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Particulate Pollution Mitigating Ability of Some Plant Species

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ABSTRACT: Foliar surface of plants is continuously exposed to the surrounding atmosphere and is, therefore, the main receptor of particulate pollutants. This physical trait can be used to determine the level of particulate pollution in the surroundings, as well as the ability of individual plant species to intercept and mitigate particulate pollutants. In the present study, leaf cuticle characters of four common roadside plant species, namely *Bougainvillea* 'Mahara', *Terminalia arjuna* (Roxb.) Wt. and Arn, *Cassia fistula* Linn, and *Polyalthia longifolia* Thw. were studied from sites with heavy particulate pollutants in the atmosphere and compared with those of control/ non polluted environs to evaluate their respective pollution mitigating ability. The particles deposited on the leaf surface were 2.5 to 10.0 µm in size and the dust load was recorded in the trend of *T. arjuna* (2.31 mg/cm^2)> *C. fistula* (1.47 mg/cm^2) > *B.* 'Mahara' (1.33 mg/cm^2) and *P. longifolia* (0.97 mg/cm^2). The increase in the size and frequency of epidermal cells and stomata were observed. Cuticle rupture was a major injury symptom, that was observed in *T. arjuna, C. fistula* and *P. longifolia* while no cuticular damage was not observed in *B.* 'Mahara'. On the basis of these observations it can be concluded that *B.* 'Mahara' is a dust mitigator and it adsorbs and / or absorbs the pollutants from the environment in which it grows.

Key words: Particulate pollution, Cuticle rupture, Foliage, Roadside plants, *Bougainvillea*

INTRODUCTION

Plants growing in the dusty environment generally show visible injury symptoms as the surface of the leaf got deposited with heavy load of particulate pollutants emitted anthropogenically and naturally into the atmosphere through industrial processes, road traffic, as well as volcanic eruptions, dust storms etc. The use of vegetation in filtering out the dust, soot and particulates from the atmosphere has long been accepted and is common practice in some developed countries. A large quantity of dust cover on vegetation has been observed by Yunus et al. (1985) on eight common plants sampled from open fields and closed canopy of the plants and a convincing relationship between their morphological traits and the amount of particulates in the ambient air was established. As plants are very efficient in trapping atmospheric particles, leaves have been used as monitors of particulate pollution (Nriague, 1989, Freer-Smith *et al.,* 1997). Deposition of dust depends on the physical characteristics of particles, such as, their size, shape and also the plant species (Harrison and Yin, 2000). Depending on the dust load, duration and tolerance of the plants, particulates may cause negative changes in the leaf surface ultra structures, inhibit growth of the plants, reduce the area of leaves and hence, reduce the total biomass (Shukla *et al.,* 1990).

Morphological characters of plants are very important in determining plant resistance to air pollution. Characteristics, such as sunken stomata, thick cuticle, small and dense cells and suberised cell walls are in favor of reducing pollutant entry into leaves and cells (Pal *et al.,* 2002). Pollutants also cause erosion of epicuticular wax, which protects the entry of pollutants through leaf cuticle by serving as a barrier. Therefore, the structural resistance of epicuticular wax to the erosion effect of air pollutants would be an important factor in providing overall resistance of plants to air pollution

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(Dixit, 1988; Huttunen, 1994; Bacic, 1999). Out of the four plants selected for this study, *Terminalia arjuna* (Roxb.) Wt. and Arn., *Cassia fistula* Linn. and *Polyalthia longifolia* Thw. are trees, and *Bougainvillea* 'Mahara' (a bud sport of Bougainvillea X buttiana Holttum & Standley) is a woody, climbing shrub of great ornamental value. The multibracted cultivars with rhodamine purple colour are very attractive and extensively used in the bioaesthetic planning and are planted along the roadsides as dust filters (Sharma *et al.*, 2005; Sharma and Goel, 2006). Its wide adaptability to different agro-climatic conditions and multifarious usage has made this plant very popular in tropical and subtropical regions.The present investigation was planned to study the leaf surface traits of *Bougainvillea* 'Mahara' growing in the area predominantly exposed to particulate pollution and its traits were compared with those of *Terminalia arjuna* (Roxb.) Wt. and Arn, *Cassia fistula* Linn and *Polyalthia longifolia* Thw. The underlying was to interpret whether *B.* 'Mahara' is a mitigator of the particulate pollution as confirmed by the leaf morphology and ultra structural studies rather than the vegetation survey.

MATERIALS & METHODS

The study was carried out in the peri-urban environment of Lucknow, the capital of north Indian state of Uttar Pradesh (India). It has a population of over 2.2 million. The city is situated between 26Ú85'N latitude and 80Ú92'longitude, 120 m above sea level. The climate is warming subtropical and the year can be divided into three seasons: summer, rainy and winter. The temperature range is extreme varying from about 45 °C (113 °F) in the summer to 3 °C (37.4 °F) in the winter. Mean monthly temperatures range between 14.7 °C (January) and 32.9 °C (June). Hot dry wind blowing during the summer carries loads of dust. Annual rainfall is about 101 cm., and it is received mostly from the south-west monsoon winds during July and September. The data for the present paper are recorded for the year 2005-2006.The study area is a centrally located place called 'Sikanderbagh Square' where the particulate pollution is predominant.

Four plant species, namely *Terminalia arjuna* (Roxb.) Wt. and Arn., *Cassia fistula* Linn., *Polyalthia longifolia* Thw. and *Bougainvillea* 'Mahara' were selected for this study, as they were common along roadsides or on the road dividers (polluted site). The control site was the National Botanical Research Institute, Botanic garden campus.Five samples from healthy and mature leaves of each plant were trimmed (5 x 5mm size) from areas between the margin and midrib of leaves collected from the control and polluted sites. Each sample was fixed in FAA (formaldehyde: acetic acid: alcohol; 9:0.5:0.5 v/v), dehydrated in ethanol series and dried in a critical point drier using liquid CO_2. Dried samples were fixed with adhesive tape on aluminium stubs and coated with a thin layer of gold (about 200A°) in an ion sputter coater and examined for the cuticle and epidermal traits under a scanning electron microscope (SEM) (Philips XL-20, The Netherlands).

For the light microscopic (LM) study, leaf samples collected from the control and polluted sites were thoroughly washed with tap water followed by de-ionized water to eliminate dust particles from the leaf surface. Cuticle preparations were made following the replica technique (Yunus *et al.*, 1982). The size and frequency of epidermal cells and stomata, and the length and width of trichomes were observed under light microscope (Leica ATC 2000) and the data are presented in (Table 1).

The methodology followed for collection and measurement of dust load was after Prusty et al. (2005). From each plant fully mature leaf samples from different heights were randomly collected and placed in a beaker and washed thoroughly by a hairbrush with distilled water. This dusty water was then completely evaporated in an oven at 100°C and weighed with an electronic balance (AB 64) to record the total dust quantity trapped. The leaf area (cm^2) was recorded with a leaf area analyzer (Biovis, Mumbai, India).

The amount of dust was calculated following the equation:

$W=(w_2-w_1)$ /n,Where,

W = amount of dust (mg/cm^2), w_1 = initial weight of beaker with dust,

w_2 = final weight of the beaker with dust,

n = total area of the leaf (cm^2).

Particle size and their concentrations in the urban dust used in this experiment were obtained by suspending dust in water (w/v). Samples were

Table1. Comparative analysis of frequency and size of epidermal cells, stomatal frequency & stomatal index

Traits		T. arjuna		C. fistula		P. longifolia		B. 'Mahara'	
		US	LS	US	LS	US	LS	US	LS
Epi. freq. (SD**)	C	77.1±3.9	72.0±3.6	99.0±24.0	67.0±3.1	116±78	89.0±24	71.6±3.6	67.5±3.3
	P	83.0±41	70.2±3.4	116 .0±78	93.0±41.0	130±7.7	95.0±12.3	77.6±3.6	79.1±4.0
Epi. cell size	C	98x72	86x74	79x68	78x57	64x30	59x44	84x67	73x65
	P	82x77	84x69	70x 62	72x48	57x 46	57x49	79x56	64x57
Stom.freq. (SD**)	C	____	24.0±1.7	____	34.0±19.0	____	35.0±1.8	30.1±1.6	42.0± 3.8
	P	____	23.9±1.2	____	36.7±1.8	____	53.9±2.7	32.4±1.6	52.1±2.6
Stom. Size	C	____	34x32	____	34x28	____	34x30	30x24	36x28
	P	____	30x26	____	30x28	____	30x26	27x19	31x23
Stom. Index	C	____	125	____	33	____	26	41	38
	P	____	37	____	27	____	36	29	39

Epi. freq. = epidermal cell frequency, Epi. cell size= epidermal cell size, Stom. Freq. = stomatal frequency, Stom. Ind.=stomatal index, US = Upper Surface, LS = Lower Surface, ** SD = Standard Deviation, C=control, P= polluted

taken while shaking the suspension and mounting them on a slide beneath a cover slip. Measurement was made by calculating the maximum diameter of 100 randomly chosen particles in each of five drops per suspension, with the help of micrometers of the light microscope. The data are presented in (Table 2).

Table 2. Frequency of ultra fine, fine and coarse particles in urban dust (total of 500 particles)

Categories (Particles)	Particle size(µm)	Frequency	Percentage (%)
Ultra fine	≥2.5	79	15.8
Fine	2.5 -	376	75.2
Coarse	10.0	45	9.0
	>10.0		

RESULTS & DISCUSSION

The particulates suspended and re-suspended in the roadside air or originated from the traffic, studied in this work, were up to <2.5 to >10 µm in diameter and were classified into coarse, fine and ultra-fine in nature (Table 2). The dominant class was ultra fine, up to 75.2% and mainly of anthropogenic origin. They may be chemically active or inert (Hirano *et al.,* 1995). They were constituted by either soot (C) or dust Si, Al, Fe, Mg, N, S, Ca, K, Cl) and with minor constituent of Pb, Zn, Ni, V, As, Ti, Cu and Cd and mostly sticky in nature (Tomasevic *et al.,* 2005). These particles were frequently observed on the plant leaves of *T. arjuna, C. fistula, B.* 'Mahara' and *P. longifolia* (Table 3). When they get deposited on the leaf surface, raindrops do not wash them easily.

Table 3. Dust load on leaf surface (mg/cm^2)

S.N.	Plant species	Dust load
1.	*Terminalia arjuna* (Roxb.) Wt. and Arn.	2.31
2.	*Cassia fistula* Linn.	1.47
3.	*Bougainvillea* 'Mahara'	1.33
4.	*Polyalthia longifolia* Thw.	0.97

In the, light and scanning electron microscopic studies, in *T. arjuna*, *C. fistula* and *P. longifolia* leaf surfaces showed withered epicuticular wax (Fig. 1B), ruptured cuticle, de-shaped epidermal cells and also the increased frequency of epidermal cells and stomata in comparison to control plants. *B.* 'Mahara', though growing in the same environment does not show any visible symptoms. It was observed that leaf morphological characters play a major role in the interception of dust load from the ambient air. In addition, Seinfeld and Pandis (1998) reported the deposition of dust dependence on the physical characteristics of the particles such as size, shape and also the morphological characters of leaf surface. Further, these particles are reported to affect stomatal movement, leaf temperature (Borka, 1984), photosynthesis, transpiration, penetration of toxins and also the removal of cuticular wax (Eveling, 1986). The organic hydrocarbons adsorbed onto the particulates containing reactive substances on the plant surfaces may accelerate the degradation of epicuticular wax (Bermadinger *et al.,* 1988; Finlayson-Pitts and Finlayson, 1989).

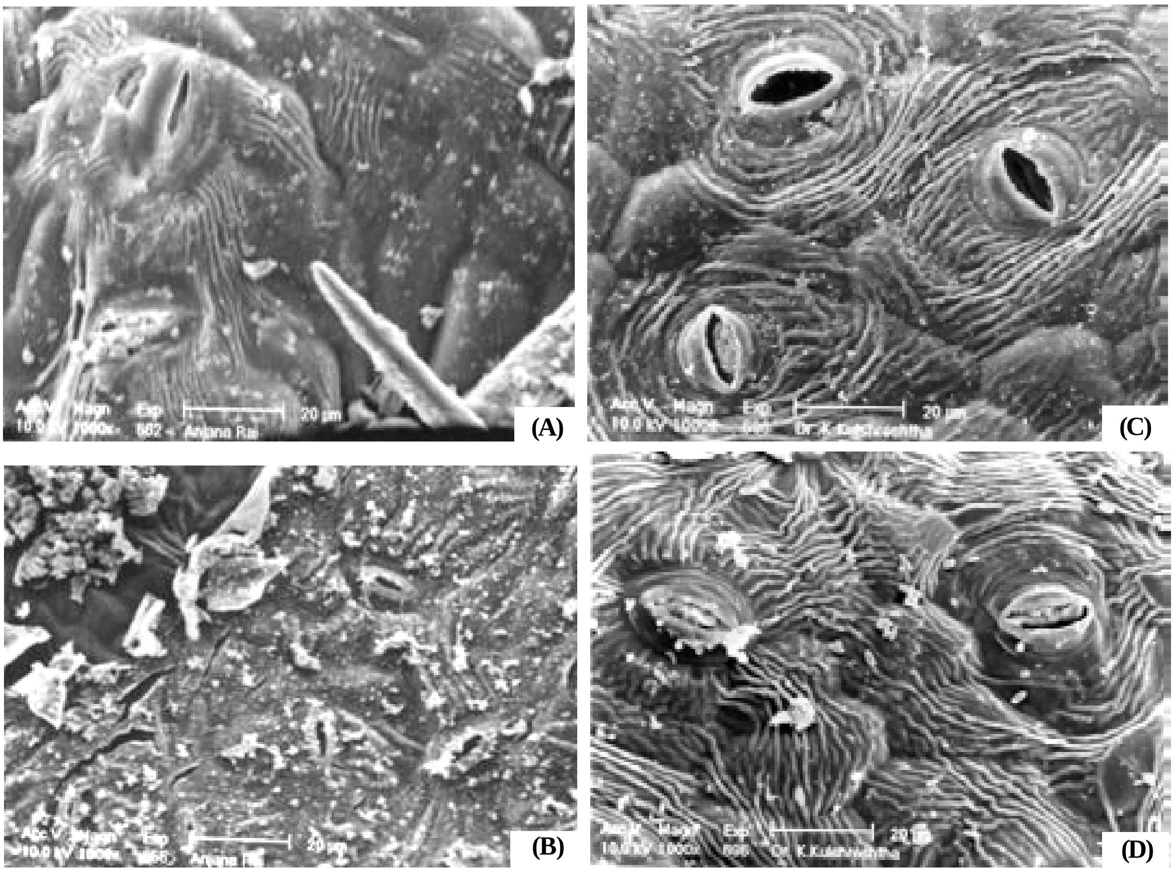

Fig. 1. Scanning electron microphotographs of leaf surfaces (A) *T. arjuna* (control) smooth surface, (B) *T. arjuna* (polluted) damaged surface (C) *P. longifolia* (control) showing striations (D) *P.longifolia*. (polluted) showing slightly wrinkled striations

Levels of pollution tolerance may vary from species to species, depending on the capacity of plants to withstand the effect of pollutants without showing any external damage. The air pollution tolerance index (APTI) of *Bougainvillea* spp. was also recorded higher in some of the earlier studies (Shannigrahi *et al.,* 2004). *B.* 'Mahara' is a drought tolerant and hardy plant, which tolerates also pollution stress. The leaves may act as persistent absorbers in the polluted environment and they act as pollution receptors and therefore reduce the dust concentration of the air. This particular capacity of plant leaves as dust receptors reported to be dependent of their surface geometry, phyllotaxy, epidermal and cuticular features, leaf pubescence and height and canopy of trees (Neinhuis and Barthlott, 1988). In all the four plants studied the trend of dust trapping among the species (from higher to lower) was *T. arjuna* (2.31mg/cm^2) >*C. fistula* (1.47mg/cm^2) >*B.* 'Mahara' (1.33mg/cm^2) >*P. longifolia* (0.97mg/cm^2) The cuticular damage raised the sensitivity (Fig 1B) and the frequency of epidermal cells and stomata was recorded high in comparison to control plants (Table 1). However, in *B.* Mahara the cuticle was smooth with no injury symptoms (Fig 2C & D). The dust made the epidermal cells collapsed in *C. fistula* (Fig 2B) and degraded epicuticular wax blooms were noticed in *T. arjuna* (Fig 1B).

Varshney and Mitra (1993) assessed the particulate abatement capacity (PAC) of three commonly grown hedge species, *Bougainvillea spectabilis* Willd., *Duranta plumieri* Jacq. and *Nerium indicum* Mill. The PAC of species was found in order of *D. plumieri* >*B. sectabilis* >*N. indicum*. They also concluded that the row of roadside hedges trapped nearly 40% of particulate matter, most of which arises from the traffic movement. The dust filtering ability of the plant species was directly correlated with foliar surface characteristics. As reported by Musselman (1988), in stressed conditions, damage to the plant tissue first appears in epidermal cells, which can collapse,

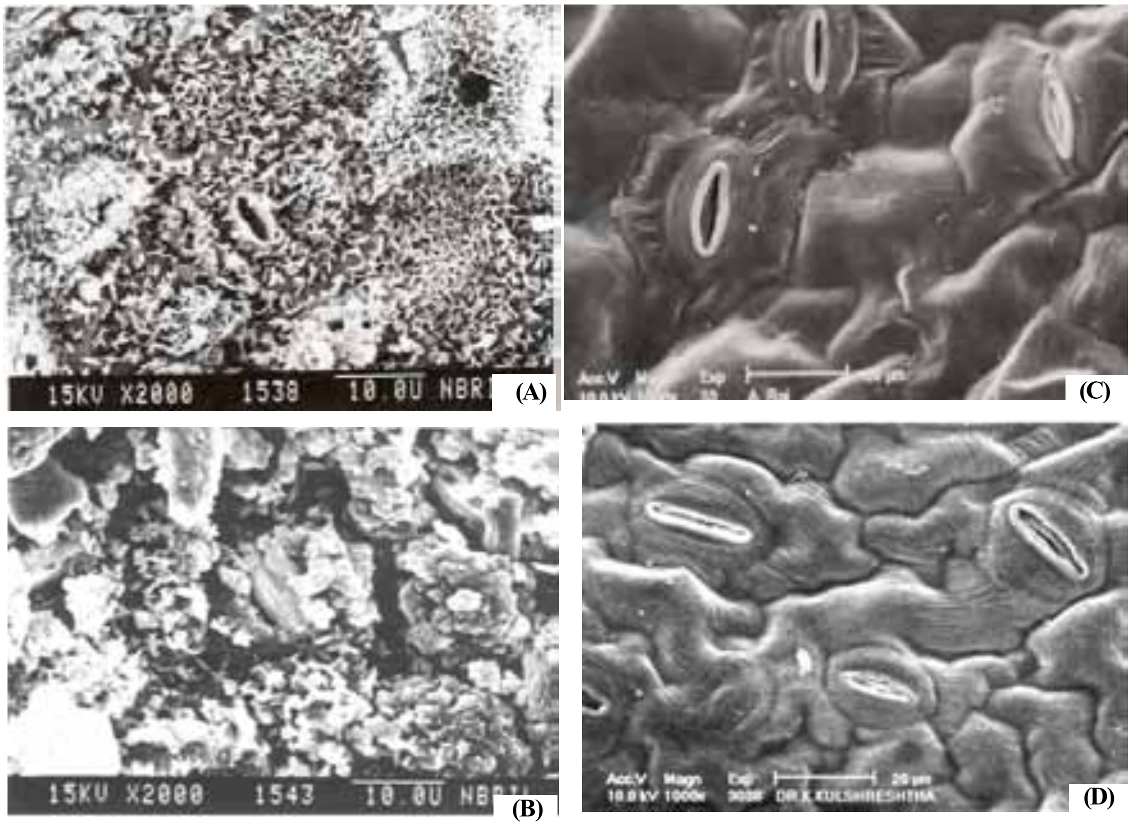

Fig. 2. Scanning electron microphotographs of leaf surfaces (A) *C. fistula* (control). showing waxy cuticle with open stomata, (B) *C. fistula*.(polluted) showing deformed wax and closed stomata, (C) *B.* 'Mahara' .(control) showing smooth cuticle with healthy epidermal cells, (D) *B.* 'Mahara' (polluted) showing slightly striated epidermal cells

reduce in size and further increase in their numbers in the absence of any obvious damage to the cuticle. Unlike other plants, *B.* 'Mahara' does not show any cuticular damage (Fig 2 C & D), and hence it may be called as mitigator.

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CONCLUSION

The present study reveals that the sticky particulate matter emitted from the automobile exhausts is the major constituent of particulate pollution, which is deposited on the leaf surface of common roadside plants. Among the investigated plant species the amount of particulate deposition order is *T. arjuna* (2.31 mg/cm^2)> *C. fistula* (1.47 mg/cm^2) > *B.* 'Mahara' (1.33 mg/cm^2) > *P. longifolia* (0.97 mg/cm^2). These plants have shown characteristic cuticle injury and increase in the epidermal cell and stomata size and frequency. In *B.* 'Mahara' no visible symptoms were noticed. This cultivar can be recommended for plantation in urban and industrial areas where particulate is a problem. Being well adapted to different growing techniques, this can be planted in traffic island, central verge and various other ways. In addition, *B*. 'Mahara' is a recurrent bloomer and having bright colourful bracts, which will add colour to the landscape besides mitigating pollution.

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