EVALUATION OF SOME JAPANESE'S GARDEN PLANT SPECIES FOR ITS TOLERANCE TO AIR POLLUTION
B. COMPARISON OF DIFFERENT SPECIES OF THE FAMILY GROWN IN DIFFERENT PARTS OF THE GARDEN

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Abstract

This part of the study was also carried out at the laboratories of both Hort. Res. Inst., ARC, Giza and Agric. & Biol. Res. Div., NRC, Dokki on about 31 ornamental plant species belong to 12 families chosen from different places inside the field of Japanese garden, that lies at Helwan industrial City, Cairo, Egypt during the summer season 2017 in order to compare the tolerance degree of these various species against the air pollution prevailing in this city, beside testing the effect of their planting place on their tolerance. Thus, leaf samples from the selected plants were monthly collected in the early morning for 3 times and analyzed to evaluate 4 physio-biochemical characters involving: ascorbic acid content, relative water content (RWC), leaf extract pH and total chlorophyll content, which were used afterwards to calculate the values of air pollution tolerance index (APTI). The APTI scale was also used for determination of tolerance degree (level) for every plant species. The results have shown that means of ascorbic acid content, RWC, leaf extract pH, total chlorophyll content and APTI values were markedly differed with various significance levels due to variation of plant species and planting place. So, each species (under each family) exhibited a different tolerance degree against air pollution than the other species of its family. Such tolerance degree was also changed with changing of planting place inside the area of the garden. Accordingly, at least it can be recommend to choose the following ornamental species (from each family) for tolerance against the air pollution at Helwan city: *Schinus molle (*Anacardiaceae), *Plumeria alba* (Apocynaceae), *Cycas revoluta* (Cycadaceae), *Cassia fistula*, *C. nodosa* and *delonix regia* (Leguminosae), *Yucca elephantipes* (Liliaceae), *Hibiscus rosa-sinensis* (Malvaceae), *Ficus benghalensis* (Moraceae), *Washingtonia filifera* (Palmaceae), *Pinus halepensis* (Pinaceae) and *Lantana camara* (Verbenaceae).

Key words: air pollution, trees and shrubs of Japanese garden, APTI, relative water content (RWC) %.

INTRODUCTION

Until now, air pollution is considered the major and most complex challenge of environment, as all countries failed to yield fresh ambient air due to the continuous and increased industrial activities, unplanned urbanization, vehicle emissions, population growth and random future planes of city development (Jayanthi and Krishnamoorthy, 2006). On the other hand, ornamental plants are still the most important choice for balancing the ecological system of our environment (Kumari and

Deswal, 2017), although tolerance and sensitivity of these plants to air pollution is differ from species to species and from place/site to another. In this regard, Liu and Ding (2008) suggested that some ornamentals, such as *Metaplexis japonica*, *Amelopsis aconitifolia* var. glabra, *Rhamnus parvifolia*, *Ziziphus jujuba* var. Spinosa, *Pharbitis purpurea*, *Vitex negundo*, *Broussonetia papyrifera*, *Robinia pseudoacacia* and *Ailanthus altissima* exhibited APTI variation related to changes in air temperature and water status of the tree. Likewise, Akilan and Nandhakumar (2016) reported that higher APTI values were attained by *Nerium oleander*, *Tamarindus indica*, *Azadirachta indica* and *Pungamia pinnata* trees grown in industrial and urban areas compared to areas free from industries and transport. *Nerium oleander* recorded higher APTI values exhibiting more tolerance than the other selected trees.

These facts are documented by those discovered by Dwivedi and Tripathi (2007) on *Ricinus communis* and *Lepidium sativum*, Tripathi *et al.*, (2009) on *Ficus rumphii*, *Pongamia Pinnata*, *Alstonia scholaris*, *Saraca indica*, *Cassia simea*, *Bauhinia variegata*, *Azadirachta indica* and *Grewelia robusta*, Begum and Harikrishna (2010) on *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata*, Chandawat *et al.*, (2011) on *Ficus benghalensis*, *F. religiosa*, *F. glomerata*, *Azadirachta indica* and *Polyalthia longifolia*, Bhattacharya *et al.*, (2013) on *Acacia arabica*, *Azadirachta indica*, *Ficus benghalensis*, *Mangifera indica*, *Peltophorum pterocarpum* and *Polyalthia longifolia*, Aji *et al.*, (2015) on *Anacardium occidentale*, *Azadirachta indica*, *Cassia angustifolia*, *Ecalyptus* spp., *Khaya senegalensis* and *Mangifera indica*, Madan and Chauhan (2015) on *Azadirachta indica*, *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*, *Psidium guajava* and *Syzygium cumini* and Akilan and Nandhakumar (2016) who revealed that Arcot industrial area was more polluted than Ranipet urban area, while the college farm recorded least pollution due to less exposure to industries, transport and urbanization. So, APTI values of *Nerium oleander*, *Tamarindus indica*, *Azadirachta indica* and *Pungamia pinnata* trees at the college farm were low compared to Arcot and Ranipet industrial and transportation areas.

This study, however aims to determine the behaviour of each tree or shrub grown in different parts of Japanese Garden towards air pollution prevailed in Helwan industrial area using air pollution tolerance index (APTI), as a logical tool for measuring tolerance and sensitivity of plants to air pollution.

MATERIALS AND METHODS

In this part of study that conducted at the laboratories of both Hort. Res. Inst., ARC, Giza, Egypt and Agric. and Biol. Res. Div., NRC, Dokki, Egypt during summer, 2017 to compare the tolerance degree of some trees or shrubs cultivated in different parts of Japanese Garden at Helwan City.

Study area:

Japanese garden lies at Helwan City, as a puplic park subjected to a great industrial pollution since many decades, is selected and devoted for such study. Description of the study area is mentioned before, in details in the first part of this study (Part A) amended with photos No. 1.

Plant species under study:

The chosen trees and shrubs used in such part of trial were collected from different parts of the garden, they belong to various families as follows:

* *Ficus benghalensis*, *F. benjamina*, *F. decora*, *F. elastica*, *F. lyrata*, *F. microcarpa* "Hawaii", *F. retusa* and *F. sycomorus* from Fam. **Moraceae**.
* *Bauhinia variegata*, *Cassia fistula*, *C. nodosa*, *Delonix regia* and *Tipuana speciosa* from Fam. **Leguminosae**.
* *Clerodendron inerme*, *Duranta erecta*, *D. erecta* "Variegata" and *Lantana camara* from Fam. **Verbenaceae**.
* *Schinus molle* and *S. terebinthifolius* from Fam. **Anacardiaceae**.
* *Nerium oleander* and *Plumeria alba* from Fam. **Apocynaceae**.
* *Thuja orientalis* from Fam. **Cupressaceae**.
* *Cycas revoluta* from Fam. **Cycadaceae**.
* *Acalypha marginata*, *Euphorbia pulcherrima* and *Codiaeum variegata* from Fam. **Euphorbiaceae**.
* *Yucca elephantipes* from Fam. **Liliaceae**.
* *Hibiscus rosa-sinensis* from Fam. **Malvaceae.**
* *Washingtonia filifera* from Fam. Palmaceae.
* *Pinus halepensis* and *P. canariensis* from Fam. **Pinaceae**.

The botanical characters and main uses of the previous plant species are described briefly in part A of the study.

Procedures and physio-biochemical parameters determination:

The fully mature leaf samples were monthly collected in the morning hours for three times during the period from 15th June to 15th August 2017 from the selected plant species grown in the different beds (from bed No.1 to bed No. 12). The leaves are brought to the laboratory and firstly washed with tap water, then with distilled water. Thereafter, the leaf samples were analyzed for determination of relative water content (RWC %), leaf extract pH, total chlorophylls (mg/g f.w.) and ascorbic acid content (mg/100 g f.w.) using the standard methods described by Henson *et al.*, (1981), Prasad and Rao (1982), Yadava (1986) and Sadasivam and Manickam (1996), respectively (as explained in part A).

Estimation of air pollution tolerance index (APTI):

The APTI values of the chosen trees and shrubs were calculated by the method suggested by Singh and Rao (1983), using the following equation:

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 = pH value of the leaf extract and RWC = Relative water content (%).

According to APTI values, the different plant species used in such work can be categorized into sensitive, moderately tolerant (Intermediate) and tolerant by the scale proposed by Begum and Harikrishna (2010), in which APTI values were ranged from 1 to 100 as shown in the following Table:

APTI value	Response degree
> 1	Very sensitive
1-16	Sensitive
17-29	Moderately tolerant (Intermediate)
30-100	Tolerant

Data were then tabulated and subjected to analysis of variance using the program of SAS Institute (2009), which followed by Duncan's New Multiple Range Test (Steel and Torrie, 1980) for elucidating the significancy between the means of various plant species.

RESULTS AND DISCUSSIONS

Effect of planting place inside the garden on physio-biochemical characters of the different plant species belong to:

1- Fam. Moraceae:

It is obvious from data presented in Table (1) that various species of Ficus genus exhibited a clear variation in the means of physio-biochemical characters with significant differences among themselves in some cases. However, the highest concentration of ascorbic acid was noticed in the leaves of *F. benghalensis* grown in bed No. 12 (26.5 mg/ 100 g. f.w.), followed by *F. benjamina* that attained 24.91 mg/100 g f.w. All other species gave concentrations ranged between 14.29-18.64 mg/ 100 g f.w., except for *F. benjamina* (grown in bed No. 3), *F. mi crocarpa* "Hawaii" and *F. retusa* (both in bed No.7) that acquired 23.41, 22.51 and 22.48 mg/100 g. f.w., respectively.

Higher ascorbic acid in the leaves of some Ficus species is a sign of their tolerance to air pollution because ascorbic acid plays a vital role in cell wall synthesis, defense and cell division, while lower content in the leaves of some others supports their sensitivity against air pollutants. Such gains are in accordance with those detected by Tripathi *et al*., (2009) on *Ficus remphii*, Begum and Harikrishna (2010) on *Ficus religiosa*, Chandawat *et al*., (2011) on *Ficus benghalensis*, *F. religiosa* and *F. glomerata*, Bhattacharya *et al*., (2013) on *Ficus benghalensis* and Madan and Chauhan (2015) who noticed that *Ficus religiosa* was the best tolerant species for the different polluted sites in Haridwar City, India.

In general, the relative water content (%) in the leaves of Ficus species employed in this work is considered high, as it ranged between 80.4 to 96.2 % with few significant differences among them. However, the highest RWC (96.2 %) was found in the leaves of *F. elastic decora* grown in bed No. 6, may be due to its higher leaf area and thickness relative to other species and followed by *F. elastica* (bed No.7) *F. microcarpa* "Hawaii" (bed No. 1) and *F. benjamina* (bed No. 6), which gave means closely near to that of *F. decora* with non-significant differences among themselves. The high RWC in plants is useful for drought resistance and acidity dilution of leaf extract. Thus, the plants with high RWC under pollution may be more tolerance (Krishnaveni *et al*., 2013). In this respect, Bhattacharya *et al*., (2013) found that RWCs of *F. benghalensis* sampled from polluted sites were higher in monsoon season than that of unpolluted one. Likewise, Kumari and Deswal (2017) observed that the RWC of *F. religiosa* as tolerant species for air pollution was higher (83 %) than that of the sensitive *Polyalthia longifolia* (49 %). This finding was emphasized by Patel and Kumar (2018) who found that *F. religiosa* grown in polluted industrial area has the maximum RWC of 64 %, followed by *Polyalthia longifolia* (60 %) and *F. benghalensis* (55 %).

As for pH values, data in Table (1) showed that leaf extract pHs of most Ficus species used in this study were slightly tended towards alkalinity, with the exception of *F. benghalensis* (in beds No. 7 and 12), *F. decora* (in bed No.6), *F. elastica* (in bed No. 4), *F. lyrata* (in bed No. 6) and *F. microcarpa* "Hawii" (in bed No. 1) which recorded pH values tended trivially to acidity. Nevertheless, the differences between pH values of most species were significant. However, pH level plays a great role in regulation of pollution sensitivity of the plants, where low pH reduces the conversion of hexose sugar to ascorbic acid, influence the stomata sensitivity and may reduces photosynthetic process, whereas high one favours ascorbic acid activity and thus can increase the tolerance of plants against pollution (Bora and Joshi, 2014). Such gains are in harmony with those of Tripathi *et al*., (2009) on F. rumphii, Begum and Harikrishna (2010) on *F. religiosa*, Chandawat *et al*., (2011) on *F. benghalensis*, *F. religiosa* and *F. glomerata* and Bhattacharya *et al*., (2013) they postulated that *F. benghalensis* samples collected from 9 polluted sites exhibited pH values towards acidic side. Furthermore, Patel and Kumar (2018) pointed out that samples of *F.*

benghalensis and *F. religiosa* plants collected from polluted area exhibited an acidic pH of 5.93 and 6.98, respectively compared with that of control (8.0).

The total chlorophyll content in the leaves of tested Ficus species cultivated in various parts of the garden ranged between 0.143 and 0.362 mg/g f.w. (Table, 1). The maximal concentration was found in the leaves of *F. retusa* (0.362 mg/g) grown in bed No. 3, followed by *F. elastica* in bed No. 4 (0.344 mg/g), *F. benghalensis* in bed No. 6 (0.334 mg/g), *F. benjamina* in bed No. 3 (0.319 mg/g), *F. retusa* in bed No. 2 (0.318 mg/g), *F. lyrata* in bed No. 6 (0.315 mg/g), *F. elastica* in bed No. 7 (0.307 mg/g) and *F. benjamina* in bed No. 6 (0.303 mg/g), with non-significant differences among themselves, whilst the minimal concentration scored by *F. microcarpa* "Hawaii" cultivated in either bed No. 1 (0.143 mg/g) or bed No. 12 (0.172 mg/g) due to its variegated leaves.

The high level of air pollution may blocking the stomatal pores on the leaf surfaces due to accumulation of suspended particulate matters which may dispersed in the air from combustion processes, industrial activities and natural sources might be one of the important reasons for decreasing chlorophyll content in the leaves of contaminated plants. Air pollutants may cause a degradation of chlorophyll molecule and reduce the efficiency of chloroplasts, finally affecting the rate of photosynthesis and stomatal conductance, fall of premature leaf and hence reducing growth and productivity (Bora and Joshi, 2014). Concentration of chlorophyll was also varied from species to species, leaf age and biotic and abiotic conditions prevailing in the polluted area (Rai and Panda, 2015). Similar observations to the aforenamed ones were also obtained by Dwivedi and Tripathi (2007) on *Ricinus communis* and *Lepidium sativum*, Chandawat *et al*., (2011) on *F. benghalensis*, *F. religiosa* and *F. glomerata*, Geeta and Namrata (2014) on *Alstonia scholaris*, *Polyalthia longifolia* and *Thevetia nerifolia,* as well as Madan and Chauhan (2015) found that samples of *Ficus religiosa* and *Mangifera indica* collected from different sites of Haridwar City, India possessed higher chlorophyll content than those of *Polyalthia longifolia* and *Psidium guajava*.

A noticeable variation in the values of APTI was also observed among the different species of Ficus utilized in this investigation regardless its place with significant differences in few cases, as the means of such index ranged between 19.25 and 29.77 (Table, 1) indicating that all the rested Ficus species are considered moderately tolerant to air pollution of Helwan industrial city, except for *F. benghalensis* plants grown in bed No. 6 that gave the highest APTI value (48.48) to be the only tolerant species among the various Ficus species examined in this study. The plant species with high APTI values are tolerant to air pollution and can be used as filters/sink to alleviate air pollution, while those with moderate and low APTI values are intermediate and sensitive to air pollution and can be used as bioindicators (Patel and Kumar, 2018). Presence of tolerant plants in the industrial area can improve air quality by uptake of the gaseous pollutants and precipitate suspended particulate ones (Kumari and Deswal, 2017).

According to the values of APTI and tolerance degree presented in Table (1), the selected Ficus species sampled from various places of Japanese garden can be arranged in a descending order as follows: *Ficus benghalensis* (bed No. 6) > *F. benjamina* (bed No. 6) > *Ficus benghalensis* (bed No. 12) > *F. sycomorus* (bed No. 11) > *F. benjamina* (bed No. 3) > *F. microcarpa* "Hawaii" (bed No. 7) and *F. retusa* (bed No. 7) > *F. elastica* (bed No. 9) ….. and then the other species.

Table 1. Comparison of physio-biochemical parameters of Ficus species (Fam. Moraceae) grown in different parts of the garden

Plant species	Bed No	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
Ficus benghalensis	6	16.31e-h	88.31c-h	7.17g	0.334a-c	48.48a	Tolerant
	7	14.98g-i	92.62a-c	6.82i	0.282b-d	19.90g	Intermediate
	12	26.50a	91.30a-e	6.70j	0.254de	27.56c	Intermediate
Ficus benjamina	3	23.41bc	92.30a-c	6.98h	0.319a-c	26.32cd	Intermediate
	6	24.91ab	94.43ab	7.86a	0.303a-d	29.77b	Intermediate
Ficus elastica "decora"	6	14.40hi	96.20a	6.42k	0.273cd	19.25g	Intermediate
Ficus elastica	2	14.29i	91.49a-d	7.50c	0.208ef	20.17fg	Intermediate
	4	18.55d	83.58hi	6.40k	0.344ab	20.86fg	Intermediate
	7	15.82f-i	94.47ab	7.50c	0.307a-d	21.80fg	Intermediate
	9	18.64d	90.17b-f	7.26f	0.299b-d	23.10e	Intermediate
Ficus lyrata	6	17.45d-f	84.84g-i	6.40k	0.315a-d	20.20fg	Intermediate
Ficus microcarpa "Hawii"	1	17.80de	94.61ab	6.80i	0.143g	21.82ef	Intermediate
	7	22.51c	85.47f-h	7.41d	0.287b-d	25.88d	Intermediate
	12	14.91g-i	89.01c-g	7.52c	0.172fg	20.37fg	Intermediate
Ficus retusa	3	16.07e-i	80.40i	7.70b	0.362a	21.00fg	Intermediate
	7	22.48c	87.23d-h	7.34e	0.296b-d	25.89d	Intermediate
	2	16.53e-g	90.25b-f	7.35e	0.318a-c	21.71ef	Intermediate
Ficus sycomorus	11	23.41bc	86.50e-h	7.71b	0.255de	27.29cd	Intermediate

Means followed by the same latter in a column do not differ significantly according to Duncan's New Multiple Range Test at 5 % level.

2- Fam. Leguminosae:

A similar response to that of Fam. Moraceae occurred as well in respect of Fam. Leguminosae, as the means of various physio-biochemical characters showed a marked variation among the different species of Fam. Leguminosae selected for such trial and planted in different places inside the field of Japanese garden (Table, 2).

The highest concentrations of ascorbic acid were achieved by *Cassia nodosa* (in bed No. 6), *C. fistula* (in bed No. 6), *Delonix regia* (in bed No. 1), *C. fistula* (in bed No. 11) and *D. regia* (in bed No. 10) plant species which acquired 81.46, 59.27, 45.88, 31.68 and 29.40 mg/100 g f.w., respectively with significant differences among them, while the lowest concentrations were recorded by *Delonix regia* (in bed No. 7), *Cassia fistula* (in bed No. 9), *Tipuana speciosa* (in bed No. 6), *Bauhinia variegata* (in bed No. 3) and *D. regia* (in bed No. 2) plant species that registered 16.40, 16.43, 18.59, 19.42 and 19.53 mg/100 g f.w., respectively with mostly non-significant differences among them.

The relative water content as percentages (RWC %) was generally high in most chosen species from such family, as it was more than 90 % in the leaves of *Delonix regia* trees sampled from beds No. 1, 2, 7 and 10 and more than 80 % for other selected species grown in different beds, with the exception of *D. regia* (in bed No. 3), *Tipuana speciosa* (in bed No. 6) and *Cassia fistula* (in bed No. 9), in which the RWC % decreased to 77.14, 71.55 and 65.52 %, respectively.

Regarding the pH values of leaf extracts, they were slightly less than 7 in most selected species of this family grown in different places exhibiting a trivial tend toward acidity, but the highest acidity was discovered in the leaf extracts of *Cassia fistula* (in bed No. 9), *C. nodosa* (in bed No. 6) and *Bauhinia variegata* (in bed No. 3) that attained pH values of 5.45, 5.85 and 5.90, respectively.

The total chlorophyll content (mg/g f.w.) reached to the maximal records in the leaves of *Bauhinia variegata* grown in beds No. 2 and 3 (0.394 and 0.354 mg/g) and in the leaves of *Delonix regia* sampled from beds No. 2 and 6 (0.338 and 0.359 mg/g) with non-significant differences among them (Table, 2), but ranged in the other species between 0.245 and 0.335 mg/g f.w. with various significance levels in between. However, the lowest concentration of such component was noticed in the leaves of *C.fistula* plants cultivated in bed No. 9, as it gave only 0.177 mg/g f.w.

It is also noticed from data presented in Table (2) that more than one species of Fam. Leguminosae were tolerant to air pollution of Helwan industrial city compared to species of Fam. Moraceae that involved only one tolerant species (*Ficus benghalensis*). These tolerant species of Fam. Leguminosae were: *Cassia nodosa* (grown in bed No. 6), *C. fistula* (in bed No. 6), *Delonox regia* (in bed No. 1), *C. fistula* (in bed No. 11) and *D. regia* (in bed No. 10) where such species gave APTI values of 58.25, 49.28, 40.48, 31.15 and 30.02, respectively, while all the other tested species scored APTI values ranged between 20.29 and 26.86 indicating their moderate ability to tolerate air pollution prevailing in study area. On the other side, the lowest value of APTI (15.94) was attained by *C. fistula* plants sampled from bed No. 9 to be the only sensitive species among the different examined species of Fam. Leguminosae.

Hence, the different tree species of Fam. Leguminosae selected from various places inside the Japanese garden could be scale-down in this order: *Cassia nodosa* (bed No. 6) > *C. fistula* (bed No. 6) > *Delonix regia* (bed No. 1) > *C. fistula* (bed No. 11) > *D. regia* (bed No. 10) > *Bauhinia variegata* (beds No. 2 and 7) > *Cassia nodosa* (bed No. 7) > *C. fistula* (bed No. 9 due to its giving the least means of ascorbic acid, RWC, total chlorophyll content and APTI value).

The previous results may be discussed and interpreted as done before in case of Fam. Moraceae. Similarly, were those observations postulated by Dwivedi and Tripathi (2007) on *Ricinus communis*, *Lepidium sativum*, Bora and Joshi, (2014) on *Azadirachta indica* and *Eucalyptus sp*., *Ficus religiosa, Saraca indica* and *Tictona grandis* and Aji *et al*., (2015) they declared that *Mangifera indica* and *Anacardium occidentale* collected from high, moderate and low pollution rate locations in Maiduguri city, India are tolerant species, while *Khaya senegalensis*, *Azadirachta indica* and *Eucalyptus sp*. are intermediate and *Cassia angustifolia* is sensitive. On six plant species collected from 4 different sites of Haridwar City, India, Madan and Chauhan (2015) detected that *Ficus religiosa* was found under very good category, while *Azadirachta indica*, *Mangifera indica* and *Syzygium cumini* were categorized as good performer but *Polyalthia longifolia* and *Psidium juajava* to be very poor performer. Besides, Akilan and Nandhakumar (2016) claimed that *Nerium oleander* recorded higher APTI values from the industrial and transportation areas than areas free from industries and transport showing more tolerance than *Azadirachta indica*, *Pungamina pinnata* and *Tamarindus indica*.

Table 2. Comparison of physio-biochemical parameters of selected plant species belong to (Fam. Leguminosae) grown in different parts of the garden.

Plant species	Bed No	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
Bauhinia variegata	2	23.36gh	84.58d-f	6.80ab	0.394a	25.26ef	Intermediate
	3	19.42i	88.82b-d	5.90h	0.354a-c	21.36hi	Intermediate
	7	28.23ef	86.47c-e	6.15g	0.302d-f	26.86e	Intermediate
Cassia fistula	6	59.27b	87.80b-e	6.50e	0.333b-e	49.28b	Tolerant
	9	16.43ef	65.52i	5.45i	0.177g	15.94j	Sensitive
	11	31.68d	88.28b-d	6.75b	0.297c-f	31.15d	Tolerant
Cassia nodosa	6	81.46a	80.95fg	5.85h	0.311b-e	58.28a	Tolerant
	10	25.68fg	80.96fg	6.20g	0.315b-e	24.83f	Intermediate
Delonix regia	1	45.88c	95.89a	6.40f	0.335b-d	40.48c	Tolerant
	2	19.53i	95.74a	8.81a	0.338a-d	23.53fg	Intermediate
	3	21.12hi	77.14g	6.66c	0.302a-d	22.41gh	Intermediate
	6	18.68ij	83.11ef	6.41f	0.359ab	20.96hi	Intermediate
	7	16.40j	90.80bc	6.78ab	0.245f	20.60hi	Intermediate
	10	29.40de	92.56ab	6.79ab	0.273ef	30.02d	Tolerant
	11	23.48gh	83.39ef	6.60d	0.287d-f	24.51f	Intermediate
Tipuana speciosa	6	18.59ij	71.55h	6.77ab	0.296c-f	20.29i	Intermediate

Means followed by the same latter in a column or row do not differ significantly according to Duncan's New Multiple Range Test at 5 % level.

3- Fam. Verbenaceae:

The trend observed in case of Moraceae and Leguminosae families, was also noticed in the behaviour of different species belong to Fam. Verbenaceae sampled from various places of Japanese garden. Therefore, a great variance in the means of most determined physio- biochemical characters was also occurred due to diversity of either plant species or culture place (Table, 3).

This trend was clear in the matter of ascorbic acid content, that reached to the maximal values in the leaves of *Lantana camara* plants cultivated in beds No. 1 and 10 (25.10 and 26.01 mg/100 g f.w., respectively with non-significant differences in between) and followed by the same plant species grown in bed No. 2, which gave a concentration of 22.48 mg/100 g f.w. occupying the second rank, with significant differences relative to those grown in beds No. 1 and 10. Such constituent, however, was significantly depressed to the minimum in the leaves of *Duranta erecta* (in bed No. 3) and *D. erecta* "Variegata" (in bed No. 8) which recorded means of 14.33 and 14.31mg/g f.w., successively. In general, ascorbic acid content in the leaves of *Clerodendron* and *Duranta* species was not affected by planting place, but the opposite was the right concerning *Lantana camara* species.

Likewise, the percent of relative water content (RWC %) that greatly differed in the leaves of various plant species of Fam. Verbenaceae selected from different parts of the garden, as it ranged between 71.53 and 96.56 %. The RWC was more than 90 % in the leaves of *Clerodendron inerme* cultured in bed No. 6 (96.56 %), followed by *Lantana camara* in beds No. 2 (96.17 %) and No. 3 (95.14 %), *D. erecta* "Variegata" in bed No. 1 (94.64 %) and *L. camara* in bed No. 1 and *D.erecta* "Variegata" in bed 12 (90.01 %), while in the set of other species it was more than 80 %, except for *Clerodendron inerme* (in bed No. 3) and *L. camara* (in bed No. 10) that possessed only 49.40 and 71.53 % RWC in their leaves.

Leaf extract pH values of most species chosen from Fam. Verbenaceae and used in this study tended toward acidity regardless their cultivating place, with the exception of *Lantana camara* plants cultivated in beds No. 2, 10 and 12 that significantly raised pH values to 7.51, 7.17 and 7.45, respectively over all the other selected species, revealing its tending to alkalinity. However, the highest acidity was attained by *Clerodendron inerme* climber, which scored 5.75 pH value.

Also, total chlorophyll content in the leaves of plant species selected from Fam. Verbenaceae varied from species to species and from place to another as shown in Table (3). However, the utmost high concentrations were achieved by *Clerodendron inerme* sampled from bed No. 3 (0.326 mg/g f.w.) and *Duranta erecta* grown in bed No. 3 (0.331 mg/g f.w.), followed by *D. erecta* "Variegata" in bed No. 8 (0.323 mg/g f.w.) and *L. camara* in bed No. 1 (0.312 mg/g f.w.). On the other hand, the lowest concentrations were found in the leaves of *D. erecta* sampled from bed No. 12 and *L. camara* cultivated in bed No. 3, where such two species contained only 0.110 and 0.099 mg/g f.w., respectively in their leaves with significant differences in comparison to other species grown in various places.

According to APTI values and tolerance degree of various plant species selected from Fam. Verbenaceae and ranged between 17.55 and 27.10 (Table, 3), it is clear that all species are moderately tolerant irrespective of their planting places inside the field of Japanese garden. So, arranging them in sequence in not worthy.

The aforementioned results could be explained and discussed as previously stated in case of Fam. Moraceae. These gains, however are in harmony with those revealed by Liu and Ding (2008) on *Amelopsis aconitifolia*, *Rhamnus parvifolia*, *Pharbitis purpurea*, *Ailanthus altissima Robinia pseudoacacia* and *Ziziphus jujuba* var. Moreover, Madan and Chauhan (2015) clarified that *Ficus religiosa* and *Mangifera indica* were more tolerance for the air pollution than *Polyalthia lon*

gifolia and *Psidium juajava*. Recently, Patel and Kumar (2018) elicited that *Ficus benghalensis* and *F. religiosa* are the appropriate plant species for development of green belt in industrial area, and for mitigating the pollution.

Table 3. Comparison of physio-biochemical parameters of selected plant species belong to (Fam. Verbenaceae) grown in different parts of the garden.

Plant species	Bed No	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
Clerodendron inerme	3	16.45cd	49.40d	6.78d	0.326a	19.63c-e	Intermediate
	6	17.74c	96.56a	6.19i	0.265b-d	21.11bc	Intermediate
	11	15.58cd	81.37d	5.75j	0.287a-d	17.55f	Intermediate
Duranta erecta	3	14.33d	86.80be	6.50f	0.331a-d	18.47d-f	Intermediate
	12	21.18b	87.28bc	6.21hi	0.110e	22.11b	Intermediate
Duranta erecta "Vriegata"	1	16.41cd	94.64a	6.60e	0.242d	21.69bc	Intermediate
	8	14.31cd	88.03bc	6.16i	0.323ab	18.02ef	Intermediate
	12	16.31cd	90.01b	6.25h	0.287a-d	19.65c-e	Intermediate
Lantana camara	1	25.10a	90.01b	6.30g	0.312a-c	25.63a	Intermediate
	2	22.48b	96.17a	7.51a	0.264b-d	27.10a	Intermediate
	3	16.42cd	95.14a	6.26gh	0.099e	19.96cd	Intermediate
	10	26.01a	71.53e	7.17c	0.251d	26.46a	Intermediate
	12	17.62c	83.21cd	7.45ab	0.260cd	21.91b	Intermediate

Means followed by the same latter in a column or row do not differ significantly according to Duncan's New Multiple Range Test at 5 % level.

4- Fams. Anacardiaceae, Apocynaceae, Cupressaceae, Cycadaceae, Euphorbiaceae, Liliaceae, Malvaceae, Palmaceae and Pinaceae:

Owing to the low number of available species belong to some families, such as: Anacardiaceae, Apocynaceae, Cupressaceae, Cycadaceae, Euphorbiaceae, Liliaceae, Malvaceae, Palmaceae and Pinaceae, we choose the already available species that grew in various places of the garden and listed them in Table (4) to compared their physio-biochemical properties between each other.

Fam. Anacardiaceae:

Data in Table (4) showed that the two species of *Schinus* had greatly near concentrations of ascorbic acid, but *S. terebinthifolia* grown in bed No. 3 possessed higher RWC (97.16 %) and total chlorophyll (0.323 mg/g f.w.) than *S. molle* grown in bed No.6. The opposite was the right regarding pH value, where *S. terebinthifolius* exhibited higher acidity for its leaf extract (4.90) than that of *S. molle* (6.16). Thus, the two species gave, to some extent close values of APTI showing a moderate tolerance against air pollution.

Fam. Apocynaceae:

This family was exemplified in the garden by only to species; *Nerium oleander* (sampled from beds No. 3 and 10) and *Plumeria alba* (sampled from bed No. 6). The two species revealed a significant variance in the means of ascorbic acid, RWC, pH of leaf extract and APTI values, while total chlorophyll means were closely near together with non-significant differences among them. However, these two species exhibited an intermediate tolerance for air pollution, although the difference of their species and cultivating place.

Fam. Cupressaceae:

The only species found from such family in Japanese garden was *Thuja orientalis* which planted in beds No. 2, 6 and 7. Data in Table (4) clear that such species behaved a different behaviour in the 3 beds giving a significant difference in the means of most physio-biochemical parameters to be sensitive against air pollution when planted in bed No. 2 (North of the garden), but was moderately tolerant when grown in beds No. 6 (Middle of the garden) and 7 (West of the garden).

Fam. Cycadaceae:

As shown in Table (4) *Cycas revoluta* was the only representative species of this family in Japanese garden, as it was cultivated in beds No. 6 (Middle part of the garden) and No. 12 (East part of the garden). This palm-like species gave higher concentrations of ascorbic acid and total chlorophyll when grown in bed No. 6 than its grown in bed No. 12. The opposite was the right concerning leaf extract pH mean. On the other hand, means of RWC and APTI were statistically at par with each other referring to that such plant is moderately tolerant for air pollution prevailing in Japanese garden irrespective of its planting place.

Fam. Euphorbiaceae:

Three plant species belong to this family (*Acalypha marginata*, *Euphorbia pulcherrima* and *Codiaeum variegata*) were found distributed in the different parts of Japanese park. The variation in means of most physio-biochemical traits between these species was significant only among *Acalypha marginata* (in bed No. 1) and *Codiaeum variegata* (in bed No. 12) *A. marginata* (in bed No. 10) and *Euphorbia pulcherrima* (in bed No. 6). Generally, the lowest APTI value was attained by *A. marginata* in bed No. 10 (15.99) indicating its sensitivity toward air pollution, while other species recorded higher APTI values exhibiting their moderately tolerance.

Fam. Liliaceae:

Yucca elephantipes is the only species from such family who was found flourished in beds No. 3 and 6 revealing a highly tolerance ability in the two beds (places), with the superiority of its plants grown in bed No. 3 that gave 237.2 APTI value versus 169.9 for those grown in bed No. 6. This may emphasized that behaviour of plant species differs from place to another.

Fam. Malvaceae:

Hibiscus rosa-sinensis was the most plant species of such family presented in Japanese garden, as it was cultivated in beds No. 1, 2, 8 and 12 in abundance. Such plant showed a great variance in the means of various phsio-biochemical characters with significant differences due to its planting in various places. However, its ability against air pollution of Helwan industrial City was intermediate, as it acquired APTI values ranged between 17.09 to 19.92 in the different places.

Fam. Palmaceae:

The only species of such family cultivated in beds No. 6 and 9 inside the area of Japanese park was *Washingtonia filifera*. It gave higher averages of ascorbic acid, RWC and APTI in bed No. 9 than in bed No. 6, but the opposite trend was occurred in the matter of leaf extract pH and total chlorophyll content. This palm species is considered moderately tolerance for air pollution because the calculated APTI of it was 20.51 (in bed No. 6) and 26.10 (in bed No. 9) as shown in Table (4).

Fam. Pinaceae:

Two species of pine were planted in Japanese garden; *Pinus halepensis* in bed No. 1and *Pinus canariensis* in bed No., 7 (both in West of the garden). It was noticed from data in Table (4) that *P. halepensis* recorded higher ascorbic acid content and pH value than *P. canariensis*, meanwhile the latter recorded higher RWC and total chlorophyll content than the former. However, APTI value of *P. halepensis* was 31.70 indicating its tolerance for the pollution, while that of *P. canariensis* was 18.03 to be categorized as intermediate.

The previous gains may be discussed and interpreted as we done before in case of Fam. Moraceae. In brief, the results of such study indicated that tolerance and/or sensitivity of trees species for air pollution differs from species to species and from place/site to another, i.e. each plant species can exhibit a special behaviour or response according to its genetics and the pollution load of the polluted area. This truth could be documented by the results discovered by Liu and Ding (2008) who mentioned that some plant species exhibited APTI variation due to variance of air temperature and water status of the plant. Tripathi *et al.*, (2009) who suggested that plants developed a characteristic response as a result of subjecting to particular types and level of pollution. It has also been reported that when plants exposed to air pollutants, most of them experience physiological disorders before showing a special visible damage to leaves.

Table 4. Comparison of physio-biochemical parameters of selected plant species belonging to some families collected from different parts of the garden.

Plant species	Bed No.	Ascorbic acid (mg/100 g f.w.)	R.W.C. (%)	pH	Total chlorophyll (mg/g.f.w.)	APTI values	Tolerance degree
Fam. Anacardiaceae							
Schinus molle	6	29.73a	86.28b	6.16a	0.295b	27.82a	Intermediate
Schinus terebethifolius	3	28.10a	97.16a	4.90b	0.323a	24.39a	Intermediate
Fam. Apocynaceae							
Nerium oleander	10	15.07c	66.50b	6.39b	0.296a	16.65c	Intermediate
	3	27.43a	60.00c	6.10f-h	0.320a	23.61b	Intermediate
Plumeria alba	6	24.66b	88.21a	7.00a	0.299a	26.82a	Intermediate
Fam. Cupressaceae							
Thuja arientalis	2	15.52c	66.09b	5.55c	0.317a	15.71b	Sensitive
	6	19.85b	91.93a	6.14a	0.246b	21.87a	Intermediate
	7	23.31a	64.85b	5.89b	0.311a	20.96a	Intermediate
Fam. Cycadaceae							
Cycas revoluta	6	20.20a	83.12a	6.57b	0.279a	22.15a	Intermediate
	12	17.20b	83.18a	6.92a	0.123b	20.43a	Intermediate
Fam. Euphorbiaceae							
Acalypha marginata	1	23.60a	96.41a	6.20b	0.267b	24.91a	Intermediate
	10	10.61c	94.62a	6.06b	0.308a	15.99b	Sensitive
Euphorbia pulcherrima	6	13.11c	92.91a	5.84c	0.305a	17.34b	Intermediate
Codiaeum variegata	12	18.68b	93.25a	6.86a	0.167c	22.45a	Intermediate
Fam. Liliaceae							
Yucca elephantipes	3	427.60a	69.02b	5.20a	0.185b	237.2a	Highly tolerant
	6	283.10b	91.19a	5.41a	0.271a	169.9b	Highly tolerant
Fam. Malvaceae							
Hibiscus rosa-sinensis	1	14.05b	87.49a	6.80a	0.309a	18.74a	Intermediate
	2	18.36a	79.49b	6.30c	0.223b	19.92a	Intermediate
	8	12.60b	88.13a	6.50b	0.199c	17.25b	Intermediate
	12	18.63a	52.57c	6.22d	0.132d	17.09b	Intermediate
Fam. Palmaceae							
Washingtonia filfera	6	18.35b	83.33b	6.29a	0.348a	20.51b	Intermediate
	9	29.19a	90.59a	5.53b	0.309b	26.10a	Intermediate
Fam. Pinaceae							
Pinus halepensis	1	45.45a	72.35b	5.71a	0.193b	31.71a	Tolerant
Pinus canariensis	7	22.40b	81.19a	4.15b	0.272a	18.03b	Intermediate

Means followed by the same latter in a column or row do not differ significantly according to Duncan's New Multiple Range Test at 5 % level.

Some plant species tcan live in environments that others can not, these resistant plants can clean-up the environment from various pollutants, while sensitive ones can be used as bioindiactors in pollution monitoring (Begum and Harikrishna, 2010). Moreover, Bhattacharya *et al*., (2013) stated that air pollution tolerance level differs from plant to plant.

According to the foretasted results, it can be advise to cultivate the following ornamental species in the polluted area: *Schinus molle* (from Fam. Anacardiaceae), *Plumeria alba* (from Fam. Apocynaceae), *Cycas revoluta* (from Fam. Cycadaceae), *Yucca elephantipes* (from Fam. Liliaceae), *Cassia fistula*, *C. nodosa* and *Delonix regia* (from Fam. Leguminosae), *Hibiscus rosa-sinensis* (from Fam. Malvaceae), *Ficus benghalensis* (from Fam. Moraceae), *Washingtonia filifera* (from Fam. Palmaceae), *Pinus halepensis* (from Fam. Pinaceae) and *Lantana camara* (from Fam. Verbenaceae).

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تقييم قدرة بعض أنواع نباتات الحديقة اليابانية على تحملها لتلوث الهواء
(ب) مقارنة الأنواع المختلفة بالعائلة الواحدة المنزرعة في أجزاء مختلفة بالحديقة

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أجري هذا الجزء من الدراسة أيضا بمعامل كلا من معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، وشعبة البحوث الزراعية والبيولوجية، المركز القومي للبحوث، الدقي على حوالي 31 نوع من نباتات الزينة التابعة لحوالي 12 عائلة، تم اختيارها من أماكن مختلفة داخل الحديقة اليابانية، التي تقع في مدينة حلوان الصناعية، القاهرة الكبرى، مصر، خلال موسم 2017، لمقارنة درجة تحمل هذه الأنواع النباتية المختلفة للتلوث الهوائي السائد بهذه المدينة. لذلك أخذت عينات ورقية كل شهر من النباتات المنتخبة في الصباح الباكر ثلاث مرات لتقدير أربع صفات طبيعية – كيموحيوية، هي: محتوى حمض الأسكوربيك، محتوى الرطوبة النسبية، حموضة (pH) المستخلص الورقي ومحتوى الكلوروفيللات الكلي. حيث استخدمت هذه العوامل الأربعة بعد ذلك في حساب قيم دليل تحمل التلوث الهوائي (APTI) لكل نوع نباتي على حدة في المكان الذي ينمو فيه. استخدم أيضاً المقياس المدرج لدليل التحمل (APTI scale) لتحديد حساسية كل نوع نباتي للتلوث من عدمه.

أوضحت نتائج هذا الجزء من الدراسة أن متوسطات تركيز حمض الأسكوربيك بالأوراق، محتوى الرطوبة النسبية بالأوراق، حموضة المستخلص الورقي، المحتوى الكلي للكلوروفيللات بالأوراق، وكذلك قيم دليل تحمل التلوث الهوائي (APTI) قد اختلفت بشكل واضح وبمستويات معنوية متباينة باختلاف النوع النباتي والمكان الذي زرع فيه. لذلك فقد أظهر كل نوع نباتي (تحت كل عائلة) درجة تحمل مختلفة للتلوث الهوائي عن الأنواع الأخرى بعائلته، كما أن درجة التحمل هذه تغيرت بتغير مكان الزراعة داخل حدود الحديقة المذكورة.

بناء على ذلك، يمكن التوصية باختيار الأنواع التالية من نباتات الزينة (من كل عائلة تحت الدراسة) لتنسيق وتجميل مدينة حلوان على الأقل و غيرها تحت ظروف تلوث الهواء التي تتعرض لها: فلفل بورق رفيع (العائلة المانجية Anacardiaceae)، ياسيمن هندي (العائلة الدفلية Apocynaceae)، سيكاس ذيل الجمل (العائلة السيكادية Cycadaceae)، خيار شمبر، كاسيا نودوزا و البوانسيانا (العائلة البقولية Leguminosae)، اليوكا (العائلة الزنبقية Liliaceae)، هيبسكس (العائلة الخبازية Malvaceae)، فيكس التين البنغالي (العائلة التوتية Moraceae) نخيل الواشنجتونيا (العائلة النخلية Palmaceae)، الصنوبر الحلبي (العائلة الصنوبرية Pinaceae)، واللانتانا كمارا (العائلة الفيربينية Verbenaceae).

B. COMPARISON OF DIFFERENT SPECIES OF THE FAMILY GROWN IN DIFFERENT PARTS OF THE GARDEN