EVALUATION OF SOME JAPANESE'S GARDEN PLANT SPECIES FOR ITS TOLERANCE TO AIR POLLUTION A. COMPARISON OF DIFFERENT SPECIES GROWN IN A SPECIFIC PART OF THE GARDEN

FAWZIA GH. ZENNA [1], LOBNA S. TAHA[2] and SAYED M. SHAHIN [1]

1. *Botanical Gardens. Res. Dept., Hort. Res. Inst., ARC, Giza, Egypt.*
2. *Ornamental Plants and Woody Trees Dept., NRC, Dokki, Egypt.*

(Manuscript received 12 June 2019)

Abstract

Because the different plant species showed a different behaviour against air pollution in the different sites and even in the same site, the present study was conducted on some selected ornamental plants grown together in different parts of Japanese garden, industrial Helwan City, the greatest Cairo, Egypt during the summer season 2017 to determine the relative tolerance of these plants to air pollution prevailing in this city using the air pollution tolerance index (APTI), which estimated by the use of four physio-biochemical parameters of the leaves, i.e. ascorbic acid content, relative water content (RWC %), leaf extract pH and total chlorophyll content as a practical tool for determining tolerance level of the plants and comparing among themselves. Mature leaf samples were monthly collected for 3 times during the morning hours from the selected ornamental plants grown in the North, Middle, South, East and West parts of the garden for analyzing. The APTI scale was used for determination of sensitivity/tolerance degree for every plant species.The obtained results indicated that a considerable variation in the means of ascorbic acid content, RWC %, pH of the leaf extract, total chlorophyll content and APTI values were observed among the different plant species selected from each part. Thus, every species exhibited a sole behaviour than the other ones under air pollution conditions of the same place. Based on the APTI values of various species in every individual place of the garden and the corresponding tolerance degree, it can be advised to plant *Yucca elephantipes*, *Ficus benjamina*, *Bauhinia variegata* and *Lantana camara* species in the North part; *Yucca elephantipes*, *Cassia nodosa*, *C. fistula* and *F. benjamina* species in the Middle part; *C. fistula, Delonix regia* (Poinciana), *Ficus cycomorus* (Gemez), *Lantana camara* and *Washingtonia filifera* palm in the South part; *Ficus benghalensis, Codiaeum variegata* (Croton), *Duranta erecta* and *Lantana camara* species in the East part, while for the West part, it is prefer to plant *Delonix regia* (Pionciana), *Pinus halepensis*, *Bauhinia variegata*, *Ficus retusa* (*F. nitida*), *F. microcarpa* "Hawii", *Lantana camara* and *Brachychiton porpulenum* species as the most suitable ornamental plants for air pollution load prevailing in every part of Japanese garden.

Key words: Air pollution, air pollution tolerance index (APTI), ornamental plants.

INTRODUCTION

It is well known that various plant species exhibited a different behaviour for the different air pollutants, and any plant part could be without bias used as biomonitors, especially the leaves, which are usually the most glore and most obvious vital receptors for large number of air pollutants (Jyothi and Jaya, 2010). The response of plants towards atmosphere was evaluated by air pollution tolerance index (APTI), which was successfully used by several authors as an important tool for measuring tolerance and sensitivity of plant species to air pollution. In this regard, Tripathi *et al*., (2009) concluded that *Pongamia pinnata* (15.8), *Pithecolobium dulcis* (34.8), *Holoptelea integrifolia* (55.8) and *Saraca indica* (52.0) had very high APTI values over control, so they are the highest tolerant tree species, *Ficus rumphii* (35.7), *Azadirachta indica* (30.5) and *Grevillea robusta* (34.3) have slightly more APTI values over control, so they ranked as moderately tolerant tree species. On the other hand, *Alstonia scholaris* (21.5), *Cassia simea* (6.09) and *Bauhinia variegata* (18.22) have less APTI values than control, so they are considered sensitive species. Further, Begum and Harikrishna, (2010) mentioned that the most tolerant tree species with respect to APTI and heavy metal concentration were *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata*, whereas the APTI for *Acacia melanoxylon*, *Caesalpinia pulcherrima*, *Ficus benghalensis*, *F. religiosa*, *Delonix regia*, *Morinda pubescens* and *Saraca indica* species are reported lower and are considered as sensitive species.

Similar observations were also revealed by Dwivedi and Tripathi (2007) on *Ricinus communis* and *Lepidium sativum*, Dwivedi *et al*., (2008) on *Ficus religiosa*, Jyothi and Jaya (2010) on *Polyalthia longifolia*, *Alstonia scholaris*, *Mangifera indica* and *Clerodendron* sp., Chandawat *et al*., (2011) on *Ficus benghalensis*, *F. religiosa*, *F. glomerata*, *Azadirachta indica* and *Polyalthia longifolia*, Krishnaveni *et al*., (2013) on *Nerium oleander*, *Ficus benghalensis*, *Psidium guajava*, *Spathodea campanulata* and *Opuntia ficus-indica*, Babu *et al*., (2013) on *Aegle marmelos*, *Bougainvillea spectabilis*, *Cassia auriculata* and *Ziziphus zizyphus*, Bora and Joshi (2014) on *Azadirachta indica*, *Eucalyptus* sp., *Ficus religiosa*, *Saraca indica* and *Tictona grandis*, Noor *et al*., (2015) on 15 common flora plant species of India, Akilan and Nandhakumar (2016) on *Nerium oleander*, *Tamarindus indica*, *Azadirachta indica* and *Pungamia pinnata*, as well as Kaur and Nagpal (2017) who reported that highest APTI (82.14) was recorded by *Nerium oleander* plants growing along the roadsides during the pre-monsoon season, while the least APTI (18.59) was attained by *Tabernaemontana coronaria* in the post-monsoon season. According to the APTI value, the four roadside shrub species of Fam. Apocynaceae could be arrangement in the following descending order: *Alstonia scholaris* > *N. oleander* > *T. coronaria* > *Thevetia peruviana*.

On *Ficus religiosa*, *Delonix regia*, *Polyalthia longifolia*, *Plumeria* sp. and *Azadirachta indica* grown on highly polluted roadside, Kumari and Deswal (2017) found that all the previous species are sensitive to air pollution. Moreover, Salaa and Al-Kawaz (2017) noticed that *Conocarpus lancifolius* can be more tolerant towards air pollution that produce from brick factory than *Dodonaea viscosa*. Recently, Patel and Kumar (2018) cited that based on APTI and API values, *Ficus benghalensis and F.*

religiosa are the most tree species appropriate for green belt development in industrial area.

However, the purpose of this study is evaluating the ability of some tree and shrub species grown in specific part of the Japanese garden in Egypt to tolerate air pollution of Helwan industrial area using air pollution tolerance index (APTI), as a practical method for determining plant species tolerance towards air contamination.

MATERIALS AND METHODS

The present study was carried out at the laboratories of both Hort. Res. Inst., ARC and Agric. and Biol. Res. Div., NRC, Giza, Egypt during summer season, 2017 in order to compare tolerance of some tree and shrub species grown in specific parts of Japanese Garden at Helwan district as a major industrial city includes iron, steel, textiles, cement, fertilizers, ceramics and asbestos industries, which result in dusts, heavy metals, particulate matter, ammonia (NH_3), formaldehyde (HCOH), fluorides (F) and fibrous silicate minerals. The previous sources also emit great amounts of gases, such as SO_2, H_2S, CO and NO_2 due to inadequate combustion of feul high in sulphur content (Andrew, 2005).

The Japanese garden locates the North-East Helwan city, covering area of 40468 m^2 (9.64 fed.) and bounded from the North by Sherif st., from South by Mohamed Sayed Ahmed st., from East by Fayzi Basha st. and from West by Dr. Mostafa Safwat st., where the main entrance of the garden is present. To perform such trial, the garden is divided to 12 beds, as every bed has various types of plant species (Photo, 1).

Photo 1. The Japanese garden after division into 12 beds.

Plant species under study:

The botanical and common names of trees and shrubs species selected for this study are given in the following table as mentioned in Bailey (1976).

No	Botanical name	Common name	Family	Native
1	*Acalypha marginata* Mull. *Arg.*	Copper-leaf	Euphorbiaceae	Pasific Island
2	*Araucaria heterophylla* (Salisb) Franco.	Norfolk Island pine	Araucariaceae	Norfolk Island
3	*Bauhinia variegata* L.	Orchid tree, or khof-el-Gamal	Leguminosae	India, China
4	*Bougainvillea glabra* Choisy.	Paper-flower	Nyctaginaceae	Brazil
5	*Brachychiton populneum* R.Br.	Bottle tree	Sterculiaceae	Queens land
6	*Breynia disticha* J. R. Forst & G. Forst.	Snowbush	Euphorbiaceae	Pasific Island
7	*Cassia fistula* L.	Golden shower	Leguminosae	India
8	*Cassia nodosa* Buch. Ham. ex Roxb.	Pink and White shower	Leguminosae	Eastern Himalaya
9	*Clerodendron inerme* (*Volkameria inerme* L.)	Glory bower	Lamiaceae	Australia, Asia, Malesia
10	*Codiaeum variegatum* (L.) A. Juss.	Variegated laurel, Croton.	Euphorbiaceae	Malaya, Sirlanka, Pasific Islands, Java Africa
11	*Cycas revoluta* Thunb.	Sago palm	Cycadaceae	Japan
12	*Delonix regia* Raf.	Poinciana, Flame tree	Leguminosae	Madagascar
13	*Dendrocalamus giganteus* Nees.	Giant Bamboo	Gramineae	India
14	*Dodonaea viscosa* (L.) Jacq.	Hap bush	Sapindaceae	Tropic and subtropics.
15	*Duranta repens* L.	Brazilian Sky Flower (duranta)	Verbenaceae	Caribbean and South America
16	*Duranta repens* "Variegata"	Flower (duranta)	Verbenaceae	Caribbean and South America
17	*Eucalyptus camaldulensis* Dhnh.	Red gum	Myrtaceae	Australia, New Guinea, Philippine, Tasmania, Timor and Java
18	*Ficus benghalensis* L.	Banyan tree	Moraceae	India-Pakistan
19	*Ficus benjamina* L.	Benjamin tree, Weeping ficus	Moraceae	India, Malay, Australia
20	*Ficus elastica* "Decora" (Jack) Hort.	Mistltoe ficus	Moraceae	Malay
21	*Ficus elastica* Roxb. ex. Hornem.	Rubber tree	Moraceae	India, Nepal
22	*Ficus lyrata* Warb	Fiddle-leaf fig	Moraceae	Tropical Africa
23	*Ficus microcarpa nitida* "Hawaii" L.	Hawai fig	Moraceae	Tropical Asia
24	*Ficus retusa* L. (*F. nidida* L.)	Indian laurel	Moraceae	India
25	*Ficus sycomorus* L.	Sycamore	Moraceae	S. Africa to Egypt and Lebanon
26	*Grevillea robusta* A. Cunn.	Silky oak	Proteaceae	Queens land
27	*Hibiscus rosa-sinensis* L.	Rose of China	Malvaceae	China
28	*Kigelia pinnata* Oliv.	Sausage tree, Mashtura	Bignoniaceae	Tropical Africa
29	*Lantana camara* L.	Yellow sage	Verbenaceae	Tropical America
30	*Nerium oleander* L.	Oleander	Apocynaceae	Mediterranean region to Japan
31	*Pinus canariensis* Sweet ex. K. Spreng	Canary Is. pine	Pinaceae	Canary Island
32	*Pinus halepensis* Mill	Aleppo pine	Pinaceae	Mediterranean region
33	*Pittosporum tobira* Thunb. (Ait.)	Japanese P., Australian laurel	Pittosporaceae	China, Japan
34	*Plumeria alba* L.	Temple tree, Frangibani	Apocynaceae	PuertoRico
35	*Punica granatum* L.	Pomegranat	Punicaceae	South East Europe and South Asia
36	*Schinus molle* L.	California pepper tree	Anacardiaceae	Peru
37	*Schinus terebenthifolius*, Roddi	Brazilian pepper tree	Anacardiaceae	Brazil
38	*Strelitzia reginae* Ait.	Bird-of-paradise	Strelitziaceae	South Africa
39	*Tamarix articulata* Vahl.	Athel	Tamaricaceae	N.E. Africa and W. Asia
40	*Thuja orientalis* (L.) Franco.	Oriental arborvitae	Cupressaceae	China, Korea
41	*Tipuana speciosa* Benth.	Tipu tree	Leguminosae	S. America
42	*Washingtonia filifera* H. Wendl.	Desert fan palm	Palmae	California
43	*Yucca elephantipes* Regel	Spineless Y. Arborescent	Agavaceae	Guatemala
44	*Ziziphus spina-christi* L.	Sidder	Rhamnaceae	Tropical and N,E. Africa

Collection of leaf samples:

Leaf samples were monthly collected for 3 times in the summer during the period from 15th June to 15th August 2017, as the fully mature leaves were picked in the triplicates in the morning hours from the selected plant species grown in the north part of the garden (represented by beds No. 2, 3 and 4), middle part (represented by beds No. 5, 6 and 8), south part (represented by beds No. 9, 10 and 11,) east part (represented by bed No. 12) and west part (represented by beds No. 1 and 7).

Determination of the four physio-biochemical parameters:

In order to estimate the air pollution tolerant index as an index denotes the ability of plant to withstand any pollution, the leaf samples were analyzed for relative water content (RWC%), pH of leaf extract, total chlorophylls and ascorbic acid contents using the methods of Prasad and Rao (1982), Moran (1982) and Sadasivam and Manickam (1996), respectively.

Air pollution tolerance index (APTI) calculation:

Finally, the four physio-biochemical parameters mentioned above were used for computing the APTI for the selected trees and shrubs using the equation proposed **by Singh and Rao (1983):**

APTI = [AsA (T. Chlo. + pH) + RWC] ÷ 10.

Where: AsA = ascorbic acid content (mg/100g f.w.), T. Chlo = total chlorophyll content (mg/g f.w.), pH of the leaf extract and RWC: relative water content (%).

According to APTI values, plant species can be categorized into sensitive, moderately tolerant (Intermediate) and tolerant, where APTI values were ranged from 1 to 100 by Begum and Harikrishna (2010), and sensitivity/tolerance degree of plants can be determined from the following APTI scale:

APTI value	Response degree
< 1	Very sensitive
1-16	Sensitive
17-29	Intermediate/moderately tolerant
30-100	Tolerant

Data were then tabulated and statistically analyzed using the program of SAS Institute (2009), followed by Duncan's New Multiple Range Test (Steel and Torrie, 1980) for means comparison.

RESULTS AND DISCUSSION

Comparing physio-biochemical characters among the different tree and shrub species grown in:

1- The North part of the garden:

It is obvious from data averaged in Table (1) that ascorbic acid content (mg/100 g f.w.) was greatly high in the highly tolerant *Yucca elephantipes* plants cultivated in bed No.3, (427.6 mg/100 g f.w.) with highly significant differences compared to the other plant species grown in the North part. The content of such constituent, however, reduced in the intermediate plants to a range of 14.3-28.1 and in the sensitive ones to a range of 13.1-15.5 (mg/100 g f.w.).

The high concentration of ascorbic acid in *Yucca elephantipes* that tolerated air pollution of Helwan City may indicate the role of ascorbic acid in preventing the harmful effects of air pollutants on plant tissues. In this regard, Kaur and Nagbal (2017) stated that ascorbic acid is the active antioxidant which keeps cell division and cell membrane stability in plants during pollution stress by removing cytotoxic free radicales and reactive oxygen species (ROS) produced by photo-oxidation of pollutants. Moreover, Jyothi and Jaya (2010) suggested that ascorbic acid play a vital role in cell wall synthesis, defense and cell division. Higher ascorbic acid in leaf tissues of the plant is a sign of its tolerance to air pollution, while lower content in the leaves of other plants supports their sensitivity towards air pollutants.

The previous results are well supported by many other findings detected by Dwivedi and Tripathi (2007) on *Ricinus communis* (as most resistant wild plant) and *Lepidium sativum* (as sensitive plant), Tripathi *et al.*, (2009) on *Pongamia pinnata*, *Saraca indica*, *Azadirachta indica*, *Ficus remphii*, *Grevillea robusta*, *Cassia simea* and *Bauhinia variegata*, Chandawat *et al.*, (2011) on *Ficus benghalensis*, *F. religiosa*, *F. glomerata*, *Azadirachta indica* and *Polyalthia longifolia*, Noor *et al.*, (2015) on *Amaranthus viridis, Cannabis sativa, Chenopodium album*, *Lantana camara*, *Melia azadirachta*, *Eucalyptus globules*, *Ricinus communis*, *Withania somnifera* and *Ziziphus nummulari* and Akilan and Nandhakumar (2016) who declared that *Nerium oleander* was more tolerance in industrial and transportation areas than *Azadirachta indica*, *Pungamia pinnata* and *Tamarindus indica*. Recently, Patel and Kumar (2018) cited that higher ascorbic acid contents (mg/100 g f.w) were recorded by the high tolerant plant species, included: *Michelia champaca* (7.31), *F. religiosa* (6.98), *Azadirachta indica* (6.79), *Polyalthia longifolia* (6.42), *Cassia siamea* (6.19) and *C. fistula* (6.09). Ascorbic acid is concentrated mostly in chloroplasts that act as an antioxidant enhances resistance to adverse environmental conditions, including air pollution.

On the other hand, moderately tolerant species possessed higher relative water content (%) than tolerant and sensitive species, with few exceptions. However, the high RWC was observed in the leaves of *Schinus terebenthifolius* tree grown in bed No.3 (97.16 %), followed by *Lantana camara* shrub (96.17 % for plants cultivated in bed No.2 and 95.14 % for those cultivated in bed No.3) and *Delonix regia* grown in bed No.2 (95.74%) with non-significant differences among themselves, while the least RWC recorded by *Nerium oleander* shrub (60.00 % in bed No.3), followed by *Tamarix articulata* tree (63.69 % in bed No.4) and *Thuja orientalis* shrub (66.09 % in bed No.2) as shown in Table (1).

Water plays a great role in maintaining the physiological balance of plants under air pollution stress, as the high RWC in plants is useful for drought resistance and acidity dilution inside the leaf cell sap (Babu *et al.*, 2013). Relative water content is directly affect with the protoplasmic permeability in cells causes loss of water and dissolved nutrients, resulting in early senescence of leaves. So, the plants with high RWC under pollution may be tolerant to contaminants (Jyothi and Jaya 2010; Krishnaveni *et al.*, 2013). The results of RWC in the present study are in accordance with those of Begum and Harikrishna (2010) on *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata*, Jyothi and Jaya (2010) on *Polyalthia longifolia* and *Clerodendron infortunatum*, Krishnaveni *et al*., (2013) on *Ficus benghalensis*, *Nerium oleander, Opuntia ficus-indica* and *Psidium guajava*, Babu *et al*., (2013) on *Aegle marmelos, Bougainvillea spectabilis*, *Cassia auriculata* and *Ziziphus zizyphus* and Bora and Joshi (2014) who found that *Eucalyptus spp.* and *Tectona grandis* recorded 75 % RWC, whereas *Saraca indica* and *Shorea robusta* recorded 68 % in air polluted area. In this concern, Kaur and Nagpal (2017) revealed that within-site, RWC depicted statistically significant variation among *Nerium oleander* and *Tabernaemontana coronaria*, whereas no significant variation was observed among *Alstonia scholaris* and *Thevetia peruviana*. Likewise, Kumari and Deswal (2017) noticed that the RWC of *Plumeria* sp., *Delonix regia*, *Ficus religiosa* and *Azadirachta indica* (as tolerant species) were 91, 90, 83 and 79 %, respectively compared to 49 % for the sensitive *Polyalthia longifolia*, although all of them are the common trees of the highly polluted roadside of Noida, Uttar, Pradesh, India. Recently, Patel and Kumar (2018) decided that *Ficus religiosa* grown in polluted industrial area has the maximum RWC of 64 %, followed by *Polyalthia longifolia* 60 %, *Spathodea campanulata* 55 % and *Ficus benghalensis* 55 %. Under air pollution, transpiration rates are uaually high, consequently leads to dryness. Thus, the maintenance of RWC by the plant may assess its relative tolerance to pollution. Hence, the high RWCs of plants in the industrial area may be responsible for the normal function of active processes (Dwivedi and Tripathi, 2007).

As for pH values, data in Table (1) clear that pH means of plant species grown in the North part of the garden were below 7 with non significant differences in between, except for *Delonix regia*, *Ficus retusa*, *Lantana camara*, *F. elastica* and *Tamarix articurala* plant species which significantly rose pH values to 8.81, 7.70, 7.51, 7.50 and 7.16, respectively. However, the least pH records were scored by *Schinus terebenthifolius* (4.90), followed by *Yucca elephantipes* (5.20), *Thuja orientalis* (5.55) and *Bauhinia variegata* (5.90) exhibiting high acidity of the leaf extract.

The leaf extract pH level plays a critical role in regulation of pollution sensitivity in plants. The acidic nature of pH may be ascribed to the diffusion of gaseous air pollutants, such as NO_2, CO_2 and SO in the cell sap and conversion them to acid radicales (Noor *et al*., 2015). Low pH reduces the conversion of hexose sugar to ascorbic acid (Jyothi and Jaya, 2010), while high pH favours more activity of ascorbic acid and hence can increase the air pollution tolerance level in plants (Bora and Joshi, 2014). The changes in pH of leaf extract may influence the stomata sensitivity under of air pollution. Thus, sensitive plants had higher pH than tolerant ones. Low leaf pH reduces photosynthetic process in plants (Yan and Hui, 2008).

The trend of pH in this study is coincidence with those explored by Dwivedi *et al.*, (2008) on *Ficus religiosa*, Babu *et al.*, (2013) on *Aegle marmelos*, *Bougainvillea spectabilis*, *Cassia auriculata* and *Ziziphus zizyphus* and Kaur and Nagpal (2017) who reported that pH of leaf samples of different shrub species collected from different sites ranged from 5.46 to 6.48 and from 5.20 to 5.59 for *Alstonia scholaris*, 5.61-6.36 and 5.53-5.89 for *Nerium oleander*; 5.84-6.44 and 5.53-5.96 for *Tabernaemontana coronaria* and 5.56-6.29 and 4.49-5.81 for *Thevetia peruviana* during the pre- and post-monsoon seasons. In addition, Patel and Kumar (2018) pointed out that leaf pH acidity of *Michelia champaca, Cassia fistula, C. siamea* and *Cascabela thevetia* species increased in the polluted area compared with that of control. It has been reported that the lower leaf pH is due to presence of acidic pollutants.

As shown in Table (1), there were no significant variations in total chlorophyll content (mg/g f.w.) among most tree and shrub species cultivated in the North part of Japanese garden, as the means of such component were closely near together in most cases, but the highest content was observed in the leaves of *Bauhinia veriegata* in bed No.2 (0.394 mg/g f.w.) and followed by *Delonix regia* grown in bed No.3 (0.380 mg/g f.w.). On the contrary, the lowest content was achieved by the leaves of *Lantana camara* in bed No.3 (0.099 mg/g f.w.), which followed by *Tamarix articulata* and *Yucca elephantipes* that gave 0.166 and 0.185 mg/g f.w., respectively.

Evaluation of chlorophyll content is one of the important ways to assess the effects of air pollution on plants, as it plays the major role in providing greening to the plants and helping in sunlight catchment and its conversion to chemical energy necessary for photosynthesis process (Dwivedi and Tripathi, 2007). High pollution load, high moisture content and blocking on the stomatal pores on the leaf surface because of dust accumulation might be the main reasons for the low chlorophyll concentration in leaf samples obtained from plants grown in polluted sites (Noor *et al.*, 2015). Air pollutants may cause a degradation of chlorophyll molecule to pheophytin by substituting Mg^{++} ions with two hydrogen atoms (Rahmawati *et al.*, 2014). Air pollution decreases the efficiency of chloroplasts, leading to reducing of photosynthetic rate and stomatal conductance, premature leaf fall, and hence low productivity (Bora and Joshi, 2014). Chlorophyll concentration usually varies from species to another, leaf age, pollution level, as well as biotic and abiotic conditions prevailing in the polluted area (Noor *et al.,* 2015). Similar observations to the above ones were also documented for *Bauhinia variegata* and *Cassia siamea* by Tripathi *et al.*, (2009), *Alstonia scholaris*, *Clerodendron infortunatum*, *Polyalthia longifolia*, *Mangifera indica* and *Eupatorium odoratum* by Jyothi and Jaya (2010), *Conocarpus lancifolius* and *Dodonaea viscosa* by Salaa and Al-Kawaz (2017), and for *Azadirachta indica*, *Cassia fistula, C. siamea, Ficus religiosa* and *Polyalthia longifolia* by Patel and Kumar (2018).

Air pollution tolerance index (APTI), as a real indicator for air pollution tolerance was used in the current work to categorize tree and shrub species grown in Japanese garden under air pollution of industrial Helwan City to various degree of tolerance according to APTI–scale prepared before by Begum and Harikrishna (2010).

Data averaged in Table (1) revealed that a marked variation in the values of APTI was observed between the different plant species cultivated in the North part of the garden. These values ranged between 237.2 to 15.71. However, the maximal one was attained by *Yucca elephantipes* (237.2 in bed No.3) to be the highly tolerant species in the North part at all, whereas the minimal values were recorded by *Thuja arientalis* shrub (15.71 in bed No.2) and *Delonix regia* tree (15.92 in bed No.3) to become the sensitive species in this place. The other tree and shrub species scored values ranged between 27.09 and 18.03 exhibiting a moderately tolerance for air pollution load in such part. It was also noticed that *Bauhinia variegata* in bed No.2 gave APTI value of 25.26 and in bed No. 3 a value of 21.03, as well *F. elastica* in bed No.2 (20.17) and in bed No.4 (20.86) and *F. retusa* in bed No.3 and 4 (21.00), all showing a moderately tolerance against pollution irrespective of bed site, but the opposite was the right concerning *Delonix regia* that gave 23.53 APTI value in bed No.2 exhibiting intermediate tolerance and 15.92 value in bed No.3 revealing a slight sensitivity to air pollution.

It is evident from APTI values registered in Table (1) that *Yucca elephantipes* is the highly tolerant species grown in the North part of the garden due to its production of the utmost high concentration of ascorbic acid (427.6 mg/100 g f.w.) over all other species. This may indicate that ascorbic acid content has a significant positive effect on the APTI values of the plants under study compared to the other parameters (pH, RWC and T. Chlo.). In this connection, Kaur and Nagpal (2017) demonstrated that Pearson's correlation coefficient matrix revealed a significant positive correlation between APTI values and ascorbic acid contents in the leaves of *Alstonia scholaris*, *Nerium oleander*, *Tabernaemontana coronaria* and *Thevetia peruviana* species during the two seasons of monsoon, while Patel and Kumar (2018) found a positive correlation between APTI and both ascorbic acid content and total chlorophylls content, and this means that both ascorbic acid content and total chlorophylls content of the leaf are responsible factors on which the APTI relies. The plants with high APTI values are tolerant to air pollution and can be used as filters/sink to mitigate air pollution, while plants with moderate and low APTI values are intermediate and sensitive to pollution and can be used as bio-indicators (Patel and Kumar, 2018). Presence of tolerant trees and shrubs in the industrial area can improve air quality by uptake of the gaseous and particulate pollutants. However, the high tolerance level of a specific plant species in a specific polluted area is not a general rule (Kaur and Nagpal, 2017).

Based on the values of APTI and tolerance degree listed in Table (1), the selected tree and shrub species grown in the North part of Japanese garden can be arranged in the following descending order: *Yucca elephantipes* > *Lantana camara* > *F. benjamina* > *Bauhinia variegata* > *Schinus terebenthifolius* > *Nerium oleander* > *Delonix regia* (in bed No2) > *Pittosporum tobira* > *F. retusa* > *F. elastica* > *Hibiscus rosa-sinensis* > *Tamarix articulata* > *Clerodendron inerme* > *Duranta erecta* > *D. erecta* "Variegata" > *Delonix regia* (in bed No.3) > *Thuja orientalis*.

Table 1. Comparison of physio-biochemical parameters of selected plant species grown in the North part of the garden.

Bed No.	Plant species	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
2	*Bauhinia variegata*	23.36c	84.58e-g	6.80d-f	0.394a	25.26bc	Intermediate
	Delonix regia	19.52d	95.74a-c	8.81a	0.338a-c	23.53c	Intermediate
	Ficus elastic	14.29fg	91.49cd	7.50bc	0.208a-d	20.17de	Intermediate
	Hibiscus rosa-sinensis	18.36de	79.49h	6.30e-g	0.223a-d	19.92d-f	Intermediate
	Lantana camara	22.48c	96.17ab	7.51bc	0.264a-d	27.09b	Intermediate
	Thuja arientalis	15.52e-g	66.09jk	5.55hi	0.317a-c	15.71g	Sensitive
3	*Bauhinia variegata*	19.42d	88.82de	5.90gh	0.354a-c	21.03d	Intermediate
	Clerodendron inerme	16.45d-f	79.40h	6.78d-f	0.326a-c	19.63d-f	Intermediate
	Delonix regia	13.13g	70.86i	6.35e-g	0.380ab	15.92g	Sensitive
	Duranta erecta	14.33fg	86.80ef	6.50d-g	0.331a-c	18.47ef	Intermediate
	Duranta erecta "Vriegata"	14.23fg	88.02de	6.16f-h	0.323a-c	18.03f	Intermediate
	Ficus benjamina	23.41c	92.30b-d	6.98c-e	0.319a-c	26.32b	Intermediate
	Ficus retusa	16.07e-g	80.40gh	7.70b	0.362a-c	21.00d	Intermediate
	Lantana camara	16.42d-f	95.14a-c	6.26e-g	0.099d	19.96d-f	Intermediate
	Nerium oleander	27.44b	60.00 l	6.10f-h	0.320a-c	23.61c	Intermediate
	Pittosporum tobira	23.26c	82.66f-h	6.20f-g	0.326a-c	23.44c	Intermediate
	Schinus terebethifolius	28.10b	97.16a	4.90i	0.323a-c	24.39c	Intermediate
	Yucca elephantipes	427.60a	69.02ij	5.20i	0.185b-d	237.2a	Highly tolerant
4	*Ficus elastic*	18.55de	83.58f-h	6.40e-g	0.344a-c	20.86d	Intermediate
	Ficus retusa	16.07e-g	80.40gh	7.70b	0.362a-c	21.00d	Intermediate
	Tamarix articulate	18.47de	63.69kl	7.16b-d	0.166cd	19.90d-f	Intermediate

2- The middle part of the garden:

A similar response to that of plant species grown in the North part against air pollution prevailing in the atmosphere of Helwan industrial city was occurred as well concerning those grown in the Middle part that was represented by beds No. 5, 6 and 8, as a significant differences in the means of ascorbic acid content, RWC, leaf extract pH and total chlorophyll content were observed between the various tree and shrub species sampled from such place (Table, 2).

The highest concentration of ascorbic acid was also gained in this part of garden by *Yucca elephantipes* plants, which significantly raised such constituent in their leaves to 283.1 mg/100 g f.w. The second rank was occupied by *Cassia nodosa* (81.46 mg/100 g f.w.) and the third one by *Cassia fistula* (59.37 mg/100 g f.w.) with significant differences in between. The lowest concentration, however achieved by *Hibiscus rosa-sinensis* (12.6), *Euphorbia pulcherrima* (13.11) and then both *Kigelia pinnata* (14.27) and *Ficus elastica* "decora" (14.40) with no significant differences among themselves, while all the other species gave values ranged between 38.39 to 16.31 (mg/100 g f.w.) with various significant levels between themselves.

Marked variables were also noticed in the matter of RWC (%) of the different plant species selected from this part. The highest percent of RWCs were acquired by *Ficus elastica* "decora" (96.84 %), *Clerodendron inerme* (96.56 %), *Delonix regia* (95.36 %), *F. benjamina* (94.43 %), *Euphorbia pulcherrima* (92.91 %) and *Strelitzia reginae* (92.53 %) plant species with non-significant differences in between, but were significantly reduced to 91.93, 91.19 and 90.40 % in the leaves of *Thuja orientalis*, *Yucca elephantipes and Ziziphus spina-christi* species, respectively. The other species attained also high RWCs ranged between 89.91 to 80.95 % with the inferiority of *Tipuana speciosa*, which gave only 71.55 % of RWC in its leaves. In general, most plant species grown in the middle part of Japanese garden possessed higher relative water content than species grown in the other parts.

The leaf extract pH of *F. benjamina* (7.86), *F. benghalensis* (7.17) and *Plumeria alba* (7.0) plant species were either neutral or significantly tended to be alkaline, showing its unaffected by air pollutants in such place, whilst the other species were variously affected giving acidic leaf extract had pH values less than 6.5 in most species. However, the highest acidity was fulfilled by *Dendrocalamus giganteus* leaves which scored pH value of 5.0 and then *Yucca elephantipes* leaves that gave pH mean of 5.41. It is clear from pH data presented in Table (2) that pH differences among various plants cultivated in this part were significant.

Besides, data in Table (2) imply to a pronounced variance in the leaf content of total chlorophyll among the different trees and shrubs grown in the middle part of the garden. The level of variance was insignificant between the tolerant species and some intermediate ones, except for *Yucca elephantipes*, in which total chlorophyll content was significantly reduced to 0.271 mg/g f.w. compared to some tolerant and intermediate other species, although it is categorized as a highly tolerant to air pollution in such place of the garden. Total chlorophyll content reached to the maximum in the leaves of *F. benghalensis* (0.353 mg/g f.w.), meanwhile reached to the minimum in the leaves of *Hibiscus rosa-sinensis* (0.199 mg/g f.w.) and ranged for other species between 0.227 and 0.344 (mg/g f.w.) with various significance levels in between.

According to APTI values and tolerance levels of the different trees and shrubs grown in the middle part recorded in Table (2), there weren't any plant sensitive to air pollution in such part. So, they could be arrange in this order: *Yucca elephantipes* > *Cassia nodosa* > *C. fistula* > *F. benjamina* > *Ziziphus spina-christi* > *Delonix regia* > *Schinus molle* > *Plumeria alba* > *Cycas revoluta* > *Thuja orientalis* > *Strelitzia reginae* > *Clerodendron inerme* > *F. benghalensis* > *Washingtonia filifera* > *Tipuana speciosa* > *F. lyrata* > *Duranta erecta* "Veriegata" > *F. elastica* "decora" > *Kigelia pinnata* > *Dendrocalamus giganteus* > *Euphorbia pulcherrima* > *Hibiscus rosa-sinensis*.

The aforementioned results could be discussed and interpretted as done before in case of the selected plants grown in the North part. These results are in the same line with that observed by Dwivedi and Tripathi (2007) on *Ricinus communis* and *Lepidium sativum*, Tripathi *et al.*, (2009) on *Alstonia scholaris, Azadirachta indica, Bauhinia variegata, Cassia simea*, *Ficus rumphii*, *Grivellea robusta* and *Saraca indica*, Begum and Harikrishna (2010) on *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata* and Chandawat *et al.*, (2011) who expressed an order of tolerance, in which *Ficus benghalensis* exhibited the highest APTI values at the different polluted sites, and followed by *F. religiosa* > *F. glomerata* > *Azadirachta indica* > *Polyalthia longifolia*. Furthermore, Krishnaveni *et al.*, (2013) inferred that *Nerium oleander* has APTI value of 16.65 and identified as intermediate tolerance species, whereas *F. benghalensis*, *Psidium guajava*, *Spathodea campanulata* and *Opuntia ficus-indica* had APTI scores of 15.92, 15.41, 9.92 and 9.74 were identified as sensitive species. Bora and Joshi (2014) on 6 plant species, found that the order of tolerance index was as follows: *Saraca indica* (13.71), *Azadirachta indica* (12.98), *Shorea robusta* (12.64), *Eucalyptus* sp. (12.61), *F. religiosa* (12.61) and *Tectona grandis* (12.33). On 4 plant species selected from transportation and industrial areas, Akilan and Nandhakumar (2016) noticed that *Nerium oleander* recorded higher APTI value and exhibited more tolerance than *Tamarindus indica, Azadirachta indica* and *Pungamia pinnata*.

Table 2. Comparison of physio-biochemical parameters of selected plant species grown in the Middle part of the garden.

Bed No.	Plant species	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
5	*Dendrocalamus giganteus*	17.78gh	85.23i-k	5.00m	0.255d-g	17.87l	Intermediate
6	*Cassia fitula*	59.37c	87.80g-j	6.50f	0.333a-c	49.28c	Tolerant
	Cassia nodosa	81.46b	80.95i	5.85k	0.311a-d	58.28b	Tolerant
	Clerodendron inerme	17.74gh	96.56a	6.19i	0.265d-f	21.11h-j	Intermediate
	Cycas revolute	20.21g	83.12kl	6.57e	0.280c-f	22.15h	Intermediate
	Delonix regia	30.17e	95.36a-c	5.99j	0.227fg	28.29d-f	Intermediate
	Euphorbia pulcherrima	13.11j	92.91a-e	5.84k	0.305a-e	17.35l	Intermediate
	Ficus benghalensis	16.31hi	88.31f-j	7.17b	0.353a	21.10h-j	Intermediate
	Ficus benjamina	24.91f	94.43a-d	7.86a	0.303a-e	29.78de	Tolerant
	Ficus elastica "decora"	14.40ij	96.84a	6.42g	0.273c-f	19.59jk	Intermediate
	Ficus lyrata	17.45gh	84.84j-l	6.40g	0.315a-d	20.20ij	Intermediate
	Kigelia pinnata	14.27ij	89.46e-i	6.26h	0.344ab	18.36kl	Intermediate
	Plumeria alba	24.67f	88.21f-j	7.00c	0.299a-e	26.82f	Intermediate
	Schinus molle	29.73e	86.28h-k	6.16i	0.295a-e	27.82ef	Intermediate
	Strelitzia reginae	18.40gh	92.53a-f	6.30h	0.272c-f	21.34h-j	Intermediate
	Tipuana speciosa	18.59gh	71.55m	6.77d	0.297a-e	20.29ij	Intermediate
	Thuja orientalis	19.85g	91.93b-g	6.14i	0.246e-g	21.87hi	Intermediate
	Washingtonia filfera	18.35gh	83.33kl	6.29h	0.348ab	20.51h-j	Intermediate
	Yucca elephantipes	283.1a	91.19c-g	5.41l	0.271c-f	169.9a	Highly tolerant
	Ziziphus spina-christi	30.11e	90.40d-h	6.40g	0.316a-d	29.26de	Intermediate
8	*Duranta erecta "Variegata"*	16.32hi	89.91e-h	6.25h	0.287b-f	19.65jk	Intermediate
	Hibiscus rosa-sinensis	12.60j	88.13f-j	6.50f	0.199g	17.25l	Intermediate

3- The South part of the garden:

This part included beds No. 9, 10 and 11 (Photo., 1).

The different physio-biochemical traits of the selected plant species cultivated in this place revealed also clear variances with significant differences in most instances (Table, 3). In this respect, ascorbic acid content in the leaves of plants grown in such area varied from 31.68 to 10.61 mg/100 g f.w. However, the utmost high concentration of this constituent was found in the leaves of *Cassia fistula* (31.68 mg/100 g f.w.) bed 11, followed by *Delonix regia* (29.39) bed 10 and *Washingtonia* *filifera* (29.19) bed 9 with non-significant differences among them, whereas the utmost low concentration was found in the leaves of *Acalypha marginata* that scored only 10.61 mg/100 g f.w bed 10. The other plant species gave concentrations ranged between 26.01 and 15.59 mg/100 g f.w. with various significancy levels in between. It is well known that plants had high ascorbic acid are more tolerant to air pollutants (Kumari and Deswal, 2017).

Likewise, the results of relative water content (RWC %) increased to the maximum in *Acalypha marginata* (94.62 %) and *Delonix regia* (92.57 %) leaves, but decreased to the minimum in the leaves of two moderately tolerant shrubs; *Dodonaea viscosa* (60.64 %) and *Thuja orientalis* (61.15 %) with non-significant differences among them. In the other trees and shrubs sampled from this part, RWC % ranged from 65.52 to 90.59 % with significant differences between species. Similar trend was also obtained by Kumari and Deswal (2017) who decided that RWC of *Plumeria* sp. and *Delonix regia* was the highest, but decreased to the lowest in *Polyalthia longifolia* (49 %).

Values of leaf extract pH in *Ficus sycomorus* (7.71), *F. elastica* (7.26) and *Lantana camara* (7.17) tended toward alkalinity, whereas in other tree and shrub species deviated to acidity, especially *Washigtonia filifera*, *Cassia fistula*, *Eucalyptus camaldulensis* and *Clerodendron inerme* species that attained pH values of 5.53, 5.54, 5.70 and 5.75, respectively. Reducing pH value in some plant species may be ascribed to presence of acidic pollutants. Low pH of leaf extract showed good correlation with sensitivity to air pollution and may reduces photosynthetic process in plants (Yan and Hui, 2008). In this regard, Singh and Rao (1983) mentioned that pH of leaf reflects the acidic and alkaline nature as a response to a sensitivity of air pollution. On 5 tree species, Kumari and Deswal (2017) found that *Ficus religiosa* was the most alkaline (pH: 7.54) among all, while *Plumeria* sp. (6.5) and *Azadirachta indica* (6.61) was the most acidic.

Concerning the total chlorophylls content, data in Table (3) revealed that a slight variation was occurred among the different species of plants grown in this part as they all gave closely near concentrations with non-significant differences in between, except for *Eucalyptus camaldulensis* that contained 0.321 mg/g f.w. and *Grevillea robusta* that possessed 0.318 mg/g f.w. in their leaves, while the lowest chlorophyll content was found in the leaves of *Cassia fistula* plants sampled from bed No.9 (0.177 mg/g f.w.), although such plant gave significantly higher content (0.297 mg/g f.w.) when grown in bed No. 11. That was not true for *Delonix regia*, which sampled from beds No. 10 and 11, as it gave a near content of chlorophyll. A similar response was also obtained by Kumari and Deswal (2017) on *Delonix regia*, *Ficus* *religiosa* and *Plumeria* sp. and Salaa and Al-Kawaz (2017) who reported that chlorophyll content ranged from 1.31-2.41 mg/g f.w. in *Conocarpus lancifolius* of site 1, but ranged from 0.26-0.49 mg/g in site 2, while in *Dodonaea viscosa* in site 1, it ranged from 0.83-1.75 mg/g and in site 2 from 0.28-0.70 mg/g. This indicates that productivity was higher in site 1 compared with site 2 for the two species. This may be attributed to the adversely effect of acidic pH of the leaf sap.

Table 3. Comparison of physio-biochemical parameters of selected plant species grown in the South part of the garden.

Bed No.	Plant species	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
9	*Cassia fistula*	16.43ef	65.52g	5.54j	0.177d	15.94h	Sensitive
	Ficus elastica	18.64d-f	90.14bc	7.26b	0.298a-c	23.10de	Intermediate
	Grevillea robusta	19.18de	81.06e	6.16g	0.318a	20.53fg	Intermediate
	Washingtonia filfera	29.19a	90.59bc	5.53j	0.309a-c	26.10bc	Intermediate
10	*Acalypha marginata*	10.61g	94.62a	6.06h	0.308a-c	15.99h	Sensitive
	Cassia nodosa	16.39ef	80.96e	6.20g	0.315ab	24.83cd	Intermediate
	Delonix regia	29.39a	92.57ab	6.79d	0.273a-c	30.02a	Tolerant
	Eucalyptus camaldulensis	20.48cd	72.73f	5.70i	0.321a	19.56g	Intermediate
	Lantana camara	26.01b	71.53f	7.17c	0.251c	26.46bc	Intermediate
	Nerium oleander	23.36bc	65.97g	6.18g	0.292a-c	21.72ef	Intermediate
11	*Cassia fistula*	31.68a	88.28cd	6.75d	0.297a-c	31.15a	Tolerant
	Clerodendron inerme	15.59f	81.37e	5.75i	0.288a-c	17.54h	Intermediate
	Delonix regia	23.48bc	83.39e	6.60e	0.289a-c	24.51cd	Intermediate
	Dodonaea viscosa	16.39ef	60.64h	6.36f	0.312ab	17.00h	Intermediate
	Ficus sycomorus	23.41bc	86.64h	7.71a	0.255bc	27.29b	Intermediate
	Thuja orientalis	16.45ef	61.15h	6.40f	0.277a-c	17.09h	Intermediate

Due to the variability observed in ascorbic acid content, RWC, pH and total chlorophylls content, APTI values and tolerance levels were also varied (Table, 3). *Delonix regia* (in bed No.10) and *Cassia fistula* (in bed No.11) are considered tolerant, as they gave APTI values of 30.02 and 31.15, respectively, whereas *Cassia fistula* in bed No. 9 (15.94) and *Acalypha marginata* in bed No. 10 (15.99) were sensitive. The rest plants, however were moderately tolerant. On the basis of calculated APTI and the corresponding tolerance degrees indicated in Table (3), the tree and shrub species in this part can be arranged in this order: *Cassia fistula* (in bed No. 11) > *Delonix regia*> *Ficus sycomorus* > *Lantana camara* > *Washingtonia filifera* > *Cassia nodosa* > *F. elastica* > *Nerium oleander* > *Grevillea robusta* > *Eucalyptus camaldulensis* > *Thuja orientalis* > *Dodonaea viscosa* > *Acalypha marginata* > *Cassia fistula* (in bed No. 9).

The previous results may be discussed and explained as stated before in case of selected plant species grown in the North and middle parts of the garden.

4- The East part of the garden:

This part lies adjacent to Fayzi Basha St. from East direction, and involved only the bed No.12.

It is obvious from data averaged in Table (4) that different plant species cultivated in such part showed considerable variations in their susceptibility to air pollution prevailing in atmosphere of the industrial Helwan City, giving different means of ascorbic acid content, RWCs, leaf extract pH and total chlorophyll content. In general, ascorbic acid content ranged between 26.50 mg/100 g f.w. attained by *F. benghalensis* to14.91 mg/100g f.w. scored by *F. microcarpa* "Hawaii". High ascorbic acid content is usually associated with tolerant plant species and vice-versa. Relative water content was more than 83 % in most plant species found in this place, but it was increased in the leaves of *Codiaeum variegatum* to 93.25 % and *F. benghalensis* to 91.30 %, however, decreased to 52.57 % in the leaves of *Hibiscus rosa-sinensis*. The RWC usually affects the leaf extract pH, the higher RWC the more dilute of the sap (Salaa and Al-Kawaz, 2017). The pH values were more than 7 in the leaf extract of *F. microcarpa* "Hawaii" (7.52) and *Lantana camara* (7.45), but turned to acidity in other plant species to be slightly less than 7, except for *Duranta erecta* that recorded the highest acidity of leaf sap (4.21) relative to other species. Although total chlorophylls content varied from species to another, the differences between them were not significant. However, the highest content was found in the leaves of *Lantana camara* (0.260 mg/g f.w.), followed by *F. benghalensis* (0.254 mg).

The previous 4 factors were combined to calculate the values of pollution tolerance index, which were ranged as shown in Table (4) from 17.09 to 27.56. These values indicate that all the eight plants selected from this part are intermediates/moderately tolerant to air pollution according to APTI-scale suggested by Begum and Harikrishna (2010), as APTI values are restricted between 17-29 (see APTI scale).

These gains could be discussed and interpreted as previously shown in case of selected plants grown in the North part of the garden.

Table 4. Comparison of physio-biochemical parameters of selected plant species grown in the East part of the garden.

Bed No.	Plant species	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
12	*Breynia disticha*	15.02d	88.51bc	6.57ab	0.163	18.81d	Intermediate
	Codiaeum variegatum	18.68c	93.25a	6.86ab	0.167	22.45b	Intermediate
	Cycas revolute	17.20c	83.18d	6.92ab	0.123	20.43c	Intermediate
	Duranta erecta	21.18b	87.28c	4.21c	0.11	22.11b	Intermediate
	Ficus benghalensis	26.50a	91.30ab	6.70ab	0.254	27.56a	Intermediate
	Ficus microcarpa "Hawii"	14.91d	89.01bc	7.52a	0.172	20.36c	Intermediate
	Hibiscus rosa-sinensis	18.63c	52.57e	6.22b	0.132	17.09e	Intermediate
	Lantana camara	17.62c	83.21d	7.45a	0.26	21.91b	Intermediate

5- The West part of the garden:

This part is bounded by Dr Mostafa Safwat St. from the West, and included bed No. 1 at the North West portion and bed No.7 at the South west portion, beside the main entrance of the garden that lies between the two beds mentioned above (Photo, 1).

A similar response to that obtained in the North, Middle and South parts of the garden was also occurred in such part, as the means of physio-biochemical characteristics were markedly varied from species to other, with few exceptions in some cases. So, data provided in Table (5) clear that ascorbic acid content varied from 14.05 (mg/100 g f.w.) in *Hibiscus rosa-sinensis* and 14.98 mg/100g in *F. benghalensis* to 45.88 mg/100g in *Delonix regia* (bed No.1) and 41.45 mg/100g in *Pinus halepensis* (bed No. 1), while for the other species, it was ranged between 15.78 to 28.24 mg/100g. With respect to RWC %, it reached maximum in the leaves of *Acalypha marginata* (96.41), followed by *Delonix regia* in bed No. 1 (95.89), *Brachychiton porpulenum* (95.67), *Duranta erecta* "Variegata" (94.64), *F. microcarpa* "Hawaii" in bed. No.1 (94.61) and *F. elastica* (94.47), but was minimum in the leaves of *Araucaria heterophylla* (55.57) and medium in the rest species (64.85 to 92.62). Regarding pH values, *F. elastica*, *F. microcarpa* "Hawaii" and *F. retusa* scored above neutral values ranged between 7.34 and 7.80, whereas other species resulted acidic leaf extracts varied from 4.15 to 6.82 with significant differences in most instances. The highest acidity was found due to *Pinus canariensis* grown in bed No.7, that gave pH of 4.15. Great differences were also observed in the means of total chlorophyll among plant species selected from such place. The highest content was recorded by *Delonix regia* (0.335 mg/g), *Lantana camara* (0.312 mg/g), *Thuja orientalis* (0.311 mg/g), *H. rosa-sinensis* (0.309 mg/g), *F. elastica* (0.307 mg/g), *Bauhinia variegata* (0.302 mg/g), *F. retusa* (0.296 mg/g), *F. microcarpa* "Hawaii" (0.287 mg/g) and *F. benghalensis* (0.282 mg/g) with non-significant differences in between, while the lowest contents were noticed in the leaves of *Brachychiton porpulenum* (0.148 mg/g) and *F. microcarpa* "Hawaii" in bed No.1 (0.143 mg/g).

According to APTI values, tree and shrub species grown in this part of the garden can be scaled-down in this order: *Delonix regia* > *Pinus halepensis* > *Lantana camara* > *Thuja orientalis* > *Hibiscus rosa sinensis* > *F. elastica* > *Bauhinia variegata* > *F. retusa* > *F. microcarpa "Hawaii"* > *Ficus benghalensis* > *Pinus halepensis* > *Acalypha marginata* > *Araucaria heterophylla* > *Punica granatum* > *Pius canariensis* > *Brachychiton propulenum*.

Table 5. Comparison of physio-biochemical parameters of selected plant species grown in the West part of the garden.

Bed No.	Plant species	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
1	*Acalypha marginata*	23.60de	96.41a	6.20d-f	0.267b-e	24.91c	Intermediate
	Araucaria heterophylla	15.78fg	55.57j	6.34d-f	0.232d-f	15.93g	Sensitive
	Delonix regia	45.88a	95.89ab	6.40d-f	0.335a	40.48a	Tolerant
	Duranta erecta "Variegata"	16.41fg	94.64ab	6.60c-e	0.241c-f	21.69d	Intermediate
	Ficus microcarpa "Hawii"	17.80f	94.61ab	7.80a	0.143g	21.82d	Intermediate
	Hibiscus rosa-sinensis	14.05g	87.49d-f	6.80b-d	0.309ab	18.74ef	Intermediate
	Pinus halepensis Mill.	41.45b	72.35h	5.71f	0.193fg	31.71b	Tolerant
	Punica granatum	18.57f	78.13g	6.35d-f	0.214ef	20.00d-f	Intermediate
	Lantana camara	25.10de	90.01c-e	6.30d-f	0.312ab	25.63c	Intermediate
7	*Bauhinia variegate*	28.24c	86.47ef	6.15d-f	0.302a-c	26.86c	Intermediate
	Brachychiton porpulenum	25.63d	95.67ab	5.87ef	0.148g	24.99c	Intermediate
	Delonix regia	16.41fg	90.80cd	6.78b-d	0.245c-f	20.61de	Intermediate
	Ficus benghalensis	14.98g	92.62bc	6.82b-d	0.282a-d	19.90d-f	Intermediate
	Ficus elastica	15.82fg	94.47ab	7.50ab	0.307ab	21.80d	Intermediate
	Ficus microcarpa "Hawii"	22.51e	85.47f	7.41ab	0.287a-d	25.88c	Intermediate
	Ficus retusa	22.48e	87.23ef	7.34a-c	0.296a-c	25.89c	Intermediate
	Pius canariensis Sweet ex. K. Spreng	22.40e	81.19g	4.15g	0.272b-e	18.03f	Intermediate
	Thuja orientalis	23.31de	64.85i	5.89ef	0.311ab	20.96d	Intermediate

From the aforestated results, it is concluded that each tree and shrub species in each part of the garden exhibited a different behaviour against air pollution prevailing in every part than the other species, i.e. each species gave individual response than the other species under air pollution conditions of the same place. So, it can be recommend to plant *Yucca elephantipes*, *F. benjamina*, *Bauhinia variegata* and *Lantana camara* species in the North part, *Yucca elephantipes*, *Cassia nodosa*, *C. fistula* and *F. benjamina* in the Middle part; *Cassia fistula, Delonix regia*, *Ficus sycomorus*, *Lantana camara* and *Washingtonia filifera* in the South part; *Ficus benghalensis*, *Codiaeum variegata* (Croton), *Duranta erecta* and *Lantana camara* in the East part, and *Delonix regia* (Poinciana), *Pinus halepensis, Bauhinia variegata*, *Ficus retusa (F. nitida)*, *F. microcarpa* "Hawii", *Lantana camara* and *Brachychiton porpulenum* in the west part as the most suitable ornamentals for air pollution load in the cited parts of Japanese garden.

REFERENCES

1. Akilan, M. and Nandhakumar, S. 2016. Air pollution tolerance index of selected plants in industrial and urban areas of Vellore district. Agric. Sci. Digest, 36 (1): 66-68.
2. Andrew, B. 2005. Cairo: A Cultural and Literary History. Signal Books, P.196.

3. Babu, G. B.; parveen, S. N.; Kumar, K. N. and Reddy, M. S. 2013. Evaluation of air pollution tolerance indices of plant species growing in the vicinity of cement industry and Yogi Vemana Univ. Campus. Indian J. Advances in Chem. Sci., 2 (1): 16-20.
4. Bailey, L. H. 1976. Hortus Third, Macmillan Publishing Co., Inc., 866 Third Avenue, New York, N.Y. 10022.1290 pp.
5. Begum, A. and Harikrishna, S. 2010. Evaluation of some tree species to absorb air pollution in three industrial locations of south Bengaluru, India. E.Journal of Chemitry, 7 (1): 151-156.
6. Bora, M. and Joshi, M. 2014. A study on variation in biochemical aspects of different tree species with tolerance and performance index. Ecoscan, 9 (1): 59-63.
7. Chandawat, D.K.; Verma, P. U. and Solanki, H. A. 2011. Air pollution tolerance index (APTI) of tree species at cross road of Ahmedabad city. Life Sci. Leaflets, 20: 935-943.
8. Dwivedi, A.K. and Tripathi, B. D. 2007. Pollution tolerance and distribution pattern of plants in surrounding area of coal-fired industries. J. Environ. Biol., 28: 257-263.
9. Dwivedi, A.K.; Tripathi, B. D. and Shashi, A. 2008. Effect of ambient air sulphur dioxide on sulphate accumulation in plants. J. Environ. Biol., 29 (3): 377-379.
10. Jyothi, S.J. and Jaya, D. S. 2010. Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvananthapuram, Kerala. J. Environ. Biol., 31: 379-386.
11. 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: 18881-18895.
12. Krishnaveni, M.; Chandrasekar, R.; Amsavalli, L.; Madhaiyan, P. and Durairaj, S. 2013. Air pollution tolerance index of plants at Perumal Malai Hills, Salem, Tamil Nadu, India. Inter. J. Pharma Sci. Res., 20 (1): 234-239.
13. Kumari, J. and Deswal, S. 2017. Assessment of air pollution tolerance index of selected plants unveil to traffic roads of Noida, Uttar Pradesh. Inter. J. on Emerging Technologies, 8 (1): 179-184.
14. Moran, R. 1982. Formulae for determination of chlorophyllous pigments extracted with N, N-dimethylformamide. Plant Physiol., 69, 1376–1381.
15. Noor, M. J.; Sultana, S.; Fatima, S.; Ahmad, M.; Zafar, M. and Sarfraz, M. 2015. Estimation anticipated performance index and air pollution tolerance index and of vegetation around the marble industrial area of Potwar region: Bioindicators of plant pollution response. Health, 37 (3): 441-455.
16. Patel, D. and Kumar, J. I. N. 2018. An evaluation of air pollution tolerance index and anticipated performance index of some tree species considered for green belt

development: A case study of Nandesari industrial area, Vadodara, Gujarat, India. Open J. Air Pollution, 7: 1-13.

17. Prasad, B.J. and Rao, D. N. 1982. Relative sensitivity of a leguminous and a cereal crop to sulphur dioxide pollution. Environ. Pollut., 29: 57-70.
18. Rahmawati, N.; Rosmayati, D. and Basyuni, M. 2014. Chlorophyll content of soybean as affected by foliar application of ascorbic acid and inoculation of arbuscular micorrhizal fungi in saline soil. Inter. J. Sci. Technol. Res., 3 (7): 127-131.
19. Sadasivam, S. and Manickam, A. 1996. Biochemical Methods: New Age International (P) Litd., Publishers, 2nd ed., New Delhi, pp. 152-160.
20. Salaa, M.M. and Al-Kawaz, L. S. 2017. Assessment of air pollution using air polluation tolerance index (APTI) by two plant species (*Concocarpus lancifolius* and *Dodonaea viscosa*) in Babylon province. Mesopotemia Environ. J., 3 (2): 11-17.
21. SAS, Institute. 2009. SAS/STAT User`s Guides Statistics. Vers. 6.04, 4th Ed., SAS. Institute Inc. Cary, N.C., USA.
22. Singh, S. K. and Rao, D. N. 1983. Evaluation of plants for their tolerance to air pollution. Symp. On Air Pollution Control. New Delhi, Proceedings. PP. 218-224.
23. Steel, R. G. D. and Torrie, J. H. 1980. Principles and procedures of statistics. McGrow Hill Book Co., Inc., New York, P: 377-400.
24. Tripathi, A.; Tiwari, P. B.; Mahima, A. and Singh, D. 2009. Assessment of air pollution tolerance index of some trees in Moradabad city. India. J. Environ. Biol., 30 (4): 545-550.
25. Yan, D. and Hui, J. 2008. Variation in air pollution tolerance index of plants near a steel factory. Implications for landscape plant species selection for industrial areas. Wseas Transactions on Environ & Develop., 1:24-30.

تقييم قدرة بعض أنواع نباتات الحديقة اليابانية على تحمل التلوث الهوائي
(أ) مقارنة الأنواع المختلفة النامية في جزء محدد (مكان واحد) من الحديقة

فوزية غريب عبد النبي زنة [1]، لبنى صلاح طه[2] ، سيد محمد شاهين[1]

1. *قسم بحوث الحدائق النباتية، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر.*
2. *قسم نباتات الزينة والأشجار الخشبية، المركز القومي للبحوث، الدقي، مصر.*

لأن الأنواع المختلفة من النباتات تظهر عادة سلوكاً مختلفاً ضد التلوث الهوائي في المواقع المختلفة، بل حتى داخل المكان الواحد، فقد أجريت هذه الدراسة على بعض نباتات الزينة النامية أماكن مختلفة من الحديقة اليابانية بمدينة حلوان الصناعية، القاهرة، مصر خلال موسم الصيف 2017 لتحديد درجة تحمل هذه النباتات لتلوث الهواء السائد في منطقة حلوان، كإحدى بؤر التلوث الهامة في جنوب العاصمة مستخدمين في ذلك دليل تحمل التلوث الهوائي (APTI) والذي تم حسابه باستخدام أربعة صفات طبيعية-كيموحيوية للأوراق، هي محتوى حمض الأسكوربيك، المحتوى النسبي للماء بالأوراق، حموضة مستخلص الأوراق، محتوى الكلوروفيللات الكلي بالأوراق، كأداة عملية لتحديد درجة تحمل النباتات للتلوث الهوائي و المقارنة فيما بينها. ولقد تم جمع عينات ورقية طازجة كل شهر، ثلاث مرات أثناء ساعات النهار من نباتات الزينة المختارة والتي تنمو في الأجزاء الشمالية، الوسطى، الجنوبية، الشرقية والغربية للحديقة لعمل التقديرات اللازمة للعوامل الأربعة سالفة الذكر. استخدم أيضا المقياس المدرج لدليل التحمل (APTI scale) لتحديد درجة حساسية أو تحمل كل نوع من الأنواع النباتية موضع الدراسة.

أوضحت النتائج المتحصل عليها وجود اختلاف واضح في متوسطات محتوى حمض الأسكوربيك، النسبة المئوية لمحتوى الماء بالأوراق، حموضة مستخلص الأوراق، محتوى الكلوروفيللات الكلي بالأوراق وقيم دليل تحمل التلوث المحسوبة فيما بين الأنواع النباتية المختلفة التي تم اختيارها بكل جزء من الحديقة. لذلك، أظهر كل نوع من نباتات الزينة المختارة سلوكاً فردياً عن الأنواع الأخرى تحت ظروف التلوث الهوائي بكل جزء على حدة. أي أن النباتات المختلفة داخل المكان الواحد أظهرت تبايناً واضحاً في سلوكها ضد التلوث السائد بهذا المكان. وطبقاً لقيم دليل تحمل التلوث الهوائي (APTI values) المحسوبة للأنواع النباتية المختلفة في كل جزء مستقل بالحديقة ودرجة التحمل المناظرة لها يمكن النصح بالأتي:

- زراعة نباتات اليوكا، الفيكس بنجامينا، حف الجمل واللانتانا كمارا في الجزء الشمالي للحديقة.
- زراعة نباتات اليوكا، كاسيا نودوزا، الخيار شمبر والفيكس بنجامينا في الجزء الأوسط للحديقة.
- زراعة نباتات الخيار شمبر، البوانسيانا، الجميز، اللانتانا كمارا ونخيل البرتشارديا في الجزء الجنوبي للحديقة.
- زراعة نباتات فيكس التين البنغالي، الكروتون، الدورانتا الخضراء، واللانتانا كمارا في الجزء الشرقي للحديقة، بينما في الجزء الغربي يفضل زراعة نباتات البوانسيانا، الصنوبر الحلبي، خف الجمل، الفيكس نيتدا، الفيكس هاواي، اللانتانا كمارا، وبودرة العفريت، كأكثر نباتات الزينة ملائمة لحجم التلوث الهوائي السائد بكل جزء تم اختياره بالحديقة اليابانية.