

Assessment of Air Pollution Tolerance Index of Selected Plant Species Commonly Found along Roadsides in Pulau Pinang, Malaysia

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Abstract: *This study focuses on the assessment of air pollution tolerance index (APTI) of two selected plant species commonly found along roadsides in Pulau Pinang, Malaysia. The plant species selected for the study were Bougainvillea sp. and Ficus sp. The plants were evaluated in terms of APTI by analyzing four different biochemical parameters: leaf relative water content (RWC), ascorbic acid content (AA), total leaf chlorophyll (TCh) and pH of leaf extract. Based on APTI, Ficus sp. was found to be more tolerant compared to Bougainvillea sp. in all locations. Species with lower APTI value are considered sensitive species, which can be used as a biological indicator for further monitoring of air quality. Species with higher APTI value are tolerant species and thus, can be planted for pollution abatement in order to control and reduce environmental pollution.*

Keywords: Air pollution tolerance index (APTI); biochemical parameters; roadside plants; environmental bioindicator; Malaysia

1. Introduction

One of the main environmental challenges faced by most countries across the world is air pollution. Air pollution can be described as the introduction of biological or chemical material, such as particulate matter emitted into the ambient air, mostly by anthropogenic activities that can cause harmful effects on human beings and other living organisms, thus creating an unhealthy environment and causing environmental damage [1]. Over the years, this problem is getting more serious with the expanding population, rapid development and industrialization. It is known that air pollution remains a threat to the ecosystem, where plant, as the primary producer, was identified as the most affected organism by air pollution [2].

Since the plant will stay at the same place starting from the very beginning of the growing phase, germination up until it matured, they will continuously be exposed to the surrounding atmosphere. Plants can absorb airborne pollutant into their system [3] via leaves and other outer surfaces of the plants either in gaseous or particulate form. Gaseous pollutants alone and in combination with particulate matter can cause numerous negative effects to the overall plant physiology [4].

Pollutants can be categorized into three different groups that are 1) non-accumulating pollutant; 2) accumulating pollutant and likely to involve in plant normal metabolism, especially compound containing sulphur and nitrogen; and 3) accumulating pollutant but will not interfere with plant normal metabolism [5]. The pollutants enter the plant either through leaves or outer part of the plant. It will experience a wide array of reactions before being excreted or absorbed into the plant system that may include chemical transformation, accumulation and incorporation into the plant's metabolic system [3]. Once the pollutants are inside the plasmalemma, they are able to interfere with the metabolic process at the cellular level. The interference of

the pollutants in the normal metabolic process at the cellular level will cause plants to respond in the form of respiration, enzymatic reaction, photosynthesis, membrane disruption, stomatal behavior and eventually visible physical response, such as early senescence and ultimate death of the plant [6].

Their response toward air pollution can be used as a biological indicator to evaluate air quality. Air pollution monitoring using a biological indicator is a convenient method with minimum expenditure [7]. Plant provides an enormous surface area, functioning efficiently to absorb pollutants in the air and serve as a sink for air pollutant [8]. The responses of plants towards air pollutant can be evaluated using the air pollution tolerance index (APTI). This method can determine the sensitivity and tolerance of plant species exposed to air pollution by conducting biochemical analysis involving total chlorophyll content, ascorbic acid content, relative water content and pH of the leaf extract. The determination and classification of plants into tolerant and sensitive categories are crucial because the sensitive species can be used as biological indicators and the tolerant species can serve as sinks of air pollutants.

This study aims to determine the APTI value of selected plant species commonly found in the vicinity of roadsides in respect to the above biochemical parameters. Plant response towards the pollutants from surrounding atmosphere can be used to assess the quality of air that may provide an early-warning signal for the trend of air pollution in the area.

2. Material and Method

2.1 Study Area

Three locations were selected around Gelugor, Pulau Pinang. Location 1 was at roadside of Jalan Aman in Universiti Sains Malaysia Main Campus, Location 2 and Location 3 were along the roadside of Tun Dr Lim Chong Eu Highway.

2.2 Leaf Sample Collection

Two plant species commonly found in the vicinity of roadsides were selected for this study. The plant species selected were *Ficus sp.* and *Bougainvillea sp.* Three replicates of fresh leaf samples from each plant were collected in the morning to ensure the freshness of the leaves. The samples are then immediately taken to the laboratory in a heatproof container for further analysis of biochemical parameters such as relative water content (RWC), total chlorophyll content (TCh), ascorbic acid content (AA) and pH of leaf extract. The weight of each fresh leaf samples was taken upon arriving at the laboratory.

2.3 Analysis of Biochemical Parameters

a) Relative water content (RWC)

Leaf relative water content was determined following the method described by [9]. Fresh weight of the leaf samples were obtained by weighing the fresh leaves. The leaves were then immersed in water and left over-night, blotted and re-weighed to obtain the turgid weight. Leaf samples' dry weight were obtained after the leaves were dried in an oven. The RWC calculation was done using formula:

$$RWC = [(FW - DW) / (TW - DW)] \times 100$$

where, FW = fresh weight, DW = dry weight, and TW = turgid weight.

b) Total chlorophyll content

Total chlorophyll content of the leaf samples was done using the method described by [10]. Leaf samples were macerated with 30 mL of distilled water and left aside for 15 min for thorough extraction. The leaf extract was decanted into centrifuge tubes and centrifuged at 2500 rpm for 10 min. Absorbances were read at 645 nm, 663 nm and 75 nm using UV – Visible Spectrophotometer. The calculation of total chlorophyll content was done using formula:

$$TCh = [20.2(A_{645}) + 8.02(A_{663})] \times [V / (1000 \times W)]$$

where, TCh = total chlorophyll in mg/g, A₆₄₅ = absorbance at 645 nm minus the absorbance at 750 nm, A₆₆₃ = absorbance at 663 nm minus the absorbance at 750 nm, V = total volume of the extract in mL, W = weight of the sample in g.

c) Ascorbic acid content

Ascorbic acid content was measured using spectrophotometric method by [11]. Three grams (3 g) of leaf samples were put in a beaker. Oxalic acid-EDTA (extracting solution) of 12 mL was added to the beaker followed by 3 mL of phosphoric acid, 3 mL of sulphuric acid, 6 mL of 5% ammonium molybdate and 9 mL of water respectively. The solution was left to react for 15 min. Absorbance was read at 760 nm using UV-Visible spectrophotometer. The ascorbic acid concentration was then extrapolated from a standard ascorbic acid curve.

d) Leaf pH

Five grams (5 g) of fresh leaves were homogenized in 10 mL deionized water, left for a while and filtered. The pH of the leaf extract was determined using pH meter.

2.4 Calculation of APTI

The APTI for the selected plants was determined by following method in [12]. The formula is given as:

$$APTI = [A (T + P) + R] / 10$$

where, A = ascorbic acid content, T = total chlorophyll content, P = pH of leaf extract and R = relative water content.

3. Results

The biochemical parameters and the APTI values for the selected plant species from March until May 2015 at three different study locations are shown in Table 1, Table 2 and Table 3, respectively.

Table 1: APTI of *Bougainvillea sp.* and *Ficus sp.* in March

Sample		TCh (mg/g)	AA (mg/g)	RWC (%)	pH	APTI
<i>Bougainvillea sp.</i>	Location 1	0.034	0.457	95.87	6.3	9.88
	Location 2	0.027	0.402	69.19	5.3	7.13
	Location 3	0.018	1.082	76.62	4.8	8.18
<i>Ficus sp.</i>	Location 1	0.029	0.407	81.34	6.4	8.40
	Location 2	0.026	0.212	83.23	5.8	8.45
	Location 3	0.013	1.003	79.33	6.4	8.58

RWC = Relative water content, AA = Ascorbic acid content, and TCh = Total chlorophyll content

Table 2: APTI of *Bougainvillea sp.* and *Ficus sp.* in April

Sample		TCh (mg/g)	AA (mg/g)	RWC (%)	pH	APTI
<i>Bougainvillea sp.</i>	Location 1	0.029	0.483	71.78	6.4	7.49
	Location 2	0.030	0.724	64.38	6.2	6.89
	Location 3	0.008	2.264	66.85	6.3	8.11
<i>Ficus sp.</i>	Location 1	0.025	0.736	87.67	7.0	9.28
	Location 2	0.022	0.855	77.47	6.5	8.31
	Location 3	0.015	1.945	75.95	7.3	9.02

RWC = Relative water content, AA = Ascorbic acid content, and TCh = Total chlorophyll content

Table 3: APTI of *Bougainvillea sp.* and *Ficus sp.* in May

Sample		TCh (mg/g)	AA (mg/g)	RWC (%)	pH	APTI
<i>Bougainvillea sp.</i>	Location 1	0.022	1.370	86.69	6.2	9.52
	Location 2	0.011	2.753	72.21	5.5	8.74
	Location 3	0.016	2.491	67.40	6.0	8.24
<i>Ficus sp.</i>	Location 1	0.026	1.227	88.82	6.9	9.79
	Location 2	0.009	2.491	67.4	6.0	8.24
	Location 3	0.038	1.010	90.45	7.1	9.77

RWC = Relative water content, AA = Ascorbic acid content, and TCh = Total chlorophyll content

4. Discussion

From this study, it was found that the plant species collected from Location 1 had higher APTI as compared to other locations, showing that they were in a better condition than the other two locations. Nonetheless, the APTI values of the plants at the other locations showed that there was only a slight difference in the values, indicating that they were adapting well with the environment. However, they still fell under the sensitive group based on the APTI scale. According to the APTI scale, any plant species with the value less than 1 is considered as very sensitive, plant with value from 1 to 16 is considered as sensitive, plant with value in the range of 17 to 29 is considered as intermittently tolerant and plant with value from 30 to 100 is considered as tolerant. From the overall results obtained, it was observed that the *Ficus sp.* was less sensitive in comparison with *Bougainvillea sp.* The APTI value of the *Ficus sp.* was much higher than the value of *Bougainvillea sp.*

The changes and differences in the individual parameters usually calculated and correlated with the response from the plants indicate the susceptibility level of each plant [13]. Plants with high content of total chlorophylls are generally tolerant to atmospheric pollution [14]. Chlorophylls help in starch production, which can be used as an indicator for air pollution [15]. The present study shows that the chlorophyll content in plant samples varied with the level of pollution. The more polluted the area, the lower the total chlorophyll content in the plant. This is due to the properties of certain pollutants that can reduce the chlorophyll content [7]. Sulphur dioxide (SO₂) at lower concentrations for instance, will fulfil the essential nutrient sulphur requirement of the plant but if SO₂ is present in excess quantities, it may become a toxic to the plant, which will injure the chloroplast membranes. By damaging the chloroplast membrane and breaking down the chlorophyll, it will eventually cause the plant to exhibit visual damage on the leaves. In addition, high concentrations of SO₂ also damage the plasmalemma, other important membranes and disrupt enzyme activity [16]

An overview of the results obtained from this study shows that the difference of APTI values of the plant collected at Location 3 was not significant with the plant collected at Location 1. This may be due to the high ascorbic acid content found in the plants. This study revealed that the overall ascorbic acid content in the plant sampled at Location 3 was higher than Location 1 and Location 2. Ascorbic acid is known as an antioxidant, act as reducing agent and influence resistance to harsh environmental stress, including atmospheric pollution [7] by neutralizing the pollutants that

enter the plant system via the stomata opening of the plants [15]. This also explains why the plant species at Location 3 had higher APTI values than plants at Location 2 even so they were grown near the roadside with heavy traffic. The presence of the ascorbic acid in higher amount helps the plants to resist air pollutants that enter the plant system. The reducing power of the ascorbic acid is proportional to its concentration [17].

It was also found that all plants collected at all locations exhibited lower pH values. This may be due to the presence of the acidic pollutants from traffic. pH values reveal good correlation with susceptibility of plants towards pollutants and reduce the photosynthesis reaction within the plant [20] It plays an important role in determining the plant susceptibility towards pollution [18]. pH helps plant physiology responds to stress [15]. The cells system functions well at optimum pH but being exposed to acidic pollutants over a long period will reduce pH levels in fewer tolerant species thus interrupt the biological activities of the plants [19]. High pH level will increase the efficiency for the conversion of hexose sugar into ascorbic acid [20] and upgrade the reducing power of ascorbic acid [21] thus providing a better resistance in plants against pollutants.

Measurement of the water relative content (RWC) was used to study the water status of the plants. Percentage of water content in the plant species collected at Location 1 showed the highest in comparison with the water content percentage of plants collected at other locations. From visual inspection of the plants at the three locations, the size of the leaves of each plant species varied, where the largest leaves came from the plant sample at Location 1. And also, the leaves from the sample at Location 1 looked fresher with a nice green leaf color compared to leaves from plants at Location 2 that had a greenish-yellow color while leaves from plants at Location 3 had a dull green color. The leaves become porous when desiccated because the loss of water from membranes interrupts the normal structure of the bilayer membranes [16]. This may be due to the air pollution factor in which pollutant increases the permeability in cells, which eventually caused the water and loss of dissolved nutrient, thus resulting the leaves to experience early senescence [14]. Water in plants plays an important role to maintain the temperature, nutrient conduction and help in metabolic processes [22], [23].

4. Conclusions

Air pollution tolerance index (APTI) of plants is becoming a vital parameter because it assists the assessment of plants' tolerability to air pollution since the eventual increase of air

pollution levels will be detrimental to the health of the existing vegetation. The results from this study provide information for the selection of tolerant species for future planning of the roadside landscape in order to mitigate air pollution and even ultimately reduce pollution. Species in sensitive groups is best to be used as bio-indicators to air quality and species ranked as tolerant is best to be planted around areas with poor air quality since the tolerant species have the ability to absorb air pollutants.

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