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Effect of Cement Particulates Deposition on Eco-Physiological Behaviors of Halophytes in the Salt Marshes of Red Sea

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Abstract: The effect of cement dust on pigments status was studied for *Zygophyllum coccineum*, *Salsola tetrandra*, *Cyperus conglomeratus*, *Limonium axillare* and *Suaede vermiculata*. Measurements were taken for plants very close to early constructed cement factory (Rabigh, Saudi Arabia) about 500 m and other about 4500-5000 m far from the factory. Cement dust was responsible for the mortality of young branches leading to a reduction in the height and cover of the five species. *Salsola tetandra and Suaede vermiculata*, in particular were the most sensitive to the cement dust. Generally, photosynthetic pigments including chl a, b and carotenoids were negatively correlated with dust deposition, whereas positively correlated with the distance factor. Photosynthetic pigments were declined more with cement accumulation in *Salsola tetandra* and *Limonium axillare* than in *Zygophyllum coccineum* and *Suaeda vermiculata*, whereas, increased significantly in *Cyperus conglomerotus*. Both carbohydrates and protein contents were decreased only for leaves of *Salsola tetandra* and *Suaeda vermiculata*, whereas, increased significantly for those plants near to the factory and parallel to dust accumulation in the other studied plants. Cement dust pollution greatly affected the photosynthetic pigments of the investigated species. The pH of the cell sap, the metabolism of soluble amino acids and soluble sugars into insoluble reserve substances were all adversely affected.

Key words: Halophytic species・Salt marshes・Cement dust・Photosynthetic pigments

INTRODUCTION

A biotic plant problems are sometimes termed "physiological disorders" that reflects the fact that the injury or symptom, such as reduced growth, is ultimately due to the cumulative effects of the causal factors on the physiological processes necessary for plant growth and development [1]. Higher plants, being immobile, have a greater need of protection against several stresses, including temperature (low or high), water stress, salinity, metal toxicity and others. Air pollution may interfere with the biological processes related to the general metabolism, photosynthetic activities, mitochondrial respiration and stomatal clogging of plants [2]. Over the last three decades, the industrial and human activities in the coastal area of Kingdom of Saudi Arabia have increased dramatically and resulted in the continuous invasion of different types of pollutants including heavy metals. Bader *et al*. [3] studied three coastal areas along the Red Sea of Kingdom of Saudi Arabia and they concluded that Pollution Load Index (PLI) was significantly high in Jeddah and was considered as the most polluted area, followed by Rabigh, while Yanbu was the least contaminated area. Industries emit toxic substances which adversely affect man's food supply by affecting growing plants which are particularly susceptible to pollution. Ambient level of air pollution has been shown to affect stomatal conductance, photosynthesis and root morphology of young beech [4]. One of the most recent studies of these stresses is dust accumulation, which provokes severe damage in the photosynthetic apparatus [5]. Photosynthesis is known to be one of the most stress-sensitive processes and it can be completely inhibited by stress before other symptoms of the stress are detected [6]. Different cements have different ingredients; many of them contain substances that can be hazardous, like crystalline silica (quartz), lime, gypsum, nickel, cobalt and chromium compounds [7]. Wind erosion suspends large quantities of dust in the atmosphere that settle back to the earth's surface and are deposited on plant leaves when

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wind velocities decrease [8]. Cement factories are major source of pollutants for the surrounding areas [9]. Dusted plants with quantities of dust ranging from 1 to 48 g/m^2 per day; dust falling on the soil caused a shift in the pH to the alkaline side. Dust deposition has been found to affect photosynthesis, stomatal functioning and productivity [5]. Very few studies had been conducted on the effects of cement dust on the physiology of wild halophytes. The studying area is suffering from heavy cement dust pollution originating from the cement industry. The cement dust is the source of particulate matter that deposits on the buildings and plants producing a significant adverse effect.

Our goal in the present study was to evaluate the effects of cement dust on leaf physiology and physiological parameters of five halophytic species (*Zygophyllum coccineum, Salsola tetandra, Cyperus conglomeratus, Limonium axillare and Suaeda vermiculata*). Based on the results of these physiological parameters, insight into the mechanism responsible for differences in dust tolerance would be clarified.

MATERIALS AND METHODS

The study area was chosen in Rabigh which located along the Red Sea coast 165 Km north Jeddah (Fig. 1). Vegetation of this area suffers dust pollution due to the presence of cement factory. Five dominants halophytic species, *Zygophyllum coccineum* L. (desert shrub), *Salsola tetandra* (shrublets), *Cyperus conglomerotus* (perennial herbs), *Limonium axillare* (under shrub), *Suaeda vermiculata* (low shrub) were selected at two different locations down-wind from a cement factory in the studying area. Location (1, 2) was about 450-500 m and 4500-5000 m from the factory respectively. Plant and soil samples were collected randomly from the two locations covering the study area in one season (autumn).

Soil Analysis: Soil samples were collected from each associated plants at a depth of 0-25 cm. Physical and chemical parameters of such soil samples were analyzed. Soil reaction (pH was determined in the soil paste according to the method described by Kilmer and Alexander [10] by using (4010 data. Hani. Instruments,

Fig. 1: Map showing the study location

Padova, Italy) pH-meter. Electrical conductivity (EC) of the saturated soil extracts were determined as described by Jackson [11] and expressed as dS/m. The anions and cations (Cl, SO_4, Ca, Mg, Na and K) of the soil extracts were analyzed as described by Richards [12] and Jacobson and Hill [13] and their values expressed as meq/l. The chemical and physical analysis of the dust collected in the vicinity of the Cement Factory of Rabigh was carried out. Leaves were prepared and analyzed for the determination of photosynthetic pigments in fresh leaves according to Metzner *et al*. [14], carbohydrates in dry leaves were determined according to Naguib [15] and Murata [16], soluble and total protein were determined in dry leaves according to Hartree [17] and some elements (Mg, Fe, Mn, N) were also determined according to Allen [18]. Electrolyte leakage and pH values were measured by using conductivity meter (4010 data. Hani. Instruments, Padova, Italy) according to method described by Dicagno *et al*. [19]. Leaf disks (1cm) were collected and washed with de-ionized water to remove surface-adhered electrolytes and incubated overnight at 25°C, with gently shaken on a gyratory shaker. After measurements, the tubes were then placed in boiling water for 15 min and then cooled to room temperature and shaken for 2h. Conductivity was again determined. The electrolyte leakage was calculated as the ratio of conductivity before boiling to that after boiling.

Analysis of Cement: The determination of a wide range of elements in various samples of cement was done in King Saud University using atomic absorption according to Thomas [20].

RESULTS

The elemental profile, determined in the soil extract of studied plants for the two locations, indicated that the level of calcium, magnesium, sodium, potassium and sulphate were significantly higher in the polluted soil than in the control one (Fig. 2). Analysis of the dust collected from the leaf's surface indicated the presence of some toxic heavy metals such as aluminum silicon and cadmium, in addition to some other elements (Table 1). Dust accumulation altered the chlorophyll and carotenoid contents in all plants in the polluted location (near the factory) compared with plants far from the factory in control site (Fig.4). Greater decrease in chlorophyll a and b contents was clearly observed in *Salsola tetandra* and *Limonium axillare* (For chl a about -36% and -45%, respectively). A similar pattern of decrease was occurred in *Zygophyllum coccineum* and *Suaeda vermiculata* but to lower extent (about -15 and -9%, respectively). On the other hand, Chlorophyll a, b and chl a/b ratio were significantly increased in *Cyperus conglomeratus* together with increasing dust accumulation in plant leaves near to the factory (Table 2 and Fig.3). Chlorophyll a/b

Table 1: Analysis of element in dust collected around the Cement Factory from plant studied and soil components in study area

Component	Atomic Absorption sample (%)	Soil component	%
SiO_2	22.49	Maximum water holding capacity	65.72%
Al_2O_3	4.20	Soil pH	9.53
Fe_2O_3	2.58	Soil texture	Clay loam
CaO	65.8	Calcium carbonate	22%
MgO	1.25	Alkaline carbonate	2.45 meq/1
Na_2O	0.13	Amount of chloride	8.6 meq/1
K_2O	0.29	Conductivity	506 µs/cm

Table 2: Chlorophyll a/b, total chlorophyll/ carotenoids, soluble sugars/ total sugar and soluble protein/ total protein ratios in five halophytic plants subjected to dust pollution in two localities. Location 1 (loc.1) control far from the factory, location 2(loc.2) stressed near the factory. Values are the mean of five readings (n=5).

	Chl a/b		Total Chl./ Carotenoids		Soluble Sugars/ Total Sugars		Soluble Protein / Total Protein	
Plant Species	Loc. 1	Loc. 2	Loc. 1	Loc. 2	Loc. 1	Loc. 2	Loc. 1	Loc. 2
Zugophilum coccineum	3.1 (100%)	2.5 (84%)	3.74±0.18 (100%)	2.30±0.15 (62%)	0.49±0.08 (100%)	0.70±0.11 (143%)	0.44±0.10 (100%)	0.48±0.09 (109%)
Salsola tatandra	2.5 (100%)	2.86 (114%)	6.00±0.32 (100%)	5.31±0.29 (88.5%)	0.14±008 (100%)	0.18±0.18 (128%)	0.26±0.09 (100%)	0.31±0.009 (119%)
Cyperus cnglomerotus	1.80 (100%)	3.40 (189%)	4.30±0.20 (100%)	4.98±0.22 (116%)	0.09±0.005 (100%)	0.12±0.05 (133%)	0.12±0.006 (100%)	0.16±0.07 (133%)
Limonium axillare	2.5 (100%)	2.15 (86%)	4.70±0.17 (100%)	4.40±0.20 (107%)	0.10±0.006 (100%)	0.31±0.08 (310%)	0.12±0.004 (100%)	0.35±0.09 (291%)
Suaede vermiculate	2.7 (100%)	2.10 (79%)	5.10±0.19 (100%)	4.60±0.27 (111%)	0.20±0.06 (100%)	0.32±0.009 (160%)	0.13±0.007 (100%)	0.26±0.01 (200%)

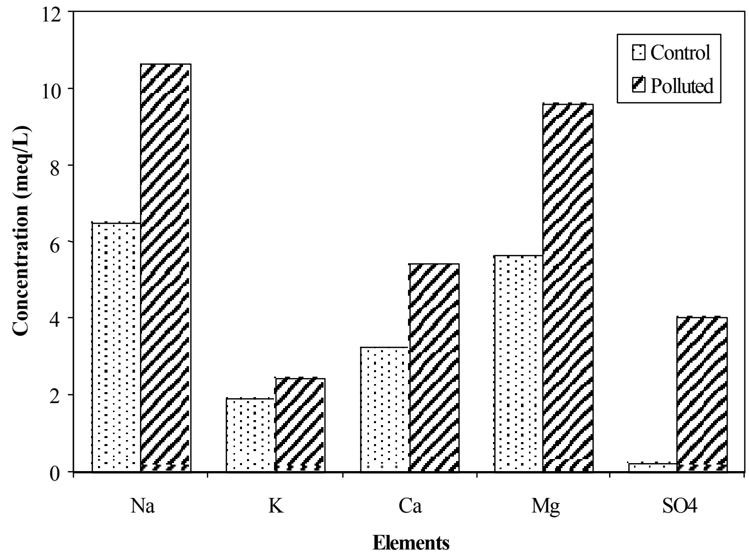

Fig. 2: Concentration of Na, K, Ca, Mg and SO_4 in soil of the studied areas, location1 far from the cement factory (control), location 2 near to the cement factory (polluted). Values significantly different from non polluted in the same plant type according to F-test ($p< 0.05$).

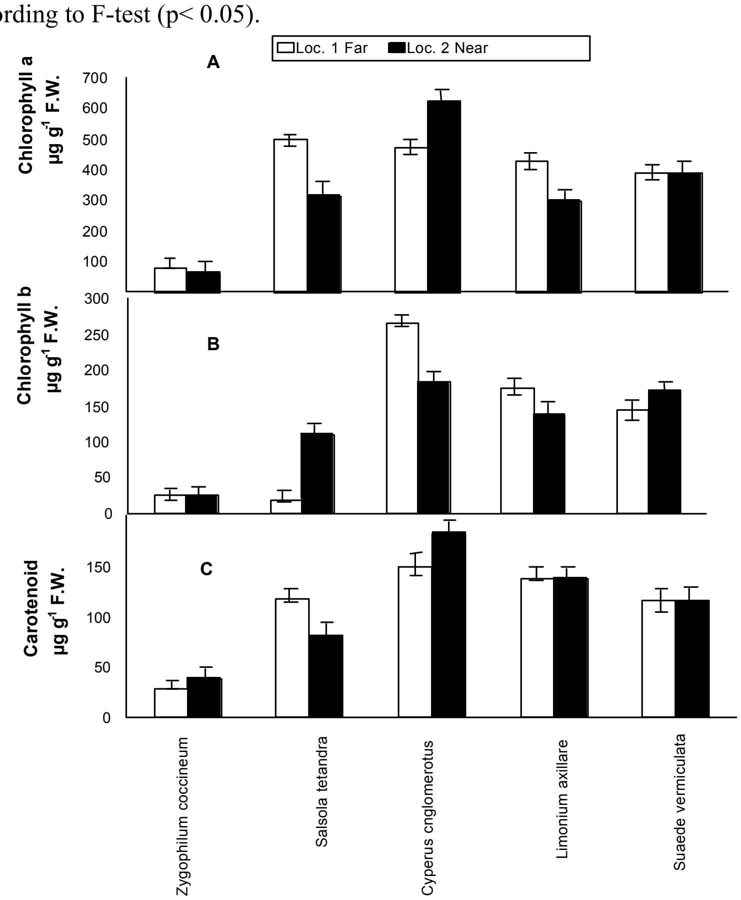

Fig. 3: Chlorophyll a (A),chlorophyll b (B) and carotenoids (C) contents in leaves of five halophytic plants open bars (location1 far from the factory) and shaded bars (location2 near to the factory1) subjected to dust pollution. Vertical bars represent standard errors (n=3). Values significantly different from non polluted in the same plant type according to F-test ($p< 0.05$).

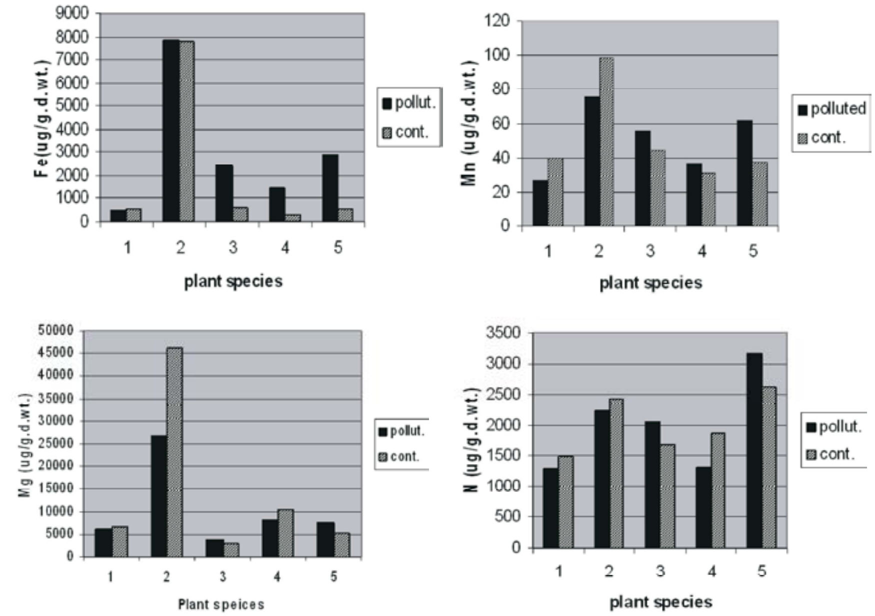

Fig.4: Element content Fe, Mn, Mg and N in leaves of five halophytic plants 1, *Zygophyllum coccineum*; 2*, Salsola tertandra*; 3, *Cyperus conglomerotus*; 4, *Limonium axillare* and 5, *Suaede vermiculata* in control plants away from the cement dust and polluted plants near to the cement factory. Values significantly different from non polluted in the same plant type according to F-test (p< 0.05).

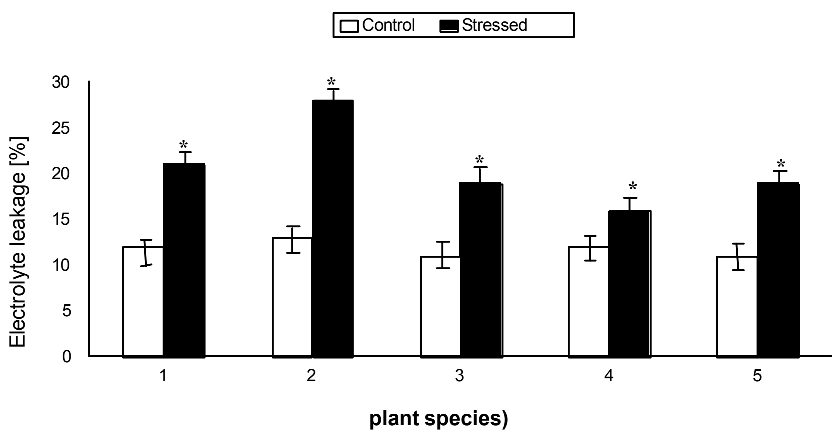

Fig. 5: Electrolyte leakage in leaves of five halophytic plants 1, *Zygophilum coccineum; 2, Salsola tetandra,; 3, Cyperus conglomerotus; 4, Limonium axillare and 5, Suaede vermiculata* in control plants far from athe cement dust and polluted plants near to the cement factory. Values significantly different from non polluted in the same plant type according to F-test (p< 0.05).

ratio for the other four studied plants were decreased in the polluted plant's leaves near the factory and compared with plants far from the dust. Also, the change in the carotenoids content showed the same pattern. There was a significant reduction in carotenoids content particularly for *Suaeda vermiculata Salsola tetrandra* and *Limonium axillare* to less than 10, 33 and 46 %, respectively (Fig.3). For the leaves of *Zygophyllum coccineum* and *Cyperus conglomeratus* a substantial increase in the carotenoids content in response to dust accumulation near the factory occurred. Thus 42 % and 23% of the increase in the content compared to the control plants, respectively. The chlorophyll/carotenoid ratio decreased in *Zygophyllum coccineum* and *Salsola tetandra* plants near to the factory indicating the increase in carotenoid content with respect to non polluted plants (Table 2).

Total carbohydrates content were markedly decreased with increasing dust pollution near the factory for the leaves of *Salsola tetandra* and *Suaede vermiculata* to less than 16 and 29%, respectively compared with non polluted plants, whereas, increased significantly near to the factory and parallel to dust accumulation in *Zygophilum coccineum*, *Cyperus conglomerotus* and *Limonium axillare*. Considerable increases in the soluble sugars that were detected in all plants except *Suaede vermiculata*. Similarly, total protein increment was recorded, especially the soluble protein content in all polluted plants near to the factory except *Salsola tetandra*. Soluble/total protein and soluble/total carbohydrates ratios were increased in all polluted plants compared with the non polluted plants (Table 2). The comparison between the accumulation levels of Fe, Mn, Mg and N in the leaves of polluted plants and control conditions are shown in (Fig.4). The accumulated elements in leaves of plants differed from one species to another in response to cement dust pollution. All the elements (Fe, Mn, Mg and N) in the leaves of *Zygophyllum* sp. and *Salsola* sp. were significantly lower in the polluted plants than in the control plants, whereas, their contents in the leaves of *Cyperus* sp. and *Suaeda* sp. were significantly higher.In leaves of *Limonium* sp., the level of element's accumulation (Mg and N) was significantly lower in polluted plant than in control plant but significantly it was higher for Mn and Fe (Fig.4).

The efflux of electrolytes and pH of all species extracts increased in response to dust pollution and significantly increased in parallel to the dust accumulation in comparison to the control (Fig.5).The present study showed that the two locations (polluted and control) received different amounts of cement dust as indicated by the measurements of pH for the leaves' washing solution. The pH ranged in polluted plant from 8.0 - 8.6 and in control site from 6.7- 7.2), whereas, the accumulation of the cement dust increased the alkalinity of the cell sap for the plant leaves near the factory (nearly 9-9.1). The polluted soil had a significantly higher pH and electrolyte conductivity (EC, 9.2, 2.7) than in the control soil (7.87, 1.6), respectively (Fig. 5).

DISCUSSION

Cement dust had a significant effect on the growth of some plant species compared with non cement dusted plants. Toxic compounds such as fluoride, magnesium, lead, zinc, copper, beryllium, sulfuric acid and hydrochloric acid were found to be produced by cement manufacturing plants [21]. The results obtained are in close conformity with those reported by Stratmann and Van Haut [9] in which dusted plants with dust ranging from 1 to 48 g/m^2/day and concluded that dust falling on the soil caused a shift in pH to the alkaline side, which was unfavorable to oats but favorable to pasture grass. Our results are also confirmed by the findings of Prasad and Inamdar [22] in *Vigna mungo* (Black gram). A quantitative estimation along with dust analysis confirms the ill effects of the cement dust on the plant growth. The pH of dust sample was alkaline in nature; its pH was 9.5 and could be correlated with the findings of Lerman and Darley [23]. They also found a similar range (9.5-11.5) of cement dust pH. The changes in the accumulation of mineral plant nutrients as a result of cement dust were also determined and showed a consistent result with those obtained by Lal and Ambash [24]. It is also suggested that the complete analysis of the cement dust contains all the toxic pollutants should be carried out in detail. The heavy metals present in the cement dust may play an important role in disturbing the various metabolic processes. As it would be possible to recommend these plants in the current study for use as screen or green belts in the industrial localities and adverse urban localities in order to mitigate dust and improve air quality [25]. Dust analysis indicated the presence of heavy metals which may disturb the physiological and some other biochemical reactions. Our results are consistent with the results of George and Ilias [26] who reported that the traces of toxic metals such as chromium and copper are common in some varieties of Portland cement and are harmful to human being and other living systems. Our data indicates that the exposure of plants to dust altered several physiological and biochemical parameters that were triggered. The most apparent effect of stress induced by dust, described in numerous species, is leaf damage [27]. This damage was observed in the dust-exposed plants although there was no leaf abscission promotion (data not shown). Heath and Castillo [28] reported that leaf injury is due to diverse alterations at the sub cellular level.Various studies have shown that the main detrimental effect of dust at the subcellular level is photosystem damage [5, 29]. Moreover, the presented results clearly showed that dust altered several biochemical aspects, such as pigment or carbohydrate concentration in leaves

A significant percentage increase in chl a/b ratio was observed only in *Cyperus conglomeratus* which was mainly caused by an increase in chlorophyll *a* content associated with decrease in chlorophyll *b* content. On the other hand, a marked percentage decrease in chl a/b ratio was observed in the other four studied plants. The changes in chlorophyll a and b are possibly due to shading and/or photosystem damage due to dust accumulation between the peltates or other effects on stomata. Dust from a cement factory seems to cause substantial changes to leaf physiology, possibly leading to reduced plant productivity. Our results are consistent with Nanos and Ilias [29] who reported that cement dust decreased the leaf total chlorophyll content and chlorophyll *a/b* ratio. As a result, photosynthetic rate and quantum yield decreased. The decrease in the chlorophyll/carotenoid ratio for stressed plants suggested that these relationships could be used as an indicator of tolerance and physiological status of the plants under these stress conditions. According to the results chl a/b ratio were significantly increased in *Cyperus conglomeratus* and correlated positively with dust accumulation near to the factory, indicating the presence of protection mechanism of the chloroplast towards the dust pollution. Lichtenthaler *et al.* [30] stated that the increase in the ratio Chl *a*/*b* is always associated with a change in pigment composition of the photosynthesis apparatus towards a more sun-type like chloroplast which possesses less light harvesting chlorophyll proteins (LHCPs). According to our results, chloroplasts, in most studied polluted plant, are known to also compose a higher carotenoid content on a chlorophyll basis than non polluted chloroplasts, which is indicated by the lower values for chlorophylls (*a*+*b*) to carotenoids ratios. In addition, carotenoids, increased in the dust-stressed plants, not play a role as accessory light-harvesting pigments only but they also protect photosynthetic systems against reactive oxygen species [31-33]. Our results are consistent with results of Lichtenthaler *et al*. [34, 3 5] and Licthenthaler and Burkart [36] who studied the response of many plants toward various stresses. Moreover, Young [31] reported that this response was induced, not only by changes in the irradiation under which the plants are grown, but also by diverse chemicals or stressors that are often associated with long term stress. Carbohydrates content was increased in the l eaves of dust polluted plants. The significant increase in the carbohydrates content seems to be involved in osmotic adjustment [37, 38]. The observed increase in the concentration of soluble sugars may be attributed to growth inhibition by dust stress than photosynthesis, increasing partitioning of fixed carbon to sucrose [39,40], osmoregulation and tolerance contributing plant survival [41]. The largest alterations observed in plant sugar metabolism preceded the drastic decrease of soluble leaf protein. These proteins are typically related to stress responses, such as freezing, osmotic and salt stress and pathogen attack [42-46]. Thus the response of studied plants seems to have characteristics in common to dust pollution and in agreement with suggestions made for other species [38, 47]. In conclusion, the comparison of five species of different dust susceptibility permitted determining that the tolerance or sensitivity to dust pollution was clearly manifested throughout the photosynthetic activity. The exposure to dust pollution stress provoked important reductions in photosynthesis in most studied plants except *Cyperus conglomeratus*. This study indicates that exposure to particulate deposition may alter plant growth without physical damage to the plant. Moreover, accumulation of dust particulates on studied halophytic leaves could be a m ajor problem in their production. We propose that the pigments content of the light harvesting complex is an important aspect related to the tolerance of plants to dust pollution.

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