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Examining the growth and performance of the effect of UV-B radiation on United Arab Emirates Date Palm Tree (Phoenix dactylifera)

Saeedallah Abdulwali Niazwali

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EXAMINING THE GROWTH AND PERFORMANCE OF THE EFFECT OF UV-B RADIATION ON UNITED ARAB EMIRATES DATE PALM TREE (PHOENIX DACTYLIFERA)

Saeedallah Abdulwali Niazwali

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Horticulture

Under the Supervision of Dr. Mohammed Abdul Mohsen Alyafei

May 2016
Declaration of Original Work

I, Saeedallah Abdulwali Niazwali, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled “Examining the Growth and Performance of the effect of UV-B Radiation on United Arab Emirates Date palm Tree (Phoenix dactylifera)”, hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Mohammed Abdul Mohsen Alyafei, in the College of Food and Agriculture at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

Student’s Signature: ________________________    Date: ________________
Advisory Committee

1) Advisor: Dr. Mohammed Abdul Mohsen Alyafei
   Title: Associate Professor
   Department of Aridland Agriculture
   College of Food and Agriculture

2) Co-advisor: Dr. Shyam S. Kurup
   Title: Associate Professor
   Department of Aridland Agriculture
   College of Food and Agriculture

3) Co-advisor: Dr. Abdul Jaleel Cheruth
   Title: Assistant Professor
   Department of Aridland Agriculture
   College of Food and Agriculture
Approval of the Master Thesis

This Master Thesis is approved by the following Examining Committee Members:

1) Advisor (Committee Chair): Dr. Mohammed Abdul Mohsen Alyafei
   Title: Associate Professor
   Department of Aridland Agriculture
   College of Food and Agriculture

   Signature  
   Date 18-5-2016

2) Member: Dr. Shyam S. Kurup
   Title: Associate Professor
   Department of Aridland Agriculture
   College of Food and Agriculture

   Signature  
   Date 18-5-2016

3) Member: Dr. Abdul Jaleel Cheruth
   Title: Associate Professor
   Department of Aridland Agriculture
   College of Food and Agriculture

   Signature  
   Date 18-5-2016

4) Member (External Examiner): Professor Mohamed Aly Badawi
   Title: Professor
   Department of Soil Microbiology
   Institution: Soil, Water and Env. Res. Inst. ARC, Giza, Egypt

   Signature  
   Date 18/6/2016
This Master Thesis is accepted by:

Acting Dean of the College of Food and Agriculture: Professor Afaf Kamal-Eldin

Signature  

Date 18 May 2016

Dean of the College of the Graduate Studies: Professor Nagi T. Wakim

Signature  

Date 19 May 2016

Copy 9 of 10
Abstract

The stratospheric ozone depletion and elevated solar UV-B radiation have a negative effect on living life forms. UV radiation is one of the unsafe components that cause hindrance to both flora and fauna on the earth. This will have important implications for ecosystem processes and food production. The present study has been designed with primary objective of the effect of UV-B radiation on five numbers of most cultivated Emirates varieties (i.e., BARHI, FRDWT, NBTSF, FRDRD and KHD). After 4 and 8 hrs/day UVB treatment the Shoot, Root and total Plant length, Total plant fresh weight, Shoot and Root fresh and dry weight. Number of leaves, Chlorophyll content, carotenoid content, Total phenols content, Proline and various elements were analyzed. The results showed that the reduction in plant growth in terms of shoot and root length, number of leaves and photosynthetic pigments like chlorophyll a, b and carotenoids. Whereas, the UV absorbing compound phenol and stress indicator proline were found to accumulate in a direct proportion to the UV-B treatment. However in case of mineral analysis, Sodium, Phosphorous, Cobalt, Calcium, Manganese were increased while Sulfur, Copper, Potassium and Nitrogen contents were decreased in the date palm varieties studied. The crop, being a desert plant, has evolved strategies to protect itself against most of these stresses. The effects of UV-B radiation on five different varieties of date palm are studied for the first time in the current research experiment. Further extension of this study to the combined effect of UV-B radiation with other stress parameters, field level study and determination of yield parameters will provide scope for identifying new stress tolerant cultivars of date palm trees.

Keywords: UV-B radiation, climate change, date palm, morphology, pigment content, biochemical and mineral nutrients.
دراسة النمو والأداء من تأثير الأشعة فوق البنفسجية - ب على النخيل في دولة الإمارات العربية المتحدة

الملخص

إن استنفاد طبقة الأوزون وارتفاع الأشعة فوق البنفسجية لهما التأثير السلبي على أشكال الحياة المعيشية. الأشعة فوق البنفسجية هي واحدة من العناصر الغير أمينة والتي تسبب عائقا أمام كلا من النباتات والحيوانات على سطح الأرض. وسيكون لذلك إنعكاسات هامة على عمليات النظم الإيكولوجية والإنتاج الغذائي. وقد تم تصميم هذه الدراسة مع الهدف الأساسي منها النظر في تأثير الأشعة فوق البنفسجية على خمسة أصناف لمصنع زراعة أصناف النخيل في الإمارات (برحي، فرض أبيض، نبتة سيف، فرض أحمر، خضراوي). بعد 4 و8 ساعات يوم، تم تعرض الأشعة فوق البنفسجية على الأوراق، الجذر، طول النبات الإجمالي، مجموع الوزن الرطب للنباتات، وزن الأوراق، الجذر الرطب والجاف، عدد الأوراق، ومحتوى الكلوروفيل، كاروتينويد، وفيونولات، البرولين، وعناصر مختلفة.

وأظهرت النتائج أن الانخفاض في نمو النباتات من حيث الأوراق وطول الجذر، عدد الأوراق والأصباغ الضوئية مثل الكلوروفيل أ، ب والكاروتينودات. في حين تم العثور على أن مركبات امتصاص الأشعة فوق البنفسجية الفينول والبرولين إنما هو مؤشر للإجهاد وترتكم في نسبة مباشرة لعلاج الأشعة فوق البنفسجية (ب). ولكن في حالة تحليل المعادن، الصوديوم، الفوسفور، الكالسيوم، المنغنيز، زادت نسبة الكبريت والنظاص والبوتاسيوم والنيتروجين في أصناف النخيل التي درست في هذه التجربة البحثية.

حيث أن المحصول " النخلة " من النباتات الصحراوية، فقد طورت استراتيجيات لحماية نفسها ضد معظم هذه الضغوط. يتم دراسة آثار الأشعة فوق البنفسجية على خمسة أصناف مختلفة من النخيل للمرة الأولى في هذه التجربة البحثية الحالية. وتشير نتائج هذه الدراسة إلى التأثير المشترك بين الأشعة فوق البنفسجية مع مؤثرات الضغط الأخرى، الدراسة الميدانية، وتحديد معايير إنتاجية توفر مجالا لتحديد أصناف متحملة جيدة لأشجار النخيل.
مفهوم البحث الرئيسية: الأشعة فوق البنفسجية (ب)، تغير المناخ، النخيل، علم التشكل المورفولوجيا، المحتوى الصبغي، والكيمياء الحيوية والمغذيات المعدنية.
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It is hard to express my indebtedness in words to my parents for their love, care, support, help and encouragement during the course of my research work.
Dedication

To my beloved parents and family
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<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>°C</td>
<td>Degree Celsius</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>g</td>
<td>Gram</td>
</tr>
<tr>
<td>mg/g</td>
<td>Milligrams per gram</td>
</tr>
<tr>
<td>mg/ml</td>
<td>Milligrams per milliliter</td>
</tr>
<tr>
<td>min</td>
<td>Minutes</td>
</tr>
<tr>
<td>ml</td>
<td>Milliliter</td>
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<td>nm</td>
<td>Nanometer</td>
</tr>
<tr>
<td>rpm</td>
<td>Revolutions per minute</td>
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<tr>
<td>UV</td>
<td>Ultraviolet</td>
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Chapter 1: Introduction

Ultraviolet (UV) radiation is the portion of the electromagnetic spectrum between X-rays and visible light that is conventionally divided into UV-A (315 to 400 nm), UV-B (280 to 315 nm) and UV-C (100 to 280 nm) radiation. Whereas UV-C is entirely absorbed by the stratospheric ozone layer, UV-A and some UV-B radiation reach the Earth’s surface and thus can affect the biosphere. The plants need to achieve a balance between optimal light capture and UV-B protection. Thus, efficient UV-B protection mechanisms are of great importance to plants. This then initiates changes in gene expression, which lead to several metabolic and morphological alterations. A major response is the activation of mechanisms associated with UV-B acclimation and UV-B tolerance, including biosynthesis of sunscreen metabolites, antioxidants and DNA repair enzymes (Ulm and Jenkins, 2015).

The stratospheric ozone depletion and elevated solar UV-B radiation have a negative effect on living life forms. UV radiation is one of the unsafe components that cause hindrance to both flora and fauna on the earth. The projected future changes in precipitation, vegetation cover, and agricultural intensification will influence the balance between the detrimental and beneficial effects of UV radiation and their bidirectional interactions with climate change. This will have important implications for ecosystem processes and food production (Williamson et al., 2014).

Plants are necessarily exposed to solar UV radiation because they require sunlight to carry out photosynthesis. They are generally adapted to environmental UV-B radiation exposure since they have evolved mechanisms to avoid being damaged. Visual symptoms consisting of chlorotic or necrotic patches on leaves exposed to UV-B were not unique. Both vegetative and reproductive morphology were altered by UV-
B radiation. Leaf anatomy was altered due to changes in thickness of epidermal, palisade, and mesophyll layers. In most systems of exposure, enhanced UV-B radiation affected crop growth directly through several first order effects. These include leaf photosynthesis (photosystems, thylakoid and grana membrane integrity) and photomorphogenic systems (developmental rates), upregulation of pathways producing defense compounds (flavonoids and related phenolic compounds or waxes), decreased vegetative growth, and decreased developmental times. These primary effects have led to a myriad of secondary and tertiary effects resulting in altered crop growth and development, which in turn affected light interception that lowered canopy photosynthesis, reduced fruit numbers and retention, and finally, biomass and yield reductions (Kakani et al., 2003).

Net photosynthesis, transpiration, and stomatal conductance were significantly greater in mature leaves exposed to sub-ambient UV-B radiation than in mature leaves exposed to near ambient UV-B radiation. Concentrations of UV-B radiation-absorbing compounds were significantly greater in mature leaves exposed to near-ambient UV-B radiation than in mature leaves exposed to sub-ambient UV-B radiation. The UV-B radiation treatments had no effects on chlorophyll content or intrinsic light harvesting efficiency of photosystem II (Schumaker et al., 1997). Enhanced UV-B radiation-induced DNA damage significantly delayed cell division until the injury is repaired, resulting in significant reductions in leaf growth and development. The combination of low temperature and increased UV-B radiation was more significant in the level of UV-B radiation-induced damage than UV-B radiation alone (Suchar and Robberecht, 2014).
UV-B radiation damages nuclear, chloroplast, and mitochondrial DNA by inducing various DNA lesions including the generation of cyclobutane pyrimidine dimers (CPDs) (as the primary UV-B-induced DNA lesions accounting approximately 75% of UV-B-mediated total DNA damage) and other photoproducts, pyrimidine (6-4) pyrimidone dimers as the major lesions, while the minor includes oxidized or hydrated bases, single-strand breaks, and others (Ballare et al., 2001). The accumulation of such damages and unrecognized and unrepaired DNA damage may cause fatal mutations which in turn can reduce plant genome stability, growth, and productivity and also threaten the organism’s immediate survival. Plants employ various strategies to either reverse, excise, or tolerate the presence of DNA damage products (Gill et al., 2015).

Bornman et al. (2015) reported that the increasing recognition that UV-B radiation has specific regulatory roles in plant growth and development that in turn can have beneficial consequences for plant productivity via effects on plant hardiness, enhanced plant resistance to herbivores and pathogens, and improved quality of agricultural products with subsequent implications for food security. UV-B radiation together with UV-A (315–400 nm) and visible (400–700 nm) radiation are significant drivers of decomposition of plant litter in globally important arid and semi-arid ecosystems, such as grasslands and deserts. UV radiation can contribute to climate change via its stimulation of volatile organic compounds from plants, plant litter and soils, although the magnitude, rates and spatial patterns of these emissions remain highly uncertain at present. UV-induced release of carbon from plant litter and soils may also contribute to global warming.
The Greek word Phoenix means “purple-red” and dactilyfera refers to finger like appearance of fruit bunch (Chao and Krueger, 2007). The date palm is botanically known as Phoenix dactilyfera. It comes under the plant family Arecaceae. The date palm tree is the tallest of the Phoenix species growing to 30m in some places. The leaf are large 4-5m, alternate, sheathing in dense terminal rosette, the ends of leaf fronds are needle sharp protecting the growth tip from grazing animals. The fruit is a Berry type (known also as Drupe) with a single seed in each. Fruit is born on clusters called Bunches and from the time of pollination, the fruit takes 150 - 200 days to reach the fully ripened stage. A fully productive palm gives 60 – 100 kg date. The date palm grows in areas with long dry summers and mild winters. It has a unique characteristic to thrive in desert and oasis where temperature could be high but with underground water close to the surface.

Date palm is thought to be originated from Iraq and the cultivation of this plant spread to the Arabian Peninsula, North Africa and the Middle Eastern Countries about 5000 years ago. Dates are produced in hot arid regions of the world and marketed worldwide as a high value confectionery. It is considered as an important subsistence crop in most of the world’s desert areas. The popular date palm producing countries are Egypt, Saudi Arabia, Iran, United Arab Emirates, Pakistan, Algeria, Sudan, Oman, Libya and Tunisia. In these countries thousands of date palm cultivars are cultivated including soft, semi-dry and dry date fruits. It contains the sugar Sucrose (semidry and dry cultivars), fructose and glucose (soft cultivars), proteins, vitamins and minerals. The dates high energy food and very
nutritious apart from that it plays as one of the important diets in the Arab countries and consumed fresh, dried or in various processed forms (Kader and Hussein, 2009).

The dates have a high content of sugar (71.2–81.6%) and low concentrations of protein (1.72–4.73%) and lipids (0.12–0.72%). The pre-dominant mineral is potassium, and the predominant sugars are glucose and fructose (Assirey, 2015). The fruit is used as food. In addition to this the other parts of the tree are used in various purposes. The leaves are used in making fences, baskets, containers for domestic uses, sheath is used as fuel as well as in rope making, the drunk is used in roof, door, light foot bridge, pillar making and also as firewood (Barreveld, 1993). The waste leaves are used as a substrate for the successful cultivation of *Pleurotus ostreatus* (Alananbeh *et al.*, 2014). The United Arab Emirates (UAE) has the largest number of date palms for any single country in the world. It was reported to have 40 million date palm trees and a minimum of 200 cultivars, 68 of which are the most important commercially (Jaradat and Zaid, 2004).

Like all plants, the date palm has a positive impact on the environment. It provides shade and comfort to human life. It also on average stores more carbon than other trees of similar size. This potential makes the date palm an important tool in the fight to stave off global warming, which is mainly caused by carbon dioxide emissions. Moreover, date palm can grow in different types of soil, including dry, clay and sandy soils. It is highly salt tolerant (Sharifa, *et al.*, 2011). Arab countries possess 70% of the 120 million world's date palms and are responsible for 67% of the global date production. During the past 50 years, date palm was extensively exploited due to increase in the human population and domestic animals. Date palm
production faces serious problems such as low yields as well as marketing constraints. Technical and socio-economic factors contributed for date palm degradation (El-Juhany, 2010).

Thus considering socio-economic importance of the date palm, the present study has been designed with primary objective of the effect of UV-B radiation on five numbers of most cultivate Emirates varieties (i.e., BARHI, FRDWT, NBTSF, FRDRD and KHD) with following other important objectives,

i) To find out the effect of UV-B radiation on root, shoot, total plant length

ii) To find out the effect on total biomass of date palm

iii) To find the effect of UV-B radiation in leaf in terms of number of leaves and photosynthetic pigments

iv) To find out the changes in the total phenol (important antioxidant) production

v) To estimate the stress hormone proline and elemental composition
Chapter 2: Review of Literature

Increased UVB irradiation is deleterious to many plant species and plants may respond to it through multiple mechanisms. For example, by changing in leaf pigments and photosynthetic system as well as by changes in epidermal layer, epicuticular waxes, leaf thickness, canopy morphology or architecture (Teramura, 1983; Gold and Caldwell 1983; Worrest, 1983; Teramura and Sullivan 1994; Murthy, and Rajagopal 1995) or by synthesizing UV absorbing compounds i.e., flavonoides (Kootstra, 1994; Lois, 1994; Stapleton and Walbot, 1994; Jansen et al., 1996).

Though some plant species are hardly affected by UVB irradiation, most of the species are sensitive to it and are damaged by these deleterious radiations (Teramura, 1983; Dumpert and Knacker, 1985; Kim et al., 1998). UVB radiation effects on plants can comprise alternations of their genome, physiology, growth, biomass and yield (Yue et al., 1998; Barsig and Malz, 2000). Yet the basis of these differences is not well understood.

Plant species differ considerably in their sensitivity to UVB and even cultivars of the same species vary markedly (Teramura and Murali 1986; Teramura et al., 1991). UVB radiation can induce several morphological responses including reductions in whole plant biomass, plant height, leaf area, leaf and stem elongation and branching, altered flowering times (Tevini and Teramura, 1989; Barnes, 1990) and increase in leaf thickness (Cen and Bornmani 1990), Phototropic pending (Curry et al., 1956) and cotyledon curling (Wilson and Greenberg, 1993).

Hunag-ShaoBai, et al. (1988) studied the effect of enhanced UV-B radiation on Chinese cabbage cv Aijiaohuang. It was found that UV-B treatment induced the
accumulation of UV absorbing flavonoids in the leaves. Enhanced UV-B radiation reduced ascorbic acid contents in leaves and inhibited catalase and superoxide dismutase activities and increased malondialdehyde content. These effects induced with the duration of treatment. The authors concluded that supplemental UV-B radiation enhanced lipid peroxidation and that the accumulation of UV absorbing flavoroids could not alleviate the damage of UV-B radiation. Moreover, the effect of ozone depletion on increased UV-A and UV-B radiation receipts at the earth’s surface and the implication for plant growth responses, plant secondary chemistry and plant reproduction were studied by Caldwell et al. (1989).

Kulandaivelu et al. (1989) observed that the effect of UV-B radiation on cowpea seedlings. The enhanced UV-B radiation resulted a large inhibition in seedling growth, particularly shoot elongation and leaf expansion. The UV-B radiation also reduced the overall photosynthetic activity as measured by chlorophyll fluorescence induction. In order to check whether UV-B cause any destruction of auxins, seedlings were grown under UV-B and non-UV conditions with either their shoot tip or primary leaves covered with black paper. Both the fully exposed and shoot tip covered seedlings showed the similar negative response on growth characteristics and physiological activities. Leaf covered seedlings showed well preserved photosynthetic activity under both light conditions. However, in these seedlings pigment content decreased more than under other treatment conditions. It is concluded that these experiments provide evidence for distinguishing between the UV-B induced responses on growth the physiological activities, while the former may be controlled through auxins, the latter is probably by direct action on the organelles.
Barnes *et al.* (1990) investigated the influence of UV-B radiation on the morphology of 12 common dicot and monocot crop or weed species. UV-B exposure was found to reduce leaf blade and internode length and increase leaf and axillary shoot production in several species. These morphological changes occurred without any significant reduction in total shoot dry matter production. There was no clear distinction in the response of crops and weeds.

Giller and Abrol (1991) observed that in laboratory experiments of cotton, barley and *Arabidopsis thaliana* plants which were exposed to a single UV-B radiation for 1, 2 and 3 hour, respectively. In cotton plants, chlorophyll a and carotenoids content increased while chlorophyll b content remain unaffected by exposure to UV-B, while in Barley, the distribution of these pigments on a leaf area basis was reduced by 25-30%. In *A. thaliana*, the initial damage caused to the photosynthetic apparatus by UV-B exposure of 12 days old seedlings was reversible where as the damage to 19 and 26 days old seedlings was quantitative and irreversible. UV-B exposure of etiolated triticale and pea seedlings reduced chlorophyll content of both the species.

Direct injuries to the photosynthetic apparatus have been studied extensively. These effects include inactivation of photosystem II (PSII), reduced activity of Rubisco, decreased levels of chlorophylls and carotenoids, down-regulation of transcription of photosynthetic genes, and decreased thylakoid integrity and altered chloroplast ultrastructure (Strid et al., 1994; Teramura and Sullivan, 1994; Jansen et al., 1996; Vass et al., 1999).

The direct evidence for the possible loss of photosystem II activity in chloroplasts of *Vigna sinensis* after ultraviolet-B (UV-B, 280-230 nm) radiation
treatment with the time period of a 30 min caused a 50% loss of PS II activity, demonstrated harmful interaction between UV-B radiation and ceros pore leaf spot disease on sugar beet (Kulandaivelu and Nedunchezain, 1991)

Jordan, et al. (1992) studied 17 day old pea plants grown in a 12 light: 12 h dark regime and exposed to UV-B radiation during the light cycle. Total soluble protein per unit leaf area changed little after 1 day but declined by 33% during 3 day of UV-B exposure although there was no change on a unit chlorophyll basis. Total RNA per unit area declined by 15% and 37% after 1 or 3 of UV-B treatment, respectively. Maximum ribulose-1,5-bisphosphate carboxylase (Rubisco) activity declined by 38% after 1 day and 71% after 3 day of UV-B exposure. Rubisco polypeptide subunits showed some decrease (-16%) after one day exposure, but declined by 56% over 3 day. The level of the mRNA transcripts for both rbc S were reduced to <20% of control values after 4 h of UV-B exposure, where the Rubisco L transcripts were reduced were reduced by 60% after 1 h Further exposure to UV-B reduced the mRNA transcripts to either trace or undetectable levels. The decrease in Rubisco S mRNA levels with the UV-B exposure could be partially ameliorated by higher photo synthetically active irradiance during the period of UV-B exposure. Plants that were exposed to supplementary UV-B radiation for short periods (4 h or 8 h) and returned to control contitions, showed no recovery after 24 h. After a further 2 d, however, the Rubisco L Rubisco S mRNA transcripts had recovered to about 60% of the control values, showing that the effect upon the mRNA transcripts was a reversible response.

Caldwell, et al. (1995) examined the influence of natural, present-day UV-B irradiance in the tropics. Significant difference between UV-B excluded and near-
ambient UV-B plants were often exhibited as increased foliar UV-B absorbing compounds and, in several cases, as reduced plant height with exposure to solar UV-B. Increases in leaf mass per area and reductions in leaf blade length under solar UV-B occurred less frequently.

Nouchi and Kobayashi (1995) described a system for supplemental UV-B irradiation of field grown plants and temporal variation in biologically active UV-B was assessed. In trials in late summer to mid-autumn with 17 lowland rice cultivars grown in pots in the field at Tsukuba, Japan, enhanced UV-B irradiation did not cause foliar injury or affect growth, but total chlorophyll content in the uppermost leaf was increased except in one cultivar, and UV- absorbing compounds also increased. Trials during the typical rice- growing season were considered necessary. WL irradiance (2-20 W/msuperscript 2) the UV-B inhibition was maximum. The determination of photosynthetic unit size and spectral analysis of chloroplasts exposed to various radiation provided evidence for the regulatory role of WL irradiance in influencing UV-B induced changes.

UV-B radiation tolerant of perennial herb Silence vulgaris on the influence of UV-B fluxed during growth on the synthesis of UV-B absorbing pigments in the leaves. Analysis of methanolic leaf extracts showed a stimulating effect of UV-B on the absorbing ability of leaf extracts. HPLC analysis made clear that UV-B radiation stimulated extractable flavonoid concentrations in leaves, but UV-B absorption could only be party attributed to this flavonoid. The concentrations of flavonoid to UV-B absorption diminishes if plants mature (Staaij et al., 1995).

Premkumar and Kulandaivelu (1996) studied UV-B enhanced solar radiation (UV-B E) equivalent to 20% ozone depletion was imposed on K- sufficient (0.88
mM K2SO4) and K-deficient (0.05 mM K2SO4) cowpeas (*Vigna unguiculata*) cv. Pusa-152 seedlings, and changes in growth, leaf photosynthetic pigments, soluble leaf protein contents and photosynthetic activities were analyzed 12 d after the start of the stress. Low K supply given either independently or in combination with UV-B significantly reduced shoot and leaf biomass. The area of 1st trifoliate leaflets greatly declined under combined between growth and photosynthesis was found in K-sufficient seedlings grown under UV-B. A wide variation between the primary and trifoliate leaves was observed in contents of soluble leaf proteins under stress. The electron transport activities and net CO₂ uptake showed a sharp decline in seedlings subjected to combined stresses although the concentration of photosynthetic pigments remained unchanged.

Lingakumar and Kulandaivelu (1997) reported the effect of short term UV-B radiation on growth and foliar characteristics in *Vigna unguiculata*. Daily UV-B exposure was varied from 0.9 to 0.45 kJ m⁻² d⁻¹ (15-75 min at 1 J m⁻² s⁻¹). Low doses of UV-B irradiation (1.8 kJ m⁻² s⁻¹) produced varying responses on growth and leaf morphology. Inhibition of growth and shoot length is attributed to the destruction of endogenous auxin levels by UV-B. Chlorophyll b content decreased more than Chlorophyll A. Xanthophylls of UV-B treated seedlings exhibited marked spectral changes which confirm that the light harvesting chlorophyll protein assembly is affected under short term UV-B treatment.

The effect of ultraviolet-B radiation on growth and photosynthetic characteristics in field grown *Vigna unguiculata* (Nedunchezhan and Kulandaivelu, 1997). Plants were grown at ambient and ambient plus a 1.8 kJ/² supplementation of UV-B radiation for 25 days. The supplemental UV-B fluence
used in this experiment simulated 16% depletion in stratospheric ozone at midday in the summer at 10 degrees N latitude. Exposure to UV-B radiation increased plant height, leaf area and leaf biomass. The level of total chlorophyll on a unit fresh weight basis showed marginally decreased in the UV-B treated seedlings. No significant difference was seen in the concentration of UV-B absorbing compounds and RuBP case activity in UV-B treated seedlings. However, when various photosynthetic activities were followed in isolated chloroplasts, UV-B enhanced radiation stimulated the whole chain, photosystem (PS) I and PS II activity during the first 5 days. Prolonged treatment under UV-B enhanced radiation electron donor, Mn2- failed to restore UV-B radiation induced loss of PS II activity, while diphenyl carbazide and NH2OH partially restored PS II activity.

Sharma, et al. (1997), studied in a pot experiment the effects of supplementary UV-B radiation on photosynthesis, flavonoid content and anatomical changes in young wheat leaves. Supplementary UV-B radiation did not affect photosystem (PS) II activity, assayed as water to phenyleyendiamine. However, PS I activity, assayed as reduced dichlorophenol indephenol to methyl viologen, showed an increase. UV-B treatment resulted in qualitative and quantitative changes in UV-B absorbing phenolic compounds. Flavonol (kaempferol) and coumain showed quantitative increases due to supplementary UV- B exposure to the wheat leaves. Synthesis of cinnamic acid was observed only after 4 days of UV-B treatment. UV-B treatment resulted in significant anatomical changes in the leaves; there was a large increase in cutin synthesis. Eidermal cells largely destroyed, while hypodermal cells were seen to replace the epidermal cells.
The effect of supplemental levels of ultraviolet-B radiation on Sorghum plants was studied by Ambasht and Agrawal (1998). Gas exchange characteristics, biomass, and leaves of photosynthetic pigments, flavonoids, catalase, peroxidase activity and ascorbic acid were determined to evaluate the changes induced by enhanced levels of UV-B irradiation. Gas exchange analysis indicated that one of the reasons for the decline in photosynthesis is stomatal limitation after 60 days of exposure. Concentrations of UV-B absorbing pigments increased linearly with age. UV-B irradiation also increased phenolic compounds. Catalase activity decreased while peroxidase activity increased in response to elevated UV-B. There was a decrease in total plant biomass and ascorbic acid content of plants exposed to UV-B. Thus, an enhanced level of UV-B irradiation over a long period has a cumulative effect on a number of physiological and biochemical process, leading to a reduction in dry matter production.

Ming-Yue, et al. (1998) studied the effect of ambient and supplemental levels of ultraviolet-B radiation to determine the potential for alteration in plant nutrients, decomposition, leaf quality and dry matter yield on Spring wheat (Tritium aestivum). Supplemental UV-B radiation simulating a 12, 20 and 25% stratospheric ozone depletion significantly decreased dry matter yield, but had no significant impact on harvest index. UV-B radiation resulted in an increase of the concentrations of N and K in all plant parts; changes of the concentrations of P, Mg, Fe and Zn varied in a tissue-dependent manner, as the in decrease of P in leaves and stems, and its increase in spikes and grains. The mass of N, P, K, Mg, Fe and Zn in various plant parts and whole plant who generally decreased except leaf N mass was increased by enhanced UV-B radiation. Enhanced UV-B radiation decreased the concentrations of soluble
carbohydrates in leaves and increased that of holocellulose and soluble proteins. After 60 and 100 days of decomposition of leaves and stems in the field, enhanced UV-B radiation stimulated the loss of organic carbon. As consequence, the nutrient content of soils might be less diminished under enhanced UV-B radiation.

Santos et al. (2004) studied the biochemical and ultrastructural changes in leaves of potato plants grown under supplementary UV-B radiation. The authors reported that the UV-B exposure increased constitutive flavonoids and two new types were induced. Chlorophyll amount, as well as, total protein content, was slightly decreased. Leaf area was decreased and leaf dry weight and leaf thickness were increased, but the gross anatomy was not changed, neither was the structural integrity of the cells. In guard cells, the fractional volume of both plastids and starch was reduced, whereas thylakoids was increased. The appearance of paracrystalline inclusions in peroxisomes in both epidermal and palisade cells was conspicuous. The fractional volume of both starch and chloroplasts in palisade cells were decreased. The activity of the antioxidant enzymes such as catalase, ascorbate peroxidase and guaiacol peroxidase increased associated with the induction of a new catalase isoform and three new guaiacol isoperoxidases.

Albert et al. (2010) studied long-term responses of ambient solar ultraviolet radiation on *Salix arctica* and *Vaccinium uliginosum* in a high arctic heath ecosystem over the period of six years. Plant responses were evaluated using specific leaf area, leaf content of UV-B absorbing compounds and PSII performance parameters derived from chlorophyll-a fluorescence induction curves. In both the species, UV exclusion significantly decreased the content of UV-B-absorbing compounds. *Salix* increased its specific leaf area, while *Vaccinium* decreased it. UV exclusion
increased the total performance index in both species during all six years of experimentation. These results demonstrated the current level of ambient UV-B to decrease photo system II performance significantly in these high arctic plants. It appears that the two plant species have improved their UV-screening capacity, but through different strategies, although this did not sufficiently prevent negative effects of the ambient UV radiation.

Cuadra et al. (2010) reported the effects of UV-B radiation in morpho-genetic characters of *Gnaphalium luteo-album*. Genetic analyses showed a high degree of polymorphism in UV-B irradiated plants when compared to controls. Among the five tested primers the four ISSR primers selected for this analysis generated a total of 189 fragments. A high proportion of polymorphic bands ranging from 70% to 28% were found using these ISSR markers. The authors used Nei and Li similarity to evaluate genetic divergence among plants. A linear relationship was observed between UV-B dose and percentage of dissimilarity which may be related to DNA damage caused by the different UV-B treatments.

Salama et al. (2011) investigated the effect of enhanced ultraviolet radiation on some annual desert plants viz., *Malva parviflora*, *Plantago major* L., *Rumex vesicarius* L. and *Sisymbrium erysimoides*. The results indicated that the chlorophyll contents were affected by enhanced UV radiation. The chlorophyll a, b, and total contents were decreased compared with the control values and reduced with the enhanced UV radiation, but the carotenoid was increased compared with the control and also reduced with the enhanced UV radiation. So, the contents of chlorophylls varied considerably. *M. parviflora* showed the highest constitutive levels of accumulated chlorophyll a, b, and total chlorophyll (0.463, 0.307 and 0.774
mg g⁻¹ fw) among the investigated plant species. *P. major* showed the lowest constitutive levels of the chloroplast pigments, 0.0036, 0.0038 and 0.0075 mg g⁻¹ fw for chlorophyll a, b, and total chlorophyll at UV-365 nm, respectively. The protein content was decreased significantly in both root and shoot systems compared with the control values but, it was increased with increasing wave lengths of UV-radiation of all tested plants. *R. vesicarius* showed the highest protein contents among the investigated plants; its content was 3.8 mg g⁻¹ fw at UV-365 nm in shoot system. On the other hand, decreasing ultraviolet wave length induced a highly significant increase in the level of proline in both root and shoot of all tested plants.

The influence of enhanced UV-B radiation on growth, root morphology, leaf morphology and anatomy, pigment concentrations and gas exchange of seedlings of four tree species (*Abies faxoniana*, *Acer mono*, *Picea asperata* and *Swida hemsleyi*) was studied by Liu et al., (2011). Enhanced UV-B radiation had significant effects on seedling growth and morphological and photosynthetic traits of the four species. Total and belowground biomass was lower in seedlings exposed to enhanced UV-B radiation in all four species. Concentrations of photosynthetic pigments (Chlorophyll (a + b)) and UV-B-absorbing compounds in the leaves of all four species was lower in seedlings exposed to enhanced UV-B radiation, but the Chlorophyll a/b ratio was not affected. Enhanced UV-B markedly reduced the net photosynthetic rate and increased the intercellular CO₂ concentration in the four species. Differences in stomatal conductance to water vapor were observed in all four species. Responses differed among the four species. Generally, exposure to enhanced UV-B radiation led to shrinkage and curling of leaves in *A. mono* and *S. hemsleyi* seedlings, and reduced the leaf number and mass in *A. mono* seedlings. Exposure to enhanced UV-B
radiation markedly reduced the palisade tissue thickness in A. mono leaves but led to thicker leaves in S. hemsleyi seedlings. These results imply that broad-leaved tree seedlings were more sensitive to enhanced UV-B radiation than conifer seedlings.

Meiling et al. (2012) studied the responses of the flavonoid pathway to UV-B radiation treatments and its correlation to the lipid peroxide and antioxidant systems in Caryopteris mongolica. The results showed that chlorophyll fluorescence parameters decreased within 24 h of treatment. The chlorophyll contents decreased within 4 h and remained stable after 24 h. Carotenoid content significantly increased. The level of malondialdehyde, the activities of superoxide dismutase, ascorbate peroxidase and peroxidase and the contents of total flavonoids and anthocyanidins increased, while catalase activity decreased under UV-B stress. The activities of phenylalanine ammonialyase and chalcone isomerase also increased with the increased content of total flavonoids. The flavonoid products anthocyanidins had a significant positive correlation with malondialdehyde level, as well as the activities of antioxidant enzyme, superoxide dismutase.

Martínez-Lüscher et al. (2013) reported the short and long term effects of UV-B radiation on leaves of Vitis vinifera (cv. Tempranillo) under glasshouse-controlled conditions. The main effects of UV-B were observed after the short term exposure. Significant decreases in net photosynthesis, stomatal conductance, sub stomatal CO₂ concentration, the actual photosystem II (PSII) efficiency, total soluble proteins and de-epoxidation state of the VAZ cycle were observed, whereas the activities of several antioxidant enzymes i.e. superoxide dismutase, guaiacol peroxidase, catalase and ascorbate peroxidase were increased significantly. UV-B did not markedly affect dark respiration, photorespiration, the maximum potential
PSII efficiency, non-photochemical quenching, as well as the intrinsic PSII efficiency. However, after 75 d of exposure to 5.98 and 9.66 kJ m$^{-2}$d$^{-1}$ UV-B most photosynthetic and biochemical variables were unaffected and there were no sign of oxidative damage in leaves. The results suggest a high long-term acclimation capacity of grapevine to high UV-B levels, associated with a high accumulation of UV-B absorbing compounds in leaves, whereas plants seemed to be tolerant to moderate doses of UV-B.

Liu et al. (2013) studied the effects of enhanced ultraviolet-B radiation on soybean yield components and seed growth characteristics of three soybean cultivars viz. Hai339 (H339), Heinong 35(HN35) and Kennong18 (KN18) in field experiment for 2 years. Enhanced UV-B radiation decreased plant height, dry weight of individual stem and yield per plant of three soybean cultivars on average by 15.5%, 16.9% and 43.7%, respectively. Pod number per plant was the most responsible component for yield change under UV-B radiation. Seed number per pod was less affected by change in light treatment in our experiment, compared with the pod number per plant. UV-B radiation had no significant effect on effective filling period, however, seed size was negatively impacted by UV-B radiation and it decreased 12.3% for three soybean cultivars. Reduction of seed size was mainly due to the decrease of cotyledon cell number. Enhanced UV-B radiation had no significant effect on cotyledon cell volume, cell growth rate or cell weight.

The effects of UV-B radiation on the urediospore germination of three physiological races of *Puccinia striiformis* f. sp. *tritici* viz. CYR31, CYR32 and CYR33, and on epidemiological components of wheat stripe rust caused by Pst were investigated by Cheng et al. (2014). The results showed that the germination ability
of Pst urediospores was reduced with an enhancement of the radiation intensity and an increase in the radiation time and that CYR31 was more sensitive to UV-B radiation than CYR32 and CYR33. The results demonstrated that CYR33 was the most stable and exhibited the strongest tolerance and that CYR31 was the most vulnerable under different UV-B radiation levels. This finding indicated that CYR33 may have more advantages to survive under enhanced UV-B radiation.

Hui et al., (2015) conducted field studies to investigate the influence of ultraviolet-B (UV-B) radiation on Bryum argenteum and Microcoleus. The authors investigated chlorophyll fluorescence parameters, photosynthetic pigment contents, lipid peroxidative production, malondialdehyde, superoxide dismutase and catalase which quench free radicals and prevent oxidative stress. The higher UV-B radiation significantly decreased the Chlorophyll fluorescence parameters, Chlorophyll and carotenoid contents, and antioxidative enzymes activities. In addition, higher intensities of UV-B radiation induced dramatic increases in malondialdehyde content of B. argenteum and M. vaginatus. The results of this study showed that increased levels of UV-B radiation caused detrimental effects on chlorophyll fluorescence, photosynthetic pigment and antioxidant systems of B. argenteum and M. vaginatus. B. argenteum was more sensitive to enhanced UV-B radiation than M. vaginatus.

Zhu and Yang (2015) reported the effect of different level of ambient UVB radiation on the growth and physiological responses of Brassica napus. The authors used three experimental groups: control (ambient UV-B radiation), T1 (25% exclusion of solar UV-B), and T2 (70% exclusion of solar UV-B). Compared to the control, exclusion of solar UV-B radiation enhanced specific leaf weight and caused plant height increased with a significant increase in biomass. Ambient UV-B
radiation caused the UV-B absorbing compounds of the leaves to increase, while chlorophyll (a, b, and total) content decreased. No significant differences in carotenoid content were detected among the three groups. Compared to the control, exclusion of solar UV-B radiation reduced antioxidant enzyme activity. Moreover, the results showed that exposure to UV-B radiation caused *B. napus* to increase UV-B absorbing compounds to reduce the transmittance of UV photons through the leaf tissue, enhance antioxidant enzyme activity to scavenge reactive oxygen species (ROS), and increase carotenoids to prevent oxidative damage. However, the bleaching of chlorophyll a and damage to the photosynthetic apparatus by solar UV-B radiation caused a reduction in the photosynthetic rate.

The effects of UV and rainfall radiation on the seasonal leaf phenolic content and antioxidant activity of *Arbutus unedo* were studied by Nenadis *et al.* (2015). The authors observed a significant seasonal variation in the leaf content of phenols of *A. unedo*, with the lowest values found in spring and the highest in autumn and winter. Leaf ontogenetic development and a possible effect of low temperatures in autumn/winter may account for such findings. Regardless of the watering regime and the sampling date, plant exposure to UV-B radiation decreased the total flavanol content of leaves, while it increased the leaf content in quercitrin (the most abundant quercetin derivative identified). By contrast, UV-A radiation increased the leaf content of theogallin, a gallic acid derivative. Other phenolic compounds (two quercetin derivatives, one of them being avicularin, and one kaempferol derivative, juglanin), as well as the antioxidant activity of the leaves, showed different responses to UV radiation depending on the precipitation regime.
Randriamanana et al. (2015) investigated the interactive effects of UV-B and temperature treatments on growth, leaf traits and phenolic concentrations in *Populus tremula* (European aspen) seedlings. The authors modulated the supplemental temperature and UV-B above ambient conditions. Warming increased growth, photosynthesis and foliar nitrogen concentration but reduced leaf thickness and phenolic concentrations. On the other hand, supplemental UV-B increased total phenolic glycosides, mainly flavonols and phenolic acids, and partially counteracted the positive effects of warming on growth. Fast growing genotypes were less susceptible to the growth-reducing effect of combined UVB and temperature, less infected with rust disease and less prone to insect damage probably due to their higher salicylate and lower nitrogen concentrations. Under ambient temperature, the males of European aspen were taller and had bigger leaves than the females, while under elevated temperature, females grew bigger and, under UV-B, had more tremulacin than males. The multiple interactive effects of UV-B and temperature on growth, leaf traits and phenolic compounds, highlight the importance of multifactor experiments as a realistic predictor of plant responses to climate change.

Differential physiological and biochemical responses of two *Vigna* spp. i.e. *V. mungo* and *V. acontifolia* seedlings exposed to enhanced ultraviolet-B radiation were studied by Dwivedi et al. (2015). UV-B radiation accelerated the generation of reactive oxygen species i.e. superoxide radical, hydrogen peroxide and hydroxyl radical in leaves, and concomitantly damaging effects on lipid peroxidation, electrolyte leakage and growth in both *Vigna* spp. were noticed in dose dependent manner, but *V. mungo* exhibited greater UV-B damaging effects. UV-B stress induced positive response on antioxidants: superoxide dismutase and guaiacol
peroxidase activity, and contents of proline, ascorbic acid, total phenolic contents and total flavonoid contents in leaves of both spp., however, catalase exhibited varied activity. The study concludes that substantially higher contents of total phenolic contents and total flavonoid contents in epidermal layer, proline and ascorbic acid, and higher catalase activity before and after enhanced UV-B exposure probably attributed greater tolerance to *V. acontifolia* species, thus exhibited lesser UVB induced damaging effects on cellular components and growth than that of *V. mungo*. This study also suggests that *V. acontifolia* is comparatively resistant to UV-B and thus may be useful for practical cultivation.

The influence of postharvest UV-B on its own and in combination with fermentation (e.g. sauerkraut production) on formation and degradation of bioactive compounds was investigated in white cabbage, processed according to traditional Chinese fermentation methods. The pattern of polyphenols was affected by postharvest UV-B: Newly formed coumaroylglycoside, feruloylglycoside, caffeoylglycoside (up to 1 mg/g dry matter; 4 days) and quercetintriglycoside (0.4–0.5 mg/g dm; 4 days) might be related to postharvest increase in enzyme activity in the biosynthesis. Decreasing contents were observed for the glucosinolates glucobrassicin and 4-methoxyglucobrassicin, but the formation of the degradation products dihydroascorbigen and dihydro-4-methoxyascorbigen, which might be related to cell shrinking as mechanical damage (Harbaum-Piayda *et al.*, 2016).
Chapter 3: Materials and Methods

3.1 Experimental Site

The experiment was conducted during 2014-2015 under natural conditions at Al-Foah Experimental farm, College of Food and Agriculture, UAEU, Al Ain, in covered greenhouse, built, erected with galvanized construction bars, with side and covered with insect net.

3.2 Date Palm Varieties and Experimental Design

For the present study seedlings of five numbers of most cultivate Emirates varieties (i.e., BARHI, FRDWT, NBTSF, FRDRD and KHD) of date palm were received from Date Palm Research Laboratory used.

3.3 UV Treatment

Eight numbers of fluorescent UV-313 lamps with a characteristic emission in the range 280–320 nm were used as a source of UV-B radiation. The lamps were wrapped with presolarized 0.07 mm cellulose diacetate film to filter UV-C (<280 nm) radiation. The cellulose diacetate film was changed at 3–4 day intervals. The UV-B energy delivered at the top of the plant canopy was checked daily with a UVX digital radiometer. The date palm varieties were treated with 4 and 8 hrs in the middle of the day. The distance between the lamp and plants was 1 m. The plants without UV-B irradiation treatment were kept separated and considered as control.
3.4 Morphological Parameters

3.4.1 Shoot, Root and Total Plant Length

Shoot length was measured from the soil level to the tip of the shoot and expressed in cm. the plant root length was measured from the point of the first cotyledonary node to the tip of longest root and expressed in cm. and the total plant length was measured from the top of the plant to the tip of longest root and expressed in cm.

3.4.2 Total Plant Fresh Weight

After harvesting the plants were washed in the tap water, fresh weight was determined by using an electronic balance and the values were expressed in grams.

3.4.3 Shoot and Root Fresh and Dry Weight

After washing the plants in the tap water, fresh weight was determined by using an electronic balance (Model – XK3190-A7M) and the values were expressed in grams. After taking fresh weight, the plants were dried at 75°C in hot air oven for 24 hours. After drying, the weight was measured and the values were expressed in grams.

3.4.4 Leaves Number

The total number of leaves, which were fully developed, were counted and expressed as number of leaves per plant.
3.5 Estimation of Chlorophyll and Carotenoid Content

Chlorophyll and carotenoid were extracted from the leaves and estimated by the method of Arnon (1949).

500mg of fresh leaf material was ground with 10 ml of 80 per cent acetone at 4°C and centrifuged at 2500 rpm for 10 minutes at 4°C. This procedure was repeated until the residue became colourless. The extract was transferred to a graduated tube and made up to 10 ml with 80 per cent acetone and assayed immediately.

Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 645, 663 and 480 nm with a spectrophotometer (U-2001-Hitachi) against 80 per cent acetone as blank. Chlorophyll content was calculated using the formula of Arnon and expressed in milligram per gram fresh weight.

\[
\text{Total chlorophyll (mg/ml)} = (0.0202) \times (A.645) + (0.00802) \times (A.663) \\
\text{Chlorophyll ‘a’ (mg/ml) } = (0.0127) \times (A.663) – (0.00269) \times (A.645) \\
\text{Chlorophyll ‘b’ (mg/ml) } = (0.0229) \times (A.645) – (0.00468) \times (A.663)
\]

Carotenoid content was estimated using the formula of Kirk and Allen (1965) and expressed in milligrams per gram fresh weight.

\[
\text{Carotenoid (mg/g)} = A.480 + (0.114 \times A.663 – 0.638 \times A.645)
\]

3.6 Estimation of Total Phenols Content

Total phenol was estimated by the method of Malick and Singh (1980). 500 mg of fresh plant tissue was ground using a pestle and a mortar with 10 ml of 80% ethanol. The homogenate was centrifuged at 10 000 rpm for 20 minutes. The
supernatant was evaporated to dryness. The residue was dissolved in 5 ml of distilled water and used as the extract. To 2 ml of the extract, 0.5 ml of FolinCiocalteau reagent was added. After 3 min, 2 ml of 20% Na₂CO₃ solution was mixed thoroughly. The mixture was kept in boiling water for exactly 1 min and after cooling the absorbance was read at 650 nm. The total phenol was determined using a standard curve prepared with different concentrations of gallic acid.

3.7 Biochemical Analysis

3.7.1 Estimation of Proline

Proline content was estimated following the method of Bates et al. (1973). Five hundred mg of plant material was taken in a pestle and mortar and homogenized with 10 ml of 3 per cent aqueous sulfosalicylic acid. Then the homogenate was filtered through whatman No. 2 filter paper. The residue was re-extracted two times with 3 per cent sulfosalicylic acid and pooled. The filtrates were made up to 20 ml with 3 per cent sulfosalicylic acid and used for the estimation of proline.

Two ml of extract was taken in a test tube and 2 ml of acid ninhydrin reagent and 2 ml of glacial acetic acid were added to it. The mixture was incubated for one hour at 100°C in a water bath. The tubes were transferred to an ice bath to terminate the reaction. Then to each test tube 4 ml of toluene was added and mixed vigorously using a test tube stirred for 10-20 seconds. The toluene containing the chromophore was separated from the aqueous phase with the help of separating funnel and the absorbance was measured at 520 nm in a spectrophotometer using an appropriate blank. The proline content was determined from a standard curve prepared with proline and the results were expressed in milligram per gram dry weight.
3.8 Elemental Analysis

Plant samples and immediately brought to the laboratory using plastic bags. The samples were air dried then oven dry at 105 °C for 3 hrs and the samples were grinded and stored in a desiccator for further analysis. The CEM Mars 5 microwave digestion system was used to extract the elements from the plants samples. The digestion procedure was based upon the recommendation in USEPA method 3015A guidelines. This microwave digestion method was designed to mimic extraction using conventional heating with nitric acid (HNO\textsubscript{3}) and hydrochloric acid (HCL). The plant samples were prepared accurately by weighing 0.5 grams of sample into the microwave digestion vessels and adding 10ml of concentrated nitric acid (HNO\textsubscript{3}) and 2 ml hydrochloric acid (HCL) (US EPA 3051 Method (1994). The vessels were capped and placed in the microwave digestion system.

Varian ICP-OES model 710-ES simultaneous axially viewed plasma with full PC control of instrument settings and compatible accessories was used for the elemental analysis. For analysis a portion of homogeneous Plants samples are accurately weighed and treated with acids to destroy the organic matter and solubilized the recoverable elements. After cooling, the sample was made up to the volume with deionized water and filtered. The sample solution was aspirated through nebulizer and the resulting aerosol was transported to the plasma torch where excitation occurs. Element specific emission spectra were produced by radio-frequency inductively coupled plasma. The spectra were dispersed by a grating spectrometer, and intensities of the line spectra are monitored at specific wavelengths by a charged coupled detector. A fitted background correction was used to correct the blank signal and matrix effect.
The calibration blank was prepared by diluting 1 ml of concentrated nitric acid in 100 ml deionized water. Sufficient quantity was used to flush the system between standards and samples. The reagent blank contains the same volumes of all reagents used in the processing of the samples. The reagents blank was carried through complete procedure and contain the same acid concentration in the final solution as the sample solution used for analysis.

3.9 Statistical Analysis

The data pertained to all the characters studied were subjected to statistical analysis using SPSS (V. 21.0). The values were meant for three replicates of all the treatments and control. The calculated data expressed in Mean±SE.
Chapter 4: Results

The results on the effect of 4 hrs and 8 hrs of UVB irradiation of some Emirates date palm varieties viz. BARHI, FRDWT, NBTSF, FRDRD and KHD on morphological, biochemical and mineral content are given in Table Nos. 1-14. It was found that, enhanced UV-B radiation under field conditions has caused notable alterations in the morphology and biochemical content in the studied date palm varieties.

The results on the plant height of above mentioned date palm varieties treated with UVB radiation is given in Table No.1. All the above plants were found to be sensitive to UV-B enhanced radiation and it affected the height of the plants. The height of the control plants of BARHI, FRDWT, NBTSF, FRDRD and KHD varieties were 107.5±3.76, 105.0±3.39, 118.5±2.32, 119.16±1.68 and 121.42±3.19 cm respectively. But, the plant height of 4 hrs UVB treated date palm varieties were slightly reduced (BARHI=101.83±1.34; FRDWT=103.5±2.07; NBTSF=118.33±4.91; FRDRD=116.83±4.10 and KHD=113.66±3.91 cm). Whereas, the height of the 8 hrs treated date palm varieties were adversely affected by the UVB and the height of the plants of BARHI, FRDWT, NBTSF, FRDRD and KHD were 101.5±4.32, 100.66±3.53, 115.5±4.46, 114.16±5.28 and 112.66±6.81 cm respectively.

Table No. 2 Shows that the effect of UVB radiation on number of leaves in the studied date palm varieties. The number of leaves in the date palm varieties was significantly reduced after 4 and 8 hrs of UVB treatment. The leaves number in the control plants of date palm varieties viz. BARHI, FRDWT, NBTSF, FRDRD and KHD were 15.66±0.21, 15.66±0.33, 15.66±0.33, 15.33±0.33 and 16.00±0.25 respectively. Whereas, the leaves number of BARHI, FRDWT, NBTSF, FRDRD and
KHD varieties after 4 and 8 hrs of UVB treatments were 14.66±0.33, 14.00±0.25, 14.83±0.30, 14.66±0.66, 14.33±0.95 and 13.3±0.33, 14.33±0.21, 15.16±0.16, 15.50±0.50 and 14.50±1.08 respectively.

Table 1: Effect of UVB on Plant height (cm) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>107.5±3.76c</td>
<td>101.83±1.34a*</td>
<td>101.5±4.32a*</td>
</tr>
<tr>
<td>FRDWT</td>
<td>105.0±3.39b</td>
<td>103.5±2.07b</td>
<td>100.66±3.53a*</td>
</tr>
<tr>
<td>NBTSF</td>
<td>118.5±2.32c</td>
<td>118.33±4.91c</td>
<td>115.5±4.46c</td>
</tr>
<tr>
<td>FRDRD</td>
<td>119.16±1.68a*</td>
<td>116.83±4.10c</td>
<td>114.16±5.28c</td>
</tr>
<tr>
<td>KHD</td>
<td>121.42±3.19c</td>
<td>113.66±3.91c</td>
<td>112.66±6.81c</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P < 0.05 level

Table 2: Effect of UVB on number of leaves (leaves/plantlet) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>15.66±0.21b*</td>
<td>14.66±0.33d</td>
<td>13.3±0.33a</td>
</tr>
<tr>
<td>FRDWT</td>
<td>15.66±0.33b*</td>
<td>14.00±0.25b*</td>
<td>14.33±0.21d</td>
</tr>
<tr>
<td>NBTSF</td>
<td>15.66±0.33b*</td>
<td>14.83±0.30c</td>
<td>15.16±0.16f</td>
</tr>
<tr>
<td>FRDRD</td>
<td>15.33±0.33b*</td>
<td>14.66±0.66b*</td>
<td>15.50±0.50f*</td>
</tr>
<tr>
<td>KHD</td>
<td>16.00±0.25b*</td>
<td>14.33±0.95c</td>
<td>14.50±1.08d</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P < 0.05 level
Effect of UVB radiation on shoot fresh weight of studied date palm varieties is presented on Table No. 3. The fresh weight of control plants were BARHI=1.395±0.10; FRDWT=1.598±0.133; NBTSF=1.758±0.124; FRDRD=2.083 ±0.127 and KHD=2.208±0.042 g. Whereas, the shoot fresh weight of BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties after 4 and 8 hrs of UVB treatment were 1.110±0.053, 1.430±0.060, 1.268±0.043, 1.611±0.111, 1.533±0.129 and 0.773±0.203, 0.763±0.219, 0.978±0.188, 1.240±0.062 and 1.340±0.215 g respectively. The highest shoot fresh weight reduction was observed in FRDWT after 8 hrs of UVB treatment. The shoot weight of NBTSF after four hrs and FRDRD and KHD varieties after 8 hrs were significantly (p < 0.05 level) reduced under UVB treatment.

Table 3: Effect of UVB on Shoot Fresh Weight (Kg) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>1.395±0.102e</td>
<td>1.110±0.053c</td>
<td>0.773±0.203a</td>
</tr>
<tr>
<td>FRDWT</td>
<td>1.598±0.133f</td>
<td>1.430±0.060e</td>
<td>0.763±0.219a</td>
</tr>
<tr>
<td>NBTSF</td>
<td>1.758±0.124f</td>
<td>1.268±0.043d*</td>
<td>0.978±0.188b</td>
</tr>
<tr>
<td>FRDRD</td>
<td>2.083±0.127g</td>
<td>1.611±0.111f</td>
<td>1.240±0.062d*</td>
</tr>
<tr>
<td>KHD</td>
<td>2.208±0.042g</td>
<td>1.533±0.129f</td>
<td>1.340±0.215d*</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level

Table No. 4 summarizes the shoot dry weight of untreated date palm varieties as well as 4 and 8 hrs of UVB treatment. Shoot dry weight of studied date palm varieties also reduced after UVB treatment. Shoot dry weight of control plants of BARHI, FRDWT, NBTSF, FRDRD and KHD varieties were 0.548±0.034, 0.683±0.025, 0.656±0.052, 0.840±0.050 and 0.743±0.079 g and after 4 and 8 hrs of
UVB treatments were 0.523±0.038, 0.590±0.034, 0.641±0.023, 0.751±0.054, 0.731±0.051 and 0.493±0.049, 0.454±0.078, 0.606±0.034, 0.718±0.061 and 0.606±0.105 respectively. The shoot dry weight of FRDWT after 8 hrs of UVB treatment was significant at P< 0.05 level.

Table 4: Effect of UVB on shoot dry weight (Kg) date palm of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.548±0.034d</td>
<td>0.523±0.038c</td>
<td>0.493±0.049b</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.683±0.025h</td>
<td>0.590±0.034e</td>
<td>0.454±0.078a*</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.656±0.052g</td>
<td>0.641±0.023f</td>
<td>0.606±0.034c</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.840±0.050i</td>
<td>0.751±0.054h</td>
<td>0.718±0.061h</td>
</tr>
<tr>
<td>KHD</td>
<td>0.743±0.079h</td>
<td>0.731±0.051h</td>
<td>0.606±0.105c</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level

Table 5: Effect of UVB on root fresh weight (Kg) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.936±0.085d*</td>
<td>0.530±0.047c</td>
<td>0.453±0.043a*</td>
</tr>
<tr>
<td>FRDWT</td>
<td>1.093±0.154c</td>
<td>0.635±0.048c</td>
<td>0.505±0.034c</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.733±0.067d*</td>
<td>0.530±0.501c</td>
<td>0.491±0.041b</td>
</tr>
<tr>
<td>FRDRD</td>
<td>1.091±0.091c</td>
<td>0.625±0.040c</td>
<td>0.555±0.051c</td>
</tr>
<tr>
<td>KHD</td>
<td>0.981±0.072c</td>
<td>0.555±0.038c</td>
<td>0.501±0.038b</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level
Root fresh weight of BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties after 4 and 8 hrs of UVB treatment is presented in Table No.5. The root weight was adversely reduced when treated with UVB radiation for 4 and 8 hrs. The root fresh weight of control plant of above mentioned date palm varieties were 0.936±0.085, 1.093±0.154, 0.733±0.067, 1.091±0.091 and 0.981±0.072 respectively. Whereas, the root fresh weight of roots after 4 hrs of UVB treatment were BARHI= 0.530±0.047; FRDWT=0.635±0.048; NBTSF=0.530±0.501; FRDRD=0.625±0.040 and KHD=0.555±0.038 and after 8 hrs treatment were BARHI=0.453±0.043; FRDWT=0.505±0.034; NBTSF=0.491±0.041; FRDRD=0.555±0.051 and KHD=0.501±0.038.

Table No. 6 shows the root dry weight of studied date palm varieties after 4 and 8 hrs of UVB treatment. The root dry weight also reduced in all the varieties studied after 4 and 8 hrs of UVB treatment when compared to control.

Table 6: Effect of UVB on root dry weight (Kg) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.288±0.030</td>
<td>0.266±0.029</td>
<td>0.240±0.036</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.318±0.027</td>
<td>0.311±0.049</td>
<td>0.300±0.022</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.298±0.031</td>
<td>0.271±0.016</td>
<td>0.263±0.016</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.378±0.023</td>
<td>0.366±0.033</td>
<td>0.303±0.028</td>
</tr>
<tr>
<td>KHD</td>
<td>0.335±0.025</td>
<td>0.331±0.044</td>
<td>0.248±0.043</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level
The root dry weight of BARHI, FRDWT, NBTSF, FRDRD and KHD after 4 and 8 hrs of UVB treatments were 0.266±0.029, 0.311±0.049, 0.271±0.016, 0.366±0.033, 0.331±0.044 and 0.240±0.036, 0.300±0.022, 0.263±0.016, 0.303±0.028 and 0.248±0.043 g respectively. Whereas, the root fresh weight of control plants were BARHI=0.288±0.030, FRDWT=0.318±0.027, NBTSF=0.298±0.031, FRDRD=0.378±0.023 and KHD=0.335±0.025.

The effect of chlorophyll a content variation after 4 and 8 hrs treatments with UVB radiation is given in Table No. 7. Chlorophyll ‘a’ content was gradually decreased in FRDWT, NBTSF, FRDRD and KHD after 4 and 8 hrs of UVB treatment. But in BARHI variety, chlorophyll ‘a’ content was slightly decreased when compared to all other varieties tested.

Table 7: Effect of UVB on Chlorophyll ‘a’ content (mg/g) fresh weight) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>1.472±0.275 a</td>
<td>1.469±0.255 a</td>
<td>1.453±0.156 a</td>
</tr>
<tr>
<td>FRDWT</td>
<td>1.689±0.172 a</td>
<td>1.583±0.182 a</td>
<td>1.571±0.131 a</td>
</tr>
<tr>
<td>NBTSF</td>
<td>1.573±0.218 a</td>
<td>1.373±0.071 a</td>
<td>1.246±0.043 a</td>
</tr>
<tr>
<td>FRDRD</td>
<td>1.669±0.073 a</td>
<td>1.527±1.151 a</td>
<td>1.361±0.050 a</td>
</tr>
<tr>
<td>KHD</td>
<td>1.649±0.188 a</td>
<td>1.542±0.298 a</td>
<td>1.355±0.405 a</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day;
* - Significant at P < 0.05 level

Chlorophyll ‘a’ content of BARHI, FRDWT, NBTSF, FRDRD and KHD after 4 and 8 hrs of UVB treatments were 1.469±0.255, 1.583±0.182, 1.373±0.071, 1.527±1.151, 1.542±0.298 and 1.453±0.156, 1.571±0.131, 1.246±0.043, 1.361±0.050 and 1.355±0.405 mg/g respectively. Whereas, chlorophyll ’a’ content in all the control
plants were 1.472±0.275, 1.689±0.172, 1.573±0.218, 1.669±0.073 and 1.649±0.188 mg/g in BARHI, FRDWT, NBTSF, FRDRD and KHD varieties respectively.

As observed in chlorophyll ‘a’, the chlorophyll ‘b’ content also gradually reduced in all varieties of date palm studied after the UVB treatment and the results are presented in Table 8. Chlorophyll ‘b’ content in untreated date palm varieties viz., BARHI, FRDWT, NBTSF, FRDRD and KHD were 0.517±0.066, 0.467±0.035, 0.332±0.026, 0.452±0.009 and 0.366±0.052 mg/g. while, after the 4 and 8 hrs treatment the chlorophyll ‘b’ content were 0.484±0.130, 0.450±0.026, 0.314±0.009, 0.405±0.052, 0.347±0.119 and 0.428±0.044, 0.421±0.042, 0.262±0.112, 0.363±0.026 and 0.249±0.103 mg/g respectively.

Table 8: Effect of UVB on Chlorophyll ‘b’ content (mg/g) fresh weight) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.517±0.066^h</td>
<td>0.484±0.130^h</td>
<td>0.428±0.044^h</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.467±0.035^h</td>
<td>0.450±0.026^h</td>
<td>0.421±0.042^h</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.332±0.026^d</td>
<td>0.314±0.009^c</td>
<td>0.262±0.112^b</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.452±0.009^h</td>
<td>0.405±0.052^d</td>
<td>0.363±0.026^c*</td>
</tr>
<tr>
<td>KHD</td>
<td>0.366±0.052^f</td>
<td>0.347±0.119^d</td>
<td>0.249±0.103^a</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level

The total chlorophyll content of untreated, 4 and 8 hrs of UVB treated plants are presented in Table No. 9. The total chlorophyll content was degreased in all the varieties of date palm studied after 4 and 8 hrs of UVB treatment when compared to untreated plants.
Table 9: Effect of UVB on Total Chlorophyll content (mg/g) fresh weight) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>1.936±0.199d</td>
<td>1.900±0.401d</td>
<td>0.986±0.321a</td>
</tr>
<tr>
<td>FRDWT</td>
<td>2.155±0.205d</td>
<td>2.021±0.157d</td>
<td>2.004±0.224d</td>
</tr>
<tr>
<td>NBTSF</td>
<td>1.836±0.153d</td>
<td>1.705±0.096c</td>
<td>1.560±0.049b*</td>
</tr>
<tr>
<td>FRDRD</td>
<td>2.121±0.077d</td>
<td>1.932±0.200d</td>
<td>1.723±0.074c</td>
</tr>
<tr>
<td>KHD</td>
<td>2.015±0.240d</td>
<td>1.719±0.269c</td>
<td>1.702±0.525c</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day;
* - Significant at P < 0.05 level

The content of total chlorophyll content in untreated date palm varieties of BARHI, FRDWT, NBTSF, FRDRD and KHD were 1.936±0.199, 2.155±0.205, 1.836±0.153, 2.121±0.077 and 2.015±0.240 mg/g respectively. The total chlorophyll content in BARHI, FRDWT, NBTSF, FRDRD and KHD varieties after 4 and 8 hrs of UVB treatments were 1.900±0.401, 2.021±0.157, 1.705±0.096, 1.932±0.200, 1.719±0.269 and 0.986±0.321, 2.004±0.224, 1.560±0.049, 1.723±0.074 and 1.702±0.525 mg/g respectively.

The Carotenoid content of control, 4 and 8 hrs UVB treated plants of BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties are given in Table No. 10. Carotenoid content was decreased in all the of date palm varieties studied. The carotenoid content of FRDRD after 4 hrs UVB treatment and KHD variety after 4 and 8 hrs of UVB treatment did not showed much difference. However, the carotenoid content of NBTSF was significantly decreased after 8 hrs of UVB treatment.
In untreated plants, 0.623±0.059, 0.722±0.040, 0.629±0.068, 0.656±0.033 and 0.573±0.054 mg/g of carotenoid content were recorded in BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties respectively. After 4 and 8 hrs of UVB treatment, the carotenoid content of BARHI, FRDWT, NBTSF, FRDRD and KHD were 0.609±0.068, 0.645±0.045, 0.525±0.041, 0.656±0.013, 0.576±0.098, 0.572±0.036, 0.470±0.039, 0.568±0.010 and 0.529±0.142 mg/g respectively.

Total proline content of untreated and UVB treated date palm varieties are presented in Table. 11. Proline content was increased after 4 and 8 hrs of UVB treatment.

Table 10: Effect of UVB on Carotenoid content (mg/g) fresh weight) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.623±0.059&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.609±0.068&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.576±0.098&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.722±0.040&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.645±0.045&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.572±0.036&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.629±0.068&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.525±0.041&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.470±0.039&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.656±0.033&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.656±0.013&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.568±0.010&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>KHD</td>
<td>0.573±0.054&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.525±0.060&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.529±0.142&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P< 0.05 level

After 4 and 8 hrs UVB treatment, proline content in BARHI variety was highly increased when compared to control plant. In all other varieties also the proline content was increased gradually after UVB treatment. Proline content in control plants were BARHI=0.546±0.104, FRDWT=0.525±0.131, NBTSF=0.649±0.193, FRDRD=0.672±0.139 and KHD=0.605±0.049. After 4 and 8 hrs of UVB treatment, the proline content of BARHI, FRDWT, NBTSF, FRDRD
and KHD date palm varieties were 1.173±0.054, 0.916±0.198, 0.740±0.286, 0.939±0.255, 0.842±0.081 and 1.209±0.317, 1.052±0.299, 0.996±0.258, 1.068±0.188, 1.173±0.368 mg/g respectively.

Table 11: Effect of UVB on Proline content (mg/g) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.546±0.104&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.173±0.054&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.209±0.317&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.525±0.131&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.916±0.198&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.052±0.299&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.649±0.193&lt;sup&gt;b&lt;/sup&gt;*</td>
<td>0.740±0.286&lt;sup&gt;b&lt;/sup&gt;*</td>
<td>0.996±0.258&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.672±0.139&lt;sup&gt;c&lt;/sup&gt;*</td>
<td>0.939±0.255&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.068±0.188&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>KHD</td>
<td>0.605±0.049&lt;sup&gt;b&lt;/sup&gt;*</td>
<td>0.842±0.081&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.173±0.368&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P < 0.05 level

Table 12: Effect of UVB on Phenol content (mg/g) of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>0.035±0.003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.036±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.039±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDWT</td>
<td>0.039±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.040±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.042±0.003&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NBTSF</td>
<td>0.051±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.051±0.006&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.056±0.005&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRDRD</td>
<td>0.036±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.037±0.002&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.043±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>KHD</td>
<td>0.035±0.003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.039±0.003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.042±0.004&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are the mean of three replicates; T1 – 4 hrs UV treatment/day; T2 – 8 hrs UV treatment/day; * - Significant at P < 0.05 level
No change was observed in NBTSF variety of date palm after 4 hrs of UVB treatment. But, after 8 hrs the phenol content was increased in notable amount. The phenol content in untreated plants were BARHI=0.035±0.003, FRDWT=0.039±0.001, NBTSF=0.051±0.001, FRDRD=0.036±0.001 and KHD=0.035±0.003 mg/g. Furthermore, After 4 and 8 hrs of UVB treatment the phenol content of BARHI, FRDWT, NBTSF, FRDRD and KHD were 0.036±0.0, 0.040±0.0, 0.051±0.006, 0.037±0.002, 0.039±0.003 and 0.039±0.001, 0.042±0.003, 0.056±0.005, 0.043±0.0 and 0.042±0.004 mg/g respectively.

The effect of UVB radiation on mineral nutrient content of shoots of BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties are given in Table No. 13. Calcium content of shoots was increased in all the varieties studied except FRDWT. The shoots of FRDRD showed highest calcium content (0.97 mg/kg) and the shoots of KHD showed the lowest calcium content (0.78 mg/g) after 8 hrs of UVB treatment.

The UVB treatment gradually increased Cobalt content in shoots of all the varieties of date palm studied when compared to control. The highest cobalt content (0.92 ppm) was observed in shoots of NBTSF variety after 8 hrs of UVB treatment. The content of copper was decreased in shoots of all the varieties of date palm studied after the UVB treatment. The copper content was low in NBTSF variety including control and the high content of copper was observed in FRDWT. The result of iron analysis showed that different level between the date palm varieties studied. In BARHI and FRDRD varieties, the content of iron was increased gradually after 4 and 8 hrs of UVB treatment. Whereas, in NBTSF the iron content was decreased at 4 hrs treatment, but, 8 hrs treated plants showed high level of iron.
content. In controversy, the iron content in FRDWT and KHD varieties was increased in 4 hrs treatment and degreased at 8 hrs treated plants.

Potassium content in shoots of all the studied date palm varieties was reduced after the exposure of UVB. The highest potassium content was recorded in the control plant of NBTSF and it was reduced dramatically after 8 hrs of UVB treatment. Magnesium content in BARHI, FRDWT varieties were increased in 4 hrs UVB treatments and reduced after 8 hrs of UVB exposure. In conflicting, magnesium content of NBTSF variety was degreased after 4 hrs of UVB exposure and increased after 8 hrs of UVB exposure. In, shoots of FRDRD and KHD date palm varieties, magnesium content was gradually increased after 4 and 8 hrs of UVB exposure.

In all the varieties the manganese content of the shoots were increased after 4 and 8 hrs of UVB treatment. After 4 hrs of UVB exposure, manganese content was increased slightly in BARHI, NBTSF and FRDRD varieties. But after 8 hrs of exposure period the element content was increased dramatically. The highest content of manganese (35.12 ppm) was recorded in FRDRD after 4 hrs of UVB exposure. Molybdenum was decreased in all the varieties except NBTSF when treated with UVB. In NBTSF variety of date palm, molybdenum was recorded <0.01 ppm in all the treatments. The highest content of molybdenum (5.2 ppm) was recorded in control plant of FRDWT.

Sodium level in shoots of all the studied date palm varieties was increased after the exposure of UVB. In FRDRD variety, sodium level was increased slightly after 4 and 8 hrs of UVB treatment. In FRDWT, there was no change observed after 4 hrs of UVB. But, the 8 hrs of UVB exposure showed high level of sodium. The results of phosphorus analyses showed that, there were no changes in BARHI and
FRDWT, the content was increased after 4 hrs of UVB treatment.

The content of sulfur was decreased when the time of UVB exposure is increased in the shoots of all the varieties of date palm studied. The highest content of sulfur content (0.37 ppm) was observed in the shoots of control plant of FRDWT variety. Element analysis of shoots of all the studied date palm variety showed that varied level of zinc in control as well as in treated plants. In BARHI variety, zinc content was increased after 4 hrs of UVB treatment and degreased in 8 hrs treated plants. FRDWT and FRDRD varieties showed the zinc content was increased when the UVB exposure was extended. The zinc content in the shoots of KHD variety degreased after 4 hrs treatment and increased after 8 hrs treatment. Whereas, the zinc content was degreased after 4 and 8 hrs of UVB treatment NBTSF. In the shoots of all the varieties of date palm studied nitrogen content was degreased after 4 hrs UVB treatment and increased in 8 hrs exposure except NBTSF. In NBTSF variety the nitrogen content was degreased gradually after the time of UVB exposure increased.

The effect of UVB radiation on mineral nutrient content of roots of BARHI, FRDWT, NBTSF, FRDRD and KHD date palm varieties are given in Table No. 14.

Calcium content analysis of roots of studied date palm varieties showed that increased level of calcium after 4 hrs treatment and degreased level of calcium after 8 hrs treatment in all the varieties except KHD. In KHD, the calcium content was degreased after 4 hrs treatment and increased in 8 hrs treatment.
In BARHI, FRDWT and NBTSF varieties, the cobalt content was increased after 4 hrs of UVB treatment and degreased in 8 hrs treatment. Whereas in FRDRD and KHD, the cobalt content was gradually increased after 4 and 8 hrs of UVB exposure. The degreased level of copper content was observed after 4 hrs UVB treatment in all the varieties studied except NBTSF. Whereas after 8 hrs of UVB radiation increased the content of copper in all the varieties studied. In BARHI, FRDWT, NBTSF and KHD varieties the iron content was increased after 4 hrs UVB exposure and degreased after 8 hrs of UVB treatment. However, the iron content of FRDRD variety was increased after 4 hrs UVB treatment and same level was observed in 8 hrs treatments also.

Potassium content of roots of all the studied date palm varieties were degreased gradually after 4 and 8 hrs of UVB treatment. Magnesium content of BARHI variety was increased in 4 and 8 hrs of UVB treatment. But in NBTSF and FRDRD varieties, the content of magnesium was degreased after the UVB exposure. Whereas, in FRDWT and KHD varieties the magnesium content was increased in 4 hrs treatment and degreased in 8 hrs of UVB treatment. There was no change in manganese content of the roots of BARHI variety. But in all other varieties the manganese content was increased in 4 hrs treatment and degreased in 8 hrs of UVB treatment.

Molybdenum content was degreased in roots of all the varieties of date palm studied. The highest content of molybdenum was observed in the control plant of BARHI and FRDRD varieties. Slight sodium content variation in the root of BARHI, NBTSF and KHD varieties between 4 and 8 hrs of UVB treatment and in FRDRD
variety no notable changes was observed between the treatments. In FRDWT variety the sodium content was reduced after 8 hrs of UVB treatment.

The phosphorus content was increased in BARHI, NBTSF, FRDRD and KHD roots after 4 hrs of UVB treatment and in FRDWT variety it was increased in 8 hrs of UVB treatment. Sulfur content was decreased in BARHI, NBTSF and KHD varieties after the UVB treatment. Whereas in FRDWT variety it was decreased after 8 hrs of UVB treatment. In FRDRD variety the sulfur content was increased in 8 hrs UVB exposure. The content of zinc was decreased in the roots of BARHI variety after the UVB treatment when compared to control. Whereas all other varieties showed increased zinc content in 4 hrs UVB exposure and decreased level of zinc after 8 hrs of UVB exposure. The roots of BARHI, NBTSF and KHD showed decreased level of nitrogen after UVB exposure. But in FRDWT and FRDRD varieties the nitrogen content was increased when the plants exposed to 8 hrs of UVB radiation.
Table 13: Effect of UVB radiation on Mineral Nutrients mg/Kg (ppm) content of shoots of some date palm varieties

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Treatment</th>
<th>Name of the Elements</th>
<th>Ca</th>
<th>Co</th>
<th>Cu</th>
<th>Fe</th>
<th>K</th>
<th>Mg</th>
<th>Mn</th>
<th>Mo</th>
<th>Na</th>
<th>P</th>
<th>S</th>
<th>Zn</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARHI</td>
<td>Control</td>
<td>0.90±0.5</td>
<td>0.17±0.1</td>
<td>5.72±0.3</td>
<td>0.026±0.3</td>
<td>0.91±0.1</td>
<td>0.33±0.9</td>
<td>18.01±1.5</td>
<td>4.30±2.1</td>
<td>0.12±1.0</td>
<td>0.16±1.0</td>
<td>0.35±0.2</td>
<td>20.06±1.6</td>
<td>1.41±0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>0.92±0.3</td>
<td>0.22±0.1</td>
<td>5.07±0.9</td>
<td>0.028±0.1</td>
<td>0.85±0.1</td>
<td>0.36±0.3</td>
<td>21.09±2.6</td>
<td>3.64±0.6</td>
<td>0.13±0.9</td>
<td>0.15±0.1</td>
<td>0.32±0.03</td>
<td>28.06±2.3</td>
<td>1.17±0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.97±0.5</td>
<td>0.28±0.1</td>
<td>3.44±0.4</td>
<td>0.031±0.4</td>
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<td>29.25±1.9</td>
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<td>FRDWT</td>
<td>Control</td>
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<td>1.61±0.08</td>
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<td>T1</td>
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<td>0.030±0.3</td>
<td>0.90±0.5</td>
<td>0.35±0.2</td>
<td>21.88±2.4</td>
<td>4.35±0.3</td>
<td>0.12±0.6</td>
<td>0.15±0.1</td>
<td>0.32±1.7</td>
<td>22.92±3.1</td>
<td>1.29±0.02</td>
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<tr>
<td></td>
<td>T2</td>
<td>0.83±0.5</td>
<td>0.38±0.2</td>
<td>5.44±0.1</td>
<td>0.023±0.2</td>
<td>0.81±0.6</td>
<td>0.35±0.2</td>
<td>22.89±3.0</td>
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<td>Control</td>
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<td>T1</td>
<td>0.85±0.4</td>
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<td>3.14±0.5</td>
<td>0.022±0.2</td>
<td>0.79±0.7</td>
<td>0.31±0.2</td>
<td>20.53±1.9</td>
<td>&lt;0.01±0.0</td>
<td>0.13±0.1</td>
<td>0.10±0.1</td>
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<td>17.56±2.3</td>
<td>1.31±0.03</td>
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<td>2.58±0.4</td>
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<td>30.33±5.8</td>
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<td>0.17±0.1</td>
<td>0.18±0.1</td>
<td>0.26±0.1</td>
<td>16.26±1.2</td>
<td>1.16±0.02</td>
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<tr>
<td>FRDRD</td>
<td>Control</td>
<td>0.82±0.4</td>
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<td>1.38±0.02</td>
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<tr>
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<td>T1</td>
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<tr>
<td>KHD</td>
<td>Control</td>
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Table 14: Effect of UVB radiation on Mineral Nutrients mg/Kg (ppm) content of roots of some date palm varieties

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<tr>
<th>Name of the Variety</th>
<th>Treatment</th>
<th>Name of the Elements</th>
<th>Ca</th>
<th>Co</th>
<th>Cu</th>
<th>Fe</th>
<th>K</th>
<th>Mg</th>
<th>Mn</th>
<th>Mo</th>
<th>Na</th>
<th>P</th>
<th>S</th>
<th>Zn</th>
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<td>FRDRD</td>
<td>Control</td>
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Chapter 5: Discussion

In this study the UV-B radiation was found to reduce the height of the date palm varieties studied. The plants treated with gamma radiation showed a reduction in height of wild tomato (*Solanum Pimpinellifolium*). The reduction in the growth of plants due to UV-B radiation is reported even in lower plants like algae (Xenopoulos *et al*., 2002). The growth characteristic of an alga *Arthospira platensis* showed decrement with increase in duration of UV-B radiation as related to untreated cultures. But, in contrary, growth remained static up to 30 minutes UV-B exposure time followed by decline in subsequent 45 and 60 minutes time of UV-B exposure up to (28 – 40%) of the control causing severe damage to cellular system (Kavitha *et al*., 2015b). Generally the subsequent levels of increased UV-B radiation delayed plant growth, affected fresh weight of leaves and stems, leaf area index in *Avena fatua* and *Setaria viridis* (Golaszewska *et al*., 2003). UV-B exposure caused reductions in shoot and root lengths and dry weight of leaf and shoot in *Triticum aestivum* (Agrawal *et al*., 2004). A study conducted by Kumari *et al*. (2009) supports our results where plant height and leaf area were inhibited by UV-B radiation in *Acorus calamus*. There was reduction in the shoot, root elongation, expansion of cotyledonary leaves, fresh and dry weights of rice seedlings treated with UV-B radiation (Britto *et al*., 2011). In date palm The effects of salinity on vegetative growth parameters, leaf production rate and growth rate of newest leaves, indicated a dynamic response where the extent of reduced growth due to salinity increased over time (Tripler *et al*., 2011).

Liu *et al*. (2013) similarly reported that the enhanced UV-B radiation decreased plant height of Soybean. The height of the plant was highest among the
control plants reaching a maximum of 47 cm compared to plants irradiated with gamma rays at 150 Gy and 300 Gy reached 37 cm and 36 cm respectively (Nunoo et al., 2014). In contrast (Rekab et al., 2013) exposing the shootlets of date palm to red laser radiation for a shorter duration resulted in the maximum values of growth parameters (shoot length and number as well as number and length roots). Similarly in Vigna mungo the germination percentage remained significantly suppressed by UV-irradiance. Both root and shoot growth of the seedlings were markedly reduced by enhanced UV-B radiation. (Shaukat et al., 2013). A significant reduction in seed germination was observed in response to X-irradiation as compared to the non-irradiated control. However in contrast to the present UV-B radiation study the date palm when treated with X-irradiation increased root length and leaf size at lower concentrations (Al-Enezi, et al., 2012).

In the present study, the number of leaves, fresh and dry weight of shoot and root in the date palm varieties was significantly reduced due to UV-B treatment. Similarly a significant reduction in leaf size and biomass of leaf, stem and root were observed in response of salinity stress in three cultivars of date palm (Al-Abdoulhadi et al., 2011). In Vigna mungo, supplementary UV-B irradiation reduced the number of leaves, fresh weight and dry weight of leaves in all stages of UV-B exposed plants. Growth of all the varieties of black gram was progressively inhibited by the UV-B radiation. Suppression of root and shoot length ranged from 8.50 to 36.70 % respectively at all stages of growth resulting in reduced plant height (Rajendiran et al., 2015). Liu et al.( 2013) found decreased dry weight of individual stem of three soybean cultivars. The UV-B radiation showed a reduction in leaf length as well as the number of leaves in strawberry (Valkama et al., 2003). In contrast Sakalauskaite
et al. (2013) found that the growth parameters of basil, in terms of assimilating leaf area and fresh and dry biomass, were significantly increased by supplemental UV-B exposure.

In the present study a marked reduction in the rate of photosynthetic pigments such as chl a, chl b and carotenoids were noticed in the date palm varieties studied. Similar results were observed with UV-B radiation treated *Pisum sativum* (Strid *et al.*, 1990). The results of this study is in accordance with the study of Fedina *et al.* (2003) in which UV-B radiation showed an increase of carotenoid concentrations in Barley seedlings. Salama *et al.* (2011) reported that ultraviolet radiation reduced the chlorophyll contents of some annual desert plants like *Malva parviflora*, *Plantago major*, *Rumex vesicarius* and *Sismbrium erysimoids*. The chlorophyll a, b, and total contents were reduced with the enhanced UV radiation, but the carotenoid was increased. It was observed that the duration of UV-B exposure, the level of photosynthetic pigments such as chlorophyll a and b were found to be inversely proportional. UV-B irradiation significantly increased carotenoids at low UV-B doses.

This is due to the fact that UV-B radiation given during adaptation was only for a short duration and the intensity was strong enough to induce adaptive mechanisms, without causing any significant damage to the organism (Kavitha *et al.*, 2015a). The photosynthetic pigments, total Chlorophyll, total carotenoids and c - phycocyanin contents reduced with longer exposure time of UV-B radiation (Kavitha *et al.*, 2015b). At the lower dose the net photosynthetic rate increased, with an increase in stomatal conductance and water use efficiency. Stimulation of physiological functions in plants under the lower dose resulted in increased biomass
production. At the higher dose, total chlorophyll content showed no marked variation, whereas carotenoids and UV-B-screening pigment flavonoids increased significantly after treatment (Kumari et al. 2009).

The date palm varieties to X-irradiation total photosynthetic pigments started to diminish with low radiation and continued to decrease with increased dose. The chlorophyll a and carotenoids are more sensitive to X-irradiation than chlorophyll b (Al-Enezi and Al-Khayri, 2012). Oliveira et al. (2015) reported intra-cellular damage, such as cell wall thickness, loss of chloroplast organization, changes in mitochondrial cristae, and increasing atrophy of the Golgi bodies in the algae treated with UV-B radiation. In date palm, the salinity drastically affected plant height (cm), number of leaves/plantlet, and fresh and dry weights (g). The X-irradiation expressive gradually increase in amino acids as well as the content of Na, Ca, and Cl; however, chlorophyll a and b were significantly decreased (Darwesh, 2013).

Pigments of photosynthetic apparatus can be destroyed by UV radiation, with comparative loss of photosynthetic capacity (Jordan et al., 1994). Decrease in photosynthesis (3–90%), particularly at higher UV-B doses, was due to both direct (effect on photosystem) and indirect (decrease in pigments and leaf area) effects. The decreases in chlorophyll pigments and photosynthesis resulted in lower biomass and yield of most crop plants (Kakani et al., 2003). UV-B radiation affects the photosynthetic pigments, either through inhibition of their synthesis or effects on the enzymes involved in the chlorophyll (Chl) biosynthetic pathway (Ranjbarfordoei et al., 2011). Liu et al. (2015) stated that the UV-B radiation has strong effects on photosynthesis, chloroplast-localized components and it was discovered that the main target for UV-B radiation is photosystem II (PSII). Parameters such as
chlorophyll and carotenoid content were recognized as useful indicators of the plants response to ozone and UV-B radiation and could show whether or not physiological adaptation occurs in plants.

The proline and total phenol contents were found to be directly proportional to UV-B radiation treatment in the date palm varieties examined in this study. The ultraviolet wave length induced a highly significant increase in the level of proline in both root and shoot of annual desert plants like *Malva parviflora*, *Plantago major*, *Rumex vesicarius* and *Sisymbrium erysimoids* (Salama et al., 2011). There was an increase in the activities of some antioxidant due to UV-B irradiation and increased the contents of the UV-B absorbing compounds (carotenoids, soluble phenols, anthocyanins) in *Lactuca sativa* (Basahi et al., 2013). The UV-B radiation showed a dose dependant increase in the total phenolic content of *Hypericum retusum* (Namli et al. 2014) seedlings. UV-B radiation accelerated the generation of ROS i.e. superoxide radical (SO₂), hydrogen peroxide (H₂O₂) and hydroxyl radical (OH) in leaves, and concomitantly damaging effects on lipid peroxidation, electrolyte leakage and growth in both *Vigna* spp. were noticed in dose dependent manner, but *V. mungo* exhibited greater UV-B damaging effects. UV-B stress induced positive response on contents of proline, ascorbic acid, total phenolic contents (TPCs). The study concludes that substantially higher contents of TPCs, proline and ascorbic acid, before and after enhanced UV-B exposure probably attributed greater tolerance to *V. acontifolia* species, thus exhibited lesser UVB induced damaging effects on cellular components and growth than that of *V. mungo* (Dwivedi, et al., 2015). Among the non-enzymatic antioxidants, the accumulation of phenolic compounds, in the vacuoles of epidermal cells reduces the penetration of UV wavelengths deeper into
leaves (Berli et al., 2013). The total phenol and proline content were increased with UV-B radiation in maize and soybean plants (Shen et al., 2015). The non-enzymatic antioxidants give protection during stress. The total phenol content in Brigitta and Bluegold leaves increased in UV-B treatment (Reyes-Díaz et al., 2016). Further, the strain possessing a higher rate of phenolic compounds accumulation revealed greater tolerance to the UV-B radiation, demonstrating the key role of these metabolites in cell protection to UV-B light (Katerova et al., 2012).

Proline is an amino acid essential for primary metabolism. Its accumulation occurs under unfavorable conditions and abiotic stresses, including UV-B radiation condition. In cyanobacteria such as Anabaena cylindrica and Synechocystis proline content increased significantly with increasing doses of UV-B radiation (Rahman et al., 2015). The accumulation of proline under stress conditions is probably due to decrease in the activity of electron transport system (Venekemp, 1989).

The increasing proline content is referred to as protective mechanism due to the generation of reactive oxygen species by UV radiation. There are three possible causes of the free proline accumulation under stress: first, stimulation of proline synthesis from glutamic acids, which has been found to be dependent on the abscisic acid concentration; second, inhibition of proline oxidation to other soluble compounds; and, third, inhibition of protein synthesis (Salama et al., 2011). The long-term salinity treatment increased the proline content by 9.3- and 4.0-fold than the control in roots and leaves, respectively, the salinity shock increased the proline content by only 6.3- and 2.0-fold in roots and leaves, respectively (Yaish, 2015). However a maximum of about 2 fold increase of proline was found in the present study. In another study, a direct relationship between the X-rays dose and proline
accumulation along with increased fresh weight and water content were observed in irradiated date palm seedlings (Al-Enezi and Al-Khayri, 2012). Induction of water stress in the callus of date palm resulted in the increased proline accumulation and reduced water content (Al-Khayri and Al-Bahrany, 2004).

In the present study Sodium, Phosphorous, Cobalt, Calcium, Manganese increased while Sulfur, Copper, Potassium and Nitrogen contents were decreased in the date palm varieties studied. In a similar study, where the treatment of *Phoenix dactylifera* with X-ray caused a significant increase in sodium, potassium and phosphorus ions but a minimum dose was found necessary to significantly enhance the content of calcium and magnesium ions (Al-Enezi and Al-Khayri, 2012). A significant increase in Mg, Ca, P, Cu, and K occurred in *Brassica* plants exposed to Cd and UV-B radiation (Larson et al., 1998).

Like the present study a study conducted by Yue et al. (1998) reported that UV-B radiation had generally obvious effects on plant nutrient concentration. Enhanced UV-B radiation increased (PB0.05 or 0.01) the concentrations of N, K and Zn in all plant parts except the Zn concentration in roots. They also state that the impacts of enhanced UV-B radiation on concentrations of N, P, K, Mg, Fe and Zn in various plant parts were different. These differences indicate that responses of plant nutrient concentrations to enhanced UV-B radiation are complex, and may be the results of changes in various nutrient metabolic processes. In general, UV-B can induce two types of responses in plants: stress responses and photomorphogenic responses. The type of responses that are induced by UV-B is primarily determined by the fluence rate of exposure, and also dependent on whether the plants have been acclimated by prior exposure to UV-B (Kataria et al., 2014).
In the present study all the five varieties of date palm showed varied response to the treatment of UV-B radiation in terms of height, fresh and dry weight of shoot and root, photosynthetic pigments, UV-B absorbing compounds and mineral nutrients. For a similar kind of response Surabhi et al. (2009) suggest, significant variation in UV-B sensitivity exists among cowpea cultivars, which is apparently due to inherent genotypic variation. Cultivar selection for a niche environment should take consideration of UV-B tolerance mechanisms, and breeding cultivars tolerant to higher levels of UV-B will be beneficial in the regions where current UV-B levels are higher. In addition the perception that UV-B radiation may trigger the synthesis of new compounds, the increase of anti-oxidant activity or the increase of known compounds such as flavonoids and phenolics, can be used to improve the quality of food although it is also suggested that the synthesis of these molecules can be used as biomarkers for the identification of stressed plants (Britto et al., 2011).

Nevertheless, Phoenix species have tolerated these harsh SUR levels for over 6000 years and in fact demand full sun where “shading out” can result in decline or death to the plant in desert areas. These conditions are essential for date palm trees to have a normal complete and full productive cycle, i.e. to bear fruit. Some desert plants appear to be quite resistant to increased UV irradiation and the differential susceptibility of plants to UV stress is clearly an important factor in their competitive relationships in these terrestrial ecosystems (Jassim and Limoges, 2014). Abiotic stresses such as drought, salinity, high temperatures, and atmospheric or telluric chemical pollution, cause substantial damage to date palm resulting in annual losses estimated in billions of dollars worldwide. The crop, being a desert plant, has evolved strategies to protect itself against most of these stresses. However, if the
combined effect of the intensity of stress and exposure time is too high, major alterations are often observed in terms of plant metabolism, leading to cell death, a substantial change in growth and development habits, and ultimately a reduction in yield (Hadrami et al. 2011). Previously the effect of salinity stress, osmotic (salt) stress, X-irradiation stress were studied in date palms (Al-Bahrany and Al-Khayiri, 2012; Al-Enezi et al., 2012).

The effects of UV-B radiation on five different varieties of date palm are studied for the first time in the current research experiment. Hence the present study extends the importance of UV-B radiation’s impacts on the plant growth, photosynthetic pigments, UV absorbing chemicals and also the changes in mineral nutrient composition. This study further needs a combined effect of UV-B radiation with other stress parameters as well as an establishment at field level and determination of yield characteristics for the betterment in identifying new stress tolerant cultivars of date palm.
Chapter 6: Conclusion

In the present study all the five varieties of date palm showed varied response to the treatment of UV-B radiation in terms of height, fresh and dry weight of shoot and root, photosynthetic pigments, UV-B absorbing compounds and mineral nutrients. The studied varieties showed a reduction in plant growth in terms of shoot and root length, number of leaves and photosynthetic pigments like chlorophyll a, b and carotenoids. Whereas the UV absorbing compound phenol and stress indicator proline were found to accumulate in a direct proportion to the UV-B treatment. However in case of mineral analysis, Sodium, Phosphorous, Cobalt, Calcium, Manganese were increased while Sulfur, Copper, Potassium and Nitrogen contents were decreased in the date palm varieties studied.

Since the date palm is considered as an important subsistence crop in most of the world’s desert areas, the study on the effect of day-to-day increasing stress factors on the much important plant. Abiotic stresses such as drought, salinity, high temperatures, and atmospheric or telluric chemical pollution, cause substantial damage to date palm resulting in annual losses estimated in billions of dollars worldwide. The crop, being a desert plant, has evolved strategies to protect itself against most of these stresses. The effects of UV-B radiation on five different varieties of date palm are studied for the first time in the current research experiment. Further extension of this study to the combined effect of UV-B radiation with other stress parameters, field level study and determination of yield parameters will provide scope for the identification of new stress tolerant cultivars of date palm trees.
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