RESEARCH ARTICLE

Air pollution tolerance index of selected plants in Vijayawada city, Andhra Pradesh

G. Krishnaveni, K. Kiran Kumar

Department of PG Chemistry, KBN College, Vijayawada, Andhra Pradesh, India

Abstract

Introduction: Vijayawada is the major city with high population of Andhra Pradesh state and is highly recognized for its culture and religious heritage. Since the city is on fast-track development, pollution has been affecting its environment considerably. Screening of plants for their sensitivity/ tolerance levels to air pollution is important because the sensitive plants can serve as bioindicator and tolerant plants as a sink for controlling air pollution in urban and industrial areas. **Aim:** The present work determines the air pollution tolerance index (APTI) and certain biochemical properties of tree species commonly available in Vijayawada city. **Results and Discussions:** In this study, four physiological and biochemical parameters, namely, relative leaf water content, ascorbic acid content (AA), total leaf chlorophyll, and leaf extract pH were used to compute the APTI values of seven medicinal and five fruit species. The decreasing order of APTI values these plant species was found to be *Syzygium cumini>Carica papaya>Aegle marmelos>Psidium guajava>Vitex negundo>Artocarpus heterophyllus>Bauhinia variegata>Emblica officinalis>Punica granatum>Phyllanthus acidus>Prosopis cineraria>A. marmelos>Manilkara zapot*a. **Conclusions:** The results of present study are therefore useful for future planning and may be helpful to bring out possible control measures in air pollution.

Key words: Air pollution tolerance index, ascorbic acid, chlorophyll, Vijayawada

INTRODUCTION

Vijayawada is one of the oldest cities of Andhra Pradesh. The city is now on the fast track in rapid industrialization, and hence, air pollution is one of the serious problems faced by the people due to its transboundary dispersion of pollutants. Due to increased urbanization, industrial, and commercial activities, the levels of pollution are reaching an alarming state.[1] Literature survey reveals that lot of work has been done to study the response of traffic load on plants [1] and also the impact of industries on plants.[2,3] The major air pollutants identified in Vijayawada city limits are CO, NOX, SOX, and hydrocarbons. These air pollutants can alter the physiological process of plants, thereby affect its growth of plants, also cause damage to leaf cuticles, and affect the stomatal conductance. They can also have a direct effect on photosynthetic systems leaf longevity and patterns of carbon allocation within plants. Pollutants interact with other environmental factors and may alter plant-environment relationship on regional scales.[4] Recent studies have explored the possibility to find the ability of plants to remove pollutants from air and act as a sink for contaminants.[5] On the basis of air pollution indices, different plants can be categorized into sensitive, intermediate, and moderate tolerant plant groups.[6] To screen plants for their sensitivity tolerance level to air pollutants, a large number of plant parameters have been used including leaf or stomatal conductance, ascorbic acid content (AA), relative water content, chlorophyll content, and leaf extract pH.[4,6-14] The combination of biochemical and physiological parameters gave more reliable result than those of individual parameters since they were computed together in a formulation to obtain an empirical value signifying the air pollution tolerance index (APTI) of species on the basis of earlier studies.[15] In the present study, the tolerance levels of different plants with economical importance growing in urban and industrial region of Vijayawada city were evaluated on the basis of their APTI values.

Address for correspondence:
Dr. G. Krishnaveni, Department of PG Chemistry, KBN College, Vijayawada - 520001, Andhra Pradesh, India.
Phone: +91-9491130111.
E-mail: gkveni2003@gmail.com

Received: 04-12-2017
Revised: 22-12-2017
Accepted: 29-12-2017

MATERIALS AND METHODS

Vijayawada lies on the banks of Krishna River and is located at 16.5193°N 80.6305°E and has an altitude of 11 m (36 ft). Low range hills protect the northern, northwestern, and southwestern parts of Vijayawada city, while the central, southwestern, and northwestern parts are shielded by rich and fertile agriculture lands with three major irrigation canals. Vijayawada has a tropical climate with hot summers and a monsoon season. Temperatures can reach 47°C (117°F) in May–June, while the winter temperatures rarely fall below 15 C (59 F). The average humidity is 78%, and the average annual rainfall is 921.5 mm (36 in). Vijayawada gets its rainfall from both the southwest monsoon and northeast monsoon.

The main air pollutant sources in Vijayawada city are industries, traffic, and dense population.

Seven medicinal plant species such as *Bauhinia variegata, Syzygium cumini, Emblica officinalis, Phyllanthus acidus, Aegle marmelos, Prosopis cineraria,* and *Vitex negundo* and five fruit plant species such as *Psidium guajava, Artocarpus heterophyllus, Manilkara zapota, Punica granatum*, and *Carica papaya* from regions of Vijayawada city were investigated with respect to their APTI values. Fully mature leaves in replicates were collected in the morning hours from the selected plant species. The fresh leaf samples were analyzed for relative leaf water content (RWC), chlorophyll, AA, and leaf extract pH.

Relative Water Content

According to the method described by the Department of Biology, East China Normal University,[16] RWC is determined and calculated with the following formula:

RWC = (Wf-Wd) × 100/(Wt-Wd)

Where Wf = fresh weight, Wd = dry weight, and Wt = turgid weight.

Fresh weigh is obtained by weighing the fresh leaves. The leaves were then immersed in water overnight, blotted dry, and then weighed to get turgid weight. Next, the leaves were dried overnight in an oven at 70°C and reweighed to obtain the dry weight.

Total Chlorophyll Content(T)

For determining total chlorophyll content, 0.5 g of fresh leaves were blended and then extracted with 10 ml of 80% acetone and left for 15 min. The liquid portion was decanted into another test tube and centrifuged at 2,500 rpm for 3 min. The supernatant was then collected and the absorbance was then taken at 645 nm and 663 nm using a spectrophotometer. Calculations were made using the formula.[16]

Chlorophyll a = 12.7(A663) – 2.69 (A645)

Chlorophyll b = 22.9(A645) – 4.68 (A663)

Total chlorophyll Content = 20.2 (A645) + 8.02 (A663)

Leaf Extracts PH

5 g of the leaves was homogenized in 10 ml deionized water. This was then filtered and the pH of leaf extract was determined using digital pH meter.

AA Analysis

The method of Keller and Schwager was used for the estimation of AA content. In this method, 0.5 g of fresh leaf sample was homogenized with 20 ml of extracting solution (5 g oxalic acid + 0.75 g EDTA in 1000 ml of distilled water). It was centrifuged for 15 min at 6000× g and the supernatant was collected. The supernatant (1 ml) was added to 2,6-dichlorophenolindophenol (DCPIP) (5 ml of 20 µg/ml), the solution was turning pink. The optical density (OD) of the mixture was taken at 520 nm (Es). After taking the OD of the mixture, one drop of AA was added to bleach the pink color and again the OD was taken at the same wavelength (Et). The OD of DCPIP solution was also taken at 520 nm (Eo). The standard curve was prepared using different concentrations of AA by following the same method. The concentration of AA is calculated using the equation.

$$\text{Ascorbic acid (mg/g)} = \frac{[E_0 - (E_s - E_t)] \times V}{W \times V_1 \times 1000}$$

Where,

W = Weight of the fresh leaf taken

V1 = Volume of the supernatant taken

V = Total volume of the mixture

Value of [Eo – (Es – Et)] is estimated by the standard curve

APTI of a species was determined using the formula developed by Singh and Rao and given as follows:[17]

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

Where A is AA content of leaf in mg/g dry weight, T is total chlorophyll content of leaf in mg/g dry weight, P is leaf extract pH, and R is % relative water content of leaf. The total sum is divided by 10 to obtained APTI.

Basing on the APTI values, the plants were conveniently grouped as follows:

1. Sensitive species with values <10
2. Intermediate species with values from 10 to 16
3. Tolerant species with values >17.

RESULTS AND DISCUSSIONS

The total chlorophyll content, AA content, relative water content, pH, and APTI values are presented in Table 1.

AA

The AA content was maximum (3.81 g/L) in *A. marmelos* and minimum (1.02 g/L) in *E. officinalis*. AA being a strong reductant protects chloroplasts against SO2-induced $H2O_2$, O_2, and OH^- accumulation and thus protects the enzymes of the CO_2 fixation cycle and chlorophyll for inactivation.[16] Its reducing power is directly proportional to its concentration. However, its reducing activity is pH dependent, being more at higher pH may increase the efficiency of conversation of hexose sugar to AA is related to the tolerance to pollution. AA plays an important role in cell division, defense, and cell wall synthesis. It is a natural detoxicant, which may prevent the effects of air pollutants in the plant tissues. Thus, plants maintaining high AA under pollutant conditions are considered to be tolerant to air pollution.

Leaf extracts PH

The leaf extract pH was found maximum 7.20 and minimum 5.20 in *B. variegata* and *E. Officinalis*, respectively, in polluted area. Plants with lower pH are more susceptible, while those with pH around 7 are tolerant. The stomatal activity of these leaves changes due to change in leaf extract pH due to air pollution. Leaf extract pH plays a significant role in regulating SO_2 sensitivity of plants. In the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive species. In the presence of an acidic pollutant, cell sap pH shifts toward acid which might decrease the efficiency of conversion of hexose sugar to AA. However, the reducing activity of AA is pH controlled being more at higher and less at lower pH. Hence, the leaf extract pH on the higher side gives tolerance to plants against pollution.

Relative Water Content

The relative water content was found to be maximum (88.71%) in *E. officinalis* and minimum (21.77%) in *P. cineraria*. Water is crucial prerequisite for plant life. RWC of a leaf is the amount of water present in it relative to its full turgidity. Relative water content is associated with protoplasmic permeability in cells and causes loss of water and dissolved nutrients, resulting in early senescence of leaves.[16] Under stress conditions of air pollution when the

Table: 1. Decreasing order of selected plants according to APTI value

Plant name	AA g/L	Relative water content (%)	Total chlorophyll mg/g^{-1}	pH	APTI	Response
Medicinal plants						
S. cumini	2.36	70.28	32.58	5.41	15.99	Intermediate
A. marmelos	3.81	80.85	4.48	6.95	12.43	Intermediate
V. negundo	1.23	63.12	29.21	6.04	10.64	Intermediate
B. variegata	1.44	55.79	24.45	7.20	10.13	Intermediate
E. officinalis	1.02	88.71	4.09	5.20	9.81	Sensitive
P. acidus	1.12	63.14	14.34	7.06	8.70	Sensitive
P. cineraria	3.70	21.77	7.61	6.76	7.49	Sensitive
Fruit plants						
C. papaya	1.82	70.28	29.25	7.73	14.12	Intermediate
P. guajava	1.85	44.41	31.36	6.21	11.39	Intermediate
A. heterophyllus	1.75	56.91	20.63	6.84	10.49	Intermediate
P. granatum	2.68	42.40	14.41	5.82	9.66	sensitive
M. zapota	2.16	45.66	3.64	6.08	6.66	Sensitive

APTI: Air pollution tolerance index, *S. cumini: Syzygium cumini, A. marmelos: A. marmelos, V. negundo: Vitex negundo, B. variegata: Bauhinia variegata, E. officinalis: Emblica officinalis, P. acidus: Phyllanthus acidus, P. cineraria: Prosopis cineraria, C. papaya: Carica papaya, P. guajava: Psidium guajava, A. heterophyllus: Artocarpus heterophyllus, P. granatum: Punica granatum, M. zapota: Manilkara zapota* transpiration rates are usually high, higher water content in a leaf will help to maintain its physiological balance.[18]

Total Chlorophyll

Total chlorophyll content was found maximum in *S. cumini* (32.58 mg/g) and minimum in *M. zapota* (3.64 mg/g). Chlorophyll content of plants varies from species to species, age of leaf, and also with the pollution level as well as with other biotic and abiotic conditions. Thus, plants having high chlorophyll content show tolerance to air pollution.[18]

APTI

Plants that are continuously exposed to pollutants lead to accumulation of pollution, integration of pollutants into their own system, thereby altering the nature of leaf, and make them more sensitive. This sensitivity is measured through various biochemical changes and finally to APTI. APTI gives an empirical value for tolerance level of plants to air pollution. In this study, it found that *S. cumini* shows the highest APTI value. It was found that plants with high index values are tolerant to air pollutants, whereas low index values were generally sensitive to air pollutants.[17] Cultivation of such tolerant species in polluted habitats leads to rapid amelioration of habitats to cope with the polluted environment. From the results documented in Table-1, it has been observed that *S. cumini, A. marmelos, Vitex negundo, B. variegata, C. papaya, P. guajava,* and *A. heterophyllus* were the more tolerant species because of APTI values in polluted areas. APTI values of plants can be used as an indicator of the presence of air pollutants and they are also very helpful in greenbelt development in the Vijayawada urban-industrial areas.

CONCLUSION

APTI determinations are of importance because with increased industrialization, and there is increasing danger of deforestation due to air pollution. The results of such studies are therefore useful for future planning and may be helpful to bring out possible control measures. It is worth noting that combining a variety of parameters gave a more reliable result than when based on a single biochemical parameter. Conclusively, it was found that the plants with low APTI value were found only at less polluted areas. The plants with higher APTI value were found to be resistant and were present at most of the areas. Resistant plants act as bioaccumulators for air pollutants. It is suggestible that the resistant plants marked in the investigation can be employed in abatement and control of air pollution. Secondary benefit can be derived from them, as some are of medicinal importance or fruit yielding. Hence, the Andhra Pradesh government should take measure in reducing air pollution by planting high APT-indexed plants in industrialized areas.

REFERENCES

1. Angold PG. The impact of a road upon adjacent health land vegetation effects on plant species composition. J Appl Ecol 1997;34:409-17.
2. Chaphekar SB. Effect of atmospheric pollutants on plants in Bombay. J Biol Sci 1972;15:1-6.
3. Dwivedi AK, Tripathi BD. Pollution tolerance and distribution pattern of plants in surrounding area of coal-fired industries. J Environ Biol 2007;28:257-63.
4. Winner WE. The effects of SO2 on photosynthesis and stomatal behaviour of Mediterranean-climate shrubs and herbs. In: Margaris NS, Mooney HA, editor. Component of Productivity of Mediterranean Climate Region-Basic and Applied Aspects. The Hague: Dr. W Junk Publishers; 1981. p. 91-103.
5. Sunitha M, Rao KV. Air pollution tolerance capacities of selected plant species. J Indian Bot Soc 1997;76:95-8.
6. Singh SK, Rao DN, Agrawal M, Pande J, Narayan D. Air pollution tolerance index of plants. J Environ Manage 1991;32:45-55.
7. Keller T, Schwager H. Air pollution and ascorbic acid. Eur J Forestry Pathol 1977;7:338-50.
8. Sivakumaran S, Hall MA. Effect of age and water stress in endogenous levels of plants growth regulators in *Euphorbia lathyrus*. J Exp Bot 1978;29:195-205.
9. Farooq M, Beg MU. Effect of aqueous SO on the membrane permeability of common Indian tree leaves. New Botanist 1980;7:213-7.
10. Eckert RT, Houston DB. Foliar peroxidase and acid phosphatase activity response to low level SO exposer in eastern white pine clones. Forestry Sci 1982;28:661-4.
11. Choudhary CS, Rao DN. Study on some factors in plants controlling their susceptibility to SO pollution. Proc Indian Natl Sci Acad 1977;43:236-41.
12. Tripathi BD, Tripathi A, Mishra K. Atmospheric dust fall deposits in Varanasi city. Atmos Environ 1991;258:109-12.
13. Namita J, Chauhan A, Joshi PC. Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants. Environmentalist 2009;29:398-404.
14. William EW, Christopher JA. Absorption of air pollution by plantsand consequences for growth. Trends Ecol Evol 1986;1:15-8.
15. Kumara KS, Rao VL, Vittal Murthy KP. A viable optimum solution for air pollution and climate moderation based on selected, suitable plant species of Vijayawada Urban Area. Int J Innov Res Sci Eng Technol 2014;1:8243-53.
16. Tiwari S, Agrawal M, Marshall FM. Evaluation of ambient air pollutionimpact on carrot plants at a sub urban site using open top chambers. Environ Monit Assess 2006;119:15-30.
17. Singh SK, Rao DN. Evaluation of plants for their

tolerance to air pollution. In: Proceeding of Symposium on Air Pollution Control. Vol. 1. New Delhi: Indian Association of Air Pollution Control; 1983. p. 218-24.e
18. Department of Biology. East China Normal University, Experiment instruction of plant physiology. China: People's Education Press; 1980.

Source of Support: Nil. **Conflict of Interest:** None declared.