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Urban Plant Diversity and Air Pollution Tolerance in Simpang Lima City Park, Semarang, Indonesia

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Abstract
Urban parks in tropical cities are exposed to traffic-derived air pollution, and their vegetation also lies within urban drainage catchments that carry deposited pollutants to rivers and lakes. This study documented plant species diversity, the Air Pollution Tolerance Index (APTI), and leaf morphological characteristics, including leaf area and stomatal index, in Simpang Lima City Park, Semarang, Indonesia. A complete vegetation census and leaf sampling at four points around the park were carried out in March–April 2025, and APTI was calculated from foliar ascorbic acid, total chlorophyll, leaf-extract pH and relative water content. The census recorded 21,135 individuals of 21 species from 14 families (Shannon–Wiener H′ = 1.92; evenness E = 0.63). Diversity was lower in the tree stratum (H′ = 0.90) than in the understory (H′ = 1.75), where densely planted ground covers dominated. APTI ranged from 8.87 in *Pandanus pygmaeus* to 40.84 in *Pedilanthus tithymaloides*; fourteen species were classified as sensitive, six as intermediate and one as tolerant. Leaf area and stomatal index were documented as additional morphological characteristics of the recorded plant species. Ambient pollutant concentrations, pollutant removal, runoff and receiving-water quality were not measured, so the results are a physiological screening baseline. For limnology, they identify species likely to persist in polluted urban green spaces and frame testable hypotheses on how park vegetation modifies the atmosphere–drainage–river pathway in Indonesian cities.

Keywords: Air pollution tolerance index, Leaf traits, Semarang, Urban catchment, Urban green space.

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1. Introduction

Semarang, the capital of Central Java Province, is a rapidly urbanising coastal city in which road traffic is a major source of atmospheric pollutants. Earlier measurements in public green spaces in Semarang, including Simpang Lima, reported carbon monoxide (CO) and lead (Pb) in ambient air (Margahayu *et al.*, 2015). Urban vegetation can intercept airborne particles and particle-bound metals on leaf surfaces; in Jakarta and Depok, for example, roadside tree species differed in the amount of particulate matter and Pb retained on their leaves (Yuniati *et al.*, 2024). The size of such effects depends on species traits, pollutant exposure and site conditions (Bell *et al.*, 2017), so the choice of species is a practical decision in urban green-space management.

The Air Pollution Tolerance Index (APTI) combines four foliar variables—ascorbic acid, total chlorophyll, leaf-extract pH and relative water content—into a single value that ranks plants by their physiological capacity to withstand air-pollution stress (Singh & Rao, 1983; Singh *et al.*, 1991). It has been widely used to screen species for green belts and urban planting (Ogunkunle *et*

al., 2015; Lohe *et al.*, 2015; Sahu *et al.*, 2020; Enitan *et al.*, 2022) and has been applied in Indonesian cities and industrial areas (Salsabila *et al.*, 2020; Hamid *et al.*, 2022; Putri *et al.*, 2023; Juswardi *et al.*, 2024). APTI measures tolerance, not pollutant removal, and its interpretation is limited when ambient pollutant concentrations and exposure gradients are not measured (Salsabila *et al.*, 2020; Enitan *et al.*, 2022).

Air quality is also relevant to inland waters. Lakes, rivers and reservoirs integrate inputs from both their catchments and the atmosphere (Wetzel, 2001), and dry and wet deposition deliver nutrients, acids and metals to water surfaces directly and through runoff (Brahney *et al.*, 2022). On Java, nearly half of the rain events monitored at 13 stations between 2019 and 2023 had a pH below 5.6, and sulfate and nitrate concentrations frequently exceeded ecological thresholds, particularly in urban areas (Hidayati *et al.*, 2025). In cities, most deposited material falls on impervious surfaces and vegetation and is flushed into drains during rain. In Semarang, the Banjir Kanal Timur river system receives urban runoff, and its sediments contain Pb associated with transport and other urban sources (Nugraha Putra *et al.*, 2022; Syafrudin *et al.*, 2026). Vegetation lies between the atmosphere and this drainage network: it intercepts rainfall and affects stormwater volume and quality (Muerdter *et al.*, 2018), but particles captured on leaves can later be washed off by rain or transferred to the ground with litter (Xu *et al.*, 2020), and street trees can add nutrients to stormwater (Janke *et al.*, 2017). Selecting plants that can persist under urban air pollution is therefore one land-side component of urban catchment management, although its consequences for water quality must be measured rather than assumed.

No previous study has jointly reported plant diversity, APTI and leaf traits for Simpang Lima City Park, the main public square of Semarang. This study aimed to (1) document plant species composition and diversity in the park, separating the tree and understory strata; (2) calculate the APTI of the recorded species and classify them using a published tolerance scheme; and (3) describe leaf area and stomatal index as additional morphological characteristics of the recorded plant species. We then discuss what these results imply for land–water connectivity in Indonesian urban catchments, as hypotheses for future limnological research; no aquatic variables were measured in this study.

2. Methods

2.1 Study Site and Period

The study was conducted in Simpang Lima City Park (Lapangan Pancasila), central Semarang, Central Java, Indonesia (approximately 6°59′26″ S, 110°25′23″ E; Figure 1), from March to April 2025. The park is an open lawn bordered by planted tree and hedge belts and enclosed by a multi-lane ring road with dense traffic. Leaves were collected at four sampling points on the south (TS1: 6.991314° S, 110.422620° E), west (TS2: 6.990440° S, 110.422307° E), north (TS3: 6.989552° S, 110.423332° E) and east (TS4: 6.990418° S, 110.423502° E) sides of the park. Laboratory analyses were carried out at the Laboratory of Ecology and Biosystematics, Diponegoro University.

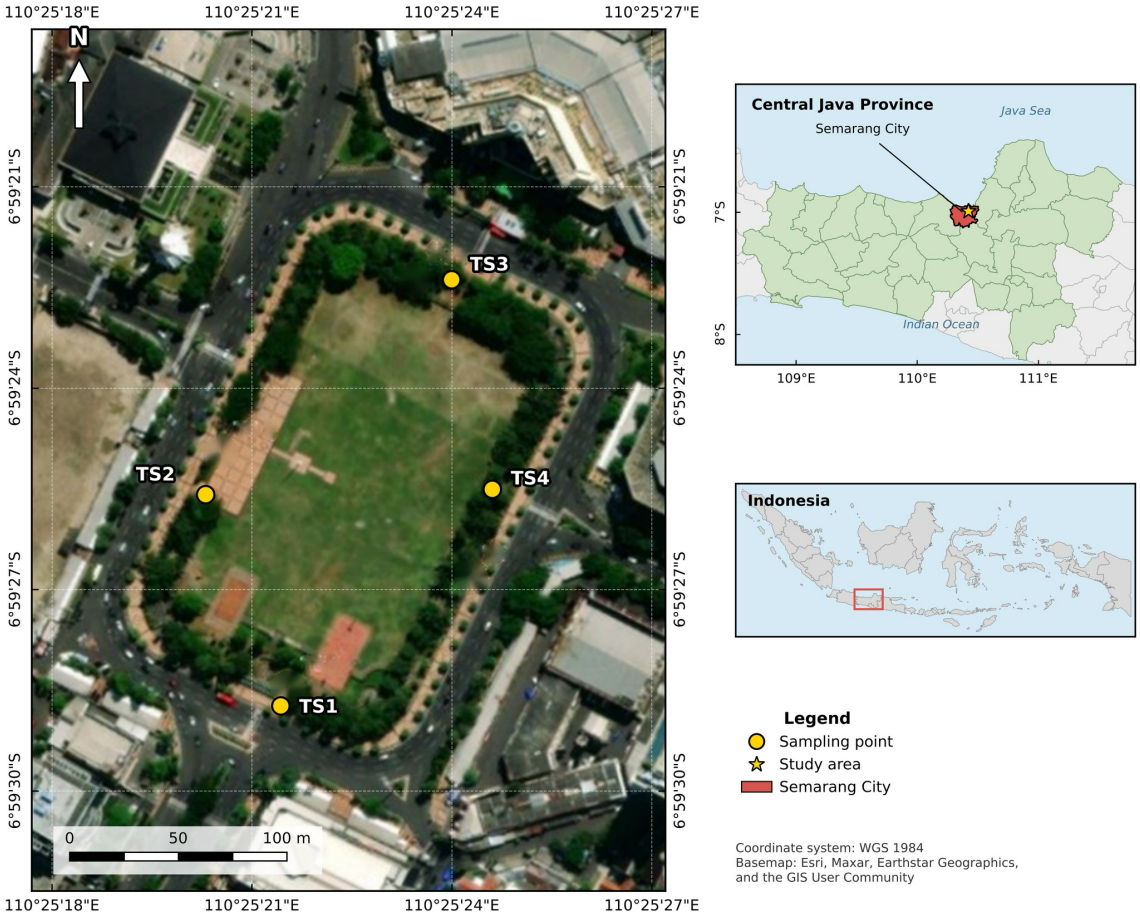


Figure 1. Location of the study area and the four leaf-sampling points (TS1–TS4) in Simpang Lima City Park, Semarang, Central Java, Indonesia. Basemap: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2.2 Vegetation Census and Diversity Analysis

All vascular plants in the park were censused, and every individual of each species was counted. Each tree or palm stem was counted as one individual; for clump-forming ground covers and clipped hedges, the number of clumps or rooted groups was estimated. Species were identified in the field with the Pl@ntNet application and field guides Buku Inventaris Jenis-jenis Pohon Hutan Kota Universitas Indonesia Seri 1: Wales Barat (Naufal *et al.*, 2014), and identifications were verified (Naufal *et al.*, 2014). Each species was assigned to a growth form (tree, shrub or herb). Species diversity was calculated with the Shannon–Wiener index, $H' = -\Sigma\, p_i \ln p_i$, where p_i is the proportion of individuals belonging to species *i* (Shannon, 1948), and evenness as $E = H'/\ln S$, where S is species richness (Pielou, 1966). Because ground covers and hedges were planted at much higher densities than trees, both indices were also calculated separately for the tree stratum and for the understory (shrubs and herbs).

2.3 Leaf Sampling Design

Leaves were sampled from every species recorded in the census. At each sampling point, available species were sampled from a different individual plant; the same individual was not resampled at another point. From each sample plant, three to five fully expanded, mature and undamaged leaves (third to fifth leaf from the shoot apex) were collected for stomatal and leaf-area observations. Approximately 11 g of leaf material was collected for biochemical APTI analyses. The exact sampling radius, crown height and sampling time were not specified in the

available field records. Leaves were sealed in labelled polyethylene bags, kept in a cool box and transported to the laboratory. The exact time between collection and laboratory analysis was not specified in the available records. Leaves from one individual were pooled to form one biological replicate, and each biochemical assay was run in triplicate technical readings that were averaged before statistical analysis. The number of biological samples varied by species according to its occurrence at the four sampling points (n = 1–4), rather than 12 biological replicates per species.

2.4 Biochemical Analyses

Relative water content (RWC, %) was calculated as RWC = [(FW − DW)/(TW − DW)] × 100, where FW is fresh mass, TW is turgid mass after the leaves were floated in distilled water for 24 h, and DW is dry mass after oven-drying at 60 °C to constant mass (Singh *et al.*, 1991).

Total chlorophyll (Ct) was extracted from 0.5 g of fresh leaf tissue in 10 mL of 80% acetone. After centrifugation, absorbance was read at 645 and 663 nm, and Ct (mg g^{-1} FW) was calculated as (20.2 A_{645} + 8.02 A_{663}) × V/(1000 × W), where V is the extract volume (mL) and W is the fresh mass of tissue (g) (Arnon, 1949).

Ascorbic acid (A) was determined spectrophotometrically. A 0.25 g of fresh leaf tissue was extracted in 10 mL of distilled water (aquades). Absorbance was read at 289 nm, and the concentration in the extract (C, µg mL^{-1}) was obtained from an L-ascorbic acid standard curve. Content was expressed on a fresh-mass basis as A (mg g^{-1} FW) = C × V/(1000 × W).

Leaf-extract pH (P) was measured after homogenising 5 g of fresh leaf tissue in 50 mL of CO_2-free distilled water; the homogenate was filtered and measured with a pH meter calibrated with pH 4.0 and 7.0 buffers.

2.5 Leaf Area and Stomatal Index

The area of each sampled leaf was measured with a leaf area meter determined from the leaf measurements recorded for each sample and expressed in cm^2. Stomatal index was calculated from the recorded numbers of stomata (S) and epidermal cells (E). Stomatal observations were made under a microscope at 400× magnification, and stomatal index (SI, %) was calculated as SI = [S/(S + E)] × 100 (Salisbury, 1928).

2.6 APTI and Tolerance Classes

APTI was calculated with the formula of Singh and Rao (1983), as applied by Singh *et al.* (1991):

$$APTI = [A\ (Ct + P) + RWC] / 10 \quad (1)$$

where A is ascorbic acid (mg g^{-1} FW), Ct is total chlorophyll (mg g^{-1} FW), P is leaf-extract pH and RWC is relative water content (%). All four variables were recalculated from the raw laboratory records in these units before APTI was computed. Species were classified with the thresholds commonly attributed to Singh *et al.* (1991) and compiled by Lohe *et al.* (2015) and Enitan *et al.* (2022): very sensitive (APTI < 1), sensitive (1–16), intermediate (17–29) and tolerant (30–100). This scheme was chosen because it is the classification originally associated with the APTI formula and remains the most widely applied, which allows direct comparison with earlier studies.

2.7 Statistical Analysis

Differences in APTI and its components among species were tested with one-way analysis of variance (ANOVA) after normality (Shapiro–Wilk test) and homogeneity of variances (Levene's test) had been checked; means were separated with Duncan's multiple range test (DMRT) at $p < 0.05$. Descriptive statistics were used to summarize leaf area and stomatal index across the recorded plant species-level means (n=21). Analyses were performed in IBM SPSS Statistics 25.

3. Results and Discussion

3.1 Plant Diversity and Composition

The census recorded 21,135 individuals belonging to 21 species and 14 families (Table 1). Fabaceae was the most species-rich family, with four species (*Saraca asoca*, *Tamarindus indica*, *Pithecellobium dulce* and *Samanea saman*). The whole community had a Shannon–Wiener index of H′ = 1.92 and an evenness of E = 0.63, indicating that individuals were unevenly distributed among species. *Ruellia angustifolia* alone accounted for 8,408 individuals (39.8%), followed by *Pedilanthus tithymaloides* (3,414; 16.2%) and *Syzygium myrtifolium* (3,164; 15.0%), whereas *Bougainvillea spectabilis* (5 individuals), *Spathodea campanulata* (6) and *Samanea saman* (8) were rare.

Separating the strata showed that this pattern is driven by planting design. The understory (13 species, 19,862 individuals) had H′ = 1.75 and E = 0.68 and was dominated by densely planted ground covers and hedges. The tree stratum (8 species, 1,273 individuals) had H′ = 0.90 and E = 0.43, because *Arenga engleri* contributed 978 individuals (76.8%). In a managed park, abundance reflects horticultural choice, planting density and maintenance (clipping and replanting) rather than natural community assembly, and abundance-based indices calculated across strata are inflated by the numerical dominance of small ground-cover plants. Stratum-specific values are therefore more appropriate for comparison with other urban parks. The park contained more species than Tugu Muda (10 species) and Taman KB (15 species) in Semarang (Margahayu *et al.*, 2015), but differences in survey year, area and effort make this comparison descriptive only. These diversity values describe the structure of the planted community and are not, in themselves, measures of air-quality improvement.

Table 1. Plant species composition, growth form and abundance in Simpang Lima City Park, Semarang.

Family	Scientific name	Common name	Growth form	Individuals	RA (%)
Acanthaceae	*Ruellia angustifolia*	Purple ruellia	Herb	8,408	39.8
Acanthaceae	*Justicia gendarussa*	Willow-leaved justicia	Shrub	224	1.1
Amaranthaceae	*Aerva sanguinolenta*	Climbing wool-plant	Herb	640	3.0
Annonaceae	*Polyalthia longifolia*	Mast tree	Tree	123	0.6
Araceae	*Spathiphyllum wallisii*	Peace lily	Herb	329	1.6
Arecaceae	*Elaeis guineensis*	African oil palm	Tree	28	0.1
Arecaceae	*Arenga engleri*	Formosa palm	Tree	978	4.6
Asparagaceae	*Dracaena marginata*	Madagascar dragon tree	Shrub	578	2.7
Asparagaceae	*Cordyline fruticosa*	Ti plant	Shrub	1,780	8.4
Bignoniaceae	*Handroanthus chrysotrichus*	Golden trumpet tree	Tree	14	0.1
Bignoniaceae	*Spathodea campanulata*	African tulip tree	Tree	6	0.0
Euphorbiaceae	*Pedilanthus tithymaloides*[a]	Devil's backbone	Shrub	3,414	16.2
Fabaceae	*Saraca asoca*	Ashoka tree	Shrub	480	2.3
Fabaceae	*Tamarindus indica*	Tamarind	Tree	50	0.2
Fabaceae	*Pithecellobium dulce*	Manila tamarind	Tree	66	0.3
Fabaceae	*Samanea saman*	Rain tree	Tree	8	0.0
Heliconiaceae	*Heliconia psittacorum*	Parrot's flower	Shrub	770	3.6
Lythraceae	*Lagerstroemia indica*	Crape myrtle	Shrub	42	0.2
Myrtaceae	*Syzygium myrtifolium*	Red lip	Shrub	3,164	15.0
Nyctaginaceae	*Bougainvillea spectabilis*	Great bougainvillea	Shrub	5	0.0
Pandanaceae	*Pandanus pygmaeus*	Dwarf pandan	Herb	28	0.1
Total				21,135	100.0
Whole community: S = 21; H′ = 1.92; E = 0.63					
Tree stratum: S = 8; N = 1,273; H′ = 0.90; E = 0.43					
Understory (shrubs and herbs): S = 13; N = 19,862; H′ = 1.75; E = 0.68					

RA = relative abundance; S = species richness; N = number of individuals; H′ = Shannon–Wiener diversity index; E = Pielou evenness index. [a] Currently accepted as *Euphorbia tithymaloides* L.

3.2 Air Pollution Tolerance Index

APTI differed significantly among species (Table 2). Values ranged from 8.87 in *Pandanus pygmaeus* to 40.84 in *Pedilanthus tithymaloides*. Following the classification of Singh *et al.* (1991), 14 species were classified as sensitive (APTI 1–16), six as intermediate (APTI 17–29), and one as tolerant (APTI 30–100). The sensitive species included *Tamarindus indica*, *Saraca asoca*, *Bougainvillea spectabilis*, and *Pandanus pygmaeus*, while species such as *Pithecellobium dulce*, *Cordyline fruticosa*, and *Spathodea campanulata* were classified as intermediate. *Pedilanthus tithymaloides* was the only species classified as tolerant. These values overlap with and extend beyond those reported for urban trees elsewhere in Indonesia, which ranged from 6.6 to 9.8 in Jakarta and Depok (Putri *et al.*, 2023) and from 7.3 to 10.0 in Ragunan and Depok (Hamid *et al.*, 2022), and with the range of 4.8–31.8 compiled for 28 species worldwide (Enitan *et al.*, 2022). Because APTI is very sensitive to the units of ascorbic acid and chlorophyll, values are comparable between studies only when both are expressed on the same basis (mg g^{-1} fresh mass).

No species was classified as very sensitive. This finding is consistent with the mathematical structure of the APTI formula. Because ascorbic acid, total chlorophyll and leaf-extract pH are positive values, APTI is always greater than RWC/10. Therefore, an APTI value below 1 would require a relative water content below 10%, which was not observed in the sampled leaves. Based on the classification scheme applied in this study, 14 species were classified as sensitive, six as intermediate and one as tolerant. *Pedilanthus tithymaloides* was the only species classified as tolerant, with an APTI value of 40.84. No species was classified as very tolerant under the classification scheme used in this study. These classifications should not be interpreted as direct evidence of environmental pollutant exposure or actual pollution-removal capacity.

These values must be interpreted within the limits of the design. First, ambient pollutant concentrations were not measured during the 2025 sampling period, and no low-pollution reference site was sampled; the earlier CO and Pb measurements at Simpang Lima (Margahayu *et al.*, 2015) provide context only, not evidence of exposure in 2025. APTI is therefore treated here as a physiological, leaf-based assessment of relative tolerance among co-occurring species, not as a response to a measured pollutant dose. Second, ascorbic acid, chlorophyll and relative water content also vary among species and with leaf age, season and water status, independently of pollution. Third, APTI quantifies tolerance, not pollutant uptake or retention; identifying tolerant species as effective pollutant sinks would require measurements of leaf dust load and foliar metal content, such as those made for urban trees in Jakarta and Depok by Yuniati *et al.* (2024).

Table 2. Leaf biochemical parameters, Air Pollution Tolerance Index (APTI) and tolerance class of plant species in Simpang Lima City Park, Semarang.

Species	A (mg g^{-1} FW)	Ct (mg g^{-1} FW)	P (pH)	RWC (%)	APTI	Class
Aerva sanguinolenta	4.98	0.27	6.10	86.00	1.77	Sensitive
Arenga engleri	9.38	0.55	5.40	90.68	14.65	Sensitive
Bougainvillea spectabilis	7.53	0.53	6.13	88.24	13.85	Sensitive
Cordyline fruticosa	18.81	0.39	5.42	79.50	18.89	Intermediate
Dracaena marginata	11.44	0.30	5.67	87.95	15.57	Sensitive
Elaeis guineensis	13.50	0.44	5.42	92.97	17.22	Intermediate
Handroanthus chrysotrichus	14.38	0.51	5.57	89.80	17.73	Intermediate
Heliconia psittacorum	5.66	0.79	5.88	90.87	12.91	Sensitive
Justicia gendarussa	15.44	0.32	5.97	74.23	17.14	Intermediate
Lagerstroemia indica	13.65	0.23	5.70	78.51	15.95	Sensitive
Pandanus pygmaeus	1.02	0.28	5.58	82.71	8.87	Sensitive
Pedilanthus tithymaloides	69.52	0.16	4.60	77.71	40.84	Tolerant
Pithecellobium dulce	14.19	0.84	5.96	73.96	17.04	Intermediate
Polyalthia longifolia	6.52	0.51	5.93	91.60	13.39	Sensitive
Ruellia angustifolia	1.03	0.33	6.13	94.80	10.15	Sensitive
Samanea saman	12.23	0.66	5.97	66.67	14.77	Sensitive
Saraca asoca	9.68	0.18	5.98	87.28	14.67	Sensitive
Spathiphyllum wallisii	0.76	0.28	6.67	84.89	9.02	Sensitive
Spathodea campanulata	18.87	0.48	5.83	83.92	20.35	Intermediate

Species	A (mg g^{-1} FW)	Ct (mg g^{-1} FW)	P (pH)	RWC (%)	APTI	Class
Syzygium myrtifolium	12.82	0.23	5.36	74.66	14.64	Sensitive
Tamarindus indica	6.22	0.31	2.73	80.68	9.97	Sensitive

Values are presented as species-level means across available sampling points. The number of biological samples varied among species (n = 1–4). Technical replicates were averaged before calculating species-level values. A = ascorbic acid; Ct = total chlorophyll; P = leaf-extract pH; RWC = relative water content; FW = fresh weight. Tolerance classes follow Singh et al. (1991).

3.3 APTI and Leaf Morphological Characteristics

Leaf area and stomatal index varied among the plant species recorded in Simpang Lima City Park (Table 3). Leaf area ranged from 2.02 to 298.01 cm², while stomatal index ranged from 7.48% to 50.27%. These variations indicate differences in leaf morphological characteristics among the recorded species.

Leaf area and stomatal index provide additional morphological information for characterizing plant species in urban green spaces. Although these parameters are not included in the APTI formula, they complement the biochemical assessment of plant tolerance to air pollution. Differences in leaf morphology may contribute to variations in plant responses to environmental conditions. However, leaf area and stomatal index alone cannot establish the actual air pollution tolerance of a species. Further investigations involving measured pollutant concentrations and repeated observations are needed to understand these responses.

Table 3. Leaf area and stomatal index of plant species in Simpang Lima City Park, Semarang.

Species	Leaf area (cm^2)	Stomatal index (%)
Aerva sanguinolenta	16.34 ± 0.13	18.82 ± 11.83
Arenga engleri	33.85 ± 1.74	9.97 ± 0.66
Bougainvillea spectabilis	17.39 ± 0.41	18.06 ± 1.17
Cordyline fruticosa	121.41 ± 12.41	8.97 ± 0.90
Dracaena marginata	48.39 ± 3.39	8.53 ± 1.64
Elaeis guineensis	169.31 ± 36.22	9.32 ± 1.50
Handroanthus chrysotrichus	169.56 ± 6.79	7.48 ± 1.79
Heliconia psittacorum	298.01 ± 33.38	13.54 ± 3.35
Justicia gendarussa	10.56 ± 0.54	13.56 ± 0.63
Lagerstroemia indica	12.15 ± 0.44	10.96 ± 1.62
Pandanus pygmaeus	16.59 ± 1.70	6.81 ± 1.12
Pedilanthus tithymaloides	31.62 ± 0.30	10.85 ± 0.69
Pithecellobium dulce	2.02 ± 1.42	18.86 ± 2.15
Polyalthia longifolia	82.28 ± 16.08	16.02 ± 3.51
Ruellia angustifolia	11.07 ± 3.19	21.62 ± 6.70
Samanea saman	3.86 ± 0.44	50.27 ± 3.63
Saraca asoca	3.05 ± 1.48	21.11 ± 1.61
Spathiphyllum wallisii	151.40 ± 0.73	7.85 ± 2.42
Spathodea campanulata	55.01 ± 11.63	12.77 ± 3.33
Syzygium myrtifolium	5.95 ± 1.01	17.62 ± 2.31
Tamarindus indica	25.91 ± 0.92	14.73 ± 1.84

Values are presented as mean ± SD. The number of observations varied among species according to data availability.

3.4 Implications for Limnology in Indonesia

No aquatic variables were measured in this study, and the implications below are hypotheses for future work rather than findings. Simpang Lima is a small, vegetated area surrounded by impervious roads and buildings. During rain, material deposited on these surfaces and on the canopy of the park can be transported through the local drainage network toward downstream urban waterways. The specific receiving channel for runoff from Simpang Lima was not established in this study. Separately, sediments in the Banjir Kanal Timur system contain Pb attributed partly to transport-related sources (Nugraha Putra *et al.*, 2022; Syafrudin *et al.*, 2026), and rain across Java is frequently acidic, with sulfate and nitrate concentrations highest in urban

areas (Hidayati *et al.*, 2025). Park vegetation is part of the broader urban atmosphere–drainage–river context.

Three implications follow. First, plants that persist under urban air pollution are a prerequisite for sustained canopy interception and transpiration, which reduce stormwater volume and contribute to pollutant removal in vegetated systems (Muerdter *et al.*, 2018); APTI can help exclude species likely to decline in polluted streetscapes. Second, tolerance does not mean permanent removal. Particles retained on leaves can be washed off by rain or transferred to the ground with litterfall (Xu *et al.*, 2020), and tree canopy near streets can increase nutrient inputs to stormwater (Janke *et al.*, 2017). In a tropical city with intense rainfall, part of the air-quality benefit of tolerant species may therefore be converted into pulses of particle-bound pollutants and organic matter entering drains, especially at the onset of the wet season. Third, planting design matters: Simpang Lima is numerically dominated by ground covers and hedges, whereas its canopy, which provides most of the rainfall-intercepting leaf area, has low diversity and is dominated by a single palm species. Increasing canopy cover with tolerant, broad-crowned species, combined with litter removal, street sweeping and bioretention of runoff, would link air-quality and water-quality objectives.

These hypotheses are relevant beyond Semarang. Indonesian lakes such as Rawapening in Central Java integrate catchment and atmospheric inputs, and their sediments have been used to reconstruct past water quality (Soeprobowati & Hadisusanto, 2009; Soeprobowati *et al.*, 2016); lake sediments elsewhere preserve long records of atmospheric Pb deposition (Renberg *et al.*, 2000). Future work should pair APTI screening with measurements of leaf-surface particulate and metal loads, throughfall and runoff chemistry from parks, sediment in street drains and the quality of receiving rivers, across wet and dry seasons. Such paired data would show whether tolerant urban vegetation acts as a long-term sink or as a temporary store that releases pollutants to inland waters, and would place urban green-space planning within catchment-scale water-quality management in Indonesia.

4. Conclusion

Simpang Lima City Park supported 21 plant species from 14 families ($H' = 1.92$; $E = 0.63$), but diversity was low in the tree stratum ($H' = 0.90$), and the community was numerically dominated by planted ground covers and hedges, reflecting design rather than ecological selection. APTI ranged from 8.87 (*Pandanus pygmaeus*) to 40.84 (*Pedilanthus tithymaloides*), with 1 species classified as tolerant, 6 as intermediate and 14 as sensitive. Leaf area and stomatal index varied among the recorded plant species, providing additional information on their morphological characteristics. These results provide a physiological screening baseline for species selection in Semarang's urban parks; they do not demonstrate pollutant removal or improved air quality. Because no runoff or receiving-water measurements were made, no limnological effect can be inferred, but the results identify testable links between urban vegetation, atmospheric deposition and urban inland waters that should be examined with paired vegetation, runoff and water-quality monitoring.

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6. Conflict of Interest Declaration

The authors declare that there is no conflict of interest regarding the publication of this article.

7. Author Contribution Statement

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C : **C**onceptualization
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I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

8. Generative AI Statement

During the preparation of this manuscript, the authors used ChatGPT to assist with language refinement and improve the clarity and readability of the text. The authors critically reviewed and edited all AI-assisted content and take full responsibility for the accuracy and integrity of the final manuscript.

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