Egypt. J. Bot. **Vol. 59,** No. 1, pp. 139 - 149 (2019)

Accumulation and Distribution of Minerals and Heavy Metals in Sugar Beet and Carrot Plants Grown on Soil Amended with Filter Mud Cake

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FILTER mud cake (FMC) collected from Qus sugarcane factory at Qena in Egypt was applied in a pot experiment to investigate the uptake and distribution of certain mineral nutrients and some heavy metals in different organs of both experimental plants. The filter mud cake was mixed with sand at three levels: 10%, 30% and 50% and the sand was used (without FMC) as control. Results showed that amendment the sandy soil with filter mud cake resulted in increasing in K and, Ca contents in both experimental plants. Moreover, Mg content had irregular behavior by decrease or increase. Na content- in contrast to Ca and K showed significant decrease of carrot and sugar beet plants. The distribution of Na and K was in another way, and mostly Na accumulated in roots while more K transported into shoots of both plants. Results indicated also that Na/K ratio was higher in plant roots than in shoots. Data revealed that FMC stimulated the accumulation of Cl, PO_4 and SO_4 content in two tested plants as compared with control. Mg, Ca, Cl, SO_4 and PO_4 distributed in shoots and roots with significant change from the roots toward the shoots. Generally, FMC treatments increased Zn, Cu, Pb and Cd accumulation in carrot and sugar beet plants compared to control. Correlation analysis between the contents of heavy metals in both organs of carrot and sugar beet plants and that in the sand-FMC mixture showed different relationships.

Keywords: Sugar beet**,** Carrot, Filter mud cake, Heavy metals, Minerals.

Introduction

Soils of the new cultivated desert in Egypt are low in their organic matter content. Organic amendments should be added to these soils to improve their chemical, physical and biological properties as well as fertility. According to Abo-baker (2017) it is important to apply organic matter to the new cultivated soils because soil cultivation enhances the rate of soil degradation and decomposition of soil organic matter. Filter mud cake (FMC) or Press mud (PM), a residue from the treatment of sugar cane juice by filtration, is a rich source of phosphorus and organic matter and has large moisture content. Prado et al. (2013) reported that using FMC as a complete or partial substance for mineral fertilizers in sugar cane cultivation, in the planting of other crops, in vermicomposting, in composting and as a substrate in the production of seedlings. Razzaq (2001) reported that, continuous land application of sugarcane FMC to agricultural crops for 5-6 years due to improve soil fertility by adding sulfur (S) and organic matter to soil. FMC is rich in sugar and contains appreciable amount of essential plant nutrients viz., macronutrients (P, K, Ca and Mg), organic carbon, nitrogen and traces of micronutrients viz., (Zn, Fe, Cu and Mn), so it use for enhancing the soil fertility and thereby improving the crop productivity (Kumar & Chopra, 2016). FMC improves soil nutrient availability and uptake by plants (Muhammad & Khatta, 2009). Rizk (2012) reported that cover crop with mineral fertilizer treatment increased mineral content in leaf petioles. Application of FMC to the soil increased the total N, P and K according to Hadad et al. (2015). Hassan (1999) indicated that wheat plants grown on sandy and sandy calcareous soils treated with composted sugar beet residues contain a significant increase in K, P and N. In addition, Taha (2000) reported that the application of different composted organic residues significantly increased the uptake of

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DOI: 10.21608/ejbo.2018.4856.1200
Edited by: Prof. Dr. Wedad Kasim, Faculty of Science, Tanta University, Tanta, Egypt.

N, P and K by corn plants over the control and the increase was proportional to the increase in the composted organic residues level. PM application induced increase in S and Ca uptake. As well, Long-term application of sulphitation PM increases the content of Cu, Fe and Zn in sugar beet (Solaimala et al., 2001). Chauhan (1995) found that Zn contents of rice plants increased when 50% of required gypsum was applied with 15mg ha^{-1} filter mud cake. Kumar & Chopra (2016) observed that *Solanum melongena* plants had the highest contents of Cd, Cr, Cu, Mn and Zn with 100% treatment of the sugarcane PM.

Carrot and sugar beet in Egypt are among most popular root vegetables. Carrots are a serious source of sugars and minerals like Ca, P, Fe and Mg (Sharma et al., 2012). This root vegetable contains valuable phytochemicals. Red sugar beet has been cultivated already in ancient Egypt. The taproot contains vitamins A, B1, B2, B3, B4, B5, B6, B12, C, anthocyanins and Fe, Ca, Mg, K, Mn, Cu Cl, F, Zn, B, Li, Mo, Co, Rb and Cs (www.trafoon.org/sites/trafoon.org/files/download/1196/olsztyn_lech_michalczuk_20160912.pdf).

Therefore the present study was carried out to evaluate filter mud cake as organic fertilizer treatments and its effect on the uptake and distribution of mineral element and heavy metals in carrot and sugar beet plants.

Materials and methods

Plant materials and growth conditions

Filter mud cake (FMC) was obtained from Qus sugarcane factory, Qena Governorate, Egypt. Different levels of FMC-sand mixture (thoroughly mixed) were used for this study. The filter mud cake was mixed with sand at three levels: 10%, 30% and 50% (w:w filter mud cake:sand). The sand was used (without FMC) as a control. The pot experiments were arranged in a complete random design using plastic pots of 35cm in diameter and 40cm in height and; each one was filled with 6kg of the investigated sand soil and 3 pots for each level were prepared (totally 12 pots). Experiments were conducted in the screen house and experimental farm, Faculty of Science, South Valley University, Egypt and the field capacity was determined for each FMC level before cultivating the seeds.

Carrot (*Daucus carota*) and sugar beet plants (*Beta vulgaris*) were used as plant materials. Seeds were provided by the Agronomy Department, Faculty of Agriculture, Assiut University. Five analogous individuals were left in each pot and irrigated regularly with distilled water to field capacity level. The amount of water lost per day was compensated for each field capacity of FMC levels. Plants were allowed to grow 10 weeks before the experiment was terminated. During germination and growth, all plants were received Hoagland's solution (Hoagland & Arnon, 1950). Hoagland's solution was added partially at five days intervals at the level of field capacity.

At the end of the experiment, shoots and roots of the plants were weighed and oven-dried and then powdered for extraction and chemical analysis. Shoots and roots extracts were prepared for minerals analysis (Cl, SO_4, PO_4, Na, K, Ca and Mg according to Richards (1954). For heavy metals analysis, the mixed acid digestion procedure as described by Allen (1989) was used for preparing the extracts of different FMC levels or the plant materials. The Total contents of Cu, Zn, Cd and Pb were estimated using an atomic absorption spectrophotometer. Chlorides were determined by silver nitrate ($AgNO_3$) titration method as described by Johnson & Ultrich (1959). Sulphates were determined by a turbid-metric technique as ($BaSO_4$) according to Bardsley & Lancaster (1965). Phosphates were estimated by the method described by Vogler (1965). Sodium and potassium were determined by the flame emission technique (Williams & Twine, 1960). Calcium and magnesium were determined volumetrically by versene titration method as described by Schwarzenbach & Biedermann (1948).

Data were statistically analyzed using SPSS version 21 software. Analysis of variance (ANOVA) was carried using a general one-way model, and Duncan's test was used for comparison between means. The correlation analysis (r-value) was carried out between the studied heavy metals in soil and plants.

Results

The content and distribution of minerals in plants

Cations

The data presented in Figs. 1 and 2 showed that there was a significant increase in K and Ca contents in carrot and sugar beet plants under FMC treatments compared to control. For example, K activity reached a maximum value (about

2.5 fold higher than control) at 30% FMC in both shoots and roots of two tested plants and remained significantly higher than control at 10 and 50% FMC (Figs. 1 and 2). On the other hand, the data presented showed that the highest content of Ca in shoots of carrot (64.7% higher than control) and in shoots of sugar beet (160% higher than control) in observed at 50% FMC. There is a random increase in Ca content in roots of two tested plants. This increase was about 1.5 fold in sugar beet at 10% of FMC. Furthermore, Mg content had irregular effects by decrease or increase. Na content in contrast to the other minerals showed significant decrease in shoots of carrot and sugar beet reach 50% of control at the higher level of FMC (50%), but in roots, there was random increase in comparison with the control plant (Figs. 1 and 2). The accumulation of Ca in control roots of carrot and sugar beet (0.21mg/g DW and 0.08mg/g DW, respectively) was higher than control shoots (0.17mg/g DW and 0.05m/g DW and 3.2mg/g DW). Also accumulation of Na control roots of carrot and sugar beet (3.91mg/g DW and 4.31mg/g DW, respectively) was higher than control shoots (2.8mg/g DW and 3.2mg/g DW). Moreover accumulation of Mg in control roots of sugar beet was increased by 77.77% than control shoots of sugar beet. Conversely, the K accumulation was increased in control shoots of carrot and sugar beet (141.66% and 100%, respectively) than control roots of carrot and sugar beet.

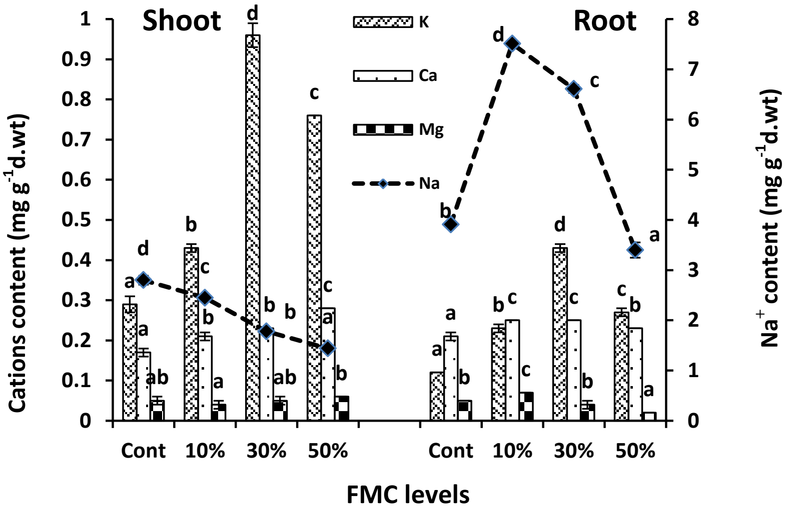

Fig. 1. Concentration of major cations (Na, K, Ca and Mg; in mg g^{-1} dry wt) in shoots and roots of carrot plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

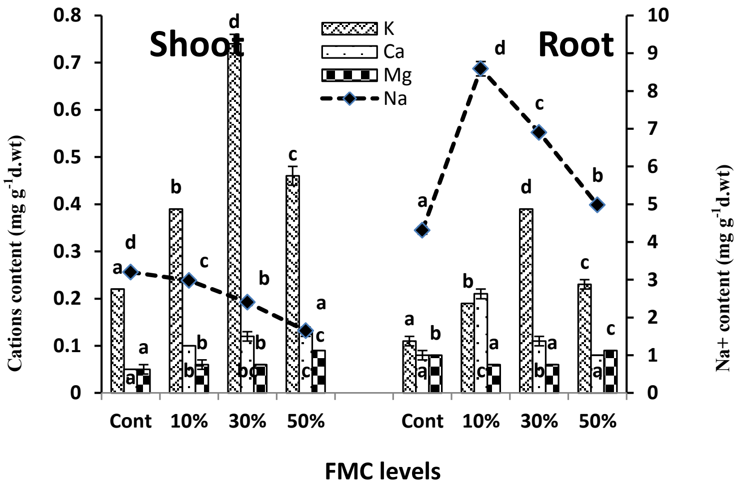

Fig. 2. Concentration of major cations (Na, K, Ca and Mg; in mg g^{-1} dry wt) in shoots and roots of sugar beet plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

The FMC significantly decreased Na/K ratio in carrot and sugar beet plants which was maximum (about 80% and lesser than control) in shoots, (62% lesser than control) in roots of carrot at 50% FMC and (55% lesser of control) in roots of sugar beet at 30% (Tables 1 and 2).

Anions

FMC stimulated the accumulation of Cl, PO_4 and SO_4 content in two tested plants as compared with control (Figs. 3 and 4).

The data showed that the highest increase of Cl was in shoots (76.92% and 50.05% of control) of carrot and sugar beet, respectively at 50% of FMC. But at the same level of FMC, the increase was (34.61% and 25.03% of control) in roots of carrot and sugar beet respectively. There are increases in Cl content in control roots of carrot and sugar beet (100% and 75.02%, respectively) than control shoots of carrot and sugar beet.

SO_4 content reach the highest increase (144.96% and 197.49% of control) in shoots of carrot and sugar beet, respectively at 30% of FMC. While in roots, the highest increase was 146.33% in carrot at 10% of FMC and 91.91% in sugar beet at 50% of FMC. The increase of SO_4 in control roots of carrot and sugar beet was 172.13% and 61.16% higher than control shoots of carrots and sugar beet, respectively.

The highest increase is (192.08% of control) in PO_4 content in roots of carrot at 30% of FMC. But the highest increase (45% of control) in PO_4 content was in both shoots and roots of sugar beet at 10% of FMC. PO_4 content in control roots of carrot and sugar beet was about 2 and 1 fold than PO_4 content in control shoots of carrot and sugar beet, respectively.

The content and distribution of heavy metals in plants

The data presented in Figs. 5 and 6 showed that in general, FMC treatments increased Zn, Cu, Cd and Pb accumulation in carrot and sugar beet under compared to control.

TABLE 1. One way ANOVA and means± SE of Na/K ratios in different organs of carrot plant grown on different levels of FMC.

Treatment \ Parameter	Na^+/K^+	
	Shoot	Root
Sand (control)	$9.81^c \pm 0.63$	$33.62^b \pm 1.44$
10%	$5.78^b \pm 0.20$	$32.25^b \pm 1.15$
30%	$1.86^a \pm 0.07$	$15.58^a \pm 0.43$
50%	$1.90^a \pm 0.08$	$12.46^a \pm 0.61$
F value	125.92^{**}	121.14^{**}

Values with different superscript letters are significantly different at P<0.05 according to Duncan Test.

* and ** are significant at P<0.05 and P<0.01, respectively.

TABLE 2. One way ANOVA and means±SE of Na/K ratios in different organs of sugar beet plant grown on different levels of FMC.

Treatment \ Parameter	Na^+/K^+	
	Shoot	Root
Sand (control)	$14.90^c \pm 0.39$	$39.30^c \pm 1.73$
10%	$7.73^b \pm 0.06$	$45.20^d \pm 1.08$
30%	$3.25^a \pm 0.13$	$17.53^a \pm 0.24$
50%	$3.60^a \pm 0.19$	$22.14^b \pm 0.36$
F value	537.65^{**}	162.66^{**}

Values with different superscript letters are significantly different at P<0.05 according to Duncan Test.

* and ** are significant at P<0.05 and P<0.01, respectively.

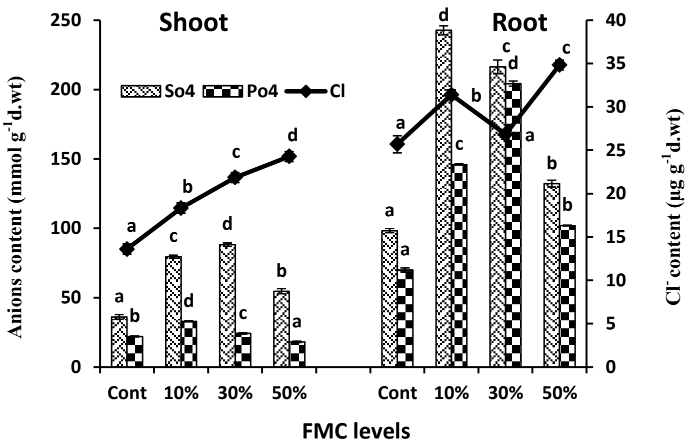

Fig. 3. Concentration of major anions (line for Cl in µg g^{-1} dry wt; SO_4 and PO_4 in mmol g^{-1} dry wt) in shoots and roots of carrot plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

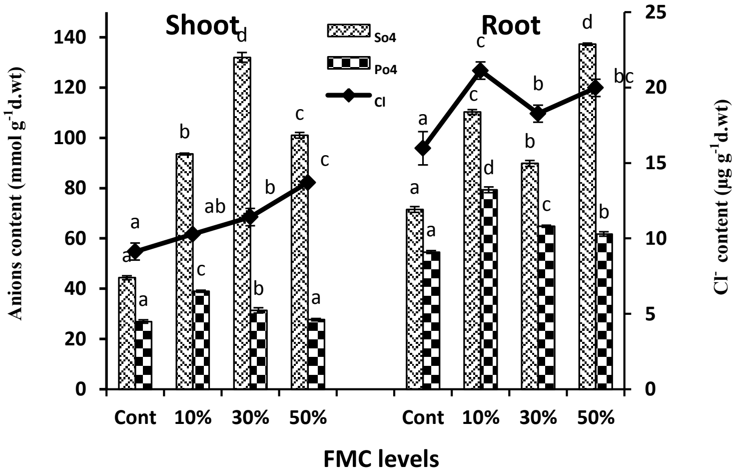

Fig. 4. Concentration of major anions (line for Cl in µg g^{-1} dry wt; SO_4 and PO_4 in mmol g^{-1}dry wt) in shoots and roots of sugar beet plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

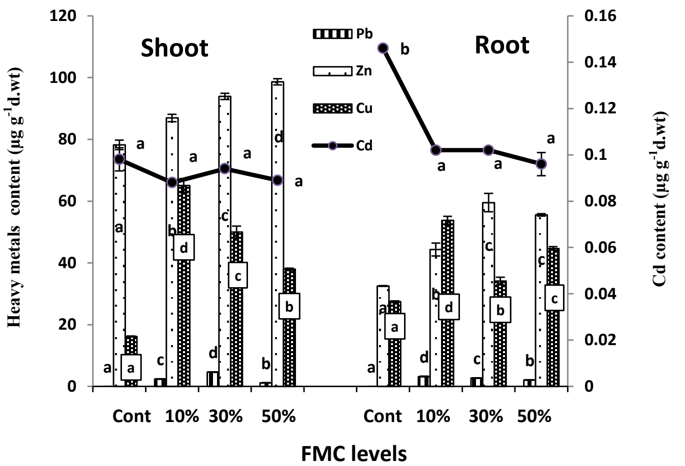

Fig. 5. Concentration of heavy metals (line for Cd in µg g^{-1} dry wt; Zn, Cu and Pb in µg g^{-1} dry wt) in shoots and roots of carrot plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

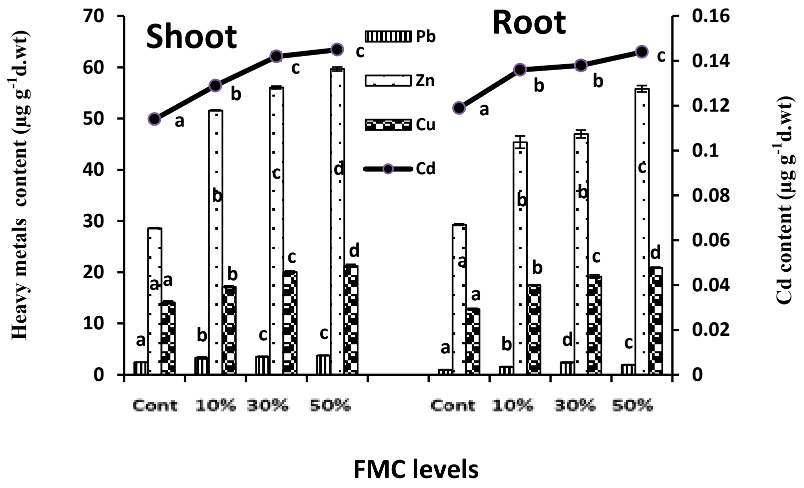

Fig. 6. Concentration of heavy metals (line for Cd in µg g-1 dry wt; Zn, Cu and Pb in µg g-1 dry wt) in shoots and roots of sugar beet plants grown on sand "control" and different levels of FMC [Data are means±SE, n= 3, data of each ion in each panel with different letters are significantly different at P> 0.05 according to Duncan Test].

The maximum increase of Zn was in roots of carrot (83% higher than control) at 30% FMC. In sugar beet, the increase of Zn in shoots and roots was 108.78% and 90.60%, respectively at 50% FMC as compared with control. The increase of Zn in carrot control shoots was 140.35% than carrot control roots. Conversely the Zn content in both controls shoots and roots of sugar beet was almost equal.

Cu had maximum increase in shoots of carrot (295.13% higher than control at 10%, FMC). While in roots of carrot, the increase was 95.79% higher than control at the same FMC level. Moreover, in shoots of sugar beet, the maximum increase was 50.81% at 50% FMC. And in sugar beet roots was 63.23% at the same FMC level. The content of Cu in carrot control roots (27.46µg/g DW) was higher than carrot control shoots (16.14µg/g DW). On the other hand in sugar beet, Cu content in control shoots (14.11µg/g DW) was higher than in control roots (12.78µg/g DW).

The maximum value in Pb was 4.64µg/g DW at 30% FMC in shoots of carrot, and was 3.22µg/g DW in roots at 10% FMC. In sugar beet, while the maximum increase in Pb of shoots was 53.68% at 50% FMC as compared with control. The increase in roots was 146.39% at 30% FMC as compared with control. The value of Pb in both controls shoots and roots of carrots control was zero. Conversely the increase of Pb in sugar beet control shoots was 151.44% than sugar beet control roots.

Cd in contradiction of Zn, Cu and Pb revealed significantly reduction when treated the carrot plants with FMC. Conversely, there is a highly significant increase in Cd content in sugar beet plants. The maximum decrease was 39.8% lesser than control in roots of carrot at 10% of FMC. Moreover, the increase in Cd in shoots and roots of sugar beet was 26.31% and 21.00%, respectively higher than control at 50% FMC concentration (Figs. 5 and 6). In carrot control, Cd content in shoots (0.098µg/g DW) was lesser than in roots (0.146µg/g DW). On the other hand the Cd content in both controls shoots and roots of sugar beet was almost equal.

Relationship between heavy metals in plant and soil

Correlation analysis was carried out between the concentrations of heavy metals in shoots & roots of carrot & sugar beet plants and the absolute contents in the soils; (calculated by using the data of their concentrations in the sand and FMC levels) (Tables 3 and 4). In carrot plants, there are a high significant positive correlation between Zn of soil with Zn of both roots and shoots; also Cd had significant correlation with Cd roots. However, there are a positive correlation between cu soil with Cu roots and shoots, Cd soil with Cd shoot and Pb soil with Pb roots. Conversely, the correlation between Pb soil and Pb shoots was negative. In sugar beet plants, there are a high significant positive correlation with both Zn and Cu soil with Zn and Cu shoots and roots. Pb showed positive correlation with shoots Pb and roots Pb. Cd of soil had negative highly significant with Cd shoots and roots .

TABLE 3. r-values of correlation analysis between concentrations of heavy metals in shoots and roots of carrot plants and absolute quantities in the soil.

	Carrot							
	Pb shoot	**Zn shoot**	**Cu shoot**	**Cd shoot**	**Pb root**	**Zn root**	**Cu root**	**Cd root**
Pb soil	-0.253	0.683*	-0.124	-0.226	0.069	0.422	0.250	-0.395
Zn soil	0.565	0.965**	0.551	-0.311	0.729**	0.895**	0.489	-0.909**
Cu soil	0.496	0.953**	0.296	-0.255	0.526	0.921**	0.220	-0.755**
Cd soil	0.047	-0.812**	-0.155	0.302	-0.324	-0.546	-0.433	0.610*

The significant r-values are marked by stars, *: P<0.05 and **: P<0.01.

TABLE 4. r-values of correlation analysis between concentrations of heavy metals in shoots and roots of sugar beet plants and absolute quantities in the soil.

	Sugar beet							
	Pb shoot	**Zn shoot**	**Cu shoot**	**Cd shoot**	**Pb root**	**Zn root**	**Cu root**	**Cd root**
Pb soil	0.572	0.530	0.670*	0.554	0.292	0.700*	0.642*	0.537
Zn soil	0.953**	0.974**	0.975**	0.973**	0.863**	0.954**	0.981**	0.871**
Cu soil	0.882**	0.882**	0.979**	0.916**	0.886**	0.891**	0.936**	0.759**
Cd soil	-0.756**	-0.715**	-0.795**	-0.736**	-0.436	-0.839**	-0.792**	-0.774**

The significant r-values are marked by stars, *: P<0.05 and **: P<0.01.

Discussion

Organic materials promote the metabolic activity inside the plant and enhance the movement of the metabolites through the roots toward the leaves; so the nutrient content of the plants may increase (Sikander, 2001). In the present study, the Filter mud cake significantly improved mineral content and heavy metals in carrot and sugar beet plants and it effect on distribution of mineral and heavy metals in roots and shoots. Our results showed that in general, there was a significant increase in K, Ca, Mg, Cl, PO_4 and SO_4 contents in carrot and sugar beet plants under FMC treatments compared to control. This increase in mineral may be due to enhanced microbial activates, which increase nutrient availability and their uptake and increasing root distribution. (Yassen et al., 2010). As well as this increase may be attributable to promotion of root growth by filter mud cake and hence increase the capacity to absorb nutrients (Abo-Baker & El-Tayeh, 2017). Kabesh et al. (2009) and Abo-Baker (2017) who reported that organic fertilizers amended with biofertilizers caused significant increases in the P and K uptake in wheat plants. Moreover, Hadad et al. (2015) reported that the increase in P and K in corn and wheat plants may be attributed to the high content of these nutrients in Filter mud cake. Our results showed significant decrease in Na content in shoots of carrot and sugar beet. The higher Na levels in roots as compared to shoots in all treatment may be due to plant restricted transport of Na to upper shoots to minimize its detrimental effects (Ramoliya et al., 2004). The distribution of Na and K was in a reverse way, and mostly Na accumulated in roots while more K transported into shoots of the plants. This may be due to the fact that K is needed for the newly developed and photosyntheticaly active tissues (Abu Zuhri, 2004). Results of the present investigation indicated that Na/K ratio was higher in plant roots than shoots. The low Na/K molar ratios in shoots of the plants because K is required by the various enzymatic processes in the cytoplasm, so less Na can compete with K for binding sites essential for cellular function and did not substitute it (Bhandal & Malik, 1988). So, disruption of various enzymatic processes did not take place. Also, because high concentrations of K is needed for protein synthesis (Blaha et al., 2000). It is well established that potassium is generally the most prevalent ion in plant tissue and that K has important role in maintaining the osmotic potential and activate certain enzymes; whereas the concentration of Na is very low and this ion has no obvious metabolic role in most plants. Data indicated that carrot and beet plants retained Na in their roots and tend to transport more K into their shoots. However, most of higher plants have developed high selectivity in the uptake of K as compared with that of Na.

PM application induced increase in S uptake by mustard and Ca uptake by wheat and maize (Solaimala et al., 2001). Since, Sulfur is a vital component of proteins through the amino acids cysteine and methionine and an active constituent of numerous coenzymes and prosthetic groups, iron sulfur centres, coenzyme-A, thiamine, lipoic acid, S-adenosylmethionine, glutathione, and many more (Kopriva et al., 2015). While calcium participates in formation of cell wall and plasma membrane, cell growth and secretion and hormonal or modulating physiological processes and serves as secondary messenger in cell (Lo´pez-Lefebre et al., 2001). Heavy metals present in soils can easily accumulate in plant tissues. Plant species differ in their uptake and distribution of heavy metals in their organs and in their effect on rhizosphere and bulk soil metal concentration. Soil properties, such as pH, organic matter content and presence of other elements affect plant uptake, solubility and mobility of these elements (Salama & El-Tayeh, 2012). The application of FMC as a source of organic matter resulted in a higher increase in Zn, Cu, Cd and Pb content in the investigated plants. The increased solubility of these metals in the soil amended with FMC could be due to the decrease in soil pH (Brallier et al., 1996). The addition of organic material to the soil increased the percentages of available Zn, Cu and Pb (Abo-Baker & El-Tayeh, 2017). Usman et al. (2004) found that the mobility of heavy metals can be increased by the addition of sewage sludge. Also Temminghoff et al. (1998) reported that the mobility of heavy metals increased with soluble organics. Ayari et al. (2010) reported that as for compost-amended soils, heavy metals in plants were significantly greater than in control. The higher contents of Pb, Cu , Cd and Zn in investigated plants treated with FMC might be due to the occurrence of additional heavy metals in treatment of the FMC, which added extra metals in the soil environment (Kumar & Chopra, 2016). The buildup of the Zn, Cu, Cd and Pb in the carrot and sugar beet plants (except Zn shoots of carrot) was noted below the permissible limit of the FAO/WHO standards for the Cd (0.20mg Kg^{-1}), Pb (5.0mg Kg^{-1}), Cu (40.00mg Kg^{-1}) and Zn (60.00mg Kg^{-1}) (FAO/WHO, 2007). The bioavailability of measured heavy metals in carrot and sugar beet plants might be increased due to the ionization in the aqueous phase in the soil which increases their reactivity and instability as earlier reported by Kumar & Chopra (2014). Nunome et al. (2001) reported the contamination of Cd, Cu, Cr, Zn and Pb in soil and *Solanum melongena* subsequent to application of sugarcane pressmud and effluent.

The present results showed that in general heavy metal accumulation was more in shoots than roots under FMC amendment. Salama & El-Tayeh (2012) reported that Ni transported up to the shoots of cotton plants, while low amounts were detected in roots. The accumulation of heavy metals in carrots and sugar beet plants grown on sandy soil amended with FMC was generally arranged in the following preference: Zn> Cu> Pb> Cd.

Correlation analysis between the contents of heavy metals in both organs of carrot and sugar beet plants and that in the sand-FMC mixture showed different relationships, for examples, Zn concentration in shoots of sugar beet (r= 0.974) and roots (r= 0.954) had a highly positive correlation with that in FMC. While, in case Cd of carrot there was correlation between Cd concentration in shoots (r= 0.302) and in roots (r= 0.610) of plants and that of FMC, this revealed that Cd accumulated in shoots less than in roots. Moreover, in case Pb in sugar beet there was correlation between Pb concentration in shoots (0.572) and in roots (0.292) of plants and that of FMC, this indicated that Pb accumulated in shoots more than in roots.

Conclusion

It can be concluded that at addition of filter mud cake (FMC) to sand soil, carrot and sugar beet plants accumulate higher contents of mineral (K, Ca, S and P) especially in roots. Moreover, roots of investigated plants had less amounts of heavy metal than shoots. So, addition of FMC increased value of yield of carrot and sugar beet plants.

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(*Received* 15/8/2018;
accepted 11/10/2018)

تراكم وتوزيع المعادن الغذائية و الثقيلة في نباتات الجزر و البنجر النامية على تربة مسمدة بحمأة مصانع قصب السكر

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تم استخدام طينة المرشحات (الحمأة) التي تم جمعها من مصنع سكر قوص بقنا في مصر في تجربة الأصص لدراسة امتصاص وتوزيع بعض العناصر الغذائية وبعض المعادن الثقيلة في الأجزاء المختلفة لكل من نباتي الجزر الأصفر وبنجر السكر. تم خلط طينة المرشحات مع الرمل على ثلاثة مستويات: 10% ، 30% و 50% والرمل كان يستخدم (بدون طينة مرشحات) ككنترول. أظهرت النتائج أن تسميد التربة الرملية بطينة المرشحات أدى إلى زيادة محتوي البوتاسيوم و الكالسيوم في كلا النباتين المختبريين. علاوة على ذلك، كان محتوى المغنيسيوم غير منتظم السلوك من حيث الإنخفاض أو الزيادة. أظهر محتوى الصوديوم انخفاضًا ملحوظًا في نباتات الجزر و بنجر السكر على النقيض من البوتاسيوم و الكالسيوم. تراكم معظم الصوديوم في المجموع الجذري بينما تم نقل البوتاسيوم إلى المجموع الخضري في النباتين. أشارت النتائج أيضا إلى أن نسبة الصوديوم/ البوتاسيوم كانت أعلى في جذور النباتات منها في المجموع الخضري. أظهرت النتائج أيضا أن طينة المرشحات حفزت تراكم محتوي الكلوريدات و الفوسفات و الكبريتات في كلا النباتين المختبرين بالمقارنة مع الكنترول. كما يوجد إختلافات معنوية في إنتقال المغنيسيوم و الكالسيوم و الكلور و الكبريتات و الفوسفات من المجموع الجذري تجاه المجموع الخضري. وعموما أدى تسميد التربة الرملية بطينة المرشحات إلى تراكم الزنك و النحاس و الرصاص و الكادميوم في نباتات الجزر و بنجر السكر بالمقارنة بالكنترول. أظهر تحليل معامل الأرتباط بين محتويات المعادن الثقيلة في كل من أعضاء النباتين المختبرين و التربة المسمدة بطينة المرشحات علاقات مختلفة.