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Air Pollution Tolerance of Several Species of Trees in the Petrochemical Industry Area Using Air Polution Tollerance Index (APTI) Method

Juswardi[1], Nabilah Sa'idah[2], Nita Aminasih[3], Singgih Tri Wardana[4]
[1,2,3,4] Department of Biology, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, South Sumatra, Indonesia.

ABSTRACT: The petrochemical industry is fertilizer industry factories whose production can have an impact on air quality. The industrial area has decreasedenvironmental quality caused by air pollution. Air pollution comes from factory activities as well as motor vehicle fumes and forest burning. The decline inair quality is characterized by the accumulation of pollutant particles in the air. Tree planting in the Petrochemical industry area aims to reduce air pollution. Trees that are able to withstand air pollution stress conditions are categorized as tolerant species. This study aims to determine the tolerance to air pollution by analyzing the *Air Pollution Tolerance Index* (APTI). Determination of the sampling area is done by *convinience sampling* method with severalsample criteria. The results showed that the APTI value of *Filicium decipiens* Wieght & Arn. (Fern Leaf Tree) was 5.08, *Swietenia macrophylla* King (Baywood) 5.62 and *Mimusops elengi* L. (Spanish Cherry) 5.93. This study shows that in the Petrochemical industry area, *F. decipiens is* categorized as a sensitive species, while *S. macrophylla* and M. *elengi are* categorized as moderately tolerant to air pollution based on tolerancecategory in Thakar and Mishra (2010).

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Corresponding Author:
Juswardi

INTRODUCTION

Urban air quality continues to decline due to high levels of air pollution. Sources of air pollution generally come from human activities such as the use of motor vehicles, combustion, and smoke from industrial factories. One of the growing industrial factories is the fertilizer industry. The fertilizer production process produces by-products in the form of pollutant particles that impact the environment.

Air pollution leads to morphological damage and physiological stress for plants, resulting in the following affects several biochemical components of plants. Tolerant plants are able to maintain chlorophyll levels under conditions exposed to air pollution (Karmakar and Padhy, 2019).

Plants that are tolerant to air pollution will increase ascorbic acid which acts as a strong reductant, electron donor, eliminates free oxygen radicals, and reduces the toxicity of pollutants (Shrestha *et al*., 2021). In addition, high leaf pH in a species indicates tolerance to air pollution (Bharti *et al*., 2018). High water content in plants under stress conditions also indicates that plants are tolerant to air pollution (Banerjee *et al*., 2021).

One of the largest Petrochemical industries in Palembang City procures Green Open Space (*Green Barrier*) as an effort to reduce air pollution and reduce noise in the factory area (Puspita *et al*., 2021). Plants that have a good physiological response to air pollution is a plant that has a high level of tolerance to polluted environments. Plants tolerant to polluted conditions can be used as objects of improvement air quality so as to re-optimize healthy air for needs living things. Tree selection is done by pay attention to the physiology and biochemistry of the plant as it grows in polluted air conditions. Efforts to plant trees in areas around the industry are a solution in overcoming air pollution problems (Azzahro *et al.*, 2020; Nugrahani, 2023).

Therefore, research was carried out which aimed to determine the tolerance of several trees located in a petrochemical industrial area against air pollution with analysis of the Air Pollution Tolerence Index (APTI) value. So this research is expected to be a source of information on species selection trees that have good tolerance to air pollution in petrochemical industrial areas.

MATERIAL AND METHODS

Sampling Area

The sampling area is located on the roads of the residential complex of one of the Petrochemical industry areas. Determination of the sampling area is carried out by the convinience sampling method (Figure 1 and Table 1).

Figure 1. Map of the research location at sampling points 1, 2 and 3 in the Petrochemical industry area, Palembang city.

Table 1. Coordinates of Sampling Area in Petrochemical Industry Area, Palembang

Research Location	Tree Species (sample)		Coordinates
	Filicium decipiens (Wieght & Arn.)	(1)	-2.972056,104.80347
1. Petanang street		(2)	-2.972056,104.80347
		(3)	-2.972035,104.803641
	Swietenia macrophylla King/	(1)	-2.970903,104.804122
2. Damar street		(2)	-2.9709075,104.804194
		(3)	-2.910827,104.804169
	Mimusops elengi L.	(1)	-2.972306,104.806118
3. Gurame street		(2)	-2.972306,104.806118
		(3)	-2.972236,104.806616

Sampling

Sampling was conducted during the dry season, namely in October 2023. According to data from the South Sumatra Climatology Station, rainfall throughout South Sumatra is in the range of 0-100 mm (Masrury, 2023). Leaf samples were taken from several mature trees that had a DBH of more than 20 cm (Rajakaruna & Maskorala, 2019).The criteria for trees that were sampled were trees with a dense crown density, thin and numerous leaves and tight planting distance (Azzahro *et al*., 2020). The characteristics of the leaves used as samples are mature leaves, solid green in color, and smooth leaf surfaces. Leaf samples were then analyzed for chlorophyll content, leaf pH, ascorbic acid content and relative water content as parameters to obtain APTI values. The APTI value is then used to determine plant tolerance criteria (Table 2).

Table 2: Plant tolerance criteria based on *Air Pollution Tolerance Index* (APTI) values.

APTI Value	Category
APTI > Mean APTI + SD	Tolerant
Mean APTI < APTI < Mean APTI + SD	Moderately Tolerant
Mean APTI – SD < APTI < Mean APTI	Intermediate
APTI < Mean APTI – SD	Sensitve

Source: (Thakar & Mishra, 2010)

Observation Variable

Total Chlorophyll Content of Leaves (TChl)

Measurement of chlorophyll content (mg/g) refers to the research conducted by Roy *et al.* (2020); Tripathi & Nema (2023) which has been modified. A 500 mg leaf sample was crushed using a mortar, then 2 ml of 80% (v/v) acetone was added. The extract was then put into an Eppendorf tube to centrifuge at 5000 rpm for 5 minutes, the supernatant was taken and transferred into a cuvette until the limit mark. A blank of 80% acetone was prepared in the cuvette. The cuvette containing the sample and blank was inserted into the centrifuge. UV-Vis spectrophotometer to measure absorbance values at wavelengths of 663 nm and 645 nm.

Leaf chlorophyll content can be calculated using the following formula:

$$Chlorophyll\ a = \frac{(12{,}7\ \times D663 - 2{,}69 \times D645 \times V)}{1000 \times W}$$

$$Chlorophyll\ b = \frac{(22{,}9 \times D645 - 4{,}68 \times D663 \times V)}{1000 \times W}$$

Total Chl (mg/g) = Chlorophyll a + Chlorophyll

Description:
W = weight of plant tissue extract (g)
Dx = absorption extract
V = total volume of chlorophyll solution (ml).

pH Measurement of Leaf Extract

The pH measurement of leaf extracts refers to Dadkhah-Aghdash *et al.* (2022) which was modified by weighing 200 mg of fresh leaves, then crushed and homogenized in 20 ml of deionized water

Determination of Ascorbic Acid Content

Determination of ascorbic acid content was done by spectrophotometric method. 10 mg of leaf sample was crushed and 10 ml of CO-free distilled water was added. Then the extract was put into an Eppendorf tube for centrifugation at 3000 rpm for 15 minutes. After that, the supernatant was taken and transferred into a cuvette. A standard solution of 20 ppm ascorbic acid was prepared, 0.2 mg of ascorbic acid plus 10 ml of CO-free distilled water.

The standard solution and supernatant were then measured for absorbance using UV-Vis spectrophotometry at a wavelength of 270 nm with distilled water as a blank (Juswardi *et al.*, 2022). Ascorbic acid content was calculated using the formula

$$AAs\ (ppm) = \frac{sample\ absorbance}{standar\ solution\ absorbance} x\ standar\ solution\ conc$$

Relative Water Content (RWC)

Leaf samples of each tree were weighed as much as 10 g as wet weight and then dried in an oven at 80o C for 48 hours to remove moisture content in the leaves, after which the dry weight of the sample was weighed again (Agbaire & Esiefarienrhe, 2010; Salsabila *et al.*, 2020). Leaf moisture content was measured by gravimetric method using the following formula:

$$RWC(\%) = \frac{Fw - Dw}{Fw} \times 100$$

Description:
Fw: fresh weight (g)
Dw: dry weight (g)

Leaf Epidermis Observation

Observation of leaf epidermis and epidermal derivatives in the form of number and density of stomata. Stomatal observations were made using the stomatal printing method (Fauziah & Izzah, 2019). The lower or abaxial surface of the leaf is smeared with transparent nail polish with the most common polymer base material, nitrocellulose, until it dries, then covered with clear tape. The tape is then slowly peeled off so that the abaxial epidermis of the leaf is attached to the tape. Then the tape was glued to a glass slide to be observed under a microscope and the stomatal density was calculated. Stomatal density was calculated using the formula:

$$Stomatal\ density = \frac{Number\ of\ Stomata}{Stomatal\ field\ of\ view}$$

Data Analysis

Observation Parameter Analysis

Data analysis of biochemical parameters such as chlorophyll content, leaf pH, ascorbic acid content and relative water content was carried out by centering the mean and standard deviation (sd) presented in the form of tables or figures.

Air Pollution Tolerance Index (APTI) Analysis

Analysis of APTI values was carried out using the formula first introduced by (Singh & Rao, 1983) to evaluate the level of tolerance of plants to air pollution (Nayak *et al*., 2018). The calculation of the APTI value uses the following formula:

$$APTI = \frac{[A(T + P) + R]}{10}$$

Description:
A: Ascorbic Acid Content (mg/g FW)
T: Total Chlorophyll Content (mg/g FW)
P: Leaf Extract pH
R: Relative Water Content (%)

RESULTS AND DISCUSSION

Based on research conducted on the *Air pollution tolerance index* (APTI) value parameter in the tree species selected as samples in the Petrochemical industry area, the following results were obtained.

Total Chlorophyll

Based on Table 3, it can be seen that the higher total chlorophyll is found in Fern tree (*F. decipiens*) leaves, then Bullet wood (*M. elengi*) and the lower in Mahogany (*S. macrophylla)* leaves. According to Budiono *et al*. (2016), each plant species has differences in chlorophyll content. Genetic influence is one of the factors causing differences in chlorophyll content that is expressed in the morphological and anatomical structure of the leaves. Zakiyah *et al*. (2018), explained that environmental factors such as light intensity, temperature, and air humidity and air pollution also affect chlorophyll content.

Table 3. Plant spesies leaf biochemical parameter observation variables at petrochemical industry area, Palembang city

Plant Species	Biochemical Parameters			
	TChl (mg/g)	pH	Aas (mg/g)	RWC (%)
Filicium decipiens	0,092±0,00	6,14±0,46	0,020±0,00	50,71±3,09
Swietenia macrophylla	0,062±0,02	5,92±0,07	0,015±0,01	56,14±3,07
Mimusops elengi	0,068±0,02	6,15±0,20	0,005±0,00	59,30±4,47

Fern Leaf Tree (*F. decipiens*) responds to air pollution by reducing the toxicity of pollutants through the crown so that excessive chlorophyll degradation does not occur. According to Ergantara & Khikmawati (2020), air pollution can reduce chlorophyll content in plants because it can damage leaf cuticles so that plant respiration and photosynthesis are inhibited. Tolerant plants are able to neutralize incoming pollutants so that they do not damage chlorophyll.

Based on the ambient air test results obtained from the Petrochemical Industry Environment Department (2023). Pollutant components such as TSP, SO_2, NO_2 , O_3 , PM_{10} and $PM_{2,5}$ are more high in areas covered with Spanish Cherry (*M. elengi*) and Baywood (*S. macrophylla*). Meanwhile, areas covered with *F. decipiens* had higher NMHC levels. Sulfur dioxide (SO_2) levels were above the environmental quality standard value, which is thought to affect chlorophyll degradation in the three plant species. According to Gautam & Shukla (2020), changes in the content of biochemical components in plants can change depending on the level of pollution and plant species. The level of contamination of SO_2 particles has an influence on chlorophyll levels because SO_2 attacks chloroplasts. Lee *et al*. (2017), added that SO_2 at high concentrations can enter plant tissues and then damage the function of thylakoids and cause the electron transport chain to be disrupted.

SO_2 pollutant particles are acidic so that in excess levels will enter through the stomata and affect the pH of the cell cytoplasm. Based on research by Hamid *et al*. (2022), plants exposed to SO_2 will produce large amounts of H+ so that if it reacts with SO_2 it becomes H SO_{24} which causes a decrease in pH. Plants that have a high pH of leaf extracts are plants that are able to absorb SO_2 and NO_2 pollutants well.

Leaf Cytoplasmic Acidity Level (pH)

The pH of leaf cytoplasmic on the three test species was still in the acidic category. The pH of *M. elengi* and *F. decipiens was* higher than that of *S. macrophylla*. According to Zuoari *et al*. (2018); Salsabila *et al*. (2020), plants that have a low pH are more sensitive to air pollution. This is because in the physiological process in the plant body, pH plays an important role in involving most enzymes in biological activities, one of which is photosynthesis. Enzyme activity will be more optimal if the pH conditions in the cell are not too acidic.

Leaf pH also plays a role in increasing ascorbic acid production. *F. decipiens* has a high pH and also has a high ascorbic acid content. According to Bui *et al*. (2021), ascorbic acid depends on the pH of the plant, a high pH increases the rate of conversion of hexose sugar to ascorbic acid so that there is a change in ascorbic acid levels under conditions of air pollution stress. Ascorbic acid plays a role in reducing *Reactive Oxygen Species* (ROS) in plant cells.

Ammonia and motor vehicle fumes and forest burning smoke that impact the Petrochemical industry environment accumulate in *Total Suspended Particulates* (TSP). TSP and *Particulate Matter* (PM_{10}) in the Petrochemical industry area are still below the environmental quality standards, while $PM_{2,5}$ levels at three sampling points exceed the environmental quality standard value (>15 µg/m3). Areas that are overgrown with *M. elengi* has higher levels of $PM_{2,5}$ than areas covered with *S. macrophylla* and *F. decipiens*. According to Chaudhary and Rathore (2018), air contaminants in the form of *Particulate Matter* are one of the oxidative stress factors that trigger an increase in *Reactive Oxygen Species* (ROS) in plant cells.

Ascorbic Acid Content

M. elengi in this case has a higher pH but lower ascorbic acid content. It is suspected that ascorbic acid is not only influenced by pH but also other factors. Low ascorbic acid in *M. elengi* may be due to higher relative water content so that cells tend not to experience drought stress. The content of ascorbic acid will be high if the plant is experiencing drought stress in the sense that it has a lower relative water content. According to Kumar & Kishore (2018), a high amount of water is a form of physiological defense from the plant body in response to pollutants that have an impact on high transpiration.

Relative Water Content

Table 3 shows that the relative water content of *M. elengi is* higher than the other two species. Environmental factors affect the moisture content of plants. The increase in temperature during the dry season and the influence of air pollution have an impact on plant water content. Based on research on the effect of season on relative water content conducted by Das and Prasad (2010); Lohe *et al*. (2015), which explains that the relative water content of leaves is higher in the rainy season, lower in winter, and the least relative water content of leaves during the summer. Water content in plants is an indicator of plant resistance to drought. Plants with high relative water content in polluted conditions can be categorized as pollutant-tolerant species.

Stomatal Density

The difference in water content in leaves is also influenced by the transpiration rate. Transpiration occurs through stomata, so the higher the number and density of stomata, the faster the transpiration rate and plants tend to lose a lot of water. From the results of the study in Table 4, it can be seen that *F. decipiens*, *S. macrophylla*, and *S. macrophylla have the highest transpiration rate. M. elengi* in conditions exposed to industrial pollution has a stomatal density in the high density category. According to Dorly *et al*. (2016), stomatal density can be grouped into three categories. Low density (<300/mm2), medium density (300-500/mm2) and high density (>500/mm2).

Table 4. Stomatal density values of *Filicium decipiens*, *Swietenia macrophylla*, and *Mimusops elengi* in Petrochemical industry area, Palembang city.

Plant Species	Stomatal Density (/mm)2
Filicium decipiens	1.829,29
Swietenia macrophylla	1.149,89
Mimusops elengi	642,03

Research by Khasanah and Na'ima (2022), with the same species but in an area that is not exposed to industrial pollution or high levels of pollutants. Species that were not exposed to pollution on the campus of UIN Walisongo Semarang, found stomata density, *F. decipiens* with density of 600.00/mm^2, *S. macrophlylla* 970.37/mm^2, and *M. elengi* 140.74/mm^2. The result show the differences in stomatal density in plants growing in areas with industrial pollution exposure and not exposed to industrial pollution. *F. decipiens*, *S. macrophylla*, and *M. elengi* in areas exposed to pollution from industrial plants in the sense of higher levels of pollutants, experienced an increase in stomatal density. This is supported by the research of Mutaqin *et al*. (2016), the stomatal density of mangoes (*Mangifera indica*) growing on the roadside is higher than mangoes growing in nature reserves. The increase in stomatal density is due to damage to stomatal cells due to the accumulation of pollutants so that damaged stomatal cells will stimulate the production of new stomata in large numbers as a form of adaptation for the continuity of the photosynthesis process.

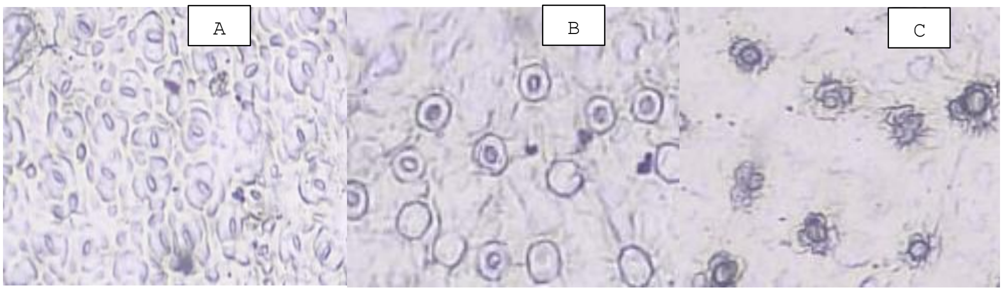

Figure 2. Stomatal density, (A) Stomata of *Filicium decipiens*, (B) Stomata of *Swietenia macrophylla*, (C) Stomata of *Mimusops elengi*

Based on Figure 2, differences in the number and density of stomata of the three tree species can be observed. The number of stomata affects the transpiration rate that occurs in the leaves. *M. elengi* has fewer stomata so that the transpiration rate is slower. This is thought to have an impact on the relative water content of the leaves, where *M. elengi* has a higher relative water content than *S. macrophylla* and *S. macrophylla*. *F. decipiens*. According to Putri *et al*. (2017), stomata function as a place for gas exchange during photosynthesis and a place for water evaporation during transpiration. An increase in the number of stomata results in an increase in stomatal openness, thus increasing the rate of transpiration and absorption of CO_2 for photosynthesis.

APTI Value

From Table 6, it can be seen that the three species have not been able to show good tolerance. Referring to the criteria in Thakar and Mishra's research (2010), *M. elengi* and *S. Macrophylla* are categorized as moderately tolerant, while *F. decipiens* is a sensitive species. But based on the tolerance criteria of Kalyani and Singaracharya (1995), APTI values in the range of 1-16 include sensitive species, so based on these criteria *F. decipiens*, *S. macrophylla*, and *M. elengi* are sensitive species.

APTI values indicate the category of tolerance level of plants to air pollution based on the influence of pollutants on changes biochemical components that occur in plants, especially in leaves. Measurement of plant tolerance levels can be done with additional analysis such as *Anticipated performance index* (API) analysis so that more accurate and representative results are obtained. According to Anake *et al*. (2019), a combination of APTI values and biological and socioeconomic parameters of plants including habitat, canopy structure, size, surface, texture, plant species, and economic functions identified in the *Anticipated performance index* (API) method.

Table 6. APTI values of *Filicium decipiens*, *Swietenia macrophylla*, dan *Mimusops elengi* in Petrochemical industry Area, Palembang

Plant Species	**APTI Value**	**Category** (Thakar dan Mishra, 2010)
Filicium decipiens	5,08	Sensitive
Swietenia macrophylla	5,62	Moderately tolerant
Mimusops elengi	5,93	Moderately tolerant

CONCLUSION

Biochemical parameters and stomatal activity play a role in determining plant tolerance to air pollution. Fern tree (*F. decipiens*) has an APTI value of 5.08 so it is categorized as a sensitive species, while mahogany (*S. macrophylla)* and has an *APTI* value of 5.62 and bullet wood (*M. elengi*) has an APTI value of 5.93 are categorized as a moderately tolerant plant to air pollution based on categorized by Thakar and Mishra (2010).

SUGGESTION

This research can be continued by re-analyzing other plant species that grow in the Palembang Petrochemical Industry area so as to obtain recommendations for species that are tolerant of air pollution. Research can be conducted during the rainy season to obtain data that explains the effect of season on plant tolerance to air pollution. The analysis can be refined by adding the *Anticipated Performanced Index* (API) method as an advanced analysis to see the influence of morphology and tree function on air pollution tolerance analysis.

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