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Air pollution tolerance, dust capturing capacity of native tropical trees for green belt development in Dhanbad and Bokaro city, Jharkhand, India

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The study has been conducted in two cities of Jharkhand, namely Dhanbad and Bokaro. We examine Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of native trees and identify the tolerant species for green belt development. Dust capturing capacity (DCC) was also evaluated. Leaves were sampled in winter for its calm and stable weather with less or no rainfall. The APTI trend of plants growing in Dhanbad were as *M. indica* > *A. indica* > *H. rosa-sinesis* > *P. guajava* > *T. divaricate* > *C. procera* > *F. bengalensis* > *A. scholaris* > *S. asoca*. While in Bokaro, APTI trend were *H. rosa-sinesis* > *C. procera* > *M. indica* > *A. indica* > *A. scholaris* > *F. religiosa* > *T. divaricate* > *F. bengalensis* > *S. asoca*. *S. asoca* had the lowest APTI in both the cities. Further, API was also evaluated, to recognize a plants' ability to abate pollution from a holistic perspective. In Dhanbad, the API trend was as, *M. indica* (6) > *F. bengalensis* = *F. religiosa* (4). Similar trends were observed in Bokaro, *M. indica* = *F. bengalensis* (4) > *F. religiosa* (3) and control site, *M. indica* (5) > *F. bengalensis* = *F. religiosa* (4) as well. Trees can absorb and trap numerous dust particles more efficiently. The maximum DCC was found in order of *A. indica* > *M. indica* > *C. procera* > *P. guajava* > *F. bengalensis* = *T. divaricate* > *S. asoca* > *H. rosa-sinesis* = *F. religiosa* > *A. scholaris* in Dhanbad, while in Bokaro the trend was *M. indica* > *A. indica* > *C. procera* > *S. asoca* > *P. guajava* = *T. divaricate* > *F. religiosa* > *F. bengalensis* > *H. rosa-sinesis* > *A. scholaris*. *A. scholaris* had the lowest DCC in both the cities. This could be due to larger rough surface area of *M. indica* retaining higher dust volume compared to relatively smoother and waxy surface of *A. scholaris,* which is unable to capture substantial dust.

Keywords: Air pollution tolerance Index, anticipated performance index, dust capturing capacity, field emission scanning electron microscope.

Introduction

Air pollution is of great concern in urban areas of developing countries. Uncontrolled industrialization and rapid urbanization cause serious problems, due to the inadequate emission controls and inefficient environmental regulations[1]. Air pollutants are a threat to the health of both human and environment. The major factors are, intense population growth and industrialization[2]. They lead to elevated concentrations of heavy metals both in soil and atmosphere[3]. Natural and anthropogenic processes help in circulating metals in the environment. Natural processes involve mobilization from rock, volcanic eruptions, forest fires, evaporation from oceansand soil formation[4,5]. Urban sources may be derived from motor oil, rubber tire wear, electroplating industries, auto workshop and gasoline combustion[6].

Biomonitoring, is an eco-reliable alternative to the conventional air monitoring methods[7,5]. Its tangible experimental designs and multiple sampling locations balances the lower precision of separate single measurements[8]. Plants can act as natural air quality bio-monitors by reducing detrimental effects of toxic metals[5]. Trace elements are transferred from abiotic to biotic environment[9,10] by them. Hence, they can accumulate potentially toxic substances[11]. The concentrations of heavy metals in air is strongly related to that in plants[4]. Soil acidification determines the concentration of heavy metals in plants, while their root uptake is linked with metals bioavailability in soil or leaf surfaces[6]. Leaves of plants are a potential environmental sink for air pollutants[12]. Hence, planting the tolerant variety can help in efficient green belt development, aturban settlements[13], which will also improve the prevailing air quality[14,9].

Air Pollution Tolerance Index (APTI) is a good tool to select bioindicator species[6]. Species scoring APTI values towards the higher end are the tolerant species, which has higher capacity to withstand polluted environments. These can be suggested for sustainable green belt development. While, those scoring low APTI values are more sensitive species hence can act as bioindicator species of air pollution. Further, the API, accounts in various biochemical and socio-economic parameters of a particular plant together, providing a holistic approach[15].

Materials and methods

(A) Study area:

Jharkhand has abundant plant diversity, owing to its rich forest area. The study has been conducted in two air polluted cities of Jharkhand, namely Dhanbad, Bokaro and control site, BIT Mesra, Ranchi (Fig. 1). Dhanbad, also known as Coal Capital of India is famous for its mining activities, while Bokaro has abundant steel industries. The control site

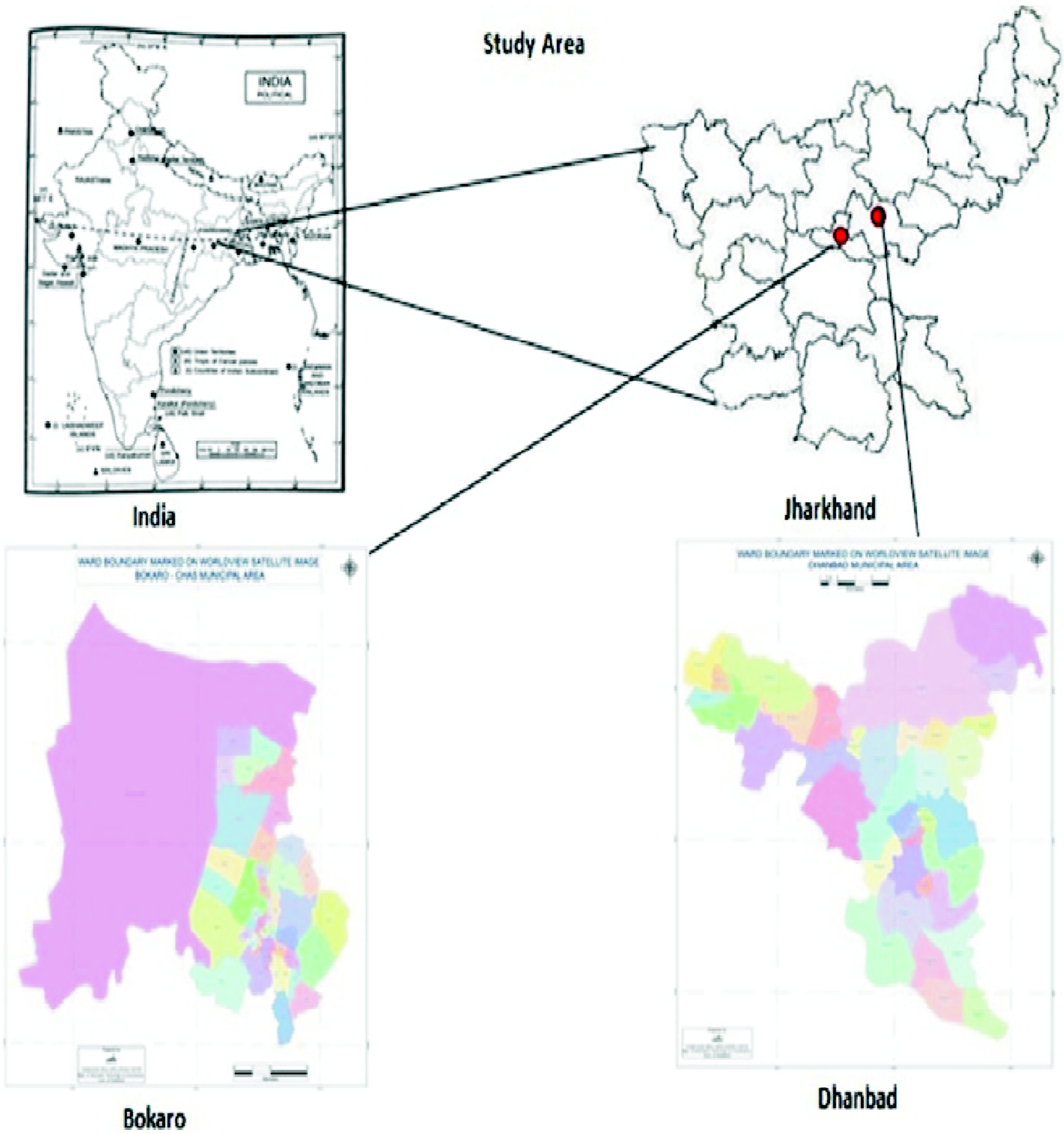

Fig. 1. Study area.

is remotely situated, undisturbed with industrial or vehicular pollution. It has large governmental forest areas within the campus, and is surrounded by cultivational lands cropped by rural people. This study examines selection of individual species having the highest potential to withstand polluted environment. These can be highly recommended to grow around such areas. Aim of this study is to examine APTI of native tree species and identify the most tolerant variety, for the development of green belt. The results from this study can be applicable over similar tropical countries, offering a wider scope of application,

(B) Preparation of sample:

Fresh leaves of different species were collected from five directions (north, south, east, west, center) in the cities of Bokaro, Dhanbad and Ranchi (control site), in the winter season due to stable atmospheric conditions. Leaves were plucked carefully, ensuring less loss of their surficial dust. They were collected in early morning time and secured in zipbags.

(C) Experimental studies:

(C.1) Ascorbic acid:

Ascorbic acid was measured using modified colorimetric 2,6-dichlorophenol indophenol method[16]. 1 g sample was extracted in 4% oxalic acid (titrating medium) and volume made upto 20 ml. It was centrifuged for 5 min at 4500 rpm. 5 ml supernatant was pipetted out to which 10 ml oxalic acid was added and titrated against the dye. End point of titration was pink color appearance.

$$AA\left(\frac{mg}{g}\right) = (0.5 \times V_2 \times 20)/(V_1 \times 5 \times W) \quad (1)$$

where,

V_1 = volume of dye titrated against working standard

V_2 = volume of dye titrated against sample

W = weight of sample

(C.2) pH:

Leaf of 1 g was ground to paste, using 50 ml deionized water and filtered to measure pH. Digital pH meter (Hanna Instruments) was calibrated using buffer solutions of pH 4 and 9 respectively, before taking the measurements.

(C.3) Total chlorophyll:

Total chlorophyll content was measured by spectrophotometric method[17]. 1 g fresh leaf was crushed and transferred into a centrifuge tube. To this acetone (80% concentration) of 30 ml was added, and kept for 15 min. This ensured complete extraction of chlorophyll. The tubes were centrifuged for 5 min at 4500 rpm and the supernatant's absorbance measured at 645 nm and 663 nm, using UV Spectrophotometer (Shimadzu corp. UV-1800).

$$TCH\left(\frac{mg}{g}\right) = [(20.2 \times A_{645} + 8.02 \times A_{663}) \times V]/(1000 \times W) \quad (2)$$

where, A_{645} = absorbance at 645 nm, A_{663} = absorbance at 663 nm, V = extract volume in ml, W = weight of leaf in gram.

(C.4) Relative Water Content:

Freshly plucked leaves were weighed to record their fresh weights. Respective turgid weights were recorded by immersing them overnight in deionized water, and their dry weights were obtained by drying at 105°C for 3 h[18].

$$RWC\ (\%) = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100 \quad (3)$$

(C.5) Air Pollution Tolerance Index:

APTI was calculated as per Singh and Rao (1983)

$$APTI = [A \times (T + P) + R]/10 \quad (4)$$

where, A = ascorbic acid, T = total chlorophyll, P = pH of leaf extract, R = relative water content. The categories of APTI are given in Table 1.

(C.6) Anticipated Performance Index:

The performance of plant species is indicated by its API, which is influenced by plant habit, canopy structure, biochemical characteristic economic and socioeconomic values and APTI[2]. The percentage scoring for API grade is given as:

$$API(\%) = \left(\text{Total}\frac{\text{Positives}}{16}\right) \times 100 \quad (5)$$

Maximum 16 grades[15] are allotted to a plant. The specific API scores can help in detecting the highly suitable species for green belt expansion in any urban area.

Table 1. Gradation of plant species based on Air Pollution Tolerance Index, morphological parameters and socio-economic importance

Grading character		Assessment pattern	Grade allotted
1. Tolerance	Air Pollution Tolerance Index	7.0–8.0	+
		8.1–10.0	++
		10.2–11.0	+++
		11.1–12.0	++++
		12.1–13.0	+++++
2. Biological and socio-economic	(i) Plant habit	Small	–
		Medium	+
		Large	++
	(ii) Canopy structure	Sparse/Irregular/Globular	–
		Spreading crown/open/semi-dense	+
		Spreading dense	++
	(iii) Type of plant	Deciduous	–
		Evergreen	+
	(iv) Laminar structure		
	Size		
		Small	–
		Medium	+
		Large	++
	Texture	Smooth	–
		Coriaceous	+
	Hardiness	Delineate	–
		Hardy	+
	(v) Economic value	Less than three uses	–
		Three or four uses	+
		Five or more uses	++

(C.7) Dust Capturing Capacity (DCC):

Oven dried filter papers were weighed to record their initial weight (D1). The leaf dust was washed using de-ionised water and brush. Water containing dust was passed through pre-weighed filter papers. These were dried at (85°C for 4 h) and their final weights recorded as D2. Leaf surface area was calculated by plotting their outlines on graph sheets (S). Calculation was done as given below[19]:

$$\mathrm{DCC}\left(\frac{\mathrm{mg}}{\mathrm{cm}^2}\right) = (\mathrm{D2} - \mathrm{D1})/\mathrm{S} \qquad (6)$$

(C.8) Field Emission Scanning Emission Spectroscopy (FESEM):

The surface morphology images were detected at different magnification levels by Field Emission Scanning Electron Microscopy (FESEM) using Sigma 300 with EDAX (Ametek).

(C.9) Quality Control and Assurance:

All analysis were carried out in triplicates and the average data reported. Analytical grade reagent and standards were used for chemical analysis. Wherever, standard curves were used their regression coefficients were 0.99.

Results and discussion

Various grades are allotted to plants based on their grading character and assessment patterns[15] (Table 1). Further depending on their scorings, they have different API[15] (Table 2). The APTI of the plants, for Bokaro and Dhanbad was assessed in the winter season. The lowest APTI values in both the cities was that of *Saraca asoca*, while the highest

Table 2. Anticipated Performance Index of plant species

Grade	% Score	Assessment category
0	Upto 30	Not recommended
1	31–40	Very poor
2	41–50	Poor
3	51–60	Moderate
4	61–70	Good
5	71–80	Very good
6	81–90	Excellent
7	91–100	Best

was in *Hibiscus rosa-sinesis* and *Mangifera indica* at Bokaro and Dhanbad respectively (Table 3). Among all other APTI parameters, a significant correlation of the RWC values with that of APTI was found (Table 4). In Bokaro, it was 0.94, while in Dhanbad it was 0.99. The variation in the individual parameters of APTI for all the species is shown in Fig. 2. Overall, the API values (Table 5) were highest for *Mangifera indica* in all the cities including control, indicating it to be the most tolerant among the studied species.

Dust or particulate matter are the most fastest growing air pollutants causing serious problems[20]. Trees help in absorbing and trapping air pollutants. Their dust capturing capacity is dependent on plant height, density, size, age and area of leaves, canopy structure, leaf inclination, and external character such as cuticle hair and cuticle[21]. Dust interception on plants also depends on orientation of leaf and its sessile or semi sessile nature. Leaves with larger petioles can move easily by minor air movement, and hence hold lesser dust. Dust retention also depends upon the foliar morphology, leaf area and the characteristics of the structure

Table 3. APTI and its parameters in Bokaro and Dhanbad

	Ascorbic acid	pH	Total chlorophyll	Relative water content (%)	Air Pollution Tolerance Index
Bokaro					
Calotropis procera	0.57±0.20	7.75±1.12	1.04±0.61	80.59±6.18	8.56
Hibiscus rosa-sinesis	1.00±0.75	6.93±0.37	1.28±0.68	77.71±8.03	8.59
Saraca asoca	0.46±0.26	7.43±0.99	1.64±0.60	59.04±22.17	6.32
Ficus bengalensis	0.46±0.13	8.04±1.03	1.64±0.32	63.61±11.32	6.75
Psidium guajava	1.06±0.64	7.40±0.74	1.45±0.41	70.15±16.46	7.95
Mangifera indica	1.20±0.82	6.62±0.73	2.06±0.55	72.25±17.70	8.26
Azadirachta indica	0.73±0.09	7.43±0.98	1.67±0.29	72.53±6.99	7.91
Ficus religiosa	0.49±0.33	8.17±1.25	1.54±0.71	69.7±15.05	7.44
Alstonia scholaris	0.88±0.51	5.43±1.33	0.91±0.34	72.25±11.19	7.78
Tabernaemontana divaricata	0.23±0.02	6.71±0.38	0.84±0.23	70.23±10.54	7.19
Dhanbad					
	Ascorbic acid	pH	Total chlorophyll	Relative water content (%)	Air Pollution Tolerance Index
Calotropis procera	0.20±0.02	7.46±1.93	1.07±0.44	76.26±4.21	7.79
Hibiscus rosa-sinesis	0.26±0.09	8.48±0.47	1.47±0.23	83.18±11.04	8.57
Saraca asoca	0.23±0.06	6.69±1.49	2.20±0.25	69.07±9.55	7.11
Ficus bengalensis	0.23±0.08	6.89±1.25	1.78±0.53	72.22±8.12	7.42
Psidium guajava	0.22±0.05	6.49±1.14	1.45±0.56	78.65±21.81	8.03
Mangifera indica	0.30±0.12	5.13±0.85	1.15±0.71	110.65±30.54	11.25
Azadirachta indica	0.24±0.04	7.27±2.16	1.37±0.29	88.16±17.17	9.02
Ficus religiosa	0.23±0.04	7.99±1.40	1.86±0.57	81.51±16.40	8.37
Alstonia scholaris	0.24±0.12	7.41±2.31	1.19±0.72	70.39±13.45	7.24
Tabernaemontana divaricata	0.30±0	8.59±0.70	1.47±1.00	76.18±13.61	7.91

<10: Sensitive species (S), 10-16: Intermediate species (I), 17-30: Moderately tolerant species (MT), >30: Tolerant species (T)

Table 4. Correlation of APTI parameters with APTI in Bokaro and Dhanbad

	A	P	T	R	APTI
Bokaro					
A	1				
P	–0.3965	1			
T	0.5081	0.0163	1		
R	0.3788	–0.2039	0.0164	1	
APTI	0.6552	–0.2300	0.2389	0.9419	1
Dhanbad					
	A	P	T	R	APTI
A	1				
P	–0.0434	1			
T	–0.1791	0.1026	1		
R	0.5583	–0.5131	–0.4266	1	
APTI	0.5806	–0.4908	–0.4221	0.99945	1

(surface roughness, leaf shape, presence of trichomes present in the upper and lower epidermis).

The surface morphology of the selected leaf species was studied by FESEM (Field Emission Scanning Electron Microscope) (Fig. 3). The dust capturing capacity is both dependent on dust load and leaf surface area along with its morphology. Increased dust loads in a particular area can result in higher DCC, even on a smooth leaf surface. The maximum DCC was recorded in Table 6 *M. indica* and *A. indica* in both the cities. The trend followed in Dhanbad was:- *A. indica* (2.21 mg/cm^2) > *M. indica* (1.22 mg/cm^2) > *C. procera* (0.88 mg/cm^2) > *P. guajava* (0.58 mg/cm^2) > *F. bengalensis* = *T. divaricate* (0.42 mg/cm^2) > *S. asoca* (0.33 mg/cm^2) > *H. rosa-sinesis* = *F. religiosa* (0.18 mg/cm^2) > *A.*

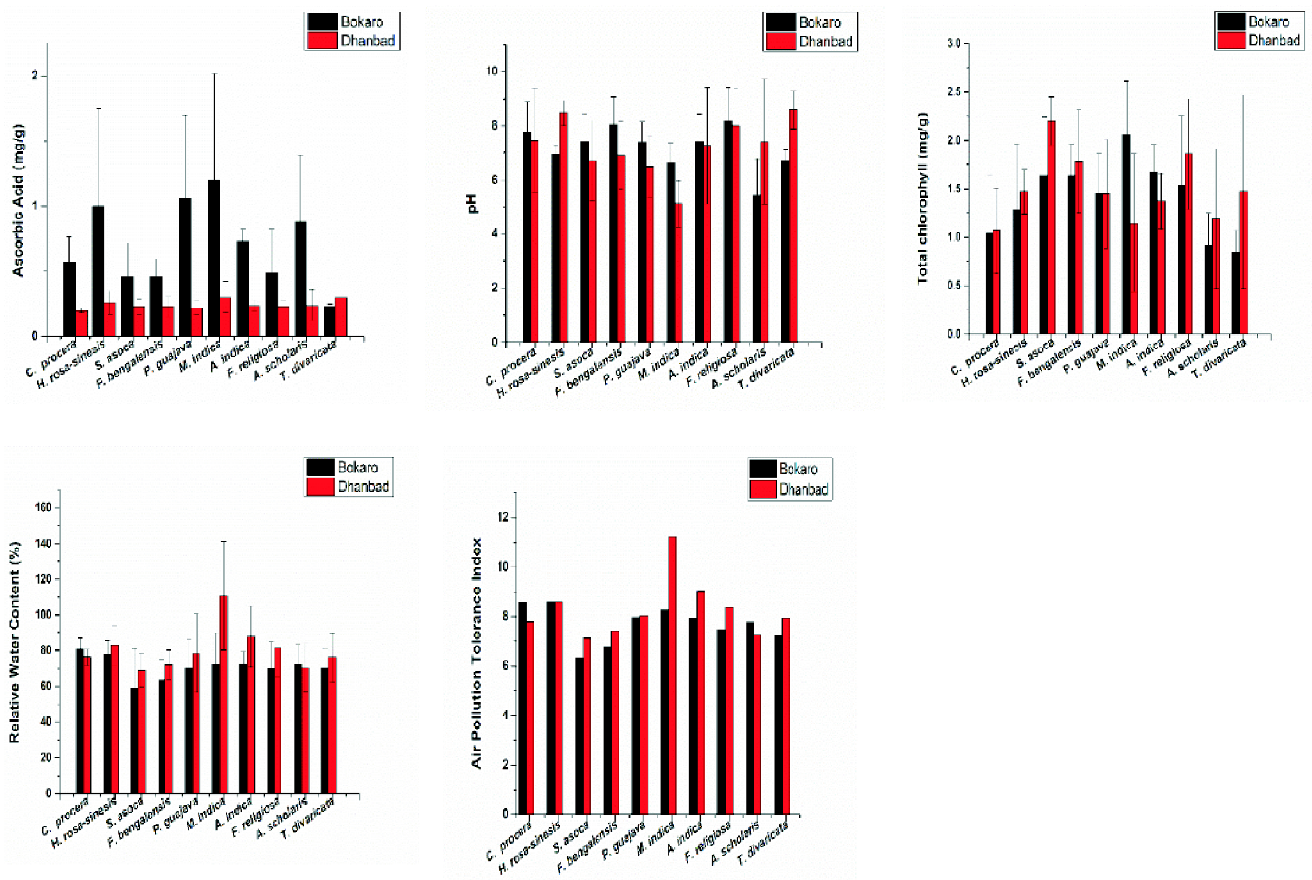

Fig. 2. Ascorbic acid, pH, total chlorophyll and relative water content of leaf samples, in Bokaro and Dhanbad for winter season.

Table 5. API grades in various plants of study and control sites

Scientific name	APTI	Plant height	Canopy structure	Plant type	Size	Texture	Hardiness	Economic value	Total positives	% scoring	API grade
					Bokaro						
A. indica	+	++	+	+	+	–	–	++	8	50.00	2
A. scholaris	+	+	–	+	–	+	+	+	6	37.50	1
C. procera	++	+	–	+	–	+	–	+	6	37.50	1
F. bengalensis	+	++	++	+	++	–	+	+	10	62.50	4
F. religiosa	+	+	++	+	+	+	+	+	9	56.25	3
H. rosa-sinesis	++	+	+	+	+	–	+	+	8	50.00	2
M. indica	++	+	+	+	++	+	+	++	11	68.75	4
P. guajava	+	+	+	+	–	+	–	+	6	37.50	1
S. asoca	+	+	–	+	+	–	–	+	5	31.25	1
T. divaricata	+	+	+	+	+	+	+	+	8	50.00	2
					Dhanbad						
A. indica	++	+	+	+	+	–	–	++	8	50.00	2
A. scholaris	+	+	–	+	–	+	+	+	6	37.50	1
C. procera	+	+	–	+	–	+	–	+	5	31.25	1
F. bengalensis	+	++	++	+	++	–	+	+	10	62.50	4
F. religiosa	++	+	++	+	+	+	+	+	10	62.50	4
H. rosa-sinesis	++	+	+	+	+	–	+	+	8	50.00	2
M. indica	++++	+	+	+	++	+	+	++	13	81.25	6
P. guajava	++	+	+	+	–	+	–	+	6	37.50	1
S. asoca	+	+	–	+	+	–	–	+	5	31.25	1
T. divaricata	+	+	+	+	+	+	+	+	8	50.00	2
					Control						
A. indica	+++	+	+	+	+	–	–	++	9	56.25	3
A. scholaris	+++	+	–	+	–	+	+	+	8	50.00	2
C. procera	+	+	–	+	–	+	–	+	5	37.50	1
F. bengalensis	+++	++	++	+	+	–	+	+	11	68.75	4
F. religiosa	+++	+	++	+	+	+	+	+	11	68.75	4
H. rosa-sinesis	++	+	+	+	+	–	+	+	8	50.00	2
M. indica	+++	+	+	+	++	+	+	++	12	75.00	5
P. guajava	+++	+	+	+	–	+	–	+	8	50.00	2
S. asoca	++	+	–	+	+	–	–	+	6	37.50	1
T. divaricata	+	+	+	+	+	+	+	+	8	50.00	2

scholaris (0.09 mg/cm^2). Similar trend was also seen in Bokaro, with only minor fluctuations. Here the trend was *M. indica* (1.35 mg/cm^2) > *A. indica* (1.28 mg/cm^2) > *C. procera* (0.75 mg/cm^2) > *S. asoca* (0.62 mg/cm^2) > *P. guajava* (0.45 mg/cm^2) = *T. divaricate* > *F. religiosa* (0.41 mg/cm^2) > *F. bengalensis* (0.36 mg/cm^2) > *H. rosa-sinesis* (0.21 mg/cm^2) > *A. scholaris* (0.08 mg/cm^2).

Conclusion

The study has identified common tropical tree species which have higher air pollution tolerance and dust capturing capacities. Bio-monitoring and bio-indicating abilities were assessed by evaluating their APTI values. Both Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API), followed a similar trend. Those scoring the highest

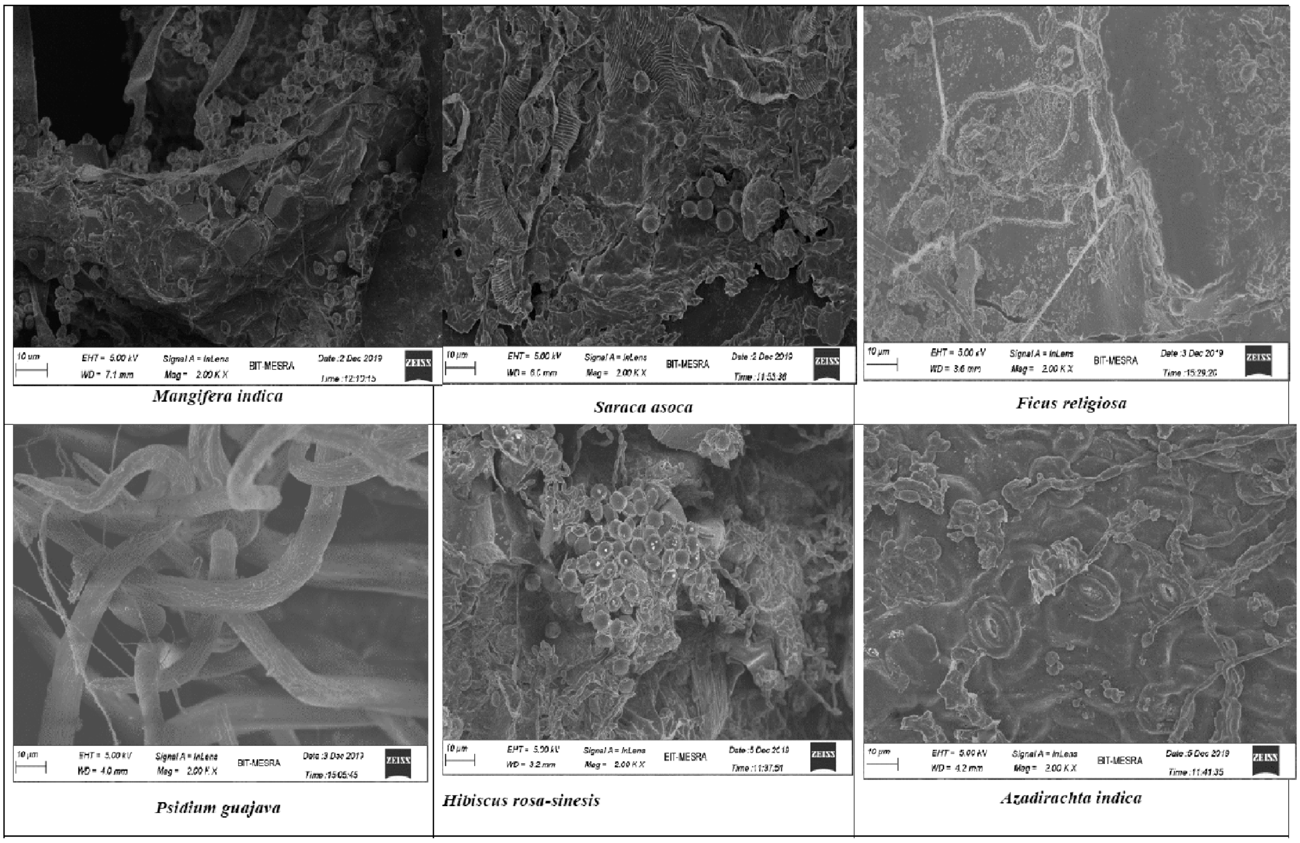

Fig. 3. FESEM images of selected leaf samples.

Table 6. Dust capturing capacities (DCC) mg/cm^2 of two cities and control site

Species	Bokaro	Dhanbad	Control
Calotropis procera	0.75±0.44	0.88±0.27	0.78±0.32
Hibiscus rosa-sinesis	0.21±0.15	0.18±0.10	0.16±0.06
Saraca asoca	0.62±0.55	0.33±0.17	0.49±0.24
Ficus bengalensis	0.36±0.13	0.42±0.18	0.25±0.14
Psidium guajava	0.45±0.40	0.58±0.39	0.33±0.13
Mangifera indica	1.35±0.73	1.22±0.10	0.33±0.10
Azadirachta indica	1.28±1.17	2.21±0.98	0.23±0.07
Ficus religiosa	0.41±0.26	0.18±0.10	0.25±0.14
Alstonia scholaris	0.08±0.03	0.09±0.07	0.07±0.04
Tabernaemontana divaricata	0.45±0.05	0.42±0.25	0.32±0.12

API, can be suggested for plantation, not only from view of green-belt development, but also for social forestry. In general, *M. indica* and *A. indica* had higher DCC and APTI in both the cities. Hence, plantation of these trees in heavily polluted areas is suggested for a sustainable environment.

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