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SOME ECOPHYSIOLOGICAL CRITERIA OF *PORTULACA OLREACAE* L. GROWING IN DELTIC REGION OF RIVER NILE, EGYPT

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Portulaca oleracea **L. was collected from different farmlands located beside industrial regions, polluted lands irrigated with drainage water and unpolluted lands (irrigated with River Nile water; site 9) in Dakahlia province. Soil of these sites was characterized by clay to silty texture, neutral to alkaline pH, high total soluble salts in the polluted sites. In soil samples macronutrients were arranged as Ca > Cl > Mg = Na > K > PO_4. However, in *P. oleracea* tissues, these nutrients accumulated in the following order: Cl = K > Mg > PO_4 > Na = Ca. Pigment contents were higher with high shoots Mg level. In contrast of soluble sugars, chl. a, b and carotenoids, soluble proteins, total free amino acids and biomass productivity were adversely affected by hydrocarbon pollution. Correlation coefficient was significantly positive between potassium of the soil with both plant tissues and soluble proteins. Furthermore, the same relation was observed between soil chlorides and Alkaloids. There was a negative correlation between soil OM and PO_4 and shoots Na and Cl. All the possible correlations were also confirmed by CCA application between soil variables and plant contents which showed silt, organic matter, Na and Ca as the most important soil variables those control this species capabilities. It is worth mentioning that *P. oleracea*, and may be most edible crops, suffered from the pollution caused by petroleum products and must be avoided as a nutritive.**

Keywords: Biomass, Metabolites, Elements, Pigments, Industrial pollution.

1. INTRODUCTION

Urban areas are recognized to be the major sources and sinks for contaminants, due to the high concentration of pollutant-emitting activities [1]. A consequence of the growth of heavy industry has been the addition of high concentrations of pollutants originating from anthropogenic inputs including industrial wastewater discharges, sewage wastewater, fossil fuel combustion, and atmospheric deposition [2].

Toxic pollution in the biosphere has accelerated manifolds due to continuous emission from agricultural, industries, mining and other anthropogenic activities such as human foodstuffs by agricultural uses of chemical fertilizers and drainage water [3].

The soil contamination is suggested to be the main causes from the random dumping of solid waste from the industry and it could be spread by rainwater and wind [4]. Sources of soil pollution can be classified into point sources and non-point sources [5]. Point sources of pollution occur when harmful substances are emitted directly into a body of water, such as emission, effluents and solid discharge from industries. These effluents contain a wide variety of both organic and inorganic pollutants such as oil, greases, plastics, plasticizers, metallic wastes, suspended solids, phenols, toxins and other chemical substances. Many of these compounds are not readily susceptible to degradation and cause very serious pollution problems. Also, vehicle exhaustion and gas-oil plant sediments may cause soil alkalinity [6]. Point sources include the discharges industrial plants and that of fertilizing and irrigation practices those lead to leaching of heavy metals and nutrients as phosphates and nitrates to the water surfaces and sediments. In Egypt, there are some very large basic industries such as companies of iron, steel, coke, aluminum, textile, etc. These industries are characterized by very high capital investments, low rate of return, high labor intensity [7].

Portulaca oleracea L. is an important plant naturally found as a weed in field crops and lawns. It is a warm-climate, herbaceous succulent annual plant with a cosmopolitan distribution belonging to family Portulacaceae [8]. Some representatives of the genus *Portulaca* showed resistance towards various types of environmental stress. It had been demonstrated that the species *P. oleracea* was tolerant towards the moderate drought [9] and salinity [10]. Populations of *P. oleracea* naturally growing on soils polluted with industrial effluents demonstrated simultaneous hyperaccumulation of several metals [11] and chelating them to inactive compartments [12] mainly in the shoots to avoid toxicity [13]. The present study aims to evaluate the *P. oleracea* capacity to accumulate nutrients in polluted sites to estimate ability of this species to remove different types of pollutants and to determine the most ferocious type of pollution.

2. MATERIALS AND METHODS

2.1. Study area

According to the map of arid regions distribution in the world [14], north of the Nile Delta lies in the arid region, while the southern part lies in the hyper-arid region. El-Dakahlia province is located in the downstream of the Damietta branch of River Nile at 31º 30' E and 30º 30'- 31º 30' N latitude to the North East of Nile Delta region of Egypt (Figure 1). Nine sites represent the study area. *P. oleracea* were collected from six sites at cultivated lands beside: Oil and Soap factory (site 1); Resin and wood factory (site 2); Block factory at Senbkht road (site 3); Recycling litter factory at Sammanod road (site 4); arable land inside *Beta vulgaris* sugar factory at Belqas city (site 5); Abu Mady Gas-Oil field (site 6); beta farmland irrigated with drainage water (site 7); Chemical Fertilizers factory of Talkha (site 8) and beta farmland irrigated from unpolluted Nile water (site 9).

Fig. 1: Location map of Deltiac part of the River Nile Village showing the nine visited sites (S1-S9)

2.2. Soil and plant sampling

Soil and plant (*P. oleracea*) samples were collected from nine sites at Dakahlia province. Plant samples were washed several times by deionized water to remove extraneous and salts then separated to shoots and roots.

Part of plant samples then dried in an oven at 50^{o}C for 48 hrs, chopped and sieved. The extracts obtained by using purslane powder with an average particle size of about 0.5 mm whose then be ready for measuring macronutrients and metabolite concentrations. The other fresh parts were kept frozen for the Alkaloids determination.

2.3. Soil analysis

Soil mechanical and chemical analyses were carried out according to the methods described by Farrag [15]. Three replicates of soil samples were collected from each site at a depth of 0-50 cm. The soil fractions; gravels, coarse sand, fine sand, silt and clay were expressed as percentage of the original weight according to Ryan *et al*. [16]. Organic matter was determined in the soil samples by loss on ignition. Ten grams of about 2 mm particles, oven-dried soil, were placed in 40 cc tarred porcelain crucibles and ignited in an electric muffle furnace at 600 C for 3 h. The crucible was placed in a desiccator, cooled to room temperature, and weighted. Loss was calculated in present of the oven-dried sample **[17]**.

Soil extracts were prepared to meet the requirements for the different parameters, 10 g of air dried soil sample was added to 50 ml of distilled water (1:5 w/v). This extract was used to determine pH values using a glass electrode pH meter (model Hanna pH 211) and electrical conductivity (EC) with (model 4310 JEN WAY). The total soluble salts in the water samples were then estimated as described by Jackson [18]: TSS = 0.64 × EC mS. Cm^{-1} × dilution factor. Sodium and potassium were determined by the flame emission technique (Carl-Zeiss DR LANGE M 7 D flamephotometer was used) according to Williams and Twine [19]. Chlorides were estimated according to Jackson [18] by direct titration against silver nitrate solution using potassium chromate as indicator. Phosphates were estimated according to Vogler [20] by colorimetric method, based on the formation of molybdate blue color with ascorbic acid as a reducing agent. Calcium and magnesium were determined volumetrically by versene titration method as described by Schwarzenbach and Biedermann [21].

2.4. Plant analysis

2.4.1. Determination of water soluble ions

Plant extract was analyzed for the cations (Na^+, K^+, Ca^{+2} and Mg^{+2}) and anions (Cl^- and PO_4^{-3}) contents as previously described for soil analysis.

2.4.2. Determination of water soluble metabolites

Total soluble proteins (SP), total free amino acids (FAA) and soluble sugars (SS) were determined calorimetrically according to procedures described by Lowry *et al.* [22], Lee and Takahashi [23] and Dubois *et al.* [24], respectively. Alkaloids as a secondary metabolite were measured according to Harborne [25] through their precipitation against concentrated ammonium hydroxide.

2.4.3. Dry matter

Biomass values can be used as an indicator to estimate the nutrient uptake capacity of the plants. Whole individuals of *Portulaca* above ground portions of plants were collected from a plot using clippers then dried for 24-48 hours at 80°C until constant weight, cooled in a desiccator jar, and reweighed (dry weight). The dry biomass then calculated as: Dry Weight (of above ground tissues) in grams / Plot area m^2 **[26]**.

2.4.4. Determination of pigments

Photosynthetic pigments (Chl. a, b and carotenoids) were extracted and determined spectrophotometrically according to the method of Welfare *et al*. [27].

2.5. Statistical analysis

One-way ANOVA was applied to assess the significance of variations in the soil, growth variables, elements, organic components, and nutritive variables in relation to the pollution degree. Kendall's tau correlation coefficient (r) was calculated for assessing the type of relationship between the spatial variations in the estimated soil in relation to the plant variables using PAST software v. 2.11 [28]. Analysis of variance (ANOVA) was carried using a general one-way model, Duncan test was used for comparison between means to evaluate the effects of changes in locations (sites) variations on the parameters tested using SPSS v.16 [29]. Canonical correspondence analysis (CCA) was performed to determine the association between plant soluble contents and measured soil variables. The variables in the CCA biplot were represented by arrows with their length proportional to the rate of change [30].

3. RESULTS

3.1. Soil Physicochemical analysis

The soil texture was showed these soils to be silty. Percentages ranged between 90.57% at site 6 and 34.82% at site 4 followed by clay with the highest percentage of 34.26% at site 2 (Figure 2A). The fine sand, coarse sand and gravels recorded a low percentage (4.82%). The soil pH values were generally fluctuated between 7.89 at site 9 (unpolluted Nile border) to 9.19 at the block factory (Site 3) followed by 9.16 at gas-oil field (Site 6) and 9.02 in the soil that irrigated with drainage water (site 7). The soil organic matter (OM) increased in the polluted sites (1-4) with a highest percentage (13.46%) at site 4 (recycling litter factory) followed by 11.96% at the oil factory soil (site 1); meanwhile the lowest value (0.74%) was recorded in the gas-oil field (Figure 2B). Also, the highest total soluble salts percentages were recorded in sites 1, 5 and 7. On the other hand; TSS acquired the lowest percentages at the block factory (0.31%) and the recycling litter factory (0.29%).

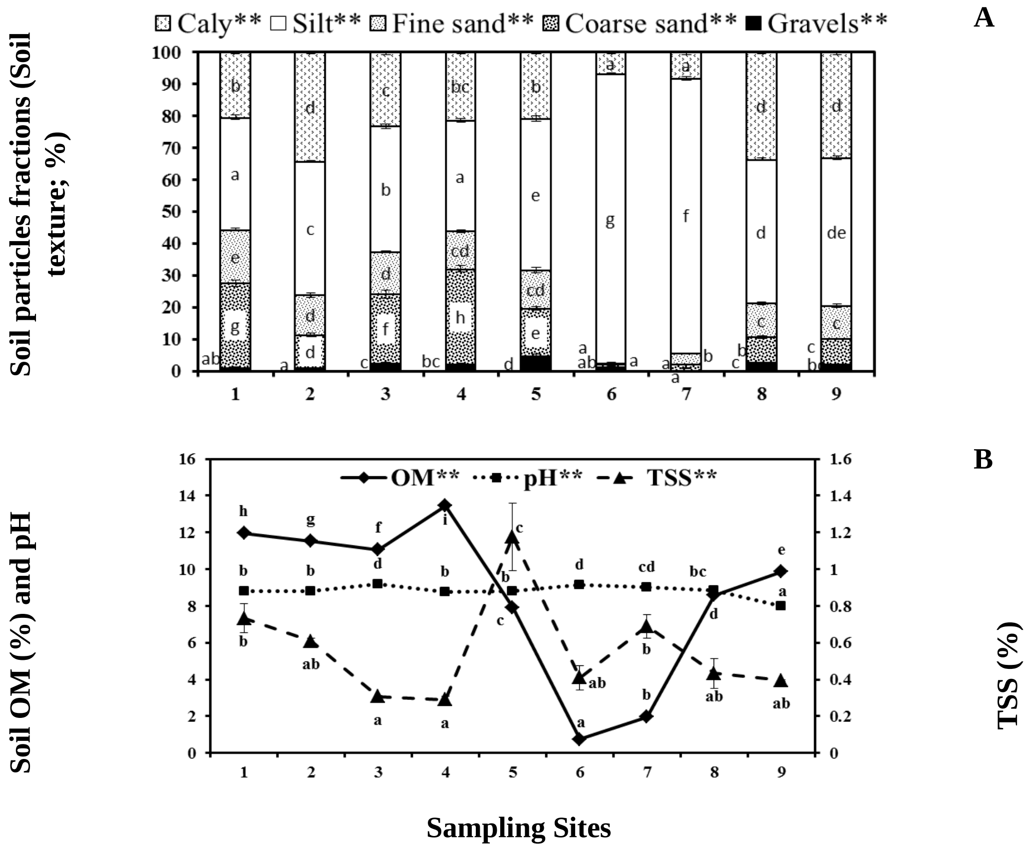


Fig. 2: Physical properties of the studied soil: A; soil fractions (%) and B; Organic Matter (OM; %) and soil solution reaction (pH). The letters on columns show the differences according to the sites. The stars on the ligands show the degree of differences inside each parameter. ** = significant at 1% confidence level.

Generally; the measured major cations and anions (Figure 3) followed the same trend of TSS, where sodium and potassium recorded the lowest contents in sites 3 and 4 (Na; 0.28 mg. g^{-1} d.wt. at site 4 and K; 0.06 mg. g^{-1} d.wt. at site 3). The same trend was observed for Ca, Mg, Cl and PO_4. On the contrary; Na was increased in the polluted sites 1, 2 and 7. Also, the highest K, Ca, Mg and Cl contents were detected at site 5. The soil Magnesium and Chlorides, in gas-oil plant were 0.91 and 1.25 mg. g^{-1} d.wt., respectively. Finally, the lowest recorded soil extract anion (PO_4) showed the highest levels at sites 1, 2 and 4 while the lowest levels were at the polluted sites (6, 7 and 8). On the whole, the differences between sites were highly significant for all the investigated sediments parameters.

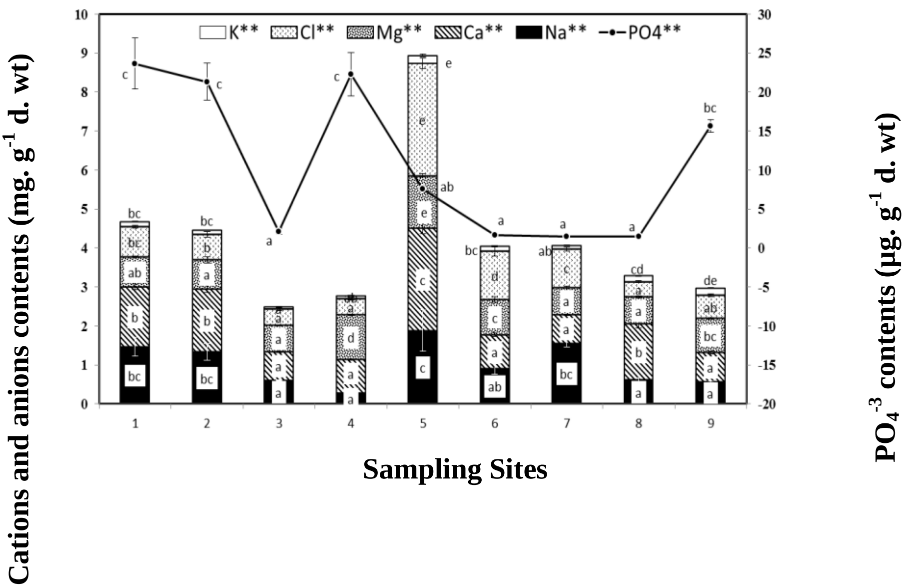


Fig. 3: Contents of major cations and anions (mg.g^{-1} dry wt.; except soil PO_4^{-3}) in soils collected from different sites in the study area. The letters on columns show the differences according to the sites. The stars on the ligands show the degree of differences inside each parameter. * = significant at 5% confidence level, ** = significant at 1% confidence level.

3.2. Plant analysis

3.2.1. Plant cations and anions

The determined ions (Na, K, Ca, Mg, Cl and PO_4) in the collected plants shoots and roots were represented in figure 4. The trend-line of each parameter in both shoots and roots revealed the predominance of potassium and chlorides as the major accumulated nutrients in both *Portulaca* organs and the lowest was for sodium and calcium. In the shoots the trend was Cl = K > Mg > PO_4 > Na = Ca meanwhile in the roots K > Cl > Mg > PO_4 > Na = Ca.

These ions contents in the shoots differed according with sites (the positive scale of figure 4) showed general high levels at sites 2 and 7. However, the other sites acquired lower levels for most anions and cations with some exceptions; e.g. PO_4 at site 1 (19.39 mg. g^{-1} d.wt.) which represented the highest value for PO_4 among the others. Also, the maximum means for potassium (37.95 mg. g^{-1} d.wt.) was at site 9 and for magnesium (24.00 mg. g^{-1} d.wt.) was at site 8. On the other hand; the lowest values of the measured cations and anions were in the third site. This site recorded the minimum values for Ca, Cl and PO_4 contents.

The same trend was observed in these plant roots (the negative scale of figure 4). The overview gives an account about the significant differences among all the investigated variables in all sites with major high levels at sites 2, 5, 6, 7 and 8. In this respect; the maximum values of Na and Ca were at site 5, K at site 2, Mg at site 6 and Cl and PO_4 at site 7. Oil and soap factory, block factory and the Nile border recorded significant decrease in these ions with the minimum value of K, Ca and Cl at site 1 and of Na at site 9.

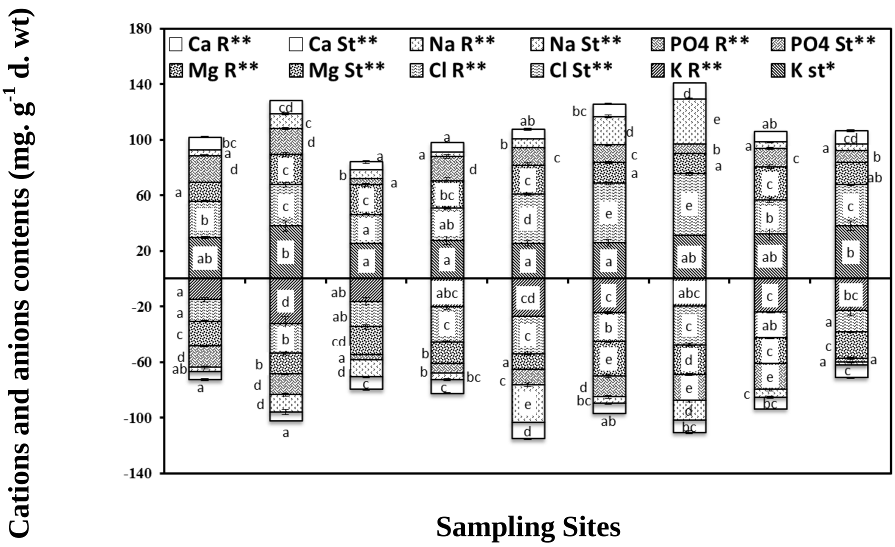


Fig. 4: Contents of major cations and anions (mg.g^{-1} dry wt.; except soil PO_4^{-3}) in the *P. oleracea* plants shoots (St) and roots (R) collected from different sites in the study area. The letters on columns show the differences according to the sites. The stars on the ligands show the degree of differences inside each parameter. * = significant at 5% confidence level, ** = significant at 1% confidence level.

3.2.2. Metabolites

The general feature of the accumulated soluble metabolites in the investigated plants organs showed high accumulation of soluble sugars (about 2-folds) instead of the soluble proteins and free amino acids in both investigated *Portulaca* organs (Figure 5A). The differences between sites were highly significant for each parameter. Notably, the major increase in these metabolites in the shoots was in the first three sites. The soluble sugars recorded the highest mean value at site 3.

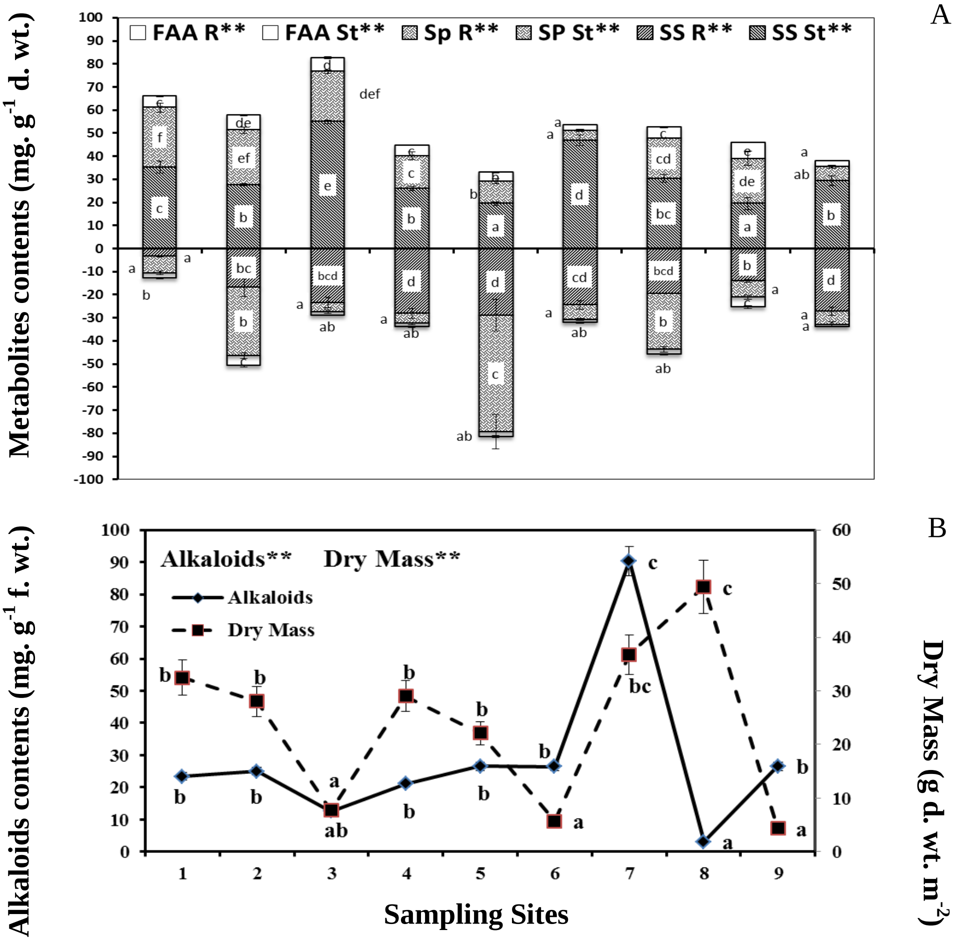


Fig. 5: A; Soluble sugars (SS), soluble proteins (SP) and total free amino acids (FAA) contents (mg.g^{-1} dry wt.) in the shoots (St) and roots (R) and B; shoot Alkaloids contents (mg.g^{-1} f. wt.) and shoot dry mass (g d. wt. m^{-2}) in *P. oleracea* plants collected from different sites in the study area. The letters on columns show the differences according to the sites. The stars on the ligands show the degree of differences inside each parameter. * = significant at 5% confidence level, ** = significant at 1% confidence level.

Also, the maximum mean of soluble proteins was found at site 1. Meanwhile; the total free amino acids contents were higher in sites 2, 3 and 8 than the others. On contrary; the soluble sugars were lowered in sites 2, 4, 5, 8 and 9 with the minimum value of 19.48 mg. g^{-1} d.wt. at the sugar factory and fertilizers factory. The soluble proteins and total free amino acids take the same trend and recorded the lowest means at the polluted site of gas-oil field (4.25 and 2.43 mg. g^{-1} d.wt., respectively).

Soluble sugars of the roots recorded a notable decrease in the polluted sites 1, 2 and 8 rather than the others with the minimum mean of 3.40 mg. g^{-1} d.wt. at site 1, meanwhile; sites 4, 5 and 9 recorded the highest means with the maximum one (28.87 mg. g^{-1} d.wt.) at site 5. However, the soluble proteins and total free amino acids of roots were increased in the polluted sites (2, 7 and 8).

The nitrogenous organic secondary metabolite, Alkaloids that measured in the shoots proved significant increase at site 7 that polluted with drainage water with the maximum value of 90.3 mg. g^{-1} f.wt. The other sites have almost same contents with no significant differences and ranged between 21.1 - 26.6 mg. g^{-1} f.wt. Meanwhile the lower content for alkaloids was at site 8 (Figure 5B).

3.2.3. Dry matter

The dry matter determination for the studied plants (Figure 5B) revealed that, the highest dry matter percentages were in the two polluted sites 7 and 8 with the mean values of 36.7 and 49.4 g dw. m^{-2}, respectively. The significant decrease was at the block factory area (site 3), gas-oil plant (site 6) and Nile borders (site 9).

3.2.4. Leaf pigments

The contents of Chlorophyll (Chl. a, Chl. b), Chl. a + Chl. b, Chl. a/Chl. b ratio and carotenoids in the collected purslane plants grown in the study area were represented in figure 6. Chlorophyll contents were differed according to the degree of pollution. The highest Chl. a content (0.5 mg.g^{-1} lf. f.wt.) was recorded in site 7 which polluted by the drainage water followed by the fertilizers factory (site 8). Meanwhile, Chlorophyll content recorded the lowest level in sites 1, 2, 6 and 9. Nearly, the same trend was observed for the Chl. b with significant increase at sites 3, 4, 5 and 7 than those of sites 1, 2, 6 and 9. Consequently, the summation of the two green pigments (Chl. a and b) take the same behavior with maximum content at site 7 (0.62 mg.g^{-1} lf. f. wt.) and minimum one at site 2 (0.30 mg.g^{-1} lf. f. wt.).

As the other pigments; carotenoids also were increased significantly in the polluted sites 4, 5, 7 and 8 with maximum contents at sites 7 and 8 and strongly decreased at sites 1, 2 and 9. Chl. a by Chl. b ratio revealed a significant increase in these ratios in the polluted sites (1, 2, 6, 7 and 8).

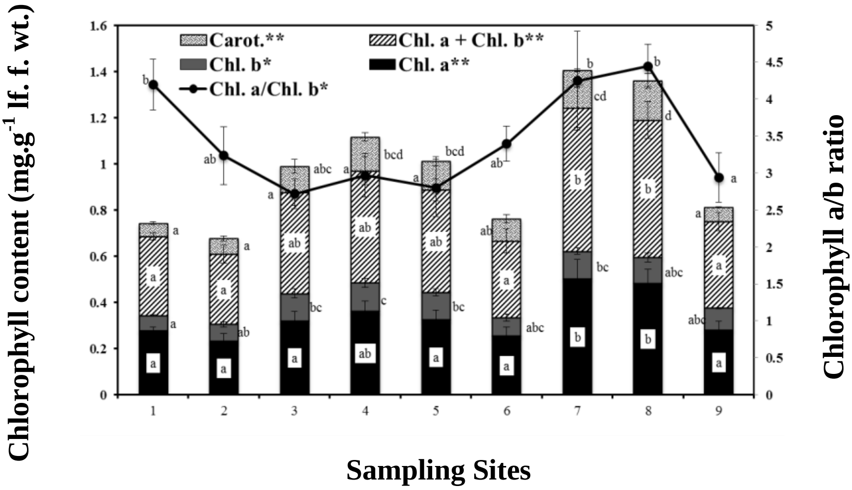


Fig. 6: Chlorophyll (Chl.) content (mg.g^{-1} lf. f. wt.) and Chl. a/Chl. b ratio in *P. oleracea* plants collected from different sites in the study area. The letters on columns show the differences according to the sites. The stars on the ligands show the degree of differences inside each parameter. * = significant at 5% confidence level, ** = significant at 1% confidence level.

3.3. Correlations between plant and soil contents

Some concentrations of mineral ions in the plant tissues were significantly correlated, positively or negatively, with those found in soil. A great variation was noticed due to the difference in plant organs and the type of pollution source (Table 1 and 2). Generally; the *P. oleracea* shoots were responded to the soil physical and chemical properties. In case of shoot metabolites; the soluble proteins (SP) had a significant positive correlations with FS, total free amino acids (FAA) showed significant negative correlation with Mg. Also, the shoot ions, Na and Cl, were positively correlated with silt, soil Na and Cl and negatively with OM and PO_4. In the meantime, shoots Mg showed significant positive correlation with clay particles. Meanwhile, the estimated secondary metabolite (Alkaloids) had significant positive correlation with soil chlorides.

Table 1: Correlation coefficient values (r) between the ions and metabolites in the studied *Portulaca oleracea* shoots and soil variables. CS = Coarse sand, FS = Fine sand, OM = organic matter, TSS = total soluble salts, SS = soluble sugars, SP = soluble proteins, FAA = total free amino acids, Chl. = Chlorophyll, Car. = carotenoids, Alk. = Alkaloids.

Soil Characters	SS	SP	FAA	Na	K	Ca	Mg	Cl	PO_4	Chl. a	Chl. b	Chl. a+b	Chl. a/b	Car.	Alk.	Dry Mass
Gravels	-0.25	-0.17	0	-0.25	-0.33	-0.57*	0.44	-0.31	-0.17	0.25	0.4	0.25	-0.44	0.2	-0.31	0.53
CS	-0.14	0.39	0.11	-0.54*	-0.11	-0.46	0	-0.48	0.28	-0.03	0.09	-0.03	-0.33	-0.09	-0.31	0.84**
FS	-0.03	0.61*	0.33	-0.25	-0.11	-0.34	0.22	-0.48	0.39	-0.25	-0.03	-0.25	-0.22	-0.31	-0.31	0.84**
silt	0.09	-0.5	-0.22	0.59*	0	0.34	-0.11	0.70**	-0.39	0.03	0.03	0.03	0.11	0.09	0.48	0.53
Clay	-0.31	0.28	0.44	-0.14	0.33	-0.11	0.56*	-0.37	0.17	-0.09	-0.16	-0.03	-0.11	-0.03	-0.37	0.84**
OM	-0.09	0.5	0.22	-0.54*	0.11	-0.23	0.11	-0.59*	0.39	-0.14	-0.16	-0.14	-0.11	-0.2	-0.37	0.53
pH	0.4	0.09	0.14	0.4	-0.42	-0.15	0.09	0.06	-0.37	0.17	0.19	0.17	0.14	0.23	-0.11	0.75**
TSS	-0.14	0.17	0	0.2	-0.11	0.23	-0.22	0.42	0.28	-0.03	-0.22	-0.09	0.22	-0.09	0.25	0.53
Na	-0.06	0.14	-0.09	0.4	-0.2	0.26	-0.2	0.46	0.09	0	-0.13	-0.06	0.14	-0.06	0.34	0.46
K	-0.37	-0.17	-0.11	-0.09	0.22	0.06	0	0.25	0.17	0.03	-0.16	0.03	0.11	-0.14	0.25	0.84**
Ca	-0.49	0.11	0.06	-0.2	0	-0.06	0.17	0.15	0.63*	-0.26	-0.38	-0.32	0.06	-0.09	-0.03	0.83**
Mg	-0.29	-0.37	-0.54*	-0.23	-0.2	-0.15	-0.09	0.23	0.31	-0.11	0	-0.11	-0.31	-0.11	0.23	0.34
Cl	0.17	-0.2	-0.48	0.34	-0.31	0.2	-0.37	0.57*	0.09	-0.23	-0.09	-0.29	0.03	-0.17	0.63*	0.59*
PO_4	-0.03	0.28	0	-0.54*	0	-0.11	-0.11	-0.37	0.5	-0.37	-0.34	-0.42	-0.11	-0.42	-0.14	0.84**

** = Correlation is significant at the 0.01 level.
* = Correlation is significant at the 0.05 level.

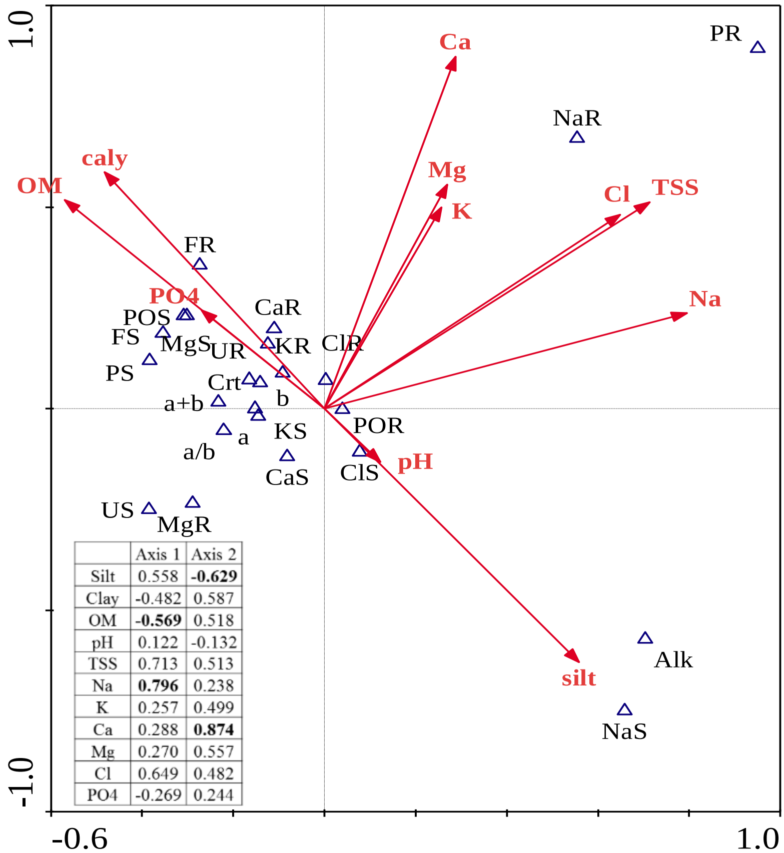
On the other hand; most of the *P. oleracea* root contents were unaffected by the soil factors with some exceptions; i.e. the roots SP had significant positive correlations with soil TSS, Na and Ca. Also, the roots Na had significant positive correlation with those found in the soil. Furthermore there was a significant negative correlation between the roots Mg and the Ca of the soil. Notably, that the plant dry mass was significantly correlated with the most investigated soil variables e.g. clay, pH, K, Ca and PO_4^{-3}.

Table 2: Correlation coefficient values (r) between the ions and metabolites in the studied *Portulaca oleracea* roots and soil variables. CS = Coarse sand, FS = Fine sand, OM = organic matter, TSS = total soluble salts, SS = soluble sugars, SP = soluble proteins, FAA = total free amino acids

		SS	SP	FAA	Na	K	Ca	Mg	Cl	PO_4
Soil Characters	**Gravels**	0.28	-0.22	-0.11	0.03	0.17	0.42	-0.17	-0.11	-0.39
	CS	0.06	-0.11	-0.06	-0.09	-0.28	0.2	-0.5	-0.11	-0.28
	FS	-0.17	0	0.29	0.03	-0.17	-0.03	-0.5	-0.23	-0.06
	silt	0.17	0.22	-0.06	0.2	0.28	0.03	0.39	0.23	0.17
	Clay	-0.17	0	0.17	0.03	0.28	-0.09	-0.39	-0.23	-0.28
	OM	-0.17	-0.22	0.06	-0.2	-0.28	-0.03	-0.39	-0.23	-0.17
	pH	-0.09	-0.14	0.09	0.29	-0.2	-0.06	0.42	0.09	0.31
	TSS	-0.28	0.78**	0.34	0.42	0.17	-0.31	-0.28	0.17	0.39
	Na	-0.2	0.70**	0.26	0.51*	0.2	-0.29	-0.09	0.35	0.42
	K	0.06	0.33	0.06	-0.14	0.28	0.03	-0.17	-0.23	0.06
	Ca	0	0.63*	0.32	0.17	0.46	-0.15	-0.69**	0.06	0.11
	Mg	0.48	0.09	-0.26	-0.11	0.31	0.23	-0.31	0.2	-0.31
	Cl	0.2	0.48	-0.15	0.29	0.2	-0.06	0.03	0.26	0.09
	PO_4	0.06	-0.11	-0.06	-0.31	-0.06	-0.09	-0.39	-0.23	-0.28

** = Correlation is significant at the 0.01 level.
* = Correlation is significant at the 0.05 level.

Canonical Correspondence Analysis (CCA) that used for summarizing all the positive and negative correlations between the soil variables and the measured plant contents (Figure 7) indicated that most of the *Portulaca* shoots and roots soluble contents were negatively correlated with most of the soluble anions and cations (i.e. Na, Cl, Ca and Mg) except for Na and Cl of both organs, Alkaloids and soluble proteins of the roots. The rest metabolites (soluble sugars, free amino acids), leaf pigments as a whole and the ions (Ca, Mg and K) were positively correlated with clay, organic matter and soil phosphates as they were blotted with each other on the negative part of CCA axis 1. The associated inter-set correlations between the soil variables and first two CCA axes introduce silt, OM, Na and Ca as the most important soil variables those regulate the *Portulaca oleracea* internal nutrients.



	Axis 1	Axis 2
Silt	0.558	**-0.629**
Clay	-0.482	0.587
OM	**-0.569**	0.518
pH	0.122	-0.132
TSS	0.713	0.513
Na	**0.796**	0.238
K	0.257	0.499
Ca	0.288	**0.874**
Mg	0.270	0.557
Cl	0.649	0.482
PO4	-0.269	0.244

Fig. 7: CCA biplot showing the importance of each soil parameter for the *P. oleracea* roots (R) and shoots (S) with the interest-correlations with the environmental variables. The abbreviations: Alk = Alcaloids, a = Chlorophyll a, b = Chlorophyll b, a+b = Chlorophyll a+b, a/b = Chlorophyll a/b, Ca = Calcium, Cl = Clorides, Crt = Carotenoids, F = Free amino acids, K = Potassium, Mg = Magnesium, Na = Sodium, OM = Organic matter, P = Soluble proteins, PO = Phosphates, U = Soluble sugars.

4. DISCUSSION

Nutrients, supplied via treated waste water, may change the existing nutrient balance in the soil, thus, contributing to the occurrence of exchanges between them, which in turn, may modify the process of plant nutrition and affect plant growth [31].

Analyzing the study area soils revealed a tendency to be clay or silty, the organic matter was higher than 11% of the soil weight in the first four sites and their reactions (pH) lead them to be mostly neutral, or alkaline in the three polluted sites 3, 6 and 7. These factors encouraged the liberation and high availability of the macronutrients from the soil to the plants.

Generally, the oil factory, resign and wood factory, sugar factory and wastewater irrigated farmlands recorded the highest TSS. This could be mainly due to wastes coming from sewage effluents, resin and oils factory which exhibited considerably higher soluble salts [32]. Notably, PO_4^{-3} contents were very low in comparing with the other soil variables that may be due to its utilization and absorption by the represented flora [33].

Elements at high concentrations in the polluted soil are taken up by plants at higher rates, which may inhibit either the uptake of other elements by roots and/or their transport to the shoots. This may eventually lead to a deficiency of some elements in the upper parts of the plant [34] and explain the efficiency of any plant portion to retain and accumulate other elements with more affinity than others [35]. In this study, *P. oleracea* seems to accumulate high contents of Cl, K and Mg and low contents of Ca and Na especially at sites 2, 5, 6 and 7. This may reflect the tolerance of this species to salt stress. Such increase in Cl contents could be due to the high transportation rate in the studied plants caused more chloride ion to be carried through the transportation stream (passive uptake), leading to the increase in its accumulation [36]. This high accumulation of water soluble anions and cations in purslane organs may due to the high soil TSS. Also, Yazici *et al*. [37] suggest that *P. oleracea* plants responded to NaCl stress by enhancing their antioxidative capacity and proline accumulation.

Comparing the contents of Na in the shoots and roots indicated that plants growing in polluted sites (except sites 6 and 7) accumulated most of the uptaked Na in their roots. This preferential accumulation of Na by roots may be explained as a specific strategy by which the plant inactivate this toxic element by accumulated it in different compartments such as the cell walls of the roots. This will reduce the ratio of toxic to nutritive ions in the photosynthetic tissues then the shoots grow well under high Na levels [38].

The positive correlation indicates that the plant acts as metal sink, while negative correlation indicates an active regulation of element uptake. On the other side, lacking of significant correlations between the plants and soil may be due to the low and variable concentrations in these ions sources [32, 34]. This was clear in the relation between soils and roots Na and soils and shoots Cl. What is worth to mention that the negative correlations between organic matter and PO_4 of the soil in one hand and the salinity factors in the shoots (Na and Cl) in the other hand indicate the organic matter and its liberated nutrients role in improving the soil quality and minimizing the metal toxicity especially under salinity stress [39].

Potassium plays a key role in plant metabolism; it activates a range of enzymes hence plays an important role in protein synthesis [40]. Potassium contents were generally lower in plants collected from the polluted sites than in those growing at the unpolluted Nile border site, which may be due to the interference between K uptake and other ions (e.g. cadmium and lead) present in the wastewater [41].These high contents of K confirmed the greater ability of the studied plants to accumulate such element. In addition, the accumulation of K could be due to a simulative role of calcium in the external water on the uptake of potassium [42].

The great PO_4 contents in purslane organs in proportion to soil phosphates draws attention and reflects their ability to absorb and accumulate high amounts of this nutrient from the soil. This could may due to its high biomass production [43] and its good P absorption capacity [44].

Accumulation of soluble sugars could be an adaptive mechanism against pollution where they are able to protect the structural integrity of cell membrane [45] which has been used as a measure of adverse environmental stress tolerance [46]. This increase in soluble sugars was clear in plants collected at gas-oil factory. However, reduction in soluble sugars under pollution might be the result of high growth and biomass productivity during their life span [47]. This shown clearly in site 8, where a significant high dry mass and low sugar content in both purlane organs was observed. These results were in agreement with Keutgen and Pawelzik [48] on *Fragaria vesca*, Amuthavalli *et al*. [49] on cotton and Turhan *et al*. [50] on Lettuce.

Proteins are one of the major components in membrane which has main role in plant cell resistance in proportional to environmental stress [51]. Also, terminal increase in soil salinity factors as Na increase the protein level in some plants such as cotton [52] and purslane [37] was reported. In accordance with these findings, there were notable increase in soluble proteins and free amino acids at the expense of soluble sugars in site 5 that acquire the higher Na content in their soil. However, this situation was completely inverted in gas-oil factory area that characterized by the lowest OM and TSS percentages and high pH. Lower soluble protein content could be due to enhancement of proteolysis and decreasing protein synthesis under hydrocarbons pollution [53].

Free amino acids accumulation were increased in plants growing at the sites polluted with organic matter (site 2) and fertilizers leakage (site 8). These results went in agreement with the finding of Steinbachovà-Vojtìškovà *et al.* [54] who noted an increase in amino acids contents in *Typha* plants by increasing nutrients like nitrogen and phosphorus in the polluted environments. The negative significant correlation between purslane shoot amino acids and soil Mg in this study was in agreement with Ma *et al.* [55] who are confirmed a decrease in tea amino acids synthesis and transport pathway under excess supplement of magnesium. That may be due to the decrease in aspartate and alanine amino transferease enzymes activity under high concentrations of Mg in the soil [56].

Many authors had demonstrated that environmental stress can stimulate the accumulation of secondary metabolites, like alkaloids, which can protect plants against diseases and environmental stresses [57, 58]. Hence the salt stress could promote the metabolism of alkaloid and increase its content [59]. This trend was assessed in this investigation by the significant positive correlation between alkaloids and soil chlorides.

Biomass estimation was an important tool in plant research such as the study of species distribution and abundance, succession and assessment of weed management operations [60]. Dry mass determination for the studied plants revealed that, the highest values were in the sites polluted with sewage effluents (site 7) and fertilizers factory (site 8). The high purslane mass production in the soil irrigated with sewage water or fertilizers leakage could be due to the high nutritive sources those leaks out to these soils. However, pollution of soils with petroleum hydrocarbons (site 6) that one of the important environmental problems in some areas, particularly around petroleum refineries and fuel stations showed low biomass production. In agreement with Mosaed *et al.* [6], whose noted clear effects of oil pollution with petroleum hydrocarbons on soil chemical (high pH, low TSS) and biological (low biomass of *Portulaca*) characteristics. While, the low mass production at Nile borders (4.4 g d.wt. m^{-2}) might be due to the natural nutritive element contents in the soil which may be considered low in comparison with the other polluted sites.

Monitoring total chlorophyll concentration and their ratio can be used as early warning systems for toxic effect of metals accumulation in plants. Bragato *et al.* [61] concluded that the low Chl a/b ratio and Chl a and Chl b contents could be the effect of possible stress conditions.

In our study, the increase in chlorophyll contents (especially for sites 3, 5 and 7) could be due to high Mg contents in plants growing at these polluted sites. Since magnesium represents 2.7% of the chlorophyll molecule [62]. This reflects the magnesium importance to photosynthesis and indicates the reason of high chlorophyll production in these sites. Chlorophyll contents reduced and chlorophyll a/b ratio increased in oils (site 1), resign (site 2), gas-oil (site 6) factories and sewage effluents (site 7) may be associated with higher concentration of mineral ions (especially chlorides) and high sensitivity of chlorophyll b to organic, petroleum and nutrients pollution. Loss of chlorophyll under soil pollution has been reported by many authors (e.g. 34, 63).

5. CONCLUSION

This study concluded that (1) the soil organic matter and phosphates were not only the most important soil components for *Portulaca oleracea* life but also they decrease the sodium and chlorides toxicity in this species. (2) Hydrocarbons were the most serious pollutants that inversely affect the plant biochemical processes. (3) This species could be considered as source of potassium, phosphates and proteins for fodders but those of hydrocarbon polluted sites must be avoided.

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السمات البيئية الفسيولوجية لنبات الرجلة النامي في منطقة الدلتا لنهر النيل . مصر

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تم جمع نبات الرجلة من مناطق زراعية مختلفة تقع بعضها في المناطق الصناعية و بعضها في مناطق ملوثة بمياه الصرف الصحي وغير الملوث (المروية بماء نهر النيل ؛ الموقع ٩) بمحافظة الدقهلية . تميزت تربة هذه المناطق بالملمس الطيني أو الطميي ، و تراوحت درجات pH بين المتعادل إلى القلوي ، كما ارتفعت قيم الأملاح الذائبة الكلية في المواقع الملوثة. كان ترتيب تركيزات العناصر الكبرى في عينات التربة كالتالي ($Ca > Cl > Mg = Na > K > PO_4$) لكنها تراكمت في أنسجة النبات بالترتيب التالي ($Cl = K > Mg > PO_4 > Na = Ca$) . أرتفع محتوى الكلورفيل و الكاروتينات في الأوراق مع زيادة الماغنسيوم في المجموع الخضري . على النقيض من السكريات القابلة للذوبان، تأثرت الأصباغ والبروتينات القابلة للذوبان و الأحماض الأمينية الحرة الكلية و الوزن الجاف للنباتات تأثرا سلبيا بالتلوث الهيدروكربوني . كما أظهر معامل الارتباط علاقة إيجابية بين البوتاسيوم في التربة و نظيره في الأنسجة النباتية والبروتينات القابلة للذوبان ، علاوة على ذلك، لوحظت نفس العلاقة بين كلوريدات التربة والقلويدات . كان هناك ارتباط سلبي بين المادة العضوية و الفوسفات في التربة مع الصوديوم و الكلوريدات في أنسجة النباتات . أيضا تم التأكيد على جميع الارتباطات الممكنة من خلال تطبيق CCA بين متغيرات التربة ومحتويات النبات التي أظهرت أن الطمي والمواد العضوية و الصوديوم والكالسيوم كأهم متغيرات التربة التي تتحكم في حياة هذا النوع من النباتات . و من الجدير بالذكر أن نبات الرجلة ، و قد يكون هذا هو حال المحاصيل المزروعة في الحقول المجاورة ، تعاني من التلوث الناجم عن المنتجات البترولية و يجب تجنبها كمصادر غذائية .

__**الكلمات المفتاحية:**__ الكتلة الحيوية، الأيض، العناصر المغذية، الأصباغ، التلوث الصناعي.