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Air Pollution Tolerance Indices of Some Plants Around Industrial Zone in South of Iran

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ABSTRACT

The study examined Air Pollution Tolerance Indices (APTI) of four plant species around petrochemical station in south west of Iran and compared with unpolluted area. Four physiological and biochemical parameters; ascorbic acid content (AA), leaf Relative Water Content (RWC), leaf extract pH and total leaf chlorophyll (TCh) were used to compute the APTI values. The result showed that combining variety of these parameters gave a more reliable result than those of individual parameter. The result showed order of tolerance in polluted area as *E. camaldulensis* (8/5)> *A. lebbeck* (8/1)> *C. salignus* (7/9)> *P. juliflora* (5/8) and in unpolluted area as *E. camaldulensis* (8/4)> *A. lebbeck* (6/7)> *C. salignus* (6/2)> *P. juliflora* (6/6). These results show that in cases that APTI increase from control site to polluted site improve the species tolerance to pollution stress.

Key words: Air pollution, tolerance, APTI, ascorbic acid, chlorophyll

INTRODUCTION

Air pollution is a major problem arising mainly from industrialization (Odilara *et al*., 2006). Air pollution is the human introduction into the atmosphere of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organism, or damage the environment. Pollutants could be classified as either primary or secondary. Pollutants that are pumped into the atmosphere and directly pollute the air are called primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutant (Agbaire and Esiefarienrhe, 2009).

Several contributors agree that air pollution affects plant growth adversely (Rao, 2006; Bhatia, 2006). In spite of adverse affections of these pollutants, there are a few reports on pollution tolerant plants (Nivane *et al*., 2001). Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, {reg} oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment (Escobedo *et al*., 2008). Studies have also shown the impacts of air pollution on ascorbic acid content (Hoque *et al*., 2007), chlorophyll content (Flowers *et al*., 2007), leaf extract pH (Klumpp *et al*., 2000) and relative water content (Rao, 1979). These separate parameters gave conflicting results for same species (Han *et al*., 1995). For the reason that single parameter may not provide a clear picture of the

pollution-induced changes, air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plants species (Liu and Ding, 2008).

Sensitivity and response of plants to air pollutants is variable. The plant species which are more sensitive act as biological indicators of air pollution. The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors determining resistance and susceptibility. Using plants, as indicator of air pollution is the possibility of synergistic action of pollutants (Lakshmi *et al*., 2009). Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Agbaire, 2009).

Singh and Verma (2007) by using the data obtained from detailed biochemical estimations of plant samples (including chlorophyll, ascorbic acid content, pH and relative water content), calculated the APTI.

In the present study, in order to determination of tolerance or sensitivity of four species plants (*Callistemon salignus, Albizia lebbeck, Eucalyptus camaldulensis* and *Prosopis juliflora*) the APTI have been identified, using four biochemical parameters. The index and all biochemical factors were computed in both polluted and unpolluted region for each type of trees.

MATERIALS AND METHODS

The samples were taken from the tree species in two places, polluted area (round petrochemical field located in the southeast of Iran) and unpolluted region (control site). Plants were randomly selected from the immediate vicinity of the station. Three replicates of fully matured leaves were used and immediately taken to the laboratory in the ice for analysis. Samples were preserved in a refrigerator. The experiments were replicated three times for each biological factor.

Relative leaf water content (RWC): According to the method described by Liu and Ding (2008) relative leaf water content was determined and calculated with the formula:

$$RWC = [(FW - DW)/(TW-DW)]\times 100$$

FW = fresh weight, DW = dry weight and TW = turgid weight

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

Total chlorophyll content (T): This was done according to method described by Lichtenthaler (1987). 0.2 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 text-tube and centrifuged at 2,500 rpm for 3 min. The supernatant was then collected and the absorbance was then taken at 645/8 nm, 663/2 and 470 nm using a spectrophotometer. Calculations were made using the formula below:

$$\text{Chl.a } (\mu g\ mL^{-1}) = 12/25A_{663/2}\text{-}2/79A_{646/8}$$
$$\text{Chl.b } (\mu g\ mL^{-1}) = 21/50A_{646/8}\text{-}5/1A_{663/2}$$
$$\text{Chl. Total } (\mu g\ mL^{-1}) = \text{Chl.a+Chl.b}$$

The results converted from μg mL^{-1} to mg g^{-1} dry weight.

Leaf extract pH: Five gram of the fresh leaves was homogenized in 10 mL deionized water. This was then filtered and the pH of leaf extracted determined after calibrating pH meter with buffer solution of pH 4 and 9 (Agbaire, 2009).

Ascorbic Acid (AA) content analysis: Ascorbic acid content (express as mg/gDw) was measured using spectrophotometric method. The absorbance of supernatant was taken in 520 nm (Smirnoff, 2000).

APTI determination: The air pollution tolerance indices of four plants were determined following the method of Liu and Ding (2008). The formula of APTI is given as:

APTI = [A(T+P) + R]/10
Where A = Ascorbic acid content (mg g^{-1} Dw), T = total chlorophyll
(mg g^{-1} Dw), P = pH of leaf extract and R = relative water content of leaf (%)

RESULTS

Air Pollution Tolerance Index (APTI) was calculated for four plant species growing in industrial area in both polluted and control site and the data is presented in Table 1. All biochemical parameters that were analyzed for ATPI played significant roll to determine the tolerance and susceptibility for plant species. According to Table 1, the result of determining the concentration of Ascorbic Acid (AA) for *C. salignus*, *A. lebbeck*, *E. camaldulensis* and *P. juliflora* growth in unpolluted area are 0/28, 0/24, 0/25 and 0/30 mg per gram dry weight (mg g^{-1} dry wt.) and in polluted area are 0/43, 0/31, 0/31 and 0/30 mg per gram dry weight (mg g^{-1} dry wt.), respectively. The results of total chlorophyll (T) concentration for *C. salignus*, *A. lebbeck, E. camaldulensis* and *P. juliflora* growth in unpolluted area are 0/8, 4/7, 3/59 and 7/69 mg g^{-1} dry wt and in polluted area are 2/20, 5, 3/61 and 6/64 mg/g dry wt, respectively. The third factor, pH (P), for the *C. salignus*, *A. lebbeck*, *E. camaldulensis* and *P. juliflora* growth in unpolluted area are 5/6, 6/8, 5, 5/8 and in polluted area are 4/8, 5/4, 4/6, 5/4, respectively. Moreover, forth factor, relative water content (R) that is determined by using specific formula, for *C. salignus*, *A. lebbeck*, *E. camaldulensis* and *P. juliflora* grown in unpolluted region are 77/24, 79/79, 82/79, 62/70 and for species grown in polluted area are 76/85, 78/14, 82/47, 55/00 shown in the Table 1, respectively. As a conclusion the final index that calculated through specific formula according to material and method described, for *C. salignus*, *A. lebbeck*, *E. camaldulensis* and *P. juliflora* grown in unpolluted region are 6/2, 6/7, 8/4, 6/6 and for plants grown in polluted region are 7/9, 8/1, 8/5 and 5/8, respectively.

Table 1: Air pollution tolerance index

APTI	R (%)	P	T (mg g^{-1} Dw)	A (mg g^{-1} Dw)	Plant species
7/9	76/85	4/8*	2/20**	0/43*	(1) *C. salignus*
6/2	77/24	5/6*	0/8**	0/28*	(2) *C. salignus*
8/1	78/14	5/4*	5*	0/31*	(1) *A. lebbeck*
6/7	79/79	6/8*	4/7*	0/24*	(2) *A. lebbeck*
8/5	82/47	4/6	3/61	0/31*	(1) *E. camaldulensis*
8/4	82/79	5	3/59	0/25*	(2) *E. camaldulensis*
5/8	55/0	5/4*	6/64	0/30	(1) *P. juliflora*
6/6	62/70	5/8*	7/69	0/30	(2) *P. juliflora*

A: Ascorbic acid content; T: Total chlorophyll; P: pH; R: Water relative content (RWC); APTI: Air pollution tolerance index – (1): polluted - (2): unpolluted; *,**respectively means significant in level of 0/05 and 0/01

DISCUSSION

The ability of each plant species to absorb and adsorb pollutants by their foliar surface varies greatly and depends on several biochemical, physiological and morphological characteristics (Singh and Verma, 2007). The sensitive species help to indicate air pollution and tolerant ones help in abatement of air pollution. The tolerant species of plants function as pollution sink and therefore a number of environmental benefits can be obtained by planting tolerant species in polluted areas. For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential (Lakshmi *et al*., 2009). There are many Factors controlling tolerance in plants. For instance, the importance of pH in modifying the toxicity of SO_2 has been shown. It was reported that Plants with lower pH are more susceptible, while those with pH around 7 are more tolerant (Singh and Verma, 2007).

Another parameter that may decide the tolerance of plant to air pollution is ascorbic acid content, which is also called vitamin C. It plays a significant role in light reaction of photosynthesis (Singh and Verma, 2007), activates defense mechanism (Arora *et al*., 2002) and under stress condition, it can replace water from light reaction II (Singh and Verma, 2007). Ascorbic acid, a natural antioxidant in plants has been shown to play an important role in pollution tolerance (Joshi and Swami, 2007).

Ascorbic acid plays a role in cell wall synthesis, defense and cell division. It is also a strong reducer and plays important roles in photosynthetic carbon fixation, with the reducing power directly proportional to its concentration. So it has been given top priority and used as a multiplication factor in the formula. High pH may increase the efficiency of conversion from hexose sugar to AA, while low leaf extract pH showed good correlation with sensitivity to air pollution (Escobedo *et al*., 2008; Pasqualini *et al*., 2001; Conklin, 2001; Liu and Ding, 2008).

Depletion in chlorophyll immediately causes a decrease in productivity of plant and subsequently plant exhibits poor vigor. Therefore, plants maintaining their chlorophyll even under polluted environment are said to be tolerant ones (Singh and Verma, 2007).

Total chlorophyll (TCh) is also related to AA productivity and AA is concentrated mainly in chloroplasts. Photosynthetic efficiency was noted strongly dependent on leaf pH. Photosynthesis reduced in plants when the leaf pH was low. Thus, in the proposed APTI formula, P, the leaf extract pH and T, the TCh have been added together and then multiplied with AA content (Liu and Ding, 2008).

Water is crucial prerequisite for plant life; the shortage of water may cause severe stress to terrestrial plants (Singh and Verma, 2007). High water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high. High RWC favors drought resistance in plants. If the leaf transpiration rate reduces due to the air pollution, plant cannot live well due to losing its engine that pulls water up from the roots to supply photosynthesis (1-2% of the total). Then, the plants neither bring minerals from the roots to leaf where biosynthesis occurs, nor cool the leaf. Therefore, the product of AA and sum of leaf extract pH and total chlorophyll is added with R, the RWC in the APTI formula (Liu and Ding, 2008).

Based on the APTI values the plants were conveniently grouped as follows based on the reports of Lakshmi *et al*. (2009):

APTI value	: Response
30 to 100	: Tolerant
29 to 17	: Intermediate
16 to 1	: Sensitive
<1	: Very sensitive

In the current study every four species showed the APTI values of less than 16 which were designated as sensitive range.

However, all samples are sensitive ones (1< APTI<16) however *P. juliflora* is the most sensitive and its APTI showed reduction in polluted site as compared with control site. This decrease may be due to decreased chlorophyll contents in the plant in respond to air pollution due to the reason of damage. Regarding other samples, ascorbic acid and chlorophyll level showed increase in polluted site in comparison with unpolluted site. In fact, *P. juliflora* exhibited more sensitiveness that can be caused from reduced chlorophyll contents.

Different plant species shows considerable variation in their susceptibility to air pollution (Singh and Rao, 1983). In the present study, among the studied species *E. camaldulensis* has highest APTI value and followed with APTI value for *A. lebbeck*.

In conclusion, APTI determination for plants is important because in recent century by increasing industrialization, danger of deforestation due to air pollution threatening the environment. Therefore results of such studies are handy for future planning. It is worth noting that combining a variety of parameters gave a more reliable result than when based on a single biochemical parameter (Agbaire, 2009).

Plants have the potential to serve as excellent quantitative and qualitative indices of pollution (Jyothi and Jaya, 2010).

Since, biomonitoring of plants is an important tool to evaluate the impact of air pollution on plants, the *C. salignus, A. lebbeck, E. camaldulensis* and *P. juliflora*, can be used as biomonitors of air pollution stress.

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