Pollution, 4(3): 439-446, Summer 2018
DOI: 10.22059/poll.2017.242396.324
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

A Comparative Study of Air Pollution Tolerance Index (APTI) of Some Fruit Plant Species Growing in the Industrial Area of Sfax, Tunisia

Zouari, M.[1,2*], Elloumi, N.[3], Mezghani, I.[4], Labrousse, P.[2], Ben Rouina, B.[1], Ben Abdallah, F.[4] and Ben Ahmed, C.[4]

1. Laboratory of Improvement of Olive Productivity and Product Quality, Olive Tree Institute, Sfax, Tunisia
2. Laboratory of Botany and Cryptogamy, Faculty of Pharmacy, Limoges, University of Limoges, France
3. Laboratory of Environment Engineering and Ecotechnology, High Institute of Biotechnology of Sfax, University of Sfax, Sfax, Tunisia
4. Laboratory of Plant Biodiversity and Dynamics of Ecosystems in Arid Area, Faculty of Sciences of Sfax, University of Sfax, Sfax, Tunisia

Received: 24.09.2017 Accepted: 03.12.2017

ABSTRACT: Air Pollution Tolerance Index (APTI) is an important tool to screen out plants, based on their tolerance or sensitivity level to different air pollutants. The present study has been conducted to evaluate APTI of four different plant species around polluted and unpolluted industrial site in Sfax, Tunisia. In order to determine the susceptibility level of the selected plant species, it has used four physiological and biochemical parameters like leaf relative water content, ascorbic acid content, chlorophyll content, and leaf pH to compute the APTI values. The results of the study reveal that among the four studied plant species, *Olea europaea* (APTI = 20.09) and *Phoenix dactylifera* (APTI = 17.10) are the most tolerant species, whereas *Ficus carica* (APTI = 8.87) and *Morus alba* (APTI = 7.49) are the most sensitive ones. The present study suggests that the most tolerant species, i.e., olive and date palm, can be planted in polluted sites for both air pollution abatement and aesthetic improvement. While, the sensitive species, namely common figand white Mulberry, help indicating air pollution and should be utilized as bio-indicators.

Keywords: Air Pollution Tolerance Index, Ascorbic acid, Chlorophyll, Bio-indicator, Tolerant

INTRODUCTION

Air is the most important resource for life sustenance. All organisms are in need clean air for their healthy growth and development. However, nowadays it has become highly polluted as a result of urbanization and industrialization (Abbaslou et al., 2017; Masoudi et al., 2017). Air pollution may be defined as any atmospheric condition, in which certain substances exist in such concentrations to produce undesirable effects on both man and ecosystem (Seyyednejad et al., 2017).

Plants are an integral basis for all ecosystems, most likely to be affected by air pollution, given that they are stationary and continuously exposed to chemical pollutants

* Corresponding Author, Email: mohamedzouari2@gmail.com

from the surrounding atmosphere. The impacts of air pollution on ascorbic acid and chlorophyll contents, leaf extract pH, and relative water content have been extensively studied (e.g. Rai & Panda, 2014; Nadgórska-Socha et al., 2017; Kaur and Nagpal, 2017). These independent parameters give conflicting results even for the same species; however, Air Pollution Tolerance Index (APTI) has been used as a more precise parameter for landscapers to identify and select both tolerant and sensitive plant species to air pollution (Sing et al., 1991). The sensitive species can serve as biological indicators for air pollution, whereas, the tolerant ones are considered as sink, able to be used to combat pollutants' level in that specific environment (Prajapati et al., 2008; Maity et al., 2017). According to Zhang et al. (2016), not only do tolerant plants help attenuate air pollution, they also maintain the ecological balance, controlling soil erosion and improving aesthetic aspects of such polluted areas.

Nowadays, Sfax Region (in Southern Tunisia) accommodates one of the most important industrial complexes, among which the lead smelter and phosphate fertilizer factories constitute the main source of pollution. Fluoride (F) and heavy metals (particularly Pb and Cd) are among the most phytotoxic air pollutants, emitted from these industries (Ben Abdallah et al., 1990; Elloumi et al., 2003; Mezghani et al., 2005; Elloumi et al., 2017). Thus, the current study aims at finding out pollution tolerance levels of dominant plant species of Sfax (namely the olive, date palm, common fig, and white mulberry) so that appropriate plants could be selected and grown in the area, expected to perform well for the development of a greener environment for a long way ahead.

MATERIALS AND METHODS

The studied plants species were taken from two experimental stations, located along the Sfax Coast: a) the Polluted Site (PS), 1 km off the lead smelter and phosphate fertilizer industries (34°70’N, 10°72’E) and b) the Control Site (CS), 20 km away from the western industries (34°54’N, 10°58’E). The main pollutants, emitted by these factories, included F, Cd, and Pb (Mezghani et al., 2005; Elloumi et al., 2017). There were no pollution sources in the control site, commonly used as an unpolluted site. The olive plants in both sites (PS and CS) were similar in age, plant density, and training system, each planted in a loamy sand soil. Polluted and control sites were submitted to an arid climate and were exposed to very similar geochemical, ecological, and climatic conditions. The mean annual precipitation was 220 mm, with the minimum mean precipitation (1 mm) occurring in July, while the maximum mean precipitation (300 mm) belonging to December. The mean annual temperature was 19.0°C with the minimum mean temperature (6.5±2°C) being in January and the maximum mean temperature (32.5±2.5°C) in July. The polluted and control sites lay 1.8 and 2.3 km off the sea, respectively, thus neither of them was submitted to sea sprays.

Four dominant plant species at both polluted and control sites were selected. These were olive (*Olea europaea* L.), date palm (*Phoenix dactylifera* L.), common fig (*Ficus carica* L.), and white Mulberry (*Morus alba* L.). For each plant species, samples of mature leaves were taken from several branches on all sides of the plant. In all, five replicates (n = 5) of leaf samples were harvested from 5 different plants at each site. In both sites, sampling was carried out in June 2011 during the flowering season. Leaves were thoroughly washed in distilled water to remove deposited particles from the surface.

Leaf relative water content (LRWC) was determined by means of the following equation, described by Esfahani et al. (2013):

$$LRWC\ (\%) = (FW - DW) / (TW - DW) \times 100$$

Leaves were excised before dawn and weighed in order to measure fresh weight (FW). Afterwards, they added to distilled water and kept in the dark for 24 h for rehydration. The next morning, leaf turgid weight (TW) was recorded. The dry weight (DW) was measured when the leaves were dried at 70°C for 72 h until reaching a constant weight.

For chlorophyll analyses, 0.5 g of fresh leaves were ground in 5 ml of 80% acetone solutions, using pestle and mortar. After filtration, extracts were adjusted to 15 ml with 80% acetone solution. Total chlorophyll contents were determined by means of a uv/vis spectrophotometer (Perkin Elmer, Norwalk, USA), based on the method of Lichtenthaler & Wellburn (1983) via the following equations:

$$\text{Chlorophyll total } (\mu g/ml) = 17.32\ (A_{645}) + 7.18\ (A_{663})$$

The pH of the leaf extract was determined with a pH-meter. Five grams of a leaf sample was digested and added to 50 ml of deionized water, and the resultant suspension was measured with a pH- meter (jenway, UK).

The contents of the ascorbic acid were assayed as described by Ali et al. (2013). The extract was prepared by grinding 1 g of fresh leaf with 5 ml of 10% trichloroacetic acid (TCA), centrifuged at 1235×*g* for 20 min. To 0.5 ml of the extract, 1 ml of 6 mM 2,4-dinitrophenylhydrazine-thiourea-$CuSO_4$ (DTC) reagent was added, then to be incubated at 37°C for 3 h, followed by 0.75 ml of ice-cold 65% H_2SO_4, which was allowed to stay at 30°C for 30 min. The resultant color was read at 520 nm with uv/vis spectrophotometer (Perkin Elmer, Norwalk, USA). Ascorbic acid contents were determined, using a standard curve prepared with ascorbic acid.

Air Pollution Tolerance Index (APTI) was determined according to the following formula, used by Singh et al (1991):

$$APTI = [A\ (T+P)] + R]/10$$

Where A is Ascorbic Acid (mg/g); T, Total chlorophyll (mg/g); P, pH of the leaf extract; and R, Relative water contents of the leaves (%).

To choose tolerant plants, the following criteria (Singh et al., 1991) were used:

* APTI-based tolerance, in evergreen species: Sensitive (S) < 12; intermediately tolerant (I) 13-16; moderately tolerant (M) 17-20; and Tolerant (T) >20.

** APTI-based tolerance in deciduous species: Sensitive (S) <14; intermediately tolerant (I) 15-19; moderately tolerant (M) 20-24; and tolerant (T) >24.

A one-way analysis of variance was performed with SPSS software, v. 17.0, and Duncan test ($p \leq 0.05$) was used to compare averages of all measured parameters.

RESULTS AND DISCUSSION

Leaf Relative Water Content (LRWC) is a useful indicator of plant's water status. Under stressful conditions, a large quantity of water in plant tissue helps maintaining its physiological balance (Seyyednejad et al., 2017). In this study, the LRWC registered in polluted site remained unaltered in olive and date palm, whereas it declined significantly ($p \leq 0.05$) by 9% and 12% in common fig and white mulberry, respectively, compared to the values registered in the control site (Fig. 1).

It was reported that air pollutants increase cell permeability, causing loss of water and dissolved nutrients, resulting in early senescence of the leaves (Bakiyaraj & Ayyappan, 2014). Moreover, reduction in LRWC of plant species, grown inside the polluted zone, could be explained by the reduction of transpiration rate in the leaves. In this situation, the plant loses its ability to raise water from the roots to the leaves. In the current study, LRWC preservation in olive and date palm plants can render them resistant to pollution stress. According to Rai & Panda

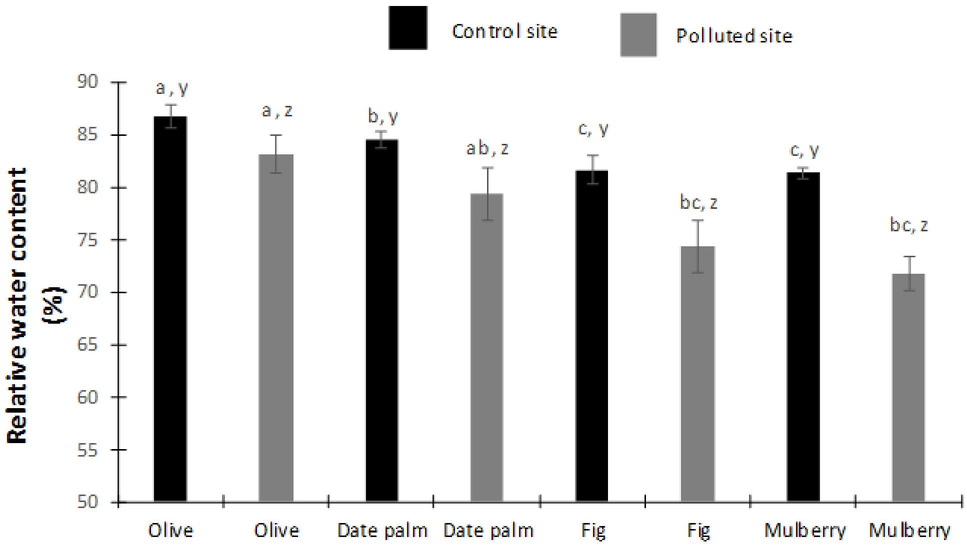

Fig. 1. Relative water content of different studied plant species in control and polluted sites. Values represent the mean of 5 replications per treatment ± SD. Different letters (a-c) indicate significant differences ($p \leq 0.05$) between plant species within each site, treated separately. Finally, different letters (y, z) indicate significant differences ($p \leq 0.05$) between the sites within each plant species, treated separately.

(2014), high LRWC under stress condition is an indication of plant species' tolerance.

Chlorophyll content of the plants signifies its photosynthetic capacity along with its growth and development. According to Achakzai et al. (2017) degradation of photosynthetic pigments was widely used as an indicator of pollution stress. It is well evident that chlorophyll content varies with tolerance as well as the plant species' sensitivity. In other words, the higher the sensitive nature of the plant to pollution stress, the lower the chlorophyll content (Rai & Panda, 2014). Results of the present study indicated a decline in total chlorophyll content in different plants species, growing in the polluted site, compared to the unpolluted one. Fig. 2 shows that the significant decrease ($p \leq 0.05$) in chlorophyll content was more important in *Ficus carica* (22%) and *Morus alba* (62%) rather than *Olea europaea* (2%) and *Phoenix dactylifera* (3%). Obtained results were in line with those of Qadir & Siddiqui (2014), who reported that one of the most common impacts of air pollution was gradual disappearance of chlorophyll and concomitant leaf chlorosis, which may be associated with a consequent decrease in photosynthetic capacity. According to Elloumi et al. (2017), the decrease of chlorophyll content in *Ficus carica* and *Morus alba* plants, exposed to air pollution stress, could be due to: (a) the inhibition of important enzymes, such as δ-aminolevulinic acid dehydratase and protochlorophyllide reductase, involved in chlorophyll biosynthesis; (b) Mg and Zn deficiency, required for synthesis of chlorophylls; and/or (c) deposition of dust on the leaf, which adversely affects metabolic activity. Furthermore, substitution of the central Mg in chlorophyll with fluoride was an important cause of chlorophyll damage in plants, growing in heavy-metal-contaminated environments (Wickramasinghe et al., 2017). This substitution may prevent the capture of photosynthetic light, resulting in a breakdown of photosynthesis in common fig and white Mulberry plants.

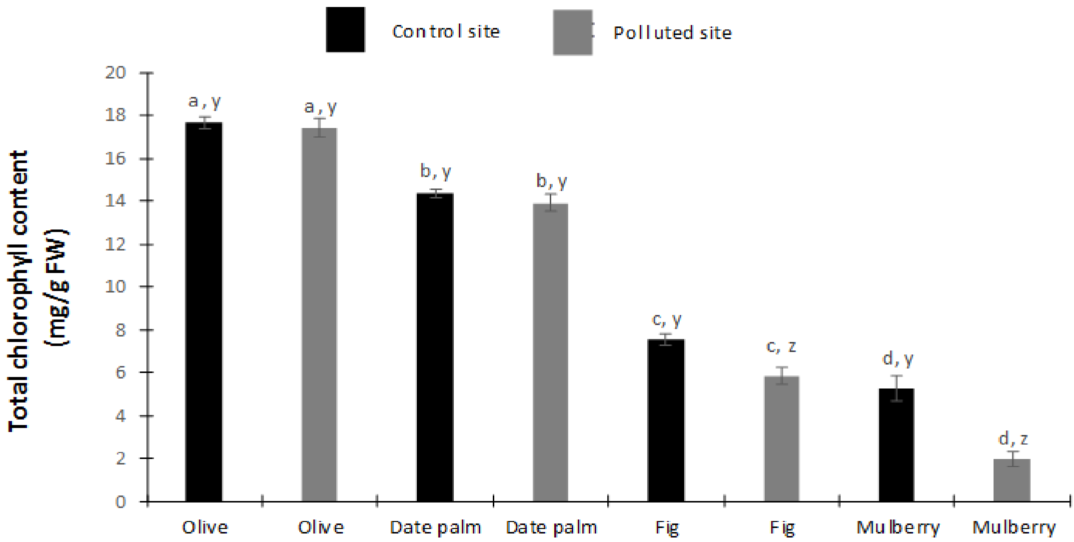

Fig. 2. Total chlorophyll content of different studied plant species in control and polluted sites. Values represent the mean of 5 replications per treatment ± SD. Different letters (a-d) indicate significant differences ($p \leq 0.05$) between plant species within each site, treated separately. Different letters (y, z) indicate significant differences ($p \leq 0.05$) between sites within each plant species, treated separately.

The pH plays a significant role in plants' physiological processes. Most of the enzymes, involved in biological activities of the organism, require relatively high pH for their effective functions. Consequently, plants with relatively low pH are more susceptible, while those whose pH is around 7 are tolerant (Nadgórska-Socha et al., 2017; Achakzai et al., 2017). In this study, the leaves' pH, measured in olive and date palm plants, from both polluted and control sites, turned out to be the same, whereas, in contrast to the control site, the leaves' pH in common fig and white Mulberry plants from the industrial area dropped significantly ($p \leq 0.05$) by 11% and 14%, respectively (Fig. 3).

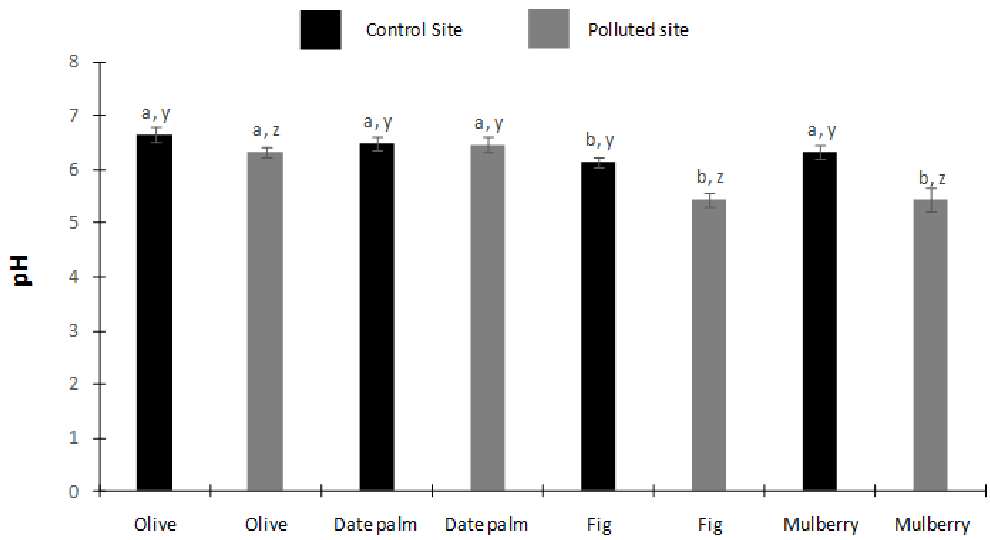

Fig. 3. pH of leaf extract of different studied plant species in control and polluted sites. Values represent the mean of 5 replications per treatment ± SD. Different letters (a, b) indicate significant differences ($p \leq 0.05$) between plant species within each site, treated separately. Different letters (y, z) indicate significant differences ($p \leq 0.05$) between the sites within each plant species, treated separately.

Fig. 4 shows a significant decrease ($p \leq 0.05$) in ascorbic acid contents of *Ficus carica* and *Morus alba* plants from polluted site, as compared to the control one. Interestingly, *Olea europaea* and *Phoenix dactylifera* showed relatively high contents of ascorbic acid in industrial area, in comparison to the control one. The highest ascorbic acid was recorded in *Olea europaea*, followed by *Phoenix dactylifera*. According to Zhang et al. (2016) ascorbic acid imparts tolerance to air pollution in plants, since it activates many physiological and defense mechanisms. It can act as: (i) an electron donator to various enzymatic and non-enzymatic reactions, (ii) a reducing agent, and (iii) an antioxidant. Esfahani et al. (2013) observed that the reducing power of ascorbic acid depends directly on its concentration; therefore, plants that maintain high ascorbic acid levels even under polluted conditions are considered tolerant. Reduction of ascorbic acid, found in the leaves of *Ficus carica* and *Morus alba* from the polluted site, suggested its sensitive nature to air pollution, particularly resulting from industrial waste.

Air Pollution Tolerance Index (APTI) plays an important role to determine sensitivity as well as tolerance of plant species to pollution levels. Sing et al. (1991) classified plants into four groups, based on their APTI values, namely (a) sensitive, (b) intermediately tolerant, (c) moderately tolerant, and (d) tolerant species. Based on Table 1, it can be seen that different plants respond differently to air pollutants.

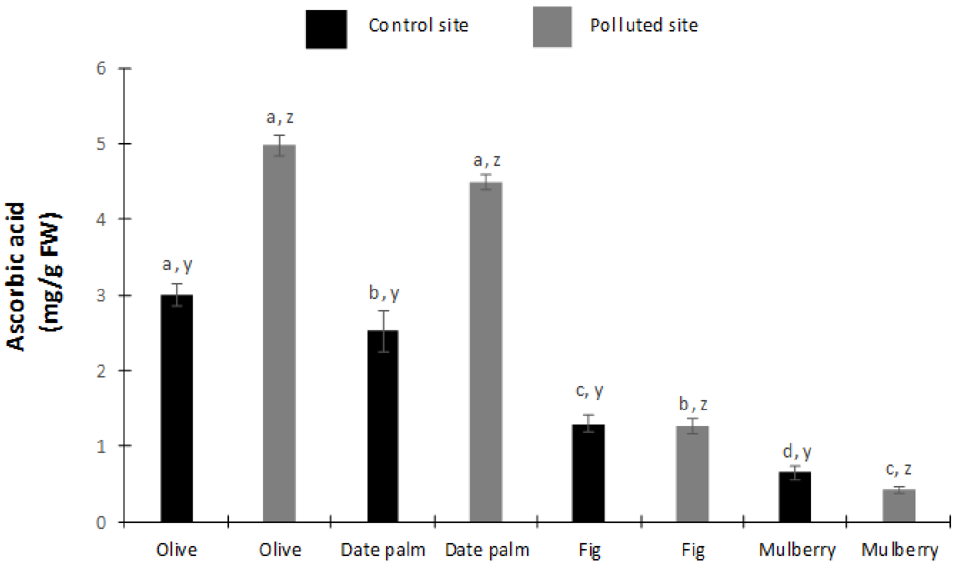

Fig. 4. Ascorbic acid content of different studied plant species in control and polluted sites. Values represent the mean of 5 replications per treatment ± SD. Different letters (a-d) indicate significant differences ($p \leq 0.05$) between plant species within each site, treated separately. Different letters (y, z) indicate significant differences ($p \leq 0.05$) between sites within each plant species, treated separately.

Table 1. APTI of selected plant species in different areas.

Plants Species	Air Pollution Tolerance Index: Control Site	Air Pollution Tolerance Index: Polluted Site
Olive	16.02 ± 0.56[a]	20.09 ± 0.63[a]
Date palm	13.72 ± 0.73[b]	17.10 ± 1.18[b]
Fig	9.94 ± 0.28[c]	8.87 ± 0.39[c]
Mulberry	8.88 ± 0.18[c]	7.49 ± 0.18[d]

Values represent the mean of 5 replications per treatment ± SD. Different letters indicate significant differences among treatments ($p \leq 0.05$).

Variation in four physiological and biochemical aspects (LRWC, chlorophyll content, pH, and ascorbic acid content) of plant species resulted in variations of APTI values. The maximum APTI values were recorded for *Olea europaea* (20.09), followed by *Phoenix dactylifera* (17.10), *Ficus carica* (8.87), and *Morus alba* (7.49). In the present study, common fig and white mulberry plants were found to be sensitive, the date palm plants turned out to be moderately tolerant, and olive palm plants proved to be tolerant in the polluted site's conditions (Table 2). This classification agreed with that of Ben Abdallah et al. (1994), who classified these plants grown in the vicinity of the phosphate fertilizer factory on the basis of their foliar damage.

Table 2. Tolerance level of plants.

	ToleranceLevel of Plants			
Plant Species	**Sensitive**	**Intermediate Tolerant**	**Moderately Tolerant**	**Tolerant**
Olive				*
Date palm			*	
Fig	*			
Mulberry	*			

CONCLUSION

It appears that with the rise of industrialization there has been an increasing threat of land degradation. Hence such type of APTI determination will gain significant account for future planning of these areas. Firstly, this study revealed the impact of air pollution in terms of changes in various biochemical parameters of the studied species. Secondly, this work shed more light on the selection of sensitive and tolerant species to air pollution with respect to their APTI values, hence providing useful information for selection of (i) tolerant species (*Olea europaea* and *Phoenix dactylifera*) in order to rehabilitate degraded environment and landscapes as well as future planning, and (ii) sensitive species (*Ficus carica* and *Morus alba)* that help indicating air pollution. Further researches need to be conducted in order to encompass a greater variety of plant species, tolerant to air pollutants in the region.

REFERENCES

Abbaslou, H. and Bakhtiari, S. (2017). Phytoremediation potential of heavy metals by two native pasture plants (*Eucalyptus grandis* and *ailanthus altissima*) assisted with AMF and fibrous minerals in contaminated mining regions. Pollution, 3(3), 471-486.

Achakzai, K. Khalid, S., Adrees, M., Bibi, A., Ali, S., Nawaz, R., and Rizwan, M. (2017). Air pollution tolerance index of plants around brick kilns in Rawalpindi. Pakistan. J. Environ. Manage., 190, 252-258.

Ali, B., Xu, X., Gill, R. A., Yang, S., Ali, S., Tahir, M. and Zhou, W. (2014). Promotive role of 5-aminolevulinic acid on mineral nutrients and antioxidative defense system under lead toxicity in *Brassica napus*. Ind. Crops. Prod., 52, 617-626.

Bakiyaraj, R. and Ayyappan, D. (2014). Air pollution tolerance index of some terrestrial plants around an industrial area. Int. J. mod. res. rev., 2(1), 1-7.

Ben Abdallah, F. and Boukhris, M. (1990). Action des polluants atmosphériques sur la région de Sfax (Tunisie). Pollution Atmosphérique, 127, 292-297.

Elloumi, N., Ben Abdallah, F. and Boukhris, M. (2003). Lead accumulation by some plant species cultivated in the vicinity of a lead factory in Sfax. Pollution atmosphérique, 178; 285-293.

Elloumi, N., Zouari, M., Mezghani, I., Abdallah, F. B., Woodward, S. and Kallel, M. (2017). Adaptive biochemical and physiological responses of *Eriobotrya japonica*to fluoride air pollution. Ecotoxicology, 26(7), 991-1001.

Esfahani, A. A., Amini, H., Samadi, N., Kar, S., Hoodaji, M., Shirvani, M. and Porsakhi, K. (2013). Assesment of air pollution tolerance index of higher plants suitable for green belt development in east of Esfahan city, Iran. Journal of Ornamental and Horticultural Plants, 3(2), 87-94.

Ben Abdallah, F., Belgacem, H. and Makki, B. (1994). Réponses des végétaux d'une région aride à une pollution atmosphérique double: (SO^{2+} composés fluorés). Pollution atmosphérique, 36(143), 117-122.

Kaur, M. and Nagpal, A. K. (2017). Evaluation of air pollution tolerance index and anticipated performance index of plants and their application in development of green space along the urban areas. Environ. Sci. Pollut. Res., 24(23), 18881-18895.

Lichtenthaler, H. K. and Wellburn, A. R. (1983). Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents (603rd Meeting, Liverpool). Biochem. Soc. Trans., 11(5), 591-592.

Maity, S., Mondal, I., Das, B., Mondal, A. K. and Bandyopadhyay, J. (2017). Pollution tolerance performance index for plant species using geospatial technology: evidence from Kolaghat Thermal Plant area, West Bengal, India. Spat. Inf. Res., 25(1), 57-66.

Masoudi, M., Asadifard, E., Rastegar, M. and Shirvani, A. (2017). Status and prediction of sulfur dioxide as an air pollutant in the city of Ahvaz, Iran. Pollution, *3*(2), 201-211.

Mezghani, I., Boukhris, M. and Chaieb, M. (1999). Accumulation of cadmium by some cultivated vegetable species around a factory producing phosphate fertilizers in Sfax (Tunisia). Pollution atmosphérique, 163, 80-88.

Prajapati, S. K. and Tripathi, B. D. (2008). Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution. J. Environ. Qual., 37(3), 865-870.

Qadir, S. U. and Siddiqui, W. A. (2014). Effect of fly ash on some biochemical parameters of selected plants growing at dumping site of badarpur thermal power plant in delhi. Int. J. Res. Appl. Nat. Soc. Sci., 2, 7-14.

Rai, P. K. and Panda, L. L. (2014). Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: an Indo-Burma hot spot region. Air Quality, Atmosphere, and Health, *7*(1), 93-101.

Seyyednejad, S. M., Motamedi, H. and Lordifard, P. (2017). Biochemical changes of *Conocarpus erectus* (combretaceae) in response to gas refinery air pollution as an air pollution indicator. Pollution, 3(2), 185-190.

Noor, M. J., Sultana, S., Fatima, S., Ahmad, M., Zafar, M., Sarfraz, M. and Ashraf, M.A. (2017). Retraction note to: estimation of anticipated performance index and air pollution tolerance index and of vegetation around the marble industrial areas of Potwar region: bioindicators of plant pollution response. Environmental geochemistry and health, 39(3), 705-705.

Singh, S. K., Rao, D. N., Agrawal, M., Pandey, J. and Narayan, D. (1991). Air pollution tolerance index of plant. J. Environ. Mgmt., 32, 45-55.

Wickramasinghe, W. A. D., Mubiana, V. K. and Blust, R. (2017). The effects of heavy metal concentration on bio-accumulation, productivity and pigment content of two species of marine macro algae. Sri Lanka Journal of Aquatic Sciences, *22*(1), 1-8.

Zhang, P. Q., Liu, Y. J., Chen, X., Yang, Z., Zhu, M. H. and Li, Y. P. (2016). Pollution resistance assessment of existing landscape plants on Beijing streets based on air pollution tolerance index method. Ecotoxicol. Environ. Saf., 132, 212-223.