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International Journal of Current Research
Vol. 9, Issue, 09, pp.57807-57811, September, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

AIR POLLUTION TOLERANCE INDEX OF SELECTED PLANTS GROWING NEAR ROAD SIDE OF NAVI MUMBAI, MAHARASHTRA

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ARTICLE INFO

Article History:
Received 17th June, 2017
Received in revised form
28th July, 2017
Accepted 20th August, 2017
Published online 30th September, 2017

Key words:
Air Pollution Tolerance Index,
pH, Ascorbic Acid,
Leaf Total Chlorophyll Content,
Relative Water Content.

ABSTRACT

In well planned cities, vehicular emission is one of the major causes of air pollution. The capacity of plants to act as bio indicator of air pollution differs from plant to plant. To identify the tolerance levels of plants APTI values were calculated based on four physiological and biochemical parameters such as leaf Relative Water Content (RWC), Ascorbic Acid (AA), Total Leaf Chlorophyll and Leaf Extract pH. By absorbing pollutants, plants create areas of clean air pockets. The study evaluated APTI and sensitivity of 12 plant species along the road side of highly polluted area of Navi Mumbai. The results showed order of tolerance *Ricinus communis* > *Acalypha wilkesiana* (green leaved)> *Millingtonia hortensis*, while the sensitivity was in the order *Ficus benjamina* > *Cassia siamea* > *Ficus religiosa.*

Citation: Lakshmi Girish, Kavya Krishnankutty and Sharda Vaidya, 2017. "Air pollution tolerance index of selected plants growing near road side of Navi Mumbai, Maharashtra", *International Journal of Current Research*, 9, (09), 57807-57811.

INTRODUCTION

The major cause of deterioration of air quality in Indian cities is due to high vehicular emission of toxic gases, toxic metals, organic molecules, radio isotopes and soot particles from the traffic sector which in long run can affect the health of human beings or other living organisms. Even though various strategies have been undertaken by Central Pollution Control Board of India (2003), to control different forms of atmospheric pollution still it always remained as a challenge. The Green Belt (GB) component of plants act as scavengers, sink and as living filters to minimize air pollution by absorption, adsorption, accumulation and metabolization due to large leaf area without sustaining serious foliar damage or decline in growth, thus improving air quality by providing oxygen to the atmosphere (Joshi and Swami, 2009; Lui and Ding, 2008; Escobedo *et al.*, 2008). Due to perennial and stationary habit, trees experience greatest exposure to pollutants and are influenced greatly by pollutant concentration (Chauhan, 2010). Air pollution injury to plants is directly proportional to intensity of pollution when exposed to air pollutants.

Sensitivity and response of plants to air pollutants is variable. Some plants may be tolerant while others may be sensitive to air pollution. The plant species which are more sensitive act as biological indicators of air pollution (Lakshmi *et al.,* 2009). Monitoring the air pollution using a biological indicator is cheap and convenient method. APTI expresses the inherent ability of plant to encounter stress arising from pollution. It is used by landscapers as biological indicators of pollution to select, rank and screen plant species with respect to their susceptibility and tolerance to air pollutants (Singh and Rao, 1983). APTI provides an understanding of response of plants to air pollution at physiological and biochemical level. Environment planners and green belt developers can use plants as bio- monitors for abating the urban air pollution. APTI is calculated by using four biochemical parameters- ascorbic acid, chlorophyll, leaf extract pH and relative water content in leaf samples. Species having higher APTI value are more tolerant to air pollution while species having lower APTI value may act as bio-indicators of pollution. In the present study, an attempt is made to bio monitor the potential of 12 plant species commonly found in the vicinity of roadsides of Palm Beach Road, Navi Mumbai, Maharashtra, with respect to the above biochemical parameters for their pollution tolerant capacity. Since on the selected area, residential complexes are present, health of the residents should be considered on priority basis. Curtailment of number of vehicles cannot offer a solution to mitigate the vehicular pollution. Plants growing naturally in

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those areas can be considered a best candidate for reducing the pollutants from atmosphere. Navi Mumbai is a well-planned city in Maharashtra. Navi Mumbai Municipal Corporation (NMMC) had planted many avenue trees along most of the roads to provide enough shade and as a part of beautification. Since many of the plants selected for the study have been growing along the road sides are old, their pollution tolerance capacity can be understood very well.

Suggestions can be given to NMMC regarding the sensitivity and tolerance capacity of various planted trees which in future may help them to select appropriate trees for plantation on upcoming road sides. With respect to APTI values the selected plants can be categorized into tolerant and sensitive species. The sensitive species can be used as biological indicators and the tolerant species can serve as sinks of air pollutants. Plant response towards the pollutants from surrounding atmosphere can be used to assess the quality of air that may provide an early-warning signal for the trend of air pollution in the area.

MATERIALS AND METHODS

Area of Study

The area for this study is stretch of Palm Beach Road, Navi Mumbai, Maharashtra, India.

Plants selected for the study

Sr. No.	Name of the Plant	Common Name	Family
1	*Terminalia catappa* Linn.	Indian Almond	Combretaceae
2	*Ricinus communis* Linn.	Castor	Euphorbiaceae
3	*Acalypha wilkesiana* Muell. Arg. (Green leaved)	Copper leaf	Euphorbiaceae
4	*Acalypha wilkesiana* Muell. Arg.	Copper leaf	Euphorbiaceae
5	*Ficus benjamina* Linn.	Weeping fig	Moraceae
6	*Ficus religiosa* Linn.	Peepal tree	Moraceae
7	*Millingtonia hortensis* Linn. f.	Indian cork tree	Bignoniaceae
8	*Vitex negundo* Linn.	Chinese chaste tree	Verbenaceae
9	*Thespesia populnea* Soland. ex Correa	Indian tulip tree	Malvaceae
10	*Allemanda cathartica* Linn.	Golden trumpet	Apocynaceae
11	*Cassia siamea* Lam.	Siamese cassia	Ceasalpinaceae
12	*Hamelia patens* Jacq.	Scarlet bush	Rubiaceae

Sampling

Fully matured fresh leaves of each plant were collected in air tight plastic bags during winter season (2016-17) from near Palm Beach Road, Navi Mumbai. The fresh weight of leaves were taken immediately upon getting to the laboratory. The samples were preserved in refrigerator for biochemical analysis. The fresh leaf samples were analyzed for total chlorophyll, ascorbic acid, leaf extract pH and relative water content using the standard procedures of Arnon (1949), Sadasivam (1987), Varshney (1992) and Singh (1977) respectively for the evaluation of air pollution tolerance index. Air pollution Tolerance Index (APTI) was determined by the method given by Singh and Rao (1983) using the formula

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

Where:
A = Ascorbic acid content (mg/g)
T = Total chlorophyll (mg/g)
P = pH of leaf extract
R = Relative water content of leaf (%).

pH

100mg of fresh leaves were homogenized in 10 ml deionized water. This was filtered and pH of the leaf extract was determined after calibrating pH meter with buffer solution pH 4 and pH 9.

Relative Water Content

Fresh weight was obtained by weighing the leaves. The leaf samples were then immersed in water over night, blotted dry and then weighed to get the turgid weight. The leaves were then dried till constant weight in a hot air oven at 70^0C and reweighed to obtain the dry weight. RWC was determined and calculated by the method as described by Singh (1977).

RWC = [(FW-DW) / (TW-DW)] x 100.

Where:

FW-Fresh Weight, DW-Dry Weight, TW-Turgid Weight.

Total Chlorophyll Content

500mg of fresh leaves were blended and then extracted with 10ml of 80% acetone and left for 15min. The liquid portion was decanted into another test tube and centrifuged at 2,500 rpm for 3min.

The supernatant was then collected and the absorbance was taken at 645nm and 663nm for chlorophyll a, b using visible spectrophotometer. Calculations were done by using the formula given below:

Total chlorophyll: Chlorophyll a + Chlorophyll b; CTc: 20.2 (D645) + 8.02 (D 663)

Tch: 0.1 CT x leaf dry weight / leaf fresh weight].

Ascorbic acid content

Ascorbic acid content was measured by Titrimetric method (Sadasivam and Balasubhramanian, 1987) using 2,6-Dichlorophenol indo phenol dye. 500mg of leaf sample was extracted with 4% oxalic acid and then titrated against the dye until pink colour develops. Similarly, a blank is also developed.

Calculation of APTI

The air pollution tolerance indices for the selected plants were determined by following method of Singh and Rao (1983). The formula is given as:

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

Where: A=Ascorbic acid content (mg/gm),
T=Total chlorophyll (mg/gm),
P=pH of the leaf extract,
R=Relative water content of leaf (%)

RESULTS AND DISCUSSION

Table 1.

Name of the plant	pH	RWC (%)	TC (mg/g)	Ascorbic Acid Content (mg/g)	APTI
Terminalia catappa Linn.	6.4	88.15	0.2140	6	12.7834
Acalypha wilkesiana Muell. Arg. *(Green leaved)*	7.5	68.51	0.8743	40	40.3482
Acalypha wilkesiana Muell. Arg. *(Brown leaved)*	6.6	60.00	0.7565	24	23.6556
Ficus religiosa Linn.	7.3	70.00	0.5625	2	8.5987
Millingtonia hortensis Linn. f.	4.5	86.67	0.3374	34	25.1141
Vitex negundo Linn.	4.5	63.63	0.6019	8	10.4445
Thespesia populnea Soland. ex Correa	6.6	90.54	0.3320	4	11.8268
Allemanda cathartica Linn.	7.5	85.71	0.5925	6	13.4265
Cassia siamea Lam.	7.4	56.00	0.6340	4	8.8136
Ficus religosa Linn.	6.9	74.67	0.2865	2	8.9043
Hamelia patens Jacq.	6.5	83.33	0.3	2	9.663
Ricinus communis Linn.	7.0	91.52	0.2924	46	42.697

Leaf Extract pH

Under pollution stress, rate of photosynthesis varies considerably. The efficiency of the leaves to perform photosynthesis is greatly dependent upon the pH of the leaf sap. The photosynthetic efficiency is greatly reduced when pH is highly acidic and remains relatively normal or little above normal in alkaline conditions. It plays an important role in determining the plant susceptibility towards pollution (Sasmita and Pramila, 2010). pH helps plant to respond to stress (Miria and Anisa, 2013). The cell system functions well at optimum pH but being exposed to acidic pollutants over a long period reduces pH levels in fewer tolerant species. This interrupts the biological activities of the plants (Saxena and Ghosh, 2013). High pH level will increase the efficiency for the conversion of hexose sugar into ascorbic acid (Lui and Ding, 2008) and upgrade the reducing power of ascorbic acid (Praveen and Madhumita, 2013) thus provides a better resistance in plants against pollutants. The change in leaf extract pH might influence the stomatal sensitivity due to air pollution. The plants with high sensitivity to SO_2 and NO_2 closed the stomata faster when they are exposed to the pollutants. Plants with lower pH are more susceptible to pollutants and reduce the photosynthetic activity (Thakar and Mishra, 2010), while those with pH around 7 are tolerant (Singh and Verma, 2007). In the present study, all the plants were recorded near neutral pH. *Ricinus communis, Acalypha wilkesiana* (green) which have high APTI values recorded a neutral pH while *Millingtonia hortensis* recorded an acidic pH. The acidic nature may be due to the presence of SO_2, NO_2 or other acidic pollutants from the vehicular emission in the ambient air causing a change in pH of the leaf sap towards acidic as has been reported by Swami *et al.,* (2004). Similar results were reported by Priya Darsini *et al.,* (2015).

Relative Water Content

Roots of the plants take up water and nutrients from the soil by absorption and distributed to different parts of the plant body. Water in plants plays an important role to maintain the temperature, nutrient conduction and helps in metabolic processes (Otuu *et al*, 2014). Studies have shown that the pollutant upon entering into the plant body tends to increase the permeability of the cell membranes. This may result in excessive loss of water and dissolved nutrients thus creating disturbances in physiological and biochemical activities and causes early senescence (Swami *et al.,* 2004). The air pollution may reduce the efficiency of leaf engine to pull water from roots, so that the plants fail to absorb minerals. High relative water content within the plant body helps in maintaining these physiological and biochemical activities normal. So the plants exposed to pollutants are expected to have high relative water content indicating that these are tolerant to the pollutants (Dedio, 1975). In the present study, relative water content ranged from 56-91.52 %. High relative water content was recorded for *Ricinus communis* and *Thespesia populnea* and least for C*assia siamea*. Thus, the higher RWC in sample may be responsible for normal functioning of biological processes in plants as has been reported by Meerabai *et al.,* (2012). From visual inspection of the plants it was observed that size of the plants and leaves of *Allemanda cathartica* and *Hamelia patens* were highly reduced. All other plants were fresh with green leaf color. Similar results were reported by Hopkins and Hűner, (2003).

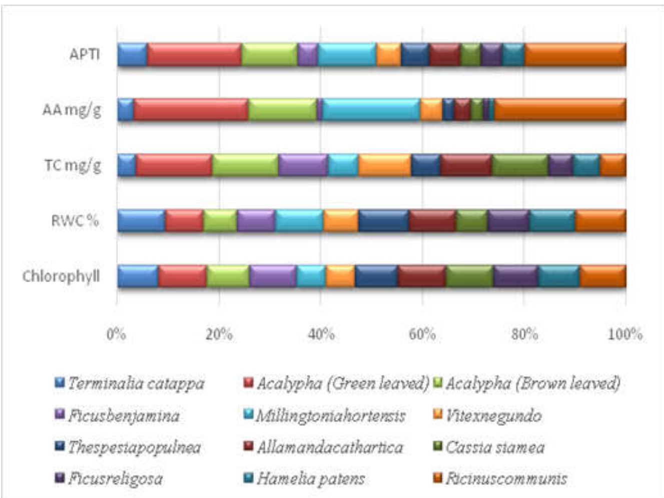
Ascorbic Acid Content (Vitamin C)

Ascorbic acid i.e., Vitamin C plays a significant role in the cell wall synthesis, defense mechanisms of the plants as well as in the process of cell division and carbon fixation during photosynthesis (Conklin, 2001). It is a natural detoxificant protecting the plant tissues from damaging effect of air pollutants and also appears to link flowering time, developmental senescence, programmed cell death and responses to pathogens through a complex signal transduction network (Escobedo *et al.*, 2008; Lui and Ding, 2008). It is an antioxidant, acting as reducing agent and influences resistance to harsh environmental stress, including atmospheric pollution by neutralizing the pollutants that enter the plant system via the stomata. The reducing power of the ascorbic acid is proportional to its concentration (Agbaire and Esiefarienrhe, 2009). Thus plants exposed to higher concentration of pollutants are expected to have high ascorbic acid content as compared to plants exposed to lower concentration of pollutants. In the present study higher levels of ascorbic acid content was observed in the leaves of *Ricinus communis* (46 mg/g), followed by *Acalypha wilkeisiana* (green leaved) (40 mg/g), *Millingtonia hortensis* (34 mg/g), indicating their higher pollution tolerance capacity. Lower ascorbic acid contents in the leaves of other plant species studied supports the sensitive nature of these plants towards pollutants particularly automobile exhausts.

Total Chlorophyll

Chlorophyll is the index of productivity in plants and decreases under pollution stress. The primary productivity depends on the chlorophyll content of the plant tissue. Amount of chlorophyll in the leaf tissue is significantly affected by the pollution load. Many plant species are able to maintain their normal chlorophyll content while under stress. It is also observed that certain species of plants may even increase their chlorophyll content under pollution stress. Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. This varies from species to species, age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Katiyar and Dubey, 2001). Degradation of photosynthetic pigment has been widely used as an indication of air pollution (Ninave *et al.,* 2001). In the present study, plants such as *Millingtonia hortensis, and Ricinus communis* showed a decrease in chlorophyll content. Similar decrease in chlorophyll content in higher plants near road sides due to automobile pollution have already been reported by Mir *et al*., (2008). This is due to the properties of certain pollutants that can reduce the chlorophyll content as has been reported by Rai *et al*., (2013). Sulphur dioxide (SO_2) at lower concentrations for instance, will fulfill the essential nutrient sulphur requirement of the plant but if SO_2 is present in excess quantities, it may become toxic to the plant, which will injure the chloroplast membranes. By damaging the chloroplast membrane and breaking down the chlorophyll, it will eventually cause the plant to exhibit visual damage to the leaves. In addition, high concentrations of SO_2 also damage the plasmalemma, other important membranes and disrupt enzyme activity. The decrease in foliar chlorophyll concentration in plants might also be due to the destruction of chlorophyll or due to reversible swelling of thylakoids (Horsman and Welburn, 1975) and **i**nhibition of RuBp carboxylase**.** In the present study low chlorophyll content may also be attributed to the high pollution level, temperature stress, low sunlight intensity and short photoperiod during winter season. The total chlorophyll content was found maximum in *Acalypha wilkeisiana* (green leaved) (0.8743)*, Acalypha wilkesiana* (brown leaved) (0.7565), *Cassia siamea* (0.6340) and *Vitex negundo* (0.6019). The higher concentration of chlorophyll in these plants having high APTI may be due to their tolerance nature which is an adaptation to sustain the pollution stress.

Air Pollution Tolerance Index (APTI): In the present study, highest APTI was recorded by *Ricinus communis* (42.697) > *Acalypha wilkesiana* (Green leaved) (40.3482) > *Millingtonia hortensis* (25.1141). The remaining plants recorded APTI values in the range 7.4536 – 23.6556.



Conclusion

Different APT Indices of different plants are due to their differential response to air pollution. The tolerance depending upon topography and pollution condition may be either stress avoidance or stress sensitivity. From the results obtained, it has been observed that *Ricinus communis, Acalypha wilkiesiana* (Green leaved) and *Millingtonia hortensis* were the most tolerant species since they have high APTI values. Tolerant plant species can be used in green belt development as they tend to serve as barriers and act as sink for air pollutants. The sensitive species were *Ficus benjamina*, *Cassia siamea and Ficus religiosa.* They can be used as bio-indicators to air quality. Such studies will help in future planning of the roadside landscape in order to reduce pollution.

Acknowledgement

The authors are thankful to the principal, Smt. C. H. M. College, Ulhasnagar-03, for allowing us to conduct this research work.

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