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IMPACTS OF AIR POLLUTANTS ON SOME ROADSIDE PLANT SPECIES IN THE NILE DELTA

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ABSTRACT

The present article provides an assessment of the impacts of air pollutants on leaf morphology and physiology of three common plant species growing on the highway between Damietta and the City of Met Ghamr to the north eastern part of Nile Delta. Plant species examined include *Salix tetrasperma* (trees), *Malva parviflora* (herb) and *Phragmites australis* (common reed). The results indicate that the pollutant's accumulation on leaf surface is dependant on the leaf characteristic including: area, texture and loads of emitted pollutants. Assessment of certain morphological parameters indicated that the growth of the studied species was markedly suppressed due to emitted air pollutants. Symptoms of their suppression included: marked malformation, reduced leaf area, burned blade tips, chlorosis and finally, bended blades.

In the meantime, the study revealed severe impacts on leaf metabolism. All the estimated metabolic parameters including: photosynthetic pigments, sugar fractions and total soluble proteins showed severe reduction with increasing air pollution in the surrounding environment compared with non polluted site. The present study indicated that heavy metals (Zn, Mn, Pb, Cu and Fe) content on leaf surface varied among species. *Phragmites australis* attracted the deposition of higher loads of heavy metals on its leaf surface more than both *M. parviflora* and *S. tetrasperma*. Samples collected from Met Ghamr sites were highly loaded with heavy metals followed by Mansoura sites. Zn and Cu, were the major heavy metal's constituents of the heavy metals load on the leaf surface of the investigated plant species while Mn and Fe were the minor ones.

Keywords: Air pollutants, Heavy metals, Higher plants, Nile Delta, Pigments, Protein, Sugars.

INTRODUCTION

Among the many forms of pollution, air pollution is unique in that it has a widespread occurrence. The atmosphere will be considered polluted when the concentration of contaminants reaches levels that may negatively affect human health and the environment as a whole. The sources of air pollution may be natural or man-made. The latter is the activities in which contaminants are produced including combustion of fossil fuels in industry such as pyrometallurigical processes, chemical production, and power stations [**Thompson (1978)**].

Most air pollution comes from one major human activities: burning of fossil fuels (natural gas, coal and oil) to power industrial processes and motor vehicles. Among the harmful pollutants this burning puts into the atmosphere are smoke, vapors, soot, fumes, acidic oxides such as carbon dioxide (CO_2) carbon monoxide (CO), nitrogen oxides (NO_x) and sulfur dioxide (SO_2), as well as tiny particles, including lead from gasoline additives, called particulates. Pollutants arising from human activities witnessed a sharp increase in the past few decades; for example, between 1900 and 1970, motor vehicles use rapidly expanded, and emissions of NO_x, some of the most damaging pollutants in vehicle exhaust increased about seven fold [**Barzergar *et al.*, (2005)**].

Road dust may be derived from a variety of sources. Unpaved roads may be covered with limestone gravel and so generate alkaline particulates. However in urban areas many of the particulates are derived from motor vehicles exhausts. Such particulates may contain a variety of heavy metals contaminants [**Santelmann & Gorham (1988)**]. Among the atmospheric pollutants found largely in the particulate phase are the heavy metals lead, cadmium, zinc, copper and the base cations calcium, magnesium, potassium and sodium. The potentially toxic heavy metals are emitted largely from metal processing industry while the base cations derived from combustion sources and have substantial natural sources in the re-suspension of soil particles by wind. The toxic and combustion-derived metals are primarily found in the sub-micron size range with mass median diameters between 0.1 - 0.5 µm while much of the re-suspended particulate material is in the larger size range, 0.5 - 5 µm and consequently has a much shorter atmospheric life time and travel distance [**Gimeno *et al.*, (1996)**].

Moreover, the reduction in photosynthetic pigments under the influence of air pollutants has been extensively cited as a reliable symptom of foliar damage [**Mehlhorn *et al.*, (1988)**]. SO_2 concentration reduce leaf chlorophyll a, chlorophyll b, total chlorophyll and total carbohydrate concentration. [**Renu & Singh (1989) and Canas *et al.*, (1997)**] observed that the higher the sulphur concentration, the more the leaves are affected, a fact that is reflected by a decrease in pigments.

The annual course of carbohydrate concentrations in the stem reflects sharp changes in export and import of carbohydrates under the influence of air pollutants [**Holl (1985)**]. Reduction in free carbohydrates was observed in leaves of wheat cultivars grown at different nutrient levels subjected to low concentrations of SO_2 gas [**Agrawal & Verma (1997) and Mostafa *et al.*, (1993)**] found that the reduction in soluble carbohydrate was correlated with obvious reduction in the activity of amylase and nitrate reductase.

The present work aims at investigating the impact of air pollutants on morphological and physiological characters of plants belonging to different life forms.

Also, the study sites have been selected on a gradient from the Mediterranean coast southward along the highway from Damietta to Met Ghamr parallel to Damietta branch of the River Nile.

MATERIAL AND METHODS

Study Area:

Four heavily air polluted sites are selected along the highway near Damietta branch of the River Nile, the sites are: Damietta, Sherbin, Mansoura, and Met Ghamr in addition to these sites there is a control site with a minimum air pollution that is New Damietta.

Climate:

The climatic conditions of the study area are warm summer (20 to 30 °C) and mild winter (10 to 20°C). The aridity index (P/E+P, where P is the annual precipitation and E is the annual evaporation) ranges between 0.03 and 0.02 at the northern Delta (arid region).

Study species:

Impact of air pollution was monitored on leaves of some plant species growing naturally in the study area namely: *Malva parviflora* (herb), *Phragmites australis* (reed) and *Salix tetrasperma* (tree), which represent different size so we can ensure that the pollutants will be received by all or at least one of these plants.

Plant sampling and analysis:

Collection of leaf samples for various investigations was carried out during May 2002 where the rainfall was null, sampling was done during daytime from 8.00 am to 12.00 am, the majority of the samples were obtained from the fully expanded sun–leaf located at fixed position, leaf samples were obtained from 9 plants at least from the control and the polluted sites of the study area, the samples of each three individual plants were paired together to represent one replicate. The results are the mean of three replicates, following the recommendation made by [**Nasralla** ***et al.*****, (1985) and Ibrahim (1992)**].

Photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids) were determined using the spectrophotometric method as described by [**Metzener** ***et al.*****, (1965)**]. Determination of anthocyanin was carried out according to the method adopted by [**Hoagland (1980)**]. The method of extraction of different carbohydrate fractions adopted in this investigation was essentially that of [**Yemm & Willis (1954) and Handel (1968)**]. Glucose was estimated in ethanolic extract using the O-toluidine procedure of [**Feteirs (1965)**]. Total soluble sugars (TSS) were determined using modifications of the procedures of [**Yemm & Willis (1954) and Handel (1968)**], respectively. The method used for estimation of polysaccharides was that of [**Thayermanavan & Sadasivam (1984)**]. Extraction: The method of protein extraction adopted herein was that described by [**Scarponi & Perucci (1986)**].

For determination of heavy metals in the leaf deposits, the leaf surface of a pre weighed leaf was washed with ether until clean; the leaf was blotted gently to remove excess ether and then reweighed. The difference in weight was taken as the amount of deposited pollutants. The deposited matter in ether was made up to a known volume with distilled water and used for determination of heavy metals. Determination of heavy metals in the leaf deposit by digestion with conc. HNO_3. Analyse the samples by using atomic absorption spectrophotometer **[Allen (1989)]**.

Statistical test:

Least significant test (LSD) was used to compare the significant variations among sites **[Anon (1993)]**.

RESULTS

Phytotoxicological symptoms:

The impact of air pollution on leaf morphology of *M. parviflora* was less clear; the physiological symptoms e.g formation of necrotic and chlorotic areas along the margins of leaves in some sites exposed to air pollution are evident (Plate 1A). In *P. australis* (Plate 1B) air pollution led to the burning and drying of the leaf tip compared with the healthy leaves of plants growing in non-polluted areas in addition to that pollution cause bending or rolling of blades. Leaves of *S. tetrasperma* (Plate 1C) exhibited many morphological alterations such as bending or rolling of blades, the leaves were markedly lobed in addition to necrotic areas along the margins in air polluted sites.

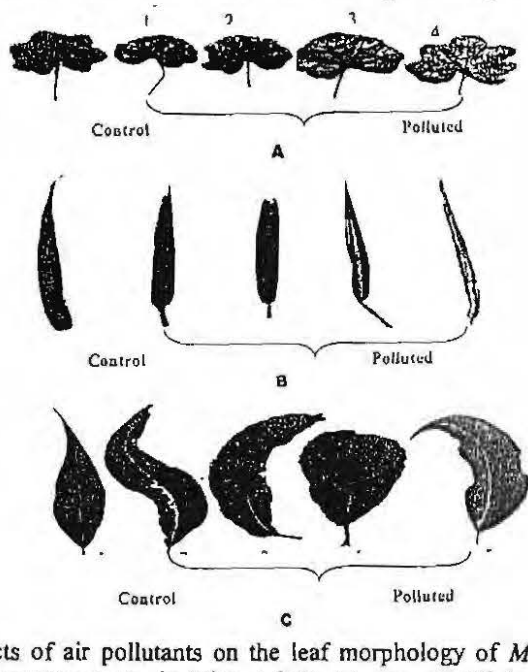

Plate (1): Impacts of air pollutants on the leaf morphology of *Malva parviflora* (A), *Phragmites australis* (B) and *Salix tetrasperma* (C) in control and polluted sites 1,2,3 and 4, namely Damietta, Sherbin, Mansoura and Met Ghamr respectively, in the Nile Delta.

Effects of air pollution on plant growth attributes:

Leaf dry weight (LDW) of *M. parviflora* showed a significant reduction at Mansoura (68.8% of the control). LDW of *P. australis* was not significantly affected at the polluted sites compared with the control site. Figure 1 shows that LDW of *S. tetrasperma* was significantly reduced comparable to that of the control at the selected sites except Damietta. Nevertheless, the most severe reduction (37.5% of the control) was found at Mansoura.

Specific leaf area (SLA) of *Salix tetrasperma* exhibited non significant increase at the polluted sites, with the highest value (11.4 cm^2g^{-1}) at Sherbin. SLA of *P. australis* was significantly reduced under the impact of air pollution; the lowest value (7.06 $cm^2 g^{-1}$) was recorded at Mansoura (Figure 2). SLA of *M. parviflora* showed a significant reduction compared with control.

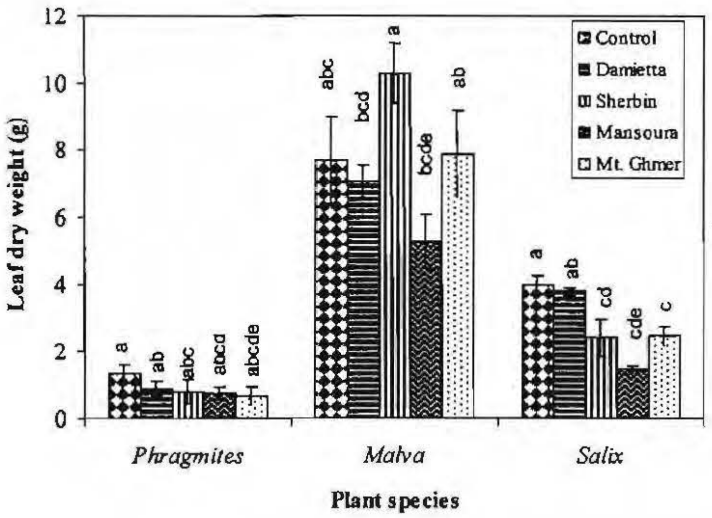

Fig. (1): Mean ±SE of leaf dry weight of plant species growing naturally in air-polluted sites along highway road in the Nile Delta. Means with common letters are not significantly different according to LSD at P<0.05.

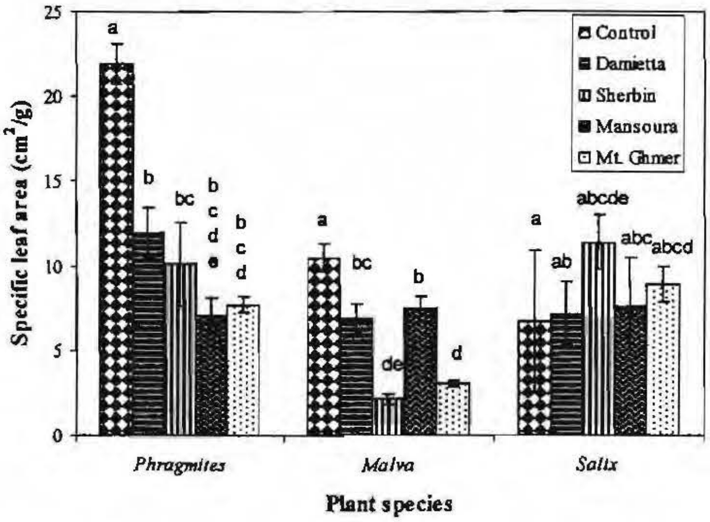

Fig. (2): Mean ±SE of specific leaf area of plant species growing naturally in air-polluted sites along highway road in the Nile Delta. Means with common letters are not significantly different according to LSD at P<0.05.

Leaf pigment:

The results of Table (1) show that chlorophyll a, Chlb. and anthocyanin of *S. tetrasperma* leaves increased with air pollution. Carotenoids content of *S. tetrasperma* leaves was non-significantly affected by air pollution and attained comparable levels at the different sites of study. On the other hand, chl. a, chlb., carotenoids and anthocyanin content of *P. australis* leaves decreased with increasing air pollution Table (2). Chlorophyll a of *M. parviflora* leaves was significantly higher at Met Ghamr. Chlb and carotenoides were not significantly different at the different sites. Anthocyanin pigments was higher at the control and showed a significant decrease at all other polluted sites Table (3).

Table (1): Effects of air pollution along Damietta branch of the Nile on the photosynthetic pigments (µg g-1 fresh weight) of *Salix tetrasperma* (Each value is the mean of 3 replicates ± SE). Means with common letters are non-significantly different at p<= 0.05.

Site	Chlorophyll a	Chlorophyll b	Carotenoids	Anthocyanin
Control Site	485.6 ± 37.8 bc	232.3 ± 18.2 bcde	307.7 ± 20.2 abcde	0.4 ± 0.02 bcde
Damietta	479.9 ± 38.9 bcd	347.8 ± 31.2 a	416.03 ± 48.5 a	0.50 ± 0.049 abc
Sherbin	477.9 ± 19.6 bcde	267.7 ± 15.4 bcd	332.5 ± 28.1 abcd	0.53 ± 0.09 ab
Mansoura	500.6 ± 27.9 ab	273.9 ± 21.7 abc	352.6 ± 23.8 abc	0.43 ± 0.04 bcd
Met Ghamr	595.7 ± 29.05 a	289.7 ± 23.9 ab	362.3 ±36.5 ab	0.73 ± 0.18 a
LSD 5%	99.213	71.692	104.105	0.299

Table (2): Effects of air pollution along Damietta branch of the Nile on the photosynthetic pigments (µg g-1 FW) of *Phragmites australis* leaves (Each value is the mean of 3 replicates ± SE). Means with common letters are non-significantly different at p<= 0.05.

Site	Chlorophyll a	Chlorophyll b	Carotnoides	Anthocyanin
Control Site	956.3 ± 71.2 a	455.8 ± 38.2 a	596.1 ± 62.05 a	0.91 ± 0.05 a
Damietta	300.1 ± 19.9 de	276.7 ± 23.2 d	210.5±31.8 cde	0.413 ± 0.035 cd
Sheerbin	372.0 ± 35.3 bcd	266.7 ± 24.5 de	306.4 ± 24.2 c	0.863 ± 0.18 ab
Mansoura	448.2 ± 39.8 b	387.8 ± 29.05 ab	299.9 ± 21.6 cd	0.41 ± 0.06 cde
Met Ghamr	444.0 ± 25.12 bc	367.1 ± 17.2 abc	432.1 ± 39.8 b	0.46 ± 0.04 c
LSD 5%	133.25	86.22	122.12	0.287

Table (3): Effects of air pollution along Damietta branch of the Nile on the photosynthetic pigments (μg g-1 FW) of *Malva parviflora* leaves (Each value is the mean of 3 replicates ± SE). Means with common letters are non-significantly different at p<= 0.05.

Site	Chlorophyll a	Chlorophyll b	Carotenoids	Anthocyanin
Control Site	1030 ± 139.3 bcde	335.7 ± 25.8 abcd	684.7 ± 72.4 a	0.88 ± 0.156 a
Damietta	1050.4 ± 70.2 bcd	364.7 ± 24.3 ab	504.03 ± 130.7 abc	0.56± 0.08 bc
Sherbin	1166.5 ± 111.8 bc	371.0 ± 24.3 a	353.9 ± 26.4 bcde	0.28 ± 0.01 cd
Mansoura	1268.8 ± 104.8 ab	341.1 ± 36.5 abc	422.2 ± 58.7 abcd	0.27± 0.038 cde
Met Ghamr	1583.9 ± 129.4 a	332.3 ± 27.7 abcde	545.6 ± 76.8 ab	0.58 ± 0.09 b
LSD 5%	358.35	88.28	253.73	0.282

Carbohydrates and protein content of leaves:

Contents of glucose sucrose, total soluble sugars and proteins in leaves of *S. tetrasperma* significantly reduced with increasing air pollution. Insoluble sugars were subjected to non-significant reduction at the polluted site, compared to the control Table (4). Glucose, sucrose, total soluble sugars of *P. australis* leaves increased with higher levels of air pollution. Polysaccharides showed non significant effect and their content decreased in polluted sites compared with control Table (5).

Glucose, sucrose, polysaccharides, total soluble sugars and protein content of *M. parviflora* leaves were highest at the control and showed a comparable significant reduction at the polluted sites Table (6).

Table (4): Effects of air pollution along Damietta branch of Nile on the carbohydrate fractions (mg glucose g-1 DW) and protein content (mg g-1 FW) of *Salix tetrasperma* leaves. Each value is the mean of 3 replicates ±SE. Means with common letters are non-significantly different at p<= 0.05.

Sites	Glucose	Sucrose	T sol. sugar	Polysaccharides	Protein
Control Site	11.79 ± 1.5 a	43.5 ± 3.6a	55.2 ± 2.4a	331 ± 26.7a	25.3 ± 2.47 a
Damietta	5.1 ±0.14 cde	20.9 ± 0.25 cde	27.6 ± 1.42 de	284 ± 29.8 abcd	14.3 ± 2.4 bc
Sherbin	10.6 ± 1.9 ab	39.9 ± 5.1 ab	50.17 ± 4.2 ab	272.1 ± 6.9 abcde	14.6 ± 1.7 b
Mansoura	5.3 ± 0.53 cd	23.2 ± 2.6 cd	29.2 ± 1.5 d	320 ± 19.8 ab	13.7 ±1.35 bcd
Met Ghamr	5.46 ± 0.68 c	32.7 ± 1.7 bc	41.2 ± 1.1 c	297 ± 21.3 abc	12.5 ± 0.99 bcde
LSD 5 %	3.63	9.84	7.57	70.43	5.91

Table (5): Effects of air pollution along Damietta branch of the Nile on the carbohydrate fractions (mg g-1 DW) and protein content (mg g-1 FW) of *Phragmites australis* leaves. Each value is the mean of 3 replicates ± SE. Means with common letters are non-significantly different at p<= 0.05.

Site	Glucose	Sucrose	T soluble sugar	Polysaccharides	Protein
Control Site	15.96 ± 1.0 cde	47.7 ± 2.0 ab	68.7 ± 3.4 ab	469.2 ± 36 a	56.08 ± 4.4 a
Damietta	17.07 ± 1.4 bcd	42.7 ± 2.7 abc	59.8 ± 3.3 bc	349.2 ± 59.4 abcd	29.5 ± 3.3 bcd
Sherbin	18.2 ± 0.85 bc	27.07 ± 2.6 de	49.28 ± 3.4 cde	371.7 ± 65.1 abcd	25.9 ± 3.4 bcde
Mansoura	21.6 ± 1.05 ab	30.6 ± 3.7 d	54.3 ± 2.2 cd	402.6 ± 41.05 abc	30.8 ± 6.9 bc
Met Ghamr	24.9 ± 2.2a	47.9 ± 3.2a	74.9 ± 5.7a	412.9 ± 19.6 ab	32.06 ± 2.6b
LSD 5%	4.73	9.14	11.91	148.8	13.8

Table (6): Effects of air pollution along Damietta branch of the Nile on the carbohydrate fractions (mg g-1 DW) and protein content (mg g-1 FW) of *Malva parviflora* shoot. Each value is the mean of 3 replicates ± SE. Means with common letters are non-significantly different at p<= 0.05.

Site	Glucose	Sucrose	T soluble sugar	Polysaccharide	protein
Control Site	4.9 ± 0.61 ab	18.5 ± 1.7 a	25.4 ± 1.88 a	141.9 ± 11.3 a	33.1 ± 1.4 a
Damietta	3.8 ± 0.18 bc	14.8 ± 2.5 abcd	18.07 ± 2.5 bcde	112.4 ± 13.3 abcd	17.04 ± 2.07 bcde
Sherbin	5.1 ± 0.38 a	16.3 ± 0.8 ab	22.4 ± 1.71 ab	119.6 ± 7.9 ab	22.7 ± 0.96 bc
Mansoura	3.3 ± 0.12 cd	15.6 ± 1.2 abc	19.4 ± 0.91 bcd	115.2 ± 17.1 abc	20.8± 1.12 bcd
Met Ghamr	4.9 ± 0.3 ab	14.0 ± 1.4 bcde	19.8 ± 1.06 abc	95.9 ± 9.7 bcde	23.2 ± 3.2 d
LSD 5%	1.14	5.12	5.39	38.71	6.09

Heavy metals content of leaf surface deposits:

The lowest content of heavy metals of leaf surface deposits was attained at the control site, increasing to different extent at the different sites according to the metal. The content of Zn, Pb, Co, Fe and Mn significantly increased above the control.

Cu content of surface deposits of *S. tetrasperma* leaves at the control sites was high (41.7μg g^{-1} deposit DW) relative to the other metals Table (7). In addition, the increment in Cu content of leaf surface deposits at the polluted sites was small amounting to about 2 times the control. Zn content of *P. australis* leaves was substantially increased at Met Ghamr reaching the maximum level (17 times the control). Mn and Pb contents reached the maximum levels (8 and 7 times the control respectively) at Met Ghamr. Fe content was significantly higher at Met Ghamr reaching a maximum of about 5 times the control Table (8). Zn content of surface deposits of *M. parviflora* leaves was fairly high at the control site (11.3μg g-1 deposit DW) and was significantly higher at the polluted sites reaching a maximum of about 7 times the control at Met Ghamr. The content of Mn, Pb, Co, Cu and Fe exhibited patterns similar to that of Zn with maximum levels of 6, 7, 9, 4 and 3 times the control respectively at Met Ghamr. The gradient of these metals except Fe can be summarized as follow: control sites <Damietta< Sherbin < Mansoura < Met Ghamr. Similar to Zn, the content of Cu at the control was relatively high (18.9μg g-1 deposit DW). The pattern Fe exhibited was control < Sherbin < Damietta < Mansoura < Met Ghamr Table (9).

Table (7): Content of heavy metals in leaf surface deposits (µg metal g-1 deposits DW) of *Salix tetrasperma*. Each value is the mean of 3 replicates ± SE. Means with common letters are non-significantly different at $p<0.05$.

Site	Zn	Mn	Pb	Co	Cu	Fe
Control Site	9.3 ± 0.21 a	0.4 ± 0.01 a	2.8± 0.19 a	3.5 ± 0.21 a	41.6 ± 2.3 a	1.98 ± 0.23 a
Damietta	17.6 ± 0.81 bc	5.4 ± 0.27 c	9.3 ± 0.4 b	4.8 ± 0.12 b	45.4 ± 1.1 ab	5.9 ± 0.15 cd
Sherbin	21.8 ± 1.7 c	5.7 ± 0.2 cd	12.9 ± 1.7 bc	5.2 ± 0.2 bc	58.1 ± 3.1 c	6.6 ± 0.4 de
Mansoura	14.4 ± 0.12 ab	3.6 ± 0.24 b	14.6 ± 2 cd	6.5 ± 0.2 d	66.9 ± 1.4 d	5.3 ± 0.24 c
Met Ghamr	65.3 ± 3 d	3.6 ± 0.12 b	17.5± 0.94 de	7.8 ± 0.2 e	79.8 ± 2.3 e	4.3 ± 0.2 b
LSD 5%	5.006	0.606	3.98	0.595	6.817	0.812

Table (8): Content of heavy metals in leaf surface deposits (µg metal g-1 deposits DW) of *Phragmites australis*. Each value is the mean of 3 replicates ± SE. Means with common letters are non-significantly different at $p< 0.05$.

Site	Zn	Mn	Pb	Co	Cu	Fe
Control	9.5 ± 0.12 a	2.46 ± 0.24 a	4.56 ± 0.5 a	2.96 ± 0.25 a	18.2 ±0.59 a	6.5 ± 0.37 a
Damietta	15.3 ± 1.6 ab	9.9 ± 1.7 b	7.6 ± 0.7 b	7.7 ± 0.21 b	35.5 ± 1.3 b	14.2 ± 0.6 c
Sherbin	30.2 ± 1.2 c	12.2 ± 2.4 bc	8.2 ± 0.9 bc	14.9 ± 1.4 c	46.5 ± 1.4 c	8.5 ± 0.7 ab
Mansoura	42.7 ± 2.5 d	17.1 ± 1.1 d	11.7 ± 0.35 d	30.8 ± 1.8 d	55.6 ± 3.2 d	15 ± 0.5 cd
M. Ghamr	150.7±3.5 e	18.2±0.28 de	28.1 ± 1.6 e	30 ± 1.2 d	70.1 ± 3.1 e	29.1 ± 1.9 e
LSD 5%	6.692	4.456	2.901	3.664	6.887	3.106

Table (9): Content of heavy metals in leaf surface deposits (µg metal g-1 deposits DW) of *Malva parviflora*. Each value is the mean of 3 replicates ± SE. Means with common letters are non-significantly different at $p< 0.05$.

Site	Zn	Mn	Pb	Co	Cu	Fe
Control	11..3 ± 0..53 a	2.3 ± 0.24 a	3.5 ±0.21 a	2.4 ± 0.09 a	18..9 ± 0.92 a	4.8 ± 0.12 a
Damietta	18.1 ± 0.12 b	7.8 ± 0.24 b	9 ± 0.59 b	7.8 ± 0.24 b	37.7 ± 1.4 b	9.7 ± 0.24 c
Sherbin	27.2 ± 2.6 c	8..2 ± 1.1 bc	12.7±0.58 bc	13.1 ± 1.94 c	48.2 ± 3.9 c	7.7 ± 0.26 b
Mansoura	32.5 ± 1.9 cd	11.7 ± 0.36 d	15.9 ±2.2 cd	14.9 ± 1.29 cd	62.8 ± 2.5 d	12.7 ± 0.39 d
M.Ghamr	81.5 ± 2.38 e	13.2 ± 1.29 de	24.9 ± 1.9 e	21.9 ± 1.2 e	74 ± 3.6 e	13.2 ± 1.06 de
LSD 5%	5.697	2.489	4.272	3.713	8.605	1.678

DISCUSSION

Air pollution represents a major threat to plants both in term of yield and crop quality [**Agrawal *et al.*, (2006)**]. Using plants as bioindicator of pollution stress and a decontaminating agent, [**Cornejo *et al.*, (1999)**] reported that a number of plant species including *Pelargonium domesticum*, *Ficus elastica* and *Chlorophytum comosum* experienced an extensive ability to clear air from pollutants. The distinguished ability of plant to accumulate metal ions can be exploited in removal of heavy metals (particularly Pb and Zn) from polluted soil [**Solhi *et al.*, (2005)**]. Furthermore, leaves are the plant organs most subjected and also more sensitive to air pollution. Leaf can exhibit a variety of unique symptom which enable in diagnosis of both biotic and a biotic stress. In this respect, [**Legge & Krupa (2002)**] claimed that pollution injury to plants is first seen in the foliage which is more sensitive to pollutants than stems, buds and reproductive organs.

It is expected that pollution due to traffic is superimposed on pollution arising from sources at the different sites, for example fertilizer industry at Mansoura and brick industry at Met Ghamr. Thus the nature of air pollution problem is quite complicated and the response found by plant can not clearly assign to a specific cause. In general, plants growing in natural habitat are subjected to the combined effect of several pollutants. Our results reveal that growth of the studied species, estimated from leaf dry weight and leaf area, was markedly suppressed under the impact of air pollution. In *S. tetrasperma*, the inhibition in leaf dry weight was more evident than in leaf area, which was reflected in high SLA of pollution-affected leaves over the control. The site which led to the most severe reduction in leaf dry weight was Damietta, at which leaf dry weight was only 38% of the control.

In contrast to *S. tetrasperma*, the reduction in leaf area of *P. australis* was more evident than that in leaf dry weight, which led to significant reduction in SLA under the impact of air pollution. The most severe reductions in SLA were found at Mansoura and Met Ghamr. *M. parviflora* exhibited a quite distinguishable trend in response to air pollution whereas LDW was significantly lowered (31% below the control) at Mansoura, it was markedly promoted (34% above the control) at Sherbin. SLA of *Malva* was lower at all polluted sites compared with the control.

In agreement with our results, Leaf area, fresh weight and dry weight of polluted *Salix tetrasperma* was severely reduced in comparison with control [**Farrukh *et al.*, (1994)**]. Roadside leaf samples showed distinct foliar injuries such as necrosis, chlorosis (low chlorophyll content) and low protein content [**Shweta *et al.*, (1992)**] and are covered with black deposits with marginal burning [**Salgare & Iyer (1991)**].
The present work refers to the possibility that chlorophyll content might be promoted by air pollution in some species while retarded in the other species. In *S. tetrasperma* chlorophyll a was promoted at Met Ghamr and was lower at the other sites including the control. Carotenoid was non-significantly affected by pollution. By contrast, anthocyanin increased under the impact of pollution over the control. Anthocyanin can be considered as an indicator of stress, and exhibited a quite different response to air pollution. In *P. australis* Content of pigment (chlorophyll a, chlorophyll b, carotenoid and anthocyanin) were markedly lowered by air pollution. In *M. parviflora* content of chlorophyll a, chlorophyll b and carotenoid were slightly affected by air pollution. These results are in accordance with El-Khatib (2003). Photosynthetic efficiency, estimated as chlorophyll fluorescence, has been reported to be negatively correlated with air-born concentration of Cu, Ni and SO_2 [**Odasz-Albrigtsen (2000)**]. Industrial pollution in the vicinity of a copper smelter in Bulgaria led to slight reduction in chlorophyll content in *Juglans regia* leaves [**Yostova-Baurenska & Derebanova (1990)**]. *Trifolium pretense* and *Malva parviflora* had visible symptoms of leaf damage, including necrosis, red pigmentation and chlorosis, at polluted sites of industrial areas affected by SO_2, NO_2, NH_3 and heavy metals [**Ali (1993)**]. Air pollution was reported to reduce total chlorophyll content of several species [**Farrukh *et al.*, (1994) and El-Khatib (2003)**]. Marked species-specific variability in response of pigments to air pollution had been demonstrated. [**Ahmed *et al.*, (1998)**] distinguished two groups of plant with contrasting response to SO_2; whereas group I plant exhibited small effect or even increased pigment concentration in response to 1000ppm aqueous SO_2. Group II plants were subjected to sever losses in chlorophyll, phaeophytin and carotenoid content.

The content of soluble sugar in *S. tetrasperma* leaves was adversely affected by air pollution with comparable reduction at the study sites. The content of insoluble sugar was however not affected by air pollution. Similar to soluble sugars, the content of protein in *S. tetrasperma* leaves was adversely affected by air pollution. The results indicated the possibility that pollution might raise sugar content of *P. australis* leaves. Protein content of *P. australis* leaves was significantly lower under the impact of air pollution.

Protein content of *Malva parviflora* was adversely affected by pollution. Total soluble sugar content was lowered by pollution. In contradiction to our results, pollution has been reported to retard photosynthesis with no clear–cut effect on respiration [**Ali (2008)**].

The content of heavy metals in leaf surface deposits may reflect the density of emission of heavy metals at the different sites. Yet, species–specific difference are quite expected according to plant habit at leaf architecture. The levels of Pb, Zn and Cd in several plant species was found to increase with increase in traffic intensity and with decrease of distance from the road. In addition, the highest heavy metals levels were recorded in plants with hairy leaves [**Turkan (1986)**]. Our results reveal that *P. australis* accumulated heavy metals in leaf surface deposits to a greater extent than *Malva parviflora* and *Salix tetrasperma*. This might be related to the perennial habit of *P. australis* in addition to the unique leaf architecture of *Phragmites australis*. The leaf surface of this species is characterized by many furrows and ridges which might trap suspended particulates in polluted atmosphere. This pattern, however, was not evident in case of Cu, where it was highly accumulated in leaf surface deposits of *S. tetrasperma* and least accumulated in those of *P. australis*. It was reported that heavy metals content of leaves was found to vary among species [**El-Katony *et al.*, (2006)**]; the concentrations of Pb and Cd were higher in *M. parviflora* leaves than in the *Trifolium pratense* leaves [**Ali (1993)**]. In general the data reveal a gradient of increasing heavy metals concentration from Damietta to Met Ghamr. This pattern was quite evident in the leaves of herbal species (*P. australis* and *M. parviflora*) but less in the leaves of the tree species (*S. tetrasperma*). This might reflect the density of industrial and domestic activities along the Nile branch from Damietta to Met Ghamr. The lack of close agreement between the concentration of heavy metals in leaf surface deposits (which reflect the amount of heavy metals in air) in one side and the magnitude of reduction in leaf growth or metabolic activities in the other hand might point to the interference of other factors that may modify the effect of heavy metals content of air. Deposits of heavy metals on plant surface is expected to decrease, along with the decrease in heavy metals content of air, i.e. in the direction Damietta to Met Ghamr, although local effect might be present that modifying the effect of heavy metals on plant performance. The results reveal that the metal most accumulated on leaf surface of the studied plant species were Zn and Cu (amounting up to 150.7 and about 80µg metal g-1 deposit respectively). By contrast the least-accumulated metals were Mn and Fe which were in the range of few µg g-1 deposits in the leaves of *S. tetrasperma*.

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الملخص العربى

تأثير ملوثات الهواء على بعض الأنواع النباتية النامية على جوانب الطرق في دلتا النيل

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تهدف الدراسة الحالية إلى استكشاف تأثير ملوثات الهواء وخاصة التلوث الناتج عن وسائل المواصلات على المظهر الخارجي والأداء الفسيولوجي لمجموعة من النباتات المختارة والشائعة الانتشار في منطقة شرق دلتا النيل ، تحديدا المنطقة الواقعة بين مدينة دمياط الجديدة ومدينة ميت غمر. تم اختيار أربعة مواقع مختلفة الكثافة المرورية ومختلفة النشاط الصناعي وذلك مقارنة بموقع قياسي وهو مدينة دمياط الجديدة والتي تتميز بنشاط صناعي وسكاني منخفض.

أظهرت الدراسة أن تلوث الهواء أدي إلي تشوهات واضحة بالأوراق مقرونة أحيانا بتقلص المساحة. شملت الأعراض المسجلة اصفرار الأوراق وتبقعها ، احتراق قمم وحواف الأوراق ، وقد بينت النتائج الفسيولوجية أن تلوث الهواء أدى إلي انخفاض مستوى أصباغ البناء الضوئي وكذلك السكريات والبروتينات وكان أكثر المواقع تأثرا بهذا التلوث موقع ميت غمر وأقلها مدينة دمياط الجديدة.

تبين من نتائج الدراسة وجود تراكم للملوثات المنبعثة من السيارات ومصادر التلوث الأخرى على سطوح الأوراق بدرجات متفاوتة تبعا لنوع تلك الملوثات ونوع النباتات موضع الدراسة. وعلي ذلك يمكن القول أن تركيز العناصر الثقيلة كانت أعلي ما يمكن في موقع ميت غمر وأقل ما يمكن في مدينة دمياط الجديدة وذلك قد يرجع إلي تلوث الهواء للانبعاث الناتج من مصانع الطوب في هذه المنطقة بالإضافة إلي وسائل المواصلات.