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Air Pollution Induced changes in Foliar Morphology of two shrub species at Indore city, India

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Abstract

The use of plants as monitors of air pollution has long been established as plants are the initial acceptors of air pollution. In Indian cities, unplanned development of industrial and residential areas has further added to this problem. The Total pollution stress of an area affects the growth of various plants in non-uniform manner. Therefore various plant parameters can be used to measure the effect of pollution. Effect of air pollution on two shrub species viz. Calotropis gigantia and Ipomoea Fistulosa at three sampling sites of Indore city were studied. The parameters examined were fresh and dry weight of leaves, L/B ratio, specific leaf area (L/D ratio), size of stomata and stomatal index of the plants growing in polluted habitats. Dust particulates remain in air for varying length of time and get deposited on various plant parts of the plants; especially on leaf surface and affect vegetation of the areas.

Keywords: Air pollution, industrial pollution, vehicular pollution, foliar morphology, stomatal index.

Introduction

Air pollution is one of the most severe environmental problems of the world today. Clean air is a mixture of gases such as 78% Nitrogen, 21% Oxygen, 1% Argon, 0.03% Carbon dioxide, very minor traces of helium, methane, krypton and 1.3% of water vapours by volume[1]. Any rise in its component is considered as a kind of air pollution which may have widespread ecological implication on global scale.

Air pollution is influenced by four major factors namely industrialized expansion of the cities, increase in traffic, rapid economic development and higher level of energy consumption. The atmosphere is a dynamic system that continuously absorbs a wide range of solids, liquids and gases[2]. These substances travel through air, disporse and react with one another both physically and chemically. When their rate of formation is faster than rate of dispersion enter atmosphere and accumulate in air causing environmental decay. The combustion of fuels adds substantial quantities of oxides of nitrogen and sulphur into atmosphere. These primary pollutants react photo chemically in the atmosphere forming ozone, peroxy acetyl nitrate (PAN) and acid rain as by product[3]. This creates ecotoxic effects on terrestrial and aquatic flora and fauna, especially on endangered species and sensitive ecosystems.

Indore city present a happy blend of historical past and it promises rapid future modernization. Indore is situated on Malwa Plateau on the banks of two small streams the Khan and the Saraswati. It was founded in the year 1715 and originally known as “Indrapur” or “Indreshwar”, from where the name ‘Indore’ is derived. It is also known as **‘Devi Ahilya Ki Nagari’**: Indore is recognized as the commercial capital of the state of Madhya Pradesh, India and is also fondly called as ‘Mini Bombay’. It is a fast growing, densely populated, most industrialized, commercialized and honored as biggest city of the state, with maximum number of vehicular population.

Sampling Stations: In order to study the air pollution on plants of Indore city a survey was carried out and sampling stations were selected on the basis of type of pollution, i.e. Industrial and Vehicular pollution. Availability of monitoring facilities and presence of common tree species were also taken into consideration. Thus, overall, three sampling sites were selected as mentioned below:

Low Pollution Area (LPA): This area is located in Scheme No. 78, Aranya and Indore; where Regional Office of M.P. Pollution Control Board is also situated. This area was taken as the reference for comparison from other sampling stations, as there is absence of any industrial activity and also vehicular traffic is very low.

Vehicular Pollution Area (VPA): This sampling station is situated near Palasia Square. This particular square has been selected as maximum traffic flows from this intersection. This is also connecting the national highway NH-3 Agra-Bombay Road. The vehicular traffic in Indore is basically running on petrol, diesel, kerosene, gas and recently on compressed natural gas (CNG). This sampling station is our first station for comparison.

Industrial Pollution Area (IPA): This area is situated near Pologround, Indore. Here, there are many plastic, pharmaceutical and other polluting industries are located. This is our second sampling station for comparison. Besides this area also has a heavy traffic.

Material and Methods

Leaf area: Mature leaves of selected plant species were sampled in years 2011 for leaf area measurements. Leaves were collected from polluted and low polluted areas. Leaves were kept in polythene bags and brought to laboratory for measurements.

Length/ breadth ratio of leaf: Length and breadth of leaf parts were measured with the help of thread and measuring scale. Leaf breadth was measured in upper, middle and lower part and average of three was taken as final breadth.

Fresh and dry weight of leaf: To find out fresh and dry weight of leaves sampling was done in control and both the polluted areas. Leaf samples were collected from the sampling station between 9-10am in polythene bags, kept in ice box and brought to the laboratory. Fresh weight and dry weight of the leaves were taken with the help of Digital Pan Balance and leaves were placed in oven at 80˚C for 24 hrs.

Structure and size of stomata: Mature leaves of selected plant species were sampled in years 2011. Number and size of stomata were measured with the help of occular and stage micrometer. Mature leaves of the plants from polluted as well as low polluted area were plucked and brought to laboratory in polythene bags kept in ice box. Leaves were washed for stomatal studies.

Stomatal index : Leaves of each species were washed carefully with water and boiled in conc. nitric acid for 2-3min. Boiled leaves were washed thoroughly with water in watch glass and lower and upper epidermis were peeled. Each epidermal surface was then stained with saffranin, mounted in glycerin on a slide and observed under (10×40) × in a microscope. Observations were taken in upper, middle and lower region of leaf lamina. Three observations were made in each region for upper and lower epidermis. Stomatal index was measured after calculating field area using stage and occular scale.

The formula used to calculate stomatal index is as follows-
Stomatal index = [S/(S+E)] X 100

Where, S = number of stomatal cells per unit area, E = number of epidermal cells per unit area

Dust deposition: The dust deposited on each leaf was carefully brushed off on a butter paper and weight of leaf dust was measured using electronic balance {Keroy, K-200}. Average dust deposition of 10 leaves was then calculated. The obtained amount was divided by the area of leaf and finally deposition was expressed as $\mu g cm^{-2}$. The average leaf area was determined using manual planimeter.

Leaf wash pH and conductivity: Ten fully mature leaves of each selected plant were plucked carefully from a height of 1 to 2 meters and placed in polythene bags. Samples were brought to laboratory and leaves were washed in separate beakers with 50ml of distilled water and each polythene bag was also washed with distilled water to remove dust remaining inside polythene bags. The pH and conductivity of leaf wash was measured by digital pH meter model 111E and conductivity meter deluxe model 601E.

Results and Discussion

The present study on two shrub species *Calotropis gigantia* and *Ipomoea fistulosa* growing at three different sites in Indore city indicates that air pollution causes significant changes in foliar morphology.

The three polluted study area, the reduction in leaf area was more in IPA than VPA in all the plant species. Amongst the two shrubs *Ipomoea fistulosa* appeared to be less affected as reduction in leaf area was less (21.2%) in this species as compared to *Calotropis gigantia* in VPA (27.1%), but reverse trend was seen in these two species in IPA i.e. for *calotropis gigantia* the reduction in leaf area was (28.5%) and in *Ipomoea fistulosa* it was (39.2%) reduction.

Calotropis gigantia reduction in L/B ratio was less (8.0%) and (30.1%) as compared to *Ipomoea fistulosa* i.e. (26.0%) and (58.0%) in both VPA and IPA.

Ipomoea fistulosa appeared to be less affected as reduction in fresh weight was less (13.8%) in this species as compared to *Calotropis gigantia* in VPA (27.3%) similar trend was seen in these two species in IPA i.e. for *Calotropis gigantia* the reduction in fresh weight was (49.1%) and in *Ipomoea fistulosa* it was (26.0%) reduction. Dry weight in both the polluted areas In VPA minimum reduction was seen in *Calotropis gigantia* (15.6%) and ipomoea fistulosa (1.8%) and in IPA minimum reduction was seen in *Ipomoea Fistulosa* (4.7%) and *Calotropis gigantia* (75.4%).

Size of stomata and stomatal index was found to be reduced in both the species growing at polluted site. In VPA reduction in length and breadth of stomata was seen in *Ipomoea fistulosa* (length 55.0 µm) and breadth of stomata was seen in (breadth 41.0 µm). While in IPA reduction in length and breadth of stomata was seen in *Ipomoea fistulosa* (length 50.0 µm) and (breadth 31.0 µm). In VPA maximum reduction in length and breadth of stomata was seen in *Calotropis gigantia* (length 58.0 µm) and breadth of stomata was seen in (breadth 40.0 µm). While in IPA reduction in length and breadth of stomata was seen in *Calotropis gigantia* (length 47.0 µm) and (breadth 34.0 µm).

In VPA stomatal index upper and lower was seen in *Ipomoea fistulosa* (23.9%) and lower of stomata was seen in (24.4%). While in IPA reduction in upper and lower of stomata was seen in *Ipomoea fistulosa* (15.9%) and (19.0%). In VPA maximum reduction in upper and lower of stomata was seen in *Calotropis gigantia* (21.4%) and lower of stomata was seen in (22.2%). While in IPA reduction in upper and lower of stomata was seen in *Calotropis gigantia* (19.8%) and (19.9%).

In VPA maximum dust deposition was seen in *Calotropis gigantia* (450%) and minimum was seen in *Ipomoea fistulosa* (170%) as compared to LPA. While in IPA maximum dust deposition was seen in *Calotropis gigantia* (501%) and minimum was seen in *Ipomoea fistulosa* (216%) as compared to LPA.

Table-1

Average area of leaf (cm²), L/B ratio, fresh and dry weight of leaves (gm.), Size of stomata (µm), stomatal index, Dust deposition (µg/m^2) and Leaf wash pH and Conductivity (µmhos/cm^2) of leaves of *Calotropis gigantia* Lamk.collected from three study area of Indore city, India

S.No.	Parameter	*Calotropis gigantia* Lamk.					
		Site-l(LPA)		Site-2(VPA)		Site-3(IPA)	
1.	Leaf area	77.0±8.7		56.1±8.0 (27.1%)		55.0±5.9 (28.5%)	
2.	L/B ratio	80.0±8.0		73.6±6.3 (8.0%)		55.9±4.9 (30.1%)	
3.	Fresh weight of Leaves	57.0±2.0		41.4±4.1 (27.3%)		29.0±12.0 (49.1%)	
4.	Dry weight of Leaves	10.2±4.0		8.6±1.9 (15.6%)		2.5±4.2 (75.4%)	
5.	Size of stomata	Length	Breadth	Length	Breadth	Length	Breadth
		75±3.6	40±2.5	58±1.7	40±3.4	47±3.0	34±2.6
6.	Stomatal index	Upper	Lower	Upper	Lower	Upper	Lower
		26±2.6	29±0.5	21±2.7	22±2.4	19±0.4	19±1.6
7.	Dust deposition	307		450		501	
8.	Leaf wash pH	7.5		6.4		5.9	
9.	Leaf wash conductivity	78		190		270	

LPA- Low polluted area, VPA- Vehicular polluted area, IPA-Industrial polluted area

Table-2

Average area of leaf (cm²), L/B ratio, fresh and dry weight of leaves (gm.), Size of stomata (µm) and stomatal index Dust deposition (µg/m^2) and Leaf wash pH and Conductivity (µmhos/cm^2) of leaves of *Ipomoea fistulosa* Mark. Collected from three study area of Indore city, India

S.No.	Parameter	*Ipomoea fistulosa* Mark.					
		Site-l(LPA)		Site-2(VPA)		Site-3(IPA)	
1.	Leaf area	64.0±4.0		50.4±2.6 (21.2%)		38.9±3.5 (39.2%)	
2.	L/B ratio	82.3±1.9		60.9±4.8 (26.0%)		34.5±0.1 (58.0%)	
3.	Fresh weight of Leaves	50.0±4.7		43.1±6.0 (13.8%)		37.0±6.7 (26.0%)	
4.	Dry weight of Leaves	10.6±0.2		10.4±3.5 (1.8%)		10.1±0.7 (4.7%)	
5.	Size of stomata	Length	Breadth	Length	Breadth	Length	Breadth
		72±3.0	47±1.5	55±4.5	41±4.9	50±4.3	31±2.2
6.	Stomatal index	Upper	Lower	Upper	Lower	Upper	Lower
		28±4.6	30±2.5	23±1.7	24±1.4	15±1.0	19±0.6
7.	Dust deposition	152		170		216	
8.	Leaf wash pH	7.4		6.8		6.5	
9.	Leaf wash conductivity	88		139		290	

LPA- Low polluted area, VPA- Vehicular polluted area, IPA- Industrial polluted area

In VPA leaf wash pH was in *Calotropis gigantia* (6.4) and *Ipomoea fistulosa* (6.8). In IPA leaf wash pH was more acidic in *Calotropis gigantia* (5.9) and was less acidic in *Ipomoea fistulosa* (6.5). Highest leaf wash conductivity was noted in *Calotropis gigantia* in IPA (290µmhos/cm^2) as well as VPA (270µmhos/cm^2). The response of *Ipomoea fistulosa* was interesting as the leaf wash conductivity was minimum in this species in IPA (139 µmhos/cm^2) and was considerably higher (190 µmhos/cm^2) in VPA.

Marked reduction in leaf area, L/B ratio, fresh weight and dry weight of leaves of shrub species in two polluted study areas confirmed the damaging effect of air pollution. Reduction in leaf area and other parameters has been reported by Ahmad K.J. [1] and Byres D.P [2] also

According to Byres D.P[2] reductions in leaf area and leaf number in response to air pollution may be due to decreased leaf production rate and enhanced senescence. The reduced leaf area may result into reduced photosynthetic rate.

The leaf and stomata plays important role in plant life. Stomatal study is emphasized to know the nature and behavior of plants in response to air pollution. Epidermal layer of leaf, being the outermost layer shows marked changes to due to air pollution. Increasing level of pollution affect normal stomatal physiology and responses by causing changes in number and frequency of stomata and size of their aperture[3- 5]. Low stomatal frequency has been observed in response to polluted air[3, 6].

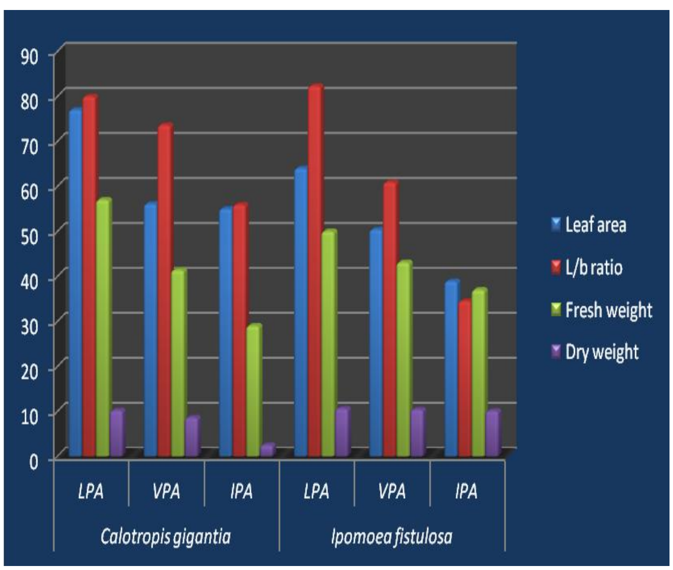

Figure- 1
Showing Response of Leaf Area, L/B Ratio, Fresh Weight and Dry Weight of both the shrub species in VPA and IPA over LPA

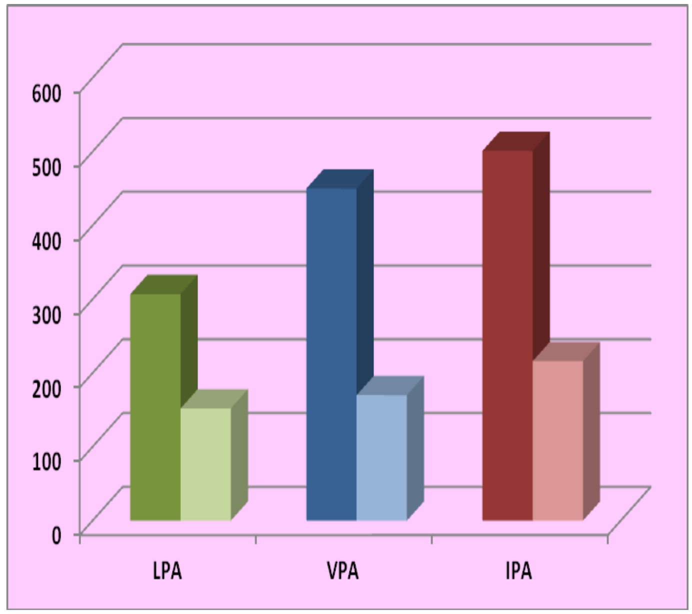

Figure -2
Showing Response of Dust deposition of both the shrub species in VPA and IPA over LPA

Studies indicate that stomatal index of both epidermal layers increases with the plant age[6]. Found a significant decrease of stomatal density and stomatal index in *Ipomoea pes-tigridis* grown under various degrees of environmental stresses. The stomatal index reduced considerably on both the lower and upper surface of leaves. Similar result has been obtained by Pawar K.[7] and Salgare S.A.[8] in some plants exposed to air pollution.

The dust deposition was higher in industrial area as compared to other areas under study. This specific difference can be attributed to the variation in leaf size, nature of leaf surface and curvature of lamina. Ahmad K.J.[1] have also emphasized that deposition of particulates is greatly influenced by epidermal and cuticular features, phyllotaxy and orientation of leaves. Thus the variation in dust deposition appeared to be more related with leaf size, orientation and curvature in the lamina rather than deciduous or evergreen nature of the trees. Dust deposition also cause reduction in number and size of stomata and clog stomatal aperture thus, interferes with gaseous diffusion and energy conserving processes of plants[7]. Similar observations have also been made by Steubing L.[9].

The leaf wash pH was found to be more acidic during summer inspite of poor dust deposition. It is due to the fact that in dry months gaseous pollutants are long lived and settle down slowly on vegetation together with other aerosols and dust [10]. The leaf wash pH is an indicator of the chemical nature of pollutants present in the surrounding. The predominance of SO_2 accompanied with NO_2 in industrial areas appears to be responsible for acidic nature of the dust.

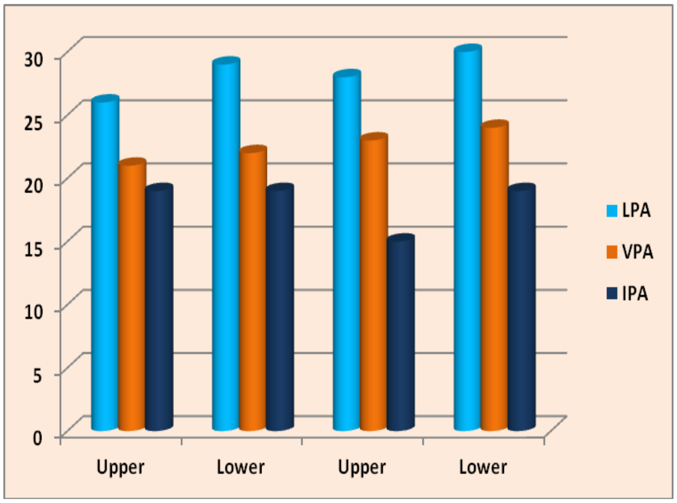

Figure- 3
Showing Response of Stomatal index (Upper and Lower) of both the shrub species in VPA and IPA over LPA

The values of leaf wash conductivity in different polluted areas showed that the conductivity is related with the nature of dust deposited on leaves. The conductivity was directly related with the amount of dust deposition on leaves as observed for most of the species under present study. Seasonal variation in leaf wash conductivity was also related with the quantity of dust deposited on leaves [6]. On the basis of leaf wash pH and conductivity it can be inferred that the dust of mixed pollution area, particularly Industrial pollution area, is chemically more active as compared to vehicular pollution area. Varshney C.K.[11] reported high amount of soluble in industrial dust.

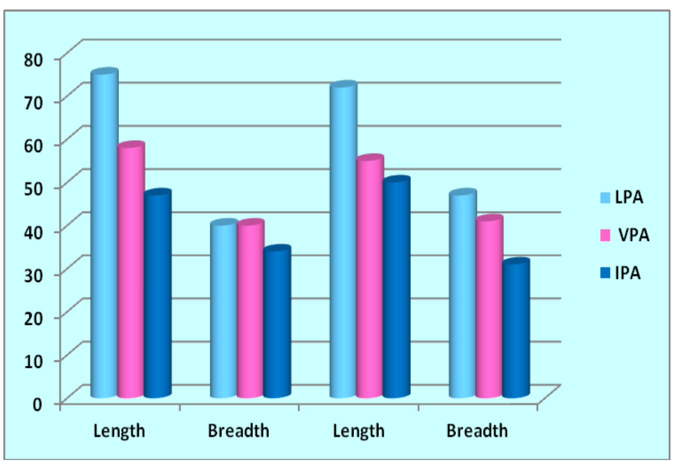

Figure-4
Showing Response of Size of stomata (Length and Breadth) of both the shrub species in VPA and IPA over LPA

Conclusion

It is evident from the present study that the air pollutants such as SPM, SOx, NO_x and O_3 from automobile exhaust and industries along with many other unknown pollutants are responsible for bad air quality. These pollutants not only affect the morphology of plants but also alter the physiology. Reduction in various parameters of two shrub species studied at three sites clearly indicates the deleterious effect of air pollution on plant health.

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