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Evaluation of air pollution tolerance index of some plants species in Kerbala city, Iraq

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Abstract

Plants provide a large surface area for impingement, absorption and accumulation of air pollutants to reduce the pollutants level in the environment, but in varying degrees. Therefore, air pollution tolerance index (APTI) was evaluated in industrial, urban and rural sites in seven plant species, namely, *Ziziphus spina christi, Conocarpus lancifolius, Ficusnitida, Dodonaeaviscosa, Eucalyptus camaldulensis, Nerium oleander, Oleaeuropaea,* which are abundant in the kerbala city, Iraq during 2017.The results showed that among seven plant species, *O.europaea* >*E. camaldulensis* are tolerant towards air pollution; Whereas, D. viscosa was found to be most sensitive. Dust accumulating capacity of the plant leaves has also been estimated. *C. lancifolius* leaves were found to have the highest dust deposition on leaf surfaces (6.45 mg/cm2), whereas, the lowest was noticed in *F. nitida* (0.99 mg/cm2).In addition, Pearson correlation between APTI with ascorbic acid showed significant correlation (r = 0.895).Tolerant plants species serve as suitable sinks to survive the air pollution and the sensitive plant species may be used as a bio-indicator of air quality.

Keywords: Air pollution tolerance index, Total chlorophyll content, Ascorbic acid,pH,Dust, Kerbala city.

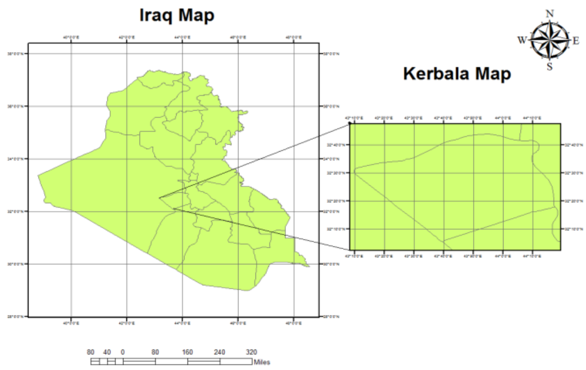
INTRODUCTION

The problem of urban air pollution has become a global issue due to increased urbanization, loss of vegetation cover, industrial emission and Increase vehicles which causes the deterioration of air quality by releasing pollutants to the atmosphere like toxic gases, particulates, heavy metals and polycyclic aromatic hydrocarbons (PAHs)(1,2). Air pollutants, affects not only the ambient air quality of urban, but also public health andassociated with respiratory and cardiovascular problem(3,4).The World Health Organization (WHO) estimates 1.3 million annual deaths worldwide, with an increased risk of respiratory and cardiovascular diseases (5) .Plants play an important role in purification of atmosphere and considered a natural tool for reducing the air pollution by absorbing toxic substances and capturing particulate matter. Plants leaves provides large surface area for impingement, absorption and accumulation of air pollutants and act as environmental sink(6).these pollutants in the atmospheremay impair the health of plants and animals, becauseplants are the initial acceptors of air pollution and used tomonitor the strength of the environment.Plants are different in their ability to remove and tolerate pollutants. Therefore, plants are classified according to air pollution tolerance index (APTI); tolerant and sensitive plants air pollution tolerance index is based on analysis of four biochemical parameters directly affected by air pollution: Ascorbic acid, total chlorophyll content, relative water content and pH of the leaves extract (7).The city of Kerbala is experiencing a steady increase in the population, in the number of tourists annually, and the decline of green areas as a result of urbanization in addition to the increase of various human activities and which led to the deterioration of air quality. Therefore, the present study was conducted to determine the tolerance of some plants to plant around and within the city in order to reduce air pollutants.

MATERIALS AND METHODS

Study area

Kerbala is located southwest of the Iraqi capital Baghdad, 105 km west of the Euphrates River on the edge of Western Sahara. It is located along a 44 ° and 40-minute line and at 33 ° and 31 ° latitude. Three areas were selected: the first is a rural area as a reference site away from sources of pollutionand the second is the city center where holy shrines, high traffic density, commercial centers and government institutions. and the last area is the industrial site, which is about 5 km from the city center.



Sample collected

Seven plant species were selected in all areas of the study as shown in Table 1 during the summer season (June). The leaves were collected randomly during the early morning and at a height of 1.5 to 2 meters. They were stored in a polythene bag and transferred to the laboratory for biochemical analysis and dust deposited on the leaves.

Measurement of dust deposition on the leaves

The area of individual leaf was calculated by tracing the outline of leaves on graph paper (8,9).The amount of dust deposition of leaf wascalculated by the following equation (10):

$W = W2 – W1 / A$

Where,

W= Amount of dust (mg/cm2).

W2=weight of leaf with dust.

W1= weight of leaf without dust.

A=Total area of leaf in cm2.

Bio-chemical analyses

Relative Leaf Water Content (RWC)

For relative leaf water content was determinedfollowing the method described by (11), and calculated with the formula:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

Where,

FW = Fresh weight

DW = dry weight

TW = turgid weight.

Total Chlorophyll Content (TCH)

About 0.2 g of leaf material was used for the study.The absorbance was measured through spectrophotometer at 645 nm and 663 nm.(12,13)

Leaf Extract pH
About 0.5 g of leaf material was ground to paste and dissolved in 50 ml of distilled water,this was then filtered and the pH of leaf extracted after determined aftercalibrating pH meter (7).

Ascorbic acid content
The ascorbic acid was evaluated following the method of (14).weighted 1 g of fresh leaf sample was placed in 25 ml conical flask, 10 ml of oxalic acid (0.05 M) solution was added and the samples were placed under shade for 24 h for extraction of ascorbic acid concentration. Each sample was then analysed ascorbic acid at 760 nm compared with the standard ascorbic acid (0.1 w/v).

Air pollution tolerance index (APTI) determination
The air pollution tolerance indexof seven common plants were determinedfollowing the method of (7). The formula of APTI is given as:

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

Where,
A = Ascorbic acid content (mg/g),
T = total chlorophyll (mg/g dry wt),
P = pH of leaf extract,R = relative water content of leaf (%).
Based on the APTI values the plants were conveniently grouped as follows; 1–11 as sensitive, 12–16 as intermediate and ≥17 APTIas tolerant (15).

Statistical analysis
Obtained data was presented as mean of three replicates ± standard deviation and Pearson correlation.for comparison between sites of each bio-chemical parameter of plant the results were statistically analyzed by using a one-way ANOVA by using SPSS software(version 22).

RESULTS AND DISCUSSION

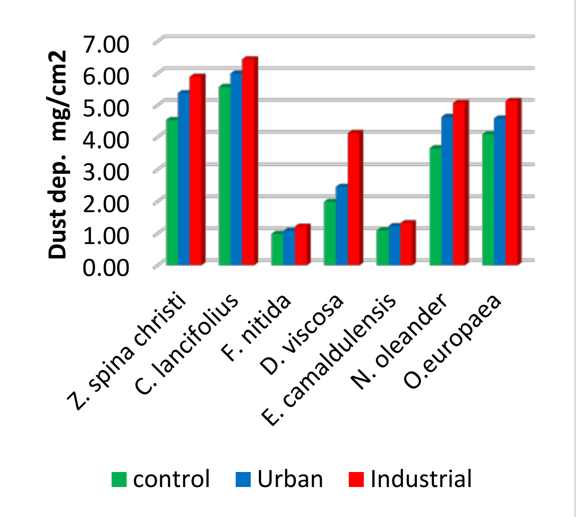


Figure 1: Dust deposition on the leaves of studied plant sites in kerbala city

Table 1: Variation of Total chlorophyll content (mg/g)(Mean ± S.D) of studied plants sites in kerbala city

S.N	Name of plant	Total chlorophyll content (mg/g)				
		Control	**Urban**	**Industrial**	**F value**	**P value**
1	*Z. spina christi*	1.50 ± 0.09	1.27 ± 0.03	1.10 ± 0.03	41.179	0.000[a]
2	*C. lancifolius*	2.11 ± 0.13	2.03 ± 0.23	1.45 ± 0.08	15.038	0.005[a]
3	*F. nitida*	2.06 ± 0.03	1.85 ± 0.57	0.17 ± 0.01	30.099	0.001[a]
4	*D. viscosa*	3.01 ± 0.03	2.46 ± 0.30	0.47 ± 0.06	173.961	0.000[a]
5	*E. camaldulensis*	4.76 ± 0.17	4.62 ± 0.39	1.96 ± 0.18	103.206	0.000[a]
6	*N. oleander*	1.60 ± 0.31	1.48 ± 0.08	0.38 ± 0.04	39.154	0.000[a]
7	*O.europaea*	2.88 ± 0.04	2.63 ± 0.37	1.02 ± 0.11	61.172	0.000[a]

[a] significant at P < 0.05

Table 2: Variation of pH (Mean ±S.D) of studied plants sites in kerbala city

S.N	Name of plant	pH				
		Control	**Urban**	**Industrial**	**F value**	**P value**
1	*Z. spina christi*	6.90 ± 0.20	6.30 ± 0.62	6.10 ± 0.10	3.545	0.096[b]
2	*C. lancifolius*	5.43 ± 0.15	5.23 ± 0.06	5.20 ± 0.00	5.375	0.046[a]
3	*F. nitida*	7.00 ± 0.20	7.10 ± 0.00	6.93 ± 0.12	1.187	0.368[b]
4	*D. viscosa*	5.57 ± 0.15	5.27 ± 0.12	4.83 ± 0.15	20.389	0.002[b]
5	*E. camaldulensis*	8.30 ± 0.10	7.67 ± 0.15	7.37 ± 0.15	36.059	0.000[a]
6	*N. oleander*	6.23 ± 0.06	6.20 ± 0.10	6.03 ± 0.21	1.824	0.241[b]
7	*O.europaea*	6.90 ± 0.10	6.60 ± 0.10	6.60 ± 0.00	13.5	0.006[a]

[a] significant at P < 0.05; [b] non- significant at P < 0.05

Table 3: Variation of Relative water content (%) (Mean ± S.D) of studied plants sites in kerbala city

S.N	Name of plant	Relative water content (%)				
		Control	**Urban**	**Industrial**	***F* value**	***P* value**
1	*Z. spina christi*	76.86 ± 1.63	70.33 ± 2.79	65.73 ± 5.38	7.152	0.026[a]
2	*C. lancifolius*	86.99 ± 1.48	84.97 ± 1.21	83.38 ± 2.24	3.405	0.103[b]
3	*F. nitida*	93.49 ± 0.64	92.70 ± 1.00	89.27 ± 1.37	13.828	0.006[a]
4	*D. viscosa*	69.45 ± 2.44	66.54± 2.41	55.53 ± 2.49	26.953	0.001[a]
5	*E. camaldulensis*	87.52 ± 1.93	82.62 ± 2.37	75.39 ± 4.18	12.478	0.007[a]
6	*N. oleander*	77.80 ± 5.69	78.99 ± 1.45	70.86 ± 2.32	4.353	0.068[b]
7	*O.europaea*	60.15 ± 2.08	56.85 ± 1.59	52.71 ± 1.32	14.516	0.005[a]

[a] significant at P < 0.05; [b] non- significant at P < 0.05

Table 4: Variation of Ascorbic acid (mg/g)(Mean ± S.D) of studied plants sites in kerbala city
[a] significant at P < 0.05; [b] non- significant at P < 0.05

S.N	Name of plant	Ascorbic acid (mg/g)				
		Control	**Urban**	**Industrial**	**F value**	**P value**
1	*Z. spina christi*	5.87 ± 0.55	6.16 ± 0.37	9.38 ± 0.70	37.199	0.000[a]
2	*C. lancifolius*	1.50 ± 0.29	2.05 ± 0.92	2.98 ± 0.25	5.041	0.052[b]
3	*F. nitida*	2.26 ± 0.13	2.49 ± 0.11	2.80 ± 0.04	22.59	0.002[a]
4	*D. viscosa*	2.19 ± 0.08	2.44 ± 0.07	2.81 ± 0.06	59.034	0.000[a]
5	*E. camaldulensis*	6.01 ± 0.22	7.40 ± 1.02	10.86 ± 1.70	14.2	0.005[a]
6	*N. oleander*	1.14 ± 0.06	1.23 ± 0.04	1.29 ± 0.07	4.935	0.054[b]
7	*O.europaea*	13.55 ± 0.52	14.69 ± 1.35	17.14 ± 0.15	14.39	0.005[a]

Table 5: Variation of Air pollution tolerance index (APTI)(Mean ± S.D) of studied plants sites in kerbala city
[a] significant at P < 0.05; [b] non- significant at P < 0.05

S.N	Name of plant	Air pollution tolerance index (APTI)				
		Control	**Urban**	**Industrial**	**F value**	**P value**
1	*Z. spina christi*	12.62 ± 0.46	11.68 ± 0.43	13.33 ± 0.68	7.073	0.026[a]
2	*C. lancifolius*	9.8 ± 0.35	9.99 ± 0.58	10.32 ± 0.23	1.064	0.402[b]
3	*F. nitida*	11.39 ± 0.08	11.50 ± 0.08	10.92 ± 0.12	22.59	0.002[a]
4	*D. viscosa*	8.83 ± 0.21	8.54 ± 0.17	7.05 ± 0.24	59.034	0.000[a]
5	*E. camaldulensis*	16.60 ± 0.41	17.35 ± 1.43	17.66 ± 1.16	0.754	0.511[b]
6	*N. oleander*	8.67 ± 0.51	8.84 ± 0.14	7.92 ± 0.26	4.935	0.054[b]
7	*O.europaea*	19.27 ± 0.30	19.25 ± 1.50	18.33 ± 0.41	1.023	0.415[b]

Table 6: Correlation between different biochemical parameters and APTI values

	Total chlorophyll (mg/g)	pH	Relative Water Content (%)	Ascorbic acid (mg/g)	Air pollution tolerance index (APTI)	Dust deposition(mg/cm^2)
Total chlorophyll (mg/g)	1	.464**0	.1830	.1650	.467**0	-0.425-**
pH		1	.287*0	.387**0	.675**0	-0.598-**
Relative Water Content (%)			1	-0.599-**	-0.240	-0.382-**
Ascorbic acid (mg/g)				1	.895**0	.0980
Air pollution tolerance index (APTI)					1	-0.164
Dust deposition(mg/cm^2)						1

**. Correlation is significant at the 0.01 level .

*. Correlation is significant at the 0.05 level.

Dust Deposition on Leaf Surface

Amount of dust deposition on leaf surfaces (mg/cm^2) was depicted in Fig. 1.The dust deposition of plant species varied from 0.99 to 5.58, 1.08 to 6.0 , and 1.22 to 6.45 mg/cm2 at control, urban and industrial site respectively.Highest dust retaining capacity is found in *C. lancifolius* 6.45 mg/cm^2 whereas, lowest was of *F. nitida* 0.99 6.45 (Fig. 1). The trend of dust Deposition on Leaf Surface was found as follows; *C. lancifolius* > *Z. spina christi* > *O.europaea* > *N. oleander* > *D. iscosa* > *E. camaldulensis* > *F. nitida* .The morphological characteristics which alone or in combination play a significant role in the interception of dust load from the ambience are: orientation of leaf on the main axis, size (leaf area in cm2) and shape, surface nature (smooth/striate), the presence or absence of trichomes and wax deposition (16,17). A moderate negative correlation was found betweendust deposition and pH of leaf extract (r = - 0.598; p<0.05) (Table 6)and insignificant low correlation exists with chlorophyll content (r = - 0.425; p<0.05), RWC (r = - 0.382; p<0.05) and APTI (r = - 0.164; p<0.05).The correlation coefficient values show that the increase in the amount of dust affects the plant's tolerance to pollution through reduced chlorophyll content as well as the low degree of pH that prevents the transformation of hexose to ascorbic acid.

Total Chlorophyll Content (TCH)

Photosynthetic pigment degradation has beenwidely considered as an indication of air pollution(18).so thattotal chlorophyll is used frequently to evaluate the impact of air pollutants on the rate of photosynthesis inplant leaves(19) the total chlorophyll content in 7 plant species were from 1.50 to 4.76 mg/g. at control site, 1.27 to 4.62 at urban site and 0.17 to 1.96 atindustrial(Table1). Total chlorophyll was found maximum in*E. camaldulensis*mg/gwhereas the lowest in *F. nitida*.The results of the present study showed that the total chlorophyll content in all plants varies with the state of pollution in the area.The reduction of chlorophyll tends towards the urban and the industrial sites. The decrease in total chlorophyll content may be due to the accumulation of dust on the plant leaf that prevents the gaseous exchange process or the intensity of light that affect photosynthesis and metabolism. This belief reinforces the negative correlation(r = - 0.425; p<0.05) between chlorophyll content and the amount of dust deposited on leaves and some published studies(20,21).

pH extracts of Leaf

The results of the study showed low pH in urban and industrial sites compared to the control site.The pH of the leaf extracts ranged from 4.83 to 8.30 (Table 2). Maximum leaf extract pH was found in *E. camaldulensis* (8.30) at control site, whereas,minimum was observed in *D. viscosa* (4.83) at industrial site.Presence of acidic pollutants such as SOx and NOx in ambient air, cause lowering of leaf extracts pH. Plants were found to be highly vulnerable to these pollutants, and the sensitive ones act as an indicator of gaseous air pollutants (22,23). In present study a positive correlation was found between pH of leaf extract and ascorbic acid and ($r = 0.387$; $p<0.05$) and thus high pH at control site assisted the tolerance capacity of plants towards air pollutants by increasing the rate of conversion of hexose sugar to ascorbic acid whereas, lower pH at industrial sites has caused reduction in photosynthesis rate by disturbing the gaseous exchange throughstomata(24,23).

Relative Leaf Water Content (RWC)

High water content within a plant body helps maintain its physiological balance under stressful conditions, such as exposure to air pollution (25).Relative water content in the plant is associated with protoplasmic permeability in cells which causes loss of water and dissolved nutrients, resulting in early senescence of leaves(26). Therefore the plants with high relative water content under polluted conditions may be tolerant to pollutants. (27).The leaf RWC ranges in the selected plant species were from (52.71%) to (89.27%) in industrial site(92.70%) to (56.85%) in urban site (93.49%) to(60.15%) in control site(Table 3). The highest and lowest values were obtained from *O.europaea* and *F. nitida*, respectively.Decrease of RWC in industrial site may be due to the dust deposited on the leaves which affects the process of transpiration due to the closure of the stomata and the absorption of water from the tissues of the leaf and the correlation coefficient showed a weak negative correlation ($r = -0.382$; $p<0.05$) between the RWC and dust deposited on the leaves.

Ascorbic acid content

The results showed a significant increase in the content of ascorbic acid in the industrial site compared to urban and control sites (Table 4)and the increase was found maximum at industrial site (17.14). Ascorbic acid ranges in the selected plant species were from 1.14 to 13.55 in control site, (1.23) to (14.69) in urban site and (1.29 to 17.14) in industrial sites. The highest and lowest values were obtained from *O.europaea* and *N. oleander*,respectively.(28,29) are of theopinion that higher ascorbic acid content of the plant is a sign of its tolerance against sulphur dioxide pollution. Ascorbic acid plays important role in cell division, defense and cellwall synthesis. It is a natural detoxicant, which may prevent the effects of air pollutants in the plant tissues (30). Pollution load dependent increase in ascorbic acid content of all the plant species may be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation of $SO2$ to $SO3$ where sulfites are generated from $SO2$ absorbed (27).The results of the study are well matched by previous reports that plants that keep ascorbic acid high under pollutant conditions are tolerant to air pollution.(31).

Air pollution tolerance index (APTI)

The results of air pollution tolerance index(APTI) calculated for each plant species studied at different sites is mentioned in the above (Table 5)*O.europaea* exhibited the highest APTI value at all the sites followed by *E. camaldulensis*>*Z. spina christi* followed by *F. nitida* >*C. lancifolius* >*N. oleander*>*D. viscosa.* Determining the tolerant and susceptible species is essential for the reduction of pollution in urban and industrial sites (32). A high positive correlation was found between APTI and ascorbic acid ($r = 0.895$; $p<0.05$) and moderate positive correlation exists between pH of leaf extract ($r = 0.675$; $p<0.05$) While a weak positive correlation was found between chlorophyll and APTI ($r = 0.467$; $p<0.05$). Some previous studies have also indicated a similar correlation between biochemical parameters and APTI (33,19). It indicates that, as the pollution load increases ascorbic acid content in plant leaf also increases to combat the stressed condition. Increased ascorbic acidcontent maintains cell division and cell membrane stability in plants by scavenging free radicals and reactive oxygen species during photo-oxidation of $SO2$ to $SO3$ (34,35).

CONCLUSION

The APTI determination provides a reliable method for screening large number of plants with respect to their susceptibility to air pollutants. It is an easy and inexpensive way to bio-monitor urban air pollution for adoption under field conditions without the use of expensive tools or devices. Various researchers have used the APTI to categorized the plant species into three categories viz. sensitive, intermediate, and tolerant (15,36). Plants with APTI value ≤11 are considered to be sensitive, while those with APTI value ranged from 12 to 16 classified as intermediate, and APTI value of ≥17 are known to be tolerant (11). Based on the results of the current study, the cultivation of *O.europaea* and *E. camaldulensis* as well as *Z. spina Christi* may be proposed to develop a design on greenbelt around or within the city, while others can be used as bio-indicators for air pollution.

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