International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:11, No:2, 2017

Trees for Air Pollution Tolerance to Develop Green Belts as an Ecological Mitigation

Rahma Al Maawali, Hameed Sulaiman

Abstract**—**Air pollution both from point and non-point sources is difficult to control once released in to the atmosphere. There is no engineering method known available to ameliorate the dispersed pollutants. The only suitable approach is the ecological method of constructing green belts in and around the pollution sources. Air pollution in Muscat, Oman is a serious concern due to ever increasing vehicles on roads. Identifying the air pollution tolerance levels of species is important for implementing pollution control strategies in the urban areas of Muscat. Hence, in the present study, Air Pollution Tolerance Index (APTI) for ten avenue tree species was evaluated by analyzing four bio-chemical parameters, plus their Anticipated Performance Index (API) in field conditions. Based on the two indices, *Ficus benghalensis* was the most suitable one with the highest performance score. *Conocarpus erectuse, Phoenix dactylifera*, and *Pithcellobium dulce* were found to be good performers and are recommended for extensive planting. *Azadirachta indica* which is preferred for its dense canopy is qualified in the moderate category. The rest of the tree species expressed lower API score of less than 51, hence cannot be considered as suitable species for pollution mitigation plantation projects.

Keywords**—**Air pollution tolerance index, avenue tree species, bio-chemical parameters, Muscat.

I. Introduction

POLLUTANTS, once released from the source in to the atmosphere, are difficult to control. They disperse widely when released into the air, and no physical or chemical method is known to ameliorate the dispersed aerial pollutants. The impacts of the dispersed pollutant then can only be mitigated by growing vegetation in and around the vicinity of pollution sources. Many studies under varying pollution circumstances [1]-[12] have recommended growing vegetation in and around the industrial/urban areas.

Air quality in Muscat is a major issue for the city administration due to increasing urbanization, particularly due to the increase in number of vehicles on the roads every year. Road side plantation and maintenance is a continuous effort by the city authorities with dedicated annual budget. All these efforts are to improve the appearance of roads and to enhance the aesthetic view of the city. The primary benefits of these plantations as their role in reducing air pollution are not well thought when selecting the tree species and their suitability to mitigate air pollution. The present study aims to screen the tree species which are suitable for air pollution tolerance and thus to enhance mitigation. The tolerant ones help in reducing the overall pollution load, leaving the air quality relatively better [13]. The study is aimed at recommending the best tree species to be considered for the green belt development in the urban areas of Oman by evaluating their APTI and API.

Rahman Al-Maawali is with the Ministry of Education, Sultanate of Oman.
Hameed Sulaiman is with the Biology Department, College of Science, Sultan Qaboos University, Muscat, Sultanate of Oman (e-mail: hameed@squ.edu.om).

II. Materials and Methods

Species selection was done after having consultation with the authorities in the General Directorate of planting in Muscat, and the most commonly planted species were selected to be studied in Sultan Qaboos Street in Muscat, Oman. Sultan Qaboos Street is one of the longest and traffic busy streets in Muscat. The traffic density is moderate-to-high with peak periods during morning and evening hours. The temperature in this street, in the duration of sampling, showed maximum and minimum range of 32 °C and 21 °C, respectively. So, the durations chosen for sampling the tree species were at 8.00 a.m. during April 2014. Fully mature leaves in triplicates were collected from the selected species from different locations. The leaves were picked from a height of 1 to 2 meters from the ground level from trees grown in iso-ecological conditions. Total chlorophyll was determined according to the method described by [14] using a spectrophotometer. Relative water contents were analyzed as percent moisture content on a dry weight basis described by [15]. Leaf extract pH was determined by [16]. Ascorbic acid was determined by [17] adapted from the original method by [18].

The APTI was computed by the method suggested from [11] using (1),

$$APTI = \frac{A(T+P)+R}{10} \tag{1}$$

where A is the ascorbic acid content of leaf (mg/g of fresh weight), T is the total chlorophyll (mg/g of fresh weight), P is the leaf extract pH, and R is the relative water content (in percentage) of the leaves.

TABLE I
GRADING CRITERIA FOR THE API OF TREE SPECIES [19]

Grade	Scores (%)	Assessment of plant species
0	Up to 30	Not recommended for plantation
1	31-40	Very poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very good
6	81-90	Excellent

The API of tree species was evaluated on the basis of APTI, and some relevant biological and socio-economic characteristics were evaluated by observation in the field and then graded accordingly after [19]. Tree categories are graded as best, excellent, good, moderate, and poor. The criteria used for gradation of tree species are shown in Tables I and II.

III. Results and Discussion

A. Air Pollution Tolerance Index (APTI)

APTI of ten examined tree species was determined by computing the four biochemical parameters which are indicative of their tolerance to pollution. The mean values of these parameters were analyzed, and the APTI calculated for each tree species were shown in Table II. *Pithcellobium dulce* exhibited highest APTI value followed by *Conocarpus erectuse* and *Azadirachta indica.* The lowest value was recorded by *Ficus benghalensis.* Higher the APTI value higher their tolerant capacity and the vice versa. All the tree species recorded higher levels of APTI (>10). Values less than 10 are categorized as sensitive species [11], [20]. From the results, it is interesting to note that *Conocarpus erectuse* scored the higher tolerance value. This tree species is widely grown in Oman in road side and community plantation due to its adaptability in harsh climatic condition.

Comparing the calculated data (F=7.52) to the tabular data (2.39) and probability 9.28 10^{-05} gives a result that the calculated F data are greater than the tabular data. So, null hypothesis (H○) is rejected. This means that there is a difference in APTI between ten examined tree species, which means that there is a difference in the tolerance level between tree species.

TABLE II.
Mean Values of Four Biochemical Parameters of Tree species and Their APTI

	Tree Species	Total Chlorophyll (mg\gm fresh wt.)	Ascorbic Acid (mg\gm dry wt.)	Leaf Extract pH	Relative Water Content (%)	APTI and Grade*
1	*Acacia tortilis*	2.78	3.80	6.76	79.01	11.51 (+)
2	*Albizia lebbeck*	3.73	1.06	7.24	90.28	10.19 (+)
3	*Azadirachta indica*	3.11	4.09	7.57	94.10	13.78 (++)
4	*Bougainvillea spectabilis*	2.96	4.19	6.97	92.68	13.44 (++)
5	*Conocarpus erectuse*	4.83	4.39	6.23	90.95	13.93 (++)
6	*Delonix regia*	2.56	1.34	7.37	91.36	10.47 (+)
7	*Ficus benghalensis*	2.20	1.43	8.47	85.85	10.11 (+)
8	*Phoenix dactylifera*	3.02	2.40	7.25	82.01	10.66 (+)
9	*Pithcellobium dulce*	4.52	6.40	7.22	84.99	16.02 (+++)
10	*Ziziphus spina* -christi	2.35	5.52	7.07	75.39	12.74 (++)
		ANOVA for APTI values of tree species				
Source of Variation	SS	df	MS	F	P-value	F critical
Between groups	108.5292833	9	12.05880926	7.51907	9.28E-05	2.392814
Within groups	32.07526667	20	1.603763333			
Total	140.60455	29				
*APTI pattern of assessment and grading		9.0-12.0 +	12.1-15.0 ++	15.1-18.0 +++	18.1-21.0 ++++	21.1-24.0 +++++

B. Anticipated Performance Index (API)

After calculating APTI values of the tree species by analyzing the bio-chemical parameters, they were evaluated for their biological and socio-economic parameters in the field such as plant habit, canopy structure, type of plant, laminar structure, and economic value. This criterion indicates how these species perform in the field conditions with respect to their adaptability. These parameters were subjected to a grading scale in order to determine the API of tree species. The grading pattern of ten tree species was evaluated in Table III, and the assessments for recommendation to planting in urban area are presented in Table IV.

Table IV showed that out of 10 species, *Ficus benghalensis* was the most suitable tree to grow in roadside plantation and can be expected to perform well. It is interesting to note that it has the lowest pollution tolerance score, but outweighs the rest of the species with its field performance parameters. It has a dense plant canopy, evergreen, which normally offers protection from pollution stress. The aesthetic and economic value of this tree is well-known and it is recommended for extensive planting. *Conocarpus erectuse*, *Phoenix dactylifera*, and *Pithcellobium dulce* were also judged as 'good' performers though their API values were less than *Ficus benghalensis.* However, *Azadirachta indica* is qualified in the 'moderate' category. Besides these species, the remaining five species were found to be not suitable as pollution sink because of their lower anticipated performance score, but can be planted in urban areas for their aesthetic value *per se*.

Among the indigenous species, *Phoenix dactylifera* was the only one evaluated as 'good' performer. However, *Ziziphus spina-christi* is qualified in 'poor' category, and *Acacia tortilis* was evaluated in 'very poor' category. *Delonix regia* has zero value of API grade, so it was assessed in 'not recommended' category.

TABLE III
EVALUATION OF API OF TREE SPECIES WITH SOME BIOLOGICAL AND SOCIO-ECONOMIC CHARACTERS

No.	Name of the species	Assessment parameters										API grade
		APTI	Tree habit	Canopy structure	Type of tree	Laminar		Economic importance	Hardiness	Grade allotted		
						Size	Texture			Total plus (+)	% Scoring	
1	*Acacia tortilis*	+	+	+	_	_	+	+	+	6	37.50	1
2	*Albizia lebbeck*	+	++	++	_	+	_	+	+	8	50.00	2
3	*Azadirachta indica*	++	++	++	_	+	_	+	+	9	56.25	3
4	*Bougainvillea spectabilis*	++	_	+	_	++	_	_	+	6	37.50	1
5	*Conocarpus erectuse*	++	+	++	+	++	+	_	+	10	62.50	4
6	*Delonix regia*	+	+	+	_	_	_	_	_	3	18.75	0
7	*Ficus benghalensis*	+	++	++	+	++	+	+	+	11	68.75	4
8	*Phoenix dactylifera*	+	+	+	+	++	+	++	+	10	62.50	4
9	*Pithcellobium dulce*	+++	+	+	+	+	_	++	+	10	62.50	4
10	*Ziziphus spina-christi*	++	+	+	_	_	+	+	+	7	43.75	2

TABLE IV
ANTICIPATED PERFORMANCE OF TREE SPECIES

Name of the tree species	Grade allotted		API value	Assessments
	Total plus	Percentage		
Ficus benghalensis	11	68.75	4	Good
Conocarpus erectuse	10	62.50	4	Good
Phoenix dactylifera	10	62.50	4	Good
Pithcellobium dulce	10	62.50	4	Good
Azadirachta indica	9	56.25	3	Moderate
Albizia lebbeck	8	50.00	2	Poor
Ziziphus spina-christi	7	43.75	2	Poor
Acacia tortilis	6	37.50	1	Very poor
Bougainvillea spectabilis	6	37.50	1	Very poor
Delonix regia	3	18.75	0	Not recommended

IV. CONCLUSION

All the evaluated ten species showed higher pollution tolerance capacity. Determining the APTI of the species is important before implementing large scale ecological pollution mitigation objectives. This study found that APTI is combined with their expected performance in the field, and their API values have changed completely. We need to take both APTI and API into account when making selection decisions for mass plantations such as green belt and social forestry programmes for the effective long-term air pollution management strategies.

ACKNOWLEDGMENT

Authors would like to thank the General Directorate of planting in Muscat for their technical information for selecting the species to be studied that might help them in selecting appropriate species for planting. We also like to thank Jamal Al-Sabahi and Jameela Al-Belushi for their support during the analysis and Lceak for helping in organizing the paper.

REFERENCES

[1] A. Bernatsky, “The influence of air pollution on plants and animals”, *Air Pollution Proceedings First European Congress*, Wageningen, pp. 382–395, 1969.

[2] J.L. Warren, “Green space for air pollution control”, School of Forest Resources, *Technical Report No. 50*, North Carolina State University, Raleigh, North Carolina, 1973.

[3] S.C. Santra, “Greenbelts for pollution abatements”, in *Advances in Environmental Science and Technology,* Vol. 1 (R.K. Trivedy, Ed.) (Ashish Publishing House, New Delhi, India, 1995, pp. 283–295.

[4] Y. Fukuoka, “Biometeorological studies on urban climate”, *Int. J. Biometeorology*, vol.40, no.1, pp. 54–57, 1997

[5] F.I. Khan and S.A. Abbasi, “Effective design of greenbelts using mathematical models”, *J. Hazardous Materials*. vol.81, pp. 33–65, 2001.

[6] F.I. Khan and S.A. Abbasi, “Design of greenbelt for an industrial complex based on mathematical modeling”, *Environ. Technol*., vol.23, no.7, pp. 799–811, 2002.

[7] R.M. Moraes, A. Klumpp, C.M. Furlan, G. Klumpp, M. Domingos, M.C.S. Rinaldi and I.F. Modesto, “Tropical fruit trees as bioindicators of industrial air pollution in southeast Brazil”, *Environ. Intern*., vol.28, pp. 367–374, 2002.

[8] A.S. Shannigrahi, R.C. Sharma and T. Fukushima, “Air pollution control by optimal green belt development for Victoria Memorial Monument, Kolkata (India)”, *Intern. J. Environ. Studies,* vol.60, no.3, pp. 241–249, 2003.

[9] A. S. Shannigrahi, T. Fukushima and R.C. Sharma, “Anticipated air pollution tolerance of some plant species considered for green belt development in and around an industrial/urban area in India: an overview”, *Intern. J. Environ. Studies,* vol.61, no.2, pp. 125-137. 2004.

[10] S.M. Seyyednejad and H. Koochak, “Some morphological and biochemical responses due to industrial air pollution in *Prosopis juliflora* (Swartz) DC plant”, J. Biol. Sci., vol.8, no.18, pp.1968–1974.2013. doi:10. 5897/AJAR10.652.

[11] A.H. Bu-Olayan and B.V. Thomas, “Assessment of the ultra-mercury levels in selected desert plants”, *Int. J. Environ. Sci. Technol*., vol.11, no.5, pp.1413–1420, 2014. doi:10.1007/s13762-013-0324-y

[12] A. H. Bu-Olayan and B. V. Thomas, “Combined effects of particulates dispersion and elemental analysis in desert plants: a modeling tool to air pollution”, *Int. J. Environ. Sci. Technol*., vol.13, pp.1299–1310, 2016. DOI 10.1007/s13762-016-0968-5

[13] D.N. Rao, “Sulphur dioxide pollution versus plant injury with special reference to fumigation and precipitation”, *Proc. Symposium on Air Pollution Control*, Vol. 1 (Indian Association for Air Pollution Control, New Delhi, India, 1983) pp. 91–96,1983.

[14] D.I. Arnon, “Copper enzymes in isolated chloroplasts”, *Plant Physiol*., vol.24, pp. 1–15, 1959.

[15] S.K. Singh and D.N. Rao, “Evaluation of plants for their tolerance to air pollution”, in *Proc. Symposium on Air Pollution Control*, Vol.1 (Indian Association for Air Pollution Control, New Delhi, India, 1983), pp. 218–224,1983.

[16] B.J. Prasad and D.N. Rao, “Relative sensitivity of a leguminous and a cereal crop to sulphur dioxide pollution”, *Environ. Pollut*., vol.29, pp. 59–70,1982.

[17] D.B. McCormick. And H.L. Greene, "Vitamins", in Burtis, C.A. and Ashwood E.R. (eds). Tietz *Textbook of Clinical Chemistry*. 3rd edn, W.B. Saunders Co., Philadelphia, 1999, pp. 999-1028.
[18] J.H. Roe and C.A. Kuether, "Estimation of ascorbic acid", *J. biol. Chem,* vol. 147, pp.3999, 1943
[19] S. Tiwari, S. Bansal and S. Rai, "Expected performance indices of some planted trees of Bhopal", *Indian J. Environ. Hlth*., vol.35, no.4, pp. 282–286,1993.
[20] P.O. Agbaire, "Air pollution tolerance indices (APTI) of some plants around Erhoike-Kokori oil exploration site of Delta state, Nigeria*". Int. J. Phys. Sci*., vol. 4, no.6, pp.366–368, 2009.