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Growth, biomass, pollen viability and photosynthetic efficiency of *Datura innoxia* Mill. under coal-smoke pollution

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ABSTRACT

One-year-old plants of *Datura innoxia* growing in natural condition in the Hamdard University campus, New Delhi (normal site) and around the Badarpur thermal power plant, New Delhi (polluted site), were studied and compared for their vegetative growth and pollen viability. The power plant emits 1450 tonnes fly ash and 100 tonnes sulphur dioxide per day. Significant variation was found in plant growth, biomass and pollen viability of the two population. The shoot growth was reduced at the polluted site but the root length, the number of branches and the plant biomass were increased, compared to the control. Pollen viability declined by about 66 per cent at the polluted site. Rate of photosynthesis and stomatal conductance were low while internal CO_2 concentration was high in polluted site. Further, levels of chlorophyll a, b total chlorophyll and carotenoids contents were reduced in polluted site.

Key words: *Datura innoxia*, Plant growth, Plant Biomass, Pollen viability, photosynthesis, stomatal conductance, pigments, Thermal Power Plant

INTRODUCTION

The burning of fossil fuel is a major source of air pollutants like CO_2 and SO_2 and NO_2 which have direct and indirect effects on biological systems (Iqbal et al., 2000). The Badarpur thermal power plant causes 63 per cent of the total air pollution due to thermal power plants in Delhi (CPCB 1994). Sulphur dioxide is a major constituent of the coal smoke emitted by the thermal power plant, and causes toxicity to a variety of plants (Darrall, 1989; Allen, 1990; Husen et al., 1999). The level of injury depends on concentration of the gase, fumigation frequency, duration of exposure and the prevailing environmental condition (Thomas and Hendrics, 1965). Fly ash, a constituent of the coal smoke, can improve structure and water -holding capacity of the soil (Chang et. al. 1977), enhance the soil fertility (Elsewi et al., 1980; Ghodrati et al., 1995) and increase the pH of soils (El-Mogazi et al., 1988). The growth of various plant species is affected by fly ash (Plank et al., 1975; Elsevi et al., 1980) which may cause toxicity to plants when in high concentrations (Aitken and Bell 1985; Kukier et al., 1994).

Datura innoxia Mill. (Solanaceae), a native of Mexico, was introduced into India and now is found on the western Himalayas, the hilly regions of the western parts of Deccan Peninsula, and a few other states of India including Delhi. With its narcotic and antispasmodic properties it is an important medicinal plant. The alkaloids obtained from *D. innoxia* are used in pre-anaesthetic surgery and ophthalmology. Its leaf contains fixed oils and vitamin C (Anonymous, 1952). The present communication deals with the influence of coal smoke on plant growth, plant biomass and pollen viability of this species.

MATERIALS AND METHODS

A randomized block design with 3 replicates of 5 plants was designed each in Hamdard University campus (considered as normal site) and around the Badarpur thermal power plant (the polluted site) in Delhi. Delhi is situated in north of India, 160 km south of the Himalayas. It has a tropical semi arid climate with extremely hot summer and moderately cold winters. July to September is the typical monsoon season. Of the three thermal power plants located at the Indraprastha Estate, Rajghat and Badarpur in Delhi, the latter is the largest and consumes 10,000 tonnes low-grade bituminous coal daily. It is located at 77°22’E longitude and 28°25N latitude and 200 m above sea level. It consists of three units, one unit of 100 MW capacity and two units of 210 MW capacity each. It regularly emits 1450 tonnes fly ash and 600 tonnes SO_2 per day. The Hamdard University (Jamia Hamdard) located on Badarpur-Mehrauli road about 10 km west of the power station. Further, details of amount of gases released and data on coal consumption of the Badarpur thermal power plant are given in Table 1 and 2 respectively. However, soil characteristics of polluted and normal sites are given in Table 3.

Fully-grown one-year-old plants were uprooted from both normal and polluted sites and fresh weights of roots, and shoots were recorded. Number of branches per plant was counted in samples from both sites. The roots and shoots were dried separately in oven at 65°C for 72 hours then their dry weights measured. The pollen viability was examined with the help of microscope. Tetrazolium test was done. 2,3,5-triphenyltetrazolium chloride (0.6 per cent) solution was prepared with sucrose (10 per cent) and the pH was adjusted (0.15 M tris HCl buffer) to 5.8. The data obtained on plant growth, biomass and pollen viability were analysed for calculating the variance and critical differences (at 5 and 1 per cent level) using the method of Scheffes which is based on F statistics.

Infra Red Gas Analyser (LI 6200 portable photosynthesis system) was used for measuring photosynthetic rate, stomatal conductance and intercellular CO_2 concentration in leaves. Chlorophyll a, b, total chlorophyll and carotenoids contents of leaves were analysed by keeping 0.1gm samples in 7ml dimethyl sulfoxide (DMSO) in oven at 65^0C for 2hrs. then 3 ml DMSO was added into 1 ml aliquot. Optical density was measured at 480, 510, 643 and 663nm using Perkin Elmer UV/VIS spectrophotometer Lamda 2S (Hiscox and Israetstam, 1979). The chlorophyll and carotenoids contents were estimated by the formula given by Duxbury and Yentsch (1956) and MaClachlan and Zalick (1963) respectively.

RESULTS AND DISCUSSION

The present study showed a significant reduction in the shoot length but on enhancement in the root length and the number of branches in conditions of the pollution stress. The plant (shoot) height was significantly shorter near the power plant than at the University Campus. Increase in the root length and number of branches at the polluted site was significant at 1% level (Table 5). It indicates a differential effect of smoke different plant parts. The positive growth on root length could be because of a deposition of fly ash in the soil. Ash deposition on foliage and may have caused toxicity to foliar functions including carbon assimilation and hormone production and to the growing young shoot apex, thus stunting the extension growth but giving way to emergence of lateral buds under the influence of pollution. Subsequently, the root/shoot ratio was also significantly higher at the polluted site because of the enhanced root growth but a reduced shoot growth possibly checked by the burning of apical bud due to deposition of unburnt coal particles.

The biomass of leaf, stem and root was increased significantly under the polluted condition (Table 6). This increase might be due to a greater availability of minerals and trace elements of fly ash origin, viz. sodium, potassium, calcium, magnesium, boron, sulphate (Elsewr et al., 1981; Wong and Wong, 1989), copper, zinc, molybdenum, and selenium (Furr et al., 1978) and negligible amount of carbon and nitrogen (Carlson and Adriano,

1993) to the growing plant. Some studies confirm that plant biomass may increase due to application of fly ash to the soil (Khan and Khan, 1996; Singh et al., 1997).

Pollen viability of *D. innoxia* plants was significantly ($P<0.01$) decreased under the pollution stress (Fig. 1) thus indicating a negative effect on the reproductive capacity of the stressed plants. Reduced pollen viability due to air pollution has been reported earlier also (Ostrolucka, 1989; Bellani and Paoletti, 1992).

Stomatal conductance in leaves of *D. innoxia* was significantly reduced at polluted site (Table 4), confirming the some earlier findings (Field et al., 1995; Kull et al., 1996; Kellomäki and Wang, 1997; Nighat et al., 2000) and could be cause of low photosynthetic rate (Farage et al., 1991). Photosynthetic rate was significantly suppressed (63.92%) under coal-smoke pollution (Table 4). Chloroplast disruption could be the reason of decrease in the net photosynthesis at low concentrations of SO_2 as 0.035 ppm (Black and Unsworth, 1979). SO_2 may directly affect photosynthesis because its various intercellular derivatives and photo-induced oxidizing free radicals interfere with the metabolic pathway (Malhotra and Khan, 1984). Inhibitory effects of SO_2 and NO_x pollutants on photosynthesis and CO2 exchanges of plants are well documented. Dust in stomata may prevent stomatal closure which trends increase uptake of gaseous air pollutants and the water loss. (Fluckiger et. al., 1979). Both intensity and direction of stomatal response to CO_2 may change due to environmental influence (Morison and Gifford, 1986; Mansfield and Atkinson, 1990). The intercellular CO_2 concentration was raised under pollution stress (Table 4).

The amount of chlorophyll a, b, total chlorophyll and carotenoids decreased significantly at $P<0.01$ level. Chlorophyll loss due to SO_2 pollution has been reported for many other species also. Chlorophyll destruction by SO_2 is caused either by its conversion to pheophytin (Rao and LeBlanc, 1966) or production of superoxide radicals by the reaction of sulphite with chlorophyll under illumination (Shimazaki et al., 1980). Damage to chlorophyll a was relatively greater than to chlorophyll b in the polluted atmosphere, thus sowing a greater degree of sensitivity for the former. However, both the chlorophyll may be equally susceptible in some other species (Singh and Rao, 1980; Singh et al., 1990a). The total chlorophyll and carotenoids contents decreased in tomato leaves with increasing sodium metabisulphate ($Na_2S_2O_3$) concentrations (Singh et al., 1990b). However Carotenoids were more sensitive than chlorophyll to the pollution hazards (Arndt 1971; Kondo et al., 1980; Khan and Usmani, 1988).

Table 1. The average amounts of gases released in different months from the Badarpur Thermal Power Plant, New Delhi

Month	**Amount of SO_2**		**Amount of NO_2**		**Amount of CO_2**	
	Kg/hr	**ppm/hr**	**Kg/hr**	**ppm/hr**	**Kg/hr**	**ppm/hr**
January	17162.14	0.017	360404.87	0.360	2217879.10	2.218
February	15315.29	0.015	321621.12	0.322	1979206.90	1.979
March	15824.24	0.016	332309.05	0.332	2011978.75	2.045
April	8980.39	0.009	217601.71	0.218	1160542.43	1.161
May	10879.49	0.011	263618.41	0.264	1405964.87	1.406
June	10076.55	0.010	244162.49	0.244	1302199.93	1.302
July	10159.71	0.010	246177.55	0.246	1312946.92	1.313
August	9890.16	0.10	239646.25	0.240	1278113.32	1.278
September	10039.87	0.10	243273.68	0.243	1297459.62	1.297
October	9205.97	0.009	223067.72	0.223	1189694.50	1.190
November	11691.67	0.012	283298.15	0.283	1510923.44	1.511
December	16947.12	0.017	355889.43	0.360	2190088.80	2.190
Average	**12181.05**	**0.012**	**277589.20**	**0.278**	**1574166.3**	**1.574**

Table 2. Data on coal consumption (in metric tonnes) in five power generation units of the Thermal Power Plant Complex of Badarpur, New Delhi (source: BTPP records)

	Power Generation Units					
	I	**II**	**III**	**IV**	**V**	**Total consumption**
Annual consumption	566068	584262	588021	1092207	927790	3758348
Average monthly	47172	48689	49002	91018	77316	313196
Average daily	1572	1623	1633	3034	2577	10439

Table 3. Soil characteristics at the polluted and normal site

Parameters		**Polluted site**	**Normal site**
pH		7.62	7.81
Nitrogen	ppm/hr	15.20 ± 1.05	19.70 ± 0.67
	Kg/hr	33.50 ± 2.30	34.50 ± 1.49
Sulphur	ppm/hr	9.76 ± 0.66	10.33 ± 0.91
	Kg/hr	21.48 ± 1.46	22.98 ± 2.02
Potassium	ppm/hr	45.80 ± 2.53	49.90 ± 2.38
	Kg/hr	100.90 ± 5.54	109.80 ± 5.26

Table 4. Effect of coal-smoke pollution on photosynthetic rate, stomatal conductance and intercellular carbon dioxide in leaves of *D. innoxia*

Parameters	**Normal site (Mean ± SE)**	**Polluted site (Mean ± SE)**	**Per cent variation**
Net photosynthetic rate (μ mol m^{-2} s^{-1})	12.14 ±1.19	4.38 ±2.04	63.92**
Stomatal conductance (mol m^{-2} s^{-1})	0.57 ±0.12	0.08 ±0.03	85.09**
Intercellular carbon dioxide (μ mol mol^{-1})	260.83 ±21.49	269.38 ±28.82	3.27^{NS}

Where, ** significant at P<0.01 level and NS stand for non-significant

Table 5. Effect of coal-smoke pollution on vegetative growth of *D. innoxia*. Values given are the mean of plants collected from each site

Collection sites	Shoot length (cm)	Root length (cm)	Root/ Shoot ratio	Number of branches
Normal site	34.30	05.98	0.18	6.07
Polluted site	26.66	11.08	0.42	7.87
Standard error	0.54	0.45	0.02	0.17
Probability	**Critical Difference**			
5%	1.13	0.93	0.04	0.36
1%	1.53	1.26	0.06	0.49

Table 6. Effect of coal-smoke pollution on biomass production of *D. innoxia***.** Values given are the mean of plants collected from each site

Collection sites	Biomass (g)			Whole plant (g)
	Leaf	Stem	Root	
Normal site	1.67	1.42	1.43	4.51
Polluted site	2.61	1.89	2.22	6.72
Standard error	0.09	0.05	0.07	0.12
Probability	**Critical Difference**			
5%	0.18	0.09	0.13	0.25
1%	0.25	0.13	0.18	0.34

Figure 1. Pollen viability (%) of *D. innoxia* plants growing at the normal and the polluted sites

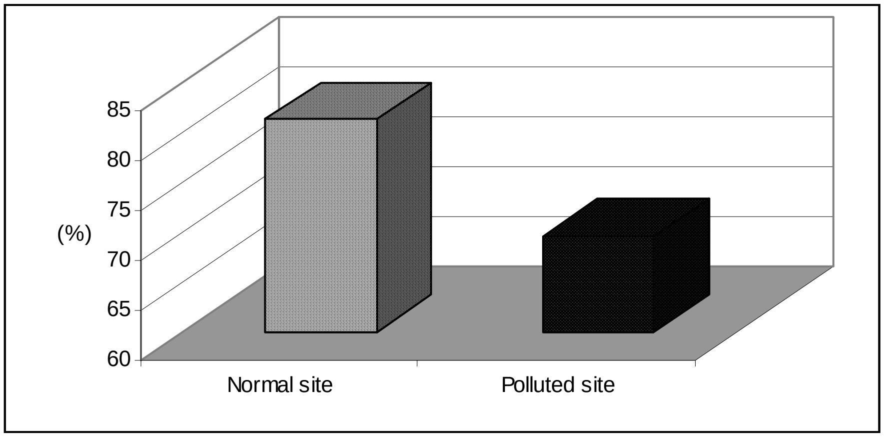
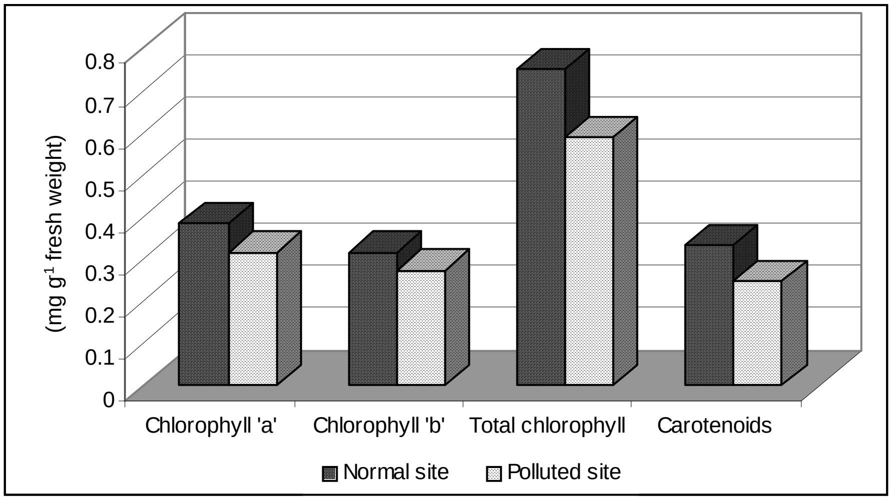


Figure 2. Effect of coal-smoke pollution on pigments content (mg g-1 fresh weight) in leaves of *D. innoxia* plants growing at the normal and the polluted sites



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