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The growth and tissue mineral concentrations of date palm (*Phoenix dactylifera* L.) cultivars in response to the ultraviolet-B radiation

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Abstract

The ultraviolet-B (UVB) radiation is an integral part of the sun light and adversely affects the growth and development of date palm (*Phoenix dactylifera*). Although, date palm is an economically important fruit tree and the majority the world's production is centered in the Arabian Peninsula, the studies evaluating date palm genotypic diversity and response to the UVB radiation are limited. To investigate this, five commercially grown date palm cultivars were exposed to the control and two elevated levels (four and eight hours per day for one year) of UVB radiations. The results showed that UVB radiation decreased plant height and leaf number by 8-14%, shoot root fresh weight by 66-87% and dry weight by 20-23%, total chlorophyll and carotenoids concentrations by 22-28%, while increased the proline and UVB absorbing compounds (phenolics) by 142% and 17.5%, respectively, across cultivars. These changes were more pronounced under the eight-hour UVB exposure. In general, roots tended to have greater concentrations of S and N by ≈1.4 folds, Co, Na, and P by 3.3-7 folds than shoots, compared to average across cultivars and treatments. However, under UVB, several mineral concentrations were either increased (e.g, Ca, Co, Fe, Mn, P) or decreased (e.g, K, Mo, S, N) consistently in shoots and roots. One exception to this rule was the Na concentration that increased in the shoot (9-45%) but decreased in the roots (8-10%) under UVB. Thus, the response of the date palm cultivars to the UVB was dependent on the measured traits, exhibiting decline in the growth parameters despite the increase in the UVB absorbing compounds and the tissue concentrations of several minerals. The principal component analysis (PCA) showed that the cultivars differed similarly in response to a given level of UVB treatments. Based on the PCA, the cultivars were grouped into two groups as BARHI and FRDWT in one group, while KHD, NBSTF, and RFDRD in other group.

Keywords: *Phoenix dactylifera*; UVB radiation; growth and development; mineral content.
Abbreviations: AR_ Analytical Reagents; Ca_Calcium; Co_Cobalt; Cu_Copper; Fe_Iron; H_2O_2_Hydrogen peroxide; HCL_Hydrochloric acid; HNO_3_Nitric acid; K_ Potassium; Mg_ Magnesium; Mn_Manganese; Mo_Molybdenum; Na_Sodium; OH_Hydroxyl radical; P_Phosphorus; PCA_Principal component analysis; S_Sulfur; SAS_Statistical Analysis System; SO_2_Superoxide radical; TPCs_Total phenolic contents; UV_Ultraviolet; Zn_ Zinc

Introduction

The ozone depletion and elevated level UV-B radiation have a negative effect on living forms. UV radiation is one of the most unsafe components that cause hindrance to both flora and fauna on the earth. The anticipated future changes in precipitation, vegetation spread, and the agricultural increase will impact the harmony between the adverse and helpful impacts of UV radiation and their bidirectional associations with ecological 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 (Carbonell-Bejerano et al., 2014). 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 (Kakani et al., 2003). In most systems of exposure, enhanced UV-B radiation affected crop growth directly through several first order effects. These comprise leaf photosynthesis and photomorphogenic systems, up-regulation of pathways producing defense compounds, 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). Bornman et al. (2015) reported 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, improved 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.

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 reaching to 30m. The date palm trees grow in regions with long dry summers and gentle winters. It has one of a kind trademark to flourish in desert and desert garden where the temperature could be high, but with underground water near the surface. Date palm seems 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. 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 (Kader and Hussein, 2009). 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 commercially important (Jaradat and Zaid, 2004). Moreover, date palm can grow in different types of soil, including dry, clay and sandy soils. It is highly salt tolerant (Sharifa et al., 2010). The 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 have contributed to date palm degradation (El-Juhany, 2010). Thus considering socio-economic magnitude 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).

Results and Discussion

The results on the effect UVB irradiation of some Emirates date palm varieties *viz.* BARHI, FRDWT, NBTSF, FRDRD and KHD on morphological, biochemical contents is shown in Table 1. It was found that, enhanced UV-B radiation under field conditions has caused notable alterations in the morphology, biochemical and tissue mineral content in the studied date palm varieties. The height of plant treated with 4 hrs UVB was slightly reduced, when compared to control plants. The height of 8-hrs treated date palm varieties were adversely affected by the UVB. The number of leaves of all the studied date palm varieties was also decreased after 4 and 8 hrs of UVB treatment.

Physiological indices

In the present study, the highest shoot fresh weight reduction was observed in FRDWT after 8 hrs of UVB treatment. The highest shoot fresh weight reduction was observed in FRDWT after 8 hrs of UVB treatment. The shoot fresh weight of NBTSF after four hrs and FRDRD and KHD varieties after 8 hrs were significantly reduced ($p < 0.05$ level) under UVB treatment. Moreover, the shoot dry weight was also reduced after 4 and 8 hrs of UVB treatment in all studied varieties. The shoot dry weight of FRDWT after 8 hrs of UVB treatment was significant at $P< 0.05$ level. The root weight was adversely reduced when treated with UVB radiation for 4 and 8 hrs.

The enhanced levels of UV-B radiation have deferred plant growth, affected fresh weight of leaves and stems, leaf area index in *Avena fatua* and *Setaria viridis* (Golaszewska et al., 2003). UV-B revelation caused reductions in shoot and root lengths and dry weight of leaf and shoot in *Triticum aestivum* (Agrawal et al., 2004). A study was conducted by Kumari et al. (2009) congruent with 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 is 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 exposed the shoots of date palm to red laser radiation for a shorter duration and observed the maximum values of growth parameters (shoot length and number as well as number and length roots). The dry weight of root was also reduced significantly in the 4 and 8 hours UVB treated date palm varieties. Similarly, in *Vigno 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. In contrast to the present study, the date palm showed increased root length and leaf size at lower X-ray 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 to 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.

Table 1. Effect of UVB on morphology and physiology of some date palm varieties after 4 and 8 hours of UVB treatment.

Parameters	Treatments	Name of the variety				
		BARHI	FRDWT	NBTSF	FRDRD	KHD
Plant Height	Control	107.5±3.76^{c}	105.0±3.39^{b}	118.5±2.32^{c}	119.16±1.68^{a}*	121.42±3.19^{c}
	T1	101.83±1.34^{a}*	103.5±2.07^{b}	118.33±4.91^{c}	116.83±4.10^{c}	113.66±3.91^{c}
	T2	101.5±4.32^{a}*	100.66±3.53^{a}*	115.5±4.46^{c}	114.16±5.28^{c}	112.66±6.81^{c}
No. of Leaves	Control	15.66±0.21^{g}*	15.66±0.33^{g}*	15.66±0.33^{g}*	15.33±0.33^{g}*	16.00±0.25^{g}*
	T1	14.66±0.33^{d}	14.00±0.25^{b}*	14.83±0.30^{e}	14.66±0.66^{b}*	14.33±0.95^{c}
	T2	13.3±0.33^{a}	14.33±0.21^{d}	15.16±0.16^{f}	15.50±0.50^{g}*	14.50±1.08^{d}
Shoot Fresh weight	Control	1.395±0.102^{e}	1.598±0.133^{f}	1.758±0.124^{f}	2.083±0.127^{g}	2.208±0.042^{g}
	T1	1.110±0.053^{c}	1.430±0.060^{e}	1.268±0.043^{d}*	1.611±0.111^{f}	1.533±0.129^{f}
	T2	0.773±0.203^{a}	0.763±0.219^{a}	0.978±0.188^{b}	1.240±0.062^{d}*	1.340±0.215^{d}*
Shoot dry weight	Control	0.548±0.034^{d}	0.683±0.025^{h}	0.656±0.052^{g}	0.840±0.050^{i}	0.743±0.079^{h}
	T1	0.523±0.038^{c}	0.590±0.034^{e}	0.641±0.023^{f}	0.751±0.054^{h}	0.731±0.051^{h}
	T2	0.493±0.049^{b}	0.454±0.078^{a}*	0.606±0.034^{e}	0.718±0.061^{h}	0.606±0.105^{e}
Root Fresh weight	Control	0.936±0.085^{d}*	1.093±0.154^{e}	0.733±0.067^{d}*	1.091±0.091^{e}	0.981±0.072^{e}
	T1	0.530±0.047^{c}	0.635±0.048^{c}	0.530±0.501^{c}	0.625±0.040^{c}	0.555±0.038^{c}
	T2	0.453±0.043^{a}	0.505±0.034^{c}	0.491±0.041^{b}	0.555±0.051^{c}	0.501±0.038^{b}
Root dry weight	Control	0.288±0.030^{e}	0.318±0.027^{f}	0.298±0.031^{f}	0.378±0.023^{h}	0.335±0.025^{g}
	T1	0.266±0.029^{d}*	0.311±0.049^{f}	0.271±0.016^{d}*	0.366±0.033^{h}	0.331±0.044^{g}
	T2	0.240±0.036^{a}	0.300±0.022^{f}	0.263±0.016^{c}	0.303±0.028^{f}	0.248±0.043^{b}
Chlorophyll 'a'	Control	1.472±0.275^{a}	1.689±0.172^{a}	1.573±0.218^{a}	1.669±0.073^{a}	1.649±0.188^{a}
	T1	1.469±0.255^{a}	1.583±0.182^{a}	1.373±0.071^{a}	1.527±1.151^{a}	1.542±0.298^{a}
	T2	1.453±0.156^{a}	1.571±0.131^{a}	1.246±0.043^{a}	1.361±0.050^{a}	1.355±0.405^{a}
Chlorophyll 'b'	Control	0.517±0.066^{h}	0.467±0.035^{h}	0.332±0.026^{d}	0.452±0.009^{h}	0.366±0.052^{f}
	T1	0.484±0.130^{h}	0.450±0.026^{h}	0.314±0.009^{c}	0.405±0.052^{g}	0.347±0.119^{d}
	T2	0.428±0.044^{h}	0.421±0.042^{h}	0.262±0.112^{b}	0.363±0.026^{e}*	0.249±0.103^{a}
Total Chlorophyll	Control	1.936±0.199^{d}	2.155±0.205^{d}	1.836±0.153^{d}	2.121±0.077^{d}	2.015±0.240^{d}
	T1	1.900±0.401^{d}	2.021±0.157^{d}	1.705±0.096^{c}	1.932±0.200^{d}	1.719±0.269^{c}
	T2	0.986±0.321^{a}	2.004±0.224^{d}	1.560±0.049^{b}*	1.723±0.074^{c}	1.702±0.525^{c}
Carotenoid	Control	0.623±0.059^{d}	0.722±0.040^{e}	0.629±0.068^{d}	0.656±0.033^{e}	0.573±0.054^{c}
	T1	0.609±0.068^{d}	0.645±0.045^{e}	0.525±0.041^{b}	0.656±0.013^{e}	0.525±0.060^{b}
	T2	0.576±0.098^{d}	0.572±0.036^{d}	0.470±0.039^{a}*	0.568±0.010^{d}	0.529±0.142^{b}
Proline	Control	0.546±0.104^{a}	0.525±0.131^{a}	0.649±0.193^{b}*	0.672±0.139^{c}*	0.605±0.049^{b}*
	T1	1.173±0.054^{f}	0.916±0.198^{f}	0.740±0.286^{b}*	0.939±0.255^{d}	0.842±0.081^{e}
	T2	1.209±0.317^{f}	1.052±0.299^{f}	0.996±0.258^{f}	1.068±0.188^{f}	1.173±0.368^{f}
Phenol	Control	0.035±0.003^{a}	0.039±0.001^{a}	0.051±0.001^{a}	0.036±0.001^{a}	0.035±0.003^{a}
	T1	0.036±0.0^{a}	0.040±0.0^{a}	0.051±0.006^{a}	0.037±0.002^{a}	0.039±0.003^{a}
	T2	0.039±0.001^{a}	0.042±0.003^{b}	0.056±0.005^{a}	0.043±0.0^{a}	0.042±0.004^{a}

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.

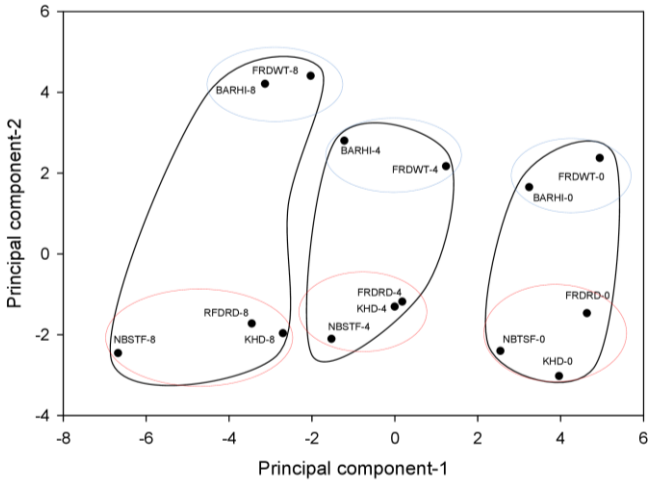

Fig 1. The principal components (PC) analysis scores on the response of five date palm cultivars across the ultraviolet-B (UVB) radiations. The scatter plot of PC-1 versus PC-2 is shown along with the grouping. The number associated with the cultivars represent the UVB levels the current (0, or no elevated levels), four hour (4), and eight hour (8) elevated exposures. The cultivars or UVB levels encircled by solid or dotted lines represent the subgroups of UVB levels and cultivars (across the UVB levels).

Table 2. Efect of UVB radiation on mineral nutrients mg/Kg (ppm) content of shoots of some date palm varieties.

Name of the Variety	Treatments	Name of the Elements												
		Ca	Co	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn	N
BARHI	Control	0.90±0.5^{a}	0.17±0.1^{b,c*}	5.72±0.3^{a}	0.026±0.3^{a}	0.91±0.1^{a}	0.33±0.9^{a}	18.01±1.5^{a}	4.30±2.1^{b,c}	0.12±0.1^{a}	0.16±0.1^{a}	0.35±0.2^{a}	20.06±0.6^{c,d*}	1.41±0.04^{d,e*}
	T1	0.92±0.3^{a}	0.22±0.1^{b,c*}	5.07±0.9^{a}	0.028±0.1^{a}	0.85±0.1^{a}	0.36±0.3^{a}	21.09±2.6^{b,c*}	3.64±0.6^{b}	0.13±0.9^{a}	0.15±0.1^{a}	0.32±0.03^{a}	28.06±2.3^{g,h}	1.17±0.01^{b}
	T2	0.97±0.5^{a}	0.28±0.1^{c,d}	3.44±0.4^{a}	0.031±0.4^{a}	0.78±0.2^{a}	0.3±0.2^{a}	29.25±1.9^{d}	3.44±1.7^{b}	0.15±0.5+a	0.15±0.3^{a}	0.30±0.2^{a}	23.71±5.7^{f,g*}	1.42±0.04^{d,e}
FRDWT	Control	0.88±0.2^{a}	0.15±0.1^{b,c*}	6.81±0.6^{a}	0.025±0.3^{a}	0.92±0.3^{a}	0.32±0.1^{a}	20.94±1.2^{b,c*}	5.20±0.9^{c}	0.12±0.4^{a}	0.13±0.2^{a}	0.37±0.2^{a}	21.80±2.6^{c,d*}	1.61±0.08^{f}
	T1	0.85±0.2^{a}	0.30±0.1^{c,d}	5.56±0.9^{a}	0.030±0.3^{a}	0.90±0.5^{a}	0.35±0.2^{a}	21.88±2.4^{b,c*}	4.35±0.3^{b,c}	0.12±0.6^{a}	0.15±0.1^{a}	0.32±1.7^{a}	22.92±3.1^{e,f*}	1.29±0.02^{c,d}
	T2	0.83±0.5^{a}	0.38±0.2^{c,d}	5.44±0.1^{a}	0.023±0.2^{a}	0.81±0.6^{a}	0.28±0.2^{a}	22.89±3.0^{b,c*}	2.97±0.7^{b}	0.23±0.1^{a}	0.13±0.1^{a}	0.31±0.3^{a}	27.02±2.04^{g,h}	1.48±0.12^{e,f*}
NBTSF	Control	0.83±0.6^{a}	0.07±0.0^{a*}	3.61±0.6^{a}	0.027±0.1^{a}	0.97±0.4^{a}	0.32±0.7^{a}	19.24±2.5^{a,b*}	<0.01±0^{a}	0.13±0.5^{a}	0.10±0.2^{a}	0.30±0.8^{a}	30.79±6.5^{h}	1.43±0.03^{d,e*}
	T1	0.85±0.4^{a}	0.33±0.0^{c,d*}	3.14±0.5^{a}	0.022±.0.2^{a}	0.79±0.7^{a}	0.31±0.2^{a}	20.53±1.9^{b,c*}	<0.01±0^{a}	0.13±0.1^{a}	0.10±0.1^{a}	0.27±0.1^{a}	17.56±2.3^{a,b}	1.31±0.03^{d,e*}
	T2	0.87±0.8^{a}	0.92±0.4^{e}	2.58±0.4^{a}	0.059±0.2^{a}	0.70±0.3^{a}	0.44±0.9^{a}	30.33±5.8^{d}	<0.01±0^{a}	0.17±0.1^{a}	0.18±0.1^{a}	0.26±0.1^{a}	16.26±1.2^{a}	1.16±0.02^{b}
FRDRD	Control	0.82±0.4^{a}	0.32±0.3^{c,d}	5.77±1.0^{a}	0.038±0.1^{a}	0.82±0.3^{a}	0.33±0.3^{a}	23.67±1.1^{b,c*}	3.79±0.2^{b}	0.12±0.1^{a}	0.14±0.1^{a}	0.32±0.5^{a}	17.90±1.5^{b,c*}	1.38±0.02^{d,e*}
	T1	0.81±0.6^{a}	0.41±0.2^{c,d}	5.57±0.3^{a}	0.041±0.1^{a}	0.78±0.3^{a}	0.35±0.2^{a}	24.31±3.6^{c}	3.64±0.3^{b}	0.12±0.1^{a}	0.14±0.1^{a}	0.29±0.1^{a}	19.01±0.16^{c,d*}	1.05±0.02^{a}
	T2	0.97±0.1^{a}	0.86±0.3^{e}	4.83±0.2^{a}	0.055±0.1^{a}	0.72±0.3^{a}	0.45±0.4^{a}	35.12±4.8^{e}	3.54±1.2^{b}	0.13±0.9^{a}	0.14±0.2^{a}	0.22±0.4^{a}	27.31±4.9^{g,h}	1.18±0.02^{b}
KHD	Control	0.73±0.6^{a}	0.12±0.1^{a,b*}	3.82±0.6^{a}	0.023±0.1^{a}	0.85±0.7^{a}	0.28±0.2^{a}	18.05±2.3^{a}	3.34±0.3^{b}	0.10±0.2^{a}	0.12±0.4^{a}	0.26±0.2^{a}	23.75±2.8^{f,g*}	1.30±0.01^{c,d}
	T1	0.73±0.3^{a}	0.17±0.1^{b,c*}	3.64±0.1^{a}	0.030±0.5^{a}	0.84±0.9^{a}	0.31±0.1^{a}	20.39±2.8^{b,c*}	3.28±0.76^{b}	0.14±0.8^{a}	0.12±0.6^{a}	0.25±0.1^{a}	22.75±2.8^{d,e}	1.15±0.01^{b}
	T2	0.78±0.5^{a}	0.52±0.0^{d}	3.29±0.7^{a}	0.027±0.5^{a}	0.73±0.4^{a}	0.36±0.1^{a}	23.7±3.7^{b,c*}	3.29±1.8^{b}	0.17±0.7^{a}	0.13±0.1^{a}	0.24±0.4^{a}	27.88±5.4^{g,h}	1.22±0.20^{b,c}

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 3. Effect of UVB radiation on mineral nutrients mg/Kg (ppm) content of roots of some date palm varieties.

Name of the Variety	Treatments	Name of the Elements												
		Ca	Co	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn	N
BARHI	Control	0.80±0.4^{a}	0.90±0.2^{b,c}*	5.39±0.5^{c,d}	0.03±0.5^{a}	0.93±0.8^{a}	0.36±0.1^{a}	26.74±3.0^{d,e}	2.34±0.4^{c,d}*	0.46±0.4^{a}	0.92±0.1^{a}	0.45±0.1^{a}	35.19±1.6^{f}	2.09±0.07^{f}
	T1	0.93±0.1^{a}	0.97±0.3^{b,c}*	5.17±0.4^{c,d}	0.06±0.2^{a}	0.83±0.8^{a}	0.39±0.7^{a}	26.81±4.4^{d,e}	2.53±1.4^{c,d}*	0.43±0.2^{a}	0.97±0.6^{a}	0.35±0.9^{a}	31.72±5.4^{e,f}	1.38±0.02^{a}
	T2	0.87±0.1^{a}	0.32±0.4^{a}	6.04±0.7^{d}	0.06±0.2^{a}	0.77±0.5^{a}	0.39±0.6^{a}	26.82±4.1^{d,e}	6.27±2.6^{f}	0.44±0.2^{a}	0.91±0.1^{a}	0.37±0.3^{a}	25.65±1.90^{c,d}*	1.86±0.05^{e}
FRDWT	Control	0.81±0.2^{a}	0.43±0.2^{a,b}*	5.23±0.7^{c,d}	0.02±0.3^{a}	0.92±0.8^{a}	0.31±0.1^{a}	20.65±1.3^{a}	3.89±0.7^{d,e}*	0.46±0.3^{a}	0.92±0.1^{a}	0.40±0.2^{a}	20.15±2.14^{a}*	2.27±0.06^{g}
	T1	0.96±0.1^{a}	0.55±0.4^{b,c}*	4.59±0.4^{c,d}	0.03±0.7^{a}	0.85±0.8^{a}	0.33±0.1^{a}	22.55±2.1^{a,b}	3.69±0.4^{d,e}*	0.46±0.1^{a}	0.91±0.6^{a}	0.40±0.5^{a}	27.63±0.1^{c,d}*	1.83±0.11^{e}
	T2	0.89±0.8^{a}	0.44±0.2^{a,b}*	5.62±0.1^{c,d}	0.02±0.2^{a}	0.70±0.1^{a}	0.31±0.1^{a}	21.13±0.8^{a}	3.36±0.3^{c,d}*	0.31±0.1^{a}	0.99±0.9^{a}	0.34±0.3^{a}	23.31±3.7^{b,c}*	1.45±0.17^{a,b}
NBTSF	Control	0.77±0.6^{a}	0.71±0.2^{b,c}*	4.17±0.4^{a,b}	0.03±0.1^{a}	0.80±0.6^{a}	0.44±0.3^{a}	23.45±2.9^{b,c}	2.01±0^{b,c}	0.57±0.6^{a}	0.91±0.7^{a}	0.47±0.3^{a}	24.06±0.63^{b,c}*	2.15±0.02^{f}
	T1	0.90±0.1^{a}	0.73±0.1^{b,c}*	3.80±3.1^{a}	0.04±0.8^{a}	0.79±0.3^{a}	0.35±0.2^{a}	24.34±2.3^{c,d}	1.32±1.3^{a,b}	0.54±0.5^{a}	0.97±0.3^{a}	0.38±0.2^{a}	29.34±5.7^{d,e}	1.61±0.02^{c}
	T2	0.81±0.4^{a}	0.60±0.2^{b,c}*	5.67±0.9^{c,d}	0.03±0.3^{a}	0.72±0.5^{a}	0.29±0.2^{a}	22.70±2.2^{a,b}	1.01±0^{a}	0.53±0.5^{a}	0.95±0.5^{a}	0.34±0.9^{a}	20.83±2.3^{a,b}*	1.45±0.01^{a,b}
FRDRD	Control	0.90±0.6^{a}	0.82±0.6^{b,c}*	5.08±0.7^{c,d}	0.03±0.3^{a}	0.92±0.6^{a}	0.40±0.7^{a}	30.22±4.6^{e}	5.07±1.2^{e,f}*	0.54±0.4^{a}	0.81±0.3^{a}	0.41±0.8^{a}	24.39±1.3^{b,c}*	2.34±0.05^{g}
	T1	0.98±0.2^{a}	0.95±0.1^{b,c}*	4.86±0.3^{c,d}	0.04±0.1^{a}	0.79±0.8^{a}	0.34±0.9^{a}	30.28±2.6^{e}	3.25±0.6^{c,d}*	0.53±0.1^{a}	0.94±0.8^{a}	0.40±0.1^{a}	27.47±0.8^{c,d}*	1.42±0.03^{a}
	T2	0.96±0.1^{a}	1.05±0.9^{c}	6.10±0.3^{d}	0.04±0.2^{a}	0.78±0.5^{a}	0.34±0.2^{a}	25.99±3.8^{d,e}	3.20±0.5^{c,d}*	0.53±0.7^{a}	0.91±0.3^{a}	0.43±0.6^{a}	23.84±3.0^{b,c}*	1.63±0.03^{c}
KHD	Control	0.78±0.7^{a}	0.80±0.2^{b,c}*	4.79±0.3^{c,d}	0.02±0.1^{a}	0.97±0.6^{a}	0.34±0.2^{a}	23.47±1.28^{b,c}	3.46±0.4^{c,d}*	0.59±0.9^{a}	0.91±0.7^{a}	0.43±0.3^{a}	23.72±2.0^{b,c}*	1.74±0.04^{d}
	T1	0.84±0.1^{a}	0.99±0.3^{b,c}*	4.43±0.4^{b,c}	0.05±0.2^{a}	0.92±0.5^{a}	0.39±0.8^{a}	28.26±2.63^{d,e}	3.0±0.6 ^{c,d}*	0.41±0.1^{a}	0.96±0.6^{a}	0.37±0.6^{a}	24.75±3.9^{b,c}*	1.52±0.03^{b}
	T2	0.75±0.1^{a}	1.04±0.4^{c}	5.16±0.2^{c,d}	0.02±0.7^{a}	0.85±0.8^{a}	0.37±0.1^{a}	27.31±4.1^{d,e}	3.20±1.6^{c,d}*	0.55±0.3^{a}	0.92±0.1^{a}	0.39±0.5^{a}	19.90±2.0^{a}*	1.50±0.01^{b}

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 and carotenoids content

The Results on the chlorophyll content of studied date palm varieties showed that, Chlorophyll 'a' and 'b' content was steadily decreased in FRDWT, FRDRD, NBTSF 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. The total chlorophyll content was decreased in all the varieties of date palm studied after 4 and 8 hrs of UVB treatment, when compared to untreated plants. The Carotenoid content was decreased in all the date palm varieties studied. The FRDRD and KHD varieties did not show much difference after 4 and 8 hrs of UVB treatments. However, the carotenoid content of NBTSF was significantly decreased after 8 hrs of UVB treatment. After 4 and 8 hrs of 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.

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. Similar results, were observed with UV-B radiation treated *Pisum sativum* (Strid et al., 1990). The results of this study are in accordance with the study of Fedina et al. (2003), in which UV-B radiation showed an increase of carotenoid concentrations in Barley seedlings. We observed that duration of UV-B exposure is inversely proportional with the level of photosynthetic pigments such as chlorophyll a and b. The UV-B irradiation significantly increased carotenoids at low UV-B doses. This is due to the fact that UV-B radiation 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 were reduced with longer exposure time to UV-B radiation (Kavitha et al., 2015b). At the lower dose, the net photosynthetic rate, stomatal conductance and water use efficiency were affected. 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 were increased significantly after treatment (Kumari et al., 2009).

Proline and phenolic contents

In this study, the proline and total phenol contents were found to be directly proportional to UV- B radiation treatment in the date palm varieties. In the present study, the principal component analysis (PCA) separated the cultivars based on the response of the measured traits into the subgroups (Fig. 1). The first three principal components summarized >61% variability of 38 measured traits. The scatter plot between the first two components effectively separated five cultivars into three subgroups based on the three UVB treatments. In addition, the PCA clustered all the cultivars into the two subgroups as (a) BARHI and FRDWT and (b) KHD, NBSTF, and RFDRD, indicating this subset of cultivars responded similarly across the UVB levels.

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 Sismbrium erysimoids* (Salama et al., 2011). There was an increase in the behavior of several antioxidants owing to UV-B irradiation and increased the contents of the UV-B absorbing compounds (carotenoids, soluble phenols, anthocyanins) in *Lactuca sativa* (Basahi et al., 2014). 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 (SO_2), hydrogen peroxide (H_2O_2) and hydroxyl radical (_OH) in leaves, and concomitantly damaging effects on lipid peroxidation. The 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 and 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).

Nutrient and mineral concentrations in shoots and roots

The results of effect of UVB radiation on mineral content of roots and shoots of studied date palm varieties are presented in Tables 2 and 3. The UV-B radiation increased ($p<0.05$ or 0.01) the concentrations of N, K and Zn in all plant parts except the Zn concentration in roots. Furthermore, 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 the present study, phosphorous, sodium, calcium, cobalt, manganese contents were increased, whereas copper, sulfur, nitrogen and potassium contents decreased in the studied date palm varieties. Similarly, 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 et al., 2012). A significant increase in Mg, Ca, P, Cu, and K was occurred in *Brassica* plants exposed to Cd and UV-B radiation (Larsson et al., 1998). Yue et al. (1998) reported that UV-B radiation had generally obvious effects on plant nutrient concentration. 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. Surabhi et al. (2009) suggested 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 be taken in to consideration for UV-B tolerance mechanisms. Furthermore, breeding of 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 can increase anti-oxidant activity or increase of known compounds such as flavonoids and phenolics. This 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).

Materials and methods

Experimental site and the plant culture

The experiment was conducted for the period of 2014-2015 under natural light conditions at Al-Foah Experimental farm, College of Food and Agriculture, UAEU, Al Ain, in a greenhouse covered with the transparent plastic on the top to permit the passage of maximum sunlight. The 24-month old of five commercially grown date palm cultivars (i.e., BARHI, FRDWT, NBTSF, FRDRD and KHD were obtained from Date Palm Research Laboratory, UAEU) were planted in the pots in the three sets consisting of two plants each pot.

UV Treatments

The UVB radiation treatments of the current level (control) and two elevated (UVB) levels as 4 hrs and 8 hrs per day were imposed using eight fluorescent UV-313 lamps with the UVB radiation (280 and 320 nm) emission characteristics. The lamps were wrapped with pre-solarized 0.07 mm cellulose diacetated film to filter the UV-C (<280 nm) radiation. The cellulose diacetate film was changed at 3–4 day intervals to account for the degradation of the cellulose diacetate film. The UVB energy delivered about 1 m above the plant canopy during the middle portion of the day and was checked daily with a UVX digital radiometer. The UVB lamps were directly mounted above each set of the plants receiving either 4 or 8 hours of the UVB radiation

Vegetative growth and leaf tissue measurements

Plants were harvested 120 days after the UVB treatments and the fresh weight of shoots was determined immediately followed by the measurements of plant height and number of leaves. The roots were washed in the clean water and fresh weight was measured after pat drying with the paper towel. The shoot and roots dry weight was measured after drying of the constant weight at 75 °C in an oven. The leaf tissue constituents were measured in the fresh leaves materials after 120 days after UVB treatments.

Estimation of chlorophylls, carotenoids, phenolic compounds and Proline

Chlorophyll and carotenoid were extracted from the matured leaves after UVB treatments using the method of Arnon (1949). The carotenoid content was estimated using the Kirk and Allen (1965) method and both chlorophyll and carotenoid contents were expressed in milligrams per gram fresh weight. Total phenolic compounds were estimated by the method of Malick and Singh (1980) and the results were expressed as mg/g of fresh tissue. The proline content was estimated following the method of Bates et al. (1973). The method was calibrated for each determination with standard proline solutions and the results were expressed in milligram per gram dry weight.

Determination of shoots and roots mineral nutrient concentrations

Thirteen mineral elements (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, P, S, Zn, and N) were determined in the dried shoot and root tissue at the final harvest. The samples were air dried then oven dried at 105 ^{0}C for 3 hrs and the samples were grinded and stored in desiccators for further analysis. The plant sample were prepared accurately by weighing 0.5 g into the microwave at 200°C for 35min to digest then 10 ml of concentrated nitric acid (HNO_3) and 2 ml hydrochloric acid (HCL) were added (Method 3015A, US Environmental Protection Agency, 1994). The analysis was conducted using Varian ICP-OES model 710-ES - Agilent Technologies. Plants samples are accurately weighed and treated with acids to destroy the organic matter and solubilized the recoverable elements. The percentages of different elements in this sample was determined by the corresponding standard calibration curves obtained by using standard AR grade solutions of the elements. The reagents blank was carried through complete method and contain the same acid concentration in the final solution as the sample solution used for investigation.

Statistical analysis

The analysis of variance (ANOVA) was performed using SPSS software (v. 21.0) to test the effect of UVB radiation. The significant difference between mean was determined by Duncan's multiple range test at the $P \leq 0.05$ level. The principal component analysis (PCA) was performed using PROC PRINCOMP procedure of SAS software (SAS 9.4). PCA is a multivariate statistical tool used to separate experimental units (UVB treatments) in to subgroups based on the measured parameters (e.g., growth and leaf constituents) by producing the loadings of these parameters (termed as eigenvector) and principal component scores for each unit.

Conclusion

The effects of UV-B radiation on five dissimilar varieties of date palm are deliberate for the first time in the present 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 consequence 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.

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