SIGNIFICANCE OF LEAF SURFACE CHARACTERISTICS IN PLANT RESPONSES TO AIR POLLUTION

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Abstract. Plant responses to air pollution were found to vary with type of leaf vesture. Considerable reduction in leaf area, leaf biomass, total plant biomass and chlorophyll content was observed in plants having pilose or pubescent leaf surface as compared to plants with glabrescent leaf surface. The study shows the importance of leaf vesture in determining response of plants to air pollution.

1. Introduction

The morphological effects of air pollution on plants have been widely documented in relation to acute and chronic exposures (Mudd and Kozlowski, 1975; Varshney and Garg, 1978; Bell, 1980). Reduction in growth as a result of air pollution is a common experience but the relationship between leaf vesture and susceptability of plants to air pollution has not been examined. The present investigation was undertaken to determine if there is any relation between leaf surface characteristics and susceptibility of plants to air pollution.

2. Materials and Methods

Five plants namely, *Cicer arietenum* (pilose leaf surface), *Dolichos lablab, Lens culinaris* and *Phaseolus aureus* (pubescent leaf surface), and *Vigna sinenses* (glabrescent leaf surface) were selected on the basis of their leaf surface characteristics. Five plants of each species per pot were raised in 16 pots having equal quantities of the same soil.

After seven days, following germination, eight pots of each species (in all 40 pots) were maintained at a distance of 500 to 600 m in the southern direction of Indrapastha Power Station to study the response of plants to air pollution caused by the power station. According to Padmanabhamurthy and Gupta (1977), the zone of maximum air pollution during April and May (the period of the study) oscillates between SSE and SW directions. The power station consumes approximately 3400 tonnes of coal every day. Air pollution near the Indraprastha Power Station is visibly clear. Reliable data on the ambient concentration of suspended particulate matter and SO_2 in the neighborhood of the power plant are not available. The second set, of an equal number of pots, was kept in the nursery, situated in the western direction at a distance of 16 km from Indraprastha Power Station. The nursery site is located at the outskirts of the city and is free from any air pollution. Climatic and other ecological conditions were similar at both sites.

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Both sets of plants were irrigated with an equal amount of water at the same frequency. After 53 days from the time pots were transported to the vicinity of Indraprastha Power Station, observations were made with respect to gross morphology, biomass and chlorophyll content in the two sets of plants.

2.1 Gross morphology

The number of nodes on the main stem and leaves at each node were recorded for each plant. Leaf area was determined using graph paper. Foliar injury symptoms such as chlorosis and necrosis were also recorded.

2.2 Biomass

Leaves of plants from polluted and non-polluted sites were harvested and dried in an electric oven at 80 °C for 24 h to determine dry weight. Similarly the biomass of stems, roots and fruits were taken separately for plants grown at two sites.

2.3 Chlorophyll estimation

One gram of leaf tissue was ground in a mortar and pestle with a small quantity of acid washed sand in 80% acetone. The optical density of the filtered extract was measured at 645 nm for chlorophyll a and at 663 nm for chlorophyll b, the total amount of chlorophyll was calculated according to the following formula. The amount of chlorophyll:

$$= 20.2\,(D_{645}) + 8.02\,(D_{663}) \times \frac{V}{1000 \times W}$$

where, D_{645} = OD at 645 nm; D_{663} = OD at 663 nm; V = Total volume of extract; and W = Weight of leaf tissue taken.

3. Results

The number of leaves at each first three nodes, were the same in both exposed and control plants (Table I). The leaf number, however, decreased gradually beyond the third node and as a result, the total number of leaves at the conclusion of the experiment were less in plants grown at polluted site. In *Dolichos lablab* reduction in number of leaves was 33%, followed by *Phaseolus aureus* (29%), *Lens culinaris* (27%) and *Cicer arietenum* (25%). *Vigna sinensis* seems to be comparatively resistant to air pollution since it showed only 9% reduction.

Data regarding the leaf area and leaf biomass are given in Tables II and III. Reduction in leaf area was in the following sequence: *Cicer arietenum* (54%), *Dolichos lablab* (44%), *Phaseolus aureus* (40%), *Lens culinaris* (39%) and *Vigna sinensis* (35%). The change in leaf biomass also followed more or less the same pattern – *Dolichos lablab* (59%), *Cicer arietenum* (50%), *Phaseolus aureus* (49%), *Lens culinaris* (42%) and *Vigna* sinensis (30%).

TABLE I

The growth of leaves on main stem in plants grown in the polluted and control area (Observations were made after 53 days, values represent average of five plants)

No. of Nodes	Number of leaves									
	Dolichos		Lens		Phaseolus		Cicer		Vigna	
	P	C	P	C	P	C	P	C	P	C
I	2	2	2	2	2	2	1	1	2	2
II	2	2	1–2	2	1	1	1	1	2	2
III	2	2–4	1	2	1	1	1	1	1	2
IV	2–4	4	1	1	1	1	–	1	1	2
V	–	2	1	1	–	1	–		1	1
VI				1	–	1			1	1
VII									1	1
VIII									1	1
IX									–	1
Total No. of leaves	8–10	12–14	6–7	9	5	7	3	4	10	11

P – Polluted; C – Control

TABLE II

Development of leaf area (cm^2) and leaf biomass (g) in plants grown in polluted and control area

Species	Leaf Area		Leaf Biomass	
	Polluted	Control	Polluted	Control
Cicer arietenum	47 ± 7.1	103 ± 10.7	0.310 ± 0.031	0.710 ± 0.049
Dolichos lablab	274 ± 16.2	486 ± 24.7	0.887 ± 0.160	1.995 ± 0.252
Phaseolus aureus	81.5 ± 1.01	150.2 ± 15.7	0.356 ± 0.018	0.687 ± 0.049
Lens culinaris	126.5 ± 11.9	206 ± 19.2	0.290 ± 0.027	0.583 ± 0.048
Vigna sinensis	637 ± 22.2	957 ± 35.5	4.755 ± 0.127	6.585 ± 0.194

Total biomass of plants exposed to air pollution caused by Indraprastha Power Station was significantly less as compared with control plants. The biomass of *Dolichos lablab* was 52% less followed by *Cicer arietenum* (51%), *Lens culinaris* (49%), *Phaseolus aureus* (46%) and *Vigna sinensis* (36%) (Table III).

TABLE III

Effect of air pollution on total plant biomass (g)

Species	Polluted	Control
Dolichos lablab	1.710 ± 0.189	3.577 ± 0.296
Cicer arietenum	0.390 ± 0.043	0.820 ± 0.061
Lens culinaris	0.765 ± 0.047	1.433 ± 0.094
Phaseolus aureaus	0.751 ± 0.029	1.388 ± 0.086
Vigna sinensis	12.390 ± 0.353	19.305 ± 0.551

In exposed plants, total chlorophyll content was 37.8% less in *Cicer arietenum* followed by *Phaseolus aureus* (31.4%) and *Vigna sinensis* (11.1%) (Table IV).

The plants grown in polluted air showed visual leaf injury such as necrotic patches, chlorosis, dead interveinal tissues and enrolled leaf margins in *Dolichos lablab*. In *Cicer arietenum*, *Lens culinaris* and *Phaseolus aureus* mild injury symptoms were observed, which could be regarded as an indication of their being relatively more resistant. No visual injury was observed in *Vigna sinensis*.

TABLE IV

Total chlorophyll content (mg g^{-1}) in plants grown in polluted and control area

Species	Polluted	Control	Percent Reduction
Cicer arietenum	2.021	3.237	38.2
Phaseolus aureaus	2.621	3.939	37.8
Lens culinaris	3.615	4.732	22.7
Dolichos lablab	3.301	4.283	20.9
Vigna sinensis	3.121	3.512	11.2

4. Discussion

The effects of air pollution on the gross morphology of plants are fairly significant (Mudd and Kozlowski, 1975; Varshney and Garg, 1978; Bell, 1980). Loss of yield as a result of air pollution has been a common experience. A considerable reduction in the growth and yield due to SO_2 and O_3 alone or in mixture have been reported in several crop plants (Reinert *et al.*, 1970). Recently Black and Unswarth (1979) have shown that only 50 μg m^{-3} of SO_2, a level characteristic of many rural areas, can induce reduction in net photosynthesis. Reduction in growth of shoot and root in *Ricinus sativus* exposed to SO_2 and O_3 alone or in combination have also been shown (Tingey *et al.*, 1971).

In the present study leaf area, leaf biomass and total plant biomass were considerably reduced in plants grown in the polluted environment. Plants with pilose and pubescent leaf vesture were found to be more affected than the plants having glabrecent leaf surface.

An adverse effect on the chlorophyll content reported by Rao and LeBlanc (1966) results from the degradation of chlorophyll to photosynthetically inactive phaeophytin. Malhotra (1977) has also reported appreciable decrease in chlorophyll content in *Pinus contorta* due to aqueous SO_2. The present study has shown that chlorophyll content in plants, grown in the polluted environment, was much less in comparison to the plants from the non-polluted area. Plants with pilose and pubescent leaf vesture (*Cicer arietenum* 37.8%; *Phaseolus aureus* 31.4%) were found to be relatively more affected as compared to the plants with glabrescent leaf surface (*Vigna sinensis* 11.1%).

The role of leaf vesture in modifying the impact of environmental stress have been suggested from the early days. Leaf hairs in *Encelia farinosa* have been known to reduce leaf absorbance and consequently leaf temperature which help it to survive in its native high temperature environment (Ehleringer and Bjorkman, 1978).

Information on the relationship between leaf vesture and the impact of air pollution in terms of leaf area, leaf biomass, total plant biomass and chlorophyll content is completely lacking. In the present study plants with pilose and pubescent leaf vestures were affected more than those with glabrescent leaf vesture, suggesting that leaf vesture may be playing an important role in determining the impact of air pollution on plants. Further studies are required to elucidate the relative importance of leaf vesture, among other environmental factors, in determining the plant responses to air pollution.

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