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ASSESSING THE AIR POLLUTION TOLERANCE INDEX AND ANTICIPATED PERFORMANCE INDEX OF ROADSIDE PLANT SPECIES FOR BIOMONITORING ENVIRONMENTAL HEALTH

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ABSTRACT

Leaf surface of plants acts as a sink for the deposition of air pollutants in the urban environment and is considered an ecologically sustainable cost-effective strategy to mitigate the impact of air pollution. In this context, assessment of air pollution tolerance index (APTI) and anticipated performance index (API) was calculated to observe the tolerant potential of fifteen plant species along roadside of Kathmandu valley. 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. Results suggested that, TChl and pH were lower, and RWC and AA were higher at heavily polluted area in comparison to the control site. The APTI for the species ranged between 7.57 and 11.51, ideal for sensitive species category (APTI < 16), and the plants are classified as bio indicators of air pollution. Highest mean ATPI (11.51) was recorded in *Callistemon citrinus* and lowest (7.57) was recorded in *Buddleja asiatica*. The API not only takes APTI into consideration but also the biological and socio-economic aspect of the species. The API grade indicates. *Ficus religiosa* and *N. arbor-tritis* (API = 5) as good performers while *Callistemon citrinus (API=4)*, *Nerium oleander (API=3)*, *Bougainvillea glabra (API=3)* and *Buddleja asiatica (API=3)* are predicted to be moderate green belt performers. On the basis of APTI and API assessment, the study suggest that out of fifteen species, only six plants species were identified as suitable green belt development. 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 environmental pollution with dust load.

KEY WORDS: Biochemical characteristics, Bio-indicators, Green belt development, Socioeconomic importance

INTRODUCTION

Air pollution is major problem in urban areas of developing countries. 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). Air pollutants cause damages to leaf cuticles and affect stomatal conductance. They can also have direct effects on photosynthetic structure, leaf longevity, and patterns of carbon allocation within plants (Winner and Atkinson, 1986). 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 (Kan *et al.* 2012) .

There is no way and technique known to well mitigate air pollution problems in 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). 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 principal 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. 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).

Similarly, roadside plants leaves are in direct contact with air pollutants, and may act as stressors for these pollutants (Rai, 2016). 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). 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) and it has also been used to categorize plants species in their order of tolerance to air pollution.

However, APTI information is limited to evaluate in the effect of pollutants on biochemical parameters only, it alone cannot be used as a tool to design urban vegetation with aim to mitigate air pollution in city areas. In order to combat air pollution using green belt development, anticipated performance index (API) is a more useful tool which is calculated based on both socioeconomic and biological characteristics (Prajapati and Tripathi, 2008). 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. (Pathak *et al*., 2011). API is based on various factors influencing the performance of a certain plant species. 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). In this study, we have explored common plant species (trees and shrubs) found in Kathmandu Valley 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. Plant 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.

MATERIALS AND METHODS

Selection of study sites

Present study was carried out along roadside of Kathmandu valley (27°42′14.40" N; 85°18′32.40" E), the capital city of Nepal. It lies in central Nepal with mean temperature from minimum 10 (January) to maximum about 25°C (July) in different months . Population of Kathmandu Valley is 2.1 million with annual population growth rate of 4.2% and population density 2,799.8/Km^2. Due to road expansion activities and pipelines of Melampchi water supply causes dust pollution in Kathmandu Total suspended particulate matters (TSPMs) has been a major problem in roadsides of Kathmandu valley.

The study area was divided into three on the basis of particulate materials) *viz.* highly polluted, moderately polluted, and less polluted (Table 1). The quantity of particulate pollutants ($PM_{2.5}$, PM_{10} and TSP) was measured by Gravimetric Method (CPCB, 2013). To see the impact of dust load on the roadside plants six sites were selected (Figure 1) – (1) heavily polluted (Koteshwor-Tinkunel area; Kalanki Bhatbhateni to Suichatar Area; and Tudikhel-Ratna Park Area; (2) Moderately polluted Budanilkantha 3. less polluted (Tribhuvan University campus area,

Table 1. Ambient air quality of study sites (Date of Sampling: March, 7-10. 2018)

SN	Location	PM_{10}	$PM_{2.5}$ (µg/Nm^3)	TSPM	Category of study site
1.	Kalanki (Top of Traffic Police Post Building)	507.0	86.0	1390.0	Heavily polluted
2	Ratnapark	454.0	105.0	1107.0	Heavily polluted
3.	Koteshwor (inside compound of traffic police post)	229.0	72.0	813.0	Heavily polluted
4.	Budanilkantha (inside compound)	193.0	23.0	248.0	Moderately polluted
5.	Kirtipur (Coronation garden)	149.0	13.0	320.0	Less Polluted
6.	Machhegaun (Matatirtha)	127.0	28.0	240.0	Less Polluted
	National Ambient Air Quality Standards (NAAQS) 2012	120.0	40.0	230.0	

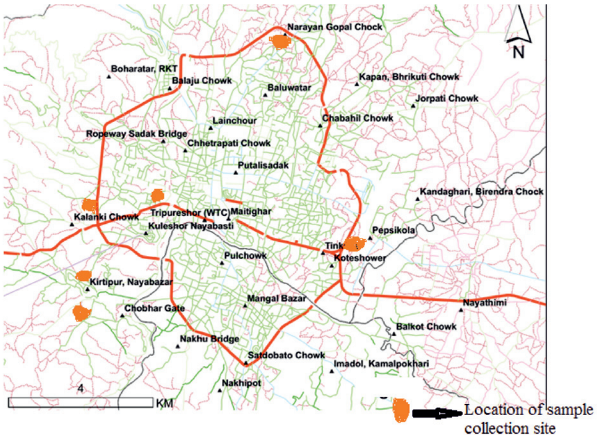

Fig. 1. Map showing location of air quality monitoring site

Kirtipur and Matatirtha area) as the control site for the comparison. Characteristic feature of sample collection site is presented in Table 2.

Selection of Plant species

Fifteen plant species *viz. Bougainvillea glabra* Choisy, *Buddleja asiatica* Lour., *Callistemon citrinus* (Curtis) Skeels, *Duranta repens L., Euphorbia pulcherrima* Willd. ex Klotzsch, *Ficusreligiosa* L., *Jasminum mesnyi* Hance, *Lagerstroemia indica* L., *Lantana camara* L., *Leucosceptrum canum* Sm., *Nerium oleander* L., *Nyctanthes arbor-tristis* L, *Ricinus communis* L., *Sambucus hookeri* Lindley and *Tecoma stans* (L.) Juss.exKunth., were selected for the present study. These plants were selected because of their common occurrence, easy accessibility and abundance at selected sites of the study. The physiology and botanical characters of plants under study are given in Table 3.

Collection of plant materials

Leaves of selected plants species were collected from six different locations (Table 2). In order to study the impact of air pollutants generated by vehicular activities on physiological characteristics viz. total chlorophyll content, ascorbic acid content, relative water content of leaves, and leaf extract pH of plants, the horizontal distance of 0-10m were selected from both sides of the road. The plants growing at selected sites on both sides of the road at isoecological sites having approximately same height and canopywere considered to maintain the uniformity. Five leaves from each of the three selected individual at each location were collected study. Fully mature leaves were collected in the morning hours (8 to 10 AM) at breast height (ca.1.3m). The collected leaf samples were then transported to the laboratory in zipper plastic and washed with tap water and then with distilled water.

Biochemical analysis

The fresh leaf samples were analyzed for total chlorophyll, ascorbic acid, leaf extract pH, and relative water content for determining APTI by following standard procedure. Relative water content (% RWC) of the leaf was determined using the method of Barr and Weatherley (1962) as follows:

$$\text{Relative water content (RWC) (\%)} = \frac{FW - DW}{TW - DW} \times 100$$

where, FW is the fresh weight, DW is the dry weight of turgid leaves after oven-drying at 115 °C for 24 h, and TW is the turgid weight after immersion in water overnight

Total chlorophyll content was determined using the spectrophotometric method (Arnon 1949), and leaf extract pH was determined using a glass electrode pH meter (PHS-3C model) by homogenizing 2.5 g of the fresh leaf sample in 10 ml distilled water; the pH was determined after pH calibration with a buffer at 4 and 9.

Ascorbic acid (AA) content of leaves was determined using the spectrophotometric method (Bajaj and Kaur, 1981). Four milliliters of oxalic acid-EDTA, 1 ml of orthophosphoric acid, 1 ml of 5 % tetraoxosulphate (VI) acid, 2 ml of ammonium molybdate and 3 ml of water were used as extractants for 1 g of the fresh leaves in a test tube. The solution was allowed to stand for 15 min and the absorbance read at 760 nm. The concentration of

Table 2. Site description

SN	Site name	Characteristics
Site 1	Koteshwar—Tinkune	Junction, Commercial, Entrance from Arniko Highway
Site 2	Kalanki Bhatbhateni –Suichatar	Junction, Commercial, Entrance to city from outside
Site 3	Tudikhel-Ratnapark	Bus park, more flow of vehicles and people
Site 4	Godawari	Away from city, settlement area, pilgrim
Site 5	Kirtipur-Coronation garden	University area, less flow of vehicles and movement
Site 6	Matatirtha-Machhegaun	Away from city area, less flow of vehicles

Table 3. Botanical characters of selected plants

Botanical name	Family	Common name	Uses
Bougainvillea glabra Choisy	Nyctaginaceae	Paper flower	Medicinal and ornamental, religious
Buddleja asiatica Lour.,	Scrophulariaceae/ Loganiaceae	Dhursilo, Bhimsenpati	Ornamental, religious and medicinal purpose
Callistemon citrinus (Curtis) Skeels	Myrtaceae	Crimson Bottlebrush	Ornamental, edible
Duranta repens L.	Verbenaceae	Golden Dewdrop, Sky Flower, or Pigeon Berry	Ornamental and medicinal
Euphorbia pulcherrima Willd. ex Klotzsch	Euphorbiaceae	Pulcherrima	Ornamental
Ficusreligiosa L.,	Moraceae	Peepal	Medicine, edible, ornamental, fodder and religious tree
Jasminum mesnyi Hance	Oleaceae	Primrose jasmine or Japanese jasmine	Ornamental, medicinal
Lagerstroemia indica L.	Lythraceae	Crepe myrtle	Ornamental
Lantana camara L.	Verbenaceae	Banmara	Medicinal, ornamental, host plant
Leucosceptrum canum Sm.,	Lamiaceae	Bhusure	Ornamental, folk medicine
Nerium oleander L.	Apocynaceae	Nerium or oleander,	Ornamental and medicinal
Nyctanthes arbor-tristis L.	Oleaceae	Parijat, Night flowering jasmine	Ornamental, medicinal and religious tree, fooder
Ricinus communis L.	Euphorbiaceae	Castor bean	Agriculture, Medicine, Biodisel, Industrial
Sambucus chinensis Lindley	Adoxaceae	Bridal bouquet	Medicinal
Tecomastans (L.) Juss. exKunth.,	Bigoniaceae	Yellow trumpetbush, yellow bells	Medicinal and ornamental

ascorbic acid in the sample was then extrapolated from a standard ascorbic acid curve.

The APTI proposed by Singh and Rao (1983) was determined by the formula:

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

where A is the ascorbic acid content (mg/g), T is the total chlorophyll (mg/g),
P is leaf extract pH of leaf sample
R is relative water content (%) of leaf sample
APTI values were categorized into four groups (Table 4) as suggested by Bharti *et al.* (2017) and Ogunkunle *et al.* (2015).

Evaluation of anticipated performance index

Anticipated performance index is a tool to determine the most suitable plant species for the development of green belts. In this study, all fifteen plants were assessed in terms of their API. The API values were estimated by using various socioeconomic, morphological, and some biochemical parameter, such as APTI, canopy structure, plant habit, and economic value (Table 5). The criteria of API for the assessment of plant species are given in Table 6. Based on this grading system, a plant species can only secure a maximum of 16 positive points which equals to a hundred percent. The scoring for allotted grades is scaled to the percentage scores to get API categories of assessment (Prajapati and Tripathi, 2008)

Table 4. Air Pollution Tolerance Index (ATPI) value and response assessment (Bharti *et al.* 2017)

ATPI	Response
30 to 100	Tolerant
29 to 17	Intermediate
16 to 1	Sensitive
<1	Very sensitive

Statistical Analysis

Statistical analysis was carried out using software SPSS-17. All biochemical parameters among the sites were compared by one way ANOVA and post hoc analyses (DMRT) were employed for comparison. All data are means of five replicates.

RESULTS AND DISCUSSION

Total chlorophyll content (TCC)

Total chlorophyll content (TCC) is an important

Table 5. Gradation of plant species based on air pollution tolerance index (APTI) as well as morphological parameters and socioeconomic importance used in API calculation (Prajapati and Tripathi, 2008; Govindaraju *et al.* (2012))

	Grading character	Pattern of assessment	Grade allotted
a. Tolerance	APTI	7.0-8.0	+
		8.1-10.0	++
		10.1-11.00	+++
		11.1-12.0	++++
		12.1-13.0	+++++
b. Morphological parameters and socioeconomic importance	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semi-dense	+
		Spreading dense	++
	Type of plant	Deciduous	-
		Evergreen	+
	Size (S)	Small	-
		Medium	+
		Large	++
	Texture (T)	Smooth	-
		Coriaceous	+
	Hardiness (H)	Delineate	-
		Hardy	+
	Economic value	Less than three uses	-
		Three or four uses	+
.		Five or more uses	++

*Maximum grades that can be scored by a plant = 16 (by counting total positive score)

biochemical factor that impacts photosynthetic activity which determines the plant growth. In present study, the highest total chlorophyll content was observed in *Bougainvillea glabra* (3.47mg/g) at less polluted site, and the least was observed in *Tecoma stans* (1.041) at the heavily polluted site. The TCC content in plant leaves decreases with increase deposition of particulate matter and gaseous pollutants on the leaf surface (Pandey *et al*., 2015; Zang *et al.,* 2016). As such, low TCC indicates the sensitivity of plant to pollution while high TCC in plant leaves indicates their tolerance potential in the polluted environment (Balasubramanian *et al.,* 2018). Several studies have reported reduction in total chlorophyll content in plants exposed to air pollutants. Reduction in total chlorophyll content to reduce gaseous exchange due to blockage of stomatal opening in response to air pollutants was also analyzed by Leghari and Zaidi (2013). The study on inverse relationship of total chlorophyll content with dust accumulation on leaves in polluted environment was reported (Manjunath and Reddy, 2019). In our study reduction in total chloprophyll content in samples of polluted site could be due to heavy load of dust in study area (Table 1). Further, detailed correlation analysis on influence of various physicochemical factors on photosynthetic pigments synthesis and activity should help in identifying adaptive plants with sustained growth in polluted environments.

Table 6. Anticipated performance index (API) of plant species (Prajapati and Tripathi 2008*)*

Grade	Scores (%)	Assessment of plant species
0	Upto 30	Not recommended for plantation
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

Ascorbic Acid Content (AAC)

Ascorbic acid is an important antioxidant which provides resistance from stress in plants by neutralizing the free radicals generated that can affect the biochemical and physiological activity (Keller, 1986; Conklin, 20010). In present study, the trend of AA of plant species at different pollution level is presented at Table 7. The AA content of leaf samples collected from heavily polluted sites ranged from 0.29 (*Lantana camara*) to 4.52 *(N. oleander)* minimum and maximum value respectively. At moderately polluted site, its value ranged from 0.27 (*L. camara*) to 3.76 (*C. citrinus*). At less polluted site (control), the minimum value was 0.24 (*L. camara*) and maximum value 3.53 *(C. cirinus).* High AAC in plants increases tolerance to pollution

Table 7. Biochemical parameters and air pollution tolerance indices (APTI) of the studied plant species. All data are means of five replicates. Significant difference between mean among sites indicated by different letters (Duncan homogeneity test, $\alpha = 0.05$).

Species	Sites	AA	TChl	pH	RWC	APTI	Mean ATPI
Bougainvillea glabra	HP	0.68± 0.11b	3.43±1.01a	5.80±1.01a	86.8±1.01a	9.60±0.45ba	9.24
	MP	0.64±0.02a	3.43±0.98a	6.9±0.98a	85.43±0.98a	9.07±0.22a	
	LP	0.62±0.01a	3.47±1.82a	6.85±1.82b	84.27±1.82a	9.04±0.13a	
Buddleja asiatica	HP	1.39±0.02c	2.24±0.019a	6.73±0.11b	70.62±4.76c	8.30±0.45c	7.57
	MP	1.12±0.12b	2.29±0.019a	6.47±0.02ab	65.91±5.76b	7.57±0.35b	
	LP	0.85±0.12a	2.35±0.018a	6.21±0.13a	61.21±8.25a	6.84±0.24a	
Callistemon citrinus	HP	4.36 ±0.02b	1.21±0.03a	5.42 ±0.13	91.36±2.13a	12.64±0.23	11.51
	MP	3.76±0.02a	1.92±0.01b	6.34±0.04	91.18±4.31a	10.46±0.14	
	LP	3.93±0.102a	2.52±0.0.02c	6.73±0.12	91.30±1.32a	11.43±0.63a	
Duranta repens	HP	0.83±0.06a	1.60±0.12b	5.60±0.12a	84.60±2.12b	9.57 ±1.34b	9.11
	MP	0.86±0.01b	1.50±0.11a	5.50±0.11a	85.50±3.11a	9.23±2.01b	
	LP	0.82±0.02a	1.63±0.21b	6.63±0.21b	78.63±2.21b	8.54±2.10a	
Euphorbia pulcherrima	HP	1.58±0.02	1.48±0.01a	5.98 ±0.21	74.58±3.24b	8.43±0.32b	8.17
	MP	1.26±0.012	2.39±0.01b	6.09 ±0.02	74.69±4.01b	8.13±0.27b	
	LP	0.85±0.002	3.24±0.01c	6.65±0.21	71.01±4.23a	7.94±0.203a	
Ficus religiosa	HP	2.69±0.50	2.51±0.018a	7.73±0.17	90.09±1.96b	11.66±0.52b	10.96
	MP	2.51±0.40	2.63±0.01a	7.12±0.11	89.62±1.52b	10.96±0.32a	
	LP	2.34±0.036	2.76±0.018b	6.52±0.13	86.15±1.11a	10.250.12a	
Jasminum mesnyi	HP	2.90±0.04	1.89±0.02a	5.01±0.03	80.73±2.34c	9.03±0.34b	8.51
	MP	1.73±0.22	3.28±0.11b	5.09±0.02	77.29±3.45b	8.39±0.23a	
	LP	1.43±0.01	3.98±0.01c	5.9±0.03	73.23±3.32a	8.13±0.213a	
Lagerstroemia indica	HP	1.36±0.02	2.23±0.11a	5.11±0.03	79.17±3.42b	8.87±0.15ab	8.67
	MP	1.17±0.03	2.52±0.03b	5.26±0.04	74.61±3.45a	8.37±1.02a	
	LP	1.13±0.002	2.61±0.01b	6.71±0.11	77.76±2.43b	8.78±0.23a	
Lantana camara	HP	0.29±0.08b	2.82±0.23b	6.10±0.23a	79.82±4.23b	7.20 ±1.0b	7.01
	MP	0.27±0.09ab	2.78 ±0.23a	6.13 ±0.13a	79.78 ±3.23a	7.22 ±0.89b	
	LP	0.24±0.09a	2.86±0.23b	6.6±0.23b	73.86±1.23b	6.61±1.21a	
Leucosceptrum canum	HP	1.42±0.019	3.13±0.037	6.14±0.088	79.80±7.90c	9.29±0.79b	8.88
	MP	1.39±0.03	3.39±0.0.05	6.39±0.081	71.79±6.42b	8.89±0.68a	
	LP	1.36±0.050	3.65±0.081	6.65±0.074	63.79±4.99a	8.47±0.48a	
Nerium oleander	HP	4.52±0.02	1.54±0.01	5.33 ±0.03	92.58±4.12c	10.21±0.23b	10.1
	MP	1.80±0.02	2.42 ±0.11	6.14 ±0.12	87.12±2.56b	10.25±0.21b	
	LP	1.45±0.02	3.19±0.21	6.45 ±0.03	85.01±2.05a	9.84±0.23a	
Nyctanthes arbor-tritis	HP	*1.60±0.04*	2.14±0.013	6.07±0.087	76.51±2.45ab	8.96±0.25b	8.76
	MP	1.32±0.03	2.35±0.02	6.57±0.07	75.88±2.50a	8.76±0.26b	
	LP	1.04±0.07	2.56±0.025	7.07±0.06	75.25±2.44a	8.57±0.25a	
Ricinus communis	HP	0.47±0.10b	2.49±0.31b	5.5±0.31a	75.9±4.31b	8.29±1.83b	8.04
	MP	0.43±0.12a	2.39±0.23a	6.10±0.43b	76.19±3.23a	7.96±2.31a	
	LP	0.45±0.21ab	3.41±0.34c	6.11±0.34b	74.41±2.34c	7.86±1.45a	
Sambucus chinensis	HP	0.69±0.10b	1.68±0.03a	5.68±0.43a	75.68±3.03a	8.51 ±2.00b	8.27
	MP	0.65±0.12a	2.38±0.36b	6.38±0.36b	76.38±2.36b	8.20 ±1.98b	
	LP	0.63±0.10a	2.65±0.31c	6.50±0.31b	80.50±3.31c	8.08 ±1.15a	
Tecoma stans	HP	2.36±0.33	1.041±0.00	6.05±0.097	74.62±2.45bc	9.39±0.37b	9.21
	MP	2.35±0.52	1.064±0.02	6.06±0.11	73.12±2.65b	9.21±0.54a	
	LP	2.34±0.715	1.087±0.03	7.01±0.13	71.62±2.99a	9.04±0.72a	

as a result of its high antioxidant potential. Conversely, plants with low AAC, exhibits low antioxidant potential, low tolerance and hence high sensitivity to air pollution (Rai *et al.*, 2013, Ogunkunle *et al.*, 2015). Thus, ascorbic acid is an important determinant that decides the plants ability to nullify and withstand the toxic effects of air pollutants (Singh *et al.*, 1991, Aghajanzadeh *et al.*, 2016). Several researchers have studied and reported positive correlation of air pollution on ascorbic acid content (Pandey *et al.*, 2015, Manjunath and Reddy, 2019).

Leaf Extracts pH

pH regulation in the cellular compartment of the plant is important for intracellular transportation of vesicles, protein, small molecules and hormones (Zhang *et al.*, 2016). In present study, the trend of pH of plant species at different pollution level is presented in Table 7. The pH of leaf samples collected from heavily polluted sites ranged from 5.01 (*Jasminum mesnyi*) to 7.73 (*Ficus religiosa*) minimum and maximum value respectively with mean value 5.96. At MP site its value ranged from 5.09 (*Jasminum mesnyi*) to *Ficus religiosa* (7.13). At less polluted site (control), the minimum value is 5.9 (*Jasminum mesnyi*) and maximum value 7.07 (*Nyctanthes arbor-tritis*). Pollutant exposed plants, most especially SO_2, produces massive H+ to react with SO_2. Resulting in the generation of H_2SO_4, as such the leaf pH reduces. Plants with low leaf pH indicate a reduction in the photosynthetic process and show a positive correlation with sensitivity to air pollution (Liu and Ding, 2008, Patel and Nirmal Kumar, 2018). In addition, higher pH in a plant increases the rate at which hexose sugar is converted to ascorbic acid as well as the tolerance capacity of the plants (Bharti *et al.*, 2017, Nadgórska-Socha *et al.* 2017). Thus, the resistance of plants to the air pollutant-induced pH changes could determine the tolerance to air pollution.

Relative Water Content

Airborne pollutants are extensively reported to increase the loss of water and nutrients from plant leaves affected by increased protoplasmic permeability, leading to senescence (Keller and Schwager, 1977).

RWC of a leaf reflects the amount of water present in response to its full turgidity. The higher relative water content of 92.58% was observed in leaf samples of *Nerium oleander* collected from heavily polluted site and the least 61.21% was recorded by *Buddlejiaasiatica* in less polluted site. Higher RWC helps plant in regulating the physiological functions under stress induced by airborne pollutants (Tsegaand Devi-Prasad, 2014). Higher water holding capacity of leaves under polluted environment may impart tolerance against the toxic airborne pollutants. Exposure to air pollution increases the density of plant stomata, resulting in a decrease in the water content of the plant's tissues. Hence, the higher the water content of a plant, the greater the plant's ability to maintain its physiological balance and to tolerate pollution and pollution stress conditions (Zhang *et al.*, 2016; Patel and Nirmal Kumar, 2018).

Air Pollution Tolerance Index (APTI)

Status of air quality in environment can be improved via the identification and cultivation of plants capable of gases and particles removal from surrounding air. APTI indices in plants reveal that the plants vary in their response; which could be determined by their ability to undergo physicochemical adaptation to either prevent pollutants or mitigate the stress induced by pollutants through the antioxidant. APTI also provides information on plants based on sensitivity and tolerance to air pollutants using the biochemical parameters and APTI grading system. Results of APTI for each plant species studied is shown in Table 7. The APTI values of the plant species for heavily polluted site ranged from 7.2 (*Lantana camara*) to 12.64 (*C. citrinus*); at moderately polluted site its value ranged from 7.22 (*L. camara*) to 10.96 (*F.religiosa*) and at less polluted site (control), the value of ATPI ranged from 6.84 (*B. asiatica*) to 11.43 (*C. citrinus*). Susceptibility to air pollution varied from species to species (Chouhan *et al.*, 2012; Radhapriya *et al.*, 2011). All the plants found in more polluted sites have higher ATPI value than in less pollutes sites. Plant species in study area can be considered sensitive species since the values recorded fell within the APTI range of 1 to 16 (Ogunkunle *et al.*, 2015; Bharti *et al.*, 2017). Hence, the investigated plant species can be assigned air pollution bio-indicators status. *B. asiatica* with 6.84 APTI value was the most sensitive amongst the species studied and was obtained from less polluted site.

Anticipated Performance Index (API)

The evaluation and grading of plant species based on their APTI and relevant socioeconomic and biological parameters is presented in Table 8. The API score categories were used in allotting scores for different selected plants as shown in Table 5 and 6. *F. religiosa* and *N. arbor-tritis* showed the higher grade (75 %), which were followed by *C. citrinus (68.75%)* while the other three shrub species *N. oleander*, *B. glabra* and *Buddleja asiatica* resulted in 56.25 % each (Table 8). Least grade (18.75) was exhibited by two species viz. *Euphorbia pulcherrima* and *Sambucus chinensis.*

Plant species found under API category of excellent, very good, good and moderate performers can be recommended for cultivation as green belts species (Pathak *et al*., 2011; Pandey *et al.,* 2015; Tsega and Prasad, 2014). In this regard, *F. religiosa* and *N. arbor-tritis* are considered to be very good performers. Their tolerant nature along with favorable morphological characters and economic values make them suitable species for urban greening.

Results of the API in Table 8 indicate *F. religiosa* and *N. arbor-tritis* can be anticipated as good performer, while *Callistemon citrinus*, *Nerium oleander*, *Bougainvillea glabra* and *Buddleja asiatica* are predicted to be moderate green belt performers. Tsega and Devi Prasad (2014) reported that plant species with high API values are recommended for establishing green belts, *F. religiosa* and *N. arbor-tritis*, have dense canopy of evergreen foliage and are well known for their economic value. *Callistemon citrinus, Nerium oleander*, *Bougainvillea glabra* and *Buddleja asiatica* are predicted to be moderate performers and can be recommended for plantation because of their economic value and also their ability to serve as a sink. However plant speies *Euphorbia pulcherrima, Lantana camera, Jasminum mesnyi*, *Sambucus chinensis*, *Tecoma stans* were categorized as poor and cannot be recommended for green belt programs. This categorization is linked to the smooth surface areas.

CONCLUSION

This study showed that the assessment of only the

Table 8. Evaluation of plant species based on their APTI values, biological parameters and socioeconomic importance

Plant species	ATPI value	Habit of tree	Canopy structure	Type of tree	Laminar S T H	Economic Importance	Grade allotted Total plus	Grade allotted Score (%)	API Grade	Assessment
B. glabra	++	+	++	+	+ - +	+	9	56.25	3	Moderate
B. asiatica	++	+	-	+	+ + +	++	9	56.25	3	Moderate
C. citrinus	++++	+	++	+	-+ +	+	11	68.75	4	Good
D. repens	++	+	-	+	- - +	+	6	37.50	1	Very poor
E. pulcherrima	++	-	-	+	+ - -	-	4	25.0	0	Not recommen-dated for Plantation
F. religiosa	+++	++	++	-	++ - +	++	12	75.0	5	Very good
J. mesnyi	++	+	+	+	+ - +	-	7	43.75	2	Poor
L. indica	++	++	+	-	+ - +	-	7	43.75	2	Poor
L. camara	+	-	-	+	-+ +	+	5	31.25	1	Very Poor
L. canum	++	+	-	+	+ - ++	+	8	50.0	2	Poor
N. oleander	+++	++	+	+	-+ +	-	9	56.25	3	Moderate
N. arbor-tritis	++	+	+	+	++ + ++	++	12	75.0	5	Very Good
R. communis	+	-	-	+	++—	++	6	37.50	1	Very Poor
S. chinensis	++	-	-	+	-	- - -	3	18.75	0	Not recommen-dated for Plantation
T. stans	++	-	-	+	+ - -	++	6	37.5	1	Very Poor

B. glabra- Bougainvillea glabra, B. asiatica- Buddleja asiatica; C. citrinus- Callistemon citrinus; D. repens- Durantarepens, E. pulcherrima - Euphorbia pulcherrima; F. religiosa- Ficus religiosa, J. mesnyi- Jasminum mesnyi, L. indica-, Lagerstroemia indica; L. camara- Lantana camara; L. canum- Leucosceptrum canum, N. oleander- Nerium oleander; N. arbor-tritis -Nyctanthes arbor-tritis; R. communis - Ricinus communis; S. chinensis- Sambucus chinensis, T. stans- Tecoma stans

APTI value for plant species may not be perfect for recommending plants for greenbelt development, but the combination of the APTI and API can be of great importance. It is evident from this study that the single criterion of the biochemical parameters played a distinctive role in determining the response of tree species to air pollution but may not be ideal for evaluation of plant responses to a variety of pollutants for green belt purposes. However, using a combination of the biochemical parameters (APTI), biological and socioeconomic characteristics has verified the possibility of endorsing plant species for green belt purposes. Based on API grading the plants are classified as reliable green belt performers and suggested as ideal species for green belts development in the study area. On the basis of APTI and API assessment, the study suggest that out of fifteen species, only six plants species were identified as suitable green belt plants and thus valuable additions to the green belt development plant list in urban sub-tropical belt.

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