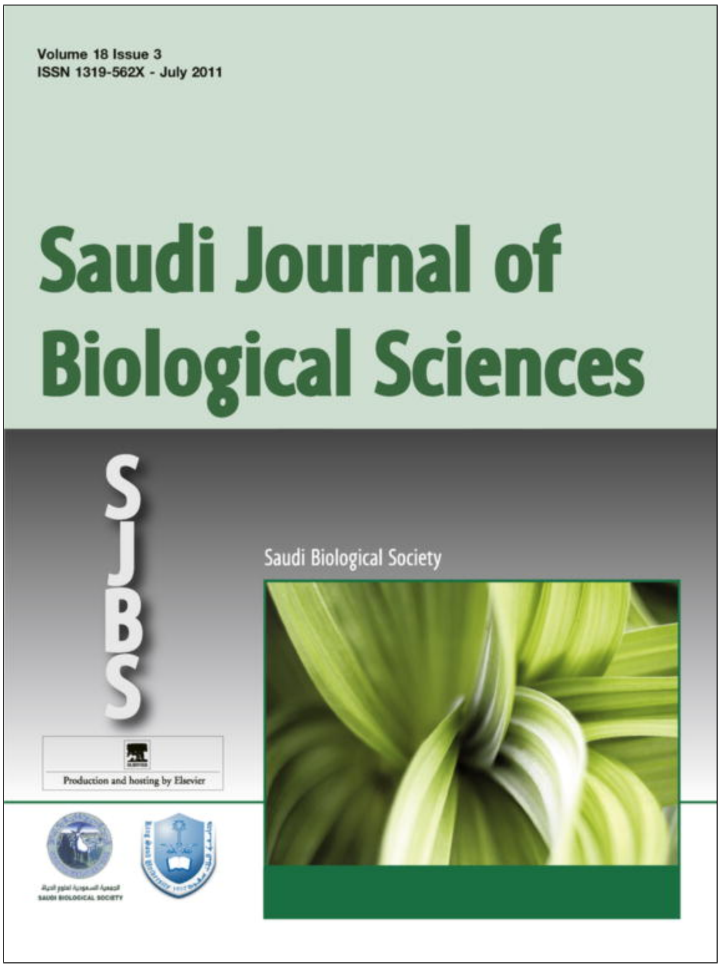
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ORIGINAL ARTICLE

Effects of Riyadh cement industry pollutions on some physiological and morphological factors of *Datura innoxia* Mill. plant

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Abstract Cement factory emissions into air cause serious air pollution and affect the plant and animal life in the environment. Herein, we report the effects of cement industry emissions (O_3, SO_2 and NO_2) in air, as pollutants, at Riyadh City on *Datura innoxia* Mill. plant. Morphological characters including plant height, leaves area and number, fresh and dry weight of shoot and root systems of *D. innoxia* showed a significant reduction from their normal control plants as a response to exposure to pollutant emissions. Chlorophyll and carotenoid contents recorded reductions in values compared to control plant, and the lowest values of chlorophyll A, B, total chlorophyll, carotenoids and total pigments were 0.431, 0.169, 0.60, 0.343 and 0.943 mg/g respectively at a distance of 1–5 m from the cement factory in fruiting stage. These changes in values may be attributed to a probable deceleration of the biosynthetic process rather than degradation of pigments. Further *D. innoxia* showed a significant ($P < 0.01$) reduction in non-reducing and total sugars, protein and total lipid contents compared with the control plant. The root system recorded the lowest values of reducing sugars (0.350 mg/g f. wt.), non-reducing sugars (0.116 mg/g f. wt.), total sugars (0.466 mg/g f. wt.), protein content (0.931 mg/g f. wt.) and total lipids content (0.669 mg/g f. wt.) in fruiting stage at a distance of 1–5 m from the cement factory. The peroxidase activity of shoot and root systems of the studied plant was also significantly higher than those of control plant. Thus a highest value of (29.616 units/g f. wt.) peroxidase activity was recorded in vegetative stage of shoot system at a dis-

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tance 1–5 m from the cement factory. Results of the study indicated that cement industry emission strongly influence the physiology and morphology of date palm D. innoxia which contribute date fruits, a staple food in the Arab world.

1. Introduction

Air pollution responsible for vegetation injury and crop yield loss are causing increased concern. Air pollution has become a major threat to the survival of plants in the industrial areas (Gupta and Mishra, 1994). Rapid industrialization and addition of the toxic matters and gases to the environment are responsible for altering the ecosystem. It is to be noted the human activities, both industrial and agricultural, contribute to the escalation in the levels of biologically active nitrogen compounds and sulfur dioxide in the atmosphere and environment. Various forms of nitrogen pollute the air, mainly nitric oxide (NO), NO_2 and NH_3 as dry deposition and NO_3 and NH_4 as wet deposition. High concentrations of sulfur dioxide (SO_2), viewed as the most important phytotoxic, cause acute injury in the form of foliar necrosis, after exposure for even relatively a short duration. Over the past 25 years an increasing number of reports have appeared on O_3 induced foliar injury in sensitive plants in many countries including Saudi Arabia (Krupa et al., 2001; Al-Qurainy, 2008).

In fact it is important to study effects of dust deposits and air pollution on vegetation and hence studies on the effect of air pollution due to industrial activities on morphology, physiology and biochemistry of plants have been carried out by a number of investigators. Air pollution directly affects the net carbon dioxide exchange rate and dry matter accumulation of many plants (Lorenc Plucinska, 1982). Elevated CO_2 increased the photosynthetic carbon uptake by seedling beginning early in the study (Olszyk et al., 2001) and persisting to the end (Olszyk et al., 2002). Previous studies also showed the impact of air pollution on ascorbic acid content (Agbaire and Esiefarienrhe, 2009) and chlorophyll content (Flowers et al., 2007; Ju Liu and Ding, 2008). Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in the air environment (Escobedo et al., 2008). Gostin and Ivanescu (2007) showed that air pollution causes structural and micro morphological changes in *Salix alba*.

The cement industry also plays a vital role in the imbalances of the environment and produces air pollution hazards (Stern, 1976; Niragau and Davidson, 1986) and consequently the impact of the cement industry emissions on the vegetation in the vicinity has been widely investigated (Singh and Rao, 1980; Farmer, 1993; Iqbal and Shafig, 2001; Lepedus et al., 2003; Ade-Ademilua and Obalola, 2008). But research on the effects of dust and air pollutants on plants has never received the same level of attention as that was given to phytotoxic pollutants such as O_3, SO_2 and NO_2. In the present study the main focus was to understand the effects of Riyadh cement factory pollutions in Saudi Arabia on the morphological and physiological status of *Datura innoxia* Mill. plant, which has great economic importance and livelihood in Arab world.

2. Materials and methods

2.1. Site description

The investigation was carried out in polluted areas situated close to the cement factory in Riyadh City and the control plants grown in unpolluted region at the Botany and Microbiology Department, Faculty of Science, King Saud University (KSU). Employing a statistical design, 4 stations were selected by randomized complete block design (RCBD) at different distances from the cement factory with the direction of the wind, which included. Station 1 (1–5 m), station 2 (500 m), station 3 (1000 m) and station 4 (2000 m) located around the cement factory. This study was carried out during 2008/ 2009, and the *Datura innoxia* Mill. plant species were grown in plastic pots (diameter 25.5 cm and height 23 cm) in an unpolluted area at KSU (Fig. 1). The six pots of plants were transferred to the 4 stations near the cement factory after completion of their growth. All morphological and physiological parameters were measured, five times, and the data recorded were tabulated as the main values of five replicates.

The climate in the study area (Riyadh City) during the period of study was continental. The maximum annual air temperature was about 44.8 °C in August, while the minimum was about 4.3 °C in January. The average annual precipitation was about 1.5 mm in both spring and winter season. The prevailing winds were with the northern, northwestern and northeastern components, at a maximum speed of about 10.4 km/h in April and a minimum speed of 6.8 km/h in August. The average relative humidity was about 36.4% during 2008.

3. Air pollution

The main toxicants in the air over the cement industry region were: Ozone (O_3), nitrogen oxides (NO, NO_2, NO_3), sulfur dioxide (SO_2), carbon oxides (CO, CO_2) and cement dust deposits. The air pollution was measured twice per week during the period of the study with Horiba Bortabli Multi – Gas Analyzer, Model P9 – 250.

4. Biochemical analyses

The plant species exposed to pollutants in the polluted areas and control plant were sampled for analysis. Fresh leaves were collected in the morning from the each plant grown. The leaves were analyzed after mechanical cleaning of leaf blades. Morphological features including leaf area, number of injury leaf, length, fresh and dry weight of shoot and root systems; and water soluble sugars, chlorophyll, carotenoids, protein, and other biochemical factors were determined by biochemical methods.

Figure 1 Photo showing the growing stages of *Datura innoxia* Mill.

Chlorophyll A, B, total chlorophyll and carotenoid were analyzed using acetone 85% (Lichthenthaler, 1987). Soluble sugars were estimated using the prepared hydro alcoholic extract of leaf powder. Total carbohydrate concentration was determined by the phenol sulfuric acid method (Dubois et al., 1956; Verma and Dubey, 2001).

Reducing, non-reducing and total sugars were determined according to the method of Miller (1959). All the values were quantified using a spectrophotometer (Pharmacia Biotech-Ultra Spec 2000).

The protein contents were analyzed according to the method of Lowry et al. (1951) and Laemmli (1970), and total lipids content were analyzed by Brain and Turner (1975). Peroxidase activity was assayed by Nasson (1979). All values were quantified with spectrophotometer (Pharmacia Biotech-Ultra Spec 2000).

5. Statistical analysis

The results were analyzed statistically by using the SPSS BASE 10.0 for windows (SPSS Inc., Chicago, IL) packages. Data were tested by ANOVA and *F*-tested LSD separated means at $P \leqslant 0.05$ and $P \leqslant 0.01$ levels to determine the significant differences between polluted and control stands.

6. Results

6.1. Variations in climate and air pollution

Mean values of meteorological parameters collected at Riyadh City, Kingdom of Saudi Arabia (KSA) are presented in Table 1. Changes in mean concentrations of O_3, SO_2 and NO_2 recorded during the period of study from January to August 2008 at the cement industry area, Riyadh, KSA are documented in Table 2. It was found that mean monthly concentration of O_3 gradually increased to 148 ppb in August (summer) and recorded a lowest concentration of 78 ppb in January. Further SO_2 and NO_2 concentrations were observed to gradually increase from 24 to 24 ppb, respectively, to higher levels of 29 and 34 ppb, respectively. Generally, high values were noted during hotter months while cool months recorded low values.

6.2. Morphological parameters

The effects of air pollution at the cement industry area on the *D. innoxia* were observed at different distances from the cement factory. Data obtained for the variables leaf area, height, fresh and dry weights of shoot and root systems at the three stages of plant development (vegetative, flowering and fruiting stages) are presented in Table 3. These values are the mean values of five replicates recorded during the investigation. The lowest values of leaf area and length of plant (40.448 cm^2 and 52.14 cm respectively) were recorded with vegetative stage of plants at distance of 1–5 m from the cement factory while the highest values (99.524 cm^2 and 78.74 cm respectively) were noted in fruiting stage of plants located at a distance of 2000 m (Table 3). The lowest values of fresh and dry weight in shoot system were recorded as 4.393 g and 1.025 g respectively in fruiting stage of plants present at 1–5 m distance, while the highest values of 41.089 g and 17.399 g were noted in vegetative stage of plants present at 2000 m distance (Table 3). The root system recorded the lowest values of fresh weight (1.125 g) and dry weight (0.135 g) in fruiting stage of plants located at distance 1–5 m, while the highest values were 10.242 g and 1.535 g in vegetative stage of plants present at 2000 m distance (Table 3). The data presented in Table 3 indicated significance differences in morphological parameters with respect to the distances from the site of cement factory. The numbers of injured leaves are the main values of five replicate measurements, where the highest number of injured leaves was 15 at 1–5 m distance in the fruiting stage, while the lowest value was 2 at 2000 m distance in vegetative stage (Table 4). The numbers of injured leaves depicted in Table 4 showed the significance of injury levels with respect to the different distances from the cement factory.

6.3. Biochemical parameters

Data presented in Table 5 indicated the effect of air pollution on the photosynthetic pigments at the three stages of plant development (vegetative, flowering and fruiting stages) of *D. Innoxia*. These values are the mean values of five replicate. The photosynthetic pigments analyzed included chlorophyll A, B, total chlorophyll, carotenoids and total pigments. From the results

Table 1 Mean values of meteorological parameters recorded at Riyadh City, KSA (January–August, 2008).

Month	Max. temperature (°C)	Min. temperature (°C)	Wind speed (km/h)	Relative humidity (%)	Rainfall (mm/month)
January	22.7	4.3	8.2	36.4	1.5
February	24.3	4.9	9.8	24.5	0.0
March	31.5	13.4	8.7	25	0.0
April	37	17.4	10.4	15.5	0.0
May	39.9	25.1	9.4	18.7	0.0
June	43.4	26	9.7	17.9	0.0
July	43.6	29.5	9.6	18.6	0.0
August	44.8	29.7	6.8	19.7	0.0

Table 2 Mean values of ozone, sulfur and nitrogen dioxides (ppb) in the air at the cement industry area (January–August, 2008).

Months	Concentration (ppb)		
	O_3	SO_2	NO_2
January	78	27	24
February	83	29	29
March	91	25	27
April	86	24	27
May	95	26	30
June	112	29	33
July	125	26	32
August	148	27	34

presented in Table 5 it was noted that the lowest values of chlorophyll A, B, total chlorophyll, carotenoids and total pigments were, 0.431, 0.169, 0.60, 0.343 and 0.943 mg/g respectively in fruiting stage of the plants of 1–5 m distance, while the highest values were, 1.78, 0.701, 2.481, 0.823 and 3.304 mg/g respectively in the vegetative stage of plants of 2000 m distance. It was found that all photosynthetic pigments contents were significantly decreased in the plants at varying distances from the cement factory.

6.4. Carbohydrate content

Results obtained for the studies on the effects of air pollution on the total soluble sugars (reducing, non-reducing and total sugars) for *D. innoxia* at the three stages of plant development (vegetative, flowering and fruiting stages) are illustrated in Table 6. It was noted that, the lowest values of reducing sugars were 0.478 and 0.178 mg/g f. wt. respectively, in shoot and root systems in fruiting stage of plants at 2000 m distance while the highest values were 5.818 and 4.638 mg/g f. wt. in vegetative stage at 1–5 m distance. Non-reducing sugars and total sugars values were noted to get decreased along with increasing distance from the cement factory. At the distance of 1–5 m from the cement factory plants in fruiting stage, recorded non-reducing sugars at lowest levels of 0.182 and 0.116 mg/g f. wt. in shoot and root systems, while the total sugars values were 1.077 and 0.466 mg/g f. wt. in shoot and root systems (Table 6). The highest values of non-reducing and total sugars recorded in vegetative stage at the distance of 2000 m from the cement factory, were 5.398 and 4.223 mg/g f. wt. in shoot and root systems (non-reducing), and 9.720 and 6.211 mg/g f. wt. in shoot and root systems (total sugars). The effect of O_3, SO_2 and NO_2 on the carbohydrate concentration of shoot and root systems was significant as there was difference in the concentration at the three stages of plant developments with the control stage.

6.5. Protein content

The impacts of elevated O_3, SO_2 and NO_2 on the protein content of *D. innoxia* are summarized in Table 7 at the three stages of plant development (vegetative, flowering and fruiting). Table 7 showed that the lowest values of protein content were 1.818 and 0.931 mg/g f. wt. in shoot and root systems in fruiting stage at 1–5 m distance, while the highest values were 9.562 and 6.687 mg/g f. wt. in vegetative stage at 2000 m. Changes in the concentration of protein content were also determined to be significant and varied at the three stages of plant development when compared with the control at all distances from the cement factory.

6.6. Total lipid content

According to existence of O_3, SO_2 and NO_2 at the cement industrial area as the result of chemical activities on the total lipids content of *D.innoxia* (Tab. 8) at the different distances from cement factory. Data presented in Table 8 indicated that total lipids content were of lowest values (1.399 and 0.669 mg/g f. wt.) in shoot and root systems, in fruiting stage at 1–5 m distance, while the highest values (12.22 and 7.37 mg/g f. wt.) in vegetative stage at 2000 m distance. These results indicated that there was significant difference in all stages of plant development compared with the control at the all distances studied.

6.7. Peroxidase activity

The data obtained for the distribution of peroxidase activity among various fractions isolated from *D. innoxia* shoot and root systems depicted in Table 9 indicated that in shoot and root systems of fruiting stage at 1–5 m distance the enzyme activities were the lowest (13.527 and 8.648 units/g f. wt.), while the highest values (22.775 and 16.737 units/g f. wt.) were in vegetative stage at 2000 m distance from the cement factory. The results showed that there was increase of peroxidase activity with a significant difference in all stages of plant development (vegetative, flowering and fruiting stages) with the control located at all the distances studied.

7. Discussion

In a typical urban atmosphere like Riyadh City, KSA, O_3, SO_2 and NO_2 concentrations increase rapidly between 12 00 and 15 00 hours of the entire day light and when the intensity of solar

Table 3 Effect of air pollution on leaf area and length, fresh and dry weight of shoot and root systems of *Datura innoxia* Mill plant at different distances from the cement factory.

Growth stages	Distance (m)	Parameters (mean ± SD)						
		Leaf Leaf area (cm^2)	Shoot			Root		
			Length (cm)	Fresh weight(g)	Dry weight (g)	Length (cm)	Fresh weight(g)	Dry weight(g)
Vegetative stage	Control	52.467 ± 1.493	68.56 ± 1.501	41.804 ± 3.523	17.526 ± 1.359	57.52 ± 1.275	10.402 ± 1.190	1.547 ± 0.143
	1–5	40.448 ± 3.326**	52.14 ± 8.112**	31.799 ± 2.776**	11.119 ± 2.043**	39.30 ± 1.557**	6.494 ± 1.816**	0.683 ± 0.221**
	500	40.597 ± 1.907**	62.50 ± 1.483*	38.371 ± 2.042*	13.488 ± 1.649**	52.04 ± 8.224*	7.520 ± 1.556*	1.015 ± 0.003**
	1000	51.332 ± 2.968	68.24 ± 1.759	40.217 ± 1.540	15.731 ± 1.831	56.70 ± 1.690	9.607 ± 1.741	1.199 ± 0.038**
	2000	52.648 ± 1.829	68.30 ± 1.666	41.089 ± 2.528	17.399 ± 1.316	57.48 ± 1.547	10.242 ± 1.767	1.535 ± 0.159
LSD at 5%		3.181	5.148	3.392	2.194	5.175	2.151	0.181
LSD at 1%		4.339	7.021	4.626	2.993	7.058	2.933	0.247
Flowering stage	Control	64.386 ± 1.453	75.78 ± 15.783	14.633 ± 1.567	4.384 ± 1.634	61.94 ± 7.204	3.649 ± 1.513	0.443 ± 0.119
	1–5	46.910 ± 2.379**	57.64 ± 5.894**	5.723 ± 2.001**	1.456 ± 0.136**	42.64 ± 0.662**	1.209 ± 0.093**	0.208 ± 0.031**
	500	57.926 ± 3.602**	65.68 ± 1.789	8.491 ± 1.351**	1.539 ± 0.182**	53.58 ± 1.593**	1.455 ± 0.509*	0.273 ± 0.026**
	1000	63.527 ± 1.440	72.36 ± 1.394	12.395 ± 1.528*	3.340 ± 0.910	58.58 ± 1.615	3.407 ± 1.492	0.303 ± 0.021**
	2000	64.305 ± 1.483	75.74 ± 14.146	14.527 ± 1.131	4.337 ± 1.617	61.72 ± 1.446	3.439 ± 1.680	0.380 ± 0.113
LSD at 5%		2.952	13.048	2.036	1.464	4.554	1.627	0.102
LSD at 1%		4.026	17.795	2.777	1.997	6.211	2.219	0.139
Fruiting stage	Control	102.024 ± 1.923	79.12 ± 9.404	10.687 ± 1.771	2.812 ± 0.933	65.82 ± 20.199	1.747 ± 0.031	0.266 ± 0.037
	1–5	71.174 ± 9.021**	67.60 ± 1.464*	4.393 ± 1.638**	1.025 ± 0.088**	47.10 ± 3.611**	1.125 ± 0.017**	0.135 ± 0.016**
	500	84.434 ± 3.393**	72.66 ± 1.759	4.714 ± 1.703**	1.074 ± 0.016**	55.24 ± 3.511	1.186 ± 0.016**	0.174 ± 0.017**
	1000	95.363 ± 3.173*	76.16 ± 0.963	6.533 ± 1.798**	1.568 ± 0.541*	60.48 ± 7.075	1.476 ± 0.129**	0.184 ± 0.018**
	2000	99.524 ± 1.221	78.74 ± 16.213	9.679 ± 1.498	2.350 ± 1.202	63.62 ± 1.451	1.653 ± 0.024*	0.262 ± 0.036
LSD at 5%		6.135	11.156	2.224	0.955	13.000	0.083	0.042
LSD at 1%		8.367	15.215	3.033	1.303	17.730	0.114	0.057

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level.

Table 4 Number of infected leaves of *Datura innoxia* Mill plant, present at different distances from the cement factory, after exposure to air pollutants.

Distance (m)	Number of infected leaves (mean ± SD)		
	Vegetative stage	Flowering stage	Fruiting stage
Control	1.80 ± 1.304	4.00 ± 1.581	8.60 ± 2.074
1–5	6.00 ± 1.581**	9.20 ± 1.923**	15.00 ± 2.739**
500	4.00 ± 1.581*	7.00 ± 1.581**	13.00 ± 1.581**
1000	3.00 ± 1.581	6.00 ± 1.581	11.00 ± 2.739
2000	2.20 ± 1.304	5.00 ± 1.581	10.20 ± 1.923
LSD at 5%	1.948	2.184	2.979
LSD at 1%	2.657	2.979	4.063

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level.

radiation is at a maximum during hot months and when the ratio of NO_2: NO is large (Krupa et al., 2001). The ratio of O_3 formation may then decline, reaching a steady state during the late afternoon to early evening hours. After that period, O_3 concentrations fall as NO_2 breakdown diminishes and as fresh emissions of NO deplete the O_3. This daily pattern was observed to be quite different at high elevations (generally, above approximately 1500 m from the surface or above the so-called mixed layer of the atmosphere), where O_3 concentrations remain relatively steady through the day and night. At that altitude, there is an O_3 reservoir, and destruction of that O_3 by the surface is insufficient to produce the type of daily patterns observed at lower elevations (Krupa et al., 2001). During the exposure period, the monthly average concentrations of major air pollutants e. O_3, SO_2 and NO_2 around the cement factory at Riyadh City, KSA, were recorded as high during hot summer months around the cement factory. Air pollution around the cement factory area had a significant effect on the morphological parameters of the studied plant species compared with the control plant. Polluted gases such as O_3, SO_2 and NO_2 were found to be emitted by the cement manufacturing plants. The results indicated a significant reduction in plants height, leaf area, fresh and dry weights of shoot and root systems of *D. innoxia*. The reduction in level of variable may be attributed to the cement factory emissions which contain toxic gases and cause air pollution. The level of reduction of these morphological factors increased along with decreasing distances from the cement factory. The results obtained were in close conformity with those reported by Iqbal and Shafig (2001). Decrease in plants height of *D. innoxia* might be due to the decrease in phytomass, net primary production and chlorophyll content in response to cement air pollutions, confirming the findings of Prasad and Inamdar (1990) in *Vigna mungo* (Black gram). The level of reduction of leaf numbers of *D. innoxia* increase with decreasing distances from the cement factory. The results showed a significant reduction in leaf number for *D. innoxia* which corroborated with the findings of Anda (1986). Prasad and Inamdar (1990) reported that, the cement air pollution kiln showed a reduction in chlorophyll content, protein, starch, yield and phytomass in groundnuts (*Arachis hypogaea* L.). On the basis of this study, it could be concluded that growth of plants was found to be affected by cement air pollution, which might be due to the presence of different toxic pollutants in cement air pollutions. The phonological studies of *D. innoxai* were found to be highly affected by air pollution. The mean values of morphological parameters were found to be highly significant ($P < 0.01$) when compared with the control value and with respect to distances from the cement factory. The quantitative analysis of chloroplast pigments revealed that the difference between plants exposed to cement air pollution and control plants. The mean values of all measured parameters of *D. innoxia* at different distances from the cement factory and the three stages of growth plants indicated changes in concentration of pigments in *D. innoxia* exposed to cement gases emissions. The photosynthetic pigments vary with respect to variation in the distances from the cement factory. Chlorophyll A, B, total chlorophyll, carotenoids and total pigment contents were higher in vegetative stage of *D. innoxia*. The results obtained for total chlorophyll supported the proposition that the chloroplast is the primary site of attack by air pollutants such as O_3, SO_2 and NO_2 (Joshi and Swami, 2009). Air pollutants make their entrance into the tissues through the stomata and cause partial destruction of the chloroplast and decrease pigment contents in the cells of polluted leaves (Mandal and Mukherji, 2000; Wang and Lu, 2006; Tripathi and Gautam, 2007; Tripathi et al., 2009). Mean concentrations of all pigment parameters of *D. innoxia* showed highly significant values ($P < 0.01$) compared with the control values and for the varying distances from the cement factory.

The carbohydrate contents of *D. innoxia* non-reducing and total sugars were reduced in plants located closer to the cement factory in all growth stages of *D.innoxia*. The decrease in non-reducing and total sugars content of damaged leaves probably corresponded with the photosynthetic inhibition or stimulation of respiration rate. Higher reducing sugar accumulation noted in *D. innoxia* may be due to higher resistance of their photosynthetic apparatus and low reducing sugar export from the mesophyll. The level of reduction in protein content increased along with decreasing distances from the cement factory and was compared with the control plants in all growth stages of plants. Decrease in protein content of *D. innoxia* might be due to the induction of the photosynthetic pigments of plants exposed to the pollution stress. Decreases in concentration of total lipids content in plant exposed to air pollution stress might be due to induced rate of the photosynthesis in plants exposed to the air pollution stress. The plant absorbs O_3 through stomata, where the ozone gas affects the total lipids content by changing them from crystalline shape to non-crystalline irregular shape. This would have reduced the

Table 5 Photosynthetic pigment contents of *Datura innoxia* Mill plant, present at different distances from the cement factory.

Growth stages	Pigments (mg/g) (mean ± SD)					
	Distance (m)	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carotenoids	Total pigments
Vegetative stage	Control	1.911 ± 0.169	0.733 ± 0.285	2.644 ± 0.116	0.970 ± 0.043	3.614 ± 0.159
	1–5	1.440 ± 0.137**	0.216 ± 0.133**	1.656 ± 0.153**	0.590 ± 0.086**	2.245 ± 0.066**
	500	1.553 ± 0.102**	0.400 ± 0.136	1.954 ± 0.133**	0.602 ± 0.046**	2.555 ± 0.130**
	1000	1.747 ± 0.096	0.549 ± 0.130	2.297 ± 0.197*	0.663 ± 0.052**	2.960 ± 0.146**
	2000	1.780 ± 0.086	0.701 ± 0.182	2.481 ± 0.135	0.823 ± 0.052**	3.304 ± 0.110*
LSD at 5%	0.223	0.334	0.269	0.100	0.229	
LSD at 1%	0.317	0.475	0.383	0.143	0.326	
Flowering stage	Control	1.585 ± 0.099	0.415 ± 0.151	2.000 ± 0.070	0.833 ± 0.041	2.833 ± 0.109
	1–5	0.773 ± 0.114**	0.214 ± 0.148	0.987 ± 0.035**	0.562 ± 0.020**	1.549 ± 0.053**
	500	1.053 ± 0.110**	0.260 ± 0.075	1.312 ± 0.179**	0.585 ± 0.016**	1.897 ± 0.191**
	1000	1.368 ± 0.069*	0.307 ± 0.167	1.675 ± 0.110*	0.695 ± 0.048**	2.370 ± 0.063**
	2000	1.561 ± 0.087	0.338 ± 0149	1.898 ± 0.237	0.757 ± 0.058*	2.656 ± 0.178
LSD at 5%	0.171	0.256	0.263	0.080	0.236	
LSD at 1%	0.244	0.364	0.374	0.114	0.336	
Fruiting stage	Control	1.477 ± 0.066	0.258 ± 0.122	1.735 ± 0.129	0.672 ± 0.047	2.407 ± 0.175
	1–5	0.431 ± 0.100**	0.169 ± 0.112	0.600 ± 0.074**	0.343 ± 0.035**	0.943 ± 0.093**
	500	0.525 ± 0.107**	0.194 ± 0.047	0.719 ± 0.096**	0.395 ± 0.048**	1.114 ± 0.110**
	1000	0.882 ± 0.132**	0.237 ± 0.120	1.120 ± 0.107**	0.507 ± 0.022**	1.627 ± 0.095**
	2000	1.331 ± 0.107	0.249 ± 0.130	1.580 ± 0.079	0.653 ± 0.058	2.233 ± 0.133
LSD at 5%	0.192	0.198	0.183	0.080	0.229	
LSD at 1%	0.272	0.282	0.260	0.114	0.326	

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level.

Table 6 Effect of air pollution on the carbohydrate contents of *Datura innoxia* Mill plant at different distances from the cement factory.

Growth stages	Distance (m)	Carbohydrate content (mg/g f. wt.) (mean ± SD)					
		Reducing sugars		Non-reducing sugars		Total sugars	
		Shoots	Roots	Shoots	Roots	Shoots	Roots
Vegetative stage	Control	3.543 ± 1.058	1.954 ± 0.528	6.291 ± 0.242	4.626 ± 0.387	9.834 ± 0.843	6.580 ± 0.689
	l–5	5.818 ± 1.002**	4.638 ± 1.040**	0.478 ± 0.004**	0.231 ± 0.112**	6.296 ± 1.005**	4.869 ± 0.958
	500	5.761 ± 0.966*	3.783 ± 1.154*	2.921 ± 0.146**	1.384 ± 0.170**	8.682 ± 1.108	5.166 ± 0.986
	1000	4.491 ± 1.317	2.692 ± 1.007	4.468 ± 2.319	3.489 ± 1.047*	8.959 ± 1.002	6.181 ± 1.082
	2000	4.322 ± 1.347	1.988 ± 0.545	5.398 ± 1.370	4.223 ± 0.774	9.720 ± 0.864	6.211 ± 1.109
LSD at 5%		2.092	1.629	2.203	1.116	1.764	1.776
LSD at 5%		2.976	2.316	3.134	1.588	2.510	2.526
Flowering stage	Control	1.283 ± 0.093	0.585 ± 0.099	5.550 ± 0.948	3.970 ± 0.861	6.833 ± 0.898	4.555 ± 0.960
	l–5	3.262 ± 0.628**	1.143 ± 0.037**	0.393 ± 0.369**	0.164 ± 0.067**	3.655 ± 0.994**	1.307 ± 0.102**
	500	3.123 ± 1.003**	1.137 ± 0.021**	2.211 ± 0.106**	0.554 ± 0.504**	5.333 ± 0.898	1.691 ± 0.523**
	1000	2.019 ± 0.766	0.896 ± 0.105**	3.628 ± 0.394**	1.773 ± 0.793**	5.646 ± 1.071	2.669 ± 0.898*
	2000	1.365 ± 0.061	0.596 ± 0.105	4.121 ± 0.827*	2.996 ± 0.914	5.486 ± 0.887	3.592 ± 1.019
LSD at 5%		1.150	0.151	1.116	1.277	1.733	1.421
LSD at 5%		1.635	0.215	1.588	1.816	2.465	2.022
Fruiting stage	Control	0.396 ± 0.174	0.164 ± 0.049	2.791 ± 1.497	1.965 ± 0.869	3.187 ± 1.499	2.129 ± 0.903
	l–5	0.895 ± 0.104**	0.350 ± 0.079**	0.182 ± 0.083**	0.116 ± 0.012**	1.077 ± 0.021**	0.466 ± 0.066**
	500	0.670 ± 0.112*	0.320 ± 0.078**	0.504 ± 0.092**	0.412 ± 0.178**	1.173 ± 0.021*	0.731 ± 0.114**
	1000	0.529 ± 0.126	0.187 ± 0.012	0.977 ± 0.351*	0.952 ± 0.034*	1.506 ± 0.441*	1.139 ± 0.027*
	2000	0.478 ± 0.121	0.178 ± 0.010	2.470 ± 0.763	1.720 ± 0.215	2.826 ± 0.861	1.898 ± 0.225
LSD at 5%		0.236	0.100	1.401	0.744	1.453	0.764
LSD at 5%		0.336	0.143	1.993	1.058	2.066	1.087

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level

Table 7 Protein contents of *Datura innoxia* Mill plant, present at different distances from the cement factory.

Protein contents (mg/g f. wt.) (mean ± SD)			
Growth stages	Distance (m)	Shoot system	Root system
Vegetative stage	Control	9.835 ± 1.065	6.946 ± 1.032
	1–5	8.219 ± 0.969	5.934 ± 1.021
	500	8.310 ± 1.065	6.057 ± 0.966
	1000	8.870 ± 1.591	6.403 ± 0.634
	2000	9.562 ± 0.489	6.687 ± 1.034
LSD at 5%		1.990	1.729
LSD at 1%		2.830	2.459
Flowering stage	Control	9.310 ± 1.065	6.210 ± 1.098
	1–5	4.425 ± 1.098**	2.229 ± 1.048**
	500	4.750 ± 1.017**	3.538 ± 1.065*
	1000	5.430 ± 0.606**	4.219 ± 1.032*
	2000	7.310 ± 1.033*	5.562 ± 1.049
LSD at 5%		1.785	1.925
LSD at 1%		2.538	2.738
Fruiting stage	Control	6.243 ± 1.097	3.322 ± 1.049
	1–5	1.818 ± 1.065**	0.931 ± 0.062**
	500	3.765 ± 1.066*	1.242 ± 0.605*
	1000	4.599 ± 1.098	2.370 ± 1.065
	2000	4.939 ± 1.017	2.805 ± 1.044
LSD at 5%		1.945	1.564
LSD at 1%		2.767	2.225

* Significantly different with control at 0.05% level.
** Highly significantly different with control at 0.01 level.

Table 8 Total lipids content of *Datura innoxia* Mill plant at different distances from the cement factory.

	Total lipids content (mg/g f. wt.) (mean ± SD)		
Growth stages	Distance (m)	Shoot system	Root system
Vegetative stage	Control	12.613 ± 0.605	7.455 ± 0.965
	1–5	8.883 ± 2.024*	6.491 ± 1.256
	500	10.350 ± 2.110	6.578 ± 1.051
	1000	11.138 ± 0.850	7.259 ± 1.027
	2000	12.220 ± 1.091	7.370 ± 0.965
LSD at 5%		2.678	1.925
LSD at 1%		3.809	2.738
Flowering stage	Control	9.916 ± 0.459	5.414 ± 1.275
	1–5	4.982 ± 0.322**	2.405 ± 0.912**
	500	5.333 ± 1.317**	4.624 ± 1.275
	1000	8.517 ± 0.459	5.295 ± 0.611
	2000	9.420 ± 0.847	5.375 ± 1.266
LSD at 5%		1.404	2.003
LSD at 1%		1.996	2.849
Fruiting stage	Control	5.716 ± 1.183	3.378 ± 0.985
	1–5	1.399 ± 0.728**	0.669 ± 0.279**
	500	2.405 ± 0.683**	1.460 ± 0.876*
	1000	3.891 ± 1.378	1.847 ± 0.634*
	2000	4.348 ± 0.912	3.373 ± 0.876
LSD at 5%		1.843	1.406
LSD at 1%		2.621	2.000

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level.

absorption of CO_2 which might have led to a decrease in the rate of photosynthesis and growth. The results obtained were in agreement with those reported by Danielsson et al. (2003).

Table 9 Peroxidase activity of Datura innoxia Mill plant at different distances from the cement factory.

Peroxidase activity (units/g f. wt.) (mean ± SD)			
Growth stages	Distance (m)	Shoot system	Root system
Vegetative stage	Control	21.377 ± 0.719	12.098 ± 1.381
	1–5	29.616 ± 0.796**	25.706 ± 0.767**
	500	26.413 ± 0.598**	24.535 ± 0.668**
	1000	24.537 ± 0.691**	20.945 ± 1.041**
	2000	22.775 ± 0.834*	16.737 ± 0.732**
LSD at 5%		1.332	1.738
LSD at 1%		1.895	2.472
Flowering stage	Control	16.474 ± 0.792	8.100 ± 1.426
	1–5	24.361 ± 0.817**	20.620 ± 1.549**
	500	22.623 ± 0.905**	18.598 ± 0.611**
	1000	19.066 ± 1.322**	15.808 ± 0.901**
	2000	17.652 ± 0.892	10.598 ± 0.880*
LSD at 5%		1.756	2.056
LSD at 1%		2.497	2.925
Fruiting stage	Control	10.612 ± 0.696	6.428 ± 0.717
	1–5	21.448 ± 2.071**	19.264 ± 0.746**
	500	19.739 ± 0.814**	16.727 ± 0.860**
	1000	15.638 ± 0.736**	11.275 ± 0.841**
	2000	13.527 ± 0.758*	8.648 ± 1.687*
LSD at 5%		2.083	1.885
LSD at 1%		2.963	2.681

* Significantly different with control at 0.05 level.
** Highly significantly different with control at 0.01 level.

The data obtained for peroxidase activity among the shoot and root systems showed that, there was an increase of enzyme activity in shoot and root systems of *D. innoxia* exposure to air pollutants O_3, SO_2 and NO_2 around the cement factory at the different distances. Peroxidases may be useful for hardening of cell membranes and the formation of bridges between tyrosine residues of membrane proteins. Such a reaction could allow polluted plants to reduce their cellular permeability. An increased peroxidase activity may also be linked to a decreased rate of growth (Castillo et al., 1984). Statistically, increase of peroxidase activity had shown high significance compared with the control plants and in response to varying distances from the cement factory.

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