International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979
Impact Factor: RJIF 5.72
Received: 13-12-2017; Accepted: 19-01-2018
www.allsubjectjournal.com
Volume 5; Issue 1; January 2018; Page No. 45-54

Assessment of air pollution tolerance index and anticipated performance index of common roadsides trees

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Abstract
Enhanced intensity of pollution in modern society has become a serious and aggravating global issue; thus air pollution is ranked in the top 10 causes of death in the world. Besides others technical solutions to abate air pollution, vegetation is increasingly recognized as an alternative ameliorative method by removing pollutants mainly through deposition, absorption, adsorption, and accumulation process, moreover they can clean air naturally by releasing oxygen to the atmosphere. In this study, seven common trees species in three different areas based on air quality status of Chiang Mai city were selected for evaluating air pollution tolerance index (APTI) by analyzing four important biochemical parameters, which are (ascorbic acid content, total chlorophyll content, leaf extract pH, and leaf relative water content). The anticipated performance index (API) of these trees species are calculated as well by considering their APTI value together with other socio-economic and morphological characteristics. The results of the API index revealed an order of tolerance to be *Mangifera indica* L. (93.75%) as the best performer, *Butea monosperma* (Lam.) Taub. (87.5%), and *Ficus religiosa* L. (87.5%) were proved to be excellent performers, whereas *Lagestroemia speciosa* (L.) Pers. (62.5 %), *Alstonia scholaris* (L.) R.Br. (62.5%), and *Polyalthia longifolia* sonn. (62.5%) were recognized as good, and lastly, *Plumeria rubra* L. (50 %) was suggested as poor species for urban plantation.

Keywords: air pollution tolerance index, anticipated performance index, air pollution, tolerant trees, Chiang Mai

1. Introduction

Pollution is primarily caused by human activities, for example, excessive use of natural resources, dumping of waste, combustion of fossil fuel, burning of fuel woods or other hazardous products, which are harmful to living organisms (Thambavani and Prathipa, 2012) [39]. Air is one of the significant resources for provision of lives, and all organisms need clean air for their normal healthy growth and activities. Currently, air has become contaminated due to over population, rapid industrialization, urbanization and lack of enough public transportation facilities. Air pollution can be defined as the atmospheric condition having high level of pollutants, which might produce undesirable effects on overall materials, plants, animals and human beings, it may be introduced by human into the atmosphere of chemicals or biological materials that cause harm to living organisms and damage their environments (Lohe *et al.*, 2015) [15]. Pollutants can be classified as either primary or secondary. The pollutants that are released into the atmosphere and directly pollute the air are called primary pollutants, while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants (Prajapati and Tripathi, 2008; Agbaire and Esiefarienrhe, 2009) [19, 1].

Air pollutants like sulfur dioxide, ozone, particulate matters, and nitrogen oxide can alter the whole physiological process of plants, thereby affecting patterns of growth (Agbaire and Esiefarienrhe, 2009) [1]. Air pollutants effects on plants have long been known (Pandey, 1981) [16]. Air pollutants cause damages to leaf cuticles and affect stomata conductance. They can also have direct effects on photosynthetic structure, leaf longevity, and patterns of carbon allocation within plants (Wolfenden and Mansfield, 1990; Winner and Atkinson, 1986) [47, 45]. Exposure of primary and secondary pollutants is associated with numerous effects on individual human health as well, for instance, respiratory symptoms, and coronary heart diseases. The elderly and children may be affected by moderate concentration of air pollutants that can trigger acute heart failures (PCD, 2013) [18].

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 threat from air pollution. Two third of the world's air pollution related casualties occurred in Asia(Horton, 2012). In Thailand, Chiang Mai city as a capital of northern region with an associated increase of population and urbanization is facing many environmental problems emerging from agricultural sector, vehicular emission, biomass burning, trans-boundary haze in rural and border areas, and industrial discharges in concentrated industrialized areas (Vichit-Vadakan and Vajanapoom, 2011) [44].

There is no way and technique known to well mitigate air pollution problemsin urban areas. Best alternative approach may be to develop a biological method by growing plants in and around industrial and urban areas (Shannigrahi *et al.*, 2004) [17]. Plants provide naturally cheap and easy way of cleansing the atmosphere. Plants are essential for all life form on earth, the uptake of carbon dioxide, which is one of the principle greenhouse gases, during photosynthesis is the major pathway by which carbon is removed from the atmosphere and made available to humans and animals for growth and development. Plant diversity also underpins all terrestrial ecosystems and these provide the basic life-support system on which all life depends (Sharrock *et al*., 2014) [29]. They are the fundamental green belt component; operate as a sink to mitigate air pollution by filtering, intercepting, and absorbing in a sustainable manner without serious foliar damage or decline in growth (Prajapati and Tripathi, 2008) [19]. Similarly, roadside plants leaves are in direct contact with air pollutants, and may act as stressors for these pollutants (Rai, 2016) [22]. The ability of each tree species to absorb pollutants by their foliar surface varies, and depends on several biological, physiological and morphological features of the plants (Seyyednjad *et al*., 2011) [26].

Air pollution tolerance index (APTI) based on four parameters has been used for identifying tolerance levels of plant species (Agbaire and Esiefarienrhe, 2009; Singh *et al*., 1991) [1, 31]. The APTI and API method is useful for urban planners, landscape architects, and policy makers to select plant species tolerant to air pollution (Agbaire and Esiefarienrhe, 2009) [1]. Air pollution tolerance index has also been used to categorize plants species in their order of tolerance to air pollution (Singh *et al*. 1991; Subramani and Devaanandan, 2015) [31, 38]. The air pollution tolerance index (APTI) and anticipated performance index (API) determination provide a method for screening large number of plants with respect to their vulnerability to air pollutants (Pathak *et al*., 2010) [17]. API is based on various factors influencing the performance of a certain species of tree. Most suitable trees species for development of urban forest can be determined by obtaining their API values. Higher is the API, higher will be the performance of the tree (Pandey *et al*., 2015) [15]. In this study, we have explored common tree species found in Chiang Mai city and calculated their air pollution tolerance index and anticipated performance index. The method is simple and very easy to conduct in all types of field conditions without adopting costly environmental monitoring instruments. Tree species having lower API value may act as bio-indicators for detection and monitoring of pollution effects and species with higher API value are introduced for future plantation to areas for long term air pollution management.

2. Material and Methods

2.1 Study area

This study was carried out in Chiang Mai city, a part of Chiang Mai province, which is consider as a second largest province after Bangkok, located in the north of Thailand, lies between 17.242^{o} and 20.148^{o} North latitude and 98.010^{o} to 99.513^{o} East longitude at an elevation about 310 meter above sea level (Janta and Chantara, 2017) [12]. 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 (Janta and Chantara, 2017) [12]. Chiang Mai has three distinct seasons, the hot (summer) season from March through May, the rainy season from June to October, and the cool (winter) season from November to February. The average annual temperature is a pleasant 25^{o}C. During the hot (summer) season, day-time high temperatures can reach 42 ^{o}C, but the cool (winter) season, night-time lows can drop below 10 ^{o}C in the city and 4 ^{o}C in mountainous areas (WWO,2017). The city has grown rapidly in the past decades with an associated increase in air pollution and respiratory health problems (Sriyaraj *et al*.,2008) [37]. 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 (Sriyaraj *et al*. 2004) [36]. Geographically, Chiang Mai city, situated in a natural basin and is surrounded by high mountainous ranges is another important influencing factor (Wiriya *et al*., 2013) [46]. The study was performed along the main roads of the urban area (Chiang Mai city), a suburban area (Chiang Mai University), and a rural area (700 years roadsides) (Figure1). The particular sites for data collection were selected based on Sransupphasirigul study of 2013 [35] (Air quality mapping of Chiang Mai city using lichens as indicators and its relationship with ambient nitrogen dioxide) (Sransupphasirigul, 2013) [35].

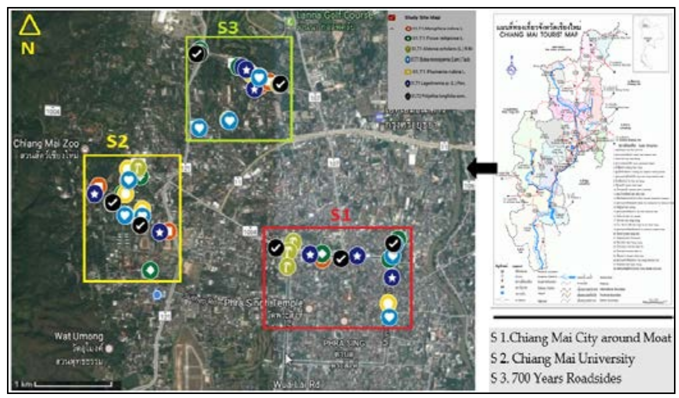

Fig 1: Chiang Mai province(Sransupphasirigul, 2013) [35], and the studied locations in Chiang Mai City.

2.2 Tree selection

During the period from June to August 2016, a pilot survey was conducted in the study areas. The main objective of the survey was to target the most common urban trees species in Chiang Mai city. Seven (7) common trees species which were *Mangifera indica* L., *Ficus religiosa* L., *Plumeria rubra* L., *Lagerstroemia speciosa* (L.) Pers., *Alstonia scholaris* (L.) R., *Butea monosperma* (Lam.) Taub., *and Polyalthia longifolia* Sonn., were indicated. Three individuals of each species at each of sites were marked. Overall, sixty-three (63) individual trees were selected. Care was taken to ensure that all selected trees species have same ecological conditions with respect to soil, water, sunlight, exposure to pollutants and distance from main road.

2.3 Leaf sample collection

Leaf samples were collected from four: East, West, North, and South directions of each of the selected trees. At each of the directions, two branches, 2 to 4 meter high from ground level were marked, to make sure that leaves are in optimum ages. The marked branches were then divided into four equal parts, the middle two parts were chosen for best mature leaves. The leaf samples from each of the selected tree were collected for 100-200 grams in marked polythene bags, and were immediately put into a foam box with ice and transferred to laboratory for further biochemical analysis. The leaf samples were stored at -20^{o}C until the biochemical analysis. With respect to Chiang Mai city air quality situation, the sample collection were made in the month of October, 2016, the highest peak of rainfall, and in the hot summer and dry season of the region in March, 2017. During the sample collection, geographical coordinates of the selected areas and each of the selected trees were recorded.

2.4 Air pollution tolerance index (APTI)

Air pollution tolerance index (APTI) is a method calculated by combination of leaf extract pH, total chlorophyll content, ascorbic acid content, and leaf relative water content percentage values into a mathematical expression as described by Singh and Rao(Singh *et al*., 1991) [31].

2.4.1 Analysis of ascorbic acid content (ASA)

The ascorbic acid content was estimated following the method of (Deepa *et al*., 2006) [7] with some modifications. In brief; one gram of leaf sample was sliced and homogenized in 10 mL of 3 % Meta phosphoric acid for 30 seconds at 4 ^{o}C. The homogenate sample was centrifuged at 3000 x g for 20 minutes at 4 ^{o}C. Next, 2 mL of the crude extract was added to 5 mL of 3 % Meta phosphoric acid, and finally, the sample was titrated with 0.1 mM2, 6-Dichlorophenolindophenol (DPIP) to the end point. Calculations were made using the formula below:

$$\text{ASA (mgg}^{-1}) = \frac{(X - B) * A * D * V}{(S - B) * E * Y}$$

Where

X = Volume of DPIP used to titrate sample (mL), B = Volume of DPIP used to titrate blank (mL), S = Volume of DPIP used to titrate standard ascorbic acid (mL), A = Concentration of standard ascorbic acid (mgmL^{-1}), D = Volume of standard ascorbic acid (mL), V = Total volume of crude extract (mL), E = Weight of leaf sample (gr), Y = Volume of crude extract in titration (mL).

2.4.2 Analysis of total chlorophyll content (TCh)

Total chlorophyll content was estimated using the method of(Arnon, 1949). Briefly, 30 milligrams of leaf sample was sliced and placed in a test tube containing 5 mL of 80% acetone. The test tube was covered by aluminum foil and placed in a dark room at 25 ^{o}C for one day. The absorbance of the extracted solution was measured with visible spectrophotometer at 645 and 663 nm, and the solution of 80 % acetone was used as a blank. Calculations were made using the formula below:

$$\text{TCh (mgg}^{-1}) = [20.2\ (\text{OD645nm}) + 8.02\ (\text{OD663nm})] * \left(\frac{V}{1000 * W}\right)$$

Where;

V=Total volume of extract (mL), and W=Weight of leaf material in gram.

2.4.3 Measurement of Leaf Extract pH (LEPH)

Leaf extract pH was done according to method described by (Agbaire and Esiefarienrhe 2009) [1]. In brief, five grams of leaf sample was homogenized in 10 mL of distilled water, the homogenate sample was centrifuged and supernatant was collected, and finally pH was measured by a digital pH meter.

2.4.4 Measurement of leaf relative water content % (LRWC)

The leaf relative water content percentage was estimated following the method adapted by (Agbaire and Esiefarienrhe 2009) [1].

$$\text{LRWC (\%)} = \frac{FW - DW}{TW - DW} * 100$$

Where;

FW= Fresh weight (mgg^{-1}), DW = Dry weight (mgg^{-1}), TW= Turgid weight (mgg^{-1})

These parameters were computed together in a formulation to obtain an empirical value signifying the air pollution tolerance index of studied trees species (Singh and Rao,1983) [33], which is as follow:

$$\text{APTI} = \frac{[ASA * (TCh + LEpH) + LRWC)]}{10}$$

Where;

ASA = Ascorbic acid content (mgg^{-1}) of fresh weight, TCh = Total chlorophyll content (mgg^{-1}) of fresh weight, LEpH = Leaf extract pH, and LRWC = Leaf relative water content (%).

2.5 Anticipated performance index (API)

By combining the results of air pollution tolerance index (APTI) values with the appropriate morphological and socio-economic characters, for example, plant habit, canopy structure, type of plant, laminar structure and socio-economic value, the anticipated performance index (API) was calculated for the selected trees species. Based on both of the assessment methods, different grades (+) were allotted to each tree species (Table 1).

Table 1: Gradation of plant species on the basis of air pollution tolerance index (APTI) and others morphological and socio-economic characters (Prajapati and Tripathi 2008) [19].

Grading characters	Pattern of assessment	Grade allotted
(a)Tolerance APTI	9.0 -12.0	+
	12.1-15.0	+ +
	15.1-18.0	+ + +
	18.1-21.0	+ + + +

	21.1-24.0	+ + + + +
(b) Morphological characters		
1.Plant habit	Small	_
	Medium	+
	Large	+ +
2. Canopy structure	Spare/irrigular/globular	_
	Spreading crown/open/semi-dense	+
	Spreading dense	+ +
3. Type of plant	Deciduous	_
	Evergreen	+
4. Laminar structure		
4.1Size	Small	_
	Medium	+
	Large	+ +
4.2Texture	Smooth	_
	Cariaceous	+
4.3 Hardiness	Delineate	_
	Hardy	+
(c) Socio-economic value		
	Less than three uses	_
	Three or four uses	+
	Five or more than five uses	+ +

According to the criteria and the (+) grades obtained by trees during observation in the field and laboratory, the trees were then categorized based on anticipated performance index, where; High grade and high score means very tolerant against air pollution and low grade and small score indicate sensitivity to air pollution (Table 2).

Table 2: Anticipated performance index (API) of plant species (Prajapati and Tripathi 2008) [19]

Grade	%Scoring	Assessment category
0	UP to 30	Not recommended
1	31 – 40	Very poor
2	41 – 50	Poor
3	51 – 60	Moderate
4	61 – 70	Good
5	71 – 80	Very good
6	81 – 90	Excellent
7	91 – 100	Best

3. Results and discussion

3.1 Changes in ascorbic acid content

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 its tolerance against the adverse effects of oxidizing pollutants (Sharma *et al.*, 2016) [28]. Ascorbic acid, together with mineral deficiencies, are among the factors responsible for the formation of reactive oxygen species (ROS) concentration produced by photosynthetic apparatus during pollution stress (Ramakrishna and Ravishankar, 2011). High level of ascorbic acid in leaves increase air pollution tolerance ability (Das *et al.*, 2016) [5]. Study have reported that the higher ascorbic acid content of the plant is a sign of its tolerance against sulfur dioxide pollution (1984). Ascorbic acid plays an important role in photosynthetic carbon fixation. Because of its importance, ascorbic acid is used as a parameter in formula used to calculate air pollution tolerance index (Gholami *et al.*, 2016) [9].

As shown in Table 3, the highest ascorbic acid content in (mgg^{-1}) was recorded by *Mangifera indica* during the dry season in site1 (14.38±1.68), site2 (13.23±3.35), and site3 (11.23±1.96), while during the rainy season observation, the ascorbic acid content was recorded in site1 (13.65±2.16), site2 (12.78±4.76), and site3 (10.16±1.83). The ascorbic acid was recorded least by *Plumeri arubra* in site1 during the dry and the rainy seasonobservation *(*5.06±0.23), and (4.29±0.24) respectively. The result showed in case of *Mangifera indica*, the concentration of ascorbic acid during the dry season with respect to the rainy season was more by 5.35%, 3.52%, and 10.53% in site1, site2 and site3 respectively. For *Ficus religiosa,* similar inclination by6.86%, 7.80%, and 17.74% in site1, site2 and site3 was observed. Identical trend was detected in case of *Lagestroemia speciosa*(11.19%, 6.39%, 3.01%), *Alstonia scholaris* (12.33%, 10.43%, 3.92%), *Butea monosperma* (9.56%, 11.83%, 11.05%), and finally in case of *Polyalthia longifolia* the increase was found by6.52%, and 0.59 % in site1 and site2 respectively, whereas in site3 the reduction in ascorbic acid content by 0.78% was observed (Table 3). It is clear that ascorbic acid content for the same set of trees were found higher during dry and polluted season and lower at least polluted sites during rainy season. Increase level of ascorbic acid content enhances pollution tolerance, which is a response of defense mechanism of the relevant tree species.

3.2 Changes in total chlorophyll content

Chlorophyll is the most important photosynthetic pigment in plants, it is an index of productivity of plants (Bojovic and Stojanovic, 2005) [3]. Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development (Bojovic and Stojanovic, 2005) [3]. The trees keeping up their chlorophyll pigment even under stress condition were supposed to be tolerant against air pollution (Singh and Tuteja, 2011; Uka, 2017) [30, 41]. Previous studies have illustrated that chlorophyll content in plant species varies with the pollution status of the area i.e. higher the pollution level in the form of vehicular exhausts, lower the chlorophyll content.

It also varies with the tolerance as well as sensitivity of the plant species (Chavan, 2011) [4]. Degradation of chlorophyll pigment has been widely used as an indication of air pollution (Ninave *et al*., 2001) [4]. Study have reported that high level of road traffic pollution decrease chlorophyll content in plants near roadsides (Tripathi and Gautam, 2007) [4]. Present investigation revealed that the total chlorophyll content in (mgg^{-1}) was found highest by *Polyalthia longifolia* during the rainy season in site1 (10.10±0.69), site2 (9.97±0.89), and site3 (11.52±0.77), whereas during the dry season observation the total chlorophyll content was recorded in site1 (9.37±0.35), site2 (9.62±0.77), and site3 (10.27±1.42). The other tree species with high total chlorophyll content was *Mangifera indica* during the rainy season in site1 (8.72±0.42), site2 (9.38±0.38), and site3 (9.88±0.18), while during the dry season observation the total chlorophyll content was recorded in site1 (8.68±0.21), site2 (9.22±0.45), and site3 (9.42±0.36) respectively. However total chlorophyll content was recorded minimum by *Plumeria rubra* during the rainy season in site1 (3.53±0.47), site2 (3.91±0.36), and site3 (4.48±0.31), while during the dry season observation the total chlorophyll was noticed in site1 (3.95±0.61), site2 (3.46±0.19), and site3 (5.10±1.72) respectively (Table 3).

The result showed that in case of *Mangifera indica*, the total chlorophyll content in the rainy season with respect to the dry season was found to decrease by 0.46%, 1.71%, and 4.66% in site1, site2, and site3. While, in case of *Ficus religiosa* a reduction by 5.23%, and 1.33% was observed in sit1, and site2 respectively, however in site3 the value of total chlorophyll was found to increase by 3.09%. For *Plumeria rubra*, a reduction in total chlorophyll content during the rainy season with respect to the dry season was observed by 5.23%, and 11.51% in site1, and site2 respectively, while in site3 the total chlorophyll content in the dry season was found to increase by 13.84%. For *Lagestroemia speciosa* a reduction was found by 12.47%, 2.54%, and 15.85% in site1, site2, and site3 respectively. Identical trend of reduction was observed in case of *Alstonia scholaris* (10.79%, 12.04%, 14.26%), and *Polyalthia longifolia* (7.23%, 3.51%, 10.85%), whereas in case of *Butea monosperma* the concentration of total chlorophyll content during the rainy season with respect to the dry season was more by 0.54% in site1, while in site2, and site3 the fall in total chlorophyll content by 3.30%, and 1.34% was observed (Table 3). In the present investigation the total chlorophyll content was comparatively found higher during rainy season and least polluted sites, and lower during the dry season and polluted sites. This might be due to the destruction of chlorophyll content, hence the photosynthetic pigments are the most likely to be damaged by air pollution (Rabe and Kreeb, 1980) [20]. Chlorophyll pigments exist in highly organized state, and under stress it may undergo several photochemical reactions including oxidation, reduction, pheophytinisation, and reversible bleaching (Giri *et al*., 2013) [10].

Table 3: Seasonal variation in ascorbic acid content and total chlorophyll content of the studied tree species

Name of tree species	Site	ASA (mgg^{-1})		TCh (mgg^{-1})	
		Rainy season	Dry season	Rainy season	Dry season
Mangifera indica	S_1	13.65 ± 2.16	14.38 ± 1.68	8.72 ± 0.42	8.68 ± 0.21
	S_2	12.78 ± 4.76	13.23 ± 3.35	9.38 ± 0.38	9.22 ± 0.45
	S_3	10.16 ±1.83	11.23 ± 1.96	9.88 ± 0.18	9.42 ± 0.36
Ficus religiosa	S_1	8.45 ± 0.30	9.03 ± 0.49	5.74 ± 0.22	5.44 ± 0.16
	S_2	7.69 ± 0.39	8.29 ± 0.70	6.77 ± 0.37	6.68 ± 0.27
	S_3	6.99 ± 0.09	8.23 ± 0.57	7.45 ± 0.37	7.68 ± 1.41
Plumeria rubra	S_1	4.29 ± 0.24	5.06 ± 0.23	3.53 ± 0.47	3.95 ± 0.61
	S_2	4.71 ± 0.56	5.23 ± 0.55	3.91 ± 0.36	3.46 ± 0.19
	S_3	4.80 ± 0.47	5.07 ± 0.52	4.48 ± 0.31	5.10 ± 1.72
Lagestroemia speciosa	S_1	5.36 ± 0.69	5.96 ± 0.25	5.59 ± 0.34	4.39 ± 1.05
	S_2	4.38 ± 0.38	4.66 ± 0.39	6.30 ± 0.29	6.14 ± 0.27
	S_3	4.65 ± 0.35	4.79 ± 0.20	6.75 ± 0.26	5.68 ± 1.09
Alstonia scholaris	S_1	4.54 ± 0.51	5.10 ± 0.19	4.54 ± 0.30	4.05 ± 0.25
	S_2	4.22 ± 0.35	4.66 ± 0.37	4.57 ± 0.28	4.02 ± 0.48
	S_3	4.08 ± 0.30	4.24 ± 0.30	4.70 ± 0.53	4.03 ± 0.60
Butea monosperma	S_1	8.68 ± 0.08	9.51 ± 0.58	5.52 ± 0.41	5.55 ± 0.64
	S_2	7.86 ± 0.76	8.79 ± 0.42	6.37 ± 0.26	6.16 ± 0.27
	S_3	7.42 ± 0.49	8.24 ± 0.26	7.45 ± 0.62	7.35 ± 0.48
Polyalthia longifolia	S_1	5.06 ± 0.22	5.39 ± 0.64	10.10 ± 0.69	9.37 ± 0.35
	S_2	5.06 ± 0.24	5.09 ± 0.28	9.97 ± 0.89	9.62 ± 0.77
	S_3	5.14 ± 0.59	5.10 ± 0.39	11.52 ± 0.77	10.27 ± 1.42

3.3 Changes in leaf extract pH value

The high value of the leaf extract pH is recognized to improve tolerance to air pollution (Prajapati and Tripathi, 2008) [19]. Changing of pH value in leaves might change the stomata conductivity. Stomata in leaves remain closed in leaves with low pH condition, and become open in leaves with high pH (Lohe *et al*., 2015) [15]. pH also influences the photosynthetic efficiency rate in leaves, photosynthetic rate increases in leaves with high pH and reduce in leaves with lower pH value (Lohe *et al*., 2015) [15]. High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid, while low leaf extract pH shows a good correlation with sensitivity to air pollution (Rehman and Gul, 2015; Escobedo *et al*., 2008) [24, 8]. Study have reported that in presence of an acidic pollutant, the leaf extract pH was lowered, and the decline was greater in sensitive species (Scholz and Reck,1977) [25]. The result of the present study revealed that the leaf extract pH was recorded highest by *Ficus religiosa* during the rainy seasonin site1 (6.74±0.39), site2 (6.72±0.43), and site3 (6.82±0.02), while during the dry season observation the leaf extract pH values recorded in site1 (6.34±0.10), site2 (6.66±0.23), and site3 (6.71±0.02) respectively. However, the leaf extract pH was found least in *Plumeria rubra* during the rainy season in site1 (5.31±0.10), site2 (5.27±0.58), and site3 (5.44±0.10), whereas during the dry season observation the leaf extract pH was found in site1 (5.26±0.05), site2 (5.30±0.04), and site3 (5.41±0.09) respectively (Table 4). The result of the present investigation indicated that in case of *Mangifera indica*, the pH of the leaf extract during the rainy season with respect to the dry season was found to increase by 1.25%, and 0.17% toward slightly alkaline side in site1, and site2 respectively, while in site3 the pH value was found to decrease by 0.68% toward acidic side. In case of *Ficus religiosa*, the pH of leaf extract of the rainy season samples with respect to dry season sample was found to decrease by 5.93%, 0.89%, and 1.61% towards acidic side in site1, site2, and site3 respectively. Similar trend was observed in case of *Alstonia scholaris*, in which pH of leaf extract in the dry season was found to decrease towards acidic sides by 2.08%, 1.48%, and 0.69% in site1, site2, and site3 respectively. Moreover, *Polyalthia longifolia* followed the identical trend, in which pH of leaf extract in the dry season was found to decrease by 6.59%, 1.73%, and 0.52% in site1, site2, and site3 respectively. However in case of *Butea monosperma*, the pH of leaf extract of the dry season was found to increase throughout towards nearly neutral side by 0.82 % in site1,while in site2 and site3; the pH of leaf extract was found to decrease slightly by 0.77%, and 0.62% respectively (Table 4).

3.4 Changes in leaf relative water content (%)

Leaf relative water content is a crucial prerequisite for plant life; and shortage of water may cause severe stress to terrestrial plants (Singh and Verma, 2007) [32]. High amount of relative water content helps in maintaining physiological balance under stress condition. Moreover, enough water content in plants is useful for drought resistance (Lohe *et al*., 2015; Soltys-Kalina *et al*., 2016) [15, 34]. The relative water content is usually associated with the protoplasmic permeability of cells, which is involved in the loss of water and dissolved nutrients in plants, resulting in senescence of leaves (Escobedo *et al*., 2008) [8]. Relative water content plays a very important role in cell integrity during pollution stress, and in the same way, leaf relative water could have diluted chemical effects of pollutants absorbed by plants during physiological activity to maintain optimum physiological pH for metabolism (Singh and Verma, 2007; Dedio, 1975) [32]. Hence the plants with high relative water content even under polluted situations may be tolerant to air pollution. The result of the present investigation showed that the leaf relative water content percentage was recorded highest for *Plumeria rubra* during the rainy season in site1 (87.63±1.44%), site2 (87.55±2.48%), and site3 (90.11±0.73%), while during the dry season observation the LRWC was recorded in site1, (87.32±0.83%), site2 (87.23±0.93%), and site3 (87.83±1.17%) respectively. The other tree species with high leaf relative water content percentage was *Butea monosperma* during the rainy season in site1 (81.64±1.35%), site2 (82.47±1.39%), and site3 (83.11±2.07%), whereas during the dry season observation the leaf relative water content was found in site1 (79.51±0.87%), site2 (80.46±1.08%), and site3 (82.43±0.81%) respectively. However, the leaf relative water content was recorded least by *Alstonia scholaris* during the rainy season observation in site1 (68.52±1.62%), site2 (67.35±0.83%),and site3 (68.22±1.01%), while during the dry season observation the leaf relative water content was recorded in site1(67.13±0.92%), site2 (71.70±0.85%), and site3 (66.62±1.72%), respectively (Table 4). The investigation revealed that in case of *Mangifera indica* leaf relative water content (%) in the rainy season samples with respect to the dry season samples was found to increase by 0.10%, and 1.51% in site1, and site2, while in site3 a reduction by 1.03% was observed. From the result it appears that the relative water content (%) in the rainy season with respect to the dry season was found decrease by 0.35%, 0.37%, and 2.53% in site1, site2 and site3 respectively for *Plumeria rubra*. Moreover, a reduction by 2.61%, 2.44%, and 0.82% in site1, site2, and site3 respectively recorded for *Butea monosperma*. Almost all studied tree species except *Mangifera indica*, and *Ficus religiosa* in site1, *Mangifera indica* and *Alstonia scholaris* in site2, and *Lagestroemia speciosa* in site$_3$, showed reduction in leaf relative water content (%) during the dry season with respect to rainy season observation (Table 4).

Table 4: Seasonal variation in leaf extracts pH and leaf relative water content (%) of the studied tree species

Name of tree species	Site	pH(value)		%LRWC	
		Rainy season	Dry season	Rainy season	Dry season
Mangifera indica	S_1	5.60 ± 0.15	5.67 ± 0.07	78.00 ± 1.83	78.08 ± 1.48
	S_2	5.74 ± 0.04	5.75 ± 0.03	78.08 ± 0.85	79.26 ± 1.08
	S_3	5.88 ± 0.07	5.84 ± 0.05	80.54 ± 1.04	79.71 ± 2.98
Ficus religiosa	S_1	6.74 ± 0.39	6.34 ± 0.10	76.46 ± 1.03	77.31 ± 0.84
	S_2	6.72 ± 0.43	6.66 ± 0.23	76.65 ± 1.13	75.94 ± 0.95
	S_3	6.82 ± 0.02	6.71 ± 0.02	77.51 ± 2.24	76.48 ± 1.91
Plumeri arubra	S_1	5.31 ± 0.10	5.26 ± 0.05	87.63 ± 1.44	87.32 ± 0.83
	S_2	5.27 ± 0.58	5.30 ± 0.04	87.55 ± 2.48	87.23 ± 0.93
	S_3	5.44 ± 0.10	5.41 ± 0.09	90.11 ± 0.73	87.83 ± 1.17
Lagestroemia speciosa	S_1	5.69 ± 0. 62	6.10 ± 0.09	78.78 ± 0.57	76.88 ± 0.39
	S_2	6.28 ± 0.33	6.25 ± 0.30	79.13 ± 0.92	78.24 ± 0.55

	S_3	5.38 ± 0.33	5.35 ± 0.10	80.37 ± 0.71	80.48 ± 1.03
Alstonia scholaris	S_1	5.29 ± 0.14	5.18 ± 0.02	68.52 ± 1.62	67.13 ± 0.92
	S_2	5.40 ± 0.64	5.32 ± 0.02	67.35 ± 0.83	71.70 ± 0.85
	S_3	5.76 ± 0.20	5.72 ± 0.22	68.22 ± 1.01	66.62 ± 1.72
Butea monosperma	S_1	6.12 ± 0.34	6.17 ± 0.17	81.64 ± 1.35	79.51 ± 0.87
	S_2	6.47 ± 0.17	6.42 ± 0.03	82.47 ± 1.39	80.46 ± 1.08
	S_3	6.47 ± 0.04	6.43 ± 0.04	83.11 ± 2.07	82.43 ± 0.81
Polyalthia longifolia	S_1	6.07 ± 0.47	5.67 ± 0.10	80.03 ± 0.73	79.47 ± 1.15
	S_2	5.79 ± 0.44	5.69 ± 0.27	80.52 ± 1.40	79.98 ± 1.44
	S_3	5.79 ± 0.01	5.76 ± 0.02	81.04 ± 0.93	84.73 ± 4.70

3.5 Changes in air pollution tolerance index value

The result of the present investigation illustrated that the seven studied tree species shows considerable variation in their susceptibility to air pollution and they responded differently to air pollutants. The average APTI index value was highest by *Mangifera indica*in site1 (27.90±2.81), site2 (27.51±6.22), and site3 (24.59±2.99), followed by *Butea monosperma* in site1 (18.69±0.97), site2 (18.72±0.94), and site3 (19.12±0.83), while the least average APTI value was found in *Alstonia scholaris* i.e. site1 (11.37 ± 0.45), site2 (11.24±0.60), and site3 (10.94±0.46) respectively (Table 5).

It is revealed from present study in case of *Mangifera indica*, the value of APTI index in the dry season with respect to the rainy season was increased by 4.10%, 2.39%, and 4.32% in site1, site2, and site3 respectively. For *Ficus religiosa* an increased was recorded by 1.05%, 3.55%, and 9.59%, while in case of *Plumeria rubra*an increase by 6.61%, 1.60%, and 1.89% was observed in site1, site2, and site3 respectively. Identical trend was detected for *Butea monosperma* an increase of 4.65%, 4.14%, and 5.15% was recorded in site1, site2, and site3 respectively. However *Polyalthia longifolia* showed a reduction during the dry season with respect to the rainy season by 0.74%, 1.37%, and 2% in site1, site2, and site3 respectively (Table 5).

Table 5: Seasonal variation in air pollution tolerance index (APTI) value the studied tree species

Name of tree species	Site	APTI (Value)		APTI (mean)
		Rainy season	Dry season	
Mangifera indica	S_1	27.34 ± 3.08	28.46 ± 2.57	27.90 ± 2.81
	S_2	27.18 ± 7.26	27.83 ± 5.42	27.51 ± 6.22
	S_3	24.07 ± 2.97	25.11 ± 3.10	24.59 ± 2.99
Ficus religiosa	S_1	18.18 ± 0.37	18.37 ± 0.41	18.27 ± 0.39
	S_2	18.04 ± 0.64	18.68 ± 1.32	18.36 ± 1.06
	S_3	17.73 ± 1.25	19.43 ± 0.65	18.58 ± 1.31
Plumeria rubra	S_1	12.56 ± 0.34	13.39 ± 0.35	12.97 ± 0.54
	S_2	13.09 ± 0.66	13.30 ± 0.56	13.20 ± 0.60
	S_3	13.78 ± 0.56	14.04 ± 0.48	13.91 ± 0.52
Lagestroemia speciosa	S_1	13.95 ± 1.06	13.95 ± 0.84	13.95 ± 0.93
	S_2	13.43 ± 0.64	13.61 ± 0.64	13.52 ± 0.62
	S_3	13.67 ± 0.35	13.32 ± 0.46	13.50 ± 0.44
Alstonia scholaris	S_1	11.31 ± 0.60	11.42 ± 0.25	11.37 ± 0.45
	S_2	10.95 ± 0.51	11.53 ± 0.56	11.24 ± 0.60
	S_3	11.09 ± 0.39	10.79 ± 0.49	10.94 ± 0.46
Butea monosperma	S_1	18.26 ± 0.41	19.11 ± 1.19	18.69 ± 0.97
	S_2	18.34 ± 1.09	19.10 ± 0.60	18.72 ± 0.94
	S_3	18.64 ± 0.78	19.60 ± 0.57	19.12 ± 0.83
Polyalthia longifolia	S_1	16.17 ± 0.57	16.05 ± 0.92	16.11 ± 0.74
	S_2	16.01 ± 0.34	15.79 ± 0.45	15.90 ± 0.40
	S_3	16.98 ± 0.85	16.64 ± 1.11	16.81 ± 0.97

As revealed in Figure 2, the overall air pollution tolerance index (APTI) values of the studied trees species ranged between 11.18±0.53 to 26.66±4.48. The highest APTI value was recorded by *Mangifera indica* (26.66±4.48), followed by *Butea monosperma* (18.84±0.92), *Ficus religiosa* (18.4±0.98), *Polyalthia longifolia* (16.28+0.83), *Lagestroemia speciosa* (13.66±0.71), *Plumeria rubra* (13.36±0.68), and *Alstonia scholaris* (11.18±0.53), respectively. The high APTI value points tolerance response of trees, while the lower APTI indicates the sensitivity of tree species against air pollution stress.

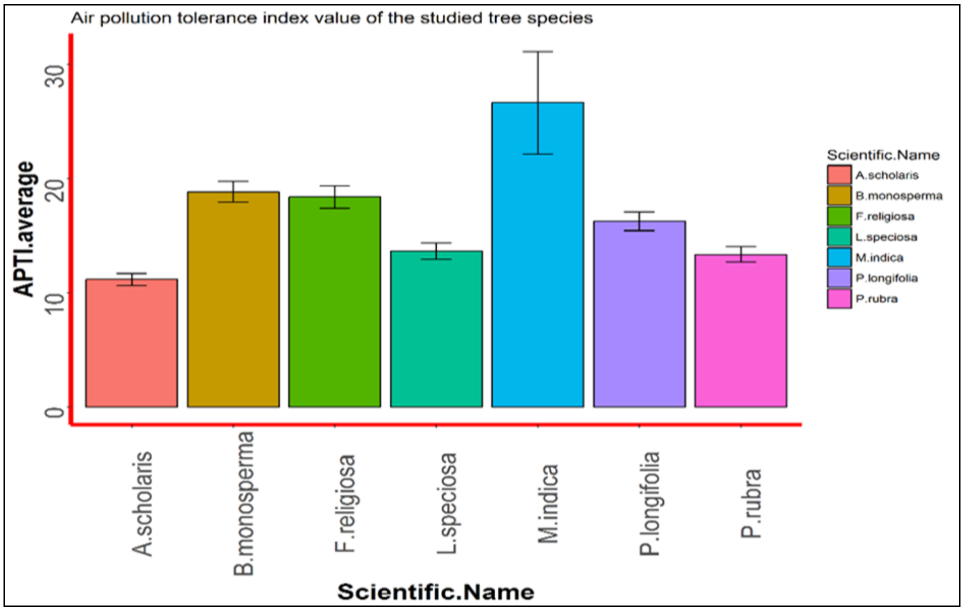

Fig 2: Average air pollution tolerance index value of the studied tree species

3.6 Anticipated performance index assessment of the studied tree species

Each plant species has a different ability to absorb, and adsorb pollutants by their foliar surfaces, which is influenced by several biochemical, physiological and morphological characteristics (Rehman and Gul 2015) [24]. Morphological characters of plalnts are very important in determining plant resistance to air pollution (Verma and Chandra 2014; Rahul and Jain 2014) [43, 14]. Dust intercepting and adsorption capacity of trees species mostly depend on their surface geometry, phyllotaxy, leaf external charactersitics, for example, presence or absence of hairs, cuticle, stomata, trees heighet, feature and size of canopy (Rahul and Jain 2014; Prajapati and Tripathi 2008) [43, 19].

Table 6: Evaluation of the studied tree species based on their APTI value and biological and socio-economic characteristics.

Name of tree species	APTI value	Tree habit	Canopy structure	Type of tree	Laminar structure			Economic important
					Size	*Texture*	*Hardness*	
Mangifera indica	+ + + + +	+ +	+ +	+	+	+	+	+ +
Ficus religiosa	+ + + +	+ +	+ +	+	+ +	+	+	+
Plumeria rubra	+ +	-	-	-	+ +	+	+	+ +
Lagestroemia speciosa	+ +	+ +	+	-	+	+	+	+ +
Alstonia scholaris	+	+ +	+ +	+	+	+	+	+
Butea monosperma	+ + + +	+ +	+	+	+ +	+	+	+ +
Polyalthia longifolia	+ + +	+	+	+	+	+	+	+

The grading patterns of the studied tree species are shown in Table 6 and the API base evaluation are described in Table 7 depictsing and summarizing the air pollution tolerance index values together with the morphological, socio-economic and anticipated performance index values. It is revealed that *Mangifera indica* by achieving the API of 7 value was likely to be the best performer against air pollution. *Ficus religiosa* and *Butea monosperma* by obtaining the API value of 6 were recognized to be excellent performing tree species. On the other hand, *Lagestroemia speciosa*, *Alstonia scholaris*, and *Polyalthia longifolia* getting the API value 4 are peredicted to be good performers, however, *Plumeria rubra* with the anticipated performer value of 2 was recorded as a poor tree species for air pollution tolerance.

Table 7: Anticipated performance index of the studied tree species

Name of tree species	Grade allotted		API value	Assessment category
	Total (+)	%Scoring		
Mangifera indica	15	93.75	7	Best
Ficus religiosa	14	87.5	6	Excellent
Plumeria rubra	8	50	2	Poor
Lagestroemia speciosa	10	62.5	4	Good
Alstonia scholaris	10	62.5	4	Good
Butea monosperma	14	87.5	6	Excellent
Polyalthia longifolia	10	62.5	4	Good

4. Conclusion

Air pollution in Chiang Mai city can be mitigated by choosing and cultivation tolerant trees species in and around urban areas. To accomplish this aim, the air pollution tolerance index (APTI) and the anticipated performance index (API) of the seven common roadsides tree species were estimated. The average APTI value ranged from 11.18±0.53 to 26.66±4.48. The descending order of APTI values were *Mangifera indica*>*Butea monosperma*>*Ficus religiosa*>*Polyalthia longifolia*>*Lagestroemia speciosa*>*Plumeria rubra*>*Alstonia scholaris*. Furthermore, it is revealed that impact of air pollution in terms of changes during study from the rainy to the dry and polluted season took place significantly in both seasonal groups of ascorbic acid, while two seasonal groups of the remaining biochemical parameters and air pollution tolerance index values were not significant differences. The result of API index illustrated that *Mangifera indica* would be the best performeramong all the tree species. Similarly, *Butea monosperma*, and *Ficus religiosa* were expected to be excellent performers. While, *Polyalthia longifolia*, *Lagestroemia speciosa*, and *Alstonia scholaris*, were recognized as good performing trees species, and hence these species can be recommended for cultivation in and around industrial and urban areas for mitigation air pollution problem.

5. Acknowledgments

Financial support provided by the Thailand International Cooperation Agency (TICA), and Program of Environmental Science, Faculty of Science, Chiang Mai University, are gratefully acknowledge. A great deal of appreciation goes to Plant Physiology and Post-Harvest Technology Laboratory, Biology Department, Faculty of Science, Chiang Mai University for arrangement of necessary laboratory facilities.

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