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Effect of CO_2 elevation and UV-A radiation on growth responses of Zinnia, Petunia, Coxcomb, and Marigold

Hamidreza MIRI[1], Maryam SADEGHI[2] Abdolreza JAFARI[3], Mohammad Mehdi RAHIMI[4]

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ABSTRACT

In order to evaluate the effect of CO_2 elevation and UV radiation on growth responses of zinnia, petunia, coxcomb, and marigold, a study was conducted in 2015 at Arsanjan Islamic Azad University, Iran. The experimental design was factorial arranged in completely randomized design with three replications. Treatments were included four ornamental species (zinnia, petunia, coxcomb, and marigold), CO_2 concentration at two levels (350 and 700 ppm), and UV radiation at two levels (with and without UV radiation). Results showed that elevating of CO_2 concentration from 350 ppm to 700 ppm increased morphological and physiological characters of C_3 plants, especially marigold. Meanwhile, increasing CO_2 concentration from 350 ppm to 700 ppm, decreased effects of UV damage on plants' morphological and physiological characters. The highest leaf number, shoot dry mass, plant height and water use efficiency of C_4 plant (coxcomb flower) were observed at 350 ppm of CO_2 concentration without UV radiation while, the highest leaf number, shoot dry mass and leaf pigments of C_3 plants (zinnia, petunia, and marigold flower) were obtained at 700 ppm of CO_2 concentration without UV radiation. The results showed that the activity of catalase and peroxidase enzymes under UV radiation was increased in all of plants. Overall, it is concluded that, the recognition of plants resistant to UV radiation and high levels of CO_2 concentration in the future may be better for environmental production and distribution as ornamental plants in town landscapes, where ecophysiological traits should be considered.

Key words: ornamental plants; climate change; morphological and physiological traits; UV radiation

IZVLEČEK

UČINEK POVEČANE KONCENTRACIJE CO_2 IN POVEČANEGA UV-A SEVANJA NA RASTNI ODZIV CINIJE, PETUNIJE, PETELINJEGA GREBENA IN ŽAMETNICE

Z namenom ovrednotenja učinka povečanega CO_2 in UV sevanja na rastni odziv cinije, petunije, petelinjega grebena in žametnice je bil v letu 2015 izveden poskus na Arsanjan Islamic Azad University, Iran. Poskus je bil popoln naključni faktorski poskus s tremi ponovitvami. Obravnavanja so obsegala štiri vrste okrasnih rastlin (cinija, petunija, petelinov greben in žametnica), dve koncentraciji CO_2 (350 in 700 ppm), in dve jakosti UV sevanja (brez in z UV sevanjem). Rezultati so pokazali, da je povečana koncentracija CO_2 iz 350 ppm na 700 ppm povečala vrednosti morfoloških in fizioloških znakov C_3 rastlin, še posebej žametnice. Povečanje koncentracije CO_2 iz 350 ppm na 700 ppm je zmanjšalo učinke poškodb po UV v morfoloških in fizioloških znakih. Največje število listov, največja masa suhe snovi in največja učinkovitost izrabe vode so bili pri C_4 rastlinah (petelinji greben) zabeleženi pri 350 ppm CO_2 brez UV sevanja, pri C_3 rastlinah (cinija, petunija in žametnica) je bila največja vrednost znakov kot so število listov, suha masa poganjkov in vsebnost listnih pigmetov ugotovljena pri 700 ppm CO_2 brez UV sevanja. Aktivnosti katalaze in peroksidaze sta se v razmerah UV sevanja povečali pri vseh rastlinah. V splošnem lahko zaključimo, da je pri izbiri okrasnih rastlin za učinkovitejše ozelenjevanje urbanih površin potrebno upoštevati tudi njihove morfološko fiziološke lastnosti.

Ključne besede: okrasne rastline; morfološko fiziološke lastnosti; klimatske spremembe; UV sevanje

[1] Department of Agronomy and Crop Breeding, College of Agriculture, Arsanjan Branch, Islamic Azad University, Arsanjan, Iran, corresponding author: hmiri6@gmail.com

[2] Department of Agronomy and Crop Breeding, College of Agriculture, Arsanjan Branch, Islamic Azad University, Arsanjan, Iran

[3] Department of Biology, Arsanjan Branch, Islamic Azad University, Arsanjan, Iran

[4] Department of Agronomy and Crop Breeding, College of Agriculture, Arsanjan Branch, Islamic Azad University, Arsanjan, Iran

1 INTRODUCTION

Nowadays, unstable symptoms on the Earth such as environmental pollution and species extinction caused by increased emissions of greenhouse gases, in combination with changes in solar radiations intensity appeared to be unavoidable (Xing, 2009; Ziska and Blumenthal, 2010). Morphological traits and physiological processes of plants are affected by different climate change aspects such as CO_2 elevation, high temperature, ultra violet (UV) radiation, and quantity and dispersal of rainfall (Fuhrer, 2003). It is reported that climate changes has affected flowering initiation, physiology, water relations, ions absorption, photosynthesis and respiration of plants (Mortensen, 1987).

CO_2 plays an important role in process of global warming and climate changes (Holden and Hoyer, 2005). The level of CO_2 in the atmosphere is rising at an unprecedented rate, has increased from 280 ppm at the beginning of the industrial revolution to 380 ppm today, and is expected to double pre-industrial levels sometime during this century (Hennessy et al., 2008; Karl et al., 2009). Generally, CO_2 elevation could increase net photosynthesis of potted plants, cut flowers, and vegetables (Croonenborghs et al., 2009). Significant increase of water use efficiency (WUE) and decrease of stomatal conductance were observed in plants treated by CO_2 elevation (Lincoln and Couvet, 1989; Prior et al., 2011). Kamali et al. (2011) reported that CO_2 elevation from 380 to 1050 ppm could increase shoot and root dry mass, height, number of leaves and leaf area of coxcomb (*Celosia argentea* L.). Shoor et al. (2010) showed that increasing CO_2 level to 700 ppm could accelerate marigold (*Tagetes patula* L.) flowering time.

Plants, as sessile organisms that require sunlight for growth and development, are inevitably exposed to UV wavelengths (200–400 nm), which represent almost 7 % of the electromagnetic radiation emitted from the sun. Plants responses to ozone layer destruction and high UV radiation include widespread range of bio-chemical, physiological, morphological, and anatomical changes (Zhang et al., 2003). High doses of UV radiation may damage macromolecules, including DNA and proteins, and induce the production of reactive oxygen species (ROS), affecting photosynthetic pigments, cell membrane integrity and viability (Horii et al., 2007). Rahimzadeh et al. (2011) reported that UV-A radiation decreased shoot dry mass, protein, and chlorophyll content of savory (*Satureja hortensis* L.). Kazemi Ghale et al. (2011) showed that in radish plants treated with UV radiation photosynthesis rate decreases due to leaf area reduction, leaf thickness increases, and observes bio-chemical changes of chlorophyll pigments. Golbazhagh et al. (2010) reported the reduction of sunflower growth such as shoot dry mass, root length, and leaf area caused by increasing exposure time of different doses of UV-A radiation. Sarikhani (2013) showed that the UV-A radiation reduced peppermint yield. Also, antioxidant and secondary metabolite activity increased when peppermint was treated by UV-A radiation.

By considering the climatic changes the objective of this research was to determine the influence of CO_2 elevation and UV-A radiation on morphological and physiological properties of zinnia, petunia, coxcomb, and marigold . Study of climate changes effect on zinnia, petunia, coxcomb, and marigold production, quality, and marketable properties are very important because these plants are widespread ornamental species.

2 MATERIALS AND METHODS

In order to evaluate the effect of CO_2 elevation and UV-A radiation on morphological and physiological parameters of zinnia (*Zinnia elegans* Jacq.), petunia (*Petunia x hybrida* 'Grandiflorus'), coxcomb (*Celosia cristata* L.), and Mexican marigold (*Tagetes erecta* L.) a study was conducted in 2015 at Islamic Azad University, Arsanjan branch, Iran (53° 19' E, 29° 55' N and 1690 m). The Experimental design was factorial arranged in completely randomized design with three replications. Treatments included plant species (zinnia, petunia, coxcomb, and marigold), CO_2 concentration at two levels (ambient CO_2 (350 ppm) and elevated CO_2 (700 ppm)), and UV radiation at two levels (with and without UV-A radiation).

The experiment was conducted in two environmentally controlled growth chambers with four compartments to apply CO2 and UV-A treatments, with the mean air temperature of 25/14 °C (day/night) and relative humidity of 75 (day) and 60 % (night). At the beginning of the experiment, five seeds were planted in 5 cm deep of each of the 48 pots (18 cm height and 14 cm diameter) filled with a silty-loam soil with 1.16 % organic matter, 15 to 18 % sand, 50 to 56 % silt, 10 to 15 % clay and pH of 7.5. After seed germination, seedlings were thinned to one per pot at the four-leaf stage. Then, half of the pots were moved into the ambient CO_2 chamber and the other half, into the elevated CO_2 chamber. Pots were uniformly irrigated (EC = 0.78 ds m^{-1} of water) every 3 days. Half of the pots in the chambers was exposed by UV-A radiation (5 min per days) from fluorescent tubes (T9 Black light blue fluorescent- Schwan Company), used to produce UV-A radiation.They were installed at 50 height from each pot.

Measured traits were leaf number, shoot dry mass, plant height, water use efficiency, chlorophyll-a and carotenoid content, and activity of catalase and peroxidase enzymes. In order to the assessment leaf pigments content, 20 ml aceton (80 %) was mixed with 0.5 g of leaf fresh mass, then, the mixture was centrifuged (with 3000 rpm for 10 min). Then, leaf pigments were determined by spectrophotometer (UV2100 Plus model - USA) device (wavelength 470 and 663 nm) (Arnon, 1967).

In order to measure activity of catalase and peroxidase, 5 ml of potassium phosphate buffer (100 m mol and pH 7.5) was blend with 0.5 g of leaf fresh mass, then, the mixture was centrifuged (with 12000 rpm for 60 min). Afterwards, activity of catalase and peroxidase were determined using method described by Pereia et al. (2002) and Fielding and Hall (1978) , respectively. All data were submitted to an analysis of variance (ANOVA) and Duncan test was used to verify the significant differences among treatment means at the 5 % probability level (Little and Jackson, 1978).

3 RESULTS AND DISCUSSION

Effect of CO_2 and species interaction was significant on leaves' number, shoot dry mass, plant height, water use efficiency, chlorophyll a, activity of catalase and peroxidase (Table1). Results showed that the highest leaf number and shoot dry mass were observed in coxcomb flower + ambient CO_2 (Figure1 (a) and (b)). The highest WUE was obtained in coxcomb flower + ambient CO_2 (Figure1 (d)) and the highest catalase activity was achieved in coxcomb flower + elevated CO_2 (Figure1 (g)).

Results showed that the highest plant height was observed in *Zinnia* + elevated CO_2 (Figure1 (c)) also, the highest chlorophyll a was achieved in marigold + ambient CO_2 (Figure1 (e)) while, the highest peroxidase activity were achieved in petunia + ambient CO_2 (Figure1 (h)). Generally, the highest leaf number and shoot dry mass were observed in coxcomb in comparison to the C_3 plants due to quickly establishment and better use of soil nutrients by coxcomb seedlings (Hammer et al., 2005; Wortman et al., 2011). Shoor et al. (2010) reported that elevating CO_2 concentration to 700 ppm could be increased marigold height (approximately 50 %) as a result improved plant photosynthesis capacity and allocated more assimilates to vegetative growth. It seems that elevating CO_2 concentration improved WUE due to high CO_2 concentration into inter-cellular space and transpiration reduction by stomatal closer (Fuhrer, 2003). Furthermore, increasing chlorophylla and carotenoid pigments by elevated CO_2 had significant role in photosynthesis rate and photosystem II protection for improving radiation absorption and increasing photosynthesis capacity (Mavrogianopoulos et al., 1999; Joseph et al., 2008). Miri and Rastegar (2012) showed that elevated CO_2 could increase chlorophyll index (approximately 6 to 30 %) in soybean, lambsquarters, panicum, and pigweed.

In addition, shoot dry mass, WUE, chlorophyll a, catalase and peroxidase activity were significantly influenced by UV-A radiation and species interaction (Table 1). According to results, morphological and physiological parameters showed a reduction as affected by UV-A radiation. The highest leaf number, shoot dry mass, and WUE, and chlorophyll a were observed in coxcomb and marigold , respectively, without UV-A radiation (Figure 2 (a), (b), (d), and (e)). Meanwhile, the catalase activity in all plants increased by UV-A radiation (Figure 2 (g)). It seems that in plant subjected to UV-A radiation less transfer of photosynthetic assimilate occurred due to reduction of photosynthesis capacity (Balouchi et al., 2008). Reduction in growth and development and reduction of cell division also was observed by UV-A radiation (Smirnoff and Wheelev, 2000; Gao et al., 2003). But, plants response differently to UV-A radiation as affected by species and environmental factors such as plant water status, photosynthetically active radiation (PAR), and nutrients availability (Mark and Tevini, 1996; Balouchi et al., 2009).

In general, results showed that shoot dry mass, plant height, WUE, chlorophyll a and carotenoid pigments, and catalase activity were significantly influenced by CO_2 concentration, UV-A radiation, and plant species (Table 1). The highest leaf number and shoot dry mass were obtained in coxcomb + ambient CO_2 + without UV-A radiation (Figure 3 (a) and (b)). Also, the highest WUE was observed in coxcomb + at elevated CO_2 + without UV-A radiation (Figure 3 (d)). Meanwhile, the highest plant height was achieved in *Zinnia* + elevated CO_2 + without UV-A radiation (Figure3 (c)). According to our research, results showed that UV-A radiation could decrease growth parameters of plant species due to its impact on photosynthesis capacity, but, elevating CO_2 could lead to improve photosynthesis capacity and high assimilate transfer to vegetative growth (Ziska and McClung, 2008; Croonenborghs et al., 2008; He et al., 2013).

Table 1: The summary of the source of variation and the mean square of shoot dry mass (g per plant), leaf number (per plant), water use efficiency (g l^{-1}), chlorophyll a and carotenoid (mg g^{-1}), catalase and peroxidase activity (u mol g^{-1} min^{-1})

Source of variation	df	Shoot dry mass	Leaf number	Plant height	Water use efficiency	Chlorophyll a	Carotenoid	Catalase activity	Peroxidase activity
Plant species	3	0.521^{**}	154.750^{**}	1689.607^{**}	3.81^{**}	46.192^{**}	21.175^{**}	3.644^{**}	1207.464^{**}
CO2 level	1	0.000^{ns}	4.083^{ns}	552.028^{**}	1.31^{**}	1.602^{ns}	1.522^{ns}	1.367^{**}	54.957^{**}
Plant×CO2	3	0.013^{**}	26.750^{**}	30.184^{*}	1.10^{**}	3.323^{*}	0.102^{ns}	2.719^{**}	41.788^{**}
UV radiation	1	0.003^{*}	24.083^{*}	0.445^{ns}	1.97^{ns}	6.237^{*}	0.0471^{ns}	4.025^{**}	145.718^{**}
Plant×UV	3	0.003^{*}	0.528^{ns}	8.196^{ns}	7.68^{**}	9.105^{**}	0.622^{ns}	0.533^{**}	39.719^{**}
CO2×UV	1	0.001^{ns}	0.083^{ns}	80.808^{**}	1.11^{ns}	4.466^{*}	0.218^{ns}	0.035^{ns}	11.903^{ns}
Plant×CO2×UV	3	0.009^{**}	9.417^{ns}	95.731^{**}	1.35^{**}	6.633^{**}	1.828^{*}	4.572^{**}	7.987^{ns}
Error	32	0.001	4.042	10.386	1.72	0.945	0.460	0.055	4.438
CV (%)		12.70	14.10	18.00	13.60	11.50	13.07	18.20	16.90

Note: * and ** significant at the 0.05 and 0.01 level, respectively; ns, not significant

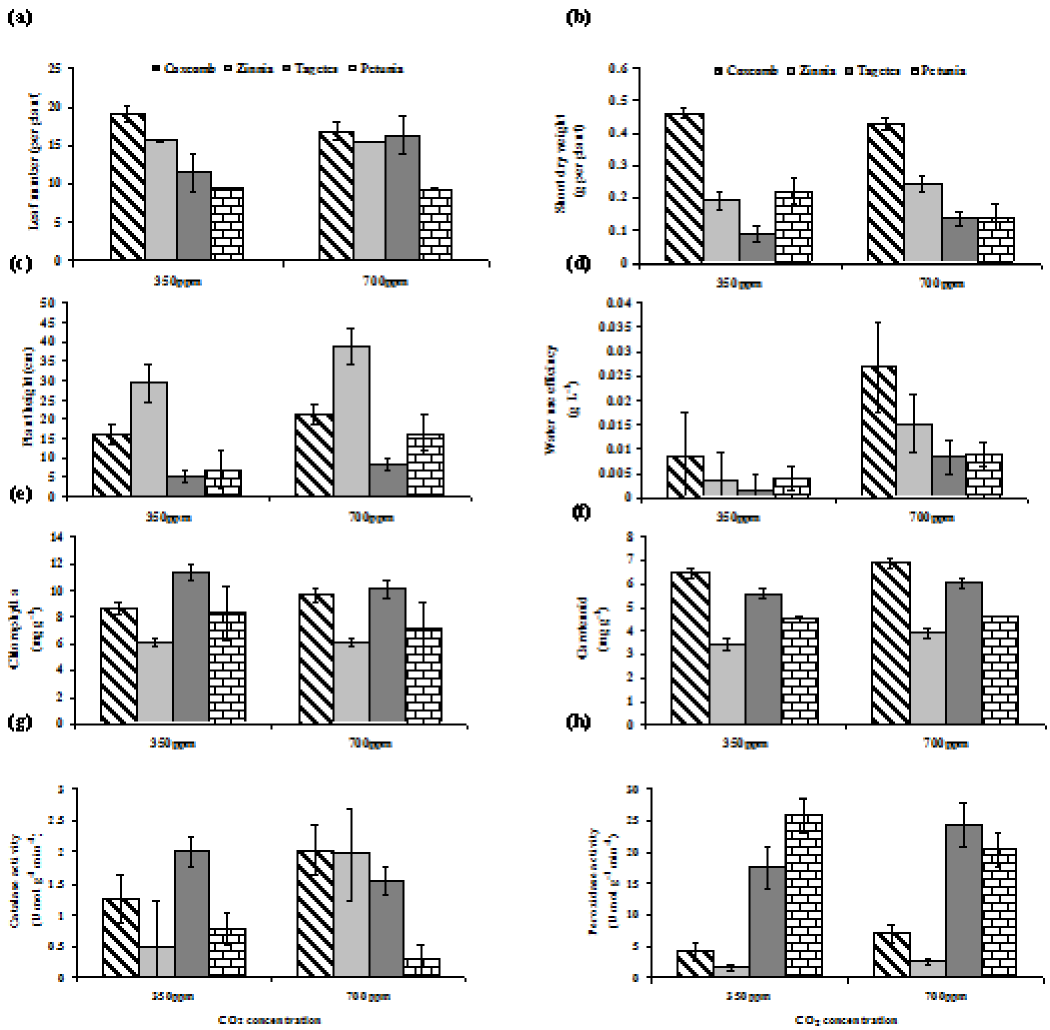

Figure 1: The effect of flower species and CO_2 concentration interaction on leaf number (a), shoot dry mass (b), plant height (c), water use efficiency (d), chlorophyll a content (e), carotenoid content (f), catalase activity (g), and peroxidase activity (h). (According to standard error, the means with same overlap not significant)

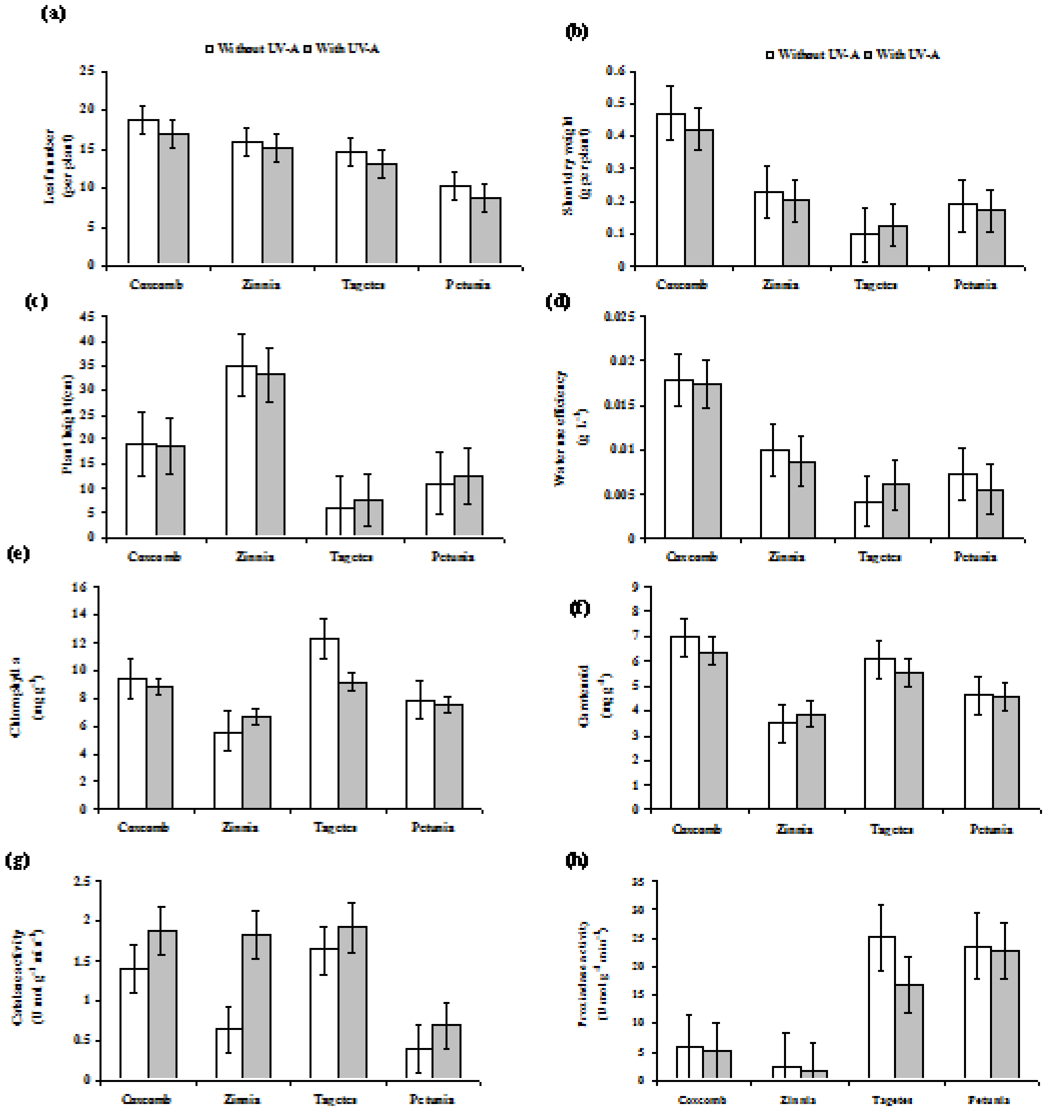

Figure 2: The effect of plant species and UV-A radiation interaction on leaf number (a), shoot dry mass (b), plant height (c), water use efficiency (d), chlorophyll a content (e), carotenoid content (f), catalase activity (g), and peroxidase activity (h). (According to standard error, the means with same overlap not significant)

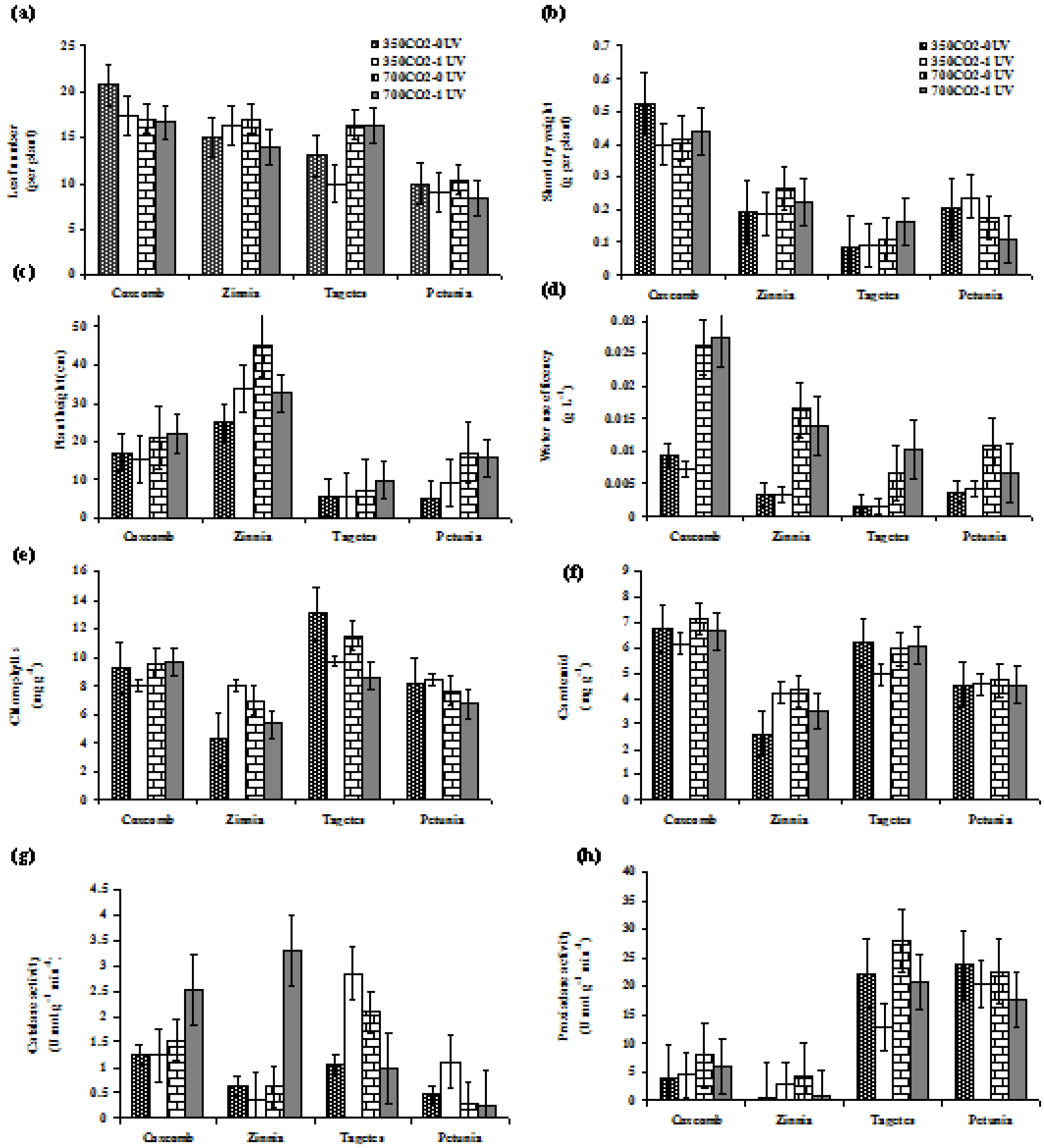

Figure 3: The effect of plant species, CO_2 concentration, and UV-A radiation interaction on leaf number (a), shoot dry mass (b), plant height (c), water use efficiency (d), chlorophyll a content (e), carotenoid content (f), catalase activity (g), and peroxidase activity (h). (According to standard error, the means with same overlap not significant).

It seems that elevating CO_2 concentration could increase growth of C_3 plants (zinnia, petunia, and marigold) in comparison to the C_4 ones (coxcomb) due to a better use of environmental sources for growth and development. However, UV-A radiation reduced plant growth parameters, but, increasing CO_2 concentration could reduce destructive effects of UV-A radiation on analysed plants species. It is concluded that, the highest growth parameters of zinnia, petunia, and marigold were achieved under elevated CO_2 without UV-A radiation, but, the highest growth parameters of coxcomb were obtained in ambient CO_2 without UV-A radiation.

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