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Changes in Growth and $^{14}CO_2$ Fixation of *Hordeum vulgare* and *Phaseolus vulgaris* Induced by UV-B Radiation

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ABSTRACT

Increased UV-B radiation on the earth's surface due to depletion of stratospheric ozone layer is one of the changes of current climate-change pattern. A field experiment was concluded to study the effects of solar ultraviolet-B (UV-B) radiation on growth parameters, photosynthetic efficiency ($^{14}CO_2$-fixation) and biochemical characteristics of barley (*Hordeum vulgare*) and common bean (*Phaseolus vulgaris*). Plants grown under ambient UV-B radiation were compared with those grown without UV-B by excluding ambient UV-B radiation. To exclude solar ambient UV-B radiation, the sunlight was filtered through a polyester film that selectively absorbed UV-B. For ambient UV-B effects, plants were grown under polyvinyl chloride (PVC) filters that transmitted the complete light spectrum. The results indicated increased shoot length, leaf area, dry matter accumulation, leaf area ratio and specific leaf weight in plants of both the crops grown without UV-B compared with those grown under ambient UV-B. Similarly, the rate of photosynthetic activity, chlorophyll content, nitrate reductase (NR) enzyme activity and sugar content. The effect of UV-B exclusion was clearer in common bean compared with that in barley. We conclude that monocot species may be less sensitive to increased solar UV-B due to ozone depletion than with dicots.

Key Words: Photosynthesis; UV-B radiation; Nitrate reductase activity; Chlorophyll; Growth

INTRODUCTION

In the past 50 years, the concentration of ozone has decreased by about 5%, mainly due to the release of anthropogenic pollutants, such as chlorofluorocarbons (Pyle, 1996). Consequently, a large proportion of the UV-B spectrum reaches the earth's surface with serious implications for all living organisms (Xiong & Day, 2001; Caldwell *et al.*, 2003). There are reports of the impact of increased doses of UV-B radiation on crop plants (Singh, 1994). A high level of UV-B radiation has deleterious effects on growth of plants, photosynthesis activity, flowering and crop yield (Teramura, 1983; Singh, 1994). Variability in crop responses to increased UV-B radiation has been observed due to differences in sensitivity of plant species (Teramura, 1983). There is also a tremendous natural variation in the daily effective UV-B radiation reaching the earth's surface (Ziska & Teramura, 1992). This variation occurs due to natural latitudinal gradient, atmospheric ozone column thickness, solar angle at different latitudes and elevation above sea level (Caldwell *et al.*, 1980). Plants grown in low latitudes are exposed to higher flux of UV-radiation due to greater solar angle as compared with high latitude. Ambient solar UV-B affects plant growth and development in various ways (Pal *et al.*, 1997; Krizek *et al.*, 1997). Ruhland and Day (2000) observed a reduction in the vegetative growth of two vascular plant species of Antarctica when grown with and without ambient UV-B radiation.

Much of the early work concerning the effects of UV-B radiation on terrestrial plants was conducted indoors using growth chamber or greenhouse. By the 1990s, consensus was that many of these reports of UV-B effect were exaggerated and that extrapolation of these results to field responses was not appropriate (Caldwell & Flint, 1997). Since then, there has been emphasis on field studies either by supplementing natural UV-B or by lowering ambient U-B by means of UV-B absorbing filters. Little is known about the response of crop plants to ambient solar UV-B radiation (Sharma *et al.*, 1991; Searles *et al.*, 1995; Pal *et al.*, 1997; Krizek *et al.*, 1997). The level of solar UV-B radiation is different during summer and winter due to solar angle. Therefore, the effectiveness of UV-B present in current solar radiation may vary during these two seasons. Thus, two winter crops, barley and common bean, were studied in the present investigation to evaluate their response to UV-B radiation during winter season in the Delta region of Egypt.

MATERIALS AND METHODS

Plant material and growth conditions. A field experiment

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was conducted under natural sunlight at one of the Delta region (Menoufia Governorate) of Egypt. Two crops species, viz., barley (*Hordeum vulgare* cv. Giza 123) and common bean (*Phaseolus vulgaris* cv. Giza 3), were grown in the field under optimal growth conditions. The soil of the study site was sandy loam texture and neutral in reaction (PH 7.0 to 7.4). The photosynthetically active radiation (PAR) averaged 955 µmol m^{-2} s^{-1}. Plots of 2 m x 2 m size were prepared using standard agronomic practices for growing the above crop species. The experiment was conducted in a randomized block design and there were three replications each for control and treatments. Irrigation was given as and when required for optimal growth of the crops.

Solar UV-B exclusion. In the first set of the experiments, plants under 110 µm thick polyester filter (UV-B–) that selectively absorbed UV-B (280-320 nm). In the second set, plants were grown under 100 µm thick polythene sheets that transmitted the ambient UV-B radiation (UV-B+). The polyester film filtered out all the radiation below 310 nm and allowed only 23% of the 320 nm wavelength. The level of visible radiation through the polyester filter was 85% of the un-filtered radiation at the ground level. Polythene film transmitted about 90% of the radiation in the UV-B region of solar spectrum. The visible radiation received through polythene film at the ground level was 89% of the ambient radiation. The spectral characteristics of the polyester and polythene filters were measured as described by Pal *et al.* (1997). The filters were replaced every two weeks as they became brittle due to solarization. Both polyester and polythene films were erected over a hut-shaped wooden frame fixed in north-south directions over the plots. This orientation ensured that solar radiation reached the plot only after passing through the filters as the sun moved from east to west. Bases of the wooden frames (0.35 m above ground) were left un-covered to ensure free airflow. Air temperature inside the wooden frames did not increase by more than 1°C above ambient.

UV-B measurements. The level of ambient UV-B radiation on plant canopy was measured using UV-Biometer (Solar Light Co., PA, USA) and expressed as MED (minimum erythermal dose) and converted to µW $cm^{-2}nm^{-1}$ according to Srivastava *et al*. (1989). The UV-B radiation under the polythene filter was recorded 20.71 µW $cm^{-2}nm^{-1}$ (2.18 MED), which was more than 90% of ambient UV-B radiation. Solar UV-B radiation under the polyester was negligible (0.09 MED).

Plant growth analysis. Plant growth measurement on shoot length, leaf area, leaf and stem dry weight were made at three stages: 25, 50 and 75 days after sowing (DAS). Ten plants of uniform size were selected for growth analysis from control and treatment plots each. Plant samples were separated into stem and leaves and their leaf area was calculated with a photoelectric area meter (model L1-3100, Lincoln, USA). For dry weight determination, samples were dried in a hot air oven at 70°C to constant weight. Leaf area ratio (LAR) and specific leaf weight (SLW) were calculated using the formulae given by Gardner *et al.* (1985).

Photosynthetic efficiency ($^{14}CO_2$-fixation) and biochemical analysis. Photosynthetic activity was measured in the Atomic Energy Authority, Radioisotope Department, Cairo, Egypt, according to Moussa (2006). One pot from each treatment was placed under a Bell jar, which was used as a photosynthetic chamber. Radioactive $^{14}CO_2$ was generated inside the chamber by a reaction between 10% HCl and 50 µCi (1.87×10^6 Bq) $NaH^{14}CO_3$ + 100 mg Na_2CO_3 as carrier. Then the samples were illuminated with a tungsten lamp. After 30 min. exposure time, the leaves were quickly detached from the stem, weighed and frozen for 5 min. to stop the biochemical reactions, then subjected to extraction by 80% hot ethanol. The ^{14}C was assayed from the ethanolic extracts in soluble compounds using a Bray Cocktail and a Liquid Scintillation Counter (LSC2-Scaler Ratemeter SR7, Nuclear Enterprises). Chlorophyll content was quantified according to Porra *et al*. (1989). Nitrate reductase enzyme activity was estimated following the method of Ferrario *et al*. (1998). Reducing and total sugars were determined using the Nelson's arsenomolbdate method (Nelson, 1944). Non-reducing sugar content was estimated by subtracting the value of reducing sugar from total sugars.

Statistical analysis. Analyses of variance of data were done as given by Panse and Sukhatme (1967). The critical difference (CD) values were calculated at 5% probability level.

RESULTS

Barley and common bean plants grown without solar UV-B (UV-B–) attained greater shoot length than plants grown under solar UV-B radiation (UV-B+). There was up to 7% greater shoot length due to exclusion of solar UV-B in barley plants (Table I). However, the increase in shoot length was more in common bean, 15% by excluding solar UV-B. During the initial stages, an increase of 17-21% in shoot length of common bean plants grown without UV-B was recorded, but the differences were smaller at later stages (7% at 75 DAS) (Table II). Higher shoot length was accompanied by a significant increase in stem dry weight of UV-B-free common bean and barley plants (Table I & II).

Leaf area of both barley and common bean plants grown without UV-B was higher than that for ambient UV-B. UV-B-free barley plants possessed an average of 8% more leaf area than those grown under ambient UV-B (Table I). In the case of common bean, leaf area per plant increased by an average of 17% by excluding solar UV-B. Leaf dry weight of UV-B-free barley plants was slightly higher than that under ambient UV-B at all stages (Table I), but in the case of common bean, there was a significant increase. Common bean plants showed 14-23% more leaf dry weight as compared with ambient UV-B grown plants (Table II).

Exclusion of solar UV-B did not affect significantly

Table I. Effect of solar UV-B exclusion (UV-B–) on growth parameters of barley at different stages of growth. All values are means±SE (n=10). Figures in parenthesis indicate percent change between control (UV-B–) and ambient UV-B treated (UV-B+) plants

	Days after sowing (DAS)					
	25		50		75	
Growth parameter	**(UV-B+)**	**(UV-B–)**	**UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**
Shoot length (cm plant^{-1})	17.5±0.68	18.9±0.57 (+8.0)	40.4±1.61	44.1*±1.52 (+9.2)	54.7±1.66	57.2±1.48 (+4.5)
Leaf area (cm^{2} plant^{-1})	68.3±3.14	74.7*±3.88 (+9.3)	215.67±12.07	234.12±12.48 (+8.5)	230.52±10.62	247.34±11.85 (+7.0)
Leaf dry weight (g plant^{-1})	0.624±0.019	0.661±0.023 (+6.0)	1.460±0.049	1.580±0.047 (+8.2)	1.554±0.041	1.61±0.054 (+3.8)
Stem dry weight (g plant^{-1})	0.655±0.017	0.712±0.028 (+8.7)	2.680±0.072	0.083*±3.020 (+12.7)	4.360±0.152	4.62±1.34 (+6.0)
Leaf area ratio (cm^{2} g^{-1})	52.63±0.30	53.66±0.44 (+2.0)	52.31±0.37	50.62±0.27 (–3.2)	38.53±0.25	39.5±0.32 (+2.5)
Specific leaf weight (mg cm^{-2})	9.18±0.11	8.82±0.10 (–3.9)	6.74±0.09	6.70±0.10 (–0.6)	6.71±0.07	6.58±0.09 (–1.9)

Table II. Effect of solar UV-B exclusion (UV-B–) on growth parameters of common bean at different stages of growth. All values are means±SE (n=10). Figures in parenthesis indicate percent change between control (UV-B–) and ambient UV-B treated (UV-B+) plants

	Days after sowing (DAS)					
	25		50		75	
Growth parameter	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**
Shoot length (cm plant^{-1})	24.4±0.51	29.5*±0.55 (+21.0)	72.0±1.61	84.7*±1.54 (+17.5)	108.2±2.22	115.7±2.41 (+7.0)
Leaf area (cm^{2} plant^{-1})	74.6±3.42	87.3*±4.07 (+17.0)	305.2±14.68	366.5*±18.40 (+20.0)	317.8±15.12	364.3*±17.55 (+14.5)
Leaf dry weight (g plant^{-1})	0.385±0.01	0.442*±0.014 (+14.8)	1.743±4.92	2.150*±0.068 (+23.0)	1.905±0.052	2.222*±0.061 (+16.6)
Stem dry weight (g plant^{-1})	0.468±0.01	0.553*±0.017 (+18.0)	3.186±0.090	3.720*±0.111 (+16.8)	6.770±0.207	8.162*±0.223 (+20.5)
Leaf area ratio (cm^{2} g^{-1})	86.37±2.86	88.40±2.55 (+2.4)	72.13±3.16	64.58±2.12 (–10.5)	37.24±1.67	34.83±1.48 (–6.5)
Specific leaf weight (mg cm^{-2})	5.02±0.111	5.14±0.098 (+2.40)	5.74±0.177	5.83±0.132 (+1.60)	6.02±0.121	6.081±0.140 (+1.00)

leaf area ratio (LAR) and specific leaf weight (SLW) of both barley and common bean. In the case of barley, LAR of UV-B free plants was marginally higher than that of ambient plants except at 50 DAS, where it showed a reduction of about 3% (Table I). In UV-B-free common bean plants, changes in LAR and SLW were almost opposite to those in barley, where LAR was reduced significantly (at 50 DAS) and SLW was slightly higher than that for ambient grown plants at all stages (Table II).

Leaf photosynthesis increased in both barley and common bean plants grown in the absence of solar UV-B. In barley plants, UV-B exclusion had very little effect on net photosynthesis that increased by an average of 8% (Table III). In the case of common bean, the increase in net photosynthesis was more and was recorded up to 24% higher (at 50 DAS) due to exclusion of UV-B (Table IV).

No significant changes occurred in chlorophyll pigments of both the crop species due to solar UV-B exclusion. In barley, chlorophyll (b) content was significantly higher in UV-B-free grown plants at all the stages (Table III), but total chlorophyll content did not show an appreciable change at either stage. Chl.ʿaʿ content was lower in UV-B-free grown barley plants except at 50 DAS. In the case of common bean, UV-B-free grown plants had higher Chl.ʿaʿ and ʿbʿ contents at all stages (Table IV). The increase in Chl.ʿaʿ due to UV-B exclusion was only slight at all stages but Chl.ʿbʿ showed significant gain at 25 and 75 DAS. Total chlorophyll content in common bean also showed only marginal gain as a result of solar UV-B exclusion.

Reducing and non-reducing sugar contents of the leaves were also affected by the exclusion of solar UV-B. Both the sugar contents increased significantly in common bean plants grown without UV-B, whereas in the case of barley, the changes were relatively smaller (Table III). The highest increase in non-reducing sugar of barley was 8% at 50 DAS in UV-B-free plants and no significant changes occurred in reducing sugars at either stage (Table III). The non-reducing sugar content of common bean increased up to 18% increase in UV-B-free plants in comparison with plants grown under ambient UV-B and reducing sugar content showed an increase of up to 23% (at 25 DAS). Changes in total sugar content were lower in barley plants compared with common bean without UV-B treatment. Maximum

Table III. Changes in photosynthetic efficiency, chlorophyll, sugar content and nitrate reductase activity of barley due to exclusion of solar UV-B radiation at different stages of growth. All values are means±SE (n=10). *kilo Becquerel (10^3 Bq)

	Days after sowing (DAS)					
	25		50		75	
Parameter	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**
Photosynthetic activity (*KBq mg fw^{-1})	9.906±0.353	11.430±0.422	12.954±0.511	14.478±0.367	12.878±0.562	14.326±0.721
Chlorophyll *a* (mg g fw^{-1})	1.21 ±0.04	1.15±0.05	1.45±0.07	1.49±0.04	1.13±0.04	1.12±0.03
Chlorophyll *b* (mg g fw^{-1})	0.47±0.02	0.48±0.02	0.49±0.01	0.51±0.01	0.47±0.02	0.49±0.01
Total chlorophyll *(a+b)* (mg g fw^{-1})	1.68±0.05	1.63±0.03	1.94±0.06	2.00±0.08	1.60±0.06	1.61±0.03
Reducing sugar (mg g fw^{-1})	2.8±0.05	2.9±0.05	2.9±0.05	3.0±0.15	3.0±0.16	3.2±0.09
Non-reducing sugar (mg g fw^{-1})	5.9±0.24	6.2±0.19	5.7±0.23	6.2±0.25	5.7±0.22	6.1±0.30
Total sugar content (mg g fw^{-1})	8.7±0.26	9.1±0.36	8.6±0.26	9.2±0.35	8.7±0.27	9.3±0.19
Nitrate reductase activity (μgNO_2^- g fw^{-1} h^{-1})	8.0±0.24	9.4±0.47	10.3±0.51	11.8±0.46	11.6±0.35	11.9±0.48

Table IV. Changes in photosynthetic efficiency, chlorophyll, sugar content and nitrate reductase activity of common bean due to exclusion of solar UV-B radiation at different stages of growth. All values are means±SE (n=10). *kilo Becquerel (10^3 Bq)

	Days after sowing (DAS)					
	25		50		75	
Parameter	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**	**(UV-B+)**	**(UV-B–)**
Photosynthetic activity (*KBq mg fw^{-1})	9.067±0.253	9.906± 0.465	11.659±0.593	13.792±0.196	13.564±0.532	14.630±0.781
Chlorophyll *a* (mg g fw^{-1})	0.83±0.02	0.94 ±0.04	0.85±0.03	0.96±0.06	0.78±0.04	0.81±0.05
Chlorophyll *b* (mg g fw^{-1})	0.42±0.02	0.48±0.03	0.44±0.02	0.49±0.03	0.39±0.04	0.39±0.04
Total chlorophyll *(a+b)* (mg g fw^{-1})	1.25±0.05	1.42±0.06	1.29±0.05	1.45±0.05	1.17±0.03	1.20±0.04
Reducing sugar (mg g fw^{-1})	1.6±0.06	1.9±0.07	1.3±0.04	1.6±0.06	1.5±0.06	1.8±0.07
Non-reducing sugar (mg g fw^{-1})	3.0±0.06	3.5±0.17	3.6±0.11	4.4±0.22	2.9±0.14	3.4±0.17
Total sugar content (mg g fw^{-1})	4.6±0.18	5.4±0.27	4.9±0.15	6.0±0.30	4.4±0.25	5.2±0.16
Nitrate reductase activity (μgNO_2^- g fw^{-1} h^{-1})	12.3±0.06	14.6±0.73	12.0±0.36	15.0±0.60	12.5±0.38	15.4±0.63

increase in total sugar was noted at 75 DAS (22%) due to exclusion of solar UV-B (Table IV).

Solar UV-B exclusion also caused an increase in nitrate reductase (NR) activity in both barely and common bean plants. An appreciable increase in NR activity of UV-B-free grown barley plants was observed at early stages (17 & 14% at 25 & 50 DAS, respectively), but the differences were not significant at maturity (2% at 75 DAS) (Table III). Common bean grown without UV-B also showed significantly higher NR activity at all the stages and the highest increase was observed at 50 DAS (25%) (Table IV).

DISCUSSION

UV-B radiation causes reductions in plant height, leaf area, biomass accumulation and photosynthesis in various crop species suggesting that higher UV-B radiation is inhibitory to plant growth (Teramura, 1983; Singh, 1994). The present study showed that the current ambient UV-B radiation present in the Delta region had a significant effect on the growth of barley and common bean plants. Elimination of solar UV-B (UV-B–) caused up to 21% increase in the height of common bean plants whereas in barley there was only a marginal increase (up to 9%). An increase in plant height was accompanied by higher stem dry weight in UV-B-free grown plants of both the species. This suggests that the level of UV-B radiation present in solar radiation can potentially affect the plant growth and thus even small changes in ozone depletion may have important biological consequences. UV-B radiation higher than ambient UV-B radiation caused reduction in stem length and dry mass in pea (Mepsted *et al*., 1996). Similar effect of enhanced levels of UV-B radiation has been reported to affect plant growth of various other crop species like *Phaseolus mungo* (Singh, 1995), *Vigna radiata* (Pal *et al*., 1999), cucumber (Murali & Teramura, 1986) and cotton (Ambler *et al*., 1975).

The elimination of solar UV-B radiation also affected the leaf area development as observed in this study. Up to a 20% increase in leaf area was observed in UV-B-free grown common bean plants. Pal *et al*. (1997) reported a similar increase in leaf area of mung bean due to solar UV-B exclusion. Krizek *et al*. (1997) reported a 27% gain in stem length and a 35% increase in leaf area of cucumber plants grown in the absence of solar UV-B radiation. They also observed 34 and 55% greater accumulation in leaf and stem biomass, respectively of cucumber. In the present study, UV-B-free grown common bean plants gained 23% more leaf dry height than ambient-grown plants. However, UV-B-free grown barley plants showed only small differences in leaf area and dry weight as compared with common bean. This suggests that leaf orientation may be one of the reasons for barley being less sensitive to ambient UV-B radiation than common bean; barley leaves are nearly vertical, whereas common bean leaves are horizontal in orientation. He *et al*. (1993) found that the effects of UV-B radiation were more severe in artificially constrained horizontal leaves than in the nearly vertical leaves of two rice cultivars. Gonzalez *et al*. (1998) also found that enhanced UV-B radiation caused a reduction in leaf area of pea.

The process of photosynthesis is considered to be sensitive to UV-B radiation. Such reductions in rate of photosynthesis have been attributed to changes in photophosphorylation, electron transport and carbon assimilatory processes (Teramura, 1983). Similarly, Krause *et al*. (2003) have reported a reduction in net CO_2 uptake and photosystem I efficiency in tree seedlings when exposed to solar UV-B radiation. The net photosynthesis increased in *Populus* clones under sub-ambient (UV-B–) radiation (Schumaker *et al*., 1997). In this study, we found a higher photosynthetic capacity in UV-B-free grown common bean plants (up to 33%) against only a marginal increase (12%) in barley plants grown under similar conditions. These results are consistent with earlier findings for maize and mungbean (Pal *et al*., 1997). Zhao *et al*. (2004) did not find changes in growth and rate of photosynthesis at lower levels of UV-B radiation, but at higher levels they did find significant reductions in leaf area and rate of photosynthesis and loss of rubisco activity. The increased plant growth and dry matter accumulation in UV-B-free grown plants may primarily be the result of increased photosynthesis.

The solar UV-B radiation also showed its impact on the process of nitrogen metabolism, as evident from changes in nitrate reductase enzyme activity (Table III & IV). Dohler *et al*. (1987) showed that activity of nitrate reductase and other key enzymes of nitrogen metabolism were inhibited under enhanced UV-B radiation. In this study, the nitrate reductase activity increased by an average of 11% in barley and 22% in common bean plants grown in the absence of solar UV-B radiation (UV-B–) (Table III & IV). The cause for the reduction in the nitrate reductase activity under enhanced UV-B might be the inhibition of ATP supply through a reduction in the activity of photosystem II (Strid *et al*., 1990). Ming *et al*. (1998) have reported increased N content in the leaves of spring wheat due to enhanced UV-B treatment, which might be the result of inhibited N accumulation by the plants. In both the crop species, rate of photosynthesis increased due to exclusion of solar UV-B, but chlorophyll content remained unaffected. This was in contrast to the findings with mungbean and mustard grown under enhanced UV-B radiation where UV-B-irradiated plants showed reduced chlorophyll content along with lower photosynthesis rate (Pal *et al*., 1999).

In this study, UV-B-free grown plants of both barley and common bean showed a marginal change in their total chlorophyll content (Table III & IV). Laposi *et al*. (2002) reported an increase in chlorophyll content in peach when grown under solar UV-B exclusion. Reduction in chlorophyll content along with lower rate of photosynthesis occurred in cotton under enhanced UV-B radiation (Kakani *et al*., 2004). We also found a higher level of reducing and non-reducing sugars in UV-B-free grown plants (UV-B–) of both the specie (Table III & IV). This could be the result of a higher rate of photosynthesis in the absence of solar UV-B. High levels of UV-B radiation have reportedly caused down-regulation of photosynthetic genes, leading to reduced levels of glucose in common bean leaves (Mackernesi *et al*., 1997). Day *et al*. (1996) also reported that chlorophyll content decreased due to high UV-B irradiation in pea owing to reduction in expression of chlorophyll a/b binding proteins. Similar reductions in chlorophyll levels have bean reported in rice (Ambasht & Agrawal, 1997).

In conclusion, solar UV-B present in solar spectrum in Delta conditions affect plant growth, photosynthesis and other biochemical processes of crop plants, particularly of dicots species, because of their greater sensitivity to UV-B as compared with monocots. Further increases in the level of solar UV-B radiation due to depletion of stratosphere ozone level could be expected to be relatively inhibitory to dicots species than to monocots grown in this region.

REFERENCES

Ambasht, N.K. and M. Agrawal, 1997. Influence of supplementary UV-B radiation on photosynthetic characteristics of rice plants. *Photosynthetica*, 34: 402–8

Ambler, J.E., D.T. Krizek and P. Semeniuk, 1975. Influence of UV-B radiation on early seedling growth and translocation of ^{65}Zn from cotyledons in cotton. *Physiol. Plant,* 34: 177–81

Caldwell, M.M. and S.D. Flint, 1997. Uses of biological spectral weighting functions and the need of scaling for the ozone reduction problems. *Plant Ecol.,* 128: 66–76

Caldwell, M.M., R. Robberecht and W.D. Billings, 1980. A steep latitudinal gradient of solar UV-B radiation in the arctic alpine life ozone. *Ecology,* 61: 600–11

Caldwell, M.M., C.L. Ballatre, J.F. Bornman, S.D. Flint, L.O. Bjorn, A.H. Teramura, G. Kulandaivelu and M. Tevini, 2003. Terrestrial ecosystems, increased solar ultraviolet radiation and interactions with other climatic change factors. *Photochem. Photobiol. Sci.,* 2: 29–39

Day, T.A., B.W. Howells and C.T. Ruhland, 1996. Changes in growth and pigment concentration with leaf age in pea under modulated UV-B radiation field treatments. *Plant Cell Environ.,* 19: 101–8

Dohler, G., R.C. Worrest, I. Biermann and J. Zink, 1987. Photosynthetic $^{14}CO_2$ fixation and (^{15}N)-amino assimilation during UV-B radiation of Lithodesmium variable. *Physiol. Plant,* 70: 511–5

Ferrario, M.S., M.H. Valadier and C. Foyer, 1998. Overexpression of nitrate reductase in tobacco delays drought induced decreases in nitrate reductase activity and mRNA. *Plant Physiol.,* 117: 293–02

Gardner, F.P., R.B. Pearce and R.L. Mitchell, 1985. *Growth and Development, Physiology of Crop Plants*, pp: 187–208. The Iowa State University Press, Ames

Gonzalez, R., A.R. Wellburn and N.D. Paul, 1998. Response of two pea lines to ultraviolet- B radiation (280-315 nm). *Physiol. Plant,* 104: 373–8

He, J., L.K. Hung, W.S. Chow, M.R. Whitecross and J.M. Anderson, 1993. Effect of supplementary UV-B radiation on rice and pea plants. *Australian J. Plant Physiol.,* 20: 129–42

Kakani, V.G., K.R. Reddy, D. Zhao and W. Gao, 2004. Senescence and hyperspectral reflectance of cotton leaves exposed to ultraviolet B radiation and carbon dioxide. *Physiol. Plant,* 121: 250–7

Krause, G.H., E. Grube, A. Virgo and K. Winter, 2003. Sudden exposure to solar UV-B radiation reduces net CO_2 uptake and photosystem I efficiency in shade-acclimated tropical tree seedlings. *Plant Physiol.,* 131: 745–52

Krizek, D.T., G.F. Kramer and R.M. Mirecki, 1997. Influence of UV-B radiation and putrecine on shoot and root growth of cucumber seedling growing in nutrient solution. *J. Plant Hort.,* 20: 613–23

Laposi, R., Sz. Veres, O. Mile and I. Meszaros, 2002. Photosynthesis-ecological properties of beech under the exclusion of ambient UV-B radiation. *Acta Biol. Szegediensis,* 46: 243–5

Mackernesi, S.A.H., S.L. Surplus, B.K. Jordan and B. Thomas, 1997. Ultraviolet B effects on traus crop levels for photosynthetic genes are not mediated through carbohydrate metabolism. *Plant Cell Environ.,* 20: 1431–7

Mepsted, R., N.D. Paul, J. Stephen, J.E. Corlett, S. Nogures, N.R. Bader, H.G. Jone and P.G. Ayres, 1996. Effect of enhanced UV-B radiation on pea grown field condition in U.K. *Global Change Biol.,* 2: 325–34

Ming, Y., Y. Li and X. Wang, 1998. Effects of enhanced UV-B radiation on plant nutrients and composition of spring wheat under field conditions. *Environ. Expt. Bot.,* 40: 187–96

Moussa, H.R., 2006. Influence of Exogenous Application of Silicon on Physiological Response of Salt-Stressed Maize (*Zea mays* L.). *Int. J. Agric. Biol.,* 8: 293–7

Muurali, N.S. and A.H. Teramura, 1986. Effectiveness of UV-B radiation on growth and physiology of field growth soybean modified by water stress. *Photochem. Photobiol.,* 44: 215–20

Nelson, N., 1944. A photometric adoption of the Somogy's method for the determination of glucose. *J. Biol. Chem.,* 1153: 375–80

Pal, M., U.K. Sengupta, A.C. Srivastava, V. Jain and R.C. Meena, 1999. Changes in growth and photosynthesis of mungbean induced by UV-B radiation. *Indian J. Plant Physiol.,* 4: 79–84

Pal, M., A. Sharma, Y.P. Abrol and U.K. Sengupta, 1997. Exclusion of solar UV-B radiation from normal spectrum on growth of mungbean and maize. *Agri. Eco. Environ.,* 61: 29–34

Panse, V.G. and P.T. Sukhatme, 1967. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi

Porra, R.J., W.A. Thompson and P.E. Kriedemann, 1989. Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophyll a and b extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absorption spectroscopy. *Biochem. Biophys. Acta*, 975: 384–94

Pyle, J.A., 1996. Global ozone depletion observation and theory. *In:* Lumbsden, P.J. (ed.), *Plant and UV-B Responses to Environmental Change,* pp: 3–12. Cambridge University Press, Cambridge

Ruhland, C.T. and T.A. Day, 2000. Effects of ultraviolet-B radiation on leaf elongation, production and phenylpropanoid concentrations of *Deschampsia anatarctica* and *Colobanthus quuitensis* in Antarctica. *Physiol. Plant,* 109: 244–50

Schumaker, M.A., J.H. Bassman, R. Robberecht and G.K. Radamaker, 1997. Growth, leaf anatomy and physiology of Populus clones in response to solar ultraviolet-B radiation. *Tree Physiol.,* 17: 617–26

Searls, P.S., M.M. Caldwell and K. Winter, 1995. The response of five tropical dicotyledons species to solar ultraviolet-B radiation. *Canadian J. Bot.,* 82: 445–53

Sharma, A., Y.P. Abrol and U.K. Sengupta, 1991. Effect of solar UV-B radiation on growth of mungbean (*Vigna radiata* L. Wilzeck) plants. *In:* Abrol, Y.P., P.N. Wattal, A. Gnanam, Govindjee, D.R. Ort and A.H. Teramura (eds.), *Impact of Global Climatic Changes on Photosynthesis and Plant Productivity,* pp: 175–82. Oxford and IBH Publishing Co. Pvt. Ltd., India

Singh, A., 1994. Effects of enhanced UV-B radiation on higher plants. *Trop. Ecol.,* 35: 321–47

Singh, A., 1995. Influence of UV-B radiation on tropical legumes. *Trop. Ecol.,* 36: 249–52

Srivastava, B.N., M.C. Shrama and R.S. Tanwar, 1989. Measurement of solar ultraviolet radiation and turbidity at Delhi. *Indian J. Radio Space Phys.,* 18: 296–302

Strid, A., W.S. Chow and J.M. Anderson, 1990. Effect of supplementary UV-B radiation on photosynthesis in *Pisum sativum*. *Biochem. Biophys. Acta.,* 1020: 260–8

Teramura, A.H., 1983. Effect of UV-B radiation on the growth and yield of crop plants. *Physiol. Plant,* 58:415–27

Xiong, F.S. and T.A. Day, 2001. Effect of solar ultraviolet-B radiation during spring time ozone depletion on photosynthesis and biomass production of Antarctic vascular plants. *Plant Physiol.,* 125: 738–51

Ziska, L.H. and A.H. Teramura, 1992. Modifications of CO_2 enhanced growth and photosynthesis in rice by increased UV-B radiation. *Plant Physiol.,* 99: 473–80

Zhao, D., K.R. Reddy, V.G. Kakani, A. Mohammed, J.J. Read and W. Gao, 2004. Leaf and canopy photosynthetic characteristics of cotton under elevated CO_2 and UV-B radiation. *J. Plant Physiol.,* 161: 581–90

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