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RESEARCH ARTICLE

Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of plants found in Matara city area, Sri Lanka: An approach for recommending plants for landscaping city areas.

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Abstract: This study aims to recommend plant species for urban landscaping based on a biomonitoring study accompanied by comparison of Air Pollution Tolerance Indices (APTI) and Anticipated Performance Indices (API) of five tree species (*Mangifera indica, Muntingia calabura, Cassia fistula, Azadirachta indica, Ficus benjamina*) and four ornamental species (*Bougainvillea spectabilis, Ixora coccinea, Ervatamia coronaria, Nerium indicum*) found in Matara city area, Sri lanka. APTI was determined by combining the four biochemical and physiological parameters Relative water content (RWC), Total chlorophyll content (TChl), Ascorbic acid content (AA) and Leaf extract pH using a pre-defined formula. Each parameter of all the species was compared with that of it for the control site, Wellamadama premises of University of Ruhuna. Results suggested that RWC, TChl and pH were lower, and AA was higher for the city area in comparison to control site. APTI varied in the decreasing orders *C. fistula* (13.09), *A. indica* (11.23), *M. indica* (11.12), *F. benjamina* (10.68), *M. calabura* (9.12) for tree species and *E. coronaria* (10.22), *I. coccinea* (10.20), *N. indicum* (8.85), *B. spectabilis* (8.43) for ornamental species. Based on APTI, *M. indica, C. fistula, A. indica* were intermediately tolerant and other species were sensitive to air pollution. The calculated API values suggest, *M. indica* is 'excellent', *C. fistula* is 'very good', *F. benjamina* and *A. indica* are 'good' and *M. calabura* is 'moderate' in their suitability to be planted on urban landscape as tree species. API values of the tested ornamental plant species showed that *B. spectabilis, I. coccinea, E. coronaria* as 'moderate' and *N. indicum* as 'poor' for urban landscaping. The overall results highlight the suitability of APTI and API as simple, inexpensive, and convenient methods for recommending plant species for urban areas with sound automobile pollution.

Keywords: *Air pollution; Biochemical; Biomonitoring; Sensitivity; Stress*

Introduction

Air pollution has been a conflicting global environmental issue by present. Urban air pollution is being intensified day by day as an outcome of industrialization and increase in vehicular population. Controlling such pollution is found to be more complex than that of other environment challenges (Gholami et al., 2016). Recently, interest of scientists has been grown towards the studies on the ability of plants to eliminate pollutants from air. Therefore, biomonitoring studies have been extremely relevant in air pollution science in the aspect of urban ecosystem restoration (Rai & Panda, 2013).

Air pollutants affect plants either directly on leaves or indirectly through soil acidification (Begum & Harikrishna, 2010). Since plants and the atmosphere are in constant dynamic continuation with each other, any imbalance in the composition of air is reflected by plant functioning. Gaseous pollutants diffuse into intercellular air spaces. Then they can be either absorbed into water films in the plant body or chemically altered by plant tissues. After detoxification of pollutants such as Sulphur dioxide,

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nitrogen dioxide and ozone, they are translocated via phloem or xylem into leaves. Finally, they are released into atmosphere or transported towards roots where they are detoxified by microbes (Begum & Harikrishna, 2010). Thus, within the plant, pollutants undergo various fates which induce changes in biochemistry, physiology, morphology, genetics and anatomy of plants (Begum & Harikrishna, 2010).

Plant's response to air pollution at biochemical and physiological level can be assessed by analysis of factors that determine susceptibility and resistance. It has been shown that air pollution makes impacts on total chlorophyll content, leaf extract pH, ascorbic acid content and relative water content (Rai & Panda, 2013). Use of these four different parameters individually has given contrasting results for the same species, therefore these parameters individually, may not create a clear picture of pollution induced changes taken place within plants (Ogunkunle et al., 2015). These four parameters are expressed in a formula to evaluate the sensitivity or tolerance level of plants to air pollutants, which is termed as Air Pollution Tolerance Index – APTI (Singh & Rao, 1983). APTI is an inherent quality of plants that encounter pollution stress (Thakar & Mishra, 2010). It can be expressed quantitatively, and the resulted value is considered as the measure of a plant's ability to fight against air pollution. Plants having higher APTI values are tolerant to air pollution and can be used as sinks to alleviate contamination while those of lower APTI values are sensitive to air pollution and can be used as biological indicators (Uka et al., 2017). Bio monitoring of air quality in terms of APTI is a simple, cost effective and a universal method. Such studies provide keys for landscapers, horticulturists, greenbelt designers and environmental scientists for the selection of suitable plant species for designing vegetation (Jyothi & D., 2010; Tanee & E., 2013).

As APTI only gives an idea of the tolerance level of the plants, based on biochemical and physiological parameters, it alone cannot be used as a tool to design urban vegetation with aim to mitigate air pollution in city areas. Anticipated Performance Index (API) is an improvement over APTI. It is an effective tool to select species for landscaping in vicinity of urban areas. API is an index derived by incorporating APTI value of a particular plant along with its pre-defined biological characters and socio-economic importance (Table 1). This combined approach of APTI and API can be applied as a tool in the selection of the most suitable plant species for a particular landscape such as city areas, industrialized areas, etc. Prominent victim of the vehicular smoke is the atmosphere of roadsides along cities in which a great vehicular traffic exists daily. This suggests that the roadside vegetation would be effective, once used for a biomonitoring study.

In order to contribute to the world campaign of sustainable development, Sri Lanka on its own needs to work for a clean atmosphere parallel with the technical development. Although numerous studies have been performed on this topic worldwide and utilized in designing urban vegetation so as to mitigate urban air pollution, there is a scarcity in the relevant literatures on similar studies performed in Sri Lanka. Therefore, it is apparent that an enough attention has not been paid on the application of green plants for air pollution mitigation and monitoring in planning the urban vegetation in Sri Lanka. Thus the present study was carried out in Matara city area, considering as a model which aims to find out applicability of a combined approach of APTI and API for recommending the most suitable plant species for urban landscaping in order to mitigate air pollution.

Table 1: Key criteria and corresponding scores for API determination (Gupta et al., 2016)

Character of grading		Pattern of assessment	Grade allocated
01. Tolerance	APTI	12.1 – 13.0	+++++
		11.1 – 12.0	++++
		10.1 – 11.0	+++
		8.1 – 10.0	++
		7.0 – 8.0	+
02. Biological	Plant habit	Large	++
		Medium	+
		Small	-
	Canopy structure	Spreading dense	++
		Spreading crown/Open/Semi dense	+
		Sparse/Irregular/Globular	-
	Type of plant	Evergreen	+
		Deciduous	-
	Size	Large	++
		Medium	+
		Small	-
	Texture	Coriaceous	+
		Smooth	-
	Hardiness	Hardy	+
		Delineate	-
03. Socioeconomic	Economic value	Five or more uses	++
		Three or four uses	+
		Five or more uses	-

Maximum grade that can be scored by a plant =16

Materials and methods

Study Site

The present study was conducted in the city of Matara, one of the largest cities in Sri Lanka which is 2m above the mean sea level. The annual rainfall is averaged to 2147 mm and average temperature is 26.8 ºC for this area. The study site (Fig.1 and Fig.2) was the main road that runs across this city [From the landwards end of "Mahanama" bridge (5.9461 º N, 80.5488 ºE) to "Nupe" junction (5.9480829 ºN, 80.5368998 ºE)]. The Wellamadama premises of University of Ruhuna were selected as the control site which is an undisturbed site that is situated 5.7 km away from the studied city area.

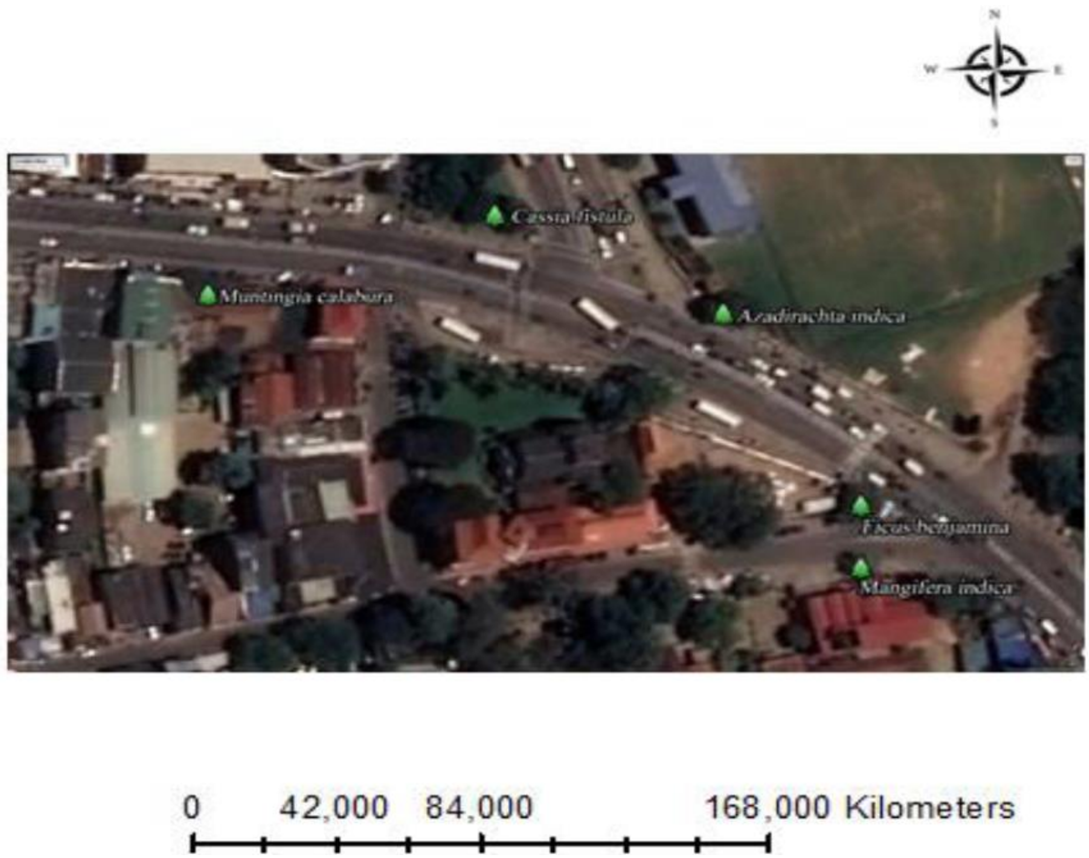

Figure 1: Map showing the study area, Matara city, Sri Lanka with the sampled trees; (from left to right) *Muntingia calabura, Cassia fistula, Azadirachta indica, Ficus benjamina, Mangifera indica*.

Test plant species

Plants were selected based on a preliminary study on abundance of tree species and ornamental plant species in both Matara city area and selected control site. Five tree species, *Mangifera indica* , *Muntingia calabura* , *Cassia fistula* , *Ficus benjamina* , *Azadirachta indica* and four ornamental plant species *Bougainvillea spectabilis, Ixora coccinea, Ervatamia coronaria, Nerium indicum* were selected for the study.

Sample collection

Sample collection was done from the city area in three turns during the months of September, October, and December of year 2017 as sampling 1, sampling 2 and sampling 3 respectively. Mature trees having a DBH exceeding 20 cm and mature ornamental plants of 1-meter height from a distance within 5 meters from the edge of the main road were selected. Composite samples were made from the fully exposed twigs from four directions (North, East, South, West) of each plant, within a height below 5 meters and 1 meter in tree species and ornamental species, respectively.

Figure 2: Map showing the study area, Matara city, Sri Lanka with the sampled ornamental plants; (from left to right) *Ervatamia coronaria, Nerium indicum, Bougainvillea spectabilis, Ixora coccinea*.

Laboratory analysis

Determination of relative water content (RWC) in leaves

Relative water contents in leaves were determined according to the method described by (Rai & Panda, 2013) with slight modifications. Fresh weight just after sampling, turgid weight after immersion in water overnight and dry weight after oven drying at 75º C till constant weight received were recorded for calculation of relative water content. ADAM Analytical Balance and Gallenkamp Hotbox Oven were used for measuring weight and drying, respectively.

$$\boldsymbol{RWC = \left[\frac{Wf - Wd}{Wt - Wd}\right] * 100}$$

Where *RWC* is the Relative water content (%), W*f* is the fresh weight (g), W*d* is the dry weight (g) and W*t* is the turgid weight (g).

Determination of Ascorbic acid (AA) content

Ascorbic acid contents in leaf material were determined by the spectrophotometric method, 2,4 – Dinitrophenyl hydrazine method described by (Khan et al., 2006) and (Rahman et al., 2007) with slight modifications. Sample preparation was done by homogenizing 5g of blended plant material in 50 ml of 10% Orthophosphoric acid – 10 % Acetic acid solution and a 10-fold dilution was made just before analysis. 3% Br2 water (until brown color appeared) followed by 10% Thiourea solution (until brown color disappeared) were added dropwise into 4 ml of the dilution. Then 1 ml of 2,4 – Dinitrophenyl hydrazine solution was added, and mixture was maintained at 37 º C for 3 hours followed by cooling in ice for 30 minutes. Finally, 5 ml of chilled 85 % H2SO4 was added and absorbance was measured at 521 nm using EVOLUTION 260 BIO UV-Visible Spectrophotometer. Blank was performed using 4 ml of 10% Orthophosphoric acid – 10 % Acetic acid solution. Ascorbic acid content in plant material was determined using the calibration curve obtained for standard Ascorbic acid solution series, 5ppm, 10ppm, 15ppm, 20ppm, 25ppm.

Determination of pH of leaf extract

0.5g of ground leaf material was homogenized in 50 ml of deionized water and pH was measured using STARTER 300 pH meter (Rai & Panda, 2013).

Determination of total chlorophyll content (TChl) of leaves

Total Chlorophyll content was determined by the method described by (Maclachalam & Zalik, 1963). A small piece of leaf near the tip was cut and weight was measured. It was placed in 5 ml of 80% Acetone under cool, dark conditions for 24 hours and absorbance was measured at 645 nm and 663 nm using EVOLUTION 260 BIO UV-Visible Spectrophotometer with 80 % Acetone as the blank. Total Chlorophyll content was calculated according to the following formulas.

$$\boldsymbol{Ca = \frac{\{[(12.3 * D663) - (0.86 * D645)] * V\}}{d * 1000 * W}}$$

$$\boldsymbol{Cb = \frac{\{[(19.3 * D645) - (3.60 * D663)] * V\}}{d * 1000 * W}}$$

$$\boldsymbol{TChl = Ca + Cb}$$

Where *Ca* is the concentration of Chlorophyll a (mg g^{-1} FW), *Cb* is the concentration of Chlorophyll b (mg g^{-1} FW), *D* is the optical density at wavelength indicated, *V* is the final volume of 80% Acetone (ml), *W* is the fresh weight of leaf material (g), *d* is the length of the cuvette (cm) and *TChl* is the Total Chlorophyll content (mg g^{-1}).

APTI determination

APTI values were evaluated according to the formula introduced by (Singh & Rao, 1983), which is given below, using the values obtained for its parameters.

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

A = Ascorbic acid content (mg / g FW)
T = Total Chlorophyll content (mg / g FW)
P = Leaf extract pH
R = Relative water content (%)

Tree species and ornamental species were then categorized based on their tolerance or sensitivity level.

API determination

APTI values were incorporated with the pre-defined, standard biological and socio-economic parameters in each tree species and API values were calculated according to the method described by (Rai, 2016). Each criterion is given a score. According to his definition, the maximum score that can be obtained by a tree species is 16. API values of ornamental species were calculated with a slight modification of the original method - The standard criterion, "economic importance" was removed since all the ornamentals have the same economic importance, ornamental value. Then the maximum score for ornamental species becomes 14. API values were then used to assess the feasibility of tree species and ornamental species for urban vegetation.

Results and discussion

Matara city area, accompanied with continuous vehicular activity facilitates an unceasing circulation of automobile exhaust pollutants throughout the year. The tested parameters in this study have been used for evaluation of the plants' tolerance to air pollution.

Relative water content

The higher the water content within a plant body, higher is its physiological balance even under stressful conditions such as air pollution (Gholami et al., 2016). Similarly, the lower the reduction in relative water content, higher is the above-mentioned physiological balance. Air pollution leads to higher transpiration rates (Rai & Panda, 2013). As well, they increase cell permeability thereby inducing water loss along with dissolved nutrients (Rai, 2016). Therefore, the plants that maintain higher relative water contents even under polluted air are said to be tolerant. According to the results (Fig.3 and Fig.4), RWC of plants in the city area has always been lower in comparison to the control site. The t-test reveals that RWC of city area plants are significant ($p < 0.05$) over the control site. In this study, once considered solely based upon results of relative water content, averaged percentage reduction of relative water content of tree species has been the highest (18.47%) for *M. calabura* suggesting that it is the most susceptible, *F. benjamina* (10.02%) was the next and the reductions of *M. indica* (7.44%), *C. fistula* (4.47%) and *A. indica* (6.90%) were varying more or less similarly with the least reduction. Hence the last three tree species were the fittest under pollution stress (*C. fistula, A. indica, M. indica*). *B. spectabilis* showed the least reduction of relative water content (5.35%) in response to pollution among the ornamentals. Hence it is the fittest in terms of relative water content whilst *E. coronaria* was the most susceptible in terms of relative water content, having the highest reduction of relative water content (11.28%) in presence of pollution stress.

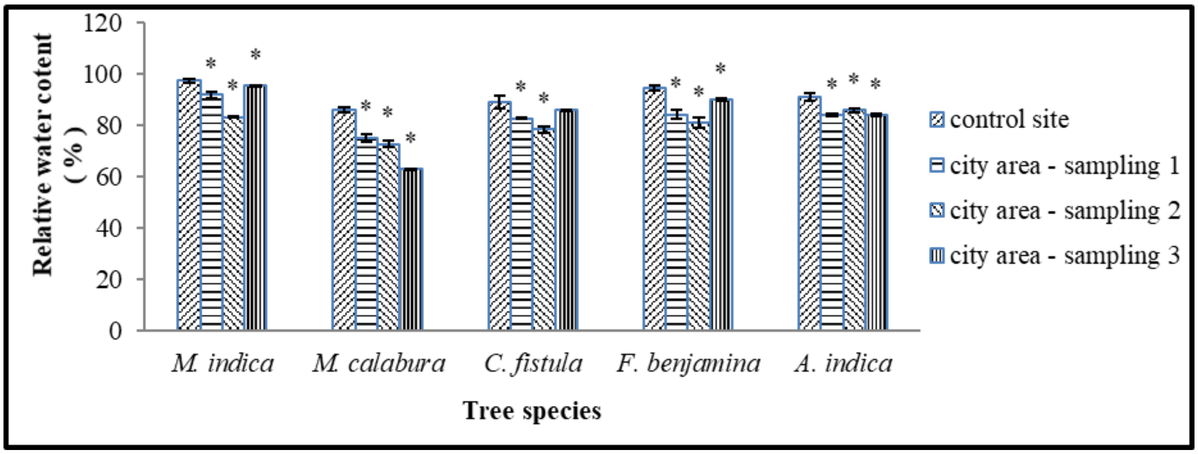

Figure 3: Mean relative water contents of tree species with standard deviation. * Indicate significant difference (p< 0.05) in the value in comparison to the control site.

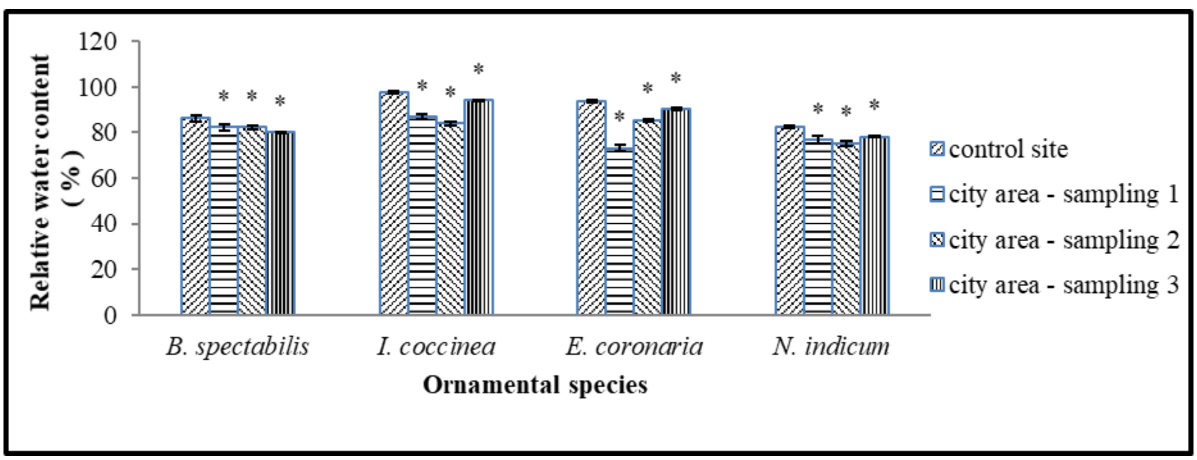

Figure 4: Mean relative water contents of ornamental species with standard deviation. * Indicate significant difference (p< 0.05) in the value in comparison to the control site.

Based on a performed ANOVA, there was a significant difference ($p < 0.05$) among relative water contents reported for the 3 months, for all test species except *B. spctabilis*. This suggests that the tolerance of plants against air pollution varies upon time. Reasons for this would be, fluctuations in the pollution load during the study period.

Ascorbic acid content

According to (Pandey et al., 2015) ascorbic acid content of plants increases with increasing pH and vice versa. Hence ascorbic acid content within a plant is more or less pH controlled. Ascorbic acid is a natural detoxicant of air pollutants (Ogunkunle et al., 2015). As well, it is a scavenging molecule of free radicals that hinder enzymes and a catalyst for various physiological and biochemical processes (Gupta et al., 2016).

Results (Fig.5 and Fig.6) show that the AA contents reported in the city area have always exceeded that of the control site in both plant categories. The averaged percentage increments of ascorbic acid contents in city area in comparison with control site were reported as, 60.18% for *M. calabura*, 42.25% for *C. fistula*, 38.90% for *A. indica*, 28.96% for *M. indica* and 13.03% for *F. benjamina*. These increments were significant ($p < 0.05$) for each sampling of *l* and *C. fistula*. As well, these two tree species have shown the highest percentage increments of ascorbic acid contents. It might be due to the higher production of Ascorbic Acid in plants as a defense mechanism to tolerate the stress caused by air pollution. However not all the ascorbic acid increments were significant for other plants of both tree and ornamental plant category. From the ornamental species, *B. spectabilis* (40.04%) and *E. coronaria* (40.30%) showed higher apparent ascorbic acid increment levels suggesting higher tolerance, while *I. coccinea* showed 20.48% and *N. indicum* showed 19.05%. All the tree species have increased their ascorbic acid contents over time. This suggests a sort of increment in pollution load.

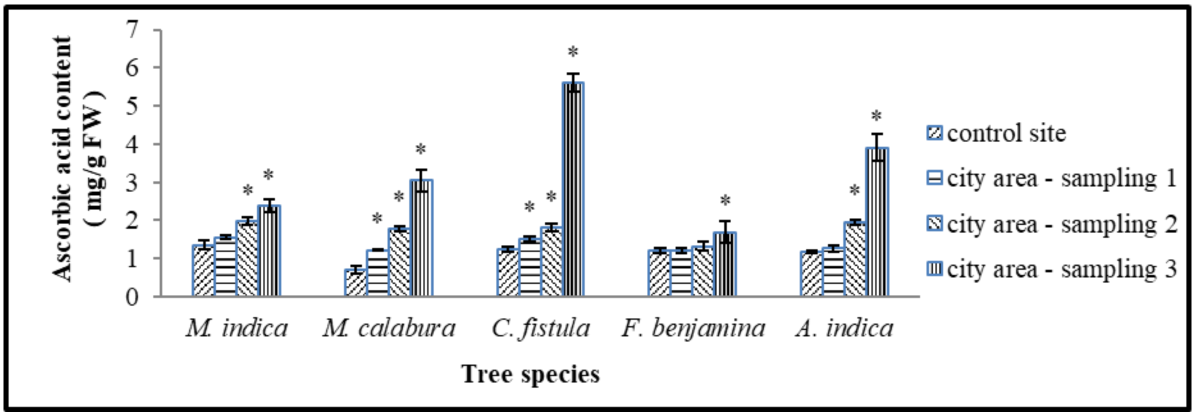

Figure 5: Mean ascorbic acid contents of tree species with standard deviation. * Indicate significant difference (p< 0.05) in the value in comparison to the control site.

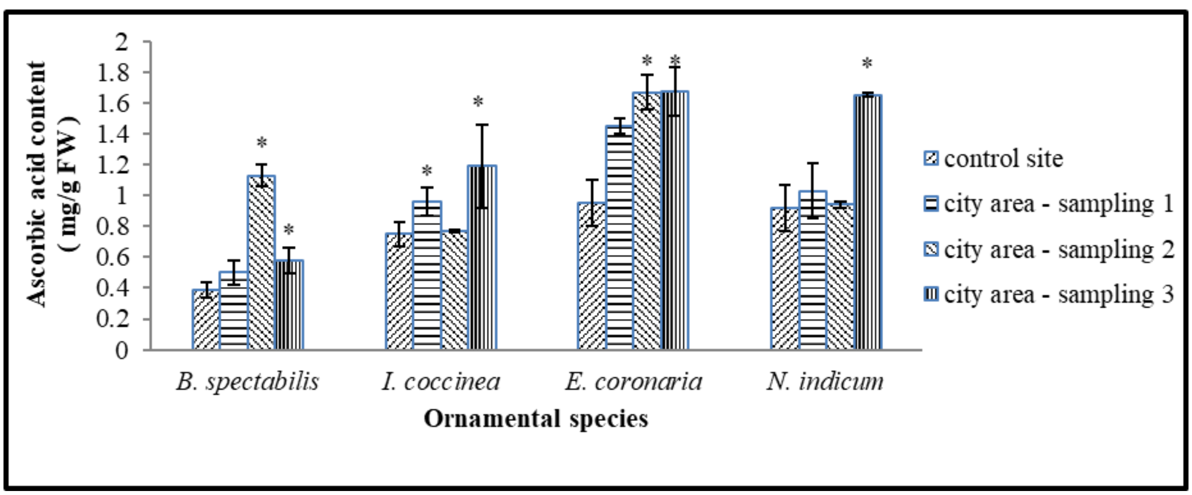

Figure 6: Mean ascorbic acid contents of ornamental species with standard deviation. * Indicate significant difference (p< 0.05) in the value in comparison to the control site.

In this study, the plants *M. indica*, *F. benjamina*, *B. spectabilis* and *N. indicum* obey previously mentioned theories to a great extent. Increased ascorbic acid contents during the month of December suggest the presence of a high concentration of air pollutants that exerted more oxidative stress on plants. As shown by the results, it is fair to state that the consecutive order of trees, *M. calabura*, *C. fistula*, *A. indica*, *M. indica*, *F. benjamina* is in the priority order that was tolerant for pollution in terms of ascorbic acid. Ornamentals *B. spectabilis* and *E. coronaria* are more tolerant to air pollution in the context of ascorbic acid content while the other two were less tolerant.

According to the ANOVA, a temporal variation in ascorbic acid content in all the plants except for *B. spectabilis* was obvious. Hence ascorbic acid content can be introduced as a very sensitive parameter for air pollution. In part, it suggests that the pollutant concentration/ composition have varied upon the selected time scale.

pH of leaf extracts

As shown by the results for pH values of leaf extracts (Fig.7 and Fig.8), most plants from city area have shown their pH values within a range 5 to 7. This suggests the presence of an acidic pollutant. However it would be conflicting that the control site also showing acidic pH values, the best explanation for this would be that, even the control site showed acidic pH, always the polluted site has shown more acidic values than control site. An acidic pollutant's ability to reduce leaf extract pH is lower for tolerant species and vice versa (Gholami et al., 2016). Thereby exhibiting the least averaged pH drop over control site, *A. indica* (1.24%) of tree species and *E. coronaria* (1.62%) of ornamental species are the most tolerant species to air pollution in terms of leaf extract pH. In contrary, the other species that show more fluctuations in leaf extract pH can be said sensitive in this attribute. *M. calabura* (5.70%) and *N. indicum* (8.27%) have been most sensitive to pollution stress among tree species and ornamental species, respectively.

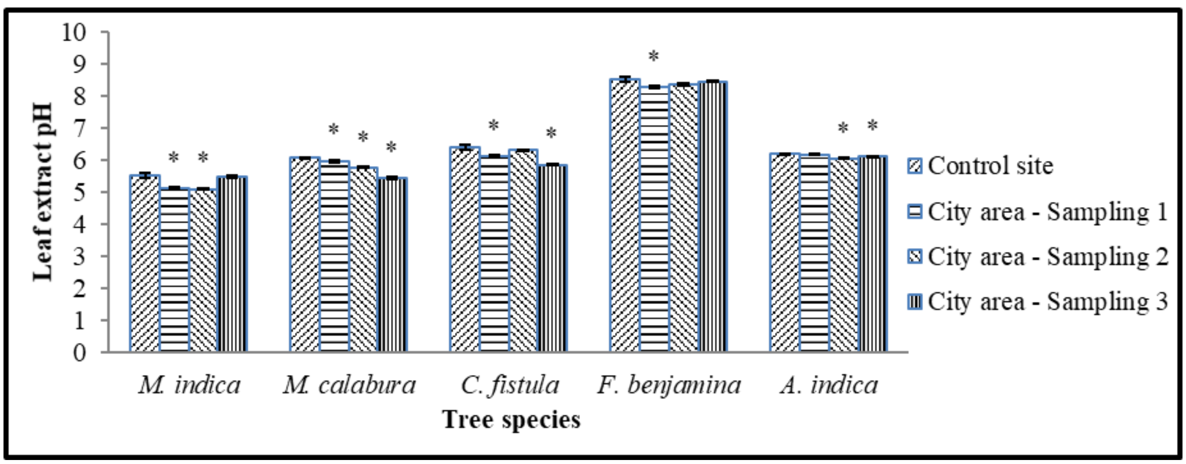

Figure 7: Mean pH values of leaf extracts of tree species with standard deviation.* Indicate significant difference ($p < 0.05$) in the value in comparison to the control site.

The city area is most exposed to the air pollution from the source of automobile exhaust. Here, the burnt fossil fuels release SOx and NOx to the ambient air and these two gases are acidic, that also makes the leaf sap acidic (Leghari et al., 2011). This could be the reason why each of the plants has reduced their pH for the city area. Lower drop in leaf extract pH reflects the plant's ability to withstand such acidic pollutants (Gholami et al., 2016). Therefore, plants that are capable of maintaining their inherent leaf extract pH even in the presence of acidic pollutants are tolerant. There is a good correlation between sensitivity to air pollution and low pH (Thakar & Mishra, 2010).

The ANOVA performed on the leaf extract pH suggests that there is a temporal variation in leaf extract pH for all the selected tree and ornamental species except *E. coronaria*. pH is a good criterion for the determination of composition of air pollutants. The lower the pH, higher is the composition of acidic pollutants in the surroundings.

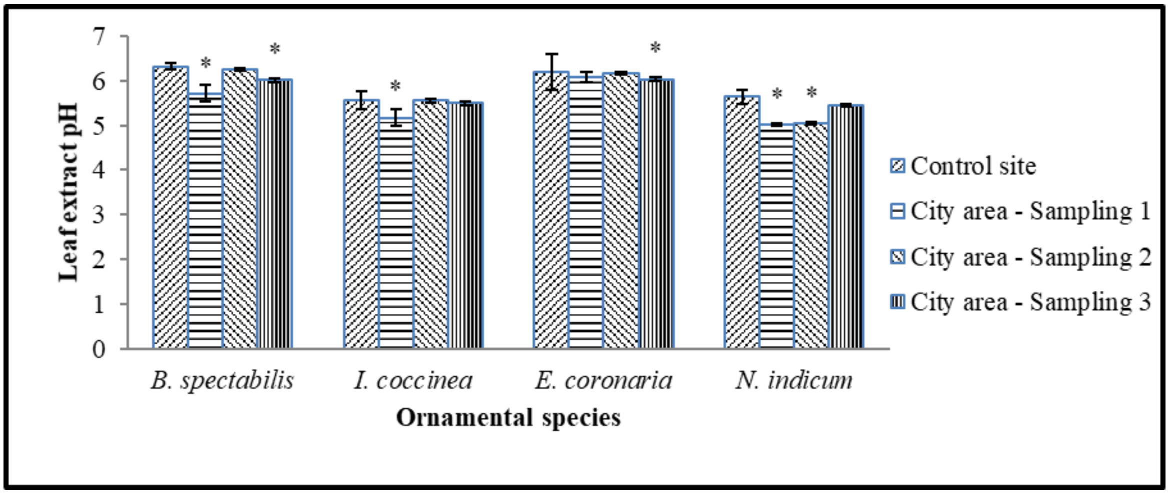

Figure 8: Mean pH values of leaf extracts of ornamental species with standard deviation. * Indicate significant difference ($p< 0.05$) in the value in comparison to the control site.

Total chlorophyll content

A plant's photosynthetic activity is signified by the total chlorophyll content. It determines the growth and development of plants. Total chlorophyll content is species specific as well as affected by the external pressures such as air pollution (Rai & Panda, 2013). Since lower total chlorophyll contents were recorded for the city area, these results (Fig.9 and Fig.10) are in complete agreement with above authors' ideas. According to (Gupta et al., 2016), stressful conditions are indicated by lowering of total chlorophyll contents in plants. Such a reduction of chlorophyll contents may be due to various reasons such as degradation by oxidation, reduction and bleaching and inhibition in biosynthesis of chlorophyll molecules by the action of various functional groups among pollutants (Rai, 2016). Acidic pollutants degrade chlorophyll by stomata blockage (Rai & Panda, 2013).

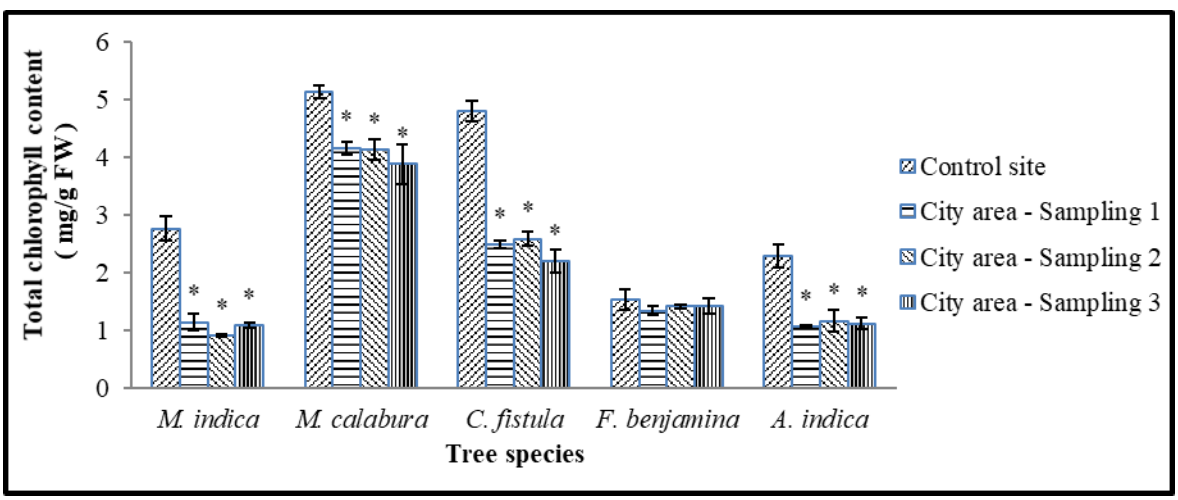

Figure 9: Mean total chlorophyll contents of tree species with standard deviation. * Indicate significant difference ($p< 0.05$) in the value in comparison to the control site.

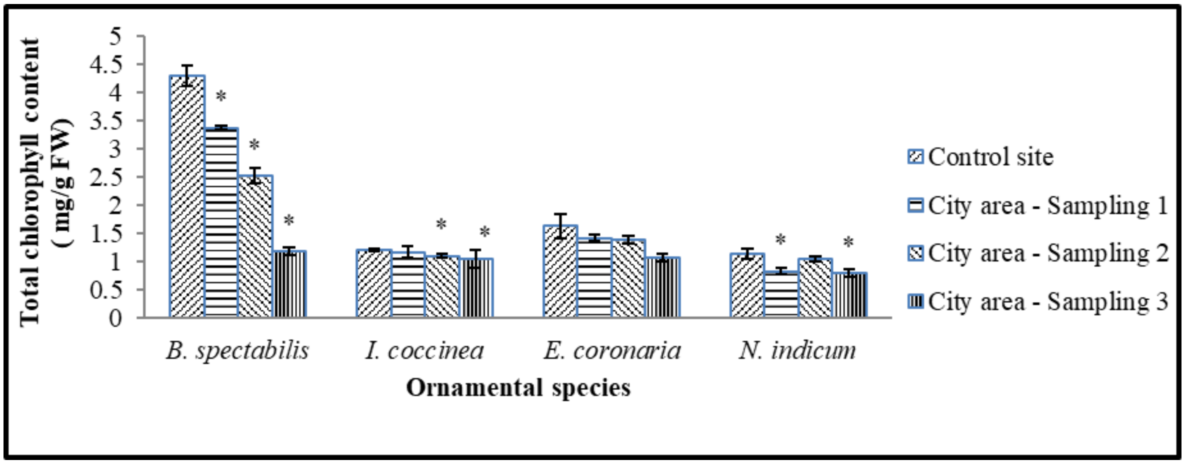

Figure 10: Mean total chlorophyll contents of ornamental species with standard deviation. * Indicate significant difference ($p< 0.05$) in the value in comparison to the control site.

Since the results for leaf extract pH suggested more acidic pollutants in the city air, the chlorophyll reduction can be partly attributed the acidic pollutants. Ascorbic acid contents suggested that the pollution load during December would be more. Since all the ornamentals and the tree species *M. calabura* and *C. fistula* have reported their lowest total chlorophyll content during December, previously mentioned prediction using the ascorbic acid content is further reinforced because both reduction of chlorophyll and increment of ascorbic acid content are functions of increasing pollution load. The observed gradual increment of ascorbic acid content in many selected plants can be coupled with the gradual reduction of chlorophyll content. Increase in pollution load over time could be the reason for this. Sensitive species loose their chlorophyll contents in a greater scale than tolerant species.

When considering the results for each sampling, based on the averaged percentage reductions over control site, it is visible that *F. benjamina* (8.71%) has least reduced the chlorophyll content from all set of trees and even this reduction is not significant. This suggests that it is the most tolerant one in terms of total chlorophyll content. Tolerance in this aspect for other species varies as *M. indica* (62.23%) < *A. indica* (51.35%) < *C. fistula* (49.51%) < *M. calabura* (20.95%). Among the ornamentals, *I. coccinea* (8.48%) is the most tolerant and *B. spectabilis* (44.99%) is the least tolerant.

A temporal variation in total chlorophyll content was revealed for only *M. indica* and *M. calabura* from the tree species. All the ornamentals show a temporal variation in this aspect. Tree species *C. fistula*, *F. benjamina* and *A. indica* might have developed mechanisms to maintain their chlorophyll contents at a more or less stable level.

Air Pollution Tolerance Index (APTI)

From these results, it was obvious that a plant's ability to tolerate air pollution in terms of different parameters were species specific as well as temporally varied. Different plants showed different priorities in their tolerance in terms of different parameters which are predictors of quality of air. A single species shows conflicting results for different parameters (Ogunkunle et al., 2015). However, APTI reflects much generalized output of all the four parameters. Hence it is a good tool to combine the results of each of the measured parameters.

Results (Table 2 and Table 3) suggest that plants have shown the highest tolerance during December. Assuming that the largest component of air pollution tolerance capability of plants is contained during this month, plant categorization was done based on December test results.

Table 2: APTI values of test tree species.

Tree species	APTI		
	Sept.	Oct.	Dec.
M. indica	10.16	9.51	11.12
M. calabura	8.75	9.05	9.12
C. fistula	9.57	9.45	13.09
F. benjamina	9.59	9.38	10.68
A. indica	9.32	9.99	11.23

Table 3: APTI values of test ornamental species.

Ornamental species	APTI		
	Sept.	Oct.	Dec.
B. spectabilis	8.68	9.21	8.43
I. coccinea	9.30	8.90	10.20
E. coronaria	8.40	9.80	10.22
N. indicum	8.29	8.10	8.85

In this study, APTI varied for tree species as *C. fistula* > *A. indica* > *M. indica* > *F. benjamina* > *M. calabura*. And for ornamental species, the variation was *E. coronaria* > *I. coccinea* > *N. indicum* > *B. spectabilis*. From the results of each parameter individually, different plants responded differently for different parameters. Hence an index like APTI seems to be very useful in integrating all the results. It can be deduced that the tree species *M. indica*, *C. fistula* and *A. indica* can be used both as sensitive species and tolerant species since it was 'intermediate' in response. According to (Ogunkunle et al., 2015), low APTI values (< 15.0) indicate a moderate level of air pollution in the respective atmosphere. In this study, since all the recorded APTI values were below 15, city of Matara can be mentioned as an area having a moderate level of air pollution. Sensitive species are those that indicate levels of air pollution that can be used as bioindicators and tolerant species are those that can be used as sinks to mitigate pollution (Leghari et al., 2011). All the other tree species and all the ornamentals are sensitive plants. Therefore *M. indica*, *C. fistula* and *A. indica* are effective pollution sinks while other tree species and ornamental species are effective bio indicators.

Anticipated Performance Index (API)

The conventional criteria for selection of plants for urban vegetation does include only few visible features such as color, shed, shape, size, etc. APTI alone is insufficient for species selection for urban vegetation since it is strictly biological. But once these two types of criteria are combined, it would bring about a great fraction of the extent of suitability of a plant for urban vegetation. Therefore APTI, morphological and socio-economic characteristics of a plant are combined to obtain API (Ogunkunle et al., 2015). API assesses the potential with plants in scavenging pollutants in atmosphere (Gupta et al., 2016).

According to the results (Table 4 and Table 5) of this study, suitability of the tree species for urban roadside vegetation varied as *M. indica* > *C. fistula* > *A. indica* = *F. benjamina* > *M. calabura* . From ornamental species, B. *spectabilis*, *I. coccinea* and *E. coronaria* were of moderate suitability for urban landscaping and *N. indicum* was poor as an urban landscaping plant. Analysis of API was done with slight modifications for ornamental species. Since there is no economic importance with selected ornamental species despite their ornamental value, this criterion was not considered. Therefore, the maximum score was 14.

Table 4: Determination of API in test tree species.

Tree species	APTI	H[a]	C[b]	T[c]	Laminar structure			E[g]	Grade allotted		API grade	A[h]
					Sd	Xe	Df		Total plus	% score		
M. indica	++++	++	++	+	++	+	+	+	14	87.5	6	Excellent
M. calabura	++	++	++	+	+	-	-	+	9	56.25	3	Moderate
C. fistula	+++++	++	++	+	+	-	+	-	12	75	5	Very good
F. benjamina	+++	++	++	+	+	-	+	-	10	62.5	4	Good
A. indica	++++	++	+	+	+	+	-	+	11	68.75	4	Good

[a] Tree habit, [b] Canopy structure, [c] Type of tree, [d] Size, [e] Texture, [f] Hardiness, [g] Economic importance, [h] Assessment

Table 5: Determination of API in test ornamental species.

Ornamental species	APTI	H[a]	C[b]	T[c]	Laminar structure			Grade allotted		API grade	A[h]
					Sd	Xe	Df	Total plus	% score		
B. spectabilis	++	+	+	+	+	++	-	8	57.14	3	Moderate
I. coccinea	+++	-	++	+	-	+	+	8	57.14	3	Moderate
E. coronaria	+++	+	++	+	+	-	-	8	57.14	3	Moderate
N. indicum	++	+	-	+	+	+	-	6	42.85	2	Poor

[a] Tree habit, [b] Canopy structure, [c] Type of tree, [d] Size, [e] Texture, [f] Hardiness, [h] Assessment

According to (Rai, 2016), plants that are 'excellent', 'good' or 'moderate' are suitable for future plantation and plants under 'poor' category are unsuitable as pollution sinks. Hence more generally, all the tree species considered in this study are suitable for urban roadside vegetation and urban plantations. From the tested ornamentals, *B. spectabilis*, *I. coccinea* and *E. coronaria* are suitable for further plantation for urban landscaping. *N. indicum* is not a good species for urban landscaping. Therefore, the former 3 ornamentals can be recommended for urban landscaping. Thus the individual species specific biochemical parameters of a particular plant can be incorporated to assess the tolerance/ sensitivity level which it expresses and finally can be transformed in to an index that determines its suitability level for urban roadside vegetation and landscape vegetation.

Conclusion

APTI and API are effective tools to be utilized in planning urban vegetation. The APTI values from each tree species and ornamental species bring information about the quality of air in the study area that it is moderately polluted (APTI < 15). Based on APTI values, the tree species *M. indica*, *C. fistula* and *A. indica* can be recommended as tolerant species to be used as sinks for urban air pollution whilst the tree species *M. calabura*, *F. benjamina* and ornamental species *B. spectabilis*, *I. coccinea*, *E. coronaria*, *N. indicum* can be recommended as sensitive species to be used as bio indicators of air pollution. It was also shown by this study that the individual parameters of APTI, relative water content, ascorbic acid content, pH of leaf extract and total chlorophyll content varied temporally. Since APTI value alone cannot be used as a tool to assess a plant's feasibility for urban vegetation, this index is transformed into API thereby incorporating with other biological and socio-economic characteristics. API suggests that from the tested tree species, *M. indica* is 'excellent', *C .fistula* is 'very good', *F. benjamina* and A. indica are 'good' and *M. calabura* is 'moderate' in their suitability to be planted on urban roadsides. The suitability of ornamentals for urban landscaping varied as 'moderate' for *B. spectabilis*, *I. coccinea* and *E. coronaria* and 'poor' for *N. indicum*. Hence APTI and API are approaches that are species specific and are simple, inexpensive, and convenient methods for recommendation of plants for urban areas with sound automobile pollution.

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