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Air Pollution Tolerance Index of Selected Trees in Major Roadsides of Metro Manila, Philippines

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ABSTRACT

This study aims to assess the air pollution tolerance index of selected trees in major roadsides of Metro Manila. The air pollution tolerance index (APTI) of trees was assessed using the parameters: total chlorophyll, ascorbic acid, pH and relative water content. A total of 47 tree species were assessed in all major roadsides of Metro Manila. A number of trees observed were categorized as intermediate tolerant to air pollution. Significant differences on the APTI of the trees were evident depending on the species examined and had significant correlation to the locations of the major roadsides where they were collected ($P < 0.05$). Planting of trees, which are either tolerant or intermediate tolerant to air pollution, is necessary as these mitigate the effects of air pollution in the metropolis.

INTRODUCTION

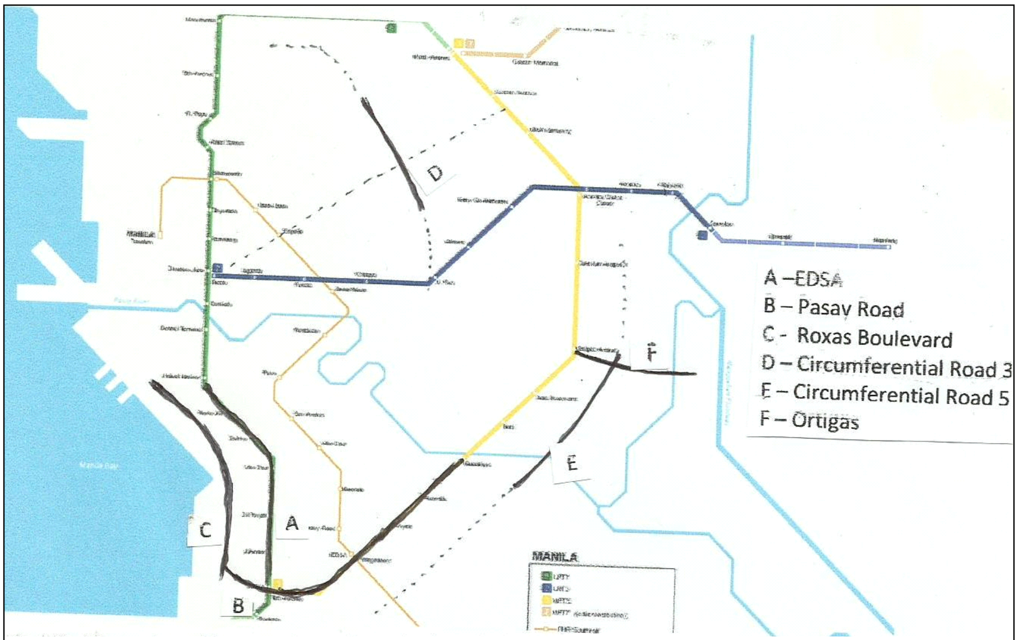
Air pollution remains to be one of the foremost problems that continue to affect the well being of people. The problem is particularly acute in Metro Manila, the primary urban area in the Philippines. The poor quality of air impacts on the lives of those who are exposed to the harmful substances in the atmosphere. Studies (Prisby et al. 2008, Yang et al. 2008, Parent et al. 2007) have shown that exposure to the deteriorating air quality poses numerous effects to one's health, where subtle biochemical and physiological changes can contribute to respiratory and cardiac conditions. These can lead to cancer and even death. Likewise, laws such as the Clean Air Act of 1999 have been enacted and implemented to help curb air pollution, but the problem persists.

Different physical and chemical methods have been considered and employed in the past to help ameliorate air quality, but these are continuously challenged by the exorbitant costs of setting up and maintaining these systems. A suitable alternative to the use of physical and chemical methods of controlling air pollution is by using biological methods like growing green plants in and around the urban areas of Metro Manila. Greening projects in urban areas can mitigate the effects of air pollution (Baro et al. 2014) as plants play an important role in the ecological balance, particularly in the cycling of nutrients and exchange of gases. Plants also provide us with innumerable benefits that include providing shade (Nowak 2006), enhancing the aesthetics in the environment and providing habitats (Esfahani et al. 2013), acting on the scavengers of air pollutants (Joshi & Swami 2009) and absorbing pollutants and regulating the urban atmospheric environment (Nowak 2006, Liu & Ding 2008). However, these benefits of mitigating air pollution and improving the environmental quality can only be realized if the green plants grown in and around the urban areas are capable of withstanding the stressors brought about by air pollution. The response of plants to air pollution can be determined by measuring the air pollution tolerance index (APTI). APTI is an index used for biological monitoring and assessing bio-indicator species. It is a process that assesses the response of plants biochemically and physiologically (Singh & Verma 2007). The sensitive plant species help indicate air pollution and the tolerant ones help in pollution abatement, as the plants act as sinks in the areas (Lakshmi et al. 2009).

To date, there are limited studies in assessing the air pollution tolerance level of plants in the Philippines. Hence, this study aims to assess the air pollution tolerance index of trees in major roadsides of Metro Manila. The result of this study is vital as it provides baseline information that can help in urban greening projects in the country and in other parts of the world.

MATERIALS AND METHODS

All major roads of Metro Manila were included in the study, namely the Circumferential Road 3 (C3), Circumferential Road 5 (C5), EDSA, Ortigas Avenue, Pasay Road, Roxas



Modified from: http://www.urbanrail.net/as/manila/manila-metro-map.png

Fig. 1. Map of major roads of Metro Manila showing collection sites

Boulevard, and Taft Avenue. Metro Manila or commonly known as the greater metropolitan, is an urban centre where several industries and commercial centres are found. Not all the trees along the roads were sampled. Trees were selected randomly along the roads based on accessibility. Collections of leaves were done using a pole cutter. Only mature trees having a diameter breast height (DBH) of $\geq$ 10 cm in the major roadsides of Metro Manila were assessed (Chazdon et al. 2005). The leaves were taken from the periphery of the crown and from the top, middle and bottom of the canopy and the mature leaves were taken after the fourth internode (Ragragio et al. 2014).

The APTI for each tree sample was calculated using the parameters, namely, pH, relative water content, total chlorophyll and ascorbic acid, using the standard procedures. The leaf extract pH was determined through the homogenization of 5 g of fresh leaf material with 50 mL of deionized water, homogenate was centrifuged at 5000 rpm for 10 minutes and the pH was determined using a pH meter. The relative water content was determined using a gravimetric method where the leaf weights under different conditions were determined like the initial fresh weight, turgid weight and dry weight (Varshney 1992). The total chlorophyll content was determined spectrophotometrically after extraction with 80% acetone. The extracted leaves were decanted and centrifuged at 2500 rpm for 3 minutes. Supernatant was collected and absorbance read at 645 nm and 663 nm, and the total chlorophyll content was computed using the formulas described by Agbaire (2009). The ascorbic acid was measured using the spectrophotometric method described by Agbaire (2009). One-gram leaf sample was homogenized to 4 mL oxalic acid-EDTA extracting solution. One millilitre of orthophosphoric acid and 1 mL of 5% tetraoxosulphate (vi) acid was subsequently added and 2 mL of ammonium molybdate was poured to solution followed by 3 mL of deionized water. The solution was allowed to stand for 15 minutes and read at an absorbance of 760 nm. The APTI was computed using the formula APTI = [AA (TC + P) + R]/10, where AA stands for the ascorbic acid in mg/g, TC stands for the total chlorophyll in mg/g, P stands for the pH and R stands for the relative water content in mg/g.

The APTI category described by Lakshmi et al. (2009) is given in Table 1.

Significant differences on the APTI of the tree species in every roadside and in all major roadsides of Metro Manila were determined using the Kruskal-Wallis test. Significant

Table 1: APTI category (Lakshmi et al. 2009).

Species	APTI computed values
Tolerant species	30-100
Intermediate tolerant species	17-20
Sensitive species	1-16
Very sensitive species	<1

correlation on the APTI of the tree species to the major roadsides of Metro Manila was determined using the Spearman's rho. Significance was set at $P < 0.05$. All statistical analysis were performed using the GNU PSPP software.

RESULTS

A total of 47 tree species was collected and assessed in all major roadsides examined in Metro Manila. Table 2 gives the list of tree species and the APTI values in the different roads of Metro Manila.

Among all the trees examined along the major roadsides of Metro Manila, *Gemelina arborea* Roxb.ex. Sm showed the highest mean APTI seen in the Circumferential Road 5 (C-5). The lowest mean APTI was that of *Bombax* sp. as observed along Roxas Boulevard. Consequently, different APTI results of the selected trees examined showed varied APTI results at different major roadsides. No common tree observed on different major roadsides showed consistent APTI results. For example, *Mangifera indica* leaves were collected from 4 individuals from 4 sites. In Taft Avenue and C3 roads, two trees were categorized as intermediate tolerant, one collected from Ortigas categorized as tolerant and one collected in Ortigas categorized as sensitive. A greater disparity occurs in *Leucana glauca*, which is categorized tolerant in EDSA, but sensitive in Ortigas Ave. This may be due to variability among the individual trees. Statistical analysis showed that the APTI of the trees examined in all major roadsides collected were significantly different from each other ($F = 16.98$; $P < 0.05$). Likewise, a significant correlation was observed between the major roadsides and the APTI of the tree species was observed (Spearman rho = 0.372; $P <0.05$). This may be attributed to the quality of air that differs from each other in each of the collection sites.

No tree species observed in all major roadsides was very sensitive to air pollution. Tree species examined were either sensitive or intermediate tolerant to air pollution with a few species tolerant to air pollution.

In EDSA, only 2 trees or 17.6 % of trees had APTI of 17 and above and most trees were in the sensitive category. On the other hand, trees along the C3 road had the least number of sensitive species (9%) followed by the trees found in Ortigas (21%).

DISCUSSION

The *Gmelina arborea* Roxb. ex Sm, (in C3) *Mangifera indica*, *Ficus elastica* Roxb. and *Samanea saman* (Jacq.) Merr. (all in Ortigas Ave.) were the only tree species observed to have high APTI that were classified to be tolerant to air pollution. Plants with high APTI found to be tolerant to air pollution act as important bioaccumulators of air pollutants (Prasanna et al. 2005), whereas plants that show low APTI and classified as sensitive to air pollution act as bioindicators of pollution (Rai et al. 2013). Many of the tree species examined from the major roadsides of Metro Manila act as important bioindicators of air pollution based on the APTI results observed. Our results have shown that no tree species observed at different major roadsides had similar APTI results. There were tree species observed to be sensitive in one major roadside and intermediate on another. Likewise, there were tree species observed to be intermediate in one major roadside and tolerant on another. Significant differences on the APTI of the tree species were seen across all the major roadsides examined. This result was consistent with those of other researchers (Chouhan et al. 2012, Jissy Jyothi & Jaya 2010 and Radhapriya et al. 2011). The variations in the APTI results as observed from the tree species examined may likely be attributed to the variations in the parameters used to determine the APTI that includes the relative water content, ascorbic acid content, pH and total chlorophyll content of the plant. Plants subjected to stressors in its environment may bring changes within the plant and adjusts to the stressors by responding defensively to the stressors that it is exposed to. Studies (Agbaire & Esiefarienrhe 2009, Raza & Murthy 1988) have shown that stressed plants act defensively by either increasing or decreasing its relative water content, ascorbic acid content, total chlorophyll content and pH so as to help the plant maintain its physiological balance under the stress conditions brought about by air pollutants.

Quality of air: Most species showing intermediate tolerant and tolerant indices were found along Ortigas while sensitive species were found along EDSA. This may reflect the difference in the quality of air of the two roadsides since the trees along EDSA may be more exposed to various air pollutants from vehicles. In Taft Avenue, 71% of the trees are categorized as sensitive. Along this road, most pollutants come from vehicular emissions with particulate matter (PM) that range from <2.5 to <10 $\mu g/m^3$ which are of greater health concern when they penetrate the lungs (DENR-EMB, 2013). In the Philippine General Hospital along Taft Avenue, it was recorded that there was a $PM_{2.5}$ value of 45 $\mu g/m^3$ which was higher than the National Ambient Air Quality Guideline Value, i.e. 35 $\mu g/m^3$ (Simpas & Cruz 2014, unpublished thesis). This is regarded as 'unhealthy for sensitive groups' by the US Environmental Protection Agency (US EPA 2013). The major air pollutants for the study sites are mobile sources which come from vehicular emissions that contribute to up to 90% of air pollution (DENR-EMB 2013). Because it was found that there is a significant correlation between the major roadsides and the APTI of the tree spe-

Table 2: APTI of trees in each major road (mean +/- SD).

Scientific Name	EDSA	Pasay road	Roxas blvd	C3	C5	Taft	Ortigas
Acacia auriculiformis	16.483±0.225	28.480±0.157		24.944±0.020			25.244±0.145
Albizia lebbeck (L.) Benth.			12.598±0.029				
Antidesma bunius (L.) Spreng.		27.389±0.067					
Artocarpus heterophyllus Lam.	16.565±0.028			15.572±0.119			
Azadirachta indica (A.) Juss.			20.294±0.253		25.677±0.256		
Barringtonia asiatica (Linn.) Kurz.	16.502±0.223	14.470±0.035					
Bauhinia purpurea Linn.					21.120±0479		
Bombax heptaphyllum Can.			8.882±0.141				
Broussonetia luzonica (Blanco) Bur.	16.814±0.526						
Cassia fistula L.		12.376±0.152			24.548±0.156		
Ceiba pentandra Linn.				18.152±0.391			
Chrysophyllum cainito Linn.	16.297±0.061						
Cratoxylum formosum						23.696±0.227	
Crescentia cujete L.						15.918±0.231	
Delonix regia (Hook.) Raf.			9.283±0.029			17.814±0.064	14.396±0.028
Eucalyptus globulus Labill					23.692±0.150	10.733±0.115	29.615±0.400
Ficus benjamina Linn.	14.088±2.865		11.792±0.022	18.585±2.499			19.890±2.184
Ficus elastica Roxb.	10.600±1.057					19.159±0.205	34.773±0.278
Ficus hauili Blanco				21.708±0.226			
Ficus nota (Blanco) Merr.		13.296±0.375					
Ficus religiosa Linn.	18.236±0.105		10.149±0.026				14.102±0.039
Ficus septica Burm. F.		19.829±0.514					
Ficus stipulosa Miq.	14.655±4.990		13.557±0.142		12.609±0.051		
Gmelina arborea Roxb. ex Sm.	15.536±0.047				47.460±0.071		
Lagerstroemia speciosa (L.) Pers.		16.438±0.182			18.290±4.396	14.482±2.110	
Leucaena glauca Benth.	19.934±0.331						11.300±0.170
Mangifera indica Linn.			11.959±0.784	21.107±1.838		18.302±4.837	38.072±0.757
Michelia champaka (L.) Baill. ex Pierre						12.703±0.049	
Morinda citrifolia Linn.	14.749±0.139						
Muntingia calabura Linn.		21.682±0.098			20.953±0.105	11.378±0.152	
Persea americana Mill.				22.473±0.123			
Pisonia umbellifera (J.R. Forst. et G. Forst) Seem.			9.894±0.029	15.920±0.266			
Plumeria acuminata Air.	16.266±0.390	13.393±0.085			15.163±0.070		
Plumeria rubra L.					15.499±0.020		
Polyalthia longifolia Benth. & Hook. f.		25.777±0.448		28.893±0.181	23.526±0.550	13.067±0.040	
Pouteria campechiana (HBK) Baehni							29.556±0.178
Premna odorata Blanco			28.988±0.396				
Pterocarpus indicus Willd.		9.685±0.038	11.304±0.446		21.454± 0.169	12.540±0.117	
Reutealis trisperma (Blanco) Airy Shaw			27.683±0.457				
Samanea saman (Jacq.) Merr.	14.773±4.005				11.312±0.092	12.000±0.260	33.085±0.927
Sandoricum koetjape Merr.	17.950±0.122	17.030±0.192				15.054±0.493	18.993±0.029
Swietenia sp.	9.701±0.018	27.601±0.072	20.646±0.052		23.302±3.294		26.260±2.370
Syzygium cumini (L.) Skeels		23.123±0.274	18.103±0.138				25.540±4.842
Syzygium malaccense						21.765±0.197	
Tabebuia sp.		16.902±0.163					
Terminalia catappa	11.576±0.718		20.787±0.100	23.374±0.350			25.289±0.207

cies (Spearman rho = 0.372; $P < 0.05$), it is assumed that among the 5 major roadsides where sampling occurred, EDSA is the most polluted and Ortigas Avenue, the least polluted.

CONCLUSION AND RECOMMENDATIONS

A total of 47 species of trees along major roadsides in Metro Manila were collected and only 4 species of these had APTI above 30, which is a tolerant category. These 4 species are: *Gmelina arborea*, *Mangifera indica*, *Ficus elastica* and *Samanea saman*. No tree species examined was very sensitive to air pollution.

It is recommended that continuous monitoring of the trees along the major roadsides be made. This monitoring can provide information on the quality of air in these areas. In addition to this, the planting of various tree species along major roadsides can contribute to the greening of the metropolis, provide fresh air and ecosystem services in mitigating air pollution in the metropolis.

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