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Identifying pollution scavenging potential of perennial plants growing in Maitreyi College Campus, University of Delhi

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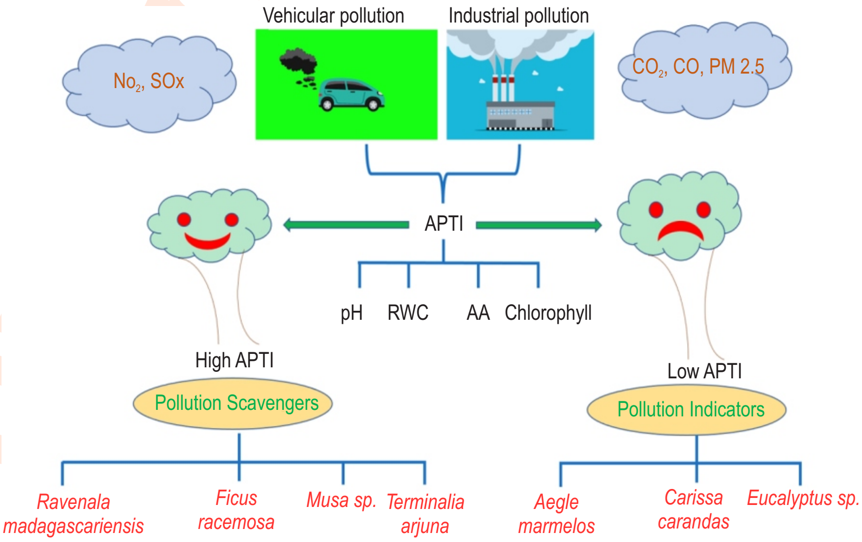
Abstract

Aim: Air Pollution Tolerance Index (APTI) represents the potential of a plant to combat air pollution. In the present study, APTI value of 77 perennials growing in the Maitreyi College Campus, New Delhi was calculated, and these plants were classified into tolerant and sensitive species.

Methodology: APTI was calculated by assessing four physiological and biochemical parameters, pH, Relative Water Content (RWC), Total Chlorophyll (TCh), and Ascorbic Acid (AA).

Results: The highest APTI was observed in *Musa* sp. (10.52) indicating it to be the most tolerant, while the lowest in *Aegle marmelos* (1.93), showing it to be the most sensitive for pollution. Results showed *Musa* sp., *Salmelia* sp., *Terminalia arjuna, Murraya exotica, Hamelia patens, Ravenala madagascariensis, Ficus racemosa, Cascabela thevetia, Eugenia uniflora, Nyctanthes arbortristis* to have good potential in reducing air pollution in a sustainable manner. Species such as *Aegle marmelos, Plumeria rubra, Dracaena, Carissa carandas, Eucalyptus* sp. were sensitive to air pollution.



Interpretation: Analysis of results suggested the importance of APTI analysis in a campus for cataloging the pollution tolerant and sensitive plants. The pollution tolerant plants could be used for the green belt formation, while plants, which are sensitive to pollution can be used as an indicator of pollution. Moreover, mapping and compilation of information of trees (deciduous and evergreen) and shrubs growing in the campus helped in documenting the rich flora of the campus with pollution tolerance potential.

Key words: Air Pollution, Air Pollution Tolerance Index, Air quality, Trees

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Introduction

Environmental pollution is one of the biggest global challenges, having an adverse effect on the natural resources and human health. The most severe pollution is the air pollution, as it causes the highest number of deaths, for e.g., in 2019, air pollution was responsible for approximately 9 million deaths (Fuller *et al.,* 2022). Globalisation, increased use of automobiles and lesser use of sustainable energy sources has led to the rise of toxic gases and particulate matter in the atmosphere (Shrestha *et al.,* 2021). This has led to increased concentration of sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), Suspended Particulate Matter (SPM), hydrocarbons and soot particles as well as smaller amounts of organic molecules and radioactive isotopes (Enitan *et al.,* 2022). Pollutants affect the physiology and metabolism of plants, causes chlorophyll degradation, reduction in the photosynthesis, and productivity (Sharma *et al.,* 2013). Air pollutants has negative effects on leaf number, stomatal conductance, flowering, reproduction, enzymatic activity, ascorbic acid (AA) content, protein function, sugar levels, pH value and relative water content (RWC) (Rizwan *et al.*, 2013). Air quality index (AQI) transforms weighted values of individual air pollution related parameters (e.g., SO_2, CO, visibility, etc.) into single number or set of numbers and is widely used for air quality communication (Enitan *et al.,* 2022).

The response of plants toward air pollution is assessed by Air Pollution Tolerance index (APTI) (Bala *et al.,* 2022). APTI denotes the potential of a plant to combat air pollution (Singh and Rao, 1983). It is assessed on the biochemical parameters like pH, AA content, RWC and chlorophyll content. Based on the APTI values, plants can be categorised into sensitive, intermediate tolerant and tolerant species. APTI is used to select eco-friendly plant species in urban environments including college campus, which can be employed for reducing of air-borne particulate pollution. APTI is also valuable for landscapers and green belt designers for controlling air pollution. It is used to rank plant species in their order of tolerance to the air pollution. Development of green cover around and inside college campus can decrease air pollution. For plantation, selection of plant species is an important factor. Plants provide a huge leaf area for absorption, and accumulation of air pollutants and therefore, reduces the pollutant level in the surrounding air. Plants being the initial receivers of air pollution, act as scavengers for many air-borne particulates in the atmosphere. As a result, it is advisable to have a diverse collection of flora around institutions, offices,and even roadsides.

Maitreyi College, University of Delhi is located in Chanakyapuri, New Delhi and was established in July 1967. The campus is full of green plants including perennials, biennials and annuals. As the campus is located in Delhi, which is well known for its poor air quality, it is an obvious choice for pollution related research. According to the recent air quality report of IQAir, Delhi ranks first among capital cities of 106 countries (on the basis of PM2.5 concentration) (Dutta and Jinsart, 2022). Moreover, as per WHO, Delhi is the sixth-worst polluted city, amongst 13 notable cities in India (Dutta and Jinsart, 2022). Despite continuous efforts, which has been put for reducing air pollution, high PM2.5 pollution persists across all the seasons in Delhi. This indicates that Maitreyi campus plants are continuously being exposed to increasing air pollutants, therefore, the present study was undertaken to evaluate the APTI of perennials growing in the campus, to be classified into pollution tolerant and sensitive species on the basis of their APTI value. Moreover, it is a novel study as analysis of pollution tolerance has not been conducted in Maitreyi college campus till now. The research findings from this study will provide a list of plants with have high pollution reducing potential, which could be used for the plantation in gardens, for green belt development and thereby, reducing pollution in an economical way.

Materials and Methods

Collection and identification of plant materials: The twigs and fully mature leaves were collected in labelled zipper pouches, during early morning hours from the trees growing within the campus. The samples were immediately washed with distilled water, blot dried and then used for the experiments. The samples were processed for preparing herbariums, which submitted in the Maitreyi College Museum (Maheshwari, 1963).

Estimation of Air Pollution Tolerance Index (APTI): APTI was determined by estimating pH, RWC, Total Chlorophyll (TCh), and AA content (Singh and Rao, 1983; Singh *et al.*, 1991)", where, AA is the ascorbic acid content of leaf in mg g^{-1} dry weight, TCh is the total chlorophyll of leaf in mg g^{-1}dry weight, pH of the leaf-extract, and RWC is the percent relative water content of leaf tissue. To avoid the enzymatic degradation, pH was measured within 5 min of extraction using a pH metre (HANNA - pHep). RWC was calculated by taking fresh-, turgid- and dry-weights of the leaves (Shrestha *et al*., 2021)

To avoid leakage of the leaf sap, entire and undamaged leaf samples were taken. Leaf was properly immersed in the water for measuring turgid weight. Total chlorophyll content was estimating by measuring optical density of green solution at 645 nm (D645), and 663 nm (D663) using a spectrophotometer (Systronics – UV – VIS Spectrophotometer 118) and calculated by the formula (Arnon, 1949):

Classification of perennials: The spectrum of APTI was divided as four grades of air pollution tolerance: tolerant (T or grade I), moderately tolerant (MT or grade II), intermediate (I or grade III), and sensitive (S) (Liu *et al.,* 1983). The tolerance grades are as follows:

Tolerant: APTI> MEAN APTI+SD; Moderately tolerant: mean APTI<APTI<mean APTI+SD; Intermediate: mean APTI-SD<APTI<mean APTI and Sensitive: APTI< mean APTI-SD.

Statistical analysis: All the experiments were performed in three biological replicates. Mean and standard deviation were obtained by descriptive statistics using MS - Excel 16.

Results and Discussion

In the present study, survey and mapping of perennials growing in the Maitreyi College campus was performed as a primary step for estimating APTI of perennials growing in the college. Maitreyi College is situated in the South Campus of the University of Delhi. It is spread over 10 acres with beautiful front lawns and lush green gardens. The campus was divided into six zones for making a database of the trees. Plants growing in pots or beds were not included in this study. A systematic survey of the perennial plants is important, to familiarise the students, college fraternity and visitors, with the diverse flora of the campus. The survey included identification of perennial plants, their localization on a schematic map and their characterization on the basis of botanical name, family and common name (Malkani and Sehrawat, 2017). All the perennials were identified and classified as angiosperms or gymnosperms, which were further divided into evergreen trees, deciduous trees,and shrubs following Bentham and Hooker's classification. Trees were also observed for their phenological stages (vegetative, flowering or fruiting).

Scientific names along with their vernacular names (Hindi and English names) and the numerical codes were assigned to each perennial growing in campus area. A composite list of plants along their numbers gives an idea not only about the biodiversity of the campus but also about the abundance of plants. The mapping of the entire Maitreyi college campus was also performed as shown in Fig. 1A. The college map was first hand prepared with the help of Google Map (version: Maps 10.21.2 (1021201040) and the original map of college obtained from the records. The college map was further modified with the help of CorelDRAW (Graphics Suite 2019) and Paint Brush (version 2.6). Listing and mapping of the plants on the campus shows that it nurtures a total number of 744 trees belonging to 77 genera, out of which there were 71 angiosperms, of which 31 (40%) are evergreen trees, 16 (21%) are deciduous, 23 are (30%) shrubs, 1 (1%) is an evergreen grass. Six gymnosperms were also identified, out of which 5 were shrubs (7%) and 1 evergreen (1%) (Fig. 1B). This showed diversity in the campus to sustain a reasonably green appearance throughout the year. The highest number of plants were of *Dracaena* sp., an angiosperm shrub.

Plants are known to act as a natural sink for air pollution as they not only provide a surface for the absorption of the pollutants but also their accumulation (Verma *et al.,* 2022). These air pollutants negatively affect plant growth and development. There are many factors, which govern and affects the tolerance level of plants towards air pollution, including pH of leaf extract, RWC, chlorophyll, AA, dust, and pest invasion (Lohe *et al.*, 2015). Pollution decreases the leaf number and leaf area, negatively regulates flowering, thereby affecting the morphology, as well as the physiology of plants. According to a study, the leaves of plants exposed to pollution are smaller than the leaves of plants, which were not exposed. Furthermore, pollution reduces stomatal density and stomatal width (Pourkhabbaz *et al.*, 2010). Significant reduction in growth have been reported in the leaves of *Platanus acerifolia, Ficus benghalensis, Guaiacum officinale* and *Eucalyptus* in heavily polluted cities (Johan and Iqbal, 1992), indicating the influence of air pollution on leaf expansion. Reduction in stomatal density and pore size could be important in regulating absorption of pollutants; however, it limits the photosynthesis. Various methods and models are used for the quantification of pollutants and their physical as well as biochemical effects on plants. APTI of a plant is used to indicate the health of a plant and is used as an important tool to classify plants into tolerant, intermediate, and sensitive categories. In the present study, APTI of perennials was measured with the help of a standard equation based on four biochemical parameters *i.e.,* pH of leaf extract, Relative water content, Total chlorophyll content and ascorbic acid content. The effect of pollution on each parameter was analysed on the plants.

The pH of leaf extract plays a crucial role in regulating the pollution sensitivity in plants. The pH of leaf sap indicates its physiological, biochemical condition, and its surrounding environment in which the plant is growing. In the present study, analysis of various plant extracts showed variation in the colour from shades of green to brown. Colour of extract randomly varied irrespective of their pH. The lowest pH (pH 3.3) was observed in *Emblica officinalis,* indicating it to have the most acidic leaf cytoplasm, while the highest pH (pH 7.8) was observed in *Ficus panda*, suggesting it to have the most alkaline leaf cytoplasm. Almost 88% (68 species) of perennials have pH above 5.3, indicating that the plants are moderately exposed to acidic air pollutants such as SO_2 and NO_x. These primary pollutants enter the plants through the stomatal aperture during gaseous exchange and drop the pH. The rise in the pH could be due to the formation of hydroxide of aluminium in leaves, therefore, increasing the pH. High pH is shown to increase the production of AA by increasing the efficiency of conversion of hexose sugar to AA, indicating the positive correlation between pH and AA (Das *et al.*, 2018). The pH of leaf extract also changes with the stomatal opening in a polluted area. Dust and ions can make plants sap acidic or alkaline according to their ionic charges (Lohe *et al.,* 2015). it has been observed that plants with low pH are more susceptible to pollution, while those with an alkaline pH (around 7) are more tolerant (Kumar and Nandini, 2013; Bakiyaraj and Ayyappan, 2014).

Pollution data showed lesser amount of acidic pollutants in the atmosphere of studied area with average of 6.35 units of SO_2, *i.e.,* very low from the prescribed standard (80 units) and NOX have the average of 55.39 units from prescribed standard of 200 units, therefore explaining the probable cause for higher pH in the majority of plants. In only 12% perennials [9 species, *Emblica officinalis* (pH 3.3); *Pinus roxburghii* (pH 3.4); *Hamelia patens* (pH 3.9); *Syzygium cumini* (pH 4.5); *Eugenia uniflora* (pH 4.5); *Punica granatum* (pH 4.7); *Prosopis juliflora* (pH 4.8); *Ficus benghalensis* (pH 4.8) and *Thuja* sp. (pH 4.9)], pH showed an acidic range (3.3 - 4.9), which may be due to their high affinity towards acidic gaseous pollutants (NO_2, CO_2 and SO_2) and their diffusion in cell sap. When plants suffer from air pollution, especially SO_2, their cellular fluid produces more H^+ ions which further react with SO_2, resulting in the formation of H_2SO_4 and a reduction in leaf pH (Ghassanen *et al.,* 2016). pH contributes to APTI value proportionally, with alkaline cytoplasmic leaves tend to be more tolerant towards air pollution.

Relative water content is important for the growth and physiological activity of plants. It is the water content present in the leaves relative to full turgidity and is considered as the most significant measurement of plant water status. In the present study, RWC of the plant species ranged from 14.6 to 98.7% have shown that RWC could vary from 98% in fully turgid transpiring leaves to 30% in severely drying leaves (Shrestha *et al.,* 2021). High water content within the plant helps in overcoming drought and high temperature stress. RWC acts as an indicator of leaf water status in drought stress, as it has the relation to cell volume balance and water supply in the leaf sap (Liu and Ding, 2008). Reduction in the RWC in leaves is due to impact of pollutants on transpiration rate, deposition of dust on leaf surface and opening of stomata for a longer period. Increase in pollution causes decrease in the RWC resulting in drought stress in pollution-affected plants. Stress affected plants show imbalance in physiological activities, such as decline in the rate of photosynthesis and photosynthetic pigments (Rangani *et al*., 2018). In the present study, *Musa* sp. showed the highest RWC (98.78%) with fresh weight of 0.52 g, turgid weight of 0.525 g and dry weight of 0.115 g. RWC value ranged from 80-89.58% in the maximum number of plant samples (19 species). In three species RWC ranged between 14.66-19.74%, in 6 species. In 40.2-47.27%, in 11 species between 51.6-59.83%, in 9 species between 60.05-68.25% and in 11 species it ranged 70.52-77.23%.

The highest range of RWC value (90.15-98.78%) between was found in 14 species, indicating that these plants have high capacity to absorb as well as retain water, indicating drought resistance in plants. Increase in RWC leads to an increase in the APTI value, which renders more tolerance to pollutants. For example, in *Ravenala madagascariens*, RWC was 96.5% and APTI was 10.18, in *Salmalia*, RWC was 97.39% and APTI was 10.21 and for all the 14 species that showed the higher RWC.

Plumaria rubra showed lowest RWC (14.66%) with fresh weight of 1.05 g, turgid weight of 5 g and dry weight of 0.371 g. In addition, 2 species (*Aegle marmelos* and *Eucalyptus* sp.) also showed low RWC (less than 20%) indicating loss of water and dissolved nutrients and early senescence of leaves. In the present study, RWC values were maximum in shrubs, in comparison to evergreen trees and deciduous trees. High RWC helps in preventing chlorophyll degradation during stress conditions and supports the plant in overcoming environmental adversity (Zhang *et al.,* 2016). Moreover, higher RWC indicates high water content, which helps in the dilution of acid inside the leaf sap thereby, reducing the toxicity (Palit *et al.,* 2013). In this study, RWC was 87.67% and 3.3 pH in *Emblica officinalis* while in *Hamelia patens* the RWC was 95.58% and pH is 3.9. In the present study, most of the species showed high RWC, indicating them to be tolerant or moderately tolerant.

Tch content of a plant is an indicator of its photosynthetic activity and plant's biomass. Chlorophyll content of leaves varies from species to species depending on the age, species, and seasonal variation, with maximum chlorophyll content in the rainy season (Jyothi and Jaya, 2010). In the present study, estimation of chlorophyll content (Chl-*a* and *b*) in perennials was performed, which showed chlorophyll content in the range between 2.19-2.98 mg g^{-1} in majority of species (51 species). Amongst all, the highest Tch value was found in *Leucaena leucocephala* (6.5 mg g^{-1}) and the least (1.8 mg g^{-1}) in *Ficus elastica*. Pollutants may degrade chlorophyll molecules by increasing the activity of enzyme chlorophyll ase. A considerable loss in total chlorophyll content in the leaves exposed to air pollution and stress indicates that chloroplast is the primary site of attack by air pollutants. Chlorophyll content in all the plants varied with the tolerance as well as sensitivity of the plant species to pollution load.Automobile pollution decreases chlorophyll content. Plants having high chlorophyll content are generally tolerant to air pollutants (Singh and Rao, 1983). Ascorbic acid is a strong reductant, which acts as an antioxidant and protects the plant from adverse atmospheric conditions (Kakde and Tak, 2017).

Estimation of ascorbic acid content in the leaves of college perennials was performed. An average of 0.6 mg g^{-1} content of AA was obtained and therefore most of the plants (51 species) contained ascorbic acid content ranging between 0.6-0.65 mg g^{-1}. Twenty species of perennials showed ascorbic acid content in the range 0.51-0.59 mg g^{-1}, while 3 species contain ascorbic acid content in the range 0.4-0.45 mg g^{-1}. Ascorbic acid is a component of ascorbate-glutathione cycle by which it scavenges harmful reactive oxygen species and protects the thylakoid structure, chlorophyll content and maintains photosynthetic electron transport chain (Deepika *et al.,* 2016). It also plays an important role in photosynthetic carbon fixation, in cell wall synthesis, cell ontogenesis, regulation of stomatal movement, defence, and cell division. Moreover, its high level indicates tolerance against pollution, while its low value indicates sensitivity of plants against air pollution. Higher concentration of ascorbic acid is an indicator of exposure to high concentration of SO_2. Ascorbic acid reduces air pollutants by conversing SO_2 to SO_3, thereby helping in detoxification. Its reducing power is directly proportional to its concentration. Ascorbic acid and pH are related, as both help in determining the SO_2 sensitivity. Its reducing power is more at high pH and less at low pH, therefore, ascorbic acid might protect chloroplast and chlorophyll from pollutants through its pH-dependent reducing power. Also ascorbic acid, protects chloroplasts against SO_2-induced H_2O_2, O_2, and OH accumulation and therefore, protects the enzymes of CO_2 fixation cycle and chlorophyll from inactivation.

Identification and categorization of plants into sensitive and tolerant groups is important as the former can serve as

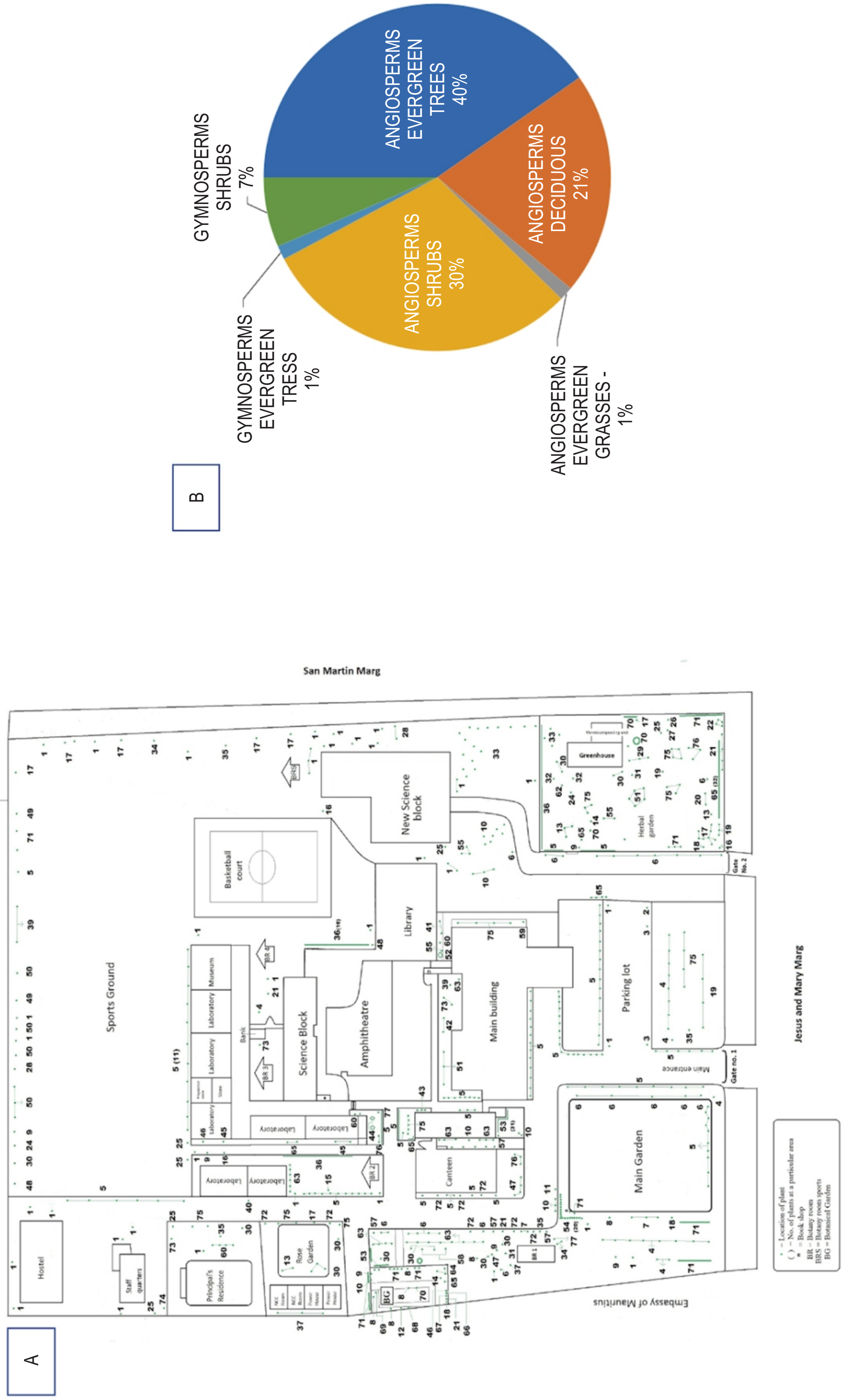

Fig. 1: (A) Map of Maitreyi College marked with perennials with their given code and (B) Pie chart showing percentage of different perennials growing in the Maitreyi College Campus.

Table 1: APTI of perennials growing in Maitreyi College Campus

Plant species	Plant code	Family	pH	RWC (%)	Total chlorophyll (mg g^{-1})	Ascorbic acid (mg g^{-1})	APTI score*
ANGIOSPERMS							
EVERGREEN TREES							
MONOCOTS							
Trachycarpus sp.	56	Arecaceae	7.1±0.05	40.91±1.15	2.64 ±0.16	0.61±0.002	4.68
Washingtonia robusta	60	Arecaceae	5.9±0.02	71.05±1.01	2.34 ±0.13	0.63±0.043	7.62
Chamaedorea sp.	61	Arecaceae	6.7±0.05	47.27±1.02	2.65 ±0.32	0.60±0.001	5.28
Dypsis lutescens	63	Arecaceae	5.9±0.05	89.58±0.43	2.44 ±0.08	0.60±0.001	9.46
Roystonea regia	72	Arecaceae	6.2±0.11	59.83±0.17	3.40±0.82	0.4±0.000	6.37
Ravenala *madagascariensis*	58	Strelitziaceae	6.3±0.16	96.5±1.52	2.51 ±0.37	0.60±0.002	10.18
DICOTS							
Polyalthia longifolia	6	Annonaceae	6.2±0.02	76.74±0.40	2.48 ±0.19	0.62±0.008	8.2
Grevillea robusta	28	Proteaceae	6.0±0.11	52.75±1.52	3.03 ±0.07	0.51±0.000	5.73
Senna siamea (Syn. Cassia arborea)	15	Fabaceae	6.0±0.16	46.28±0.28	4.5±0.17	0.05±0.000	4.73
Calliandra sp.	70	Fabaceae	5.8±0.00	83.75±0.40	4.1 ±0.78	0.60±0.003	8.97
Leucaena leucocephala	71	Fabaceae	6.8±0.00	87.46±0.28	6.50 ±0.64	0.60±0.003	9.55
Ficus virens	4	Moraceae	5.8±0.08	91.15±0.28	2.38 ±0.04	0.60±0.001	9.6
Ficus religiosa	16	Moraceae	6.4±0.05	74.07±1.15	2.71 ±0.05	0.61±0.000	7.96
Ficus benghalensis	26	Moraceae	4.8±0.11	82.24±0.40	2.34 ±0.09	0.51±0.000	8.59
Ficus racemosa	46	Moraceae	7.6±0.02	93.64±0.40	2.72 ±0.12	0.61±0.005	9.98
Ficus elastica	73	Moraceae	5.5±0.05	81.36±0.28	1.8±0.64	0.42±0.000	8.44
Holoptelea integrifolia	39	Ulmaceae	6.4±0.11	90.44±0.28	2.59 ±0.13	0.59±0.082	9.57
Carica papaya	7	Caricaceae	6.5±0.11	71.3±1.15	3.97 ±0.24	0.61±0.002	7.76
Bixa orellana	38	Bixaceae	5.3±0.10	68.25±1.15	2.95 ±0.09	0.54±0.001	7.26
Salmalia sp.	24	Malvaceae	6.3±0.05	97.39±1.35	2.89 ±0.08	0.52±0.003	10.21
Terminalia arjuna	45	Combretaceae	5.3±0.16	97±1.15	2.91 ±0.08	0.60±0.000	10.19
Callistemon sp.	10	Myrtaceae	5.6±0.05	53.33±1.45	2.92 ±0.02	0.61±0.005	5.84
Syzygium cumini	21	Myrtaceae	4.5±0.16	82.89±1.52	2.47 ±0.10	0.51±0.000	8.6
Eucalyptus sp.	40	Myrtaceae	6.8±0.05	19.74±1.35	1.97 ±0.05	0.59±0.078	2.49
Mangifera indica	35	Anacardiaceae	6.0±0.10	91.41±0.17	2.86 ±0.13	0.51±0.001	9.63
Murraya koenigii	18	Rutaceae	6.2±0.65	70.52±0.28	2.88 ±0.42	0.61±0.002	7.6
Mimusops elengi	33	Sapotaceae	6.0±0.05	57.03±1.15	3.12 ±0.40	0.56±0.004	6.21
Alstonia scholaris	30	Apocynaceae	6.0±0.10	73.06±1.15	2.75 ±0.19	0.57±0.005	7.78
Cascabela thevetia	34	Apocynaceae	6.3±0.10	97.76±0.35	3.19 ±0.71	0.55±0.000	10.3
Plumaria alba	75	Apocynaceae	6.3±0.00	81.47±1.15	3.19 ±0.65	0.61±0.009	8.73
Plumaria obtusa	76	Apocynaceae	5.6±0.00	85.35±0.43	2.78 ±0.29	0.61±0.008	9.04
DECIDUOUS TREES							
DICOTS							
Albizia lebbeck	3	Fabaceae	6.3±0.12	39.83±1.15	2.41±0.04	0.60±0.005	4.5
Senna pallida	11	Fabaceae	6.3±0.16	54.57±0.40	3.25±0.24	0.61±0.002	6.03
Cassia fistula	17	Fabaceae	6.1±0.05	82.72±1.50	2.39±0.04	0.61±0.003	8.78
Delonix regia	25	Fabaceae	5.8±0.10	90.15±1.75	3.35±0.91	0.51±0.000	9.48
Prosopis juliflora	37	Fabaceae	4.8±0.10	60.9±0.17	2.35±0.06	0.51±0.066	6.56
Dalbergia sissoo	48	Fabaceae	6.4±0.15	69.71±0.52	3.12±0.12	0.60±0.005	7.54
Emblica officinalis	32	Euphorbiaceae	3.3±0.40	87.67±0.43	2.68±0.14	0.55±0.003	9.09
Morus alba	9	Moraceae	7±0.10	61.22±0.28	4.25±0.10	0.61±0.000	6.8
Moringa oleifera	27	Moringaceae	5.6±0.05	76.34±2.25	3.67±0.87	0.51±0.001	8.09
Psidium guajava	14	Myrtaceae	5.8±0.05	66.21±1.15	2.52±0.07	0.61±0.009	7.12
Azadirachta indica	1	Meliaceae	6.2±0.16	85.99±1.16	2.28±0.06	0.60±0.002	9.13
Aegle marmelos	31	Rutaceae	5.8±0.16	14.77±0.35	2.74±0.04	0.55±0.000	1.93

Table contined

Cordia myxa	2	Boraginaceae	6.5±0.10	76.43±0.40	2.50±0.17	0.61±0.009	8.2
Plumeria rubra	77	Apocynaceae	5.7±0.10	14.66±1.15	2.55±0.01	0.62±0.003	1.97
Fernando adenophyllum (*Syn. Haplophragma adenophyllum*)	50	Bignoniaceae	6.8±0.00	46.14±0.17	2.46±0.16	0.60±0.000	5.17
Tectona grandis	49	Lamiaceae	7.1±0.00	54.04±1.35	2.19±0.10	0.61±0.001	5.96
SHRUBS							
MONOCOTS							
Yucca gigantea	41	Asparagaceae	5.3±0.16	51.6±0.20	2.75±0.24	0.60±0.002	5.64
Dracaena sp.	53	Asparagaceae	6.1±0.10	45±0.15	4.51±0.39	0.60±0.003	5.14
Musa sp.	64	Musaceae	5.8±0.05	98.78±0.50	4.90±0.17	0.60±0.001	10.52
DICOTS							
Annona squamosa	66	Annonaceae	5.3±0.05	88.96±0.07	5.56 ±1.50	0.63±0.042	9.55
Bougainvillea sp.	19	Nyctaginaceae	6.2±0.24	77.2±0.02	2.93±0.08	0.62±0.003	8.2
Bauhinia variegata	42	Fabaceae	6.4±0.05	61.8±0.35	2.97 ±0.09	0.60±0.001	6.74
Caesalpinia pulcherrima	68	Fabaceae	5.6±0.00	73.87±0.45	5.25±2.58	0.60±0.002	8.03
Jatropha sp.	43	Euphorbiaceae	5.3±0.15	82.47±0.03	2.96±0.20	0.60±0.002	8.76
Acalypha wilkesiana	52	Euphorbiaceae	5.7±0.10	66.36±1.36	2.64±0.04	0.60±0.001	7.13
Ficus panda	5	Moraceae	7.8±0.05	83.08±0.70	2.39±0.02	0.60±0.001	8.91
Hibiscus rosa- sinensis	8	Malvaceae	6.3±0.15	80.81±0.07	3.68±0.20	0.62±0.010	8.69
Lagerstroemia sp.	20	Lythraceae	5.5±0.00	51.93±0.05	2.67±0.17	0.61±0.005	5.7
Punica granatum	74	Lythraceae	4.7±0.05	51.81±0.30	2.70±0.08	0.17±0.003	5.3
Eugenia uniflora	36	Myrtaceae	4.5±0.05	94.91±1.25	4.08 ±0.20	0.52±0.001	9.96
Melaleuca bracteata	51	Myrtaceae	5.6±0.05	52.24±0.35	2.33±0.14	0.61±0.006	5.7
Citrus limon	29	Rutaceae	6.6±0.00	86.33±0.15	2.49±0.14	0.55±0.000	9.13
Murraya exotica	67	Rutaceae	5.5±0.15	95.68±0.05	5.69±0.14	0.63±0.040	10.5
Tabernaemontana divaricate	13	Apocynaceae	6.4±0.30	76.47±1.05	2.76±0.21	0.61±0.006	8.2
Nerium oleander	22	Apocynaceae	5.9±0.15	86.46±0.35	2.50±0.06	0.51±0.001	9
Carissa carandas	23	Apocynaceae	5.6±0.16	40.2±1.15	2.38±0.06	0.52±0.000	4.4
Ixora sp.	12	Rubiaceae	6.0±0.05	73.91±2.15	2.20±0.04	0.45±0.011	7.76
Hamelia patens	65	Rubiaceae	3.9±0.05	95.58±1.15	5.94±0.14	0.65±0.043	10.14
Nyctanthes arbor- tristis	47	Oleaceae	5.9±0.15	91.83±0.50	2.98 ±0.07	0.60±0.001	9.71
EVERGREEN GRASSES							
MONOCOTS							
Bambusa vulgaris	44	Poaceae	6.1±0.24	66.0±1.15	2.46±0.47	0.61±0.006	7.12
GYMNOSPERMS							
EVERGREEN TREES							
Pinus roxburghii	59	Pinaceae	3.4±0.05	59.27±3.25	2.34 ±0.15	0.60±0.002	6.27
SHRUBS							
Cycas revoluta	55	Cycadaceae	6.3±0.15	77.23±1.15	2.36 ±0.15	0.60±0.000	8.24
Araucaria sp.	54	Araucariaceae	5.5±0.15	84.39±1.50	2.38 ±0.04	0.61±0.003	8.94
Juniperus sp.	57	Cupressaceae	5.9±0.30	89.2±2.15	2.34±0.09	0.60±0.002	9.41
Thuja sp.	62	Cupressaceae	4.9±0.15	91.9±1.50	1.98±0.73	0.63±0.041	9.62
Ephedra sp.	69	Ephedraceae	5.5±0.05	60.05±1.15	4.97±1.02	0.60±0.001	6.63
			Mean value APTI		7.745		
			Standard deviation		2.015		
			Tolerant		APTI>9.68		
			Moderately Tolerant		7.68<APTI<9.68		
			Intermediate		5.67<APTI<7.68		
			Sensitive		APTI<5.67		

* The spectrum of APTI was divided as four grades of air pollution tolerance: tolerant (T or grade I), moderately tolerant (MT or grade II), intermediate (I or grade III), and sensitive (S)

indicators, while the latter as a sink for the abatement of air pollution in urban and industrial habitats. Pollution-induced changes in individual parameters are usually quantified and correlated with the level of plant response. To screen plants for their sensitivity/tolerance level to air pollutants, a proper selection of plant characteristics is of vital importance (Singh *et al.,* 1991). Estimation of APTI of mapped plant species from Maitreyi College campus was performed and tabulated (Table 1). Perennials were classified into tolerant, moderately tolerant, intermediate and sensitive plant species (Liu *et al.,* 1983). In the present study, significant variation was observed in the APTI value of tree species. Eleven species (14%) were tolerant (APTI >9.68), 35 (45.45%) species were moderately tolerant (7.68 <APTI <9.68), while 19 (24.67%) and 12 (15.58%) species were intermediate (5.67<APTI <7.68) and sensitive (APTI < 5.67) respectively. It is evident that each parameter plays a distinctive role in determining of the susceptibility of plants. *Musa* sp. showed maximum APTI value (10.52), as it had maximum RWC (98.78%), and chlorophyll content (4.90 mg g^{-1}), whereas *Aegle marmelos* showed the least (1.93) APTI value. Most plant species undertaken for study are moderately tolerant against pollution load and dust particulates.

The plants with low APTI values are generally sensitive to air pollution. Trees are also more sensitive to air pollution, as these are more exposed to various pollutants in comparison to small plants. In the present study, amongst the 10 monocots, only 2 species were tolerant (16.66%), 1 specie was moderately tolerant (25%), 3 species were intermediate (25%) and 4 sensitive (33.33%). Within 61 dicots, nine species were tolerant (15.25%), 30 moderately tolerant (47.45%), 14 intermediate (23.72%) and eight sensitive (13.55%). Out of 6 gymnosperm species, 4 were moderately tolerant (66.66%) and 2 were intermediate (33.33%). Among 32 evergreen trees, 6 plant species were tolerant (18.75%), 16 moderately tolerant (46.87%), 6 intermediate (21.87%) and 4 sensitive (12.5%). Among the deciduous trees (16), 6 plant species were moderately tolerant (37.5%), 6 intermediate (37.5%) and 4 sensitive (25%). Out of 28 shrubs, 5 plant species were tolerant (17.85%), 14 moderately tolerant (50%), 5 intermediate (17.85%) and 4 sensitive (14.28%) (Table 1) respectively. The reduction in the pH chlorophyll content and RWC at the polluted site may be due to the accumulation of dust on their leaves, hampering the gaseous exchange process along with the intensity of light, which is essential for photosynthesis or metabolism.

Even a high concentration of SO_2 in a polluted environment causes chlorophyll destruction and lowers leaf pH, an inverse correlation was found between leaf pH and ascorbic acid content. High production of ascorbic acid and higher APTI values at the polluted site may be regarded as the plants response to increase a ROS production under stress conditions (Verma *et al.,* 2022). The plants respond differently to air pollution under different environmental conditions as well as geographical regions. A plant listed in an APTI category at one place may react differently to the surroundings and the category of that particular plant at another location may change depending upon the pollution levels. This is very common with the plants that fall under the Intermediate category in pollution tolerance. They may become sensitive or tolerant as cultivars and varieties due to change in the environmental conditions (Davis and Wilhour, 2017). In a particular area, the tolerant plants can be grown successfully as shelter belts for scavenging atmospheric pollutants like SO_2, O_3, and NO_3. The sensitive plants can be used for biomonitoring of the area.

The present study reports a database of APTI value of perennials growing in the campus of Maitreyi College, which is useful in identifying pollution tolerant plants, and indicator species for an effective air pollution management program with a low APTI values such as *Aegle marmelos*, *Dracaena* sp., *Carissa carandas*, *Eucalyptus* sp. have been found to be the most sensitive to air pollution and can be used as bio-indicators in the low polluted areas. In contrast, plant species with high APTI values such as *Musa* sp., *Murraya exotica, Salmelia* sp., *Terminalia arjuna, Hamelia patens, Ravenala madagascariensis* and *Ficus racemosa*, can be used in highly polluted areas to mitigate air pollution. Delhi is one of the most polluted cities in the world with a poor air quality index, therefore, the use of suggested pollution tolerant species is an economical method for combating pollution, by designing urban green belts and vegetation traffic barriers. Moreover, the findings of this study might be useful for other colleges or Universities in selecting plants for maintaining the green cover. In addition, a database of trees (deciduous and evergreen) and shrubs growing in the campus of Maitreyi College was prepared for the first time, which highlights the rich flora of the campus. This study will serve as a guide to further additions of plants and will promote conservation of the flora in Maitreyi College. Future work will include generation of QR codes for all the perennials, scanning of which will give complete detail about the botanical name, family, common name, economic importance and APTI values. This will help in understanding the significance of a plant in reducing pollution and global warming.

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