EVALUATION OF AIR POLLUTION TOLERANCE INDEX OF TREE SPECIES OF BIKANER CITY (RAJASTHAN)

Leela Kaur*, Prabhu Dan Charan*, Rajaram Choyal*

* Maharaja Ganga Singh University, Department of Environmental Science, Bikaner, Rajasthan, India

corresponding author: Prabhu Dan Charan, e-mail: prabhuenviro@gmail.com

Original scientific paper
Received: July 5th, 2022
Accepted: October 12th, 2022
HAE-2261
https://doi.org/10.33765/thate.13.4.1

ABSTRACT

The air pollution tolerance index (APTI) is one of the modern tools for assessing the impacts of air pollutants on plant physiology. The value of APTI is different for different plant species. Plants with higher values of APTI are tolerant and act as a sink due to their bioaccumulation ability for air pollutants. Hence, they can be planted to establish green belts in areas with severe air pollution, especially in industrial zones. The present investigation was carried out to assess the APTI values of top twenty urban tree species of the Bikaner city of North-Western Rajasthan. The leaf samples were taken from selected roadside trees distributed in the residential, commercial and industrial zones of the city. On the basis of APTI values, it was observed that *Leucaena leucocephala* (23.41), *Eucalyptus camaldulensis* (21.87) and *Cassia siamea* (21.39) had an APTI value above 20 and they are therefore classified as tolerant species. Similarly, *Pongamia pinnata* (9.48) showed APTI under 10, therefore it falls into the sensitive category. 80 % of the total species in the studied area are categorized as a moderately sensitive category. There were no plant species in very sensitive (APTI < 1) and very tolerant (APTI > 30) category.

Keywords: *air pollution tolerance index (APTI), bio-indicator species, tolerant species, roadside trees, green belts*

INTRODUCTION

Air pollution has emerged as a global public health problem. It has been identified as a major environmental health hazard. There are many causes of air pollution, including industrialization [1, 2], urbanization [3, 4], vehicle exhaust, deforestation, mining etc. [5]. The number of vehicles is increasing day by day. It was observed that India became the fourth largest automobile market in 2017 [6]. India was the fourth largest emitter of greenhouse gases (GHGs) and accounts for about 5 % of total GHG emission at the global level [7]. The total number of registered cars and motorized two wheelers in India was 137 million in 2012 [8]. Vehicle exhaust emission depends on various factors, including fuel quality, maintenance and servicing of vehicles, quality of roads etc. It has been observed that the diesel vehicles emit more particulate matter and oxides of nitrogen compared to petrol vehicles; therefore, diesel is less eco-friendly fuel than petrol [9]. Due to the government subsidy for diesel, the share of diesel cars was reached 58 % in 2012-13 [10] from 27 % in 2006 [11].

The multiple pressures on the environment lead to the release of various pollutants into the atmosphere, resulting in drastic environmental and ecological impacts. The calculation of detrimental effects of pollution in terms of monetary value is very difficult, but an estimate from OECD (Organization for Economic Co-operation and Development) suggest that ambient air pollution alone may cost India more than 0.5 trillion dollars per year [12]. About 80 % of cities violate air pollution regulation standards in India [13]. The plants are very sensitive to such pollutants and therefore respond accordingly. Such plant species are considered bioindicators of air pollution. They are used as a tool for prediction and recognition of various environmental stresses [14, 15]. Various pollutants can enter into the plant tissues through opening of stomata [16], cuticle [17], cell walls and membranes [18].

Several studies have been carried out on the physiological and biochemical responses of plants to various pollutants [19 - 22]. The plants exposed to air pollutants show physiological changes prior to the visible damage to leaves [23]. These physiological changes include pH of leaf extract [24], relative water content [25], chlorophyll content [26 - 28] and ascorbic acid content [26, 29 - 31]. The response of plants to various pollutants is different for different species. The analysis of individual physiological parameter is not enough to describe cumulative impact of air pollution. Therefore, an air pollution tolerance index (APTI) serves as powerful tool for assessing overall impact of pollution on plant species. APTI is a realistic method which evaluates the tolerance level of plant species towards air pollution by assessing biochemical parameters of its leaves. APTI provides reliable information for establishing green belts in industrial area and selection plant species with regard to their sensitivity to pollution [32]. After reviewing the researches carried out by different researchers [33 - 37], the sensitivity of various plants to different air pollutants can be classified as shown in Table 1.

Table 1. The range of APTI and sensitivity level of plant species

APTI value	Sensitivity level
< 1	Very sensitive
1 - 10	Sensitive
11 - 20	Moderately sensitive
21 - 30	Tolerant
31 - 100	Very tolerant

The sensitive species can be used as bioindicators, while tolerant species can be used as a sink for air pollution. Several studies have been carried out on APTI at national and international levels [38 - 42], but vegetation of the city of Bikaner in North-Western Rajasthan has not been investigated from their air pollution tolerance perspective. Therefore, the present study was carried out to assess the APTI of selected plant species commonly found along the roadsides of the residential, commercial and industrial area of the Bikaner city.

EXPERIMENTAL

Study area

The city of Bikaner is located in the North-Western part of Rajasthan between 28.02°N and 73.3°E (Figure 1). According to the 2011 census, the city had 644,406 inhabitants. The region has an arid type of climate with an average annual rainfall of 277.55 mm in the district (1991 - 2010), while the normal rainfall (1901 - 1971) is lower than average rainfall and amounts to 257.8 mm [43]. Almost 90 % of the total annual rainfall falls during the south-west monsoon, which enters the district in the first week of July and withdraws in the middle of September. The study area is located in the central area of the Thar Desert, which measures extreme values of heat in the summer and cold in the winter. The temperature varies from about 1 °C in the winter to 48 °C in the summer. Atmosphere is generally dry, except for the monsoon period. The humidity is highest in August with average daily relative humidity of 71 % in the morning and 52 % in the evening.

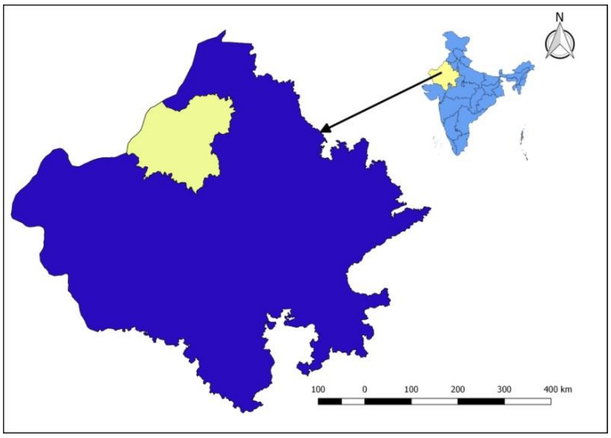

Figure 1. Location of Bikaner district in Rajasthan

In this research, trees planted along the city roads were observed. All 11 major roads in the Bikaner city (Station Road, Poogal Road, Jaipur Road, Jodhpur Road, Jaisalmer Road, Ganganagar Road, Rani Bazar Road, Dauji Road, KEM Road, Udasar Road, and Nagnechi Road) were included in the study. Dauji Road, Station Road and KEM Road pass through major commercial areas of the city. Poogal Road, Rani Bazar Road and Ganganagar Road pass through three major industrial areas of the city: Beechhwal industrial area, Rani Bazar industrial area and Karni Nagar industrial area. The remaining roads pass through or nearby major residential colonies. Therefore, this research was focused on the commercial, industrial and residential areas of the city.

Sampling and analyses

The assessment of air pollution tolerance index (APTI) of vegetation of the city started with selection of tree flora. The study was carried out in the period from January to June 2018. After conducting a random survey, top twenty tree species were selected for the present investigation. The selection of these plants was based on their common presence at road sides of the residential, commercial, and industrial area of the Bikaner city. The top twenty tree species commonly found in the city are: *Acacia nilotica*, *Acacia senegal*, *Ailanthus excelsa*, *Albizia lebbeck*, *Alstonia scholaris*, *Azadirachta indica*, *Cassia siamea*, *Colophospermum mopane*, *Dalbergia sissoo*, *Delonix regia*, *Eucalyptus camaldulensis*, *Ficus benghalensis*, *Ficus religiosa*, *Leucaena leucocephala*, *Moringa oleifera*, *Pongamia pinnata*, *Prosopis cineraria*, *Salvadora oleoides*, *Salvadora persica* and *Tecomella undulata*. Three specimens of fully matured leaves of selected trees (having girth at breast height (GBH) > 20 cm) were collected in polythene bags, labelled and immediately brought to the laboratory for analysis. Standard methods were adopted for analysis of total chlorophyll [44], pH of leaf extract [33], relative moisture content [45] and ascorbic acid content [31]. The previously mentioned parameters were used for analysis of air pollution tolerance index (APTI). The APTI values for different plant species were computed by using following formula proposed by Singh and Rao [33]:

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

where is: A - ascorbic acid (mg/g), T - total chlorophyll (mg/g), P - pH of the leaf extract, R - relative water content of a leaf (%).

RESULTS AND DISCUSSION

The average values of different parameters and APTI are shown in Table 2. The sensitivity and response of plants was different for different species, which is represented as different APTI values. It was observed that the APTI values of top twenty tree species of the Bikaner city vary from 9.48 to 23.41. The plant species that have lower APTI act as bioindicators of air pollution, while those that have higher values and are tolerant to air pollution are used for development of green belts in the urban area [41]. Based on sensitivity, it was observed that most of the studied plants can be classified into the moderately sensitive category (Table1). Only *Pongamia pinnata* (9.48) showed APTI under 10 (therefore it belongs to the sensitive category), while *Leucaena leucocephala* (23.41), *Eucalyptus camaldulensis* (21.87) and *Cassia siamea* (21.39) were had APTI more than 20 and therefore classified as tolerant species. The rest of the plants are categorized as moderately sensitive, accounting for 80 % of the studied species (Figure 2). It was observed that the plants with higher pH values of the leaf extract are more tolerant to air pollutants. Three species, *Leucaena leucocephala* (pH = 8.95), *Eucalyptus camaldulensis* (pH = 9.45) and *Cassia siamea* (pH = 8.93) showed highest pH values and are also tolerant to the air pollution. These findings correspond to the findings of Ogunkunle et al. [46] who worked on the air pollution tolerance index and anticipated the performance index of some tree species for biomonitoring environmental health.

Table 2. Average values of different physiological parameters and APTI of top 20 tree species of the Bikaner city

	Plant species	Leaf extract pH	Relative moisture (%)	Total chlorophyll (mg/g)	Ascorbic acid (mg/g)	APTI value
1.	*Acacia nilotica*	5.72	73.06	8.52	5.43	15.04
2.	*Acacia senegal*	6.64	72.11	7.55	4.88	14.14
3.	*Ailanthus excelsa*	8.54	80.56	11.54	3.54	15.16
4.	*Albizia lebbeck*	8.32	79.54	12.8	4.5	17.46
5.	*Alstonia scholaris*	8.73	79.54	6.84	4.87	15.54
6.	*Azadirachta indica*	7.87	78.33	11.55	4.47	16.51
7.	*Cassia siamea*	8.93	82.54	13.66	5.84	21.39
8.	*Colophospermum mopane*	8.76	74.8	8.47	4.56	15.34
9.	*Dalbergia sissoo*	6.24	76.51	7.74	3.94	13.16
10.	*Delonix regia*	8.73	76.58	12.53	1.35	10.53
11.	*Eucalyptus camaldulensis*	9.45	78.51	13.42	6.41	21.87
12.	*Ficus benghalensis*	7.66	75.94	10.43	2.41	11.95
13.	*Ficus religiosa*	6.92	73.5	9.37	1.82	10.31
14.	*Leucaena leucocephala*	8.95	82.41	14.12	6.73	23.41
15.	*Moringa oleifera*	7.92	73.51	13.86	2.44	12.67
16.	*Pongamia pinnata*	6.37	64.87	6.43	2.34	9.48
17.	*Prosopis cineraria*	8.34	68.23	8.79	6.22	17.48
18.	*Salvadora oleoides*	8.92	79.25	13.54	3.75	16.35
19.	*Salvadora persica*	8.67	80.14	13.72	4.09	17.17
20.	*Tecomella undulata*	6.85	73.64	7.88	3.76	12.90

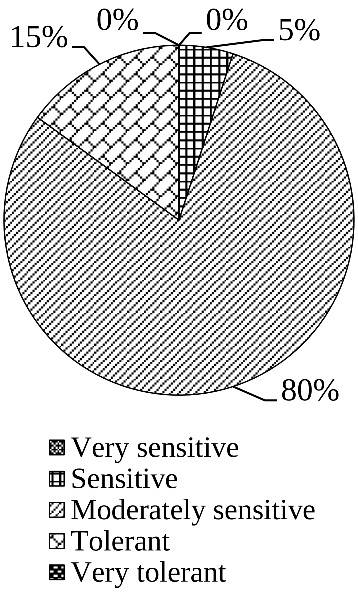

Figure 2. Percentage of plant species of the studied area in different categories according to APTI values

The moisture content of the plant maintains the turgidity of the leaves and supports the vital physiological balance under stress conditions. Any environmental stress, such as air pollutants, can increase the water content in leaves to reduce the stress. Accordingly, a higher relative water content in the leaves of a plant is directly proportional to tolerance of that plant species to the stress caused by emission of pollutants. The results of the present investigation are positively correlated with earlier findings [47 - 49]. Dhankar et al. [48] have found that the relative water content is an indicator of stress and that its concentration increases with the induction of stress in the form of air pollutants. Sharma et al. [49] showed that *Grevillea robusta* had higher relative water content with increasing air pollution.

The results of the analysis of the total chlorophyll content have shown that tolerant plant species, i.e., *Leucaena leucocephala* (14.12 mg/g), *Eucalyptus camaldulensis* (13.42 mg/g) and *Cassia siamea* (13.66 mg/g) have a higher chlorophyll content, while sensitive plant species (*Pongamia pinnata*) have the lowest chlorophyll content (6.43 mg/g). The results of the study are in accordance with research carried out by Joshi et al. [50] who worked on air quality monitoring of Indore city. The content of ascorbic acid in the samples was ranged from 1.35 mg/g (*Delonix regia*) to 6.73 mg/g (*Leucaena leucocephala*). Ascorbic acid is a natural detoxicant, so it helps plants to withstand injuries caused by air pollution and also prevents the harmful effect of toxic emissions [34]. This study revealed that plants have ascorbic acid content in the following order: tolerant plants > moderately sensitive plants > sensitive plants. This proves the fact that level of ascorbic acid improves the tolerance of plants to the negative impacts of air pollutants. These results are supported by earlier findings [51 - 53]. Zhang et al. [51] showed ozone tolerance of plants with a high content of ascorbic acid, while Ghosh et al. [52] and Cheng et al. [53] found that the ascorbic acid content promotes plant growth as well as the resistance level of plants to air pollutants.

CONCLUSION

In this study, APTI values of top twenty species of trees along the major roadsides of different residential, commercial and industrial zones of Bikaner city were determined. It was observed that only three species showed APTI values above 20: *Leucaena leucocephala* (23.41), *Eucalytptus camaldulensis* (21.87) and *Cassia siamea* (21.39). *Pongamia pinnata* (9.48) showed APTI lesser than 10, therefore it belongs to the sensitive category. The remaining 16 species had the APTI values from 10 to 20, which is why they are categorized as moderately sensitive species. No tree species were found in very sensitive (APTI < 1) and very tolerant category (APTI > 30). Since roads and highways are one of the important line sources of air pollution, suitable plant species must be planted along major roadsides of the city to fight air pollution. It will not only increase the greenery, but it will also help to reduce air pollution and ultimately improve the social as well as environmental health.

REFERENCES

[1] R. Akhtar, C. Palagiano, Climate Change and Air Pollution: An Introduction, in: Climate Change and Air Pollution: The Impact on Human Health in Developed and Developing Countries, eds.: R. Akhtar, C. Palagiano, Springer International Publishing AG, 2018, 3-8. https://doi.org/10.1007/978-3-319-61346-8_1

[2] C.A. Odilara, P.A. Egwaikhide, A. Esekheigbe, S.A. Euma, Air Pollution Tolerance Index (APTI) of some plant species around Ilupeju Industrial Area, Lagos, Journal of Engineering Science and Applications 4(2006) 2, 97-101.

[3] P. Grennfelt, A. Engleryd, M. Forsius, Ø. Hov, H. Rodhe, E. Cowling, Acid rain and air pollution: 50 years of progress in environmental science and policy, Ambio 49(2020), 849-864. https://doi.org/10.1007/s13280-019-01244-4

[4] P.D. Charan, H. Sahel, Study of respirable dust in ambient air of Bikaner city and its impacts on human health, Applied Journal of Hygiene 3(2014) 1, 11-14. https://doi.org/10.5829/idosi.ajh.2014.3.1.74133

[5] J.M. Samet, Y.S. Chung, Air Quality, Atmosphere and Health: the 10-year anniversary, Journal of Air Quality, Atmosphere and Health 1(2008), 1-2. https://doi.org/10.1007/s11869-008-0007-x

[6] S. Miglani, The Growth of the Indian Automobile Industry: Analysis of the Roles of Government Policy and Other Enabling Factors, in: Innovation, Economic Development, and Intellectual Property in India and China, eds.: K.-C. Liu, U.S. Racherla, ARCIALA Series on Intellectual Assets and Law in Asia, Springer, Singapore, 2019, 439-463.

[7] S. Grover, G. Tiwari, K.R. Rao, Low carbon mobility plans: A case study of Ludhiana, India, Procedia - Social and Behavioral Sciences 104(2013), 785-794. https://doi.org/10.1016/j.sbspro.2013.11.173

[8] MoRTH, Road Transport Year Book 2011-12, Transport Research Wing, Ministry of Road Transport and Highways, Government of India, New Delhi, 2012.

[9] J.E. Jonson, J. Borken-Kleefeld, D. Simpson, A. Nyiri, M. Posch, C. Heyes. Impact of excess NO_x emissions from diesel cars on air quality, public health and eutrophication in Europe, Environmental Research Letters 12(2017) 9, Article number: 094017. https://doi.org/10.1088/1748-9326/aa8850

[10] ICRA, Indian automobile industry-passenger vehicle and commercial vehicle volume trends and outlook-in view of reduction in fuel prices and changes in excise duty, ICRA research services, ICRA Limited, 2015.

[11] R. Chugh, M. Cropper, U. Narain, The cost of fuel economy in Indian passenger vehicle market, Energy Policy 39(2011) 11, 7174-7183. https://doi.org/10.1016/j.enpol.2011.08.037

[12] OECD, The Cost of Air Pollution Health Impacts of Road Transport: Health Impacts of Road Transport, OECD Publishing, Germany, 2014.

[13] CPCB, National ambient air quality status 2012, Central Pollution Control Board, New Delhi, India, 2014.

[14] T.K. Parmar, D. Rawtani, Y.K. Agrawal, Bioindicators: the natural indicator of environmental pollution, Frontiers in Life Science 9(2016) 2, 110-118. https://doi.org/10.1080/21553769.2016.1162753

[15] A. Bytnerowic, Physiological Aspects of Air Pollution Stress in Forests, Phyton (Horn, Austria), 36(1996) 3, 15-22.

[16] A.R. Wellburn, Why are atmospheric oxides of nitrogen usually phytotoxic and not alternative fertilizers?, New Phytology 115(1990) 3, 395-429.

https://doi.org/10.1111/j.1469-8137.1990.tb00467.x

[17] M. Krywult, J. Hom, A. Bytnerowicz, K.E. Percy, Deposition of gaseous nitric acid and its effects on foliage of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings, Proceedings of the 16th international meeting for specialists in air pollution effects on forest ecosystems, Air Pollution and Multiple Stress, Fredericton, Canada, IUFRO, 7-9 September, 1994.

[18] A. Bytnerowicz, N.E. Grulke, Physiological effects of air pollutants on western trees, in: The response of western forests to air pollution, eds.: R.K. Olson, D. Binkley, M. Bohm, Springer Verlag, New York, 1992, 183-233. http://doi.org/10.1007/978-1-4612-2960-5_6

[19] M. Das, M. Chatterjee, A. Mukherjee, Air Pollution Tolerance Index (APTI) Used for Assessing Air Quality to Alleviate Climate Change: A Review, Research Journal of Pharmaceutical, Biological and Chemical Sciences 9(2018) 1, 45-54.

[20] N. Joshi, A. Chauhan, P.C. Joshi, Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants, The Environmentalist 29(2009), 398-404. https://doi.org/10.1007/s10669-009-9218-4

[21] A.P. Sharma, B.D. Tripathi, Biochemical response in tree foliage exposed to coal-fired power plant emission in seasonally dry tropical environment, Environmental Monitoring and Assessment 158(2009), 197-212. https://doi.org/10.1007/s10661-008-0573-2

[22] A.K. Tripathi, M. Gautam, Biochemical parameters of plants as indicators of air pollution, Journal of Environmental Biology 28(2007) 1, 127-132.

[23] G.P. Dohmen, A. Koppers, C. Langebartels, Biochemical Response of Norway Spruce (*Picea abies* (L.) Karst.) toward 14-Month exposure to ozone and acid mist: Effect on amino acid, Glutathione and polyamine Titers, Environmental pollution 64(1990) 3-4, 375-383. https://doi.org/10.1016/0269-7491(90)90059-L

[24] G. Klumpp, C.M. Furlan, M. Domingos, A. Klumpp, Response of stress indicators and growth parameters of *Tibouchina pulchra* Cogn. exposed to air and soil pollution near the industrial complex of Cubatão, Brazil, Science of the Total Environment 246(2000) 1, 79-91. https://doi.org/10.1016/S0048-9697(99)00453-2

[25] C.S. Rao, Environmental pollution Control Engineering, Revised Second Edition, New Age international Publishers, New Delhi, India, 2006.

[26] B.A. Falusi, O.A. Odedokun, A. Abubakar, A. Agoh, Effects of dumpsites air pollution on the ascorbic acid and chlorophyll contents of medicinal plants, Cogent Environmental Science 2(2016) 1, Article number: 1170585. https://doi.org/10.1080/23311843.2016.1170585

[27] S.K. Prajapati, B.D. Tripathi, Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution, Journal of Environmental Quality 37(2008) 3, 865-870. https://doi.org/10.2134/jeq2006.0511

[28] M.D. Flowers, E.L. Fiscus, K.O. Burkey, F.L. Booker, J.-J.B. Dubois, Photosynthesis, chlorophyll fluorescence and yield of snap bean (*Phaseolus vulgaris* L.) genotypes differing in sensitivity to ozone, Environmental and Experimental Botany 61(2007) 2, 190-198. https://doi.org/10.1016/j.envexpbot.2007.05.009

[29] R. Gupta, M. Purohit, Bio-monitoring of road side air pollution using ascorbic acid content of selected trees at Ujjain, International Journal of Scientific Research in Recent Sciences 1(2015) 1, 26-29.

[30] M.A. Hoque, M.N.A. Banu. E. Okuma, K. Amako, Y. Nakamura, Y. Shimoishi,

Y. Murata, Exogenous proline and glycinebetaine increase NaCl-induced ascorbate-glutathione cycle enzyme activities, and proline improves salt tolerance more than glycinebetaine in tobacco bright yellow-2 suspension-cultured cells, Journal of Plant Physiology 164(2007) 11, 1457-1468. https://doi.org/10.1016/j.jplph.2006.10.004

[31] T. Keller, H. Schwager, Air pollution and ascorbic acid, Forest pathology 7(1977) 6, 338-350. https://doi.org/10.1111/j.1439-0329.1977.tb00603.x

[32] B. Sharma, S. Sharma, S.K. Bhardwaj, L. Kaur, A. Sharma, Evaluation of Air Pollution Tolerance Index (APTI) as a tool to monitor pollution and green belt development: A review, Journal of Applied and Natural Science 9(2017) 3, 1637-1643. https://doi.org/10.31018/jans.v9i3.1414

[33] S.K. Singh, D.N. Rao, Evaluation of plants for their tolerance to air pollution, Proceedings of Symposium on air pollution control held at IIT Delhi, 1983, 218-224.

[34] S.K. Singh, D.N. Rao, M. Agrawal, J. Pandey, D. Naryan, Air pollution tolerance index of plants, Journal of Environmental Management 32(1991) 1, 45-55. https://doi.org/10.1016/S0301-4797(05)80080-5

[35] Y. Kalyani, M.A. Singaracharya, Biomonitoring of air pollution in Warangal city, Andhra Pradesh, Acta Botanica indica 23(1995) 1, 21-24.

[36] X.-K. Wang, W.-Z. Lu, Seasonal variation of pollution index: Hong Kong case study, Chemosphere 63(2006) 8, 1261-1272. https://doi.org/10.1016/j.chemosphere.2005.10.031

[37] P.S. Lakshmi, K.L. Sravanti, N. Srinivas, Air Pollution Tolerance Index of Various Plant Species Growing in Industrial Areas, The Ecoscan 2(2008) 2, 203-206.

[38] A.K. Pandeya, M. Pandeya, A. Mishra, S.M. Tiwary, B.D. Tripathi, Air pollution tolerance index and anticipated performance index of some plant species for development of urban forest, Urban Forestry & Urban Greening 14(2015) 4, 866-871. https://doi.org/10.1016/j.ufug.2015.08.001

[39] P.K. Rai, L.L.S. Panda, B.M. Chutia, M.M. Singh, Comparative assessment of air pollution tolerance index (APTI) in the industrial (Rourkela) and non industrial area (Aizawl) of India: An eco-management approach, African Journal of Environmental Science and Technology 7(2013) 10, 944-948. https://doi.org/10.5897/AJEST2013.1532

[40] S.J. Jyothi, D.S. Jaya, Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvananthapuram, Kerala, Journal of Environmental Biology 31(2010) 3, 379-386.

[41] P.O. Agbaire, E. Esiefarienrhe, Air Pollution tolerance indices (APTI) of some plants around Otorogun Gas Plant in Delta State, Nigeria, Journal of Applied Sciences and Environmental Management 13(2009) 1, 11-14. https://doi.org/10.4314/jasem.v13i1.55251

[42] P.C. Joshi, A. Swami, Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India, The Environmentalist 27(2007) 3, 365-374. https://doi.org/10.1007/s10669-007-9049-0

[43] CGWB, Ground water information of Bikaner district, Rajasthan, Central Ground Water Board, Ministry of Water Resources, Government of India, 2013, 1-15.

[44] D.I. Arnon, Copper Enzyme in Isolated Chloroplast. Polyphenoloxidase in *Beta vulgaris*, Plant Physiology 24(1949) 1, 1-15. https://doi.org/10.1104/pp.24.1.1

[45] D.N. Sen, M.C. Bhandari, Ecological and water relation to two *Citrullus* spp., in: Indian Arid Zone, Environmental Physiology and Ecology of Plants, ed.: A.M. Althawadi, 1978, 203-228.

[46] C.O. Ogunkunle, L.B. Suleiman, S. Oyedeji, O.O. Awotoye, P.O. Fatoba, Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health, Agroforestry Systems 89(2015), 447-454. https://doi.org/10.1007/s10457-014-9781-7

[47] S.K. Singh, Practical Plant Physiology, Kalayani Publishers, New Delhi, India, 1977.

[48] R. Dhankhar, V. Mor, S. Lilly, K. Chopra, A. Khokhar, Evaluation of anticipated performance index of some tree species of Rohtak city, Haryana, India, International Journal of Recent Scientific Research 6(2015) 3, 2890-2896.

[49] B. Sharma, S. Sharma, S.K. Bhardwaj, Effect of pollution on relative water content in temperate species growing along National Highway 5 in Himachal Pradesh, International Journal of Advances in Science Engineering and Technology 5(2017) 3, Spl. Iss-1, 15-18.

[50] O.P. Joshi, K. Pawar, D.K. Wagela, Air quality monitoring of Indore city with special reference to SO_2 and tree barks pH, Journal of Plant Physiology 148(1993), 249-257.

[51] P.-Q. Zhang, Y.-J. Liu, X. Chen, Z. Yang, M.-H. Zhu, Y.-P. Li, Pollution resistance assessment of existing landscape plants on Beijing streets based on air pollution tolerance index method, Ecotoxicology and Environmental Safety 132(2016), 212-223. https://doi.org/10.1016/j.ecoenv.2016.06.003

[52] P.K. Ghosh, T.K. De, T.K. Maiti, Ascorbic acid production in root, nodule and Enterobacter spp. (Gammaproteobacteria) isolated from root nodule of the legume *Abrus precatorius* L, Bio-catalysis and Agricultural Biotechnology 4(2014) 2, 127-134. https://doi.org/10.1016/j.bcab.2014.11.006

[53] F.-Y. Cheng, K.O. Burkey, J.M. Robinson, F.L. Booker, Leaf extracellular ascorbate in relation to ozone tolerance of two soya bean cultivars, Environmental pollution 150(2007) 3, 355-362. https://doi.org/10.1016/j.envpol.2007.01.022

Acknowledgements

Authors are grateful to the National Remote Sensing Centre, Hyderabad (India) for providing financial support under IGBP-NCP-VPA project.