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Evaluating the Tolerance and Dust Capturing Capacity of Tree Species Affected by Coal Dust Polluted Area

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ABSTRACT

The air pollution tolerance index (APTI) of any plant shows the tolerance capacity of plant against the air pollution. The present study exhibited the APTI and API of twenty-two trees present on the roadside coal dust-affected air pollution area of Chhal, Raigarh. APTI consists of the analysis of leaf extract pH, relative water content, total chlorophyll content, and ascorbic acid of leaves while the API consists of the APTI values of trees, morphological characteristics, and socio-economic attributes of trees. The leaf extract pH was observed to range from 6.61±0.11 - 3.28±0.11, relative water content from 95.4±0.4 - 83±0.89 %, total chlorophyll content from 1.16±0.06 - 0.385±0.04 mg g^{-1} and ascorbic acid from 30.54±0.67 - 10.61±0.84 mg g^{-1}. The highest APTI was 30.88±0.75 for *Tectona grandis* while the lowest was observed 15.58±0.54 for *Alstonia scholaris.* The highest API value 93.75% for *Shorea robusta* and *Ficus religiosa* was observed. The maximum dust held by a tree on the leaf surface by *Shorea robusta* (3.18±0.09 mg cm^{-2}) was recorded. *Shorea robusta, Mangifera indica, Schleichera oleosa, Terminalia ballerica, Ficus benghalensis, Anthocephalus cadamba, Ficus religiosa, Peltophorum pterocarpum, Madhuca indica,* and *Terminalia tomentosa* are best performers among the selected tree species and suitable for the plantation of trees surrounding of air polluted zones.

INTRODUCTION

Urban air pollution is an ongoing problem that affects the country that is developing as well as developed, exerting a negative impact on the ecosystem (Rai et al. 2013). The concentration of gaseous and particle pollution appears to have increased over the last several decades due to continued growth in the human population, vehicle traffic, and industry (Krishnaveni & Lavanya 2014). Transportation plays the monster in air pollution (Sharma et al. 2017). India ranks third in the world for having worse air quality. Worldwide, it emits almost 305.3 MtCO$_2$, which is 0.64 percent of total GHG emissions. Only 5% of heavy-duty vehicles in India still account for 71% of the nation's CO$_2$ emissions and 74% of its particulate matter (https://www.ceew.in/cef/quick-reads/explains/vehicular-emissions-in-india). There is plenty of research on the initial impact of industrialized and urbanized emissions on human health (Singh et al. 2018). No mechanical or chemical technique exists that can completely obstruct pollutants that are emitted at the source. The discharge of contaminants into the atmosphere and the degradation of air quality around roadsides have an impact on the morphology and biochemical parameters of the plants (Kaur & Nagpal 2017). As plants are the main pollution receptors, they are often employed for analysis (Rai et al. 2013). Plants are essential for enhancing air quality because they absorb gases and particulates (Kaur & Nagpal 2017). Additionally, plants scavenge a variety of airborne particles in the environment (Sharma et al. 2019).

The inherent quality of plants to tolerate air pollution is called the air pollution tolerance index (APTI) and may assist in choosing the kinds of trees to be planted near or around polluted zones.

Plant species with greater APTI values that are tolerant seem to be buffers, whereas species with a smaller value might be useful for biomonitoring (Sahu et al. 2020). Uka et al. (2019) classified plants into different categories based on their APTI value i.e., tolerant (>17), intermediate (12-16), and sensitive (<12). This statistic might be used to grow trees in various polluted locations so they are capable of encountering air pollution (Kumari & Deswal 2017). While assessing plant responses against air pollution for green belt development may not be appropriate with a single physiological parameter estimate, the complex combination of APTI and API may have substantial implications (Ogunkunle et al. 2015). An API value can provide a reasonable answer for expanding the green belt, planting trees, and restoration because it consists of the ecological and socioeconomic characteristics of the tree species as well as APTI values (Sahu & Sahu 2015, Bora & Josi 2014). Yadav & Pandey (2020) examined the APTI and API values of several trees to choose tolerant plants that would be good for the growth of greenery in Bhatinda city's regions impacted by air pollution from traffic and industry. To suggest tolerant plants for landscaping, Sharma et al. (2019) looked at the APTI of a selection of tree species that were found alongside the National Highway-5 Solan. Trees perform as a significant pollution absorber; they are the most effective at capturing and absorbing a wide range of particulates. Plant height, density, size, age, leaf area, canopy structure, leaf inclination, exterior characteristics, and climatic conditions all affect a plant's ability to accumulate dust (Roy et al. 2020).

Raigarh is famous for several coal mines and thermal power plants and the extraction of coal from mine expansion increasing day by day. The coal used by many industries such as iron melting and thermal power plants and trucks and railways are the main transportation sources used to transport coal from mines to industries. Transportation of coal through heavy trucks produces coal dust air pollution on the roadside and the surrounding environment. Wide ranges of tree species are present on the roadside either planted or naturally. They provide a barrier to the expansion of air pollution by trapping air pollutants on the leaf surface. This study examined the tolerance capacity of trees against coal dust air pollutants around the roadside of SH-18 near Chhal, Raigarh. Chhal is famous for its open-cast coal mine project. The forests of the area are tropical, moist, and dry deciduous types of forests. Many tree species are highly beneficial for rural livelihood; they include mahua flowers, mahua seeds, kusum seeds, tendu leaves, sal seeds, char seeds, and amchur which are collected from the surrounding forest.

MATERIALS AND METHODS

The study was conducted along the roadside of State Highway-18, Chhal (India), situated at latitude 22.1105858° N and longitude 83.1222833° E (Fig. 1). The climate of the study area in the summer is much warmer (45°C–50°C), and in the winter is much colder (11°C–20°C), with 1225 mm of rainfall over a year.

Twenty-two tree species were selected, which frequently occurred along the roadway (Table 1). Tree species were selected based on abundance in the area, socioeconomic significance to the local populace, and ease of sample collection. The morphology of the tree (tree height, diameter, age) was also observed. The sampling was done from July to October 2022. Freshly, green mature leaves of trees

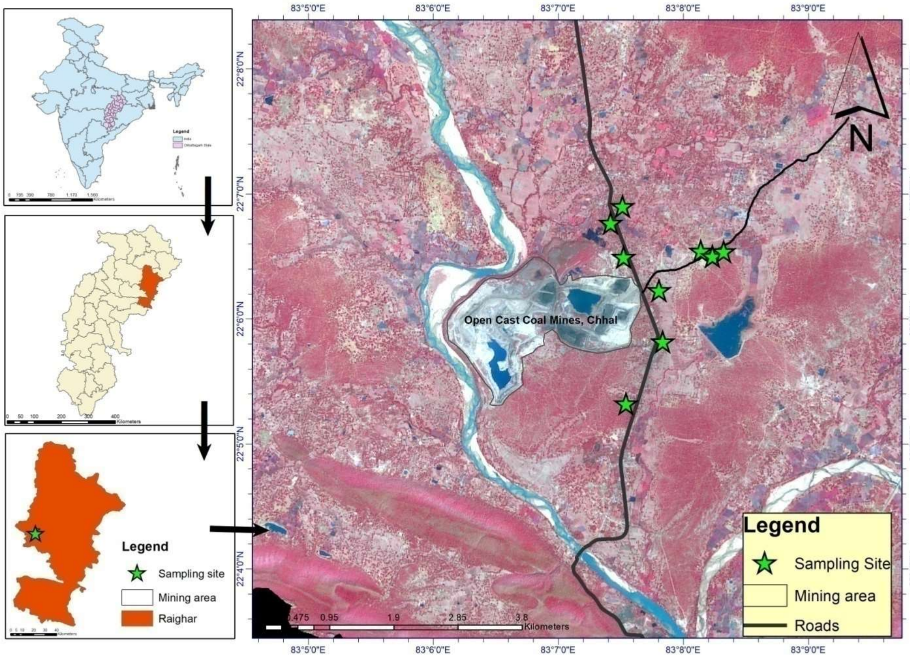

Fig. 1: Map of the study area.

Table 1: Description of tree species.

Sn	Tree species	Family	Description of tree
1	*Shorea robusta*	Depterocarpaceae	*Sal* is a semi-deciduous woody tree
2	*Bombax ceiba*	Malavaceae	*Semul* extremely large, tropical deciduous tree.
3	*Mangifera indica*	Anacardiaceae	*Mango* is a large, erect-bunch nature, evergreen fruit tree.
4	*Alstonia scholaris*	Apocynaceae	*Satparni* is an evergreen glabrous tree.
5	*Millettia pinnata*	Fabaceae	*Karanj* is a medium-sized semi-evergreen glabrous tree.
6	*Schleichera oleosa*	Sapindaceae	*Kusum* occurs in dry and mixed deciduous forests.
7	*Cassia seamia*	Fabaceae	*Kassod* is a medium-sized evergreen tree.
8	*Zyzyphus mauritiana*	Rhamnaceae	*Ber* is a medium-sized, evergreen, prickly tree.
9	*Butea monosperma*	Fabaceae	*Palash* is a medium-sized deciduous tree.
10	*Ailanthus excelsa*	Simaroubaceae	*Maharukh* is a huge deciduous tree.
11	*Sysygium cuminii*	Myrtaceae	*Jamun* evergreen - tropical tree.
12	*Buchanania lanzan*	Anacardiaceae	*Chironji* is a sub-deciduous tree.
13	*Terminalia bellirica*	Combrataceae	*Harra* is a deciduous tree.
14	*Ficus benghalensis*	Moraceae	*Bargad* is a huge-spread evergreen tree.
15	*Azadirachta indica*	Meliaceae	*Neem* is a medium height-evergreen tree, termite-resistant wood.
16	*Anthocephalus cadamba*	Rubiaceae	*Kadamba* is a mid-huge deciduous tree.
17	*Ficus religiosa*	Moraceae	*Peepal* is a large, semi-evergreen tree.
18	*Tectona grandis*	Lamiaceae	*Sagon* is a tall and gorgeous tree.
19	*Peltophorum pterocarpum*	Fabaceae	*Yellow gulmohar* is a semi-evergreen tree.
20	*Madhuca indica*	Sapotaceae	*Mahua* is a mid-sized to large tropical deciduous tree.
21	*Albizia procera*	Fabaceae	*Safed siris* is an exposed crown semi-deciduous tree.
22	*Terminalia tomentosa*	Combrataceae	*Saja* is a large deciduous tree.

were collected from the roadside in the early morning at the lower branches (at a height of 2-4 m). Leaves samples were collected and bagged in polythene, quickly transferred to the laboratory, and kept in refrigerator (3-5°C) for analysis.

Ascorbic Acid Analysis (AA)

The AA was analyzed by using the 2, 6 dichlorophenol Indephenol dye titration methods (Roy et al. 2020). 1gm of leaf sample was crushed with a 4% oxalic acid addition and centrifuged for 10 minutes at 3000 rpm. The centrifuged sample was filtered, and the made-up volume was 25 mL with 4% oxalic acid added. 5 mL of leaf sample was pipette out with 10 mL of oxalic acid (4%) and titrated against the dye. Titration was stopped when a pink color appeared.

$$AA\,(\mathrm{mg\,g^{-1}}) = \frac{0.5 * \mathrm{V2} * 25\,\mathrm{mL} * 100}{\mathrm{V1} * 5\mathrm{mL} * \text{Weight of sample (g)}}$$

Here, V1 is the volume of dye titrated against the ascorbic acid working standard.

V2 is the volume of dye titrated against the sample.

Relative Water Content (RWC)

The RWC was formulated by taking the fresh weight (FW), turgid weight (TW), and dry weight (DW) of a leaf sample (Kaur & Nagpal 2017).

$$\mathrm{RWC}\,(\%) = \frac{\mathrm{FW-DW}}{\mathrm{TW-DW}} \times 100$$

Leaf Extracts pH

A digital pH meter was used to analyze the pH of the leaf extract. 0.5 g of leaf sample was crushed using a mortal pestle, and pH was analyzed (Singare & More 2020).

Total Chlorophyll Content (TCC)

The TCC was analyzed using the 80% acetone method using a spectrophotometer (Roy et al. 2020). 0.5 g of leaf sample was crushed with 80% acetone and centrifuged with the extract (at 3000 rpm for 10 min.) and makeup sample for 25 mL. The absorbance of the supernatant was analyzed at 663nm and 645nm through a spectrophotometer.

$$TCC\,(\mathrm{mg\,g^{-1}}) = \frac{(20.2 * \mathrm{A}\,645 + 8.02 * \mathrm{A}\,663) * \mathrm{V}}{1000 * \text{Weight of sample (g)}}$$

Here, A 645 is the absorbance at 645 nm, A 663 is the absorbance at 663 nm, and V is the volume of the sample.

Air Pollution Tolerance Index (APTI)

The APTI was demonstrated by the following equation (Sharma et al. 2019).

$$\text{APTI} = \frac{\text{AA (TCC+pH)+RWC}}{10}$$

Here, AA= Ascorbic acid (mg g^{-1})

TCC= Total chlorophyll content (mg g^{-1})

pH= pH of leaf extract

RWC= Relative water content (percentage)

Anticipated Performance Index

API was determined by encompassing the biological features of the tree, such as tree habit, tree type, structure of the canopy, and structure of the lamina, along with the air pollution tolerance index of each tree (Table 2). The highest plus that can be received for any tree species is 16 (Yadav & Pandey 2020). The score percentage can be categorized as:

$$\text{Score \%} = \frac{\text{Total (+) recieved by tree species}}{16} \times 100$$

Dust Capturing Capacity

Dust deposition on the surface of the leaf was determined (Rai & Panda 2014, Noor et al. 2015). The amount of dust was calculated for twenty-two tree species by taking the initial and final weight of the beaker in which the leaf samples were washed. It is expressed in milligrams per square centimeter (mg cm^{-2}) and calculated by using the formula as follows:

Dust capturing capacity =

$$\frac{\text{Weight of leaf with dust (milligrams)} - \text{Weight of leaf without dust(milligrams)}}{\text{Total area of leaf (centimeter square)}}$$

Statistical Analysis

A one-way ANOVA at a 5% level of significance was used (SPSS software IBM version 16.0). For all variables, the mean with a standard error of five replicated values was used

Table 2: Gradation of tree species based on the anticipated performance index values (Sharma et al. 2019, Uka et al. 2019).

SN	Grading characters		Pattern of Assessment	Grading allotted
1	Tolerance	APTI	< 5	+
			5.1 -10	++
			10.1 – 15	+++
			15.1 -20	++++
			>20	+++++
2	Biological and socioeconomic	Tree Height	Small	-
			Medium	+
			Large	++
		Canopy structure	Sparse/irregular/globular	-
			Spreading crown/open/semi-dense	+
			Spreading dense	++
		Type of tree	Deciduous	-
			Evergreen	+
3	Lamina structure	Size	Small	-
			Medium	+
			Large	++
		Texture	Smooth	-
			Cariaceous	+
		Hardness	Delineate	-
			Hardy	+
4	Socio-economic importance	Economic value	<3 uses	-
			3 – 4	+
			>5 uses	++

to indicate all of the results. The degree of interaction among the variables was calculated using the linear regression analysis.

RESULTS AND DISCUSSION

Green plants release huge quantities of oxygen into their environment, which enhances the quality of the air in a particular area through adsorption, absorption, accumulation, and purification of pollutants. They function as living filters that mitigate air pollution with no adverse effects (Kaur & Nagpal 2017).

Tree Growth Characteristics

Table 3 shows the growth characteristics of selected trees. The highest girth (m) was recorded for *Schlecharia oleosa* (4.32±0.21), and the lowest was reported for *Zyzyphus mauritiana* (0.69±0.01). The highest tree diameter (cm) was observed for Shorea robusta (90.94±3.18) and the lowest for *Zyzyphus mauritiana* (21.89±0.48). The maximum tree height (m) received was Shorea robusta (26.38±0.23), and the minimum was *Alstonia scholaris* (8.12±0.12). The maximum tree age (year) received by Madhuca indica was about 110.2±2.4, and the minimum was 11.6±0.51 for *Alstonia scholaris*. The maximum leaf area (cm^2) was recorded for *Tectona grandis* (293.6±0.87), and the minimum was *Albizia procera* (5.2±0.37). In the present study, tree growth parameters such as girth, diameters, height, age, and leaf area differed because all tree species have their phenological characteristics, like some trees being very tall and others having a slow growth rate (Nayak et al. 2015). The leaf area of *Tectona grandis* is relatively higher than that of the other tree species because it's larger in leaf size.

Relative Water Content

In the results of the current study, RWC fluctuated significantly ($P<0.05$) for all types of trees. The highest percentage of RWC was recorded for *Ficus religiosa* (95.4±0.4) and the lowest was recorded for *Azadirachta indica* (83±0.89) as shown in Table 4. Amulya et al. (2015) revealed that plant leaves provide the most RWC in areas affected by air pollution. Under exposure to air pollution, the increases in transpiration rates therefore plants get higher water content to maintain their physiological process (Rai et al. 2013, Kumar et al. 2018). At the very low relative

Table 3: Growth parameters of selected trees.

Tree Species	Girth (meter)	Diameter (centimeter)	Height (meter)	Age (Year)	Leaf Area (cm^{-2})
Shorea robusta	2.86±0.1	90.94±3.18	26.38±0.23	84.2±1.16	112±0.71
Bombax ceiba	1.27±0.02	40.35±0.63	13.05±0.23	14.4±0.51	95.2±0.58
Mangifera indica	2.21±0.03	70.32±1.06	15.96±0.39	41.6±0.81	80±0.71
Alstonia scholaris	0.84±0.02	26.73±0.61	8.12±0.12	11.6±0.51	64.2±0.37
Millettia pinnata	1.44±0.03	45.82±1.01	10.09±0.24	28.6±0.51	99±0.84
Schlecharia oleosa	4.32±0.21	137.58±6.78	17.41±0.18	66.4±0.75	213.2±0.97
Cassia seamia	0.79±0.02	25.26±0.69	12.47±0.28	21.4±0.75	9.4±0.51
Zyzyphus mauritiana	0.69±0.01	21.89±0.48	8.32±0.19	18.4±0.51	5.2±0.58
Butea monosperma	1.39±0.06	44.36±1.83	11.37±0.23	21.2±0.58	194.8±0.58
Ailanthus excelsa	1.91±0.05	60.77±1.7	17.99±0.19	15.8±0.37	156.4±0.93
Sysygium cuminii	1.55±0.11	49.26±3.42	15.6±0.31	27.4±1.03	86.2±0.86
Buchanaia lanzan	0.82±0.05	25.96±1.5	14.2±1.57	15.2±0.58	112.2±0.86
Terminalia bellirica	1.41±0.02	44.8±0.58	13.05±0.19	74.8±1.32	90.4±0.93
Ficus benghalensis	2.71±0.05	86.36±1.44	12.18±0.33	62.2±1.16	156±0.71
Azadirachta indica	1.49±0.06	47.28±1.86	12.89±0.31	32.6±0.98	19±0.71
Anthocephalus cadamba	1.02±0.08	32.52±2.69	15.34±0.19	15.2±0.66	77.6±0.93
Ficus religiosa	1.65±0.05	52.5±1.5	10.69±0.23	74.8±0.97	111±0.71
Tectona grandis	0.74±0.03	23.55±0.97	12.4±0.35	24.8±0.66	293.6±0.87
Peltophorum pterocarpum	1.29±0.07	41.05±2.29	12.61±0.3	14.6±0.24	48±0.71
Madhuca indica	2.65±0.06	84.45±1.99	15.4±0.18	110.2±2.4	105±0.71
Albizia procera	0.73±0.05	23.1±1.71	10.5±0.24	14±0.45	5.2±0.37
Terminalia tomentosa	1.68±0.04	53.58±1.17	21.32±0.44	33.8±0.58	77.2±0.97

water content, the net CO_2 exchange, CO_2 assimilation, and photosynthetic rate ultimately obtain low. A greater RWC enhances the capacity of a plant to tolerate air pollution (Nayak et al. 2015). Many investigations conducted by researchers show that the relative water content of trees increases in response to pollution, and the RWC varies at different pollution levels. The accumulation of dust on roadside tree leaves is exacerbated by heavy traffic. A similar investigation was reported by Govindaraju et al. (2012) relative water content (%) 95.14 ± 2.81 for *Ficus religiosa* and 79.85 ± 1.49 for *Azadirachta indica*. The higher relative water content showed maximum drought tolerance capacity.

Leaf Extracts pH

The study exhibited variations in leaf extract pH significantly ($P<0.05$) for different tree species. The highest leaf extract pH was observed at 6.61±0.11 for *Albizia procera* and the lowest was 3.28±0.11 for *Cassia seamia* while most of the tree species showed an acidic nature of leaf pH (Table 4). The lowest pH value indicates that the tree has better tolerance than other trees. The regulation of plant potential for pollution is significantly influenced by pH level. The diffusion of gaseous air pollutants like NO_2, CO_2, and SO_2 in the cell sap and their subsequent conversion into acid and electrons may be due to the acidic pH. Gaseous SO_2 diffuses through cellular pores (stomata) and dissolves in water to create sulfites, bisulfate, and their ionic species. This process generates protons, which, in turn, affect the pH of cells (Sharma et al. 2019, Noor et al. 2015). High pH increases ascorbic acid synthesis in plants and increases their resistance to air pollution, while low pH inhibits the breakdown of the hexose sugar into ascorbic acid. Ogunrotimi et al. (2017) showed a similar result for *Cassia seamia* (4.62) in polluted sites of Lle Lfe City, Southeast Nigeria. A result was reported on pH 3.96 for *Cassia seamia* in the industrial polluted site in Ludhiana, India (Verma et al. 2023). The pH of leaf extracts is crucial in controlling plants' sulfur dioxide conductivity (Maawali & Sulaiman 2017). A result of acidic pollutants like SO_2 and NO_x in the surrounding air, this influences the pH of the leaf (Swami & Chauhan 2015). Low leaf pH extract exhibited a strong association with air pollution due to its reactivity and also

Table 4: Biochemical response of selected tree species.

Tree Species	pH	Relative Water Content (%)	Total Chlorophyll content ($mg.g^{-1}$)	Ascorbic acid ($mg.g^{-1}$)	APTI
Shorea robusta	5.5±0.05	92.8±0.86	1.16±0.06	15.1±0.84	19.34±0.58
Bombax ceiba	5.45±0.09	90.8±0.58	0.85±0.02	15.76±0.91	19.01±0.48
Mangifera indica	5.18±0.07	91.4±0.51	0.534±0.02	16.38±0.87	18.49±0.44
Alstonia scholaris	5.85±0.1	87.8±0.58	0.56±0.09	10.61±0.84	15.58±0.54
Millettia pinnata	6.29±0.07	91.2±0.58	0.718±0.04	11.01±0.77	16.85±0.59
Schlecharia oleosa	6.25±0.09	87.2±0.58	0.385±0.04	11.81±0.78	16.56±0.53
Cassia seamia	3.28±0.11	92.2±0.58	0.465±0.02	18.95±0.94	16.28±0.3
Zyzyphus mauritiana	6.5±0.12	90±0.55	0.937±0.02	12.9±0.68	18.62±0.62
Butea monosperma	6.58±0.11	85.2±0.58	0.552±0.02	10.71±0.74	16.16±0.59
Ailanthus excelsa	6.19±0.07	89.2±0.86	0.908±0.03	18.38±0.91	21.95±0.59
Sysygium cuminii	4.61±0.09	91.8±0.73	0.402±0.02	14.7±0.84	16.54±0.41
Buchanaia lanzan	4.82±0.05	91.8±0.58	0.749±0.07	17.86±0.68	19.12±0.37
Terminalia bellirica	4.79±0.12	84.6±0.51	0.603±0.05	19.18±0.59	18.77±0.68
Ficus benghalensis	6.38±0.06	91±0.71	0.777±0.03	20.75±0.72	23.94±0.48
Azadirachta indica	6.6±0.04	83±0.89	0.644±0.03	28.46±0.63	28.91±0.42
Anthocephalus cadamba	4.56±0.12	94.6±0.51	0.578±0.06	24.52±0.81	22.06±0.6
Ficus religiosa	6.56±0.06	95.4±0.4	0.732±0.01	17.98±0.54	22.65±0.4
Tectona grandis	6.53±0.13	91.2±0.86	0.755±0.04	30.36±0.9	30.88±0.75
Peltophorum pterocarpum	6.48±0.08	92±0.71	0.845±0.05	24.52±0.77	27.16±0.57
Madhuca indica	6.58±0.06	84.2±0.86	0.828±0.02	23.81±0.69	26.08±0.7
Albizia procera	6.61±0.11	92±0.89	0.813±0.02	25.79±0.34	28.34±0.06
Terminalia tomentosa	5.48±0.08	88.4±0.87	0.475±0.04	30.54±0.67	26.95±0.32

reduced photosynthesis by modifying the stomatal activity (Sharma et al. 2019, Rai & Panda 2014). Chauhan et al. (2012) showed that the plants at the mining site had lower pH within leaf sap, which may have been caused by the SO_2 and NO_x levels in the surrounding atmosphere. It also affects the chlorophyll content in the leaves; reducing in lower leaf extract pH (Kamesh et al. 2023, Shah et al. 2020).

Total Chlorophyll Content

Table 4 shows the total chlorophyll content of leaves (mg g^{-1}) for selected tree species and showed significant ($P<0.05$) differences for each tree species. The maximum chlorophyll content was received at 1.16±0.06 mg g^{-1} for *Shorea robusta* and the lowest was 0.385±0.04 mg g^{-1} for *Schleichera oleosa*. While the maximum tree species showed relatively lower total chlorophyll content in the study area. Dust content on the surface of leaves is the main barrier to the reaching of sunlight for chlorophyll pigments present in the leaves. One of the most harmful effects of abiotic stress is the reduction of photosynthesis. The principal effect of stress on plants is damage to chloroplasts, a sign of the breakdown of pigments in the leaves (Shah et al. 2020). The chlorophyll pigment converts solar energy into chemical energy that plant cells can utilize as a source of food. An air pollutant that includes SO_2, NO_2, CO_2, and suspended particulate matter might enter organs from stomata and partly disintegrate chloroplasts, which can reduce the chlorophyll concentration (Shrestha et al. 2021). Plant production and, consequently, their ability to withstand air pollution both decline when chlorophyll concentration falls. Less chlorophyll implies that plants are far more sensitive to polluted air. Bhattacharya et al. (2013) recorded that the chlorophyll content of leaves decreases in polluted sites, and found that the photosynthesis of plant systems has begun to deteriorate as pollution levels reach every year (Kumari & Deswal 2017).

Ascorbic Acid

The ascorbic acid of leaves (mg g^{-1}) for selected tree species observed differs significantly ($P<0.05$) level of significance. The maximum ascorbic acid content of was observed for *Terminalia tomentosa* (30.54±0.67 mg g^{-1}) and the minimum was *Alstonia scholaris* (10.61±0.84 mg g^{-1}) as shown in Table 4. Living cells need ascorbic acid for survival. Therefore, it has been shown that plants with low ascorbic acid concentrations are less tolerant of stress (Shah et al. 2020). Although it participates in various physiological processes, and highly significant organic antioxidant for plants to function properly. It has a powerful reductant, and electron donor, removes imbalanced oxidative stress, and decreases the toxicity of SO_2. When a plant suffers from stress condition, the plant produces more ascorbic acid to combat the stress condition (Bhattacharya et al. 2013). Under stressful conditions, ascorbic acid, an effective antioxidant, protects plant cell division and cell membrane stability by absorbing harmful free radicals and reactive oxygen released when protoxidized from SO_2 to SO_3. In the present study tree species such as *Ficus benghalensis, Azadirachta indica, Anthocephalus cadamba, Tectona grandis, Peltophorum pterocarpum, Madhuca indica, Albizia procera,* and *Terminalia tomentosa* showed >20 mgg^{-1} ascorbic acid which was relatively higher than other trees. The results of this investigation accord closely with the findings (Ogunkunle et al. 2015, Bora & Josi 2014, Pandey et al. 2015). Plants become more tolerant of a contaminated environment as the ascorbic content in their leaves rises. Air pollution tolerance is significantly influenced by ascorbic acid's capacity to shield plant tissues from the damaging effects of air pollutants (Shrestha et al. 2021).

Air Pollution Tolerance Index

The air pollution tolerance index significantly differed ($P<0.05$) with tree species. The highest APTI was 30.88±0.75 for *Tectona grandis* followed by *Azadirachta indica> Albizia procera> Peltophorum pterocarpum> Terminalia tomentosa> Madhuca indica> Ficus benghalensis> Ficus religiosa> Anthocephalus cadamba> Ailanthus excelsa> Shorea robusta> Buchanaia lanzan> Bombax ceiba> Terminalia bellirica> Zyzyphus mauritiana> Mangifera indica> Millettia pinnata> Schlecharia oleosa> Sysygium cuminii> Cassia seamia> Butea monosperma* while lowest was 15.58±0.54 for *Alstonia scholaris* as shown in Table 4. Results were reported by Das et al. (2010) for the industrial area of Rourkela with a 10.77 APTI value for *Alstonia scholaris*, while the unlike findings for *Tectona grandis* 8.86 APTI value. Take & Kadke (2017) reported an APTI value of 14.6 for *Tectona grandis* and 13.09 for *Alstonia scholaris*. These findings could be accounted for by the potential that plants differentiate geographically and climatically from one place to another. It also fluctuates due to variations in humidity, temperature, air quality, etc. (Kosanic et al. 2018).

The tree species have been divided into three groups by different studies using the APTI: tolerant, intermediate, and sensitive (Uka et al. 2019, Padmavathi et al. 2013). Trees with an APTI value of <12 are deemed sensitive, trees with a value between 12 and 17 are classified as intermediate, and trees with an APTI value of >17 are viewed as tolerant (Uka et al. 2019, Bharti et al. 2018). In the present study the *Shorea robusta, Bombax ceiba, Mangifera indica, Zyzyphus mauritiana, Ailanthus excelsa, Buchanaia lanzan, Terminalia bellirica, Ficus benghalensis, Azadirachta indica, Anthocephalus cadamba, Ficus religiosa, Tectona grandis, Peltophorum pterocarpum, Madhuca indica, Albizia procera,*

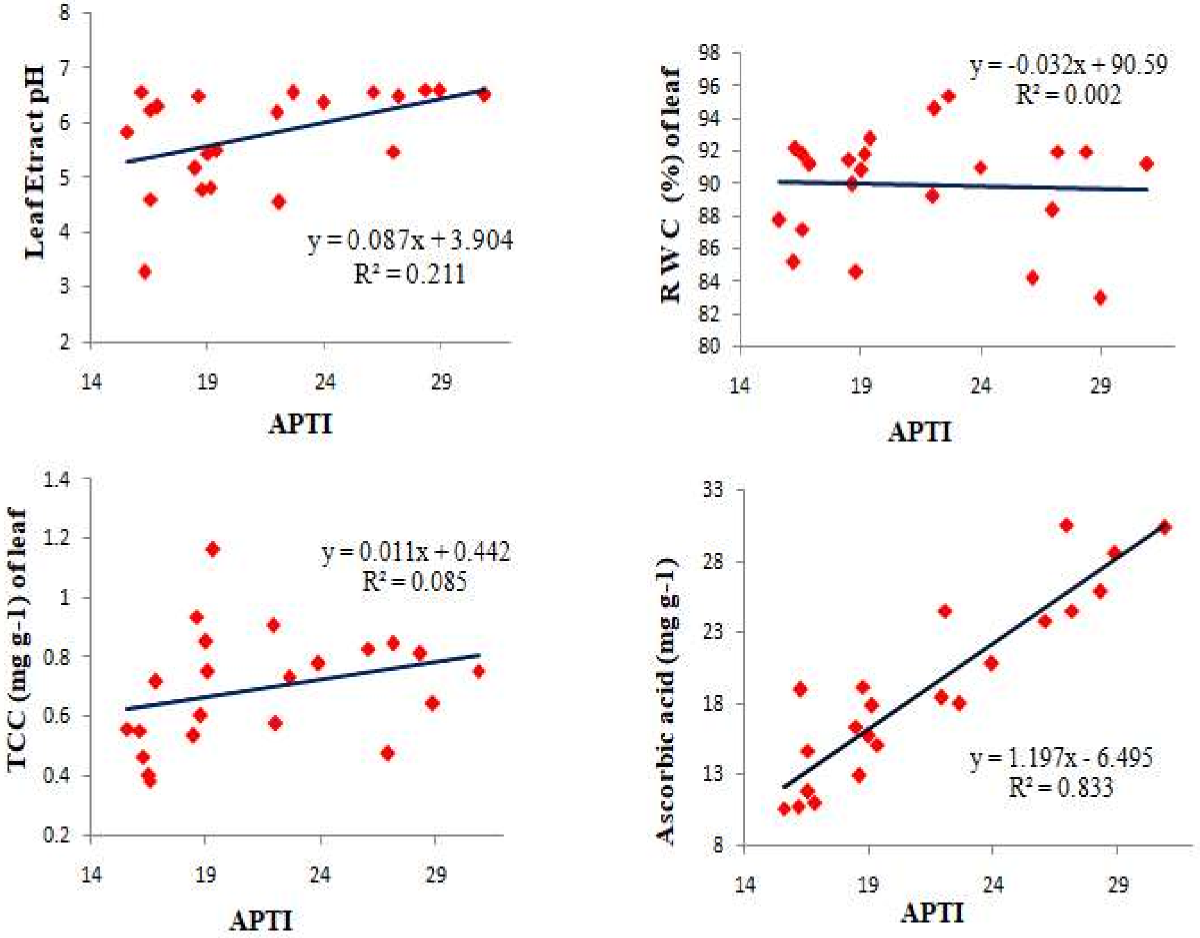

Fig. 2: Linear regressions between APTI and leaf biochemical parameters.

and *Terminalia tomentosa* showed tolerance response against coal dust air pollution and may be adopted for plant barriers to traffic pollution as well as for the establishment of urban green belts (Shrestha et al. 2021). Whereas, *Alstonia scholaris, Millettia pinnata, Schlecharia oleosa, Cassia seamia, Butea monosperma*, and *Sysygium cuminii* showed intermediate tolerance response against coal dust air pollution used a kind of bio-indicator as well as tolerant tree for air pollution.

The correlation between leaf extract pH, relative water content, total chlorophyll content of leaves, ascorbic acid content, and air pollution tolerance index (APTI) was displayed using linear regression analysis as shown in (Fig. 2). There was a marginally weak correlation between the chlorophyll content (R2 = 0.085), the leaf extract pH (R2 = 0.211), and the relative water content (R2 = 0.002). While a strong positive correlation was observed between ATPI and leaf ascorbic acid (R2 = 0.833). As a means to alleviate the stressed condition in the environment, the ascorbic acid level in tree leaves increases. Under stressful conditions, ascorbic acid, an effective antioxidant, protects plant cell division and cell membrane stability by absorbing harmful free radicals and reactive oxygen released when protoxidized of SO_2 to SO_3 (Uka et al. 2019, Rai & Panda 2014, Kamesh et al. 2023, Wang & Chen 2021). Similar correlations between APTI and biochemical parameters were found in several other studies (Nayak et al. 2015, Noor et al. 2015, Bharti et al. 2018).

Dust Capturing Capacity of Leaf

The dust-capturing capacity of the leaf significantly differs ($P<0.05$) for all species. Fig. 3 showed the highest dust-capturing capacity of the leaf surface 3.18±0.09 mg cm^{-2} for *Shorea robusta* and 0.032 mg/cm^{-2} for *Terminalia bellirica*. The size of the leaf and the properties of the leaf surface of a tree species are linked to its ability to trap and hold dust (Krishnaveni & Lavanya 2014). Moreover, leaf surface attributes like toughness, hairiness, and cuticle attributes significantly affect the ability of any species to capture dust.

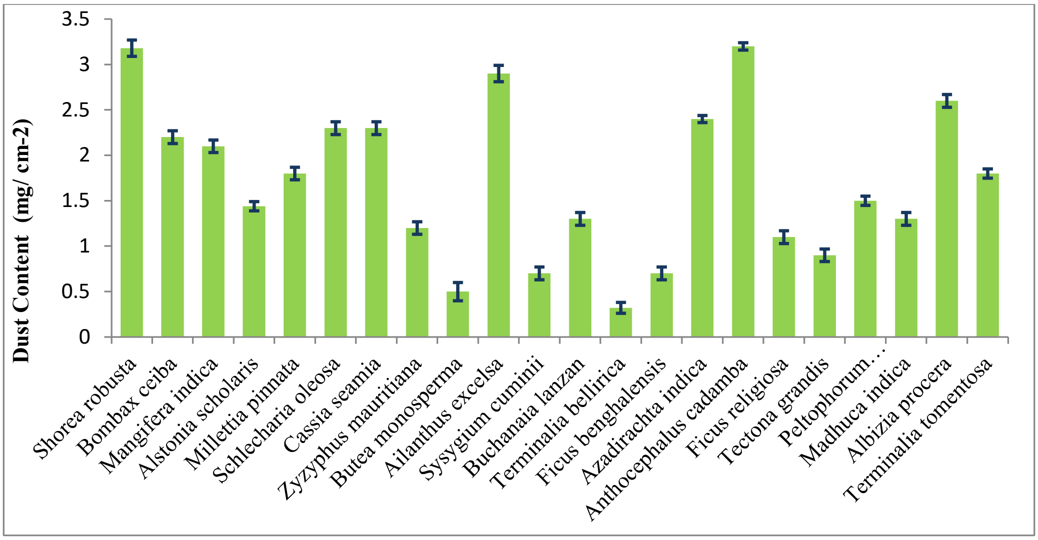

Fig. 3: Representation of dust content on the surface of the leaf for selected tree species.

Table 5: Evaluation of trees based on their APTI values and some biological and socioeconomic characteristics.

Tree species	APTI	Morphological			Laminar Structure			EI	Grade allotted		API value	Assessment
		TH	CS	TT	TX	SZ	HD		Total +	Score %		
Shorea robusta	++++	++	++	+	+	++	+	++	15	93.75	7	Best
Bombax ceiba	++++	++	+	-	+	++	+	+	12	75	5	Very Good
Mangifera indica	++++	+	++	+	+	++	+	++	14	87.5	6	Excellent
Alstonia scholaris	++++	+	-	+	+	++	+	+	11	68.75	4	Good
Millettia pinnata	++++	+	+	+	+	++	+	+	12	75	5	Very Good
Schleichera oleosa	++++	++	++	+	+	++	+	+	14	87.5	6	Excellent
Cassia siamea	++++	+	+	+	+	+	+	+	11	68.75	4	Good
Ziziphus mauritiana	++++	+	+	+	+	+	+	++	12	75	5	Very Good
Butea monosperma	++++	+	-	-	+	++	+	+	10	62.5	4	Good
Ailanthus excelsa	++++	++	-	-	+	+	+	+	10	62.5	4	Good
Syzygium cumini	++++	+	+	+	+	++	+	+	12	75	5	Very Good
Buchanaia lanzan	++++	+	-	-	+	++	+	+	10	62.5	4	Good
Terminalia bellirica	++++	+	+	+	+	++	+	++	13	81.25	6	Excellent
Ficus benghalensis	+++++	++	++	+	+	++	+	++	16	100	7	Best
Azadirachta indica	+++++	+	+	+	-	+	+	++	12	75	5	Very Good
Anthocephalus cadamba	+++++	++	+	+	+	++	+	+	14	87.50	6	Excellent
Ficus religiosa	+++++	++	++	+	-	++	+	++	15	93.75	7	Best
Tectoana grandis	+++++	++	-	-	-	++	+	+	11	68.75	4	Good
Peltophorum pterocarpum	+++++	+	++	+	+	+	+	+	14	87.50	6	Excellent
Madhuca indica	+++++	+	+	-	+	++	+	++	13	81.25	6	Excellent
Albizia procera	+++++	++	+	+	+	+	+	-	12	75	5	Very Good
Terminalia tomentosa	+++++	++	+	-	+	++	+	++	14	87.50	6	Excellent

TH tree height, CS canopy structure, TT type of tree, TX texture, SZ leaf size, HD hardness, EI economic importance

Because long petioles cause the leaves to swing rapidly in gusts of wind, they are less effective at catching dust (Rai & Panda 2014, Noor et al. 2015, Wang & Chen 2021). The dust content on the leaf also depends on the number of vehicles running in the area and the presence of dust on the ground. Those tree species with greater capacity to trap dust contribute to the reduction of fine particles in the environment surrounding highways. They perform as natural air filtering. Foliage with small height trees captured more particulate matter than the tall trees (Shrestha et al. 2021).

Anticipated Performance Index

API plays a significant role in providing reliable data through the combining of APTI value and physiological as well as socioeconomic traits, in which multiple grades were assigned for a particular tree species. The API values fell into different categories, such as not recommended (<30), very poor (31–40), poor (41–50), moderate (51–60), good (61–70), very good (71–80), excellent (81–90), and best (91–100) (Kaur & Nagpal 2017, Sharma et al. 2019, Rai & Panda 2014, Nayak et al. 2015). Those species have the best performance score in the API score; they are suitable for green belt development in polluted sites as well as urban greenery. In the present study (Table 5), the highest API score was recorded best performance for *Shorea robusta* and *Ficus religiosa* (93.75%), which were suitable to be planted along the roadside of air-polluted areas; while the lowest was recorded for *Butea monosperma*, *Ailanthus excelsa*, and *Buchanaia lanzan* (62.75%). Overall, selected tree species have been recommended for plantation at polluted sites. Similar results were reported by many researchers such as for the anticipated performance index (Sharma et al. 2019, Sahu et al. 2020, Yadav & Pandey 2020, Pandey et al. 2015).

CONCLUSIONS

This research indicates that various trees exhibit their responses against air pollution. Tree species need to be appropriately evaluated using both APTI and API values to determine tolerate capacity in pollution loads areas. The study showed the APTI value significantly differs ($p<0.05$) for tree species in coal dust air pollution. The highest API values received for *Shorea robusta, Mangifera indica, Schleichera oleosa, Terminalia ballerica, Ficus benghalensis, Anthocephalus cadamba, Ficus religiosa, Peltophorum pterocarpum, Madhuca indica,* and *Terminalia tomentosa*. Trees with low API values can function as bio-indicators of air pollution, whereas trees that have high API values can be adopted as bio-accumulators. The assessment of tolerance and performance level is the best method for identifying suitable trees for the establishment of green zones on the roadsides of polluted areas and commercial and industrially polluted regions. This study provides suitable tree species for plantations along the roadside which is affected by coal dust air pollution areas.

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