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RESEARCH ARTICLE

A STUDY ON AIR POLLUTION TOLERANCE INDEX (APTI) AND ANTICIPATED PERFORMANCE INDEX (API) OF SOME PLANTS

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Abstract

Due to industrialization, urbanization and increasing number of vehicles air pollution has turn out to be serious problem today. Now a day's particulate matter shows the undesirable effects on plants, animals and human beings also. Tree plantation programme is the best ways to control the air pollution. Most of the plants filter the air by their aerial elements. Vegetation naturally cleanses the atmosphere by absorbing gases and some particulate matters through leaves so they work as 'sink' for air pollution and reduce pollution level in atmosphere. Leaves function as an efficient pollutant trapping device. Air pollution can directly affects plants via leaves or indirectly via soil acidification. Air pollution tolerance index (APTI) is an intrinsic quality of trees to control air pollution problems. The trees higher tolerance index are tolerance towards air pollution and can be used a source to control air pollution. Air pollution tolerance index can be used as an indicator of rate of air pollution. By combining biochemical and aggregate factors the anticipated performance index (API) is prepared which is used as development of green belt. Thus, the assessment of APTI and API potential of different trees are used to control air pollution.

Introduction:-

India is a developing country.Due to industrialization, urbanization and increasing number of vehicles air pollution become a very serious problem and has resulted in huge threat to both environment and the health of living organisms (Plants, humans, animals & microorganisms) over the years has been a continuous increases human population, road transportation, vehicular traffic, and industries has resulted in increase in the concentration and particulate pollutants [1]. Plants are thought to be a most effective in pollution controlling and serve as a 'sinks' for air pollutants and reduce pollution level in the atmosphere [2]. Plants naturally clean the atmosphere by absorbing gases and some particulate matter through leaves. Plants have a very large surface area and their leaves function as an efficient pollutant trapping device [3]. Most plants experience internal changes before showing noticeable injury to leaves when they are expose to air pollutants [4].Air pollution can directly affects plants via leaves or indirectly via soil acidification[5]. It has also been reported that when exposed to air pollutants, most plants experience physiological changes before exhibiting visible damage to leaves[6].Several researchers agree air pollutants affects the plant growth adversely[7,8]. As the trees are being continuously exposed to the environment, hence they attract, gather and combine pollutants impinging on their leaf surface; therefore they show noticeable or slight changes depending on their sensitivity level [9].Leaves can act as natural filters that can eradicate great number of air borne

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pollutants and consequently recover the quality of air in atmosphere [10]. On the other hand, this function of pollution abatement can be best performed by the pollution tolerant type [11]. Air pollution tolerance index indicate the potential of vegetation to encounter air pollution [12]. Sensitive tree species are suggested as Bio-indicator [13]. Vegetation shows dissimilar behavior for various pollutants and all components of tree can be used as Bio-monitors [14].By finding air pollution tolerance index of different plant species we can employ to develop greenbelt to reduce air pollution. This method ishelping us to monitoring plant towards air pollution. Consequently, air pollution tolerance index based on biochemical parameters as chlorophyll contents, ascorbic acid, and pH of leaf extract and % of moisture content of leaves are generally employed for recognizing the tolerance level of plants.

In the present study APTI and API of plants are growing in vehicular pollutant area have been investigated. It is forecasting that this study may help in proper selection of plant species for vehicular or industrial polluted area and will assist to evaluate the resistance level of various plants.

Materials and Methods:-

Study area:-

Bhopal is the capital city of the Indian state of Madhya Pradesh. It is also known as City of Lakes. Bhopal city has a geographical area of 285.88 Km^2 and Located on the Malwa plateau. The geographical location the Bhopal city lies within North Latitude 23^0 16' and East Longitude $77^0$36'.For the present study Hamidia road which is most air polluted area of Bhopal city selected.

Sampling

Plants were randomly selected from the Hamidia road of city. Mature leaf samples were collected from various plants and taken to the laboratory immediately for analysis. A composite sample of each plant species was obtained before analysis. The fresh leaf weight was taken immediately after getting to the laboratory. The leaves were preserved in refrigerator for further analysis.

Samplecollection

Samples were collected in early morning and brought to the laboratory immediately in polythene bag in ice box to reduce the adverse effect of high temperature and light intensity. The leaves were picked up 01 to 02 meter height from the ground level.

Table 1:- Different plant species selected for phytochemical estimation.

S.N.	Botinical Name	Common Name	Family
1.	*Neolamarckia cadamba*	Cadamba	Rubiaceae
2.	*Dalbergia sissoo*	Sheesham	Fabaceae
3.	*Mangifera indica*	Mango	Anacardiceae
4.	*Cassia fistula*	Golden shower	Fabaceae
5.	*Ficus benjamina*	Weeping fig	Moraceae
6.	*Nerium oleander*	Oleander	Apocynaceae
7.	*Psidum guajava*	Guava	Myrtaceae
8.	*Azadirahcta indica*	Neem	Meliceae
9.	*Ficus religiosa*	Peepal	Moraceae
10.	*Bougainnvillea glabra*	Paper flower	Nyctaginaceae

Determination of Ascorbic acid

Sample preparation:

Take 10 ml of each of extract sample (1 mg/mL) and put in a test tube, then 1 mL of $KMnO_4$ solution (100 μg/ml) was added. This solution was let to stand for 5 minutes. The absorbances of these standard solutions were read at 530 nm against blank.

Estimation of relative moisture content:

Fresh leaf samples collected from the selected study area and were brought to laboratory immediately and washed thoroughly. The excess water was removed with help of filter paper. The initial weight of samples were taken (W_1g) and kept in oven at 600 ^{0}C until constant weight was obtained and the final weight was taken (W_2 g).

Estimation of leaf extracts pH:
0.5 g of leaf material was ground meter to paste and dissolve in 50 ml of distilled water and leaf extract pH was measured by using calibrated digital pH meter.

Estimation of ascorbic acid:
Total chlorophyll was estimated by acetone extraction method and ascorbic acid was estimated by 2,6-dichlorophenol indophenol's dye method by Sadasivam&Manickam[15] and [16].

The air pollution tolerance index (APTI) was determined by using the following formula proposed by Singh and Rao[17]

$$APTI = A(T+P)+R/10$$

Where
A= Ascorbic acid content in leaf(mg/g).
P= Leaf extract pH.
T= Total chlorophyll content in leaf (mg/g).
R= % water content of the leaf.
The some value is divided by to get the 10 value in reduced scale.

Estimation of chlorophyll contents:
This was carried out according to the method described by Arnon, (1949). 3 g of fresh leaves were blended and then extracted with 10ml of 80% acetone and left for 15 minutes for thorough extraction. The liquid portion was decanted into another test-tube and centrifuged at 2,500 rpm for 3 minutes. The supernatant was then collected and the absorbance taken at 480nm, 510nm, 645 nm and 663 nm using a spectrophotometer.

T. chl. = 20.2 DX 645 + 8.0

Determination of pH (1% Solution)
An accurately weighed 1 g of dried powder of plants were dissolved in accurately measured 100 mL of water and filtered and the pH of filtrate was checked with a standardized glass electrode. pH of dried powder of plants were measured using pH meter which was calibrated using the buffer solutions of pH 4 and pH 9.

Percentage Relative water content
Fresh weight was obtained by weighing the fresh leaves. The samples were then immediately hydrated to full turgidity under normal room light and temperature overnight. After hydration the samples were taken out of water and were well dried quickly and lightly with tissue paper and immediately weighed to obtain fully turgid weight. Samples were then oven dried at 80ºC for 24h and weighed. According to the method described by Singh and Rao, leaf relative water content was determined and calculated with the formula.

$$\text{Relative water content} = \frac{\text{FreshWeight} - \text{Dryweight}}{\text{Dryweight}} \text{x}$$

APTI (Air Pollution Tolerance Index) determination
The calculations of air pollution tolerance index for the selected plants were made by given the method. The formula of APTI is given as:
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 (%)

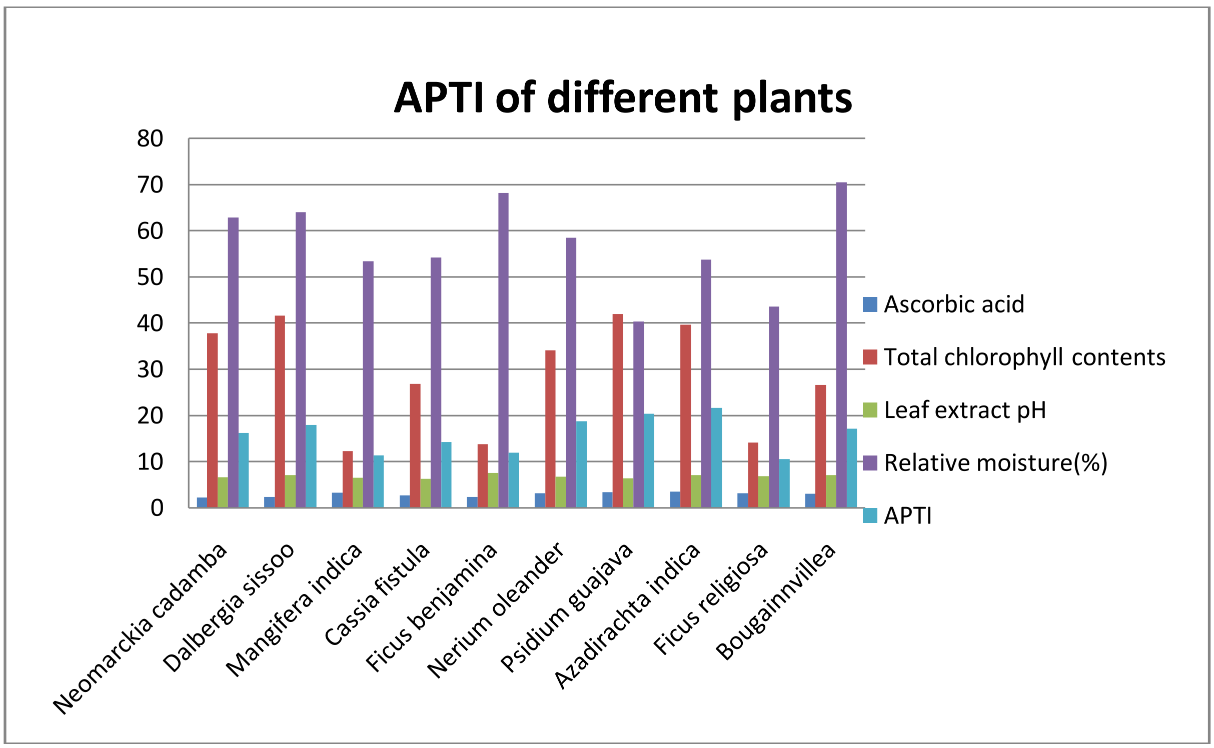
Table 2:- Tolerance index of air pollution.

Index value	Remarks
01-08	Sensitive
08-10	Intermediate

10- Above	Tolerant

Table 3:- The contents of total chlorophyll, Ascorbic acid, Leaf extract pHand Relative moisture in various tree species of Hamidia road, Bhopal with their air pollutant tolerance index.

S N.	Botanical name	Ascorbic acid ($mg.g^{-1}$)	Total chlorophyll ($mg.g^{-1}$)	Leaf extract pH	Relative moisture (%)	Air pollution tolernce index (APTI)
1	*Neolamarckia cadamba*	2.225	37.79	6.6	62.90	16.167
2	*Dalbergia sissoo*	2.356	41.57	7.1	63.99	17.867
3	*Mangifera indica*	3.214	12.27	6.5	53.36	11.370
4	*Cassia fistula*	2.658	26.81	6.2	54.17	14.193
5	*Ficus benjamina*	2.369	13.77	7.5	68.24	11.865
6	*Nerium oleander*	3.145	34.11	6.7	58.48	18.683
7	*Psidum guajava*	3.369	41.94	6.4	40.30	20.318
8	*Azadirachta indica*	3.458	39.71	7.1	53.72	21.561
9	*Ficus religiosa*	3.147	14.09	6.8	43.56	10.530
10	*Bougainnvillea glabra*	2.985	26.59	7.1	70.48	17.105



Results and Discussion:-

The capability of plants to tolerate air pollution is measured by air pollution tolerance index. Air pollution tolerance is a bio-physiological tool to monitor the pollution level and shows the capability of plant to tolerate air pollution. Plants having higher index value are tolerant to air pollution and can be used to withstand pollution, while plants having low index value show less tolerance and can be used to indicate levels of air pollution [18]. Some plants under present study showed high APTI value at polluted sites indicate their capability to combat air pollution. To understand air pollution tolerance index value, different physiological parameters like Ascorbic acid, total chlorophyll content, leaf extract pH and RWC are considered. To understand the physiological relationship between APTI in plants,the above mentioned parameters are discussed below.

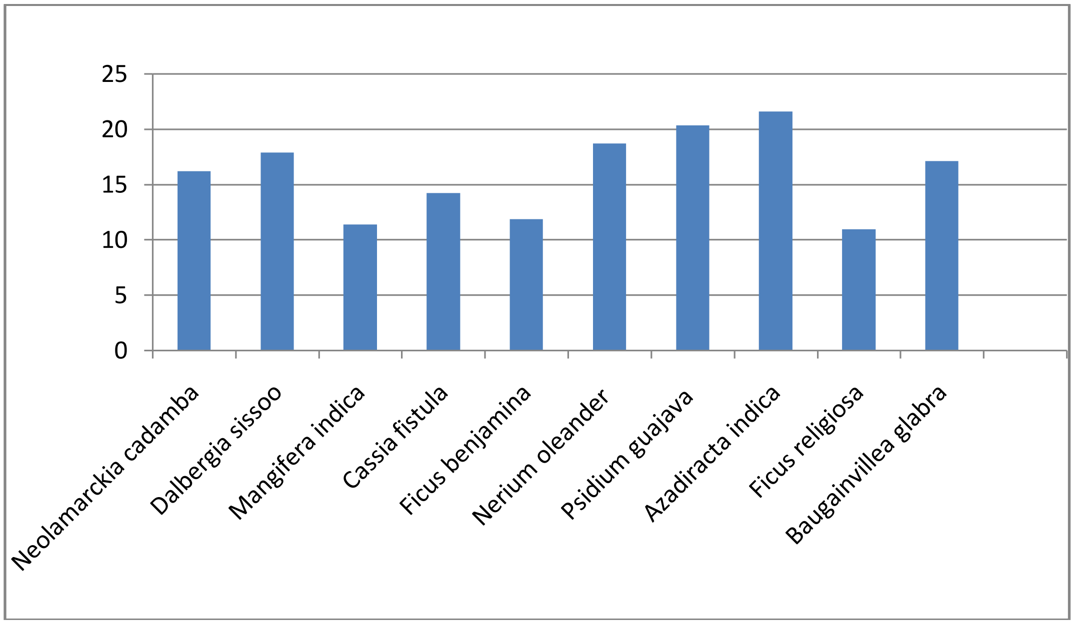
Ascorbic acid:
Ascorbic acid is regarded as an antioxidant found in plants and influences resistance to adverse environmental condition including air pollution [19]. Ascorbic acid is a strong reducing agent and it activates many physiological and defense mechanism. Its reducing power is directly proportional to its concentration. Since it is a strong reductant, it protects chloroplast against SO_2 induced H_2O_2, O_2^- and OH^- accumulation and also protect the enzyme of CO2 fixation cycle and chlorophyll from inactivation [20]. Present study showed that Azadirachtaindica, PsidumguajavaandMengiferaindicahave higher amount of ascorbic acid content, hence they are capable to tolerate with air pollution and Neolamarckia,Delbergiasissooand Ficus benjamina have low ascorbic acid in comparison to above three plants so they are less tolerant to air pollution. Thus higher ascorbic acid content of the plant can be considered as a sign of ittolerance against the environmental pollutants.

Total Chlorophyll contents:
Total chlorophyll content of plants indicates its photosynthetic as well as the growth and formation of biomass. It varies from species to species with the age of leaves along with the air pollution level and many other biotic and abiotic conditions [21].A chlorophyll pigment exists in highly organized state and may undergo several photochemical reactions under any stress induced such as oxidation, reduction, pheophytinisation, and reversible bleaching. Hence any alteration in chlorophyll concentration may change the morphological physiological and and biochemical behavior of the plants. Present study showed that chlorophyll content in all the plants varies with species to species as well as pollution level of area. It also varies with the tolerance as well as sensitivity of of the plant species i.e. higher the total chlorophyll content higher the tolerance level of the plants and lower the chlorophyll content higher the sensitivity nature of the plant species. High chlorophyll content was observed in Psidiumguajava, Delbergiasissooand Azadirachtaindica hence they are more tolerance against air pollution in comparison to Cassia fistula, Ficus benjaminaand Ficus religiosa having lower chlorophyll content.

Leaf extracts pH:
The leaf extract pH plays a major role in regulating the SO_2 sensitivity of plants.High pH may increase the efficiency of conversion of hexose sugar to ascorbic acid, while low leaf extract pH showed good correlation with sensitivity to air pollution. [22,23,24] have reported in presence of an acidic pollutant, the leafpH is lowered and decline is greater in sensitive species.The decreasing interest of ascorbic acid is pH dependent being more at better and much less at decrease pH. Hence growths in leaf extract pH deliver tolerance vegetation against air pollutants. There are such a lot of factors controlling tolerance in flowers. Plants with decrease PH are more inclined than those of pH round 7 are extra tolerant.**[25].**Present study showed that leaf extract pH in plants as *Ficus benjamina, Delbergiasissoo, AzadirachtaindicaandBougainnvilleaglabra* is more than 7 so these plants are tolerant in comparison to *Cassia fistula, Psidiumguajava, M.indica, N.Cadamba, N. Oleander* and *Ficus* religiosa is less than 7 hence they are sensitive to air pollution.

% Relative water content:
Water is crucial prerequisite for flowers. High RWCfavours drought resistant in flora. Due to the air pollutants there is reduction in transpiration price and damage the leaf engine that attracts water up to from the roots (1-2% of the overall). Consequently, the plant life neither carries minerals nor cools the leaf. **[26**]. High water content helps to maintain physiologicalbalance inside the plant body under stress condition such as exposure to air pollution when the transpiration rates are usually very high. Full turgidity of plant leaf indicating the presence of water in the leaf, hence it is shows the relation between RWC. Association of RWC with protoplasmic permeability in cells causing loss of water and dissolve nutrients, resulting in early senescence of leaves[27].According to Lakshmi et al, (2009)[28], RWC ranged between 58-73% is intermediately tolerant species and 51.3-84% is sensitive plant species and thus, in the present study few plant species i.e. High RWCin plants under polluted condition might be a strategy of tolerant species of plants to withstand pollutants.Present study showed that plant have high RWC % is more tolerant to air pollution than low RWC.

Air Pollution tolerance index:



APTI index shows that the capability of a plant speciesto fight against air pollution.In this study, changes in biochemical parameters such as ascorbic acid, Total chlorophyll content, Leaf extract pH and RWC were measured for calculation of air pollution tolerance index for 10 plants species. Plants which have high APTI values are considered as tolerant plant species to air pollution and the plants which have low values are sensitive species.

Between the 10 plant species taken for experimental analysis, the order of the species tolerant to air pollution with the percentage in APTI values is as follows:

Azadirachtaindica(21.561)>*Psidiumguajava*(20.318)>*Nerium oleander*(18.683)>*Dalbergeasissoo*(17.867)>*Baugainvilleaglabra*(17.105)>(16.167)>*Cassia fistula*(14.193)>*Ficusbenjamina*(11.865)>*Mangiferaindica*(11.370)>*Ficus religiosa*(10.530).

The result and analysis of this study shows that different plant species respond differently to air pollution, hence have different indices. The study shows that all above plans taken for this study are tolerant plant species and can be used as for Greenbelt development.

Air pollution tolerant plant species can be used in the Greenbelt development, as that typeofplants tend to serve as barriersand act as a sink for air pollutants. Air pollution tolerant plant species can play a significant role along the traffic, islands, city roadside as well as in industrial area to control the air pollution level, while sensitive plant species can act as bio-indicator of air pollution.

Anticipated performance index:

In Present study to find out API of plants, socio-economic importance of the plants growing alongside the roadside is studied. In order to study biological and socio-economic importance, characters like plant habit, type of plant, canopy structure, texture etc. is considered. The biological and socio-economic characters like plant habit, plant type, canopy structure texture, economic value and resultant APTI is worked out, API is calculated for the selected plant species. Based on these characters positive or negative grades are allotted to plants and are scored according to their grades. Allotted gradation of plant species based on APTI as well as biological and socio-economic importance has been presented in following table:

Table4:- Standard of grade point for API[28,29].

Valuation classes	Scoring percentage	Grade point
Not recommended	30	0
Very poor	31-40	1
Poor	41-50	2

Moderate	51-60	3
Good	61-70	4
Very good	71-80	5
Excellent	81-90	6
Best	91-100	7

Table:- Gradation of plant species based on APTI as well as biological parameters and socio-economic importance:

SN	Name o plants	Plant habit	Canopy structure	Type of plant	Leaf size	Texture	Hardiness	Economic value	APTI	Total plus(+)	Scoring %	Grading	Valuation classes
1.	*Neolamarckia cadamba*	++	+	+	++	_	+	++	+++++	14	87.5	6	Excellent
2.	*Dalbergia sissoo*	++	++	_	_	+	+	++	+++++	13	81.25	6	Excellent
3.	*Mangifera indica*	++	+	+	+	+	+	++	+++++	14	87.5	6	Excellent
4.	*Cassia fistula*	++	++	_	_	_	+	++	+++++	11	68.75	4	Good
5.	*Ficus benjamina*	++	++	+	_	_	+	+	+++++	12	75	5	Very good
6.	*Nerium oleander 'Hardy red'*	_	+	+	+	_	+	++	+++++	11	68.75	4	Good
7.	*Psidium guajava*	+	++	+	_	+	+	++	+++++	13	81.75	6	Excellent
8.	*Azadirachta indica*	++	++	+	_	_	+	++	+++++	13	81.75	6	Excellent
9.	*Ficus religiosa*	++	++	_	_	_	+	++	++++	11	68.75	4	Good
10.	*Bougainvillea glabra*	_	+	+	_	_	+	+	+++++	09	56.25	3	Moderate

Plant species for plantation in different pollutant areas were evaluated for various biological and socio-economic as well as a few biochemical parameters. These parameters were subjected to a grading scale to determine the anticipated performance of plant species. The grading Pattern of 10 plant species evaluated in Table 4 and which fit into the grading pattern with respect to their API were recommended for plantation in different pollutant areas. From above table showed that out of 10 plant species*Neolamarckiacadamba, Dalbergiasissoo, MangiferaindicaPsidiumguajava and Azadirachtaindica*were excellent, *Ficusbenjamina* a is very good, *Cassia fistula, Nerium oleander and Ficus religiosa* are good and *Bougainvillea glabra* is moderate plant species for planting in pollutant areas.

Conclusion:-

The present study reveals that evaluation of APTI and API of plant species is very useful in the plantation of appropriate plant species for development of greenbelt in pollutant areas. These are useful tools to assess the tolerance level of plant species towards air pollution.Neolamarckiacadamba, Dalbergiasissoo, Mangiferaindica, PsidiumguajavaandAzadirachtaindica are the most tolerant as well as anticipated performers to grow in pollutant areas and can be recommended for the development of greenbelts. On the basis of present review many plants are found to be tolerant towards air pollution are suitable for growing around roadsides and industrial area.

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