Turk J Bot
30 (2006) 413-417

Research Note

Foliar Response of *Ipomea pes-tigridis* L. to Coal-Smoke Pollution

R.B. VERMA, MAHMOODUZZAFAR, Tariq Omar SIDDIQI*, M. IQBAL
Department of Botany, Hamdard University, New Delhi-110062 - INDIA

Received: 11.02.2005
Accepted: 25.04.2006

Abstract: Air pollutants emitted from Badarpur Thermal Power Plant, New Delhi, influenced the foliar features of a common weed, *Ipomea pes-tigridis* L., as observed at distances 0.5, 2, 6, 12 and 16 km from the emission source. Observations recorded at the pre-flowering, flowering and post-flowering stages of plant growth indicated that the stomatal pore size, number of stomata, and stomatal index on both surfaces of leaves decreased near the source of pollution. Compared with the control, chlorophyll a, b and carotenoid contents decreased significantly under pollution stress. Rate of photosynthesis and stomatal conductance dropped drastically, whereas CO_2 level in the mesophyll increased at the polluted sites. The maximum adverse effects were observed at site B, situated 2 km from the emission source.

Key Words: *Ipomea pes-tigridis*, coal-smoke pollution, photosynthesis, stomata

Introduction

Consumption of fossil fuel, a major source of energy, adds to the ambient environment a complex mixture of pollutants (Gupta & Ghouse, 1987). The main air pollutants generated by coal-based power plants are CO, HF, SO_2, NO_x, and fly ash (Iqbal et al., 2000b; Pandey, 2005). Leaves, by virtue of their unique function and position on plants, experience maximum exposure to the ambient environment and hence exhibit changes in form, structure and function in response to alterations in the ambient environment. These changes may serve as markers of atmospheric pollution (Saxe, 1996; Ahmad & Ahmad, 2003).

In the present study, we investigated the effects of long-term (seed germination – seed-set stage) exposure of leaves of *Ipomea pes-tigridis* L. to coal-smoke pollutants. The chosen determinants were leaf epidermal features, chlorophyll content, and photosynthetic aspects of the test plant growing in the vicinity of a thermal power plant complex located at Badarpur, New Delhi. The herb is used in the treatment of boils, carbuncles, pimples and sores, and as an antidote to dog bites (CSIR, 1959).

Materials and Methods

The study area

The study was carried out around the Badarpur Thermal Power Plant, located on the Badarpur-Faridabad road in South Delhi (28°12' – 28°53' N and 76°50' – 77°23' E; 213-219 m above msl). This power plant consists of 5 power station units (3 units 100 MW each and 2 units 210 MW each). The 150-m-high stacks emit smoke with a flue gas density of 0.8 kg/m^3. The average coal consumption is 10,439 metric tonnes per day, which results in 12,181 kg of SO_2, 277,589 kg of NO_x and 1,574,166 kg of CO_2 per hour added to the atmosphere.

The study area experiences a dry tropical monsoon type climate. The year comprises 3 principal seasons. Winter mean temperature ranges from 8 to 21 °C. The mean minimum and maximum value of RH was 55% and 85%, respectively. The temperature rose during the pre-monsoon season, the mean minimum and mean maximum being 20 and 37 °C, respectively. The temperature decreased whereas the relative humidity increased during the post-monsoon period. The soil of the region is sandy loam with average pH 8. The soil is fertile and shows a low resistance to erosion.

*E-mail: tariq117@rediffmail.com

Plant sampling and analysis

Ipomea pes-tigridis plants grow during July to October. Plants of almost uniform age were randomly collected at 3 developmental stages (pre-flowering, flowering and post-flowering) from 6 sites, i.e. A (0.5 km from the source of emission), B (2 km away), C (6 km away), D (12 km away), E (16 km away), and F (Jamia Hamdard Campus, 12 km away in the opposite direction). Site F, with a non-polluted environment, was regarded as the control.

The foliar characteristics of 10 replicate plants from each site were studied. The study was repeated during the next 2 years. Epidermal peels of fully expanded leaves were obtained using hot nitric acid (Ghouse & Yunus, 1972) and studied under a compound microscope in order to determine the number of stomata and epidermal cells and the size of the stomatal aperture. The stomatal index (SI) was calculated by the formula given by Salisbury (1927). Stomatal conductance, intercellular CO_2 concentration, and net photosynthetic rate were measured using a LI-6200 portable photosynthesis system (LI-COR; Lincoln, Nebraska, USA) in the morning on sunny days. The concentrations of chlorophylls and carotenoids were analysed keeping 0.1 g of leaf sample in 7 ml of dimethyl sulphoxide (DMSO) in the oven at 65 °C for 2 h, and then adding 3 ml of DMSO into a 1-ml aliquot. Optical density was measured at 480, 510, 643 and 663 nm using a Perkin Elmer UV/VIS spectrophotometer (Hiscox & Israelstam, 1979). The chlorophyll contents and carotenoid contents were estimated by using the formulae given by MacLachlan & Zalik (1963) and Duxbury & Yentsch (1956), respectively. The data were analysed statistically by applying ANOVA to determine the level of significance.

Results and Discussion

In comparison to the control, the stomatal aperture, stomatal frequency and SI decreased significantly on both surfaces of the leaf at each stage of plant growth and at all the polluted sites ($P < 0.0001$), the effects being maximum at site B (Tables 1 and 2). The decline in pigment contents followed a similar trend. The chlorophyll b content was more severely affected than the chlorophyll a and carotenoid contents (Table 3). Stomatal conductance and photosynthetic rate decreased significantly, whereas intercellular CO_2 concentration increased significantly at each phenological stage and each polluted site ($P < 0.0001$). The maximum effects appeared at site B (Table 4).

Coal-smoke pollution invariably reduced the foliar growth in *Ipomea pes-tigridis* as observed earlier with some other species (Pandey & Pandey, 1996; Nighat et al., 1999, 2000). Plant growth was most severely

Table 1. Length and width of stomatal aperture (µm) on adaxial (Ad) and abaxial (Ab) leaf surfaces in *Ipomea pes-tigridis* L. as observed at pre-flowering (Prf), flowering (Fl) and post-flowering (Pof) stages of plant growth under varying degree of environmental stress.

Distance from Pollution source (km)	Length of aperture (Ad)			Lengh of aperture (Ab)			Width of aperture (Ad)			Width of aperture (Ab)		
	Prf	Fl	Pof	Prf	Fl	Pof	Pf	Fl	Pof	Prf	Fl	Pof
0.5	16.35^{d}	16.94^{d}	18.48^{c}	17.40^{d}	18.53^{d}	19.88^{c}	11.05^{d}	11.66^{d}	12.57^{d}	11.45^{d}	12.54^{d}	13.36^{e}
2	14.12^{e}	14.84^{e}	16.21^{d}	15.16^{e}	16.57^{e}	17.42^{d}	10.10^{e}	10.11^{e}	10.64^{e}	10.22^{e}	10.33^{e}	11.24^{f}
6	16.67^{d}	16.69^{d}	18.63^{c}	17.85^{d}	18.94^{c}	19.98^{c}	11.09^{d}	11.57^{d}	12.66^{cd}	11.93^{d}	12.85^{cd}	13.85^{d}
12	17.36^{c}	18.29^{c}	18.97^{c}	18.72^{c}	18.98^{c}	20.09^{c}	12.33^{c}	12.25^{c}	13.25^{c}	12.68^{c}	13.40^{c}	14.44^{c}
16	18.05^{a}	19.17^{b}	20.17^{b}	19.46^{b}	20.13^{b}	20.78^{b}	13.17^{b}	13.19^{b}	14.28^{b}	13.30^{b}	14.27^{b}	15.03^{b}
Control	19.40^{a}	20.32^{a}	21.09^{a}	20.09^{a}	20.98^{a}	21.26^{a}	14.81^{a}	15.44^{a}	15.30^{a}	14.26^{a}	15.22^{a}	16.18^{a}
L.S.D. at 5% level	0.608	0.425	0.609	0.533	0.387	0.451	0.698	0.415	0.641	0.484	0.663	0.395
Significance	***	***	***	***	***	***	***	***	***	***	***	***

* = 0.05 > P > 0.01
** = 0.01 > P > 0.001
*** = 0.001 > P

Values with same superscript (a, b, c, d, e, f) are not significantly different.

Table 2. Stomatal frequency (per microscopic field) and stomatal index (SI) on adaxial (Ad) and abaxial (Ab) leaf surfaces in *Ipomea pes-tigridis* L. as observed at pre-flowering (Prf), flowering (Fl) and post-flowering (Pof) stages of plant growth under varying degree of environmental stress.

Distance from Pollution source (km)	Stomatal Frequency (Ad)			Stomatal Frequency (Ab)			Stomatal Index (Ad)			Stomatal Index (Ab)		
	Prf	Fl	Pof	Prf	Fl	Pof	Pf	Fl	Pof	Prf	Fl	Pof
0.5	35.27^{d}	43.46^{d}	56.16^{d}	35.22^{e}	46.84^{d}	54.51^{d}	35.35^{c}	36.53^{d}	38.91^{d}	33.48^{d}	37.53^{d}	38.18^{d}
2	30.27^{e}	38.36^{e}	51.05^{e}	31.34^{f}	43.14^{e}	49.28^{e}	33.11^{d}	34.72^{e}	36.91^{e}	32.04^{e}	36.38^{e}	36.80^{e}
6	35.71^{d}	44.09^{d}	56.90^{d}	35.90^{d}	47.27^{d}	54.51^{d}	35.19^{c}	36.42^{d}	39.14^{d}	32.79^{d}	37.68^{d}	38.10^{d}
12	40.53^{c}	50.15^{c}	59.51^{c}	41.00^{c}	50.19^{c}	57.33^{c}	36.86^{b}	39.24^{c}	40.16^{c}	36.00^{c}	38.64^{c}	39.07^{c}
16	43.16^{b}	52.31^{b}	61.08^{b}	43.26^{b}	51.74^{b}	60.51^{b}	37.19^{b}	40.13^{b}	40.88^{b}	37.43^{b}	39.2^{b}	39.88^{b}
Control	46.42^{a}	55.63^{a}	64.63^{a}	46.88^{a}	55.81^{a}	64.20^{a}	38.75^{a}	41.95^{a}	42.37^{a}	39.81^{a}	40.8^{a}	41.62^{a}
L.S.D. at 5% level	0.539	0.884	0.753	0.562	0.908	0.145	0.552	0.788	0.360	0.561	0.417	0.608
Significance	***	***	***	***	***	***	***	***	***	***	***	***

* = 0.05 > P > 0.01
** = 0.01 > P > 0.001
*** = 0.001 > P

Values with same superscript (a, b, c, d, e, f) are not significantly different.

Table 3. Concentration of chlorophyll a, b and carotenoids (mg/g.fr.wt) in leaves of *Ipomea pes-tigridis* L. as observed at pre-flowering (Prf), flowering (Fl) and post-flowering (Pof) stages of plant growth under varying degree of environmental stress.

Distance from pollution source (km)	Chlorophyll a			Chlorophyll b			Carotenoids		
	Prf	Fl	Pof	Prf	Fl	Pof	Prf	Fl	Pof
0.5	0.64^{e}	0.54^{d}	0.51^{c}	0.37^{e}	0.31^{e}	0.25^{d}	0.28^{cd}	0.23^{c}	0.20^{e}
2	0.56^{f}	0.48^{e}	0.41^{b}	0.33^{f}	0.29^{f}	0.21^{e}	0.22^{e}	0.20^{d}	0.18^{f}
6	0.68^{d}	0.56^{d}	0.52^{c}	0.41^{d}	0.34^{d}	0.30^{c}	0.26^{d}	0.23^{c}	0.21^{d}
12	0.74^{c}	0.62^{c}	0.58^{b}	0.51^{c}	0.42^{c}	0.29^{c}	0.29^{c}	0.26^{b}	0.24^{c}
16	0.86^{b}	0.72^{b}	0.60^{b}	0.56^{b}	0.46^{b}	0.36^{b}	0.31^{b}	0.28^{a}	0.26^{b}
Control	0.91^{a}	0.81^{a}	0.71^{a}	0.66^{a}	0.56^{a}	0.40^{a}	0.36^{a}	0.30^{a}	0.29^{a}
L.S.D. > at 5% level	0.040	0.025	0.021	0.024	0.019	0.024	0.019	0.020	0.007
Significance	***	***	***	***	***	***	***	***	***

* = 0.05 > P > 0.01
** = 0.01 > P > 0.001
*** = 0.001 > P

Values with same superscript (a, b, c, d, e, f) are not significantly different.

affected about 6 km from the thermal power plant complex (site C). The coal smoke that was emitted from the stacks of the power plant and moved towards the collection sites possibly came sufficiently down under the influence of gravity by the time it reached site C, and had enough potential to affect adversely the vegetation of this area; the concentration of pollutants was no longer that high beyond this location. This pattern of variation in the concentration of the atmospheric pollutants with reference to the point source has been observed earlier by Williams et al. (1996), Mahmooduzzafar & Iqbal (2000) and Iqbal et al. (2000a), among others.

Table 4. Stomatal conductance (mol $m^{-2}s^{-1}$), intercellular CO_2 concentration (ppm) and photosynthetic rate (µmol $m^{-2}s^{-1}$) in leaves of *Ipomea pes-tigridis* L. as observed at pre-flowering (Prf), flowering (Fl) and post-flowering (Pof) stages of plant growth under varying degree of environmental stress.

Distance from pollution source (km)	Stomatal conductance			Intercellular CO_2			Rate of photosynthesis		
	Prf	Fl	Pof	Prf	Fl	Pof	Prf	Fl	Pof
0.5	0.45^{d}	0.52^{d}	0.64^{c}	349.31^{b}	275.01^{b}	266.82^{a}	2.63^{d}	7.55^{e}	20.67^{de}
2	0.41^{e}	0.46^{a}	0.58^{d}	359.45^{a}	279.80^{a}	271.01^{a}	2.60^{d}	6.75^{f}	19.92^{e}
6	0.45^{d}	0.53^{d}	0.64^{c}	328.26^{c}	217.96^{b}	264.48^{a}	2.79^{d}	7.95^{d}	21.06^{d}
12	0.48^{c}	0.57^{c}	0.67^{b}	320.21^{d}	263.20^{c}	252.79^{b}	4.10^{c}	8.84^{c}	22.31^{c}
16	0.51^{b}	0.59^{b}	0.69^{b}	312.65^{e}	255.24^{d}	234.14^{c}	5.96^{b}	9.94^{b}	23.44^{b}
Control	0.56^{a}	0.64^{a}	0.85^{a}	303.28^{f}	224.98^{e}	210.92^{d}	7.39^{a}	11.78^{a}	24.74^{a}
L.S.D. > at 5% level	0.019	0.019	0.017	4.743	4.085	6.580	0.263	0.255	0.831
Significance	***	***	***	***	***	***	***	***	***

* = 0.05 > P > 0.01
** = 0.01 > P > 0.001
*** = 0.001 > P

Values with same superscript (a, b, c, d, e, f) are not significantly different.

The stomatal response to environmental changes is important in controlling the absorption of pollutants by plants. A decrease in the stomatal aperture or induced-stomatal closure may be an avoidance mechanism against the inhibitory effect of a pollutant on physiological activities such as photosynthesis (Kimmerere & Kozlowski, 1981). The reduced stomatal aperture resists the entry of pollutants, thus preventing their adverse effects on plants. The marked decline in the stomatal density (SD) and SI at the polluted sites was similar to the findings on poplar clones, wherein SI was reduced under a raised CO_2 level in expanding leaves (Ceulemans et al., 1995).

Reduction in chlorophyll content, as observed in the present study, is common in plants growing under smoke pollution stress (Nighat et al., 1999; Banerjee et al., 2003). Sensitivity of chlorophyll a or b varies from species to species. Greater sensitivity of chlorophyll b, as observed in this study, has been reported in other studies also (Ajay & Subrahmanyam, 1996). The reduction in chlorophyll concentration in the polluted leaves could be due to chloroplast damage (Pandey et al., 1991), inhibition of chlorophyll biosynthesis (Esmat, 1993) or enhanced chlorophyll degradation. Chlorophyll a is presumed to be degraded to phaeophytin, whereas chlorophyll b molecule loses its phytol group (Rao & Le Blanc, 1966). The total chlorophyll and carotenoid contents have been found to decrease with increasing sodium metabisulphate ($Na_2S_2O_8$) concentration in tomato leaves (Singh et al., 1990; Pandey & Pandey, 2002).

Decrease in stomatal conductance under environmental stress is a common phenomenon (Kellomaki & Wang, 1997). The reduction may be attributed to the reduced pore size, lowered photosynthetic rate and high intercellular CO_2 concentration (Ali et al., 1999a, 1999b) under the condition of stress. However, Pandey & Pandey (1996) have observed greater carbon allocation in *Carissa carandas* due to the photosynthetic acclimation of plants to the pollution load. Photosynthesis is, in fact, one of the foremost processes to be affected by coal-smoke pollution (Nighat et al., 1999, 2000). The decline in photosynthesis can be attributed to low stomatal conductance as was observed in *Acer* leaves, which have small stomatal apertures (Jensen & Kozlowski, 1975; Carlson, 1979). The rate of photosynthesis may also be affected by damage to the electron transport system (Ishibashi et al., 1997), or by a decrease in PEP activity and concentration as a result of hydrolysis and mobilisation from leaves (Joshi et al., 1993). This study suggests that the coal smoke emitted from Badarpur Thermal Power Plant contains pollutants at phytotoxic levels.

References

Ahmad A & Ahmad S (2003). Study of sulphur accumulation in plant foliage due to coal-smoke pollution. *Geobios* 30: 284-285.

Ajay & Subrahmanyam D (1996). Heavy metal induced changes in chlorophyll pattern in the tomato *Chlorella pyrenoidosa. Ann Plant Physiol* 10: 17-22.

Ali G, Srivastava PS & Iqbal M (1999a). Morphogenic and biochemical responses of *Bacopa monniera* cultures to zinc toxicity. *Plant Sci* 143: 187-193.

Ali G, Srivastava PS & Iqbal M (1999b). Some physiochemical responses of *Bacopa monniera* (L.) Wettst. cultures to copper toxicity. *Biol Plant* 37: 1144-1147.

Banerjee S, Singh AK & Banerjee SK (2003). Impact of flyash on foliar chemical and biochemical composition of naturally occurring ground flora and its possible utilization for growing tree crop. *Indian Forester*. 129: 964-977.

Carlson RW (1979). Reduction in photosynthetic rate of *Acer, Quercus* and *Fraxinus* species caused by sulphur dioxide and ozone. *Environ Pollut* 8: 159-170.

Ceulemans R, Vanpraet L & Jiang XN (1995). Predisposition of trees by air pollutants to low temperature and moisture stress. *Environ Pollut* 87: 105-117.

CSIR (1959). The Wealth of India: A Dictionary of Indian Raw Materials and Industrial Products, Council of Scientific & Industrial Research, New Delhi, pp. 251-252.

Duxbury AC & Yentsch DS (1956). Plankton pigment nomography. *J Air Pollut Contr Assoc* 16: 145-150.

Esmat AS (1993). Damage to plants due to industrial pollution and their use as bioindicators in Egypt. *Environ Pollut* 81: 251-255.

Ghouse AKM & Yunus M (1972). Preparation of epidermal peels from leaves of gymnosperms by treatment with hot 60% HNO^-_3. *Stain Technol* 47: 322-324.

Gupta MC & Ghouse AKM (1987). The effect of coal-smoke pollutants on growth yield and leaf epidermis features of *Abelmoschus esculentus* Moench. *Environ Pollut* 43: 263-270.

Hiscox JD & Israelstam GG (1979). A method for extraction of chlorophyll from the leaf tissue without maceration. *Can J Bot* 57: 1332-1334.

Iqbal M, Mahmooduzzafar & Abdin MZ (2000a). Studies on anatomical, physiological and biochemical responses of trees to coal-smoke pollution around a thermal power plant. Project Report, Ministry of Environment & Forests, Govt. of India, New Delhi.

Iqbal M, Srivastava PS & Siddiqi TO (2000b). Anthropogenic stresses in the environment and their consequences. *In*: Environmental Hazards, Plants and People (*Eds*: M. Iqbal et al.). CBS Publishers, New Delhi, pp 1-40.

Ishibashi M, Sonoike K & Watanabe A (1997). Photoinhibition of photosynthesis during the rain treatment: Intersystem electron transfer chain as the site of inhibition. *Plant Cell Physiol* 38: 96-146.

Jensen KF & Kozlowski TT (1975). Absorption and translocation of sulphur dioxide by seedlings of four forest tree species. *J Environ Qual* 4: 379-381.

Joshi UN, Arora SK & Luthra YP (1993). SO_2-induced changes in CO_2 fixation and photosynthetic pigments in *Sorghum bicolor* leaves. *Ann Biol* 9: 102-108.

Kellomaki S & Wang KY (1997). Effect of elevated O_3 and CO_2 on chlorophyll fluorescence and gas exchange in Scots pine during the third growing season. *Environ Pollut* 97: 17-27.

Kimmerere TW & Kozlowski TT (1981). Stomatal conductance and sulphur uptake of five clones of *Populus tremuloides* exposed to sulphur dioxide. *Plant Physiol* 67: 990-995.

MacLachlan S & Zalik S (1963). Plastid structure, chlorophyll concentration and free amino acid composition of a chlorophyll mutant of barley. *Canadian J Bot* 41: 1053-1062.

Mahmooduzzafar & Iqbal M (2000). Structural responses of *Cassia sophera* to thermal power plant emissions with reference to distance from the source. *In*: Environmental Stress: Indication, Mitigation and Ecoconservation (Eds: M. Yunus et al.), Kluwer Academic, Dordrecht, The Netherlands, pp. 219-240.

Nighat F, Mahmooduzzafar & Iqbal M (1999). Foliar responses of *Peristrophe bicalyculata* to coal smoke pollution. *J Plant Biol* 42: 205-212.

Nighat F, Mahmooduzzafar & Iqbal M (2000). Stomatal conductance, photosynthetic rate, and pigment content in *Ruellia tuberosa* leaves as affected by coal-smoke pollution. *Biol Plant* 43: 263-267.

Pandey AK & Pandey GC (2002). Impact of coal washery effluent on seed germination, seedling growth and chlorophyll content of *Oryza sativum. J Indl Pollut Cont* 18: 175-181.

Pandey DD, Sinha CS & Tiwari MG (1991). Impact of coal dust pollution on biomass, chlorophyll and grain characteristics of rice. *J Biol* 3: 51-55.

Pandey J (2005). Evaluation of air pollution phytotoxicity downwind of a phosphate fertilizer factory in India. *Environ Monitor Assoc* 100: 249-266.

Pandey J & Pandey U (1996). Adaptational strategy of a tropical shrub, *Carissa carandas* L., to urban air pollution. *Environ Monitor Assoc* 43: 255-265.

Rao DN & Le Blanc F (1966). Effect of SO_2 pollution on the lichen algae with special reference to chlorophyll. *Bryologist* 69: 69-75.

Salisbury EJ (1927). On the causes and ecological significance of stomatal frequency with special reference to the woodland flora. *Phil Trans R Soc* 216: 1-65.

Saxe H (1996). Physiological and biochemical tools in diagnosis of forest decline and air pollution injury to plants. *In*: Plant Response to Air Pollution (*Eds*: M. Yunus and M. Iqbal), John Wiley and Sons, Chichester, UK, pp 449-487.

Singh SN, Yunus M & Singh N (1990). Effect of sodium metabisulphite on chlorophyll, protein and nitrate reductase activity of tomato leaves. *Sci Total Environ* 81: 269-274.

Williams AJ, Gupta BN & Banerjee SK (1996). Effect of thermal power plant emissions on vegetation. *Indian J For* 19: 330-334.