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ASSESSMENT OF AIR POLLUTION TOLERANCE INDEX AND EVALUATION OF AIR POLLUTION ANTICIPATED PERFORMANCE INDEX OF VARIOUS PLANTS AND THEIR APPLICATION IN PLANNING OF MORADABAD CITY, INDIA

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ABSTRACT

Extenuation of industrial and traffic air pollution is a big challenge to retain biodiversity and ecosystem and in such scenario, screening of plants as biomonitor is extremely significant. The present study has been designed to evaluate the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of ten common plant species, *Alstonia scholaris*, *Azadirachta indica*, *Cassia siamea*, *Ficus rumphii*, *Pterospermum acerifolium* are tree species and *Calotropis gigantea*, *Nerium odorum*, *Ocimum tenuiflorum* and selected shrub and *Tinospora cordifolia* and *Antigonon leptopus* are vines. Various biochemical parameters including leaf-pH, relative leaf water content, total chlorophyll content, and ascorbic acid content have been analyzed to compute the APTI values of the experimental plant species. The botanical and socioeconomic indices like plant height, canopy structure, and type of the plants, laminar characteristics, texture, hardness and economic values have also been studied and graded to evaluate the API of given plant species. Depending upon the intensity of a specific parameters characteristics gradings have been allotted (+ or –) to all the plants species under study. The results clearly indicate that biochemical parameters and APTI vary significantly ($p<0.05$) among tree species and research sites. *Ficus rumphii* with 6 (82.35%) API is an excellent performer for green belt development and advised to grow in various industrial cities of country. *Alstonia scholaris* with and *Azadirachta indica* with 3 API and has been considered a Moderate performer. The species of *Cassia siamea*, *Pterospermum acerifolium*, *Tinospora cordifolia* and *Antigonon leptopus* represented 2 API values show poor performance. All other investigated trees, ornamental shrubs and vines demonstrated very poor performance and hence not recommended for urban cultivation.

KEY WORDS : Ascorbic acid, Chlorophyll, pH, RWC, APTI (Air Pollution Tolerance Index) and API (Air Pollution Anticipated Performance Index).

INTRODUCTION

Air pollution is now stark acknowledged to be a significant environmental and public health problem, responsible for a growing range of health effects that are well documented from the results of an extensive research effort conducted in many regions of the world. It resulted in a huge threat to the health of living organisms like plants, animals and humans beings (Dhruti *et al.*, 2018). The pollution is diversely affecting the local as well as well as global environment by the releasing the particulate matters into the air in addition to the gases like nitrogen oxide, carbon dioxide, sulphur dioxide and carbon monoxide along with a huge amount of smoke (Chauhan *et al.*, 2019). Air pollutants represent a complex mixture of organic and inorganic substances of varying states and sizes that can enter the tissues of living organisms in a number of ways. Some plants are very sensitive to air pollutants which can damage their leaves, impair plant growth and limit primary productivity (Thakar and Mishra 2010).

According to the biennial report by Yale and Columbia Universities along with the World Economic Forum and State of India's Environment (SoE) 2018, India is among the five bottom countries on the Environmental Performance Index (EPI) 2018, plummeting 36 places from 141 in 2016, Its overall low ranking - 177 among 180 countries – has been linked to poor performance in the environmental health issue. Plants can be used naturally to mitigate environmental pollution, such as air pollution; however, it is important to evaluate plant susceptibility to air pollution when considering green space creation in urban areas. Tolerant plant species are sinks and living filters minimizing air pollution impact by absorption, adsorption, detoxification, accumulation, and/ or metabolization without sustaining serious foliar damage or decline in growth in the face of pollution (Mondal *et al.,* 2011).

This antioxidant activity of ascorbic acid is associated with resistance to oxidative stress and longevity in plants. Moreover, the endogenous level of ascorbic acid has recently been suggested to be important in the regulation of developmental senescence and plant defense against pests. Ascorbic acid (AA) is found in all eukaryotes including animals and plants and lack completely in prokaryotes except cyanobactaria, have been reported to have a small amount. AA has now gained significant place in plant science, mainly due to its properties (antioxidant and cellular reluctant etc.), and multifunctional roles in plant growth, development, and regulation of remarkable spectrum of plant cellular mechanisms against environmental stresses (Khan *et al*., 2011).

Plants vary considerably in their physiological response to various kinds of environmental stress. Plants growing along the roadsides get affected at the maximum level as they are the primary recipients to different types of air pollutants and show varied levels of sensitivity. They also play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide and oxygen (Mahecha *et al.,* 2013). The general concept of "Green Belt" has evolved in recent years to encompass "Greenspace" and "green structure", taking into account of urban green space, an important aspect of sustainable development in the 21st century (Ramesh *et al.,* 2014).

Plants play an important role in mitigating air pollution. In such a scenario where problems due to air pollution are faced worldwide screening of sensitive and tolerant plants which acts as a bio indicator and sinks for air pollution is extremely significant (Walia *et al*., 2019). Therefore, the role of plants in assessing the air pollution is being increasingly recognized. Plants are now used to in evaluate the Air Pollution Tolerance Index (APTI) which is a species dependent plant attribute and expressing the inherent ability of the specific plant species to encounter the stress arising from the air pollution. It helps in identifying the tolerance levels of plant species based on biochemical parameters *viz.* chlorophyll (Chauhan *et al*., 2017), ascorbic acid, pH of leaf extract and relative water content.

The APTI evaluates the effects of the basis of pollutants only on biochemical parameters, but in order to combat air pollution, green belts are developed, likewise some biological and socio-economic characteristics are also considered and used to develop the anticipated performance index (API) (Panda *et al*., 2018). Evergreen plants are good indicator of air pollution and can be used as an early warning tool for air pollution level harmful to human health. On the basis of the APTI and some relevant biological and socioeconomic characters, the anticipated performance index (API), from "best" to "not recommended" categories of various plant species have been determined and recommended for green belt development (Bahadoran *et al.,* 2019).

Chlorophyll contents of the leaves reduce due to the production of reactive oxygen species (ROS) in the chloroplast under water stress. It is well known that ROS are very small reactive molecules that can cause damage to cell structures during environmental stress. Higher ascorbic acid contents of leaves might be used as an effective strategy to protect thylakoid membranes from oxidative damage under such water stress (Smirnoff, 2018). Road activities no doubt hugely benefit human society's on the basis of the economy, *i.e.* growth and development the country. In spite of the benefits, road activities affect and disturb various environmental parameters like air, water, soil, noise etc., and these should be addressed and mitigating measures should be initiated APTI analysis can be used to categorize the air pollutant tolerant plant species which can be grown to combat the air pollution in the area (Bhardwaj *et al.*, 2019).

The present studies can be helpful in screening out the air pollution tolerant plant species and calculating their anticipated performance index (API) which can be used as an indicator to assess the capability of predominant species to mitigate the atmospheric pollutants and the development of the green belt along the city along the road dividers, highway and industrial area. Assessment of APTI and API potential of different plants for mitigating air pollution. Present study also provides useful information for the selection of tolerant plant species capable of streets capping and microclimate modification

MATERIALS AND METHODS

Moradabad, is popularly known as 'Peetal Nagari' is situated on Malaut (Punjab) to Askot (Uttarakhand) nation highway (NH-9). It is famous for brassware industries and has around 47 Lac population (2010 census) located on the bank of River Ram Ganga. The city is located at 76.19 AMSL in the western Gangetic plains of the Indian subcontinent at latitude of 28.51 N and longitude 78.49 E. Its total geographical area is about 5967 Km^2. There are about 600 export units and 5000 industries in the district. Moradabad exports the goods worth of Rs. 2500 crore every year. At present there are about 7137 small and large ndustries and about 36915 workers are working in different industries (Industries Directory 2011).

Selection of Sites for the Plants Study

Four air monitoring and sampling stations covered the whole city was operated during June 2019. The study area has been classified into two zones-Low traffic area and High traffic care besides the control three research sites *i.e.* residential, commercial and industrial have been included in the study. As such four air monitoring and sampling stations have been set to study. The APTI and API of some important tree species considered to be developed in green belt in the city.

Deer park/ Control (SI): The Deer Park or the eco-park is located along Ramganga and Ramganga bridge at Moradabad. It is a recreational site spread over many acres of forested land. The park is the home to many plants and animal species, includes duck, deer, and crocodiles, and works towards their conservation. The park is surrounded covered by rural field areas.

Civil Lines/Residential area (SII). This is a residential neighbourhood in Moradabad, India. Commercial buildings can also be seen in this area. The Numerous schools, hospitals and markets are also available here. Being residential there is a with low Traffic density.

Imperial\commercial area (SIII): This is a very

Fig. 1. Map of Selected Sites

S-I. Deer Park	(Control Site)
S-II. Civil Lines	(Residential Site)
S-III. Imperial	(Commercial Site)
S-IV. Peetal Nagari	(Industrial Site)

busy commercial site located in northern mid part of the city. A large number of shops, restaurants and workshops are near this site. The movement of the traffic is highly congested and slow due to high density of vehicles and encroachment on both sides of the road.

Peetal Nagari/Industrial area (SIV): This is an industrial site of Moradabad city having a large number of brassware industries. It is a very dense area with narrow streets. The emission from the industries and automobiles are the major sources of air pollution in this region.

Selection of Plant Species

Total ten plant species, where five of tree and five shrub, vine species were selected during the summer season of 2019 from every selected site, i.e. *Alstonia scholaris, Azadirachta indica, Cassia siamea, Ficus rumphii, Pterospermum acerifolium*, and *Antigonon leptopus, Calotropis gigantean, Nerium odorum, Ocimum tenuiflorum, Tinospora cordifolia* respectively. The screening and selection of the plant species was partly based on literature survey of similar work and guidelines of Central Pollution Control Board (1999 - 2000). Plant leaf samples were collected at the lower most position of canopy at a height of 6-7ft from the ground surface. Samples were cleaned with distilled water and refrigerated (22ºC) under suitable conditions for further biochemical analysis. Samples were cleaned with distilled water and refrigerated (22ºC) under suitable conditions for further biochemical analysis.

APTI was determined by calculating the chlorophyll, ascorbic acid, pH and relative water contents in the leaf samples. The value of Chlorophyll was determined with the help of spectrophotometer (Systronics 166) following the method outlined by Maclachlan and Zalik (1963). The pH of the leaf extract was obtained by digital pH meter (Systronics MKVI). Extraction and analysis of ascorbic acid (mg/g) in fresh leaves was determined with the method of Keller and Schwager (1977). Relative water contents of the leaf material was determined by the method of Sen and Bhandari, (1978). The experiment was performed by taking the initial and dry weight (Sartorius BP.160P Germany). The APTI was calculated by using the following formula (Singh and Rao, 1983):

APTI = [A (T+P) + R] / 10

Where,

A = Ascorbic acid (mg/g dry weight),

T = Total chlorophyll (mg/g dry weight),

P = pH of leaf extract and

R = Relative water contents of the leaf tissue (%).

Based on the APTI values, the plants were conveniently grouped as follows (Kalyani and Singaracharya, 1995).

Table 2. Standard gradation level of APTI and Response

APTI	Value	Response
A	> 01	= very sensitive
B	01-16	= sensitive
C	17-29	=intermediate
D	30-100	= tolerant

Table 3. Allotment of grading of sleeted plant species

No.	Score %	Value of Classes	Grade pont
1	<30	Not recommended	0
2	31-40	Very Poor	1
3	41-50	Poor	2
4	51-60	Moderate	3
5	61-70	Good	4
6	71-80	Very Good	5
7	81-90	Excellent	6
8	91-100	Best	7

Table 1. Selection of Plant species

S.N	Plant Name (Scientific)	Plant Name (Vernecular)	Family	Category
1	*Alstonia scholaris*	Sapt Parni, Chitavan	Apocynaceae	Tree
2	*Azadirachta indica*	Neem	Meliaceae	Tree
3	*Cassia siamea*	kasod	Caesalpiniaceae	Tree
4	*Ficus rumphii*	Pilakhan	Moraceae	Tree
5	*Pterospermum acerifolium*	Kanak Champa	Sterculiaceae	Tree
6	*Antigonon leptopus*	Coral Vine, Mexican creeper	Polygonaceae	vine
7	*Calotropis gigantea*	Madar	Asclepiadaceae	Shrub
8	*Nerium odorum*	Kaner	Apocynaceae	Shrub
9	*Ocimum tenuiflorum*	Tulsi	Lamiaceae	Shrub
10	*Tinospora cordifolia*	Giloy, Amrta	Menispermaceae	Climbing shrub

By combining the resultant APTI values with some relevant biological and socioeconomic characters like plant height, canopy structure, plant leaf size texture, hardness and economic value, the API was calculated for experimental plant species (Table 5). Based on these characters, different grades (+ or -) have been allotted to all the plants. All the plant schosen for the study have been arranged according to their score as per the procedure outlined by Mondal *et al.* (2011).

API = (No. of "+" obtained/total No. of "+") x 10

RESULTS AND DISCUSSION

Chlorophyll

The leaf chlorophyll contents of different plant species varied significantly from 14.98 to 3.91mg/g at industrial site and 18.12 to 4.79 mg/g at control site. In the selected stretch among the ten selected plant species maximum chlorophyll contents was obtained (18.12 mg/g) in *Ficus rumphii* at control site followed by 16.11 in residential site, 15.34 at commercial and 14.98 at industrial site. The order of total chlorophyll content in the leaves of selected plant species was *Ficus rumphii* >*Tinospora cordifolia* >*Antigonon leptopus* >*Ocimum tenuiflorum* >*Alstonia scholaris* >*Calotropis gigantea* >*Pterospermum acerifolium* >*Calotropis gigantean* >*Azadirachta indica* and *Cassia siamea*. It is well evident from the research that the chlorophyll contents varies with the tolerance as well as the plant species' sensitivity (Chauhan *et al.*, 2019). In other words, the higher the

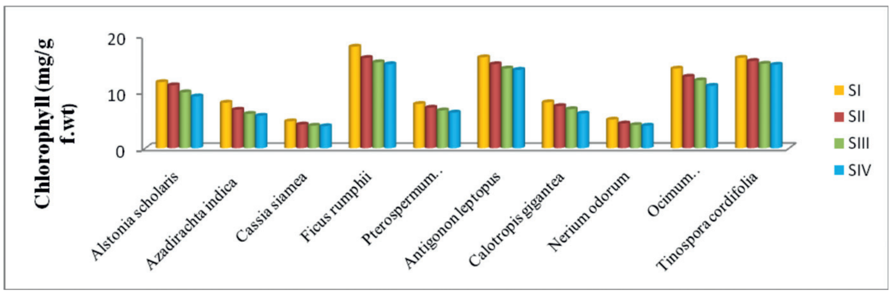

Fig. 2. Effect of air pollution on chlorophyll of different plant species at four sites.

Table 4. Standard of grade point for API

		Grading characters		Pattern assessment	Grade Allotted
(A)	Tolerance	APTI		10.0-20	+
				20.1-30	+ +
				30.1-40	+ + +
				40.1-50	+ + + +
				50.1-60	+ + + + +
(B)	Biological and socio-economic	1. Tree Habit		Small/Climber/Vine	_
				Medium	+
				Large	++
		2. Canopy		Sparse/irregular/globular	_
				Spreading	+
				Crown/open/semi-dense	+
		3. Plant type		Deciduous	-
				Evergreen	+
		4. Laminar structure	Size	Small	-
				Medium	+
				Large	++
			Texture	Smooth	-
				Coriaceous	+
			Hardness	Delineate	-
				Hardy	+
		5. Economic Value		Less then three uses	-
				3 or 4 uses	+
				5 or more uses	++

sensitive nature of the plant to pollution stresses, lower is the chlorophyll content value (Rai and Panda, 2014).

Ficusrumphii (tolerant sp.) show the highest chlorophyll contents at all sites. The value of chlorophyll contents decrease with the enhancement of the automobile exhaust in the case. The leaf chlorophyll contents of the plant signifies its photosynthetic activity as well as the growth and development of biomass. The chlorophyll content varies from species to species and also with the air pollution level as well as with other biotic and abiotic conditions of the habitat (Begum and Harikrishna, 2010). Levels of tolerance to air pollution vary from species to species, depending on the capacity of the plants to withstand the effect of the pollutants without showing any external damage. Chlorophyll content of the plants signifies its photosynthetic capacity along with the growth and development (Achakzai *et al.*, 2017).

Ascorbic Acid

The highest content of ascorbic acid was recorded in *Alstonias cholaris* (21.06 mg/g), followed by *Ficus rumphii* (17.23 mg/g), *Antigonon leptopus* (17.12 mg/g), *Azadirachta indica* (16.65 mg/g) at industrial site,. The lowest mean value was recorded 9.45 mg/g in *Calotropis gigantea at control site*. Ascorbic acid an antioxidant, is found sufficient amount, in all the growing plant parts and influences resistance to adverse environmental conditions, including air pollution (Lima *et al.*, 2000). Pollution load dependent increase in ascorbic acid content in the species may be due to high rate of production of reactive oxygen species (ROS) such as SO_3^-, HSO_3^-, OH^-, and O_2^- during photo-oxidation of SO_3^- to SO_4^- where sulphites are generated from SO_2 absorbed (Tiwari *et al.,* 2006). Its reducing power is directly proportional to its concentration. However, its reducing activity is pH dependent, being more at higher pH. It may increase the efficiency of conversation of hexes sugar to AA related to the tolerance to pollution. AA plays an important role in cell division, defense mechanism and cell wall synthesis. It is a natural detoxicant, which may prevent the effects of air pollutants in the plant tissue (Krishnaveni *et al*., 2017).

pH

The pH plays a significant role in plants' physiological processes. Most of the enzymes, involved in biological activities of the organism, require relatively high pH for their effective functions. Consequently, plants with relatively low pH are more susceptible, to the environmental conditions while those having pH is around 7 are tolerant (Achakzai *et al.,* 2017). Pollutant exposed plants, especially SO_2, produce massive H^+ to react with SO_2, resulting in the generation of H_2SO_4, as such, the leaf pH reduces. The low pH of the leaf extract shows a close relationship with the type of air pollution. Plants with low leaf pH indicate a reduction in the photosynthetic activity and show a positive correlation with sensitivity to air pollution

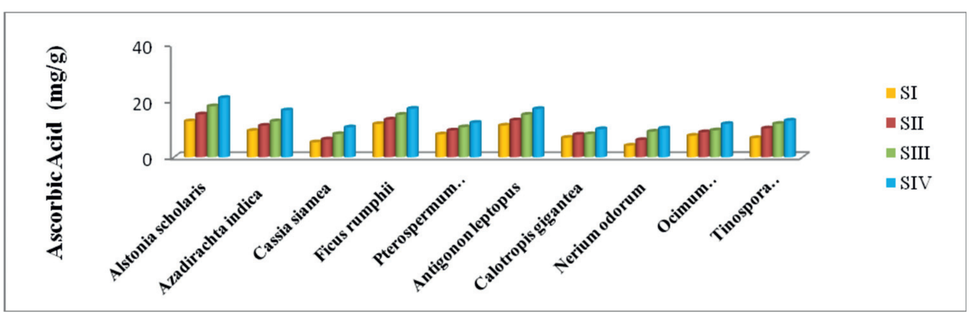

Fig. 3. Effect of air pollution on ascorbic acid of different plant species at four sites.

Table 5. Pearson correlation coefficient (r*) matrix for chlorophyll, ascorbic acid, pH and RWC at selected sites

Parameters	Chlorophyll	Ascorbic Acid	pH	RWC
Chlorophyll	1			
Ascorbic Acid	0.977*	1		
pH	0.962*	-0.997*	1	
RWC	0.969*	0.997*	0.999**	1

(*) Correlation is significant at the 0.05 level (*) and (**) at the 0.01level(1-tailed)

(Patel *et al.*, 2018).

In addition, higher pH in a plant increases the rate of hexose sugar conversion to ascorbic acid as well as the tolerance capacity of the plants (Bharti *et al.*, 2017). The mean value of leaf extract pH was recorded minimum *Nerium odorum at* S-III (4.0) and highest in *Ficus rumphii* (7.0) at S-I (Table 6). Lowest pH value was observed 4.0 in *Nerium odorum* at S-IV where maximum pH 7.0 in *Ficus rumphii* at control site S-I. *Azadirachta indica* showed maximum pH variation 25.37% from control site to most polluted site viz industrial site.

Relative Water Content (RWC)

Relative Water Content (RWC) is a useful indicator of plant tissue water status. Under stressful conditions, a large quantity of water in plant tissue helps to maintain its physiological balance (Seyyednejad *et al.*, 2017). In this study, the RWC registered at polluted site remained slightly low in *Ficus rumphii* (1.71%) whereas it declined significantly by 26.05%, 18.09% and 15.61% in *Nerium odorum*, *Cassia siamea*, and *Ocimum tenuiflorum* respectively, as compared to the values registered at control site (Table 6). Our results are confirmatory to the finding of the air pollutants increase the cell permeability causing loss of water and dissolved nutrients, resulting in early senescence of the leaves (Bakiyaraj and Ayyappan, 2014)).

Moreover, reduction in RWC of plant species, grown inside the polluted zone, could be explained by the reduction of transpiration rate in the leaves. In this situation, the plant reduces the ability to translocate water from roots to the leaves. RWC play as underlying role in plant life. High RWC under stress increases the plant species' tolerance (Kumar *et al.*, 2014). In our study significant and strong positive correlations were found between the chlorophyll, pH and RWC, such as chlorophyll and pH (r = 0.962), chlorophyll and RWC (r = 0.969) and pH and RWC (r = 0.999) whereas Table 5 shows that ascorbic acid performed non-significant correlation between Ascorbic Acid and pH.

Air Pollution Tolerance Index (APTI)

Air Pollution Tolerance Index (APTI) plays an important role to determine the sensitivity as well as the tolerance of the plant species to changing pollution levels. According to Singh *et al.* (1991) classified plants into four groups, based on their APTI values, namely (a) sensitive, (b) intermediately

Table 6. Evaluation of API values and biological and socio economic characters.

S. No.	Name of Plant species	APTI	Biological and socioeconomic			Laminar		Economic Importance	Hardness	Grade Allotted		API Grade	Assessment
			Plant habit	Canopy Structure	Type of Plant	Texture	Size			Total +	% Scoring		
1	*Alstonia scholaris*	+ + +	+	+	+	+	+	+	+	10	58.82	3	Moderate
2	*Azadirachta indica*	+ +	+ +	+ +	–	–	–	+ +	+	9	52.94	3	Moderate
3	*Cassia siamea*	+	+	+	+	–	+ +	+ +	–	8	47.06	2	Poor
4	*Ficus rumphii*	+ + + +	+ +	+ +	+	+	+ +	+	+	14	82.35	6	Excellent
5	*Pterospermum acerifolium*	+	+	+	+	+	+	+	+	7	41.18	2	Poor
6	*Antigonon leptopus*	+ + + +	–	+	+	–	+	+	–	8	47.06	2	Poor
7	*Calotropis gigantea*	+	+	+	+	+	+	–	–	6	35.29	1	Very Poor
8	*Nerium odorum*	+	+	+	–	+	+	–	–	5	29.41	0	Not recommended
9	*Ocimum tenuiflorum*	+ +	–	–	+	–	–	+	–	4	23.53	0	Not recommended
10	*Tinospora cordifolia*	+ + +	+	+	+	–	+	+	–	8	47.06	2	Poor

tolerant, (c) moderately tolerant, and (d) tolerant species. Based on the finding of the present experiment Fig. 2 represents that affect plants respond differently to the air pollutants. The maximum APTI values were recorded at S-IV for *Ficus rumphii* (45.10), followed by *Antigonon leptopus* (42.04) *Alstonias cholaris* (39.78), and *Tinospora cordifolia* (32.93). It is represented in the present study that *Cassia siamea having* APTI 13.61 and *Nerium odorum* with 12.26 were found to be sensitive, the *Azadirachta indica*, *Pterospermum acerifolium*, *Calotropis gigantean* and *Ocimum tenuiflorum* plants turned out to be moderately tolerant, and *Ficus rumphii* plants proved to be tolerant to the polluted environmental conditions (Fig. 6).

APTI based location wise arrangement of plant species under study can be summarized as follow:

Deer Park (SI): *Ficus rumphii >Antigonon leptopus >Alstonia scholaris >Tinospora cordifolia >Ocimum tenuiflorum >Azadira chtaindica >Calotropis gigantean >Pterospermum acerifolium >Cassia siamea >Nerium odorum.*

Civil Lines (SII): *Ficus rumphii >Antigonon leptopus >Alstonia scholaris >Tinospora cordifolia >Ocimum tenuiflorum >Azadirachta indica >Calotropis gigantean >Pterospermum acerifolium >Cassia siamea >Nerium odorum*

Imperial (SIII): *Ficus rumphii >Antigonon leptopus >Alstonia scholaris >Tinospora cordifolia >Ocimum*

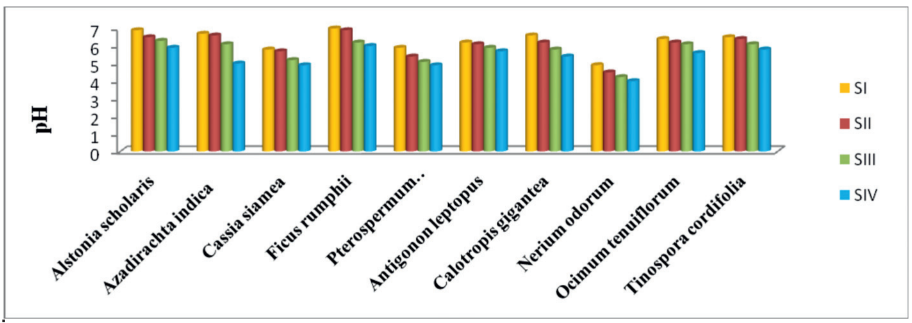

Fig. 4. Effect of air pollution on pH of different plant species.

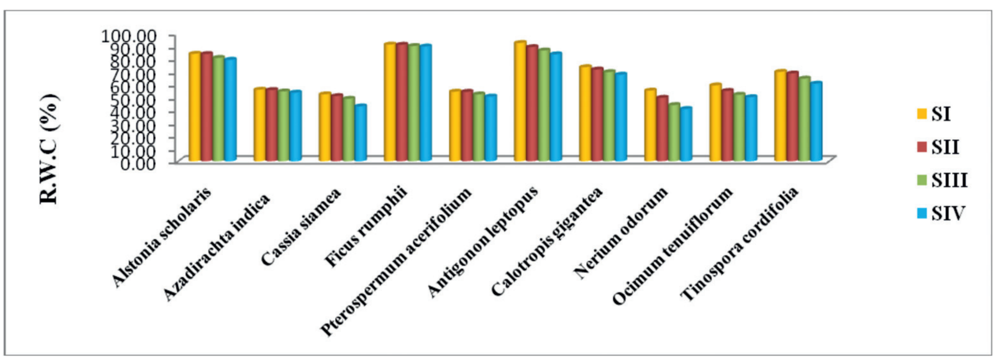

Fig. 5. Effect of air pollution on RWC of different plant species at four sites.

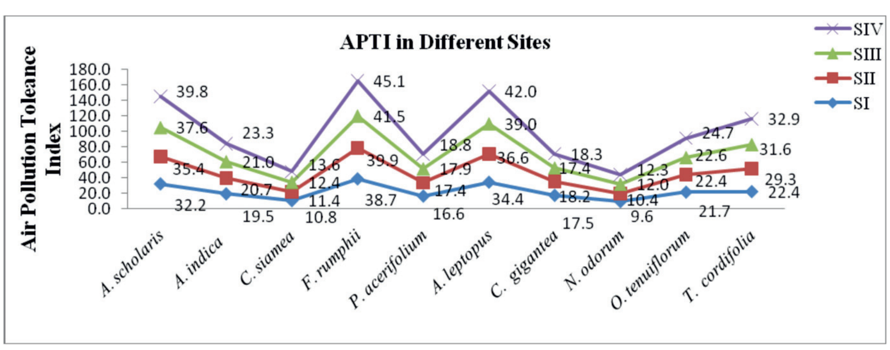

Fig. 6. Variation of APTI values in different plant species around Control, Residential, Commercial and Industrial sites in Moradabad

tenuiflorum >*Azadirachta indica* >*Pterospermum acerifolium* >*Calotropis gigantean* >*Cassia siamea* >*Nerium odorum*

Peetal Nagari (SIV): *Ficus rumphii* >*Antigonon leptopus* >*Alstonia scholaris* >*Tinospora cordifolia* >*Ocimum tenuiflorum* >*Azadira chtaindica* >*Pterospermum acerifolium* >*Calotropis gigantean* >*Cassia siamea* >*Nerium odorum*

The highest air pollution registered by *Tinospora cordifolia* (47.27%) followed by *Nerium odorum* (27.26%) and lowest by *Calotropis gigantean* (4.21%). Although, all the species represented significant ($p<0.05$) correlation for all the biochemical parameters, i.e. total chlorophyll, ascorbic acid, pH and relative water contents. The extent up to which plant species were affected varied from species to species and site to site. The results indicate that leaves of all the plant species were healthy and green at S-I in comparison to S-II, S-III and S-IV. It is also evident from the study that shrub plant species, i.e. *Tinospora cordifolia* (47.27) has more variation in APTI values then the tree species which was maximum (25.70%) in *Cassia siamea*. Among all the ten species only two plant species *Cassia simea* and *Nerium odorum* have been found are sensitive toward APTI (Figure 6). The variation in biochemical parameters in the leaves can be used as indicators of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms (Joshi and Swami, 2000; Anake *et al*., 2019).

Air Pollution Anticipated Performance Index (API)

Anticipated Performance Index is used as an indicator to assess the capability of predominant species for the abatement of the atmospheric pollutants and in green belt development. The API calculated by evaluation and grading of tree species based on their APTI and some biological and socio-economic characters showed a variation from not recommended category to the category good. The Maximum values of API (6) were calculated in *Ficus rumphii* was considered as excellent for Green belt development and *Alstonia scholaris* and *Azadirachta indica* with API value of (3) were assessed as poor. whereas *Nerium odorum* and *Ocimum tenuiflorum* with API value of zero was assessed as not recommended.

The maximum API of *Ficus rumphii* may be due to its high APTI. API value is more for the species with higher APTI having better plant and leaf characteristics (Bakiyaraj and Ayyappan, 2014). Among all the plant species *Ficus rumphii* was the most tolerant species and also this species has the high economic and aesthetic value. Hence it can be recommended for the plantation in the polluted areas. Tsega and Deviprasad (2014) also reported that plant species with high API values should be recommended for establishment of the green belts.

CONCLUSION

It is obvious from the present study that the only principle of the biochemical parameters played a unique role in determining the relation of plants (trees and shrubs) species to air pollution but may not be ideal for evaluating 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. On the basis of APTI and API assessment, this study suggests that plant species such as *Ficus rumphii*, *Alstonia scholaris* and *Azadirachta indica* are perfect for ecological purposes in the study area. The plant having poor foliar surface areas, *i.e.* linear to needle shape of leaf and cannot be recommended for green belt programs. Shrubs and ornamental plants demonstrated poor values of API which also are not recommended for green belt dovelopment as they act as bio-indicators. The shrubs and tree with lower APTI values (sensitive) have been recommended to be utilized as bioindictors for poor urban air quality whereas shrubs and tree with high APTI values (Tolerant) are to be planted around areas anticipated with high air pollution load. Both APTI and API of plants are extremely beneficial for the construction of green belts. Present study also reveals that the tree species have low API value then shrubs and ornamental plants such as *Cassia siamea*, *Ocimum tenuiflorum* and *Nerium odorum*. Sensitivity of different plants against air pollution indicates that pollution is strong factor to affect biodiversity and ecological balance. Vines/ climbers such as *Tinospora cordifolia* and *Antigonon leptopus* have poor value of API, they cannot be planted solely but with other plants since they improve the canopy structure and reduce the temperature and become helpful to trap the particulate matters on their leaves.

REFERENCES

Achakzai, K., Khalid, S., Adrees, M., Bibi, A., Ali, S., Nawaz, R. and Rizwan, M. 2017. Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakistan. *J. Environ. Manage*. 190 : 252-258.

Anake, W.U., Eimanehi, J.E. and Omonhinmin, C.A. 2019. Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of Selected Plant Species, Indones. *J. Chem.* 19 (1) : 239-244.

Bahadoran, M., Mortazavi, S.N. and Hajizadeh, Y. 2019. Evaluation of Anticipated Performance Index, biochemical, and physiological parameters of *Cupressus arizonica* Greene and *Juniperus excelsa* Bieb for greenbelt development and biomonitoring of air pollution. *Int J Phytoremediation.* 21(5) : 496-502.

Bakiyaraj, R. and Ayyappan, D. 2014. Air pollution tolerance index of some terrestrial plants around an industrial area. *Int. J. Mod. Res. Rev*. 2 (1) : 1-7.

Begum, A. and Harikrishna, S. 2010. Evaluation of some tree Species to absorb air pollutants in three industrial locations of South Bengaluru, India. *European Journal of Chemistry*. 7(1) : 151-156.

Bhardwaj, A., Aggarwal, R.K. and Bhardwaj, S.K. 2019. A Review on Impacts of Road Activities and Vehicular Emissions on Native Ecosystems in Mountainous Region.*Current World Environment*. 14(2): 194-204.

Bharti, S. K., Triṿedi, A. and Kumar, N. 2017. Air pollution tolerance index of plants growing near an industrial site. Urban Climate.

Chauhan, A., Gangwar, C., Kumar, A., Kumar, A. and Tripathi, A. 2019. Assessement of air Pollutants at selected Monitoring stations of Moradabad. *I. J. Environmental Prptection.* 39 (3) : 2019-225.

Chauhan, A., Rajput, N., Kumar, A., Verma, J.S. and Chaudhry, A.K. 2017. Interactive effects of gibberellic acid and salt stress on growth parameters and chlorophyll content in oat cultivars. *Journal of Environmental Biology.* 39 : 639-646.

CPCB Guidelines for developing greenbelts, CPCB Publication Programme Objective Series. *PROBES*/75. 1999 – 2000.

Dhruti, P., Kumar, J.I.N. 2018. An Evaluation of Ir Pollutin Tolerance Index and Anticipated Index of some Tree Species Considerd for Green Belt Dovvelopment: Case Study of Nandesari Industrial Area, Vadodara, Gujrat, India. *Open Journal of Air Pollution*. 7 : 1-13.

Environmental Performance Index – EPI, 2018.
https://epi.envirocenter.yale.edu/downloads/ epi2018policymakerssummaryv01.pdf.

Joshi, P.C. and Swami, A. 2000. Physiologigal responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. *Environmentalist*. 27 : 365-374.

Kalyani, Y. and Singaracharya, M.A. 1995. Biomonitoring of air pollution in Warangal city, Andhra Pradesh. *Acta Botnica Indica*. 23 (1) : 21-24.

Keller, T. and Schwager, H. 1977. Air pollution and ascorbic acid. *Eur J Forestry Pathol*. 7 : 338-350.

Khan, T.A., Mazid, M. and Mohammad, F. 2011. Role of ascorbic acid against pathogenesis in plants. *Journal of Stress Physiolgy and Biochemistry*. 7 (3): 222-234.

Krishnaveni, G. and Kumar, K.K. 2017. Air pollution tolerance index of selected plants in Vijayawada city, Andhra Pradesh. *International Journal of Green Pharmacy*. 11 (4) : S877.

Kumar, A., Gupta, A. and Shyam, S. 2015. Estimation of Air Pollution Tolerance Index in Various Plant species in Industrial Area, Gajraula, India. *Poll. Res.* 34 (2): 271-276.

Leghari, S.K., Akbar, A., Qasim, S., Ullah, S., Asrar, M., Rohail, H., Ahmed, S., Mehmood, K. and Ali, I. 2019. Estimating Anticipated Performance Index and Air Pollution Tolerance Index of Some Trees and Ornamental Plant Species for the Construction of Green Belts. *Pol. J. Environ. Stud.* 28 (3) : 1759-1769.

Lima, J.S., Fernandes, E.B. and Fawcett, W.N. 2000. Mangifera indica and *Phaseolus vulgaris* in the bioindicator of air pollution in Bahia, Brazil. *Ecotoxicol Environ. Safety.* 46(3): 275-278.

Maclachlan, S. and Zalik, S. 1963. Plastid structure, Chlorophyll concentration and free Amino Acid composition of a Chlorophyll mutant and Barley. *Can J Bot.* 41 : 1053- 1062.

Mahecha, G.S., Bamniya, B.R., Nair, N. and Saini, D. 2013. Air pollution tolerance index of certain plant species-A study of Madri Industrial Area, Udaipur (Raj.). *India, Int. J. Innovative Res. Sci. Engg. Tech*. 2(12) : 7927-7929.

Mondal, D., Gupta, S. and Datta, J.K. 2011. Anticipated performance index of some tree species considered for green belt development in an urban area. *International Research Journal of Plant Science.* 2(4): 99-106.

Panda, L.R.L., Aggarawal, R.K. and Bharadwaj, D.R. 2018. A review on Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API). *Curr World Environment.* 13(1).

Patel, D. and Kumar, J.I.N. 2018. An evaluation of air pollution tolerance index and anticipated performance index of some tree species considered for green belt development: A case study of Nandesari industrial area, Vadodara, Gujarat, India. *OJAP*. 7 (1) : 1-13.

Rai, P.K. and Panda, L.L. 2014. Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: an Indo-Burma hot spot region. *Air Quality, Atmosphere and Health.* 7(1) : 93-101.

Ramesh, R.M. and Nijagunappa, R. 2014 . Development of Urban Green Belts – A Super Future of Ecological

Balance, Gulbarga City, Karnataka. *International Letters of Natural Science*. 27 : 47-53.

Sen, D.N. and Bhandari, M.C. 1978. Ecological and water relation to two *Citrullus* spp. In: Althawadi, A.M. (Ed.). Indian Arid Zone. *Environ. Physiol. Ecol. Plants*. 203-228.

Seyyednejad, S.M., Motamedi, H. and Lordifard, P. 2017. Biochemical changes of *Conocarpus erectus* (combretaceae) in response to gas refinery air pollution as an air pollution indicator. *Pollution.* 3(2): 185-190.

Singh, S.K. and Rao, D.N. 1983. Evaluation of plants for their tolerance to air pollution. *In: Proc Symp on Air Pollution Control at IIT Delhi*. 218-224.

Singh, S.K., Rao D.N., Agrawal, M., Pandey, J. and Narayan, D. 1991. Air pollution tolerance index of plant. *J. Environ. Mgmt*. 32 : 45-55.

Smirnoff, N. 2018. Ascorbic acid metabolism and functions: A comparison of plants and mammals. *Free Radic Biol Med.* 122 : 116-129.

Thakar, B.K. and Mishra, P.C. 2010. Dust collection potential and air pollution tolerance index of tree vegetation around Vedanta Aluminium Limited, Jharsuguda. *The Bioscan*. 3 : 603-612.

Tiwari, S., Agrawal, M. and Marshall, F.M. 2006. Evaluation of ambient air pollution impact on carrot plants at a sub urban site using open top chambers. *Environ Monit Assess*. 119 : 15-30.

Tsega, Y.C. and Devi Prashad, A.G. 2014. Variation in air pollution tolerance index and anticipated performance index of roadside plants in Mysore, India. *Journal of Environmental Biology*. 35(1):185-190.

Walia, K., Aggrawal, R.K. and Bhardwaj, S.K. 2019. Evaluation of Air Pollution Tolerance Index and Anticipated Performance Index of Plants and their Role in Development of Green Belt along National Highway-22. *International Journal of Current Microbiology and Applied Sciences.* 8(3): 2498-2508.