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Evaluation of several plant species for the sustainability of green open spaces in three sectors

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Abstract. *Salsabila SH, Kurniadie D, Withaningsih S. 2022. Evaluation of several plant species for the sustainability of green open spaces in three sectors. Biodiversitas 23: 3861-3868.* The climate change caused by air pollution could be overcome by creating green open spaces. Plants can absorb air pollution, provide shade, and be used as aesthetics and location boundary. Furthermore, plants' resistance to air pollution varies according to physiology and morphology. The objectives of this study were to assess the species diversity of vegetation and the tolerance index to air pollution of some plant species using the APTI (Air Pollution Tolerance Index) method in household, industry, and transportation areas in Eat Java. The observed plant species in the three sectors were the same. The result showed that the Shannon-Wiener diversity index value (H') was considered medium, and based on the APTI test, *Pseuderanthemum reticulatum* had the highest tolerance level with an APTI value of 27.59in the industrial sector (I0), 38.31 in the household sector (P1) and 31.73 in the transportation sector (T0). Meanwhile, *Syzygium myrtifolium* had the lowest tolerance level to air pollution with an APTI value of 12.64 in the industrial sector (I1), 11.59 in the household sector (P1) and 12.70 in the transportation sector (T0). This research provides information regarding the environmental conditions of the ecosystem in green open spaces in the industrial, household and transportation sectors and gives recommendations on the sustainable management of green open spaces in line with Sustainable Development Goals (SDGs) number 13 based on the tolerance level of plants.

Keywords: Air pollution tolerance index, climate change, diversity index, green open spaces

Abbreviations: APTI: Air Pollution Tolerance Index, SDGs: Sustainable Development Goals, UNCED: United Nations Conference on Environment and Development

INTRODUCTION

Climate change occurs due to the accumulation of pollutant emissions. The sources of air pollutants are divided into primary and secondary, which are discharged into the environment and accumulate in the air due to chemical or photochemical interactions, respectively (Tiwary et al. 2016). Furthermore, they have their origins in human life and nature.

Efforts to increase green open spaces in several cities are one of the implementations of environmental management due to decreasing air quality to ensure the sustainability of natural resources. Several cities have increased green open space to improve the air quality and life quality of their citizens. Green open space management can positively impact the quality of life of the surrounding residents (Hansen et al. 2019) because green open space has ecological, socio-cultural, economic, and aesthetic functions. The ecological function is the primary function of green open space in improving environmental services (Liem and Lake 2018; Ruwaida et al. 2022).

The increase in biodiversity provided by green open spaces is an ecological advantage (Breuste et al. 2016; Artmann et al. 2019), so the presence of vegetation in green open spaces can increase the comfort of people's lives. Due to the current environmental issues and conditions, plants play an essential role as a medium for pollutant absorption. Stomata, located on most species' abaxial side of the leaves, are the primary entry route for the pollutant. Their aperture depends on many factors, including water content, temperature, plant development, and time of day (Paris et al. 2018). Furthermore, morphology, stomata density, and anatomy are essential criteria for plant species' ability to immobilize air pollutants (Liang et al. 2016; Tomson et al. 2021). *Hedera helix* L. is recommended for air purification and urban heat island mitigation efforts because this plant can absorb pollutants effectively since it has a high leaf area index (Perini et al. 2017). According to Jin et al. (2021), evergreen species were typically more effective at mitigating air pollution.

The Air Pollution Tolerance Index (APTI) is used to classify resistance to air pollution (Skrynetska et al. 2019). Its parameters include total chlorophyll, ascorbic acid concentration, water content, and the PH of leaf extract. Furthermore, the APTI value and biochemical parameters determine plant tolerance to environmental contaminants and the species' vulnerability to pollution (Kaur et al. 2017; Skrynetska et al. 2019).

Green open spaces have a significant impact on citizens' well-being and quality of life. As a result, the accessibility, usability, and social function of open spaces (living, recreation, and integration space) in urban environments are critical factors in meeting the diverse needs of all city users (Sturm et al. 2019; Khomenko et al. 2020). The microclimate of a city is directly influenced by green open spaces. Therefore, green open space provision must be viewed holistically; a relationship between environmental and human well-being indicators must be established (Kandziora et al. 2013; Sturiale 2019). The existing and future potential of green open spaces for improving air quality may be realized prudently by selecting appropriate plants to reduce and adapt air pollutants. Various plant species have different tolerance levels for absorbing pollutants; therefore, the tolerance of plant resistance to absorbing pollutants must also be analyzed to provide the right strategy for managing natural resources and the environment sustainably in accordance with the vision and mission of Sustainable Development Goals (SDGs) number 13, i.e., the handling of climate change. The objectives of this study were to assess the plant species diversity of vegetation and the tolerance index to air pollution of some plant species using the APTI (Air Pollution Tolerance Index) method in household, industry, and transportation areas in East Java.

MATERIALS AND METHODS

Research area

This research was conducted from January to April 2022 in Sidoarjo City. Sampling was conducted on plants in the household sector, located in Delta Sari Indah Waru (P1) and Kahuripan Nirwana Village (P0), an industrial sector located in Meiko Abadi II Buduran Industrial Estate (I1) and Berbek Waru Industrial Estate (I0), and transportation sector, a located in Three-way Junction of Lingkar Timur Buduran (T1) and Old Porong Market (T0).

Data collection

A survey was conducted to determine the research locations and plant samples. The selected locations were the regions in Sidoarjo City with the highest and lowest pollutants (according to the Low Carbon Development roadmap), representing three location sectors, i.e., household, industry and transportation. The sampled plants were of the same mature, healthy species at the specified locations with fully opened and healthy leaves.

Plant species diversity

A plot of 100 m^2 at a predetermined location was made for each sector. The species and the number of individuals were recorded. Shannon-Wiener diversity index (H') was calculated using the following formula (Kumar et al. 2022):

$$H' = -\sum \left[\frac{ni}{N}\right] \log \left[\frac{ni}{N}\right]$$

Where:
H' : Shannon-Wiener diversity index.
ni : Number of individuals of the i^{th} species.
N : Total number of individuals of all species.
The value of H' ranges from 1.35-3.5 (Bibi and Ali 2013)

APTI (Air Pollution Tolerance Index)

The APTI formula is [A (T+P)+R]/10 (Sumangala et al. 2018), where: A, P, T, and R are ascorbic acid (mg/g), leaf pH, total chlorophyll (mg/g), and concentration of leaf water (%). Table 1 shows that the data from APTI values (Air Pollution Tolerance Index) was used to determine plant tolerance to air pollution.

Determination of total chlorophyll levels

Total leaf chlorophyll was measured using a spectrophotometer. A 0.5 g of the extracted leaf sample was dissolved with 80% acetone to approximately 50 mL and filtered. The solution was centrifuged for 3 minutes at a speed of 2500 rpm. Finally, the total chlorophyll content in leaves with wavelengths of 645 nm and 663 nm was calculated with the formula Ct = 20.2 (D645) + 8.02 (D663) (Veni et al. 2014).

Determination of leaf pH

The leaf acidity was measured using a pH meter. One gram of crushed sample leaves was dissolved with 20 mL of distilled water. Afterward, the leaf extract was centrifuged at 2,000 rpm for 15 minutes. The solution was measured with a pH meter (Dash and Dash 2018).

Determination of ascorbic acid concentration

The calculation of ascorbic acid was analyzed using the iodine titration method. A half gram of leaf samples was dissolved with 50 mL of distilled water. Five milliliters of the filtrate were collected and added with two drops of starch solution and 20 mL of distilled water. Afterward, the sample was titrated with 0.1 N starch indicator solution until the color changed to solid blue. The following formula was used to perform the calculation (Simon et al. 2021):

$$AA = \frac{VI2 \times \frac{Vt}{Vf} \times A}{W}$$

Where:
VI2 : titration volume I2 (mL)
Vt : total volume of filtrate (mL)
Vf : volume of filtrate used (mL)
A : equivalence of pure vitamin C with I2 (mg)
W : mass of sample (mg)

Table 1. Criteria for plant tolerance to air pollution

Criteria	APTI
Sensitive	<1
Intermediate	1-16
Moderate	17-29
Tolerant	30-100

Determination of plant water content

Leaf samples were dried in an oven at 105ºC for 4 hours. Afterward, the water content was measured using the gravimetric method (Esfahani et al. 2013), as shown in the following formula:

$$\text{Water Content (\%)} = \frac{\text{FW} - \text{DW}}{\text{DW}} x\ 100$$

Where:
FW : fresh weight
DW : dry weight

RESULTS AND DISCUSSION

Air pollution

Air pollution is one of the most challenging problems to control. Population growth is the cause of air pollution and the population in big cities is larger than in the villages. The United Nations Conference on Environment and Development (UNCED) in 1992 and continued at the Johannesburg Summit in 2002 discussed the vision to save the environment due to the global warming phenomenon. The discussion on efforts to manage spatial planning in all countries, including Indonesia, stated that 30% of the city's land area has green open space. Furthermore, the Indonesian government issued Law Number 26 of 2007 concerning Spatial Planning, stipulating that 30% of the urban area should be designated as green open spaces. Ischak and Burhannudinnur (2020) stated that in a legal hierarchy, spatial planning is regulated through Law Number 26 of 2007, as implied by Government Ordinance Number 15 of 2010 concerning the Implementation of Spatial Planning. Afterward, it was technically regulated by Minister of Home Affairs Regulation Number 1 of 2007 concerning the Arrangement of Green Open Space in Urban Areas.

The research location was divided into three sectors, namely industry (I), household (P), and transportation (T). Furthermore, each of them could be classified into two categories, namely locations I1, P1, and T1 which had the higher air pollution level, and I0, P0, and T0, the lower. Table 2 shows the pollutants accumulation data. P1 and I1 had the highest and lowest pollutant value, respectively. The accumulation of pollution will reduce the longevity of plants in green open spaces. According to Table 2, air pollution in this sector is below the quality standard, except in P1, where the CO value is 4011 µg/m^3. This location had a high CO concentration because it is located around the dense transportation sector. Pollutants in the household sector are higher than those in the transportation counterpart. This higher value corresponds with the increase in SO_2 generated from the household sector's energy and not the transport sector in highly populated cities (Lu and Liu 2016; Rodríguez et al. 2016). Population density can significantly reduce high NOx emissions while simultaneously increasing SO_2 emissions (Bereitschaft and Debbage 2013). The increase in activities due to the high population causes more air pollution (McCarty et al. 2015; Lu and Liu 2016).

Rai (2016) stated that plants in urban environments exposed to pollutants showed different responses in photosynthesis, respiration, enzymatic reactions, stomata behavior, and membrane disturbances. Plants are components in green open spaces that absorb pollution, especially carbon that can cause climate change. Shrub species are better at controlling PM than tree species. (Nguyen et al. 2015; Yang et al. 2015).

According to Permana et al. (2022), *Sansevieria sp*. has thick leaves that can absorb toxic pollutant gases such as carbon monoxide, benzene, formaldehyde, and carbon dioxide produced by incomplete combustion in motor vehicles. The wax coating on the thick leaves of *Sansevieria* sp. is one of the factors inhibiting leaf damage due to air pollution. Its layer retains water content, reduces the loss of nutrients and metabolites, gas exchange, and protects against reactive pollutants such as CO and O_3.

The plant species influence the effect of air pollution. According to Pajević et al. (2016), most tree plants can tolerate low and moderate pollution using adaptation mechanisms. Damage to plants due to air pollution results from the disruption of the biosynthesis of proteins and fats, respiration and photosynthesis at the level of biochemical processes. This is accompanied by the ultrastructural level (disorganization of cell membranes), cellular level (the cell wall, mesophyll, the cell nucleus) and ends with the chlorosis and necrosis symptoms on leaf tissue.

Table 2. Data on air pollution in the research location

Location Sector	NO_2 (µg/m$_3$)	SO_2 (µg/m$_3$)	NH_3 (ppm)	H_2S (ppm)	TSP (ppm)	NMHC (µg/m$_3$)	CO (µg/m$_3$)	O_3 (µg/m$_3$)	Pb (µg/m$_3$)
I1	<12.00	48.00	0.01	0.002	33.00	<6.53	1608.00	<7	<0.02
I0	<12.00	40.00	<0.01	0.002	9.00	<6.53	<1146	<7	<0.02
P0	<12.00	48.00	0.01	0.001	22.00	<6.53	1529.00	<7	<0.02
P1	27.00	49.00	0.01	0.002	56.00	<6.53	4011.00	12.00	<0.02
T1	18.00	22.00	<0.01	0.001	36.00	<6.53	<1146	<7	0.0700
T0	<12.00	42.00	<0.01	0.001	23.00	<6.53	1505.00	<7	<0.02
Quality standards	65/24H	75/24H	2.00	0.02	230/24H	160/3H	4000/8H	150/1H	2/24H

Note: I1: Meiko Abadi II Buduran Industrial Estate, I0: Berbek Waru Industrial Estate, P1: Delta Sari Indah, P0: Kahuripan Nirwana Village, T1: Three-way Junction of Lingkar Timur Buduran, T0: Three-way Junction of the Old Porong Market

Many factors influence the ability of a plant leaf to hold pollutants, especially PM. The form, type, and hairiness of the leaf surface directly impact plants' PM-retaining capacities, and the combination of these traits has a considerable impact on this ability (Leonard et al. 2016). For example, Guerrero-Leiva et al. 2016 looked at three plant species with various leaf surface morphologies and discovered that those with a rough leaf surface are better at retaining PM than those with smoother leaf surfaces. Other parameters that influence the PM-holding capacity of plant leaves include the existence or absence of a wax layer, the thickness of the wax layer, and the chemical composition and structure of the wax layer. The amount of PM kept on leaf surfaces is proportional to the amount of wax layer retained on different sizes of leaves (Wu et al. 2018).

Plant species diversity

Green open space was implemented in the interests of environmental management. Its multifunctional concept is now being used in urban areas, developing several functions in the same region by combining the ecological and social factors in green infrastructure (Haaland and Van Den Bosch 2015; Hansen et al. 2017; Shams and Barker 2019). Examples of implementation efforts include creating green offices, green belts, and city parks.

Green open space functions to absorb air pollution with its physiological capabilities. Homogeneous ecosystem conditions help plants maintain their physiological conditions effectively. In addition, species diversity is affected by environmental parameters, such as the difference in location elevation (Supriya et al. 2019; Lai et al. 2021). According to Li et al. (2018), differences in altitude affect the humidity and temperature, which determine species diversity.

Table 3 shows the list of all species and the number of species in the research location. Table 4 shows that the diversity indexes (H’) in the study sites ranged from 1.29 to 1.90 at the Berbek Waru and Meiko Abadi II Buduran Industrial Estate, respectively. These values in all research locations are medium diversity because the values range of the Shannon-Wiener diversity index from 1.35 to 3.5 (Bibi and Ali 2013). The diversity of plant species provides microhabitat heterogeneity for wildlife.

Tabel 3. The list of plant species in the research location

Species	Number of species					
	I1	**I0**	**P1**	**P0**	**T1**	**T0**
Hymenocallis litoralis	3	43	112	65	8	78
Pseuderanthemum reticulatum	1	36	56	48	2	27
Syzygium myrtifolium	2	5	18	27	4	22
Ruellia simplex	0	64	58	66	18	46
Samanea saman	0	2	1	1	0	1
Polyalthia longifolia	0	0	7	0	8	3
Canna indica	2	2	22	9	46	2
Plumeria alba	3	0	0	1	3	0
Graptophyllum pictum	0	0	0	0	6	0
Pterocarpus indicus	2	0	0	0	0	0
Mangifera indica	4	0	0	0	0	0
Pandanus amaryllifolius	8	0	0	0	0	0
Cerbera manghas	0	0	0	0	0	2
Bougainvillea	0	0	0	0	0	2
Hibiscus rosa-sinensis	0	0	0	0	0	1
Codiaeum variegatum	0	0	0	0	0	3
Total	25	152	274	217	95	187

Note: I1: Meiko Abadi II Buduran Industrial Estate, I0: Berbek Waru Industrial Estate, P1: Delta Sari Indah, P0: Kahuripan Nirwana Village, T1: Three-way Junction of Lingkar Timur Buduran, T0: Three-way Junction of the Old Porong Market

Tabel 4. Values of diversity index

Location	Total individual of plants	H'	Remark
I1	25	1.90	Intermediate
I0	152	1.29	Intermediate
P1	274	1.51	Intermediate
P0	217	1.50	Intermediate
T1	95	1.58	Intermediate
T0	187	1.57	Intermediate

Note: I1: Meiko Abadi II Buduran Industrial Estate, I0: Berbek Waru Industrial Estate, P1: Delta Sari Indah, P0: Kahuripan Nirwana Village, T1: Three-way Junction of Lingkar Timur Buduran, T0: Three-way Junction of the Old Porong Market

The use of open space land to create a green belt by planting various plant species that provide aesthetic benefits, absorb pollution, and provide shade is one way to help safeguard the environment (Jieqing et al. 2017). It functions as a dust cleaner, chemicals in the air, and absorbs heat in urban areas. Furthermore, the design of the green belt should be carefully based on the location and plant species. The effectiveness of vegetation in reducing air pollution can be determined by the species of plant and leaf structure.

The open space in the household sector had an aesthetic effect, regulating the microclimate and improving the quality of community comfort. Efforts to procure green open space in the industrial, household and transportation sectors are environmental management due to decreasing air quality. Several cities have made efforts to increase the provision of green open spaces to enhance the air quality and life quality of their citizens (Kothencz 2017).

Plant resistance based on APTI (Air Pollution Tolerance Index)

Not all plant species can be used for bioremediation to overcome the problem of air pollution. The plants selected for this process should have a high tolerance to high pollution. The plant is believed to be sensitive to air pollution when they are not tolerant of these areas, having physiological damage that could lead to death. The tolerance level of a plant can be tested using the APTI (Air Pollution Tolerance Index) method.

APTI (Air Pollution Tolerance Index) is a method used to find recommendations for plants with a high tolerance index in the management of green open spaces by analyzing physiological components to determine plant sensitivity or resistance to various concentrations of air pollutants (Pandey et al. 2016).

The results in Table 5 show four species of the same plant at the six research locations. The highest and lowest levels of ascorbic acid were discovered in *Pseuderanthemum reticulatum* and *Syzygium myrtifolium* plants at locations I0 and P0, respectively, with values of 9.67 mg/g and 2.22 mg/g. According to Elawa et al. (2022), ascorbic acid is high in polluted locations because it is an antioxidant that increases plant resistance to air pollution. Species of plants with high ascorbic acid production will prevent the harmful effects of pollutants on the tissues and enhance the rate of oxygen generation, making plants more tolerant to air pollution (Meerabai et al. 2012; Karmakar et al. 2021). According to Zhang et al. (2016), ascorbic acid affects the tolerance level of plants to air pollution because it is active in physiological processes and plant defense mechanisms. It can also act as an electron donor for various enzymes and non-enzymatic reactions, reducing agents, and antioxidants.

Table 5. Criteria for plant resilience based on APTI value

Species	Location	A	T	P	R	APTI	Criteria
Hymenocallis litoralis	I1	6.34	14.50	5.68	78.17	20.61	Moderate
	I0	6.06	15.78	5.57	79.72	20.91	Moderate
	P1	5.68	16.41	5.70	86.44	21.20	Moderate
	P0	5.71	15.80	5.79	87.28	21.05	Moderate
	T1	6.10	15.51	5.52	81.07	20.94	Moderate
	T0	5.82	15.15	5.67	81.70	20.28	Moderate
Pseuderanthemum reticulatum	I1	9.67	14.61	5.31	62.91	25.55	Moderate
	I0	8.25	17.51	6.36	79.01	27.59	Moderate
	P1	7.87	30.43	7.11	87.81	38.31	Tolerant
	P0	8.04	29.19	7.19	89.07	38.17	Tolerant
	T1	9.39	16.25	6.07	77.93	28.76	Moderate
	T0	9.10	19.44	6.42	81.88	31.73	Tolerant
Canna indica	I1	4.37	8.24	5.57	77.02	13.74	Intermediate
	I0	4.65	8.16	5.58	77.25	14.12	Intermediate
	P1	3.52	12.09	5.94	88.38	15.18	Intermediate
	P0	3.48	10.49	6.07	90.76	14.83	Intermediate
	T1	3.96	11.02	5.86	82.99	14.97	Intermediate
	T0	4.50	9.88	5.69	83.41	15.35	Intermediate
Syzygium myrtifolium	I1	6.29	5.17	6.17	55.05	12.64	Intermediate
	I0	4.77	6.85	6.19	71.61	13.38	Intermediate
	P1	2.80	8.93	6.33	73.16	11.59	Intermediate
	P0	2.22	9.43	6.42	83.61	11.88	Intermediate
	T1	5.34	5.47	6.24	72.63	13.51	Intermediate
	T0	4.05	7.44	6.18	71.83	12.70	Intermediate

Note: I1: Meiko Abadi II Buduran Industrial Estate, I0: Berbek Waru Industrial Estate, P1: Delta Sari Indah, P0: Kahuripan Nirwana Village, T1: Three-way Junction of Lingkar Timur Buduran, T0: Three-way Junction of the Old Porong Market. A: Ascorbate Acid (mg/g), T: Chlorophyl (mg/g), P: pH, R: Water Content (%)

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The chlorophyll content in plant species varies according to the location observed. Furthermore, it will be more abundant in locations with low pollutant distribution (Rai et al. 2013; Karmakar et al. 2021). Chlorophyll in plants has an essential role in photosynthesis by converting light energy into chemical energy. Table 5 shows that *P. reticulatum* had the highest chlorophyll in the household sector (P1 = 30.43), while *S. myrtifolium* had the lowest chlorophyll in the industrial sector (I1 = 5.17). This decrease in polluted areas was due to the accumulation of heavy metals and dust deposits on the leaf surface. Dust deposition on the leaf surface blocks the stomata pores and inhibits the absorption of sunlight (Roy et al. 2020).

Based on Table 5. the lowest pH was *P. reticulatum* in the industrial sector (I1=5.31). According to Rai et al. (2013) the acidic characteristic could be due to SOx, NOx, or other acidic pollutants in the ambient air from industrial emissions. A higher pH in a place enhances air pollution tolerance. Plant pH levels in the three sectors were generally acidic, but in the household sector, *P. reticulatum* has a neutral pH (P1=7.11 and P0=7.19). The pH levels of plants in the three sectors were generally low, but in the household sector, *P. reticulatum* had a neutral pH (P1=7.11 and P0=7.19). Furthermore, plants have low pH when they are polluted. According to Kaur and Nagpal (2017), the leaf of tree species in urban areas has low pH to increase tolerance to air pollution. Rai et al. (2013) and Roy et al. (2020) stated that tree species growing in industrial areas showed pH of 5.0 to 7.0, caused by pollutants and activities.

The relatively high-water content in plants helps maintain physiological balance under stressful conditions such as exposure to air pollution when transpiration rates are high, leading to drought. Air humidity affects the rate of transpiration, indicating the lower the water vapor, the faster the transpiration rate is fast, while the more the air-water content, the slower the transpiration rate. This implies that air humidity affects the transpiration rate. Table 5 shows that the highest and lowest plant water contents were 90.76% and 55.05% in *Canna indica* at P0 and *S. myrtifolium* at I0, respectively. Plants will survive drought and decrease the rate of photosynthesis in locations with high pollution and poor plant physiological quality. Lack of water is a barrier to the entry of CO_2, resulting in a decrease in photosynthetic activity because some of the leaf stomata close. Furthermore, it can inhibit photosynthetic activity and protein synthesis in cell walls (Tsega and Prasad 2014). According to Seyyednejad et al. (2017), the leaf water content is an indicator to determine the water status of plants. Under stressful conditions, a large amount of water in plant tissues helps maintain their physiological balance.

The overall data showed that *P. reticulatum* has a high tolerance level to air pollution in the tolerant category. The highest APTI value of *P. reticulatum* was 38.31, 38.17 and 31.73 in P1, P0, and T0, respectively. It has a high level of water content, ascorbic acid and other components of APTI such as pH, water content and chlorophyll are balanced; hence, the plant can defend itself from the stress of air pollution. Meanwhile, plants with an intermediate tolerance level in all sectors are *Canna indica* and *S. myrtifolium*. Those with a moderate tolerance level had lower ascorbic acid and chlorophyll than *Hymenocallis litoralis* and *P. reticulatum*; hence, their tolerance for air pollution was lower. The plant with the lowest APTI value was *S. myrtifolium*, with 11.59 at P1. It had a low ascorbic acid and water content of 2.80 mg/g and 73.16%. According to Swami and Chauhan (2015), acids impact the plant in physiological processes such as growth, differentiation, metabolism, and radical reducing agents in plants. Ascorbic acid affects the synthesis and defense of cell walls and carbon fixation in photosynthesis. Rai et al. (2013) stated that plants tolerant to air pollution have high ascorbic acid content, functioning as an antioxidant or reducing solid agent that can prevent oxidation reactions.

Based on the APTI data in Table 5 *P. reticulatum* had the highest tolerance level with an APTI value of 27.59in the industrial sector (I0), 38.31 in the household sector (P1) and 31.73 in the transportation sector (T0). Meanwhile, *S. myrtifolium* had the lowest tolerance level to air pollution with an APTI value of 12.64 in the industrial sector (I1), 11.59 in the household sector (P1) and 12.70 in the transportation sector (T0). Plants with high APTI yields are tolerant to air pollution, while those with low APTI yields generally have lower tolerances and are sensitive to air pollution (Rai et al. 2016; Roy et al. 2020). According to Gholami et al. (2016), determining the tolerance and sensitivity of plant species is very important to reducing pollutants in the environment. Anjali et al. (2018) stated that the difference in the tolerance index value of plants to air pollution from one species to another depends on each species' ability to defend itself from pollutants without causing external damage. This study concluded that none of the four species observed are sensitive to pollution and therefore are recommended to be planted in green open spaces.

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