BIOEDUSCIENCE
ISSN: 2614-1558
http://journal.uhamka.ac.id/index.php/bioeduscience

Comparative Study of The Physiological Condition of Six Tree Species to Air Pollution in Depok City, West Java

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Abstract

Background: Air pollution is a threat to the environment. Sources of air pollutants in urban environments can be in the form of dust, heavy metals, and hydrocarbons. Plants can help clean air pollutants from the atmosphere by absorption through the stomata, accumulating them, or by adsorption on the leaf surface. The Air Pollution Tolerance Index (APTI) is used as an evaluation benchmark for the Physiological conditions of plants exposed to air pollution. This research aims to study the physiological conditions of six tree species in air conditions in the Depok City area and to assess the plants' tolerance level based on the APTI calculation. **Methods:** The physiological parameters measured to calculate APTI were ascorbic acid, total chlorophyll, leaf extract pH, and Relative Water Content (RWC). The six tree species used as objects in this study were *Artocarpus altilis, Artocarpus heterophyllus, Bauhinia purpurea, Ficus septica, Filicium decipiens, and Nephelium lappaceum*. **Results:** Differences in the physiological conditions of six tree species in the Depok City area based on the average ascorbic acid values, total chlorophyll, leaf extract pH, and RWC. In addition, there are also differences in APTI parameters between the two research locations. **Conclusions:** *Filicium decipiens* is the plant species with the highest APTI, while *Artocarpus heterophyllus* has the lowest. Based on the APTI scores, *Bauhinia purpurea*, *Ficus septica, Filicium decipiens, Nephelium lappaceum* belong to moderately tolerant category, *Artocarpus altilis* belongs to an intermediate category, *Artocarpus heterophyllus* belongs to sensitive category.

Keywords: APTI; Ascorbic Acid; Leaf Extract pH; Relative Water Content (RWC); Total Chlorophyll

Article history
Received: 17 Aug 2022
Accepted: 25 Jul 2023
Published: 31 Aug 2023

Publisher's Note:
BIOEDUSCIENCE stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Citation:
Ayunda et al., 2023. Comparative Study of The Physiological Condition of Six Tree Species to Air Pollution in Depok City, West Java. BIOEDUSCIENCE, 7(2), 174-181. doi: 10.22236/jbes/9749

Introduction

Air pollution threatens the environment (Nayak et al., 2018). Sources of air pollutants in the urban environment can be in the form of dust, heavy metals such as Zn, Pb, Cd, and hydrocarbons originating from burning fossil fuels and burning waste. Air pollutants are particles such as dust, aerosols, and lead (Pb), while gases such as CO, NOx, SOx, H_2S, and HC (Ratnani, 2008). Those gases can negatively impact human health (Budihardjo, 2007). Naturally, plants can absorb gases and particulate materials from the air. Plants in urban green spaces can eliminate air pollutants from the atmosphere through a dry deposition process. Dry deposition is a plant surfaces mechanism to absorb and transport gaseous and particulate pollutants. Plants can absorb gaseous pollutants through stomata along with CO_2 and O_2 during photosynthesis and respiration (Carreiro, 2008). Leaf characteristics such as shape, trichome, or stomata significantly affect its ability to adsorb particulates (Nouri et al., 2009). The Air Pollution Tolerance Index (APTI) is used to evaluate the Physiological conditions of plants exposed to air pollution (Manjunath & Reddy, 2019). The APTI calculation was obtained from four biochemical properties of the leaves, namely ascorbic acid, total chlorophyll, acidity (pH) of leaf extract, and Relative Water Content (RWC) (Pathak et al., 2015). Based on Roy et al. (2020), plants with high APTI values are tolerant of air pollution. On the contrary, plants with low APTI values are sensitive to air pollution and can be used as bioindicators of air pollution. Based on Thakar & Mishra (2010), there are four categories of APTI based on class/level of plant tolerance to air pollution: tolerant, moderately tolerant, intermediate, and sensitive.

Depok City is one of the cities in West Java province with 11 districts. Regarding the level of air pollution, based on the environmental status report of Depok City in 2009, it is known that at all observation locations, the concentration of SO2, NO2, and CO is still below the maximum limit, although CO has an increasing trend. The maximum value for SO_2 is 900 ug/m3, NO_2 is 400 ugm3, and CO is 30.000 ug/m3. On the other hand, a particulate parameter has exceeded the maximum limit at the slaughterhouse (RPH) location on Juanda-Margonda, and the UI roundabout. This is due to the increasing volume of vehicles around those locations (KLHK, 2009). Depok City has an urban forest in the 90-ha area of the Universitas Indonesia campus. An urban forest is a part of green open space. According to Nowak & Heisler (2010), urban vegetation can, directly and indirectly, affect local and regional air quality by altering the urban atmospheric environment, such as providing shade through the tree canopy, absorption of heat radiation, and increasing the relative humidity.

The City Government of Depok, through Regulation No. 03/2013 concerning Guidelines for Environmental Protection and Management, has made regulations for Urban Green space areas by planting the median strip/street edge with vegetation types of trees, shrubs, ornamental shrubs, and ground cover/grass. The Depok City Environment and Sanitation Service 2021 has recorded data on all types and conditions of trees throughout the City of Depok to determine which trees are healthy and prone to falling. Monitoring tree health is through observation and data collection on the tree's physiological condition and tolerance level of tree plants to air pollution in the Depok City area. Based on this, this research was conducted to study the physiological conditions of six tree species on air pollution and to assess the tolerance level of the plants referring to the APTI value represented by individual trees in residential areas in Depok City and Urban Forests at UI Depok Campus, West Java.

The research locations include two areas that represent residential and non-residential areas. Residential areas release air pollutants from motorized vehicle traffic (Kaur & Nagpal, 2017) and household waste (Ratnani, 2008). The residential area is represented by District Sawangan, which is also the location for monitoring air quality measurements at Depok City in 2009 (KLHK, 2009); and a second location is Bojong Sari district which is a regional expansion of District Sawangan. The Urban Forest area of the UI Depok Campus is non-residential because it is assumed to be a green open space for the Depok and South Jakarta areas. However, Afrizal et al. (2010) reported that air quality in the Urban Forest at the UI Depok Campus area is influenced by residents' vehicles in and around the UI Depok campus. The six tree species in this study were *Artocarpus altilis*, *Artocarpus heterophyllus*, *Bauhinia purpurea*, *Ficus septica*, *Filicium decipiens*, and *Nephelium lappaceum*. In this study, we chose six tree species. The research hypothesis proposed is there are differences in the physiological conditions of six tree species on exposure to air pollution in Depok City, West Java, and there are differences in the tolerance level of trees based on the calculation of the APTI value.

Methods

Determination of the location of tree sampling was done using the purposive sampling method. The Urban Forest UI Campus contains 104 species of plants (Toni, 2009). Of the 104 plant species, there are plant species that are the same as those in residential areas in Bojongsari and Sawangan district, Depok City, namely *Artocarpus heterophyllus, Bauhinia purpurea*, *Ficus septica, Filicium decipiens, Nephelium lappaceum*, and *Artocarpus altilis.*

Sample

Plant sampling was carried out based on the Kaur & Nagpal (2017) method with modified leaf packaging with aluminum foil. Plant samples were obtained by cutting twigs using a tree pruner in triplicate from each species. Individual healthy leaves were randomly collected from all samples, packed in an aluminum sheet, put in a sealed plastic, and then stored in a box containing ice gel. The leaf was then washed with running water and dried. The process of taking soil samples to test the soil's acidity (pH) was carried out based on the method of Nadgórska-Socha et al. (2017).

Environmental parameter measurement

The environmental data measured were temperature, humidity, air pollution, and soil pH. Air temperature and humidity were obtained using a hygrometer. Air pollution was obtained from the ISPU net application which was recorded during November 2021 at 07.00 AM, 12.00 AM-noon, and 05.00 PM.

Measurement of Relative Water Content (RWC)

The Relative Water Content (RWC) test was carried out based on the Ghafari et al. (2020) method with modifications in the leaf sample mass, temperature, and duration of the leaf drying process. Leaf fresh weight (FW) was obtained by collecting fresh leaves and weighing 5 grams. The leaf turgid weight (TW) was measured by soaking the leaves in distilled water for 24 hours and then weighing them. Leaf dry weight (DW) was obtained by weighing leaves that had been dried in an oven at a temperature of 50°C until the leaf weight was constant (Ghafari et al., 2020). The following formula calculates Relative Water Content (RWC):

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

FW: fresh weight of leaf
TW: turgid weight of leaf
DW: dry weight of leaf

The Ascorbic Acid Test

The ascorbic acid test was carried out based on the method of Sadasivam & Manickam (1996) by modifying the speed and duration of the centrifugation (2500 rpm for 3 minutes). The dye solution is sodium bicarbonate, and the blank solution is 2,6-dichloro phenol indophenol. The sample solution was prepared by extracting 0.5 grams of leaves with 4% oxalic acid until the volume reached 100 mL and centrifuging at 2500 rpm for 3 minutes. The supernatant from the sample extraction was taken as much as 5 mL, and 10 mL of 4% oxalic acid was added for titration to get V2. The following formula calculates ascorbic acid:

$$\text{Ascorbic acid} = \frac{0{,}5\ \mathrm{mg}}{\mathrm{V1\ mL}} \times \frac{\mathrm{V2}}{5\ \mathrm{mL}} \times \frac{100\ \mathrm{mL}}{\text{Sample weight}} \times 100$$

The Manjunath & Reddy (2019) method. Total chlorophyll is calculated by the Arnon (1949) formula:

$$\text{Chlorophyll a (mg/g)} = \frac{12.7\mathrm{D}663 - 2.69\mathrm{D}645 \times \mathrm{V}}{1000 \times \mathrm{W}}$$

$$\text{Chlorophyll b (mg/g)} = \frac{22.9\mathrm{D}645 - 4.68\mathrm{D}663 \times \mathrm{V}}{1000 \times \mathrm{W}}$$

Total chlorophyll = chlorophyll a + chlorophyll b

Measurement of leaf extract pH

A leaf extract pH test was carried out based on the method of Prasad & Rao (1982) with modifications using a digital pH meter and filtered leaf samples.

APTI calculation

APTI calculation parameters consisting of ascorbic acid content, total chlorophyll, leaf extract pH, and RWC, which have been measured previously, are formulated into the following formula (Singh et al., 1991):

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

A: Ascorbic acid (mg/g)
T: Total chlorophyll (mg/g)
P: Leaf extract pH
R: RWC (%)

APTI values obtained from all tree species are grouped by referring to the APTI category as follows:

Table 2. APTI categories based on tolerance class for air pollution

Class	Category	Description
I	*Tolerant*	APTI > mean APTI + SD
II	*Moderately tolerant*	Mean APTI < APTI < Mean APTI + SD
III	*Intermediate*	Mean APTI – SD < APTI < Mean APTI
IV	*Sensitive*	APTI < Mean APTI – SD

Based on: Thakar & Mishra (2010)

Data Analysis

The data obtained were presented in the form of tables and graphs.

Result

The average temperature in November 2021 for residential areas is 27.75°C, while for the Urban Forest area of UI Depok Campus is 27.73°C. The air temperature in the Urban Forest at UI area tends to be lower, possibly due to the large number of tree canopies, causing the sun to be less scorching than in residential areas.

The average air humidity in November 2021 for residential areas is 75.5%, while for the Urban Forest area, UI Depok Campus is 71%. Humidity is one of the components that affect the transpiration process. Transpiration is the process of water loss from the plant surface, which is influenced by CO_2 levels, light, temperature, airflow, humidity, and groundwater availability (Nowak & Heisler, 2010).

The air pollution index value in Depok City during November is shown in Table 3. The soil acidity for residential areas is 7.68, while for the Urban Forest area, UI Depok Campus is 6.79. Air pollution can cause acid rain and can acidify the soil. Acidic soil can cause morphological and anatomical damage to plants so these plants can act as biological indicators of air pollution (Zhang et al., 2016).

The results of the ascorbic acid test of leaf samples from six tree species at the two research sites can be seen in Figure 1. The average value of the ascorbic acid test of all species for residential areas in Depok City is 0.07 mg/100g. The average value of the ascorbic acid test of all species for the Urban Forest area of UI Depok Campus is 0.07 mg/100g.

Table 3. Effect of air pollution standard index on plant condition

	$PM_{2.5}$	PM_{10}	CO	HC	NO_2	O_3	SO_2
Week 1	16.86	6.90	4.81	1.86	1.48	0.38	2.52
Week 2	70.19	26.57	23.19	6.48	15.52	3.29	10.57
Week 3	50.90	17.10	18.10	6.14	17.71	5.86	19.33
Week 4	72.67	29.71	22.95	8.00	19.10	6.38	6.33
Average value	52.65 ± 25,77	20.07 ± 10,29	17.26 ± 8,63	5.62 ± 2,64	13.45 ± 8,12	3.98 ± 2,75	9.69 ± 7,22
Category		Good	Good		Good	Good	Good
Effect of Air Pollutant Standard Index		No effect	No effect		Slight smell	Wounds in some plant species due to combination with SO_2 (for 4 hours)	Wounds in some plant species due to combination with O_3 (for 4 hours)

Source: ISPUnet KLHK during November 2021 and BAPEDAL (1997)

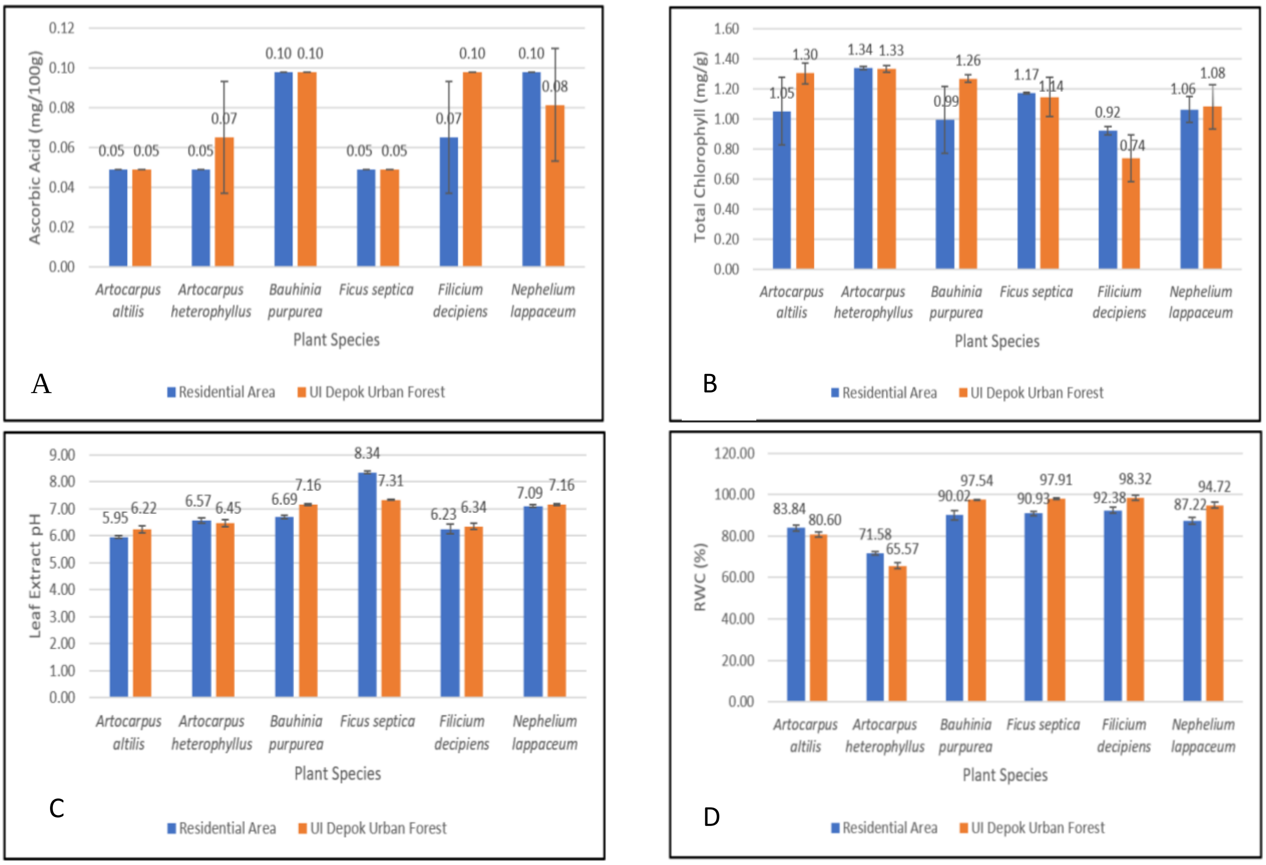

Figure 1. Biochemical parameters of leaf samples from six tree species in residential areas and the UI Depok Urban Forest. The biochemical parameters shown are ascorbic acid (A), total chlorophyll (B), leaf extract pH (C), RWC (D)

Ascorbic acid levels of *Bauhinia purpurea* species in both locations had the same value and were the highest compared to other plants in this study. Based on this, it is assumed that *Bauhinia purpurea* is a plant tolerant of SO_2 pollution. Plants with high levels of ascorbic acid are tolerant of SO_2 pollution (Uka et al., 2019).

Artocarpus altilis and *Ficus septica* had the lowest ascorbic acid levels in this study in both locations. Based on this, it is assumed that *Artocarpus altilis* and *Ficus septica* are intolerant of air pollution. Plant tolerance to pollution will increase if it has a high ascorbic acid content (Achakzai et al., 2017).

The test results of total chlorophyll content in leaf samples from six tree species in both locations can be seen in Figure 1. The average value of the total chlorophyll test of all species for residential areas is 1.09 mg/g, while the total chlorophyll for the Urban Forest area is 1.14 mg/g.

The average value of chlorophyll content in the UI Urban Forest area is higher than in residential areas. This is probably because the air temperature in the UI Urban Forest area is lower than in residential areas. High temperatures, SO_2 gas pollutants, drought, salt stress, and sunlight intensity can affect plant leaves' chlorophyll content (Nadgórska-Socha et al., 2017).

Leaf extract pH of six tree species on the roadside in residential areas and the UI Depok Urban Forest area can be seen in Figure 1. The leaf extract pH of all species for residential areas is 6.81, and for the Urban Forest area is 6.77. The leaf extract of *Artocarpus altilis* species was slightly acidic (5.95) and was the lowest among other species. Based on this, it is assumed that *Artocarpus altilis* species is intolerant of air pollution. The low leaf extract pH indicates the plant is susceptible to air pollution (Zouari et al., 2018). Plants will produce H^+ to react with SO_2 air pollution that enters the stomata and produces H_2SO_4, lowering leaf pH (Uka et al., 2019).

The pH test results of *Ficus septica* leaf extract were the highest. Based on this, *Ficus septica* species are assumed to be more tolerant of air pollution. Plants with a pH of around 7 are tolerant plants (Zouari et al., 2018). Air pollution, especially SO_2, is strongly related to plant pH (Zhang et al., 2016). The SO_2 emissions in Depok City (Table 3) can still be categorized as good.

RWC of plant species on the roadside residential areas and the UI Urban Forest area can be seen in (Figure 1). The RWC average value of all tree species for residential areas is 86%, while for the Urban Forest area is 89.11%. The results RWC test in this study show that the *Filicium decipiens* species in residential areas and the UI Urban Forest area have the highest RWC levels compared to other species. This indicates that the *Filicium decipiens* species is suspected to be tolerant of air pollution. In contrast, the species *Artocarpus heterophyllus* has the lowest RWC in residential areas and the UI Urban Forest area. This indicates that the species *Artocarpus heterophyllus* is assumed to be a more sensitive plant than the other plants in this study. The results show that the UI Urban Forest area dominates the higher RWC value. This is probably caused by the lower air temperature in the UI Urban Forest area than in residential areas. Air pollution will increase cell permeability, causing plants to lose water and dissolved nutrients (Salsabila et al., 2020). This happens because air pollution can increase the density of stomata, causing a decrease in water content in plant tissues (Zhang et al., 2016).

Air Pollution Tolerance Index (APTI) from leaf samples of six tree species calculated based on the values of ascorbic acid content, total chlorophyll, leaf extract pH, and RWC can be seen in Table 4. The data presented in Table 4 summarizes the APTI parameter values in residential areas and the UI Depok Urban Forest. The tree species with the highest APTI value was *Filicium decipiens* (9.60), while the lowest was *Artocarpus heterophyllus* (6.90). This is by the role of *Filicium decipiens* as a shade plant and can absorb lead and CO_2 in the air (Naufal et al., 2014). Plants that have a high APTI value are plants that can tolerate air pollution. Plants with a low APTI value are sensitive to air pollution, so Based on the calculation of determining the tolerance class of plant species to air pollution (Thakar & Mishra, 2010), it is known that the six tree species tested at two locations representing residential areas and urban forests can be categorized into three classes, namely Class II (moderately tolerant) consisting of *B. purpurea*, *Ficus septica*, *Filicium decipiens*, and *Nephelium lappaceum*; Class III (intermediate) *Artocarpus altilis*; and Class IV (sensitive) *Artocarpus heterophyllus*.

The research analysis results concluded that each tree species has different physiological conditions in tolerating air pollutants. The species studied in the two areas had different tendencies based on the APTI parameter values of ascorbic acid, chlorophyll content, leaf extract pH, and RWC.

Table 4. Physiological parameters and APTI samples of six tree species taken in the Depok City area in November 2021

Species	Ascorbic acid	Chlorophyll content	Leaf extract pH	RWC	APTI
Artocarpus altilis	0.05	1.175	6.085	82.22	8.26
Artocarpus heterophyllus	0.06	1.335	6.51	68.575	6.90
Bauhinia purpurea	0.055	1.125	6.925	93.78	9.42
Ficus septica	0.05	1.155	7.825	94.42	9.49
Filicium decipiens	0.085	0.83	6.285	95.35	**9.60**
Nephelium lappaceum	0.09	5.93	7.125	90.97	9.21

Conclusions

There are differences in the physiological conditions of six tree species between the two research sites in the Depok City area based on the average values of chlorophyll content, ascorbic acid, pH of leaf tissue extract, and RWC. *Filicium decipiens* is the tree species with the highest APTI value, while *Artocarpus heterophyllus* has the lowest APTI value. Referring to the APTI value obtained, the six tree species tested were divided into three classes, namely Class II (moderately tolerant) consisting of *Bauhinia purpurea, Ficus septica, Filicium decipiens*, and *Nephelium lappaceum*; Class III (intermediate) *Artocarpus altilis*; and Class IV (sensitive) *Artocarpus heterophyllus*.

Acknowledgments

The authors thank the Directorate of Research and Community Service (DRPM) Universitas Indonesia for funding this study through Hibah Publikasi Terindeks Internasional (PUTI) Prosiding 2020 No.: NKB-3584/UN2.RST/HKP.05.00/2020.

Declaration statement

The authors reported no potential conflict of interest

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