AN ASSESSMENT OF AIR POLLUTION TOLERANCE CAPABILITY OF COMMON TREES IN CHIANG MAI CITY, THAILAND

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Abstract - Vegetation is highly recognized as an alternative method for removing pollutants mainly through deposition, absorption, and accumulation processes, moreover, they can clean air by providing oxygen to the atmosphere. In this study, seven common tree species in Chiang Mai city were selected for evaluating air pollution tolerance index (APTI). Four important biochemical parameters including ascorbic acid content (AA), total chlorophyll content (TCh), leaf extract pH (LEpH), and leaf relative water content percentage were computed together to calculate the air pollution tolerance index. The study was conducted comparatively in two different seasons, i.e. in the month of October 2016, the highest peak of rain and humidity, and in the March, 2017 the dry and polluted season. Mangifera indica was found to be tolerant, Ficus religiosa, and Butea monosperma were found to be moderately tolerant, while Polyalthia longifolia, Lagestroemia speciosa, and Plumeria rubra were recognized as intermediately tolerant tree species, moreover, Alstonia scholaris was recorded as a sensitive tree species. The results were further statistically analyzed by using t-test showed that at 95% confidence level, there were no significant differences between the means of two seasonal groups of the air pollution tolerance index (APTI) value and biochemical parameters.

Index Terms - Air pollution tolerance index, Biochemical parameters, Chiang Mai, Tolerant trees.

I. INTRODUCTION

Pollution is mainly caused by human activities like dumping of waste, combustion of fossil fuels, burning of biomass or other harmful secondary products, which are harmful to living organisms. Air pollution is the human introduction into the atmosphere of chemicals, particulate matters, or biological materials that cause harm or discomfort to human, other living organisms, or damage the environment [1]. Pollutants could be classified as either primary or secondary. Pollutants that are pumped into the atmosphere and directly pollute the air called primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutant [2].The increased level of unplanned urbanization, population, and industrialization witnessed with an enhanced level of air pollution. The urban vegetation bodies greatly influenced with these air pollutants by absorbing, adsorbing, and accumulating [3]. Air pollution control is more complex than most other environmental challenges. According to 2010 and 2013 Global Burden of Diseases (GBD) reports, air pollution is ranked in the top 10 causes of death in the world. Specifically, Asia is under the highest treat from the air pollution. In northern Thailand, Chiang Mai is facing numerous environmental problems emerging from agriculture sector, road traffic and industrializations. No method is known to well ameliorate the air pollution problem. The only suitable alternative approach may be to develop a biological technique by cultivation plants in and around urban and industrial areas [1],[3]-[4]. Roadside plant foliage are in direct contact to the air pollutants, and may act as a stressors for these pollutants [5]-[6]. The ability of each plant species to adsorb or absorb pollutants by their surface structure varies and depends on several biochemical and morphological characteristics [7]-[8]. Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic activity, reduce growth, and disturb membrane permeability in sensitive plants species [1]. The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing air pollution tolerance index (APTI). It is a plant dependent aspect, which expresses the inherent capability of plants to encounter stress arising from pollution [9]. The air pollution tolerance index determination provides a reliable method for screening large number of plants with respect to their vulnerability to air pollutants. Plant species having the APTI value higher are expected to be more tolerant than those with lower air pollution tolerance index value [10]. The present study has been conducted to determine the effects of ambient air pollutants, air temperature, and relative humidity on air pollution tolerance index (APTI) value, and all corresponding biochemical parameters of APTI index, in order to

conduct a comparative study of air pollution tolerance capability of common trees species in Chiang Mai city.

II. MATERIALS AND METHODS

A. Area of Study

Chiang Mai province is situated in the North of Thailand, and considered as a capital of northern region, lies between 17.242^o and 20.148^o North latitude and 98.010^o to 99.513^o East longitude at an elevation in the city about 310 meter above sea level. Chiang Mai province covers an area around 20,110 km^2 from which 83 % of the area is forest. The province has a population around 1,640,479 people, whereas population density is 81.6 people per km^2 [11]. The city has grown rapidly in the past decades with an associated increase in air pollution and respiratory health problems [12]. Road traffic, industry expansion, burning of domestic wastes, forest fire, and agricultural residues burning are key area sources and influence factors of the air pollution in Chiang Mai city [13].

B. Sampling Procedure

A total of seven common trees species of Chiang Mai city, i.e., Mangifera indica L., Ficus religiosa L., Plumeria rubra L., Lagestroemia speciosa (L.) pers., Alstonia scholaris (L.)R. Br., Butea monosperma (Lam.) Taub., and Polyalthia longifolia sonn., were chosen, because of their presence as very common at three selected sites including urban area (Chiang Mai city), suburban area (Chiang Mai University), and rural area (700-year stadium). For investigation, 100-200 grams of leaves from four (North, South, East, and West) directions of each of the trees were collected in marked polythen bags. The samples were quickly transferred to foam boxes with ice. The fresh leaves were weighed immediately, and the samples were preserved in a refrigerator at -20^{o}C for further bio- chemical analysis.

Month	CO (ppm/3m)	NO (ppb/3m)	NOX (ppb/3m)	NO_2 (ppb/3m)	SO_2 (ppb/3m)	PM10 (ug/m^3)	PM2.5 (ug/m^3)
Oct-2016	0.89 ± 0.27	13.02 ± 9.56	7.50 ± 7.88	1.02 ± 0.01	15.26 ± 7.58	28.90 ± 7.78	15.33 ± 7.60
Mar-2017	0.98 ± 0.40	23.20 ± 6.58	17.18 ± 3.70	0.99 ± 0.59	50.77 ± 22.56	95.79 ± 15.67	73.90 ± 25.4

Table I Average air pollutants concentration

C. Air Pollution Tolerance Index (APTI)

Air pollution tolerance index (APTI) is a method calculated by incorporating of ascorbic acid content, total chlorophyll content, leaf extract pH value, and leaf relative water content percentage into a mathematical expression as described by Singh and Rao [10]. The ascorbic acid content was estimated following the method of Deepa et al. [14]. The Total chlorophyll content was estimated using the spectrophotometric method of Arnon [15]. While the Leaf extract pH and The leaf relative water content percentage (LRWC) % were measured following the method adapted by Agbaire and Esiefarienrhe [16].

These parameters were computed together in a formulation to obtain an empirical value signifying the air pollution tolerance index of the studied trees species [10], which is as follow:

$$APTI = \frac{AA(TCh + LEpH) + LRWC}{10} \quad (1)$$

Where; AA = Ascorbic acid content (mg/g) of fresh weight, TCh = Total chlorophyll content (mg/g) of fresh weight, LEpH = Leaf extract pH, and LRWC = Leaf relative water content in percentage.

III. RESULTS AND DISCUSSION

A. Assessment of Climate and Air Quality

Air temperature and relative humidity data during the sample collection (October, 2016; March, 2017) measured by Pollution Control Department (PCD) after each hour were analyzed. The result showed that the average air temperature was 26.06 ± 0.74 (^{o}C) in the month of October-2016, and 28.03 ± 2.63 (^{o}C) in the month of March-2017. While the relative humidity was 77.23 ± 1.56 (%) and 43.66 ± 5.84 (%) in the months of October-2016 and March-2017, respectively [17]. Furthermore, the air pollutants including CO, NO, NOx, NO_2, SO_2, PM10, and PM2.5, during the rainy and the dry season measured, by Pollution Control Department (PCD), after each hour and their average concentration are shown in Table 1 [17].

Name of tree species	Ascorbic acid (mg/g)		%Increase/ Decrease	Total chlorophyll (mg/g)		% Increase/ Decrease
	Rainy season	Dry season		Rainy season	Dry season	
Mangifera indica	12.20 ± 3.43	12.95 ± 2.69	6.15	9.32 ± 0.59	9.11 ± 0.47	-2.25
Ficus religiosa	7.71 ± 0.80	8.52 ± 0.68	10.51	6.65 ± 0.78	6.60 ± 1.23	-0.75
Plumeria rubra	4.60 ± 0.49	5.12 ± 0.44	11.30	3.97 ± 0.54	4.17 ± 1.24	5.04
Lagestroemia speciosa	4.80 ± 0.64	5.14 ± 0.66	7.08	6.21 ± 0.56	5.40 ±1.14	-13.04
Alstonia scholaris	4.28 ± 0.43	4.66 ± 0.21	8.88	4.60 ± 0.38	4.03 ± 0.20	-12.39
Butea monosperma	7.99 ± 0.73	8.85 ± 0.68	10.76	6.45 ± 0.92	6.35 ± 0.89	-1.55
Polyalthia longifolia	5.09 ± 0.38	5.19 ± 0.47	1.96	10.53 ± 1.04	9.75 ± 0.99	-7.41

Table II Ascorbic acid and total chlorophyll content of the studied tree species.

B. Ascorbic Acid Content (AA)

Ascorbic acid is an antioxidant in plants playing a pivotal role in activation of many physiological and defense mechanisms. The level of ascorbic acid in plants is determinant of their tolerance against the adverse effects of oxidizing pollutants [18]. High level of ascorbic acid in leaves increase air pollution tolerance ability [19]. The result of the study illustrated that Mangifera indica has the highest ascorbic acid content, i.e. 12.20 ± 3.43 (mg/g) during the rainy season, and 12.95 ± 2.69 (mg/g) during the dry season, whereas the least values of ascorbic acid during both seasons were recorded by Alstonia scholaris, i.e. 4.28 ± 0.43 (mg/g) during the rainy season, and 4.66 ± 0.21(mg/g) during the dry season. The most significant change in the ascorbic acid content from the study during the rainy and the dry season was found in Plumeria rubra, from 4.60 ± 0.49 (mg/g) to 5.12 ± 0.44 (mg/g). An increase of 11.30% was observed. The lowest change was recorded by Polyalthia longifolia from 5.09 ± 0.38 (mg/g) to 5.19 ± 0.47(mg/g), with an increase of 1.96% was detected during the rainy and the dry season (Table 2).

C. Total Chlorophyll Content (TCh)

Chlorophyll is the most important photosynthetic pigment and an index of productivity of plants [20].

Name of tree species	Leaf extract pH		%Increase/ Decrease	Leaf relative water content (%)		% Increase/ Decrease
	Rainy season	Dry season		Rainy season	Dry season	
Mangifera indica	5.74 ± 0.15	5.75 ± 0.08	0.17	78.87 ± 1.74	79.01 ± 2.06	0.18
Ficus religiosa	6.76 ± 0.32	6.57 ± 0.22	-2.81	76.87 ± 1.58	76.57 ± 1.40	-0.39
Plumeria rubra	5.34 ± 0.34	5.32 ± 0.09	-0.37	88.43 ± 2.04	87.46 ± 0.99	-1.10
Lagestroemia speciosa	5.78 ± 0.57	5.90 ± 0.44	2.08	79.43 ± 1.00	78.54 ± 1.66	-1.12
Alstonia scholaris	5.48 ± 0.43	5.41 ± 0.07	-1.28	68.03 ± 1.26	68.48 ± 2.61	0.66
Butea monosperma	6.35 ± 0.27	6.34 ± 0.16	-0.16	82.41 ± 1.69	80.80 ± 1.53	-1.95
Polyalthia longifolia	5.89 ± 0.38	5.71 ± 0.16	-3.06	80.53 ± 1.10	81.39 ± 3.70	1.07

Table III Leaf extract pH and leaf relative water content (%) of the studied tree species

Chlorophyll content of plants signifies their photosynthetic activity as well as the growth and development. The result showed that Polyalthia longifolia had the highest total chlorophyll content, about 10.53 ± 1.04 (mg/g) during the rainy season, and 9.75 ± 0.99 (mg/g) during the dry season, followed by Mangifera indica at 9.32 ± 0.59 (mg/g), and 9.11 ± 0.47(mg/g) during the rainy and the dry season, respectively. While, the least total chlorophyll content was found in Plumeria rubra at 3.97 ± 0.54 (mg/g) during the rainy season and 4.17 ± 1.24(mg/g) during the dry season. The most significant change in the total chlorophyll content in the tree leaves during the rainy and the dry season was found in Lagestroemia speciosa, from 6.21 ± 0.56 (mg/g) to 5.40 ± 1.14 (mg/g), a reduction of 13.04% was observed, followed by Alstonia scholaris at 4.60 ± 0.38 (mg/g) to 4.03 ± 0.20 (mg/g) with a reduction of 12.39% was recorded during observation. However, the least change in total chlorophyll content was predicted in Ficus religiosa about 6.65 ± 0.78 (mg/g) during the rainy season, and 6.60 ± 1.23 (mg/g) was recorded during the dry season. A reduction of 0.75%, was observed during the study (Table 2).

D. Leaf Extract pH (LEpH)

The high value of the leaf extract pH is recognized to improve tolerance to air pollution [21]. Changing of pH value in leaves might change the stomata conductivity. Stomata remain closed in leaves with low pH condition, and become open in leaves with high pH [9]. The pH value was recorded the highest by Ficus

religiosa at 6.76 ± 0.32 to 6.57 ± 0.22 during the rainy and the dry season, respectively, whereas, the least pH was noticed by Plumeria rubra, at 5.34 ± 0.34 during the rainy and 5.32 ± 0.09 during the dry season observation. The significant change in pH value was recorded by Polyalthia longifolia, a reduction of 3.06 % was observed, while the least change of the pH value was recorded by Mangifera indica, an increase of 0.17% was observed (Table 3).The leaf relative water content percentage was noticed the highest for Plumeria rubra, at 88.43 ± 2.04 (%) during the rainy season, and 87.46 ± 0.99 (%) during the dry season. Another species with high water content was Butea monosperma at 82.41 ± 1.69 (%) during the rainy, and 80.80 ± 1.53 (%) during the dry season. The highest change in the leaf relative water content was noticed by Butea monosperma, a reduction of 1.95% was observed during the study, while the least change in the leaf relative water content was noticed by Mangifera indica, an increase of 0.18% was recorded during the observation (Table 3).

E. Air Pollution Tolerance Index (APTI)

The air pollution tolerance index value was ranged between 11.12 ± 0.51 to 26.19 ± 4.92 during the rainy season and between 11.25 ± 0.30 to 27.14 ± 4.03 during dry season observation. The highest APTI value was recorded by Mangifera indica, at 26.19 ± 4.92 during the rainy season and 27.14 ± 4.03 during the dry season. The other tree species with high APTI value was Butea monosperma, at 18.42 ± 0.80 during the rainy and 19.27 ± 0.84 during the dry season observation, followed by Ficus religiosa at 17.98 ± 0.83 during the rainy, and 18.82 ± 0.96 during dry season observation, whereas the least air pollution tolerance index value was found in Alstonia scholaris at 11.12 ± 0.51 during the rainy season and 11.25 ± 0.30 during the dry season observation. The most significant change in APTI of the tree leaves was found in Ficus religiosa, from 17.98 ± 0.83 to 18.82 ± 0.96. An increase of 4.67% was observed (Table 5). The least change was found in Lagestroemia speciosa, from 13.68 ± 0.75 to 13.63 ± 0.69 with a reduction of 0.37%.

Range of APTI	Assessment category
>20	Tolerant
17-20	Moderately tolerant
13-16	Intermediate
≤12	Sensitive

Table IV Air pollution tolerance index (APTI) [22].

Name of tree species	APTI (value)		% Increase /Decrease
	Rainy season	Dry season	
Mangifera indica	26.19 ± 4.92	27.14 ± 4.03	3.63
Ficus religiosa	17.98 ± 0.83	18.82 ± 0.96	4.67
Plumeria rubra	13.14 ± 0.72	13.58 ± 0.56	3.35
Lagestroemia speciosa	13.68 ± 0.75	13.63 ± 0.69	-0.37
Alstonia scholaris	11.12 ± 0.51	11.25 ± 0.30	1.17
Butea monosperma	18.42 ± 0.80	19.27 ± 0.84	4.61
Polyalthia longifolia	16.39 ± 0.74	16.16 ± 0.91	-1.40

Table V APTI value of the studied tree species

The grading patterns of the studied tree species are shown in Table 6. The studied trees species were grouped according to the APTI index value proposed by Singh et al. [22] as shown in Table 4. The results revealed that the average APTI values of the seven studied trees species ranged between 11.18 ± 0.53 to 26.66 ± 4.48. The highest average APTI value was recorded in Mangifera indica (26.66 ± 4.48), and expected to be tolerant tree species among all the studied tree species. Butea monosperma by achieving 18.84 ± 0.92, and Ficus religiosa at 18.4 ± 0.98 were recognized as the moderately tolerant tree species. Whereas, Polyalthia longifolia (16.2 ± 0.83), Plumeria rubra (13.36 ± 0.68), and Lagestroemia speciosa with an APTI value of 13.66 ± 0.71 were grouped as an intermediate trees species. However, Alstonia scholaris was the only species having APTI value equal to 11.18 ± 0.53, which was in the range of ≤12 of the APTI index and was named as the sensitive tree species (Table 6).

F. Statistical Analysis

The t-test was carried out for all the parameters between the rainy and the dry season groups to find out if there were any statistically significant differences between the means of respective groups. The results of the t-test showed that at 95% confidence level there was no statistically significant difference between the rainy and the dry season groups for ascorbic acid ($p = 0.085$). In the same manner, there wasn't statistically significant difference between the rainy and the dry season groups for the total chlorophyll content ($p = 0.16$). Moreover, both groups of the rainy and the dry seasons for the leaf extract pH with 95% confidence level was ($p = 0.38$), and for leaf relative water content percentage of both groups ($p = 0.58$), it is revealed that they were statistically not differences.

Name of tree species	APTI (mean value)	Assessment category
Mangifera indica	26.66 ± 4.48	Tolerant
Ficus religiosa	18.40 ± 0.98	Moderately tolerant
Plumeria rubra	13.36 ± 0.68	Intermediate
Lagestroemia speciosa	13.66 ± 0.71	Intermediate
Alstonia scholaris	11.18 ± 0.53	Sensitive
Butea monosperma	18.84 ± 0.92	Moderately tolerant
Polyalthia longifolia	16.28 ± 0.83	Intermediate

Table VI Categorization of the studied tree species based on APTI index

And lastly the air pollution tolerance index (APTI) value for both groups during the rainy and the dry season showed statistically not significant different as well ($p = 0.43$). The results of the correlation analysis among the air pollution tolerance index, biochemical parameters, and air pollutants during the study period showed that, except for the ascorbic acid content, almost all the other biochemical parameters showed negative or significant negative correlation with air pollutants including CO,NOx,NO_2,SO_2,PM10, and PM2.5. The correlation recorded significantly negative between TCh and NO_2 ($p = <0.01$; $r = -0.14$), TCh with PM10, and PM2.5 ($p = <0.01$; $r = -0.14$), moreover, leaf relative water content with NOx ($p = < 0.01$; $r = -0.18$), LRWC% and SO_2 ($p = <0.01$; $r = -0.17$). However, the APTI showed weak positive correlation with CO, NOx, NO_2, and SO_2, while the negative correlation was observed with PM10, and PM2.5 ($p = 0.82$; $r = -0.012$), and $p = 0.59$; $r = -0.028$, respectively. In addition, the average APTI value showed the lowest negative correlation with temperature ($p = 0.91$; $r = -0.006$) and to relative humidity (%) ($p = 0.69$; $r = -0.021$).

CONCLUSION

With respect to air pollution tolerance index value calculated for the seven studied tree species, it can be concluded that Mangifera indica with the average APTI value (26.66 ± 4.48) is the most tolerant tree species followed by Butea monosperma (18.84 ± 0.92), and Ficus religiosa (18.40 ± 0.98). Hence, these tree species should be cultivated in and around urban roadsides as well as in industrial polluted areas for controlling effects of air pollutants. While Alstonia scholaris with the APTI value 11.18 ± 0.53 was named as a sensitive tree species, which can be used as a bio-indicatore of air pollution effects.

Furthermore, it is revealed that impact of air pollution in terms of changes during study from the rainy to the dry and polluted season were not significantly differences in both groups of all biochemical parameters and air pollution tolerance index (APTI) value of the studied tree species.

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