Sem Studies On Effects Of Dust Deposition On Foliage Of Some Avenue Plants

*Sadhna Awasthi And P.C. Joshi

Department Of Zoology And Environmental Sciences, Gurukul Kangri University, Haridwar -249404
*sadhnaawasthi02@gmail.com

Abstract: A study was carried out to correlate the combined impact of particulates and vehicular exhaust on the foliage of selected plants viz. *R.communis, F.bengalensis, F.religiosa, C.fistula* and *S.indica* at two different sites namely Amausi Airport (a site I) and its adjacent area at Lucknow-Kanpur highway and B.B.A.U Campus (Site II). Dust load was calculated after continuous exposure of particulates on the foliage of avenue plants at both the sites. It was observed that dust load was more on the leaves of plants at Site-1 than Site-2.Foliar surface morphology and an epicuticular layer of plants at both the sites were studied with the help of Scanning Electron Microscopy analysis which revealed a number of changes in micro morphology of foliage due to dust exposure and deposition such as clogged stomata, ruptured epidermis and foreign particle deposition inside the leaf. Infrared spectra of dust samples collected over the leaves of selected plants were also recorded and the dominant peak of different intensities was obtained.

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1. Introduction

The degradation of air quality is a major environmental problem that affects many urban and industrial sites and the surrounding regions worldwide. It 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 substances to the environment are responsible for altering the ecosystem (Mudd and Kozlowski, 1975; Niragau and Davidson, 1986; Clayton and Clayton, 1982). The main atmospheric pollutants are SO_2, NOx, O_3, heavy metals and particulates. Increased concentrations of the above pollutants cause a progressive reduction in the photosynthetic ability of leaves, closure of leaf stomata and mainly a reduction in growth and productivity of plants (Larcher, 1995). Deposition of dust particles affects the growth and biochemical characteristics of field crops (Prasad and Inamadar, 1990; Prasad *et al*., 1991).Effects of particulates on vegetation may be associated with the reduction in light required for photosynthesis and an increase in leaf temperature due to changed surface optical properties. Plants can act as biological filters, removing large quantities of particles from the urban atmosphere. This is predominately due to their large leaf areas relative to the ground on which they stand, and the physiological properties of their surfaces *i.e.* the presence of trichomes or waxy cuticles on the leaves of some species. Various strategies exist for controlling atmospheric pollution, but vegetation provides one of the natural ways of cleansing the atmosphere by absorption of gaseous and some particulate matter through leaves (Varshney, 1985). Recent studies have explored the possibility to find out the ability of plants to remove pollutants from the air and act as a sink for air contaminants (Sunita and Rao, 1997; Dwivedi and Tripathi, 2007; Tripathi and Gautam, 2007). Industrialization and the automobiles are responsible for the maximum amount of air pollutants and the crop plants are very sensitive to gaseous and particulate pollutions and these can be used as indicators of air pollution (Joshi *et al.,* 2009). The use of plants as monitors of air pollution has long been established as plants are the initial acceptors of air pollution. They act as the scavengers for many air borne particulates in the atmosphere (Joshi and Swami, 2009).

In the present study, the dust capturing capacity of some avenue plants have been taken as a parameter for improving and monitoring the air quality. This work also focuses on micro morphological changes in the foliar surface of selected avenue plants with the help of Scanning Electron microscope analysis.

2. Materials And Methods

2.1 Study Area: Lucknow, the capital of Uttar Pradesh, is located between 26.50° N and 80.50°E was chosen for the present work. To carry out the present investigation, two sites were selected on the basis of high traffic zone, the presence of high particulate producing industries and plant diversity (i.e. herbs, shrubs and trees).

Site I (Amausi airport): This is an industrial area as well as high traffic zone. The numbers of heavy vehicles per day are very high as it is the core area of the city. The particulate pollution in this area is mainly due to the frequent civil constructions and heavy traffic.

Site II (Babasaheb Bhimrao Ambedkar University Campus): The campus of Babasaheb Bhimrao Ambedkar University is located about 1.5 km off Raebarieli road. There is a great diversity of trees, shrubs and plants in the campus planted by university authorities. There is very less vehicular traffic in this area hence it is considered as less polluted.

2.2 Identification of Major Dust Arresting plant species: The identification of plant species was undertaken at respective sites, which have the high natural capacity to arrest particulates from the ambient air because of their morphological and anatomical features. Five plant species namely *Ricinus communis* (Arand), *Saraca indica* (Ashoka), *Ficus bengalensis* (Bargad)*, Ficus religiosa* (Peepal) *and Cassia fistula* (Amaltas) were selected for the present study.

2.2.1 Calculation of Dust load: Dust is produced by subdivision of solid material through mechanical actions in nature. The particles with large diameter tend to settle faster. Due to continuous exposure to dust particles; they get accumulated on the leaf surface and termed as "dust load".

Dust load was calculated by the following formula:

$$\text{Dust Load (mg/cm}^2\text{)} = \frac{\text{Dust load on the leaf (mg)}}{\text{Surface area of leaf (cm}^2\text{)}}$$

2.3 Sample preparation for Scanning Electron Microscopy: In order to carry out SEM studies, leaf samples of about same age harvested and fixed in 2.5% of glutaraldehyde. They were cut into pieces of approximately 0.3cm^2. These samples were fixed immediately at the site to avoid any post-plucking damage. These samples were brought to the laboratory and dehydrated in acetone series (30-100%) and further drying was carried out in a critical point drier with liquid CO_2. Materials were then coated with a thin conductive film of gold about 200ºA in thickness in an ion sputter coater and then examined under SEM.For Critical point drying; model EMITECH K 850 was used. The model used for coating was JEOL JFC-1600.The model of SEM used for the study was JEOL-JSM-6490 LV (Japan).

2.4 FTIR Spectroscopic study of dust accumulated over selected plants: Fourier transforms infrared spectrum study of dust samples was conducted in order to identify different functional groups present in dust. For FTIR analysis dust accumulated on leaves was collected and weighed. It was kept in the oven for 24 hours in aluminium foil to remove moisture. Now this dried dust was mixed with KBR and its pallets were made and the vibrational assignments, intensities of dominant peaks were obtained from absorption spectra.

3. Results And Discussions

3.1.1 Leaf surface morphology of selected avenue plants: In the present study out of total five plant species, leaves of *Ricinus communis* have maximum surface area followed by *Saraca indica*, *Ficus bengalensis*, *Ficus religiosa* and *Cassia fistula*. The dimensions of leaves of different selected plants have been given in the Table-I. Due to large surface area of these plants, they trap more dust hence are considered as ideal avenue plants. Leaf texture of these plants are also rough, hairs are present on the surface,which helps dust particles to stick to it. Plants having such leaf surface like *R.communis* and *F.bengalensis* are considered to be useful in improving air-quality by arresting particulates.

3.1.2 Dust load in selected avenue plants: The dust load observed from the leaves of selected plants has been given in the Table-II .By calculating dust load on plants we can categorize them into different categories like high, moderate and low dust capturing plants. This categorization of plants according to their efficiency of dust trapping is helpful in selection of avenue plants for the purpose of dust trapping.

The plants which are specified in **Table II.** are common on both sites. Among these plant species the maximum dust load was shown by *Ricinus communis* and least by *Saraca indica* at both the sites. It was found that Site I was more polluted as compared to Site II. It might be due to the reason that Site I is having high vehicular density and a lot of construction work is also taking place at this site whereas Site-II is university campus with very few number of vehicles and no construction activity.

On the basis of this analysis, plant species are grouped into three categories according to their dust trapping abilities:

1. **High:** *Ricinus communis*
2. **Moderate:** *Ficus bengalensis >Ficus religiosa >Cassia fistula*
3. **Low:** *Saraca indica*

The studies of upper and lower surface of the leaves confirmed the dust trapping capacity of plants at selected sites. A positive correlation has been observed between the dust trapping and micro-roughness of the total leaf area. Leaf orientation is also an important parameter for dust trapping, it is of two types i) Geotropic ii) Planophilic. Plants having leaves with geotropic orientation are considered ideal to capture dust as compared to plants having planophilic leaf orientation.

According to the investigation, *R.communis* has depicted as having maximum dust loading capacity.

Although its leaf orientation is planophilic but since its leaves are quite large and have a rough surface so it captures dust in adequate amount. *F.bengalensis* and *F.religiosa* are other species which showed good potential for dust trapping. These both trees are very popular roadside plants as they are big in size, easy to grow and long lasting. *C.fistula* is a very frequent tree for improving air quality because of its fast growth rate, easy nourishment and good absorption capacity of pollutants like oxides of Sulphur and Nitrogen, its dust capturing capacity is moderate; it may be due to small leaf surface area and Planophilic leaf orientation. *S.indica* is famous for its aesthetic value it has been used as an ornamental shrub in residential areas. Although its leaf orientation is geotropic but leaf surface is smooth, shiny, long but narrow due to which dust particles cannot bind themselves to leaf surface, hence it has poor dust capturing capacity.

3.2 Scanning Electron Microscope (SEM) image analysis: It was observed that foliar surface undergoes several structural and functional changes when particulate laden air strikes it. During SEM study of plant foliar surface morphology,which is the important receptor of atmospheric pollutants the micro morphological traits of selected avenue plants like wax,cuticle,stomata and trichomes were observed under Scanning electron microscope.In most of the images obtained from the leaves of Site I, stomata can be seen clogged with dust,a number of foreign particles can be seen on the surface.Trichomes are present in abundant number but most of them are found damaged due to dust exposure.In some leaves a hairy covering can be seen on epidermis due to which it is not clearly visible.It may be due to deposition of dust on those leaves for a long time.Such morphological changes are common in plants at Site I. Remarkable differences in foliar surface morphology were recorded in the dust laden plants when compared to the respective control plants. Trichomes were broken and epidermis was found to be ruptured badly in most of the plants. Foreign particles and dust patches were also seen at the epidermis which can block stomatal apertures and affects respiration, photosynthesis, and transpiration.Although the visible leaf injury symptoms were many but after examining these leaves under SEM alteration in stomatal configuration,damage of guard cells,thick embedding of dust on the foliar surface were recorded .Verma and Singh (2006) also observed distorted wax,damaged stomata and disturbances in the ornamentation of cuticles on leaf surface exposed to pollutants. Hence from the SEM study, it may be concluded that dust deposition causes deviations in normal patterns of surface morphology in plant leaves.

It is clear from the scanning electron micrographs (1a-5b) of leaf samples that the dust deposition on leaves has a significant effect on micromorphology.

Examination of Scanning electron micrographs (1a -1b) of leaves of *R.comminis* revealed that under polluted conditions i.e. Site-I stomata are found clogged; all stomata are embedded in epidermal layer and surrounded by subsidiary cells. Non-glandular trichomes can be seen. It is important to bring in the notice that stomata are more in the leaf examined as compared to Site-II.So it can be concluded that presence of more stomata on the surface is an adaptation to leaf to survive under pollution stress where as less number of trichomes indicate their inability to develop under such condition. The increase in the stomatal index is not a common feature of plant species exposed to air pollution it may be an adaptive feature. In spite of stomata and trichomes, some wax crystals, linear striations also are seen in the images.

In the case of *F.religiosa* at Site-I, few open stomata are present in the epidermis .Epidermis is not clearly visible and ruptured it might be due to continuous dust exposure whereas at Site-II open stomata are present along with linear striations .Trichomes are absent in the examined portion.

In the case of *S.indica* at Site-I numerous open stomata are visible but most of them are clogged due to dust particles. Stomata rise in the epidermis. Trichomes are not visible in the examined portion whereas at Site-II open stomata are present and few foreign particles are deposited.

C.fistula at Site-I, stomata are invisible, the epidermis is ruptured badly. Non-glandular and spiny trichomes are present however most of them are found broken and damaged whereas at Site-II few less damaged stomata can be observed, numerous non-glandular and spiny trichomes are present.

In the case of *F.bengalensis* numerous open stomata are present at Site-I but epidermis can be seen ruptured, stomata are risen and embedded in the epidermal layer. Trichomes are completely different from Site-II. Here trichomes are non-glandular, small and spiny. Whereas at Site-II stomata present are open and at the level with the epidermis. Here C-shaped non-glandular trichomes are present in abundance.

Though the pollution stress altered the structure of the leaves of the investigated species .But in spite of this these species are quite resistant to pollutant actions and despite the observed modifications, they continue to reach maturity. Various authors underlined the reduction of plant growth, as a consequence of pollution stress (Gupta and Iqbal, 2005; Maruthi Sridhar *et al*., 2005, 2007).The modification of the frequency and sizes of stomata as a response to the environmental stress is an important manner of controlling the absorption of pollutants by plants. The closing of stomatal aperture under pollutants stress is not uncommon. The changes in the inner anticlinal walls of the guard cells have been shown to be induced by Pb stress (Ahmad *et al*. 2005).

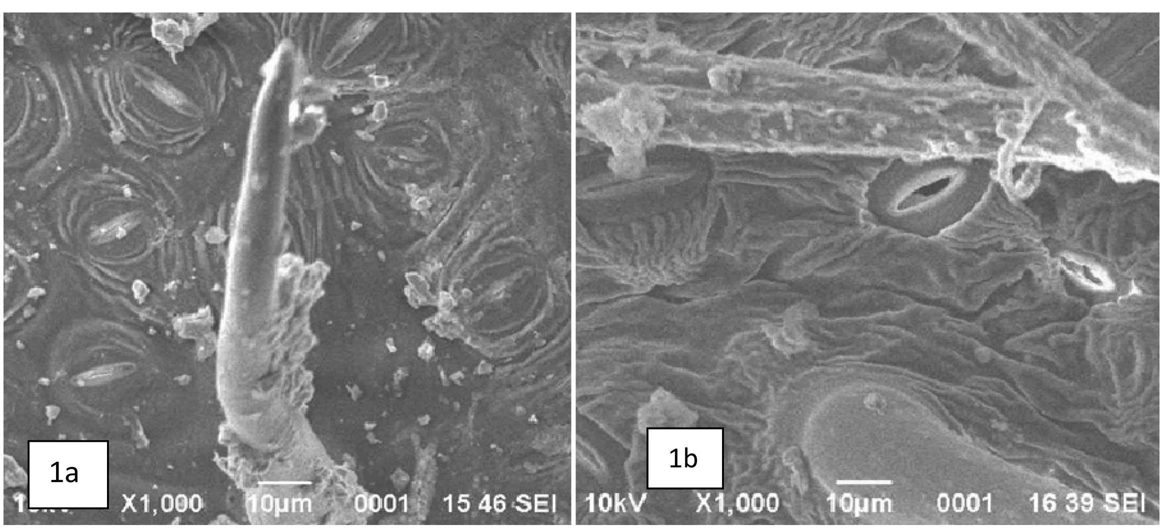
The FTIR spectra of dust collected from selected leaves are shown in Fig (6a-10b).The absorption bands, the wave number (cm^{-1}) of dominant peaks obtained from absorption spectra are presented in **Table 3**. The dominant peaks of FTIR spectroscopy indicate the presence of inorganic Phosphates, Aliphatic Primary Amides, Inorganic Carbonate, Kaolin Clays/ Alumino-Silicates, Aliphatic Hydrocarbons, Aromatic amines, Inorganic Nitrates, Methylene etc. these all compounds are the main constituent of air and particulate pollutants. Singh and Rao (1980) found the incidence of foliar injury symptoms and decrease in concentration of chlorophyll in the vicinity of a cement factory. The presence of all these compounds in the surrounding air and dust are primarily responsible for the modification in the leaf foliar morphology.

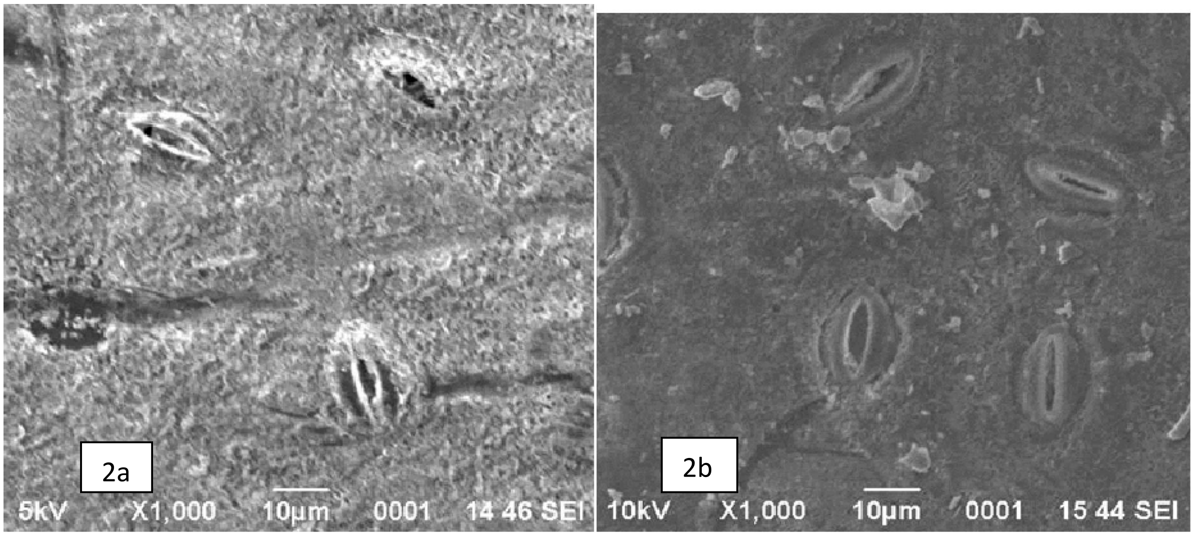
Table I. Length and breadth of leaves of selected avenue plants

Plants selected	Length of leaf (cm)	Length of petiole (cm)	Breadth of leaf (cm)
Ricinus communis	24	20	30
Saraca indica	20	1	4.2
Ficus bengalensis	18.4	4.4	13.3
Ficus religiosa	18.2	1	10.6
Cassia fistula	6.2	.3	2.3

Table II. Dust Load (mg/cm^2) of selected avenue plants at both sites of Lucknow, India

Plants selected	Amausi Airport (Site-1)	B.B.A.U (Site-2)
Ricinus communis	5.38±0.73	4.42±1.00
Saraca indica	0.21±0.01	0.20±0.04
Ficus bengalensis	2.55±0.36	2.32±0.60
Ficus religiosa	1.18±0.04	1.15±0.12
Cassia fistula	1.30±0.30	1.52±0.04

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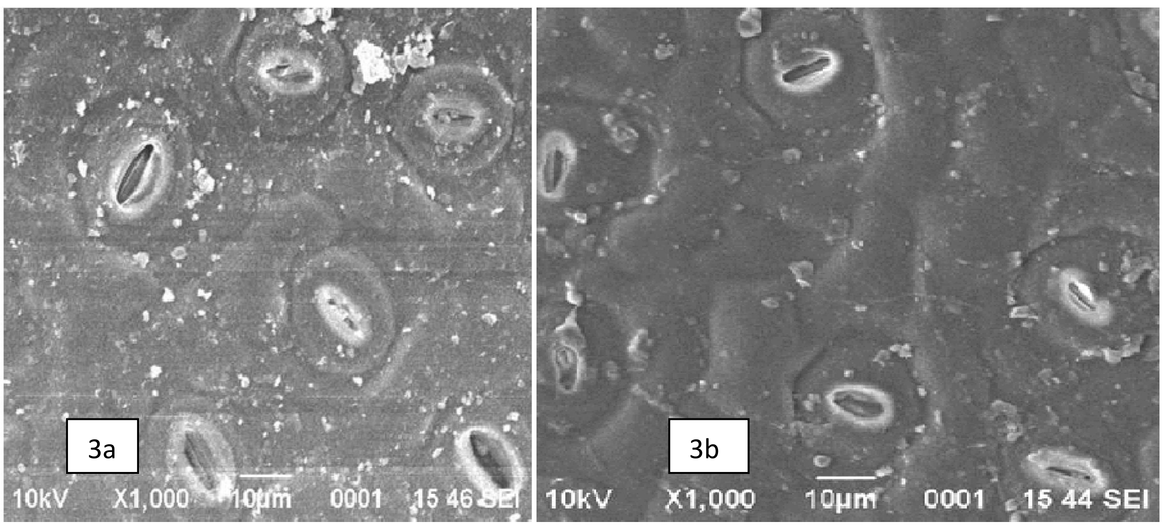
5kV X1,000 10µm 0001 14 46 SEI
2b
10kV X1,000 10µm 0001 15 44 SEI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3b
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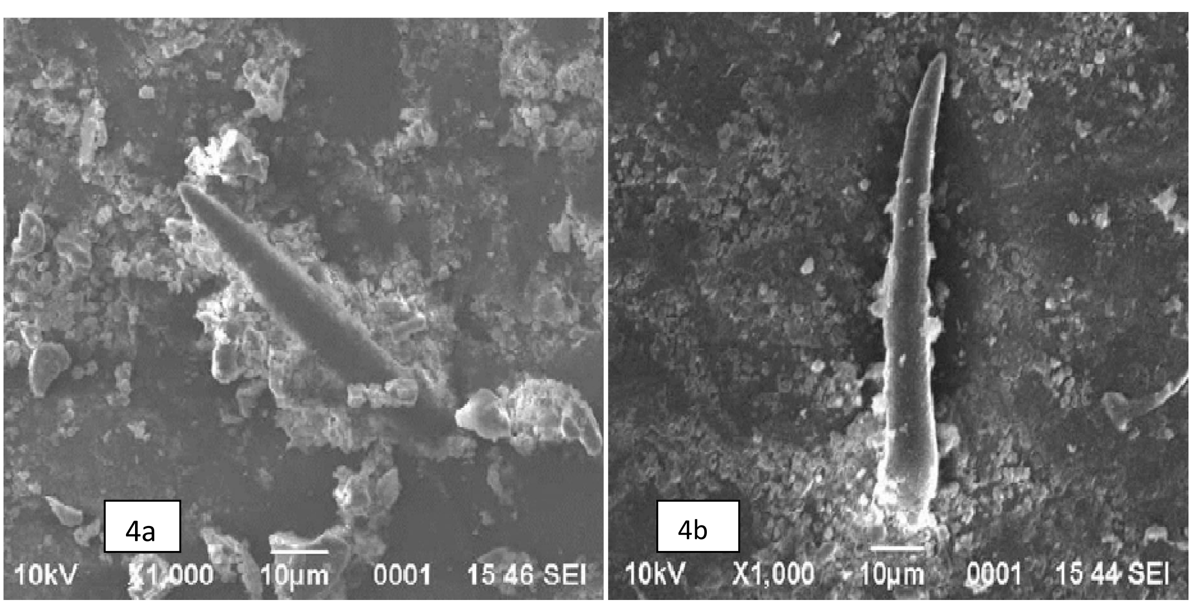
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4b
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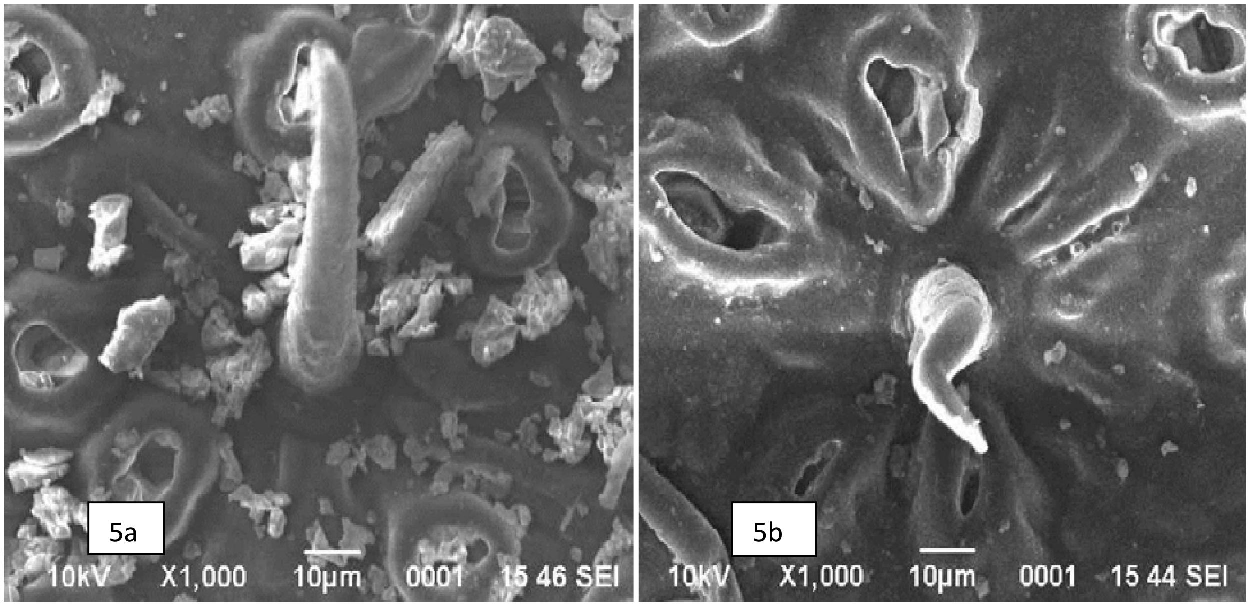
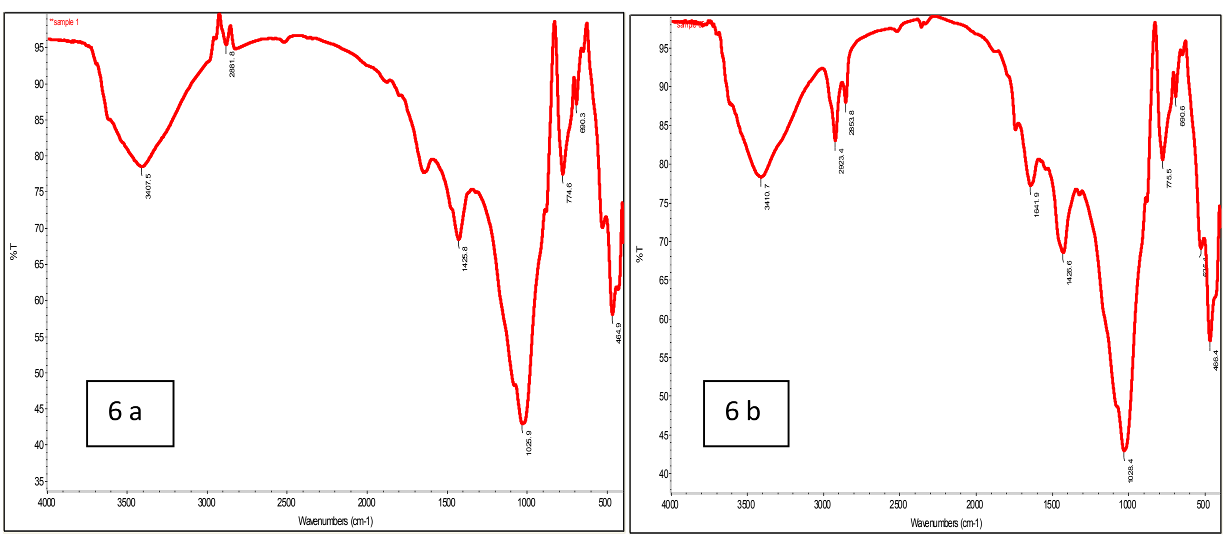
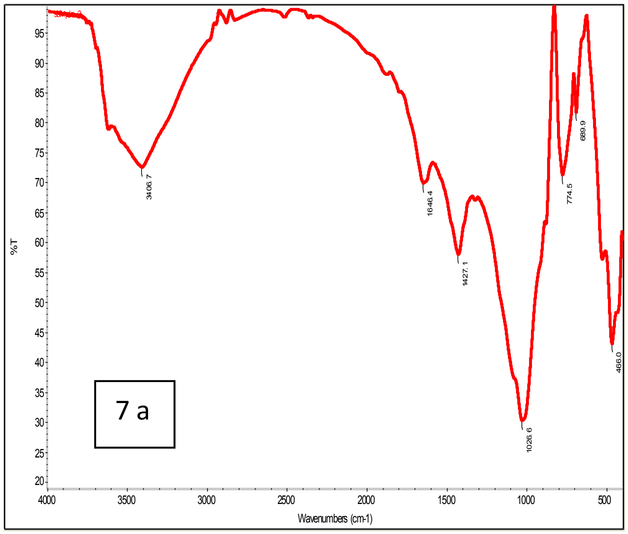
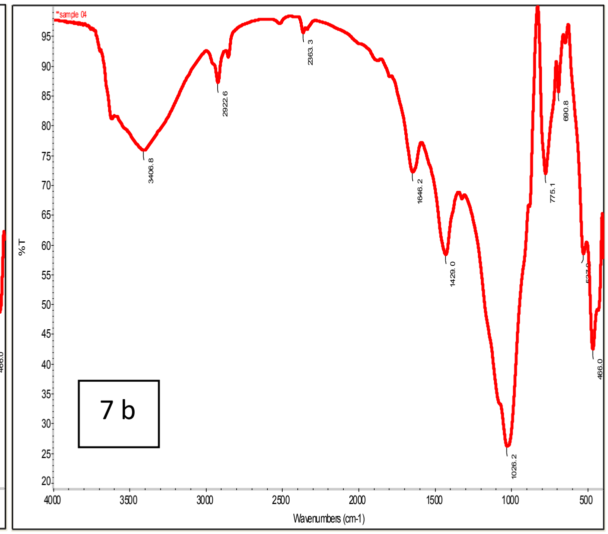
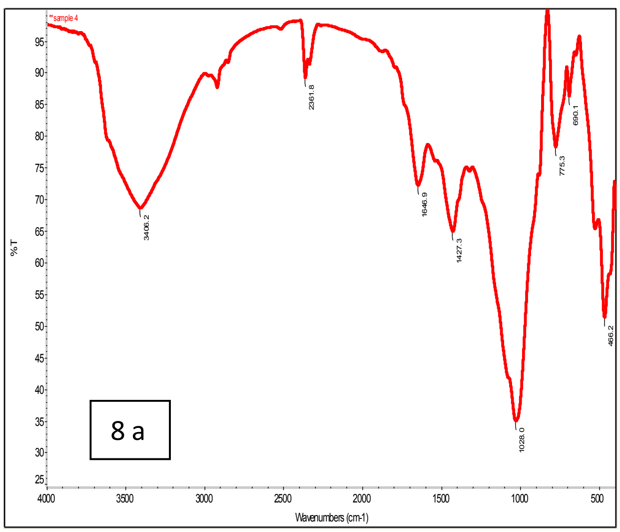


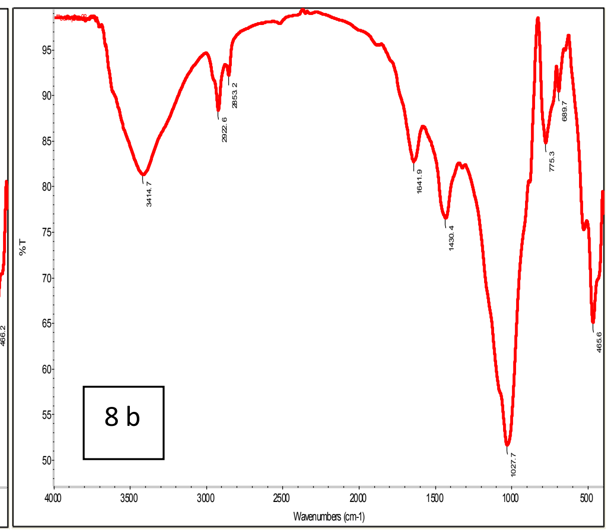
Fig.1a and 1b: Scanning electron microscope view of *R.communis* leaf at Sites I and II.
Fig.2a and 2b: Scanning electron microscope view of *F.religiosa* leaf at Sites I and II.
Fig.3a and 3b: Scanning electron microscope view of *S.indica* leaf at Sites I and II.
Fig.4a and 4b: Scanning electron microscope view of *C.fistula* leaf at Sites I and II.
Fig. 5a and 5b: Scanning electron microscope view of *F.bengalensis* leaf at Sites I and II.
Note: **Site I represents the most polluted site, while site II represents the less polluted site.**




7 a
%T
Wavenumbers (cm-1)


7 b
%T
Wavenumbers (cm-1)


8 a
%T
Wavenumbers (cm-1)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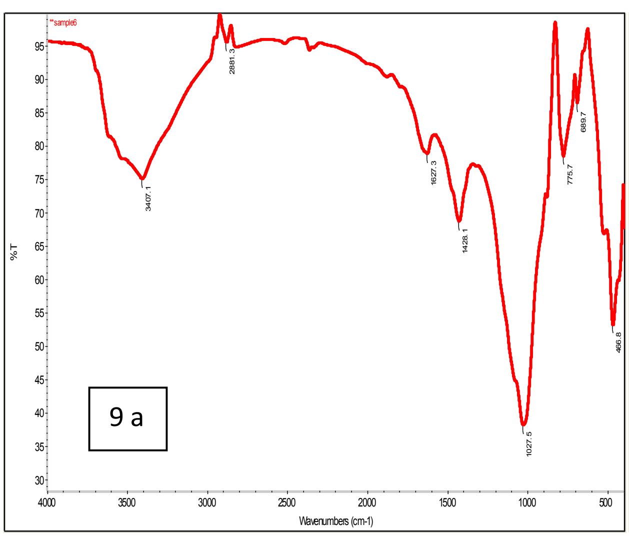
Wavenumbers (cm-1)


9 a
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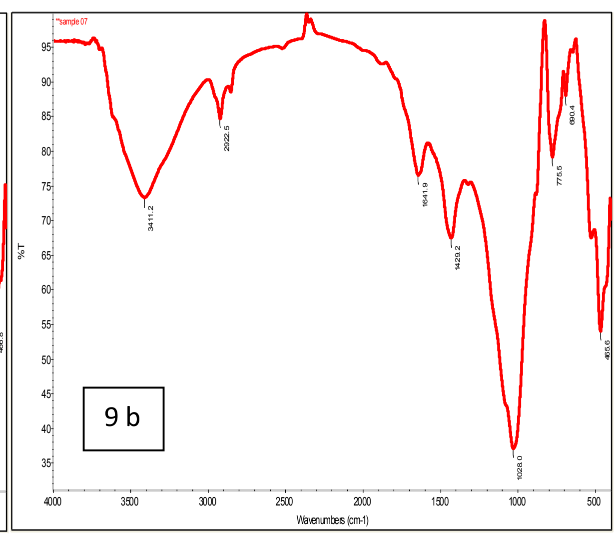
Wavenumbers (cm-1)


9 b
%T
Wavenumbers (cm-1)

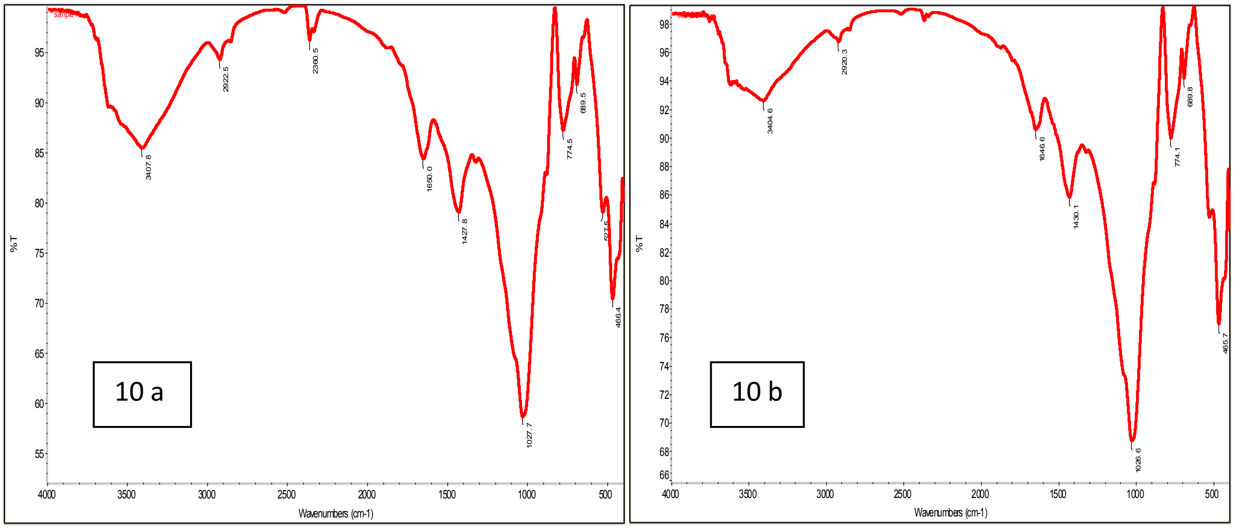


Fig.6a and 6b: FTIR of Dust deposited at *R.communis* at Sites I and II.
Fig.7a and 7b: FTIR of Dust deposited at *F.religiosa* at Sites I and II.
Fig.8a and 8b: FTIR of Dust deposited at *S.indica* at Sites I and II.
Fig.9a and 9b: FTIR of Dust deposited at *C.fistula* at Sites I and II.
Fig.10a and 10b: FTIR of Dust deposited at *F.bengalensis* at Sites I and II.

Table. III Assignment of IR absorption bands in spectra of Dust Load of plants leaves collected from site I and Site II

Plant Species and their wavenumbers (cm-1)										
R.communis		***S.indica***		***C.fistula***		***F.religiosa***		***F.bengalensis***		**Tentative assignment**
Site 1	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**	
3407.5	3410.7	3406.7	3406.8	3407.8	3403.4	3406.2	3414.7	3407.8	3404.6	Inorganic Phosphates, Aliphatic Primary Amides, Inorganic Carbonate, Kaolin Clays/ Alumino Silicates
-	2923.4	-	2922.6	-	2923.0	-	2922.6	2922.5	2920.3	Aliphatic Hydrocarbons, Methylene C-H asym./sym. Stretch, Aliphatic C-H stretch
2881.8	2853.8	-		-		-	2853.2	-	-	Aliphatic Hydrocarbons
-	-	-	2363.3	-	2361.8	2361.8	-	2360.5	-	CC and CN triple bond (Nitriles)
-	1641.9	1646.4	1646.2	1644.0	1638.9	1646.9	1641.9	1650.0	1646.6	C=O stretching of amide groups (amide I) quinine, C=O stretching of H-bonded conjugated ketones
1425.8	1426.6	1427.1	1429.0	1420.4	1428.7	1427.3	1430.4	1427.8	1430.1	Inorganic Nitrates, Methylene C-H bend; Aliphatic C-H
1025.9	1028.4	1026.6	1026.2	1027.4	1030.2	1028.0	1027.7	1027.7	1026.6	Si-O-asymmetric stretch
774.8 690.3	775.5 690.6	774.5 689.9	775.1 690.8	775.6 690.1	776.5 690.8	775.3 690.1	775.3 689.7	774.5 689.5	774.1 689.8	Si-O-Si stretching vibration, Methylene -(CH2)*n*- rocking (n≥ 3) C-H bending vibrations,
464.9	525.1 464.9	466.0	527.0 466.0	466.5	465.4	466.2	465.6	527.5 466.4	465.7	C-O-O, P-O-C bonding (aromatics) phosphates

4. Conclusion

The particulate pollution at selected sites was mainly due to construction work and vehicles. The present study has demonstrated that plants can act as an effective barrier by intercepting dust particles. The study has identified certain plant traits that have resulted in the effective trapping of dust. Broader and large surface area of a leaf in the case of shrubs are responsible for high rate of dust interception. Higher frequency of stomata results in the formation of a film of moisture that enables leaves to trap particles as it was observed in the case of *R.communis*. Leaf surface, texture, and orientation also play very important role in dust capturing mechanism. The plants having a rough surface like *R.communis* and *F. bengalensis* are more capable of trapping dust. After visualizing images obtained by SEM, remarkable differences were recorded in the foliar surface morphology of selected plants of both sites. From the SEM study, it may be concluded that dust deposition causes much deviations in normal patterns of foliar morphology in plants of Site I which is found to be more polluted as compared to Site II .With the help of FTIR spectroscopy, it can be revealed that vehicular pollution and particulate pollution, are responsible for above-mentioned alterations in the foliar surface of leaves.

Correspondence:
Sadhna Awasthi C/O Prof. P.C. Joshi
Department of Zoology & Environmental Science,
Gurukula Kangri Vishwavidyalaya,
Haridwar, India -249404
E-mail: sadhnaawasthi02@gmail.com
Phone: +91-9012677665
Co-Author: Prof. P.C. Joshi
E-mail: prakash127@yahoo.com

References

1. Clayton, G.D. and Clayton, F.E. (1982).Pattys industrial hygiene and technology. *Wiley Interscience, New York*.
2. Dwivedi, A.K. and Tripathi, B.D. (2007). Pollution tolerance and distribution pattern of plants in surrounding areas of coal-fired industries. *J. Environ Biol., 28(2):257–263*.
3. Gupta, A.K. and Mishra, R.M. (1994). Effect of lime kiln's air pollution on some plant species. *Pollution Research,13(1): 1-9.*
4. Joshi *et al*. (2009). Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants. *Environmentalist, 29: 398-404.*
5. Joshi, P.C. and Swami, A. (2009). Air pollution induced changes in the photosynthetic pigments of selected plant species. *J. Environ. Boil., 30: 295-298.*
6. Larcher, W. (1995). Physiological plant ecology. *Springer-Verlag, Berlin, Germany.*
7. Mudd, J.B., and Kozlowski, T.T. (1975). Response of plants to air pollution. *Academic Press, New York, pp 383*.
8. Niragau, J.O., and Davidson, C.I. (1986). Toxic metals in the atmosphere. *Jon Wiley and Sons, New York.*
9. Prasad, M.S.V., and Inamadar, J.A. (1991). Effect of cement kiln dust pollution on growth and yield of Vigna sp. *Indian J. Ecol.,18: 91-94.*
10. Prasad,M.S.V., and Inamadar,J.A.(1990). Effect of cement kiln dust pollution on blackgram (Vigna munga L. Hepper) *Proc. India Acad. Sci. (Plant Sci.),100(6): 435-443.*
11. Sunita, M., and Rao, K.V.M. (1997). Air pollution tolerance capacities of selected plant species. *J. Ind. Bot. Soc., 76: 95-98.*
12. Tripathi, A. K. and Gautam, M. (2007). Biochemical parameters of plants as indicators of air pollution. *Journal of Environmental Biology, 28: 127-132.*
13. Varshney, S.R.K., and Varshney, C.K. (1985). Response of peroxidase to low levels of SO_2. *Environ. Exp. Bot., 25: 107-114.*

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