (a), chlorophyll b; (Chlb) b and total carotenoids (C_{x+c}) was measured using Lichtenthaler and Wellburn (1983)'s method. Afterward, 1g of the fresh tissue of the leaf was weighted and it was scrubbed with 30 ml of acetone by 80%. According to the results, phenol and flavonoids decreased in L3 and L4 and the phenol and flavonoid levels reduced by UV-B radiation when they were compared to the control plants, while the the highest reduction was found in 90 and 120-minute treatments. (Table 1)

Table 1: Comparison of the phenol content in the third leaf (a) and the phenol content in the fourth leaf (b) under controlled conditions (0 min) and 45-minute treatments (UV45), 90-minute (UV-90) and 120-minute (UV120) Different characters indicate a significant difference at the statistical significance level of $P < 0.05$

Phenol		Flavonoids		Tretments
Third leaf	Fourth leaf	Third leaf	Fourth leaf	

16.74±1.33 a	21.73±1.22 b	669.07±9.07 a	869.20±48.87 a	Treatments
16.68±1.52 a	24.59±1.34 a	667.20±31.54 a	826.52±37.23 a	45 min
13.30±0.84 b	19.15±1.62 c	604.87±44.75 b	680.75±61.53 b	90 min
9.80±0.59 c	10.92±0.19 d	391.87±19.00 c	402.80±27.02 c	120 min

The results of analysis of variance showed that the levels of chlorophyll a, chlorophyll b and carotenoids decreased in treated plants as they were compared to control plants (Fig. 6).

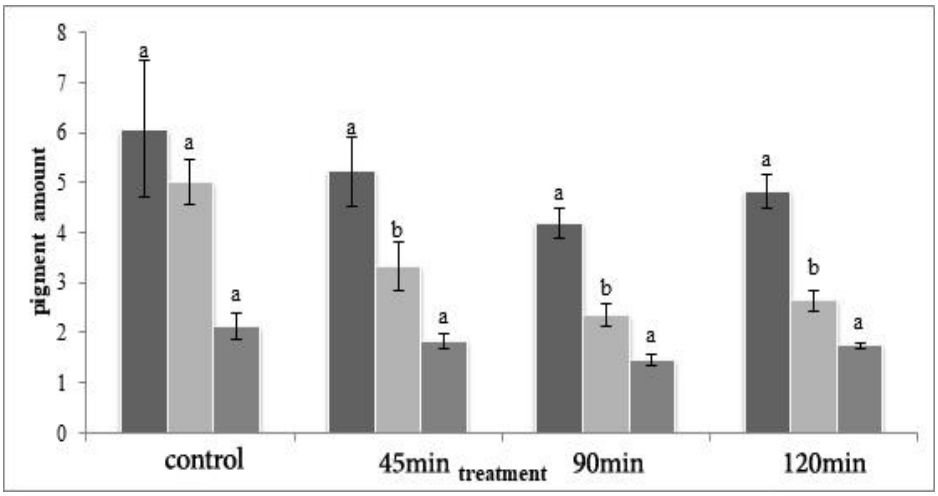

Figure 6: Comparison of chlorophyll a (a), chlorophyll b (b) and carotenoid (c) under controlled conditions (0-minute treatment) and 45-minute (UV45), 90-minute (UV-90) and 120-minute treatments. (UV120). Different characters indicate a significant difference in the statistical significance level of P <0.05.

Aptenia cordifolia originated from arid and semi-arid areas of the south Africa which represented two different types of epidermis. In this study, the ideoblast epithelium (an isolated plant cell that differs from neighboring tissues) can be seen (Fig. 7).

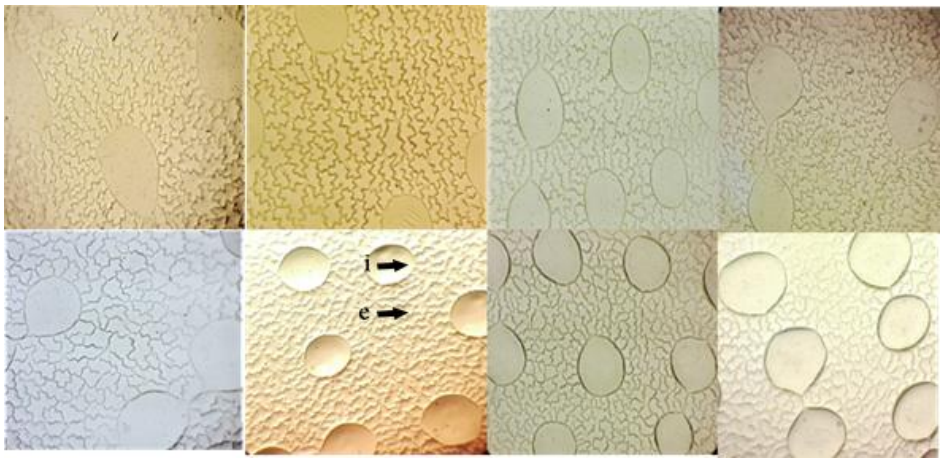

Figure 7: Comparison of third and fourth leaf areas and idioblast cells in control and treatment plants. A) Epidermis-B).45-minute treatment - C). 90-minute treatment -D). 120-minute treatment: idioblast cell (papil) -e: epidermal-stimulating cells

The anatomical structure of the growth organs including root and stem of Aptenia cordifolia was studied under the control condition and UV stress. The anatomical analysis of the root was done at 2 cm above the tip of the root for homogeneity. It was found that in the control plant, the root formation was as follows: from the outside to the pith of the first cell layer, there is a rhizodrom, which is not seen due to the presence of continuous substrates. Under the rhizoderm cells, there is a cortex area that consists of several parenchymal layers of the cortex. Since the plant enters the late growth, the xylem tissue has spread, and the cambium-vascular ring has been formed. The cells of xylem tissues are placed uniformly and regularly. The diameter of the vascular opening was the same in all parts of the root. Comparison of the control plants with UV-treated plants showed that rhizoderm was the first cell layer in all treatments which was similar to the control plants and so the cortex area was seen to the same extent and it didn't show any significant difference with the control plant. Treated plants also entered the late growth. The cambium-vascular ring has been formed and the xylem tissue cells were uniform throughout the plant. But the root diameter has increased when it was compared to the control plants due to the expansion of xylem tissue in the treated plants (Fig. 8). On average, the root diameter of the control plants was lower than that of the treated plants which entred to the late growth earlier. Cortex region and meta-xylem diameter increased in plants under the stress when it was compared to the control plants (Fig. 9). In plants under UV-B stress, the thickness of the cell wall of the xylem tissue was higher than that of the control plants and it had the highest thickness in UV-45, UV-90 treatments. Besides, the highest late growth was found in plants under UV-45, UV-90 treatments.

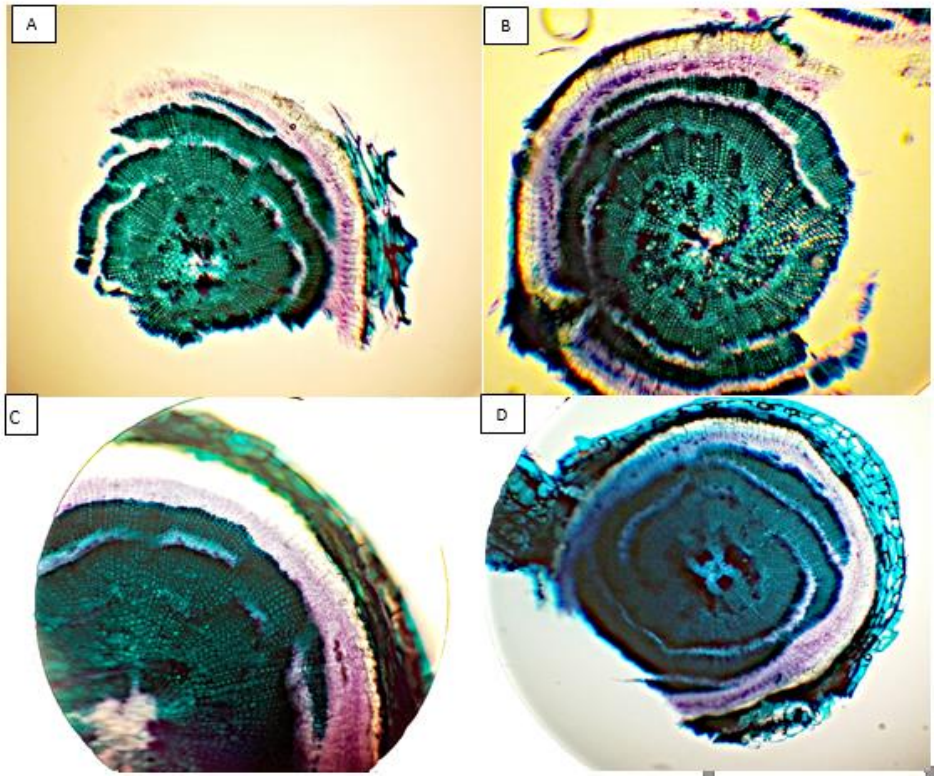

Figure 8: Comparison of Aptenia cordifolia root in the control and treated plants. Painting with Carmen Zaji. A) Control root B) 45-minute treatment C) 90-minute treatment D) 120-minute treatment

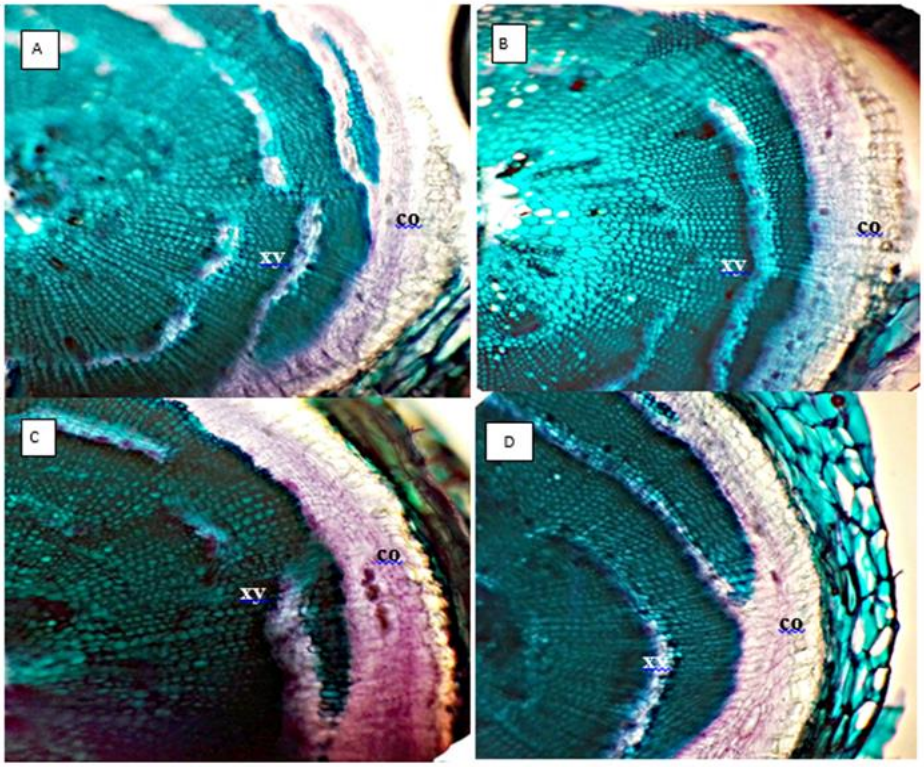

Figure 9: Comparison of Aptenia cordifolia root in the control and treated plants. Painting with Carmen Zaji. A) Control root B) 45-minute treatment C) 90-minute treatment D) 120-minute treatment

xy: xylem tissue

Anatomical analysis of the stem through manual cutting was performed using green-methyl staining. For this purpose, the third and fourth leaves have been used. Anatomical examination of the stem in the control plants revealed the internal structure of the stem that was from the outside toward the pith is as follow: epidermal tissue; an idioblast type (papillary cells that store water), is the outer layer of the cell in the control plants which is located underneath the epidermis of the parenchymal area of the cortex, with intercellular space and in eight rows. The size of the cells gets larger toward the pith of the plant. The first parenchymal cell layers are smaller and denser than cells near the cylindrical vascular region. After the parenchymal cells in the vascular cylindrical area which is common in di-cotyledon, it was found that inside this area there were vascular bundles where phloem tissue was placed on the xylem. The vascular cambium rings were formed in Aptenia cordifolia internode and the plant has entered its late growth. Calcium oxalate crystals entered the pith and cortex cells. Some distended vascular bundle were seen in the cortex area. Anatomical analysis of the plants under the treatment showed that like in the control plants, the first cell layer was an idioplastic epidermis, while the size of the idiotropic cells in treated plants was larger than that of the control plants. In the plant under the treatment, when UV-B stress increased comparing to the control plants, stem diameter did not differ significantly, but the cell wall arrangement deformed and turned from multidimensional to circular. In the control plants, the cortex cells were smaller and more compressed and intercellular spaces also decreased. Averagely, the late growth in the plants under treatment was more prominent and the stem diameter was higher in the treatment plants than in the control plants. On average, the number of vascular bundles in the control plants decreased from 12 to 9 to 10 in the treatment plants and the diameter of the vascular openings in the

control plants was bigger than its diameter in the treated plants. On the other hand, the thickness of the transverse wall of the vessels in the treatment plants was higher than the control plants due to high precipitation of lignin. The pith section in the control plants was more widely distributed rather than the treated plants. UV-90 and UV-45 treatments entered the late growth, while UV-120 treatment did not enter the late growth, indicating the sensitivity of UV-90, UV-45 treatments when they are compared with UV.(Fig. (10&11)).

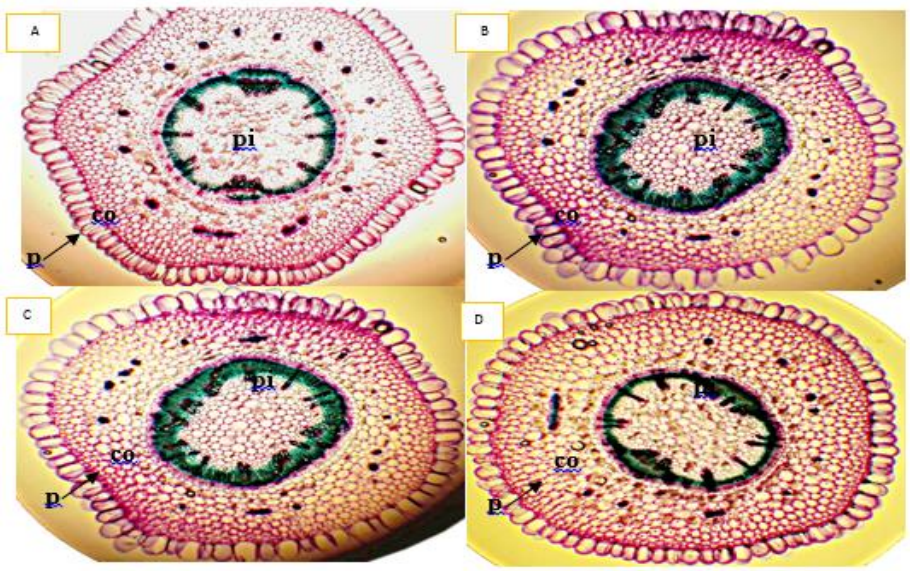

Figure 10: Comparison of stems in Aptenia cordifolia internode in a control and under treatment plant. Coloring with Carmen Zaji A) Control internod, B) 45-minute treatment C) 90-minute treatment D) 120-minute treatment

P is Papill cells, co: Cortex cells (parenchymal cells), pi: Pith

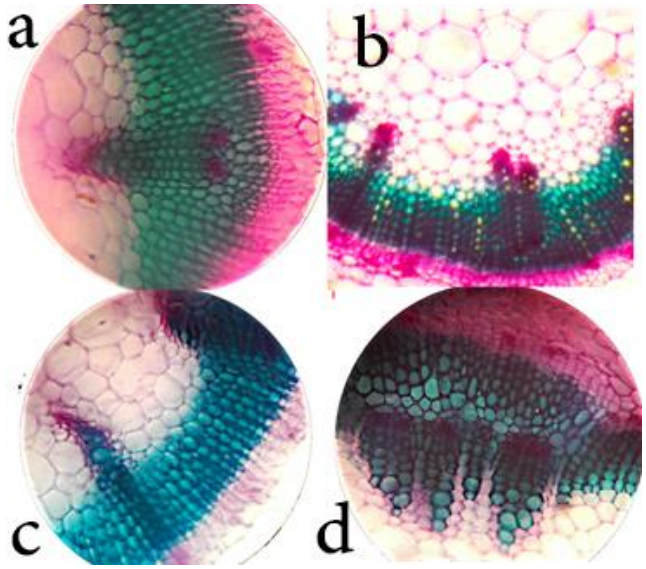

Figure 11: Comparison of stems in Aptenia cordifolia internode in a control and under treatment plant. Coloring with Carmen Zaji A) Control internod, B) 45-minute treatment C) 90-minute treatment D) 120-minute treatment

Ph is phloem, xy is xylem, , pi is Pith

Discussion and Conclusion

The results of data analysis after measuring chlorophyll *a*, chlorophyll *b* and carotenoids showed that UV radiations reduced their content. Significant reduction in photosynthetic pigmentation levels was reported in UV-treated chili pepper leaves compared to the control plants (Hosseini sarghein et al., 2008). Besides, chlorophyll content decreased due to the lack of synthesis and chlorophyllase activity increased (Piril et al., 2011), and also non-enzymatic photooxidation of chlorophyll (Mahdavian et al., 2008) occured due to ultraviolet radiation. This stage is a key biochemical reaction in the growth and defense of the plants. Therefore, any increase in the amount of phenolic compounds, flavonoids and anthocyanins can be related to the increase of PAL activity. When PAL content and action increased under UV stress, it can be due to increased expression of the gene responsible for the enzyme synthesis. Salicylic acid treatment also induced severe PAL gene synthesis, which resulted in the synthesis of compounds such as flavonoids and anthocyanins, which protected plant tissues (Chang et al., 2008). The results showed that the content of flavonoids and anthocyanins increased significantly under UV-B and UV-C radiation. An increase in the content of flavonoids and anthocyanins in paprika, treated with UV-A, UV-C radiation has also been reported (Hosseini sarghein et al., 2008). The study on sorrel showed some important phytochemical compounds in the aerial organ and root and the changes in these compounds during the growth stages in the organs collected from the genus plants showed that the antioxidant activity, total phenol and total flavonoid in the root extract were higher than this value in the leaf extract. Also, the amount of these compounds in aerial organ and root varied in different stages of the growth. Investigating changes in various compounds in the aerial part's extract showed that antioxidant, phenol and flavonoid activity in the stages of seed maturity and vegetative growth were the lowest and highest (Modares et al., 2007). In several studies, it has been shown that the amounts of secondary compounds depended on the plant's growth stage (Jakovljević et al., 2013; Naghiloo et al., 2012). Naghiloo et al. (2012) examined Astragalus compactus L., and they found that the amount of phenolic compounds and antioxidant activity in the extract of this plant depended on the growth stage of the plant, and the highest amounts can be seen in the fruit stage. Also, the amount of phenolic compounds was strongly dependent on environmental conditions such as temperature and sun radiation (Smith et al., 1973). Increasing antioxidant activity and phenolic compounds at the emergence stage of flowering stem coincided with higher temperatures and more light intensity of the sun in nature, and it can be concluded that in the wild saltin plant accumulation of antioxidant compounds (especially Phenolic compounds) before and during this stage is probably due to protecting the plant from intense sunlight or vegetarian exposure. The results of Mostafa et al. (2011) in examining R. vesicarius L. showed that the amount of antioxidant activity varied depending on the plant species. In contrast to the other studies, flavonoids and phenol have been reduced by UV-B radiation, while it increased in leaf number four more than number three. In other words, during plant development, the plant took a defensive mode against ultraviolet radiation and the amount of chlorophyll decreased.

The main cause of dry weight loss was the reduction of the photosynthesis activity in UV-treated plants. In the study on Aptenia cordifolia, UV stress reduced the fresh and dry weight of the plant, and this result was similar to the results of the studies done on different plants. The effect of UV radiation on the dry weight of plants varied among different species. Unlike most species, in potato plants UV radiation led to an increase in dry weight of plants (Santos et al., 2004). In another study, it was observed that in mopane colophospermum, the dry weight increased significantly under the

UV radiation but it decreased in shrub specious of obtusa Barleria and genistoides Cyclopia and herbaceous species of Vigna unguiculata and max glycine (Musil et al., 2002). UV-B stress in Aptenia cordifolia during soil cultivation decreased the length of the root and aerial parts, due to the decrease in the development of cellular IAA auxin hormone's phototoxidation and preventing any expansion of the cell under UV radiation (Hollosy et al., 2002). In the present study, the plants under UV reduction showed a reduction in longitudinal growth, fresh and dry weight loss and height when it was compared the plants in the control group, while the highest reduction was observed in UV-90. This decline has been observed in plants such as corn (Devix et al., 2001) and several other species. Decreasing plant growth can be associated with plant growth regulator (auxin) and, on the other hand, treatment of plants with this radiation can increase the formation of auxin inhibitors. The inhibitory effect of plants in UV-treated plants may be related to oxidizing activity such as auxin oxidase, which in turn reduces the cell wall development (Ros, 1990).

The UV stress has a decreasing effect on the leaf surface as UV-B radiations prevent cell division. Similar studies have been done on the effect of UV stress whose results were consistent with the results of Aptenia cordifolia's study, for example studies on Chickpea (Damian et al., 1998) and Petunia × atkinsiana (Staxen et al., 1993). The decrease in cell division is due to the oxidation of tubulin under UV radiation, which delayed the formation of microtubules and reduced the rate of division. Besides, UV radiation prevent the transcription of histone proteins, thereby it prevents cell division (Hopkins et al., 2002; Smirnof et al., 2000). The UV radiation reduced leaf area levels, which was significant in UV-90 comparing to the radiation was used in the control group. Similar results have been observed in corn (Kakani et al., 2003), and chickpea (Yao et al., 2006). Reduction of leaf area under the UV treatment can be due to the rate reduction and cell division development as well as degradation. Microscopic examinations of transverse roots showed no significant difference in root thickness comparing to control sample, while stem thickness increased when it was compared to the control plant and it was the highest increase in UV-45 treatment. In a study on Fagopyrum, under UV radiation, the stem thickness was reduced (Yao et al., 2006). Compared to the control plant, the leaf thickness of the plant increased under the UV treatment, with the highest increase in UV-90 treatment. Increased leaf thickness in potato plants (Santos et al., 2004) was reported. The increase in leaf thickness is a protective mechanism against UV radiations (Hollosy, 2002). In Scottish pine, thickening of the epidermal and hypodermic cell layers was observed under UV treatment (Turunen et al., 2005). UV radiation also increased the number of epidermis cells when it was compared with the control plant, which increased the highest in UV-90. Similar results have been reported in Eacliptos (Liu et al., 2005) and flax (Kakani et al., 2003).

In this study, UV radiations led to crystal formation in peroxisomes. These crystals are the activation site of the catalase enzyme. Similar changes were observed in potato leaves (Santos et al., 2004) where catalase enzymes made an increase in peroxisome crystallization. Another study demonstrated the accumulation of a catalase isoform in peroxisome crystalline matrix of sunflower cells under UV treatment (Kleff et al., 1997).

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