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Assessment of The Compost Addition and Sandification to Overcome the Calcium Carbonate Problems in Heavy Clay Calcareous Soils at El-Farafra Oasis – Egypt

Sally A. Yassin*, Salah Y. Awadalla*, El-Sayed M. El-Hadidi, Mahmoud M. Ibrahim*** and Ahmed A. Taha****

**Soil Physics and Chemistry Department, Water Resources and Desert Soils Division, Desert Research Center (DRC), Cairo, Egypt.*

*** Soils Department, Faculty of Agriculture, Mansoura University, Egypt.*

**** Soil and Water Department, Faculty of Agriculture, Tanta University, Egypt.*

THE AIM of the present study was to evaluate the effects of sandification and composted manure on some selected chemical properties; SOM, $CaCO_3$, EC, Soluble Calcium and pH, as well as the pore size distribution of heavy clay calcareous soil. The experiment included four levels of sand addition and three levels of compost in a split plot design with three replicates. The experiment was carried out in an agricultural bilateral cycle that included wheat and maize crop cultivation in the winter and summer seasons, respectively. The results showed that sandification increased the sand fraction slightly and led to a slight decrease in the clay fraction at the end of the wheat season. This was more pronounced in the 1st soil layer than in the 2nd and the 3rd subsurface layers. The residual effects of compost (after harvesting the maize crop) had no obvious effect on the soil particle size distribution. Increasing rates of sandification and compost additions led to a decrease in the soil content of $CaCO_3$% compared to the initial soil, pH values, and soil salinity, while the SOM% and soluble Ca ions increased. The best results were obtained under the highest rates of sandification (S_{15}) and compost addition (C_2). It could be summarized that the role of both sandification and compost additions has affected $CaCO_3$. This relation increases the release of calcium ions (Ca^{+2}) to soil solutions, so that buffering the pH values declines towards neutrality. The relatively high salinity of compost affected positively the calcium carbonate solubility.

Keywords: Sandification – Compost – Heavy clay soil – $CaCO_3$ – Buffering - El-Farafra Oasis.

1. Introduction

The cultivation of newly reclaimed calcareous soils has become an unavoidable necessity for increasing our agricultural production to meet the over-growing demand for food. Desert covers about 96% of the total area of Egypt; most of which are scattered in the eastern and western banks of the Nile Valley and Delta. Conversion of desert lands to agriculturally productive ones take the first priority of the government vision. Occurrence of calcareous soils are wide in the desert areas of Egypt. Most of newly reclaimed calcareous soils are mainly located in the Western Desert. Calcareous soils are those with high content of $CaCO_3$, especially the active fraction with high specific surface area causing some physical problems that affect water use and crop production in these soils (Imas 2000; Abou Hussien et al. 2019). Under such severe conditions, it is difficult to attain desired yield levels. However, economic yields can be attained through adoption of proper soil management practices (Abou Hussien et al. 2019). So, management of calcareous soil is essential to increase crop production and preserve the ecological environment in arid and semiarid regions (El-Zemrany *et al.* 2016; Abou Hussien *et al.* 2019; Ganzour *et al.* 2020 and Nada *et al.* 2023) So, management of calcareous soils are very important for development of soil fertility and crop productivity. Compost is the end product of the semi aerobic – aerobic microbial decomposition of organic matter, such as animal manures, plant residual and domestic wastes, under controlled conditions (Sullivan and Miller 2001). Land application of composted manures can be expressed as one of the most economical and attractive methods to solve two problems: waste disposal and the necessity to increase the organic matter content of soil (Bernal et al. 2008). Composts have been shown to enhance soil

*Corresponding author e-mail: syaw2411@hotmail.com
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fertility and quality and to improve crop productivity (Al-Turki 2010).

Many studies have shown that composts can improve soil quality by enhancing nutrients, organic matter, water holding capacity, soil aeration and cation exchange capacity (Al-Turki 2010). Application of composts decreased soil pH, EC and CaCO3, while soil CEC, OM and available macro- (N, P, K, S, Ca and Mg) and micronutrients increased (Amer and Hesham 2018; Abou Hussien et al. 2019). However, application of composts with high EC may result in increasing soil EC (Eu 2006). The addition of organic amendments such as compost could be the best solution for the problems of soil. These amendments could be improving the soil chemical properties. Increasing rates of added compost resulted in decreasing the soil pH, soluble Na^+ and Cl^-, whereas, these led to an increase in EC. In general, compost application improved the chemical properties of the studied soil (Radwan et al. 2019). Compost contains many plants essential nutrients (e.g., N, P, and K) and can also be a source of organic matter. Reducing soluble salts, specifically Na and Cl in composts is of high importance. Other soluble salts present in compost (e.g., K and Ca) are mineral nutrients required for plant growth and can aid in reducing soil sodicity, (Gondek et al. 2020).

On other hand, the heavy clay soil is pack tightly and make difficult for water and nutrient to move and can block the growth of plant roots. So, clayey soils required to improve to overcome these problems. One of clayey soil improvement is to add sand, (sandification), or other similar material in order to improve the properties of clay. It is commonly known that sand is a non-expansive soil with a low plasticity and no surface charge (Kolay and Ramesh 2015 and Amri et al. 2019). Thus, many studies investigated the effect of sand additions and showed that the use of sand gave satisfactory results in improving the physical and mechanical properties of the clayey soils (Salman and Wale 2018; Amri, et al. 2019; Al-Badran 2020). According to (Muzan 2021) the best way to improve the properties of clay is mixing the sand into heavy clay soils to alleviate their restrictions. Goufi et al. (2022) pointed out that the clay soil with different percentage of sand particles occurred changes in the hydrological properties of the soil. The sand can improve the geotechnical properties of the expansive clayey soil by reducing their plasticity and due to the change on the soil structure and the particles rearrangement.

Therefore, the objective of this study was to evaluate the effects of sandification and composted manure applications on some selected chemical properties; $CaCO_3$, EC, OM, Soluble Ca^{+2} ions and pH, as well as, on the particles size distribution of a heavy clay calcareous soil, (> 60% clay), in order to overcome the problems of the $CaCO_3$. To achieve this objective, the study was conducted in an agricultural bilateral cycle included wheat and maize crops cultivation as a winter and summer season, respectively, at El-Farafra Oasis in Egypt.

2. Materials and methods

2.1. Location of the study and soil properties

The experiment was carried out in the Agricultural Experimental Station of the Desert Research Centre at Al-lewaa Subeih Village in El-Farafra Oasis. It is location is 27º 53` 4``E and 27º 3` 40``N. El-Farafra Oasis is a natural depression located in the western desert of Egypt. The whole area is under hyper arid zone. It is the most isolated depression in the western desert. It includes Abu Monquar depression which lies in the center of western desert, 300 Km west of Assiut in the midway between El- Bahariya and El-Dakhla Oases at **Fig. (1).** It excavated in the limestone plateau occupying the core region of Western Egypt (Elsheikh 2015). This natural depression has a total area of ~10,000 km^2 as referred to (Saber et al. 2017). It is bounded by a northern and western escarpment rising abruptly to 200- 230 m above sea level while to the east and south its floor rises gradually to 250-350 m above sea level. The floor of the depression is situated at a ground elevation varying from 60 m to 115 m and averaging 94 m above sea level, thus being similar to the average ground elevation of the classic El-Farafra and El-Dakhla depressions (Ouda 2012).

The soil of the experimental site is a calcareous soil, heavy clay in texture according to FAO (2006), more than 60% heavy clay content. The soil of experimental site is different in its geological formation compared to Nile Delta soil according to Said (2017). The soil physical and chemical properties before conducting the experiment are shown in **Table (1).**

2.2. The experimental layout and treatments

The field experiment was arranged in split plot design with three replicates. The main plot was assigned as sand application treatments, while the sup plot treatment was the compost additions. Each plot was 3×4 m (12m^2). The treatments were as follow: -

The main treatments were four percentages of sand addition per plot; S_0 (0% as 0 kg sand), the control treatment – S_5 (5% as 142.90 kg sand) – S_{10} (10% as 285.72 kg sand) and S_{15} (15% as 428.6 kg sand). The sup blot treatments were three compost rates per plot; C_0 (0% as 0 kg compost), C_1 (1% as 28.58 kg compost) and C_2 (2% as 57.2 kg compost). The used sand for sandification was obtained from sand dunes El-Farafra oasis extension (yellow sand). Similar to Abou Hussien et al. (2019), the used compost in this study was produced from rice straw and animal wastes enriched with mineral fertilizers. Basic chemical analyses of the applied sand and compost are presented in **Table (2).**

Fig. (1) Location map of the studied area

The adopted rate of sand was added by loader machine and compost was added by weighed bags. They are mixed into the soil by plow machine at 15 cm, which makes the addition homogeneous.

The experiment was conducted in an agricultural bilateral cycle included wheat and maize crops cultivation as a winter and summer season, respectively. Wheat (*Tritcum aestivum*) variety Sids 14 as winter crop and maize (*Zea Mays*) as summer crop were sown in agricultural cycle. All the usual agricultural operations of wheat and maize plants were practiced as recommended in the study area. The irrigation water of the studied area was underground water (artesian well water). Wheat was planted on November 23, 2019, and maize on May 26, 2020. Wheat was harvested after 153 days on April 24, 2020, while maize was harvested after 110 days, on September 13, 2020. At the end of wheat and maize harvesting, disturbed soil samples were taken at a depth of 0 – 20, 20 – 40, and 40 – 60 cm from each plot and analyzed for the selected soil properties. Water samples representing the irrigation water of the studied area were collected for determining its chemical properties The chemical properties of the used irrigation water are listed in **Table (3).**

2.3. Soil and water analysis

The particle size distribution of the soil samples was described according to the pipette method by Soil Survey Staff (2014). The bulk density of the soil and compost were determined using undisturbed samples according to Soil Survey Staff (2014).

The chemical analysis was carried out for soil and sand application in soil paste but for the compost in 1:10 extract, and for the irrigation water according to the Soil Survey Staff (2014). The initial soil, sand, compost and irrigation water characters are listed as following in **Tables (2 and 3)**.

Soil organic matter was determined by Walkely and Black as mentioned by Pansu and Gautheyrou (2006). Soil Calcium Carbonate was determined as mention by Scrimgeour (2007).

2.4. Statistical analysis

Data were statically analysed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (L.S.D) at the 5% level, respectively by using computer program of Statistix version 9.

3. Results and discussions

3.1. Effect of sandification and compost applications on the soil particle size distribution

The main philosophy of sandification technique in this study is to add the sand as an inert solid natural material to the heavy textured soil to increase the air and water penetrability. So that to detect the accuracy of addition technique in the field, soil mechanical analysis has been carried out at the end of 1st wheat cultivation season (experiment season) and at the end of next maize summer season to estimate the durability of technique. **Tables (4 and 5)** illustrate the particle size distribution data for both seasons and take the total sand and clay values as indicator to the applied treatments, i.e., composting and sandification as well. The presented results in these Tables showed the following: -

1- The sandification is the main factor that affected the particle size distribution values. The percentage of total sand reached to 10.4% with the second sand addition rate (S_5), reached to 13.5% with the third sand addition rate (S_{10}) and reached comparing with the treatment of S_0, in 0 – 20 cm.

Table 1. Physical and chemical properties (mean values) of the experimental site.

	depth	Total Sand	Silt	Clay	Texture class.	ρ_b (Mg/m^3)	pH	EC (dS/m)	Ca^{+2} (meq/L)	SOM %	$CaCO_3$ %
Initial soil	0-20	6.60	31.12	62.29	HC	1.285	7.75	5.50	15.73	1.516	24.68
	20-40	5.39	30.18	64.43	HC	1.330	7.78	6.66	20.49	0.690	28.56
	40-60	2.25	33.01	64.74	HC	1.514	8.00	7.25	21.06	0.563	34.03

*(HC) Heavy clay texture.

Table 2. Some chemical properties of the applied sand and compost.

Sand			
Total sand, %	94.08	Silt, %	3.82
Clay, %	2.10	Texture class.	Sand
pH (soil paste)	7.15	Bulk density, Mg/m^3	1.72
EC, dS/m (soil paste)	1.51	Calcium carbonate %	7.02
Ca, (cmolc kg^{-1} soil)	5.13	Organic matter, %	0.19
Compost			
pH (1:10 compost: water)	7.55	Bulk density, Mg/m^3	0.60
EC, dS/m (1:10 compost: water)	12.55	Calcium carbonate %	16.44
Soluble Ca, (cmolc kg^{-1} soil)	25.00	Organic matter, %	57.73

Table 3. Chemical properties of the well irrigation water in the studied area.

Sample	pH	EC	Soluble Cations (meq/L)				Soluble Anions (meq/L)				SAR%
		dS/m	Na^{+1}	K^{+1}	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}	
Well Water*	5.51	0.332	1.15	0.52	1.00	0.65	0.00	0.34	2.40	0.62	1.27
Well Water**	5.48	0.453	1.55	0.78	1.35	0.85	0.00	0.81	2.97	0.81	1.48

***Well water during wheat season** ****Well water during maize season**

depth, in the first season.

2- At the first depth, the clay was 62% in the initial soil and changed to 59, 56 and 54% with the rates of sandification. While the ratio of clay in the second depth was 64% and became 59% with the fourth addition rate of sand.
3- The third depth has not changed compared with the initial soil.
4- There is almost negligible effect of compost in this concern. The role of compost addition can only improve soil quality by enhancing nutrients, organic matter, water holding capacity, soil aeration and cation exchange capacity (Al-Turki 2010).
5- From the studied 36 treatments, 10 ones changed from heavy clay texture (> 60% clay) to clay texture (< 60% clay) according to FAO, (2006) who mentioned that heavy clay texture is the soil having (> 60% clay).
6- Regarding the next season (after maize harvesting) for the residual effect of sandification, there were no great differences in total sand values which insist the main target of study to make durable change in such heavy textured soils which could extend to several seasons.
7- From the 36 studied treatments only 4 ones settled to clay texture (<60% clay) while the rest remain heavy clay as initial state.

These obtained results are in the same trend of that of Muzan, (2021) showed that the percentage of particles of clay, silt, and sand of the clay soil changed from mixing sand with soil in different proportions producing different curves for particle size distribution. Therefore, other textural classes can be obtained by adding sand to clay soil with 10, 20, 30, 40% sand to the clay soil. Increasing the ratio of sand mixed with the clay soil is a good indicator of the enhancement of the porous media and water environment of soils that have high clay content, which allows the use of sand covering large areas of the desert to improve the properties of clayey soil and increase its ability to deliver water conductivity. This help in controlling soil waterlogging, as well as the possibility of leaching the accumulated salts to improve the media of porous soil without expensive field-drainage systems. In the same context, also, Goufi et al. (2022) showed that adding fine sand to the clay soil changed the soil structure and the rearrangement of the particles, which led to improve the geotechnical properties of the soil by reducing its plasticity.

Table 4. Effect of sandification and compost applications on the soil particle size distribution after wheat season.

Treatments	depth	C_0				C_1				C_2			
		T. Sand	Silt	Clay	Texture class.	T. Sand	Silt	Clay	Texture class.	T. Sand	Silt	Clay	Texture class.
S_0	0-20	6.85^{E}	30.43^{EFGH}	62.72^{GHIJ}	HC	6.71^{E}	31.42^{CD}	61.87^{K}	HC	6.30^{F}	31.77^{C}	61.93^{JK}	HC
	20-40	6.29^{F}	30.22^{FGHI}	63.49^{CDEF}	HC	5.81^{G}	31.28^{CD}	62.91^{EFGHI}	HC	5.85^{G}	30.85^{DEF}	63.30^{DEFG}	HC
	40-60	2.49^{I}	32.60^{B}	64.91^{A}	HC	2.44^{I}	33.43^{AB}	64.13^{ABCD}	HC	2.21^{I}	33.35^{AB}	64.44^{AB}	HC
S_5	0-20	10.47^{C}	29.86^{GHI}	59.67^{L}	C	10.50^{C}	30.15^{FGHI}	59.35^{L}	C	10.32^{C}	29.59^{IJ}	60.09^{L}	HC
	20-40	6.09^{FG}	30.79^{DEF}	63.12^{EFGH}	HC	6.03^{FG}	31.13^{CDE}	62.84^{FGHI}	HC	6.19^{F}	30.83^{DEF}	62.98^{EFGHI}	HC
	40-60	2.51^{I}	33.38^{AB}	64.11^{ABCD}	HC	2.52^{I}	33.34^{AB}	64.14^{ABC}	HC	2.52^{I}	33.79^{A}	63.69^{BCDE}	HC
S_{10}	0-20	13.46^{B}	30.07^{FGHI}	56.47^{M}	C	13.59^{B}	30.14^{FGHI}	56.27^{M}	C	13.57^{B}	29.81^{HIJ}	56.62^{M}	C
	20-40	6.97^{E}	30.66^{DEFG}	62.37^{HIJK}	HC	6.84^{E}	30.68^{DEF}	62.48^{HIJK}	HC	6.92^{E}	30.82^{DEF}	62.26^{IJK}	HC
	40-60	3.17^{H}	33.29^{AB}	63.54^{CDEF}	HC	3.22^{H}	33.22^{AB}	63.56^{CDEF}	HC	3.18^{H}	33.28^{AB}	63.54^{CDEF}	HC
S_{15}	0-20	16.46^{A}	29.06^{J}	54.48^{N}	C	16.46^{A}	29.42^{IJ}	54.12^{NO}	C	16.61^{A}	29.75^{HIJ}	53.64^{O}	C
	20-40	8.58^{D}	31.32^{CD}	60.10^{L}	HC	8.62^{D}	31.43^{CD}	59.95^{L}	C	8.58^{D}	31.73^{C}	59.69^{L}	C
	40-60	3.36^{H}	33.27^{AB}	63.37^{CDEFG}	HC	3.22^{H}	33.69^{A}	63.09^{EFGH}	HC	3.22^{H}	33.42^{AB}	63.36^{CDEFG}	HC
LSD at 0.05		**T. Sand**		**0.32**			**Silt**	**0.80**			**Clay**	**0.80**	

*Clay texture (C) (< 60% clay content) and Heavy clay texture (HC) (>60% clay content).

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

Table 5. Effect of sandification and compost applications on the soil particle size distribution after maize season.

Treatments	depth	C_0				C_1				C_2			
		T. Sand	Silt	Clay	Texture class.	T. Sand	Silt	Clay	Texture class.	T. Sand	Silt	Clay	Texture class.
S_0	0-20	6.84^{F}	30.06^{JKL}	63.10^{DE}	HC	6.46^{G}	31.05^{HIJ}	62.49^{FG}	HC	6.32^{G}	31.57^{FGHI}	62.11^{GHI}	HC
	20-40	5.96^{H}	29.48^{KL}	64.56^{B}	HC	5.21^{I}	31.20^{GHI}	63.59^{C}	HC	5.79^{H}	30.47^{IJK}	63.74^{C}	HC
	40-60	1.80^{N}	32.57^{DEF}	65.63^{A}	HC	2.04^{N}	33.18^{BCDE}	64.78^{B}	HC	2.12^{N}	32.97^{CDE}	64.91^{B}	HC
S_5	0-20	9.29^{D}	29.00^{LM}	61.71^{HIJ}	HC	9.24^{D}	29.20^{L}	61.56^{JK}	HC	9.35^{D}	28.07^{M}	62.58^{FG}	HC
	20-40	7.02^{F}	31.59^{FGH}	61.39^{JK}	HC	7.07^{F}	32.17^{EFG}	60.76^{LM}	HC	7.08^{F}	32.11^{EFGH}	60.81^{LM}	HC
	40-60	2.67^{M}	33.82^{ABC}	63.51^{CD}	HC	2.68^{M}	33.65^{ABCD}	63.67^{C}	HC	2.64^{M}	34.39^{A}	62.97^{EF}	HC
S_{10}	0-20	12.08^{B}	26.38^{NO}	61.54^{JK}	HC	12.04^{B}	26.84^{N}	61.12^{KL}	HC	12.15^{B}	26.46^{NO}	61.39^{JK}	HC
	20-40	7.88^{E}	31.57^{FGHI}	60.55^{MN}	HC	7.99^{E}	31.55^{FGHI}	60.46^{MN}	HC	7.84^{E}	31.49^{FGHI}	60.67^{LMN}	HC
	40-60	3.33^{L}	33.69^{ABC}	62.98^{EF}	HC	3.42^{KL}	33.99^{ABC}	62.59^{EFG}	HC	3.32^{L}	34.26^{AB}	62.42^{G}	HC
S_{15}	0-20	13.77^{A}	25.63^{O}	60.60^{MN}	HC	13.48^{A}	26.34^{NO}	60.18^{NO}	HC	13.73^{A}	26.52^{NO}	59.75^{O}	C
	20-40	11.27^{C}	32.39^{EF}	56.34^{P}	C	11.10^{C}	33.06^{CDE}	55.84^{Q}	C	10.97^{C}	33.02^{CDE}	56.01^{PQ}	C
	40-60	3.69^{JK}	34.56^{A}	61.75^{HIJ}	HC	3.92^{J}	34.44^{A}	61.64^{IJ}	HC	3.89^{J}	33.98^{ABC}	62.13^{GH}	HC
LSD at 0.05		**T. Sand**		**0.35**			**Silt**	**1.10**			**Clay**	**0.52**	

*Clay texture (C) (< 60% clay content) and Heavy clay texture (HC) (>60% clay content).

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

3.2. Effect of sandification and compost applications on the studied chemical properties

3.2.1. The soil Organic Matter (SOM%)

The goal of adding the compost is to enhance soil fertility and quality and to improve crop productivity (Al-Turki 2010). As shown in **Table (6),** the SOM% decreased significantly with increasing sandification rates and significantly increased with increasing the addition rates of the compost, either after wheat or maize harvesting. The obtained data indicated the following trends: -

1- All SOM% decreased with soil depth as most of the organic manure (the used compost) was added to the soil surface with plowing, which could be caused high aeration according to (Al-Turki 2010) and improved soil physical properties as mentioned by Helmi (2018), so more organic decomposition.

2- By sandification under any composting level, the SOM% decreased greatly by sand addition up to 50% with the treatment of S_{15}.

3- Upon compost additions, SOM% going to decrease gradually proportional to sand rates, so that the highest composting level of C_2S_{15} is accompanied by the highest SOM% values which indicate overcoming effect of compost more than that of sand.

3.2.2. Calcium Carbonate

The presented data in **Table (6)** indicate that $CaCO_3$% increased with increasing the sandification levels. While it decreased with increasing rates of compost additions, after wheat harvesting. The noticed trends of these data can be listed as follows:

1- All $CaCO_3$% values increased gradually by sand additions due to the initial calcium carbonate content in the sand (5%) at **Table (2)** for all compost treatments.

2- By compost additions, all $CaCO_3$% values, decreased in sensible amounts, even with high sand rates (S_{15}). This could be attributed to the compost decomposition that releases many organic acids, like humic and fulvic acids, which could dissolve $CaCO_3$.This action coincides with roots and microbial excretion through growth season which enhancing the removable of $CaCO_3$.

3- As shown in **Fig. (2)**, there is a strongly high inverse correlation between the SOM% and $CaCO_3$%. The regression equations are

$CaCO_3$% = 35.281 – 5.0238 SOM% at 1st depth
$R^2 = 0.7096$

$CaCO_3$% = 38.471 – 13.134 SOM% at 2nd depth
$R^2 = 0.8024$

This means that every increase unit in SOM%, by the compost, may remove about 5% of $CaCO_3$ in first depth and remove about 13% of $CaCO_3$ in second depth. The percentage effect (R^2) of the independent SOM values on changing $CaCO_3$ was 0.71% at 0 – 20 cm depth and 0.80% at the 20 – 40 cm depth. There is no significant correlation (r = 0.288) at the depth of 40 – 60 cm. These results prove the essential role of the compost additions in cultivating calcareous soils. These obtained results are similar to those found by Abou Hussien et al. (2020).

The obtained data of SOM% and $CaCO_3$% at the end of the second season (after maize harvesting) are presented in **Table (7).** These data represent the residual effect of each treatment had been applied in the 1st winter season. The obtained results revealed the following: -

1- Similar trends for SOM% and $CaCO_3$% with the applied treatments by sand and compost levels, as shown in the first season after wheat harvesting.

2- A similar high correlation coefficient (r) has been found between SOM% and CaCO3% as being (0.832**) at the depth of 0 – 20 cm and (0.929**) for the depth 20 – 40 cm as shown in **Table (11)** and **Fig. (2)**. The regression equations are

$CaCO_3$% = 34.55 – 5.0022 SOM% at 1st depth
$R^2 = 0.6915$

$CaCO_3$% = 36.402 – 13.456 SOM% at 2nd depth
$R^2 = 0.863$

These results mean that every unit of SOM addition, at the surface soil layer will remove ~ 5% $CaCO_3$%. Meanwhile at the soil depth 20 – 40 cm, more dissolving $CaCO_3$ by the SOM effect, reached about 13% $CaCO_3$ for each unit of SOM. The 3rd depth (40 – 60 cm) show also highly significant correlation as by each unit of SOM the $CaCO_3$ decreased by 10%. These results may be rendered to the effect of watering cycles and root penetration in these depths which enhance the reaction between SOM and $CaCO_3$%. In addition, this result insists the residual effect of SOM% on removing $CaCO_3$ with appreciable amounts which could be reflected on crop yield.

3.2.3. Electrical conductivity (EC), pH and soluble Ca ions

Electric conductivity of soil is one of the most important factors to the productivity of any crop as crops categorized to sensitive, moderate and tolerant to salinity (Corwin 2003). The presented data in **Tables (8 and 9)** illustrate the effects of sand and compost application treatments on soil pH, EC and soluble Ca^{+2} after wheat and maize seasons, respectively**.** These results revealed the following: -

- ***Soil salinity (EC):***

1- The soil salinity (EC) increased with increasing rates of the compost applications. This could be referred to the high nutrient content of compost, as the compost preparation involved mineral fertilizers addition, according to Abou Hussien et al. (2019) and Gondek et al. (2020). This obtained results are in accordance with those of Eu (2006); Al-Turki et al. (2013); Radwan et al. 2019).

2- Compost has a positive effect on the final EC of soil for the three depths over all treatments with gradual percentages ranged from 40% to 20% for 0 – 20 cm and 40 – 60 cm depths, respectively. This could be attributed to the high salinity of the compost as shown **Table (2)**. A high positive correlation has been found between EC values and the SOM% as shown in **Table (10)**. In this concern, the organic matter has a buffering action with soil salinity through its high cation exchangeable capacity, so it can play a controlling role for the salt sensitivity of plant under organic farming systems (Awadalla et al. 2002).

3- Sandification has buffering action as it decreases the EC values generally in the three depths.

Table 6. Effect of sandification and compost addition on the soil organic matter (SOM) and calcium carbonate $CaCO_3$ after wheat season.

Treatments	Depth	C_0		C_1		C_2		Mean	
		SOM	$CaCO_3$	SOM	$CaCO_3$	SOM	$CaCO_3$	SOM	$CaCO_3$
S_0	0-20	1.497^{F}	24.65^{NO}	1.794^{E}	23.25^{P}	2.677^{A}	21.22^{Q}	**1.989**	**23.04**
	20-40	0.782^{KL}	28.52^{I}	0.815^{JKL}	26.68^{K}	1.094^{H}	24.09^{O}	**0.897**	**26.43**
	40-60	0.529^{QR}	34.22^{B}	0.567^{PQ}	33.38^{C}	0.572^{PQ}	32.66^{DE}	**0.556**	**33.42**
S_5	0-20	1.179^{G}	28.41^{I}	1.502^{F}	25.76^{L}	2.490^{B}	22.95^{P}	**1.724**	**25.71**
	20-40	0.700^{MN}	29.38^{H}	0.818^{JK}	27.73^{J}	1.079^{H}	24.96^{MN}	**0.866**	**27.36**
	40-60	0.541^{PQR}	34.5^{B}	0.670^{NO}	33.56^{C}	0.553^{PQR}	32.32^{E}	**0.588**	**33.46**
S_{10}	0-20	0.850^{IJK}	31.57^{F}	1.243^{G}	29.84^{GH}	2.140^{C}	27.27^{JK}	**1.411**	**29.56**
	20-40	0.647^{NO}	30.49^{G}	0.855^{IJ}	28.48^{I}	0.872^{IJ}	25.84^{L}	**0.791**	**28.27**
	40-60	0.510^{QR}	34.59^{B}	0.534^{QR}	34.6^{B}	0.688^{MN}	32.97^{CD}	**0.577**	**34.05**
S_{15}	0-20	0.613^{OP}	33.48^{C}	0.913^{I}	31.36^{F}	1.884^{D}	29.27^{H}	**1.136**	**31.37**
	20-40	0.558^{PQR}	31.5^{F}	0.744^{LM}	29.46^{H}	0.872^{IJ}	25.33^{LM}	**0.724**	**28.76**
	40-60	0.492^{R}	35.56^{A}	0.744^{LM}	34.37^{B}	0.654^{NO}	33.59^{C}	**0.630**	**34.51**
Mean	**0-20**	**1.035**	**29.53**	**1.363**	**27.55**	**2.298**	**25.18**		
	20-40	**0.672**	**29.97**	**0.808**	**28.09**	**0.979**	**25.06**		
	40-60	**0.518**	**34.72**	**0.629**	**33.98**	**0.617**	**32.89**		
LSD at 0.05		SOM		0.07		$CaCO_3$	0.62		

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

Table 7. Effect of sandification and compost addition on the soil organic matter (SOM) and calcium carbonate $CaCO_3$ after maize season.

Treatments	depth	C_0		C_1		C_2		Mean	
		SOM	$CaCO_3$	SOM	$CaCO_3$	SOM	$CaCO_3$	SOM	$CaCO_3$
S_0	0-20	1.284^{H}	25.89^{K}	1.738^{E}	22.72^{N}	2.641^{A}	19.84^{O}	**1.888**	**22.82**
	20-40	0.608^{RST}	27.46^{I}	0.815^{L}	24.98^{L}	1.056^{J}	22.65^{N}	**0.826**	**25.03**
	40-60	0.513^{VW}	33.34^{C}	0.629^{QRS}	32.62^{D}	0.735^{MN}	31.26^{E}	**0.626**	**32.41**
S_5	0-20	1.158^{I}	27.58^{I}	1.586^{F}	25.07^{L}	2.417^{B}	22.42^{N}	**1.720**	**25.02**
	20-40	0.547^{UV}	29.16^{G}	0.707^{NO}	26.24^{JK}	0.910^{K}	24.2^{M}	**0.721**	**26.53**
	40-60	0.561^{TUV}	33.67^{BC}	0.651^{OPQR}	32.27^{D}	0.726^{N}	31.63^{E}	**0.646**	**32.52**
S_{10}	0-20	1.080^{J}	30.2^{F}	1.421^{G}	27.54^{I}	2.315^{C}	24.81^{L}	**1.605**	**27.52**
	20-40	0.540^{UVW}	30.64^{F}	0.685^{NOPQ}	28.18^{H}	0.827^{L}	25.02^{L}	**0.684**	**27.95**
	40-60	0.514^{VW}	34.43^{A}	0.589^{STU}	33.39^{C}	0.702^{NO}	32.42^{D}	**0.602**	**33.41**
S_{15}	0-20	0.787^{LM}	32.7^{D}	1.170^{I}	29.59^{G}	2.163^{D}	27.4^{I}	**1.374**	**29.90**
	20-40	0.439^{X}	31.24^{E}	0.583^{STU}	28.2^{H}	0.640^{PQRS}	26.4^{J}	**0.554**	**28.61**
	40-60	0.483^{WX}	34.52^{A}	0.589^{STU}	34.02^{AB}	0.690^{NOP}	32.73^{D}	**0.587**	**33.76**
Mean	**0-20**	**1.077**	**29.09**	**1.479**	**26.23**	**2.384**	**23.62**		
	20-40	**0.533**	**29.63**	**0.697**	**26.90**	**0.859**	**24.57**		
	40-60	**0.518**	**33.99**	**0.615**	**33.08**	**0.713**	**32.01**		
LSD at 0.05		SOM		0.059		$CaCO_3$	0.49		

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

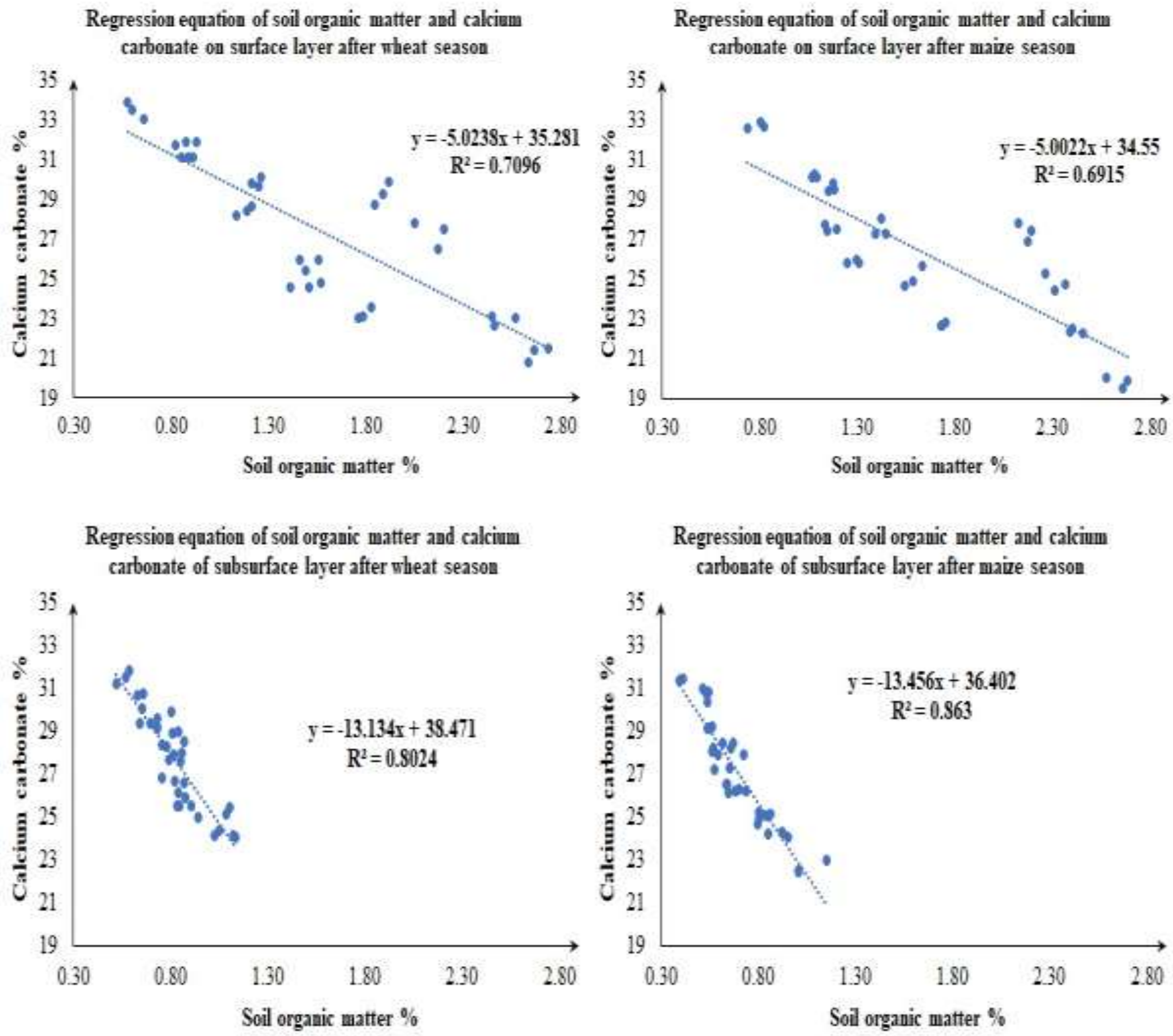

Fig. 2. Correlations between calcium carbonate content and the soil organic matter as affected by different treatments of sand and compost applications in surface and subsurface layers after wheat and maize seasons.

4- Salinity as EC increased with soil depth indicating active water movement. This may be due to the combined effect of compost and sandification in enhancing the water movement into the soil.

5- The obtained data at the end of the summer season (after maize harvesting) confirmed the residual effect of the applied treatments; i.e., compost and sandification, on EC values with the same trends as previously discussed.

6- As shown in **Table (10)** a negative relationship between calcium carbonate and EC values in first and second seasons which mean more release of Ca^{+2} ions in soil by increasing SOM%, as previously discussed.

- ***Soluble calcium ion (Ca^{+2})***

The tabulated results in **Tables (8 and 9)** showed the following:

1- Soil calcium ions content increases with the addition of compost and increases in the lower soil depths. This increase may be due to the availability of the main cations, especially calcium, which leads to the soil's pH increase, consequently providing the correct environment for nutrient release that increase productivity (Rastijia et al. 2012; Kovačević et al. 2010).

2- Increasing SOM% by compost coordinated with gradual increase in soluble Ca^{+2} in all depths even deep one (40 – 60 cm) **Tables (8 and 9)** by rates up to 40% which indicate leaching of dissolved $CaCO_3$ with irrigation to reach the deeper depths by rate of 29%.

3- Sandification has an opposite direction as by increasing sand amounts the soluble Ca^{+2} decreased in the upper depths but constant in other depths.

4- Values of Ca^{+2} had positive significant relationship with SOM and with EC, but negative one with calcium carbonate and with pH values in first and second seasons as shown in Table (10), in the first and second seasons. The negative correlation between SOM% and $CaCO_3$% means more release of Ca^{+2} ions in soil by increasing the compost rates. The same trend was found in the second summer corn season showing stability of applied treatments of compost and sandification. Furthermore, there is slight increase in the deeper depth than 1st season which mean more solution of $CaCO_3$% in 2nd season than occurred in 1st one. However, the release of Ca^{+2} ions may be more than needed, so that make the problems of phosphorus and iron deficiency due to competition on exchangeable sites. One of the solutions to these problems is the organic additions as to make some calcium organic compounds which are not competitive with P (Jokubauskaite et al. 2015). The ionic balance of soil is essential for cell growth (Laekemariam and Gidago 2012; Ilyas et al. 2014) and healthy plant growth especially in calcareous soils like the experimental site because of the accordance of appreciable amount of $CaCO_3$ as stated by El-Ramady (2014).

- ***The soil pH***

The soil reaction (pH) is one of the important characters that controlled its suitability to cultivate different crops. Organic matter plays a buffering role in soil as it has both positive and negative charges in its formation. From the presented data in **Tables (8 and 9)**, it can be concluded to the following:

1- The whole soil pH values are above 7. It ranged between 7.19 and 7.99 due to the calcareous nature of original soil (about 25% $CaCO_3$).
2- The increasing rates of added compost resulted in decreasing the soil pH values. These results are in the same line of similar results obtained by (Mohamed et al. 2008; Radwan et al. 2019; Mahmoud et al. 2020)
3- The increasing of sand additions decreased slightly the pH values.
4- pH values at the end of 1st season ranged between 7.19 and 7.38 as minimum with C_2S_{10} in (0 – 20) and (20 – 40 cm). It ranged between 7.76 and 7.88 as maximum with C_0S_0 in (0 – 20) and (20 – 40 cm). At the end of 2nd season pH values ranged between 7.24 and 7.35 as minimum with C_2S_{10} in (0 – 20) and (20 – 40 cm). It ranged between 7.73 and 7.87 as maximum with C_0S_0 in (0 – 20) and (20 – 40 cm). The values of pH in (40 – 60 cm) ranged from 7.81 to 7.98. This indicates no occurrence of soil alkalinity hazards. As shown in Table (10), in both seasons, the pH values had high negative correlation with soil organic matter. While it had high a positive correlation with calcium carbonate, at the first and second depths, except 0 – 20 cm depth in 1st season there is no correlation between pH and calcium carbonate.

4. Statistical relations among studied characters

The Pearson correlation coefficient revealed both positive and negative coefficients at both $p < 0.01$ or $p < 0.05$ in **(Table 11)**. In the 1st soil layer, a significant positive correlation was observed between SOM and both of EC and Ca^{+2}, with r = 0.938 and 0.938, after wheat season, respectively. The corresponding values after maize season were 0.950 and 0.974 for the same characters, respectively, in the 1st layer. Similarly, in the 2nd layer, significant positive coefficients of r = 0.85, 0.846 were observed between SOM and both EC and Ca^{+2}, respectively, after wheat season. The corresponding values after maize season were 0.869 and 0.855, respectively. In contrast, negative correlation coefficients were observed between SOM and both of $CaCO_3$ and pH, between $CaCO_3$ and both of EC and pH, and between pH and both EC and Ca^{+2} after wheat and maize seasons in the 1st soil layer. The same negative correlation coefficients were also observed in the in the 2nd layer. Notably, a non-significant correlation between $CaCO_3$ and pH with r = 0.17.

5. Conclusion

The purpose of this study was to assess the impact of sandification and composted manure on various chemical properties and pore size distribution of a heavy clay calcareous soil. The experiment was conducted in an agricultural bilateral cycle involving wheat and maize crops during the winter and summer seasons, respectively.

It can be concluded that compost addition played a crucial role in reducing the content of $CaCO_3$% in the soil. Sandification also had a positive effect, facilitating the release of soluble calcium ions into the soil solution, which subsequently lowered the pH toward neutrality. The relatively high salinity of the compost positively affected the solubility of calcium carbonate. The residual effects of sandification and compost application did not change the particle size distribution of the soil after the maize crop harvest. However, increasing rates of sandification and compost addition led to a decrease in the soil's CaCO3% content, pH values, and salinity, while soluble calcium ions increase.

Table 8. Effect of sandification and compost application treatments on soil pH, EC and soluble Ca^{+2}, after wheat season.

Treatments	depth	C_0			C_1			C_2			Mean		
		pH	EC dS/m	Ca^{+2} meq/L	pH	EC dS/m	Ca^{+2}	pH	EC dS/m	Ca^{+2} meq/L	pH	EC dS/m	Ca^{+2} meq/L
	0-20	7.75	5.89^{LMN}	20.55^{c}	7.51	7.12^{IJ}	24.83^{Y}	7.36	8.19^{EFG}	28.52^{Q}	**7.54**	**7.07**	**24.63**
S_0	20-40	7.87	7.42^{HI}	25.60^{V}	7.68	8.60^{DE}	29.97^{N}	7.47	9.70^{B}	33.75^{G}	**7.67**	**8.57**	**29.77**
	40-60	7.95	8.76^{DE}	30.52^{J}	7.91	9.59^{BC}	33.40^{H}	7.82	10.91^{A}	37.95^{B}	**7.89**	**9.75**	**33.96**
	0-20	7.67	5.66^{MN}	19.75^{d}	7.48	6.74^{JK}	23.50^{Z}	7.30	7.86^{FGH}	27.40^{S}	**7.48**	**6.75**	**23.55**
S_5	20-40	7.84	7.63^{GHI}	26.60^{T}	7.65	8.58^{DE}	29.88^{N}	7.42	9.74^{B}	33.91^{F}	**7.64**	**8.65**	**30.13**
	40-60	7.90	8.72^{DE}	30.37^{K}	7.87	9.72^{B}	33.85^{FG}	7.94	10.79^{A}	37.56^{C}	**7.90**	**9.74**	**33.93**
	0-20	7.64	5.45^{N}	19.05^{e}	7.43	6.41^{KL}	22.38^{a}	7.25	7.90^{FGH}	27.54^{R}	**7.44**	**6.59**	**22.99**
S_{10}	20-40	7.81	7.22^{IJ}	25.15^{X}	7.61	8.44^{EF}	29.41^{O}	7.40	9.08^{CD}	31.63^{I}	**7.61**	**8.25**	**28.73**
	40-60	7.91	8.64^{DE}	30.09^{M}	7.86	9.60^{BC}	33.42^{H}	7.92	10.82^{A}	37.66^{C}	**7.90**	**9.69**	**33.72**
	0-20	7.59	5.28^{N}	18.45^{f}	7.40	6.24^{KLM}	21.79^{b}	7.20	7.39^{HI}	25.75^{U}	**7.40**	**6.30**	**22.00**
S_{15}	20-40	7.84	7.29^{HIJ}	25.41^{W}	7.59	8.22^{EFG}	28.65^{P}	7.39	9.86^{B}	34.25^{E}	**7.61**	**8.46**	**29.43**
	40-60	7.97	8.68^{DE}	30.25^{L}	7.88	9.94^{B}	34.59^{D}	7.93	11.00^{A}	38.27^{A}	**7.93**	**9.87**	**34.37**
	0-20	**7.66**	**5.57**	**19.45**	**7.46**	**6.63**	**23.13**	**7.28**	**7.84**	**27.30**			
Mean	**20-40**	**7.84**	**7.39**	**26.92**	**7.63**	**8.46**	**29.48**	**7.42**	**9.60**	**33.38**			
	40-60	**7.93**	**8.70**	**30.31**	**7.88**	**9.71**	**33.82**	**7.90**	**10.88**	**37.86**			
LSD at 0.05			**EC**	**0.62**		**Ca^{+2}**		**0.12**		**pH**		**0.24**	

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

Table 9. Effect of sandification and compost application treatments on soil pH, EC and soluble Ca^{+2}, after maize season.

Treatments	depth	C_0			C_1			C_2			Mean		
		pH	EC dS/m	Ca^{+2} meq/L	pH	EC dS/m	Ca^{+2} meq/L	pH	EC dS/m	Ca^{+2} meq/L	pH	EC dS/m	Ca^{+2} meq/L
	0-20	7.72	7.11^{P}	24.81^{U}	7.54	8.27^{KLM}	28.8^{Q}	7.32	9.24^{FGH}	33.42^{I}	**7.53**	**8.21**	**29.01**
S_0	20-40	7.86	8.29^{KLM}	28.89^{PQ}	7.67	9.35^{FG}	32.54^{J}	7.44	10.45^{B}	37.79^{C}	**7.66**	**9.36**	**33.07**
	40-60	7.92	8.84^{HIJ}	30.79^{M}	7.86	9.91^{CDE}	34.50^{G}	7.89	11.01^{A}	39.83^{B}	**7.89**	**9.92**	**35.04**
	0-20	7.70	6.63^{Q}	23.13^{V}	7.51	7.87^{MNO}	27.41^{S}	7.30	8.84^{HIJ}	31.97^{K}	**7.50**	**7.78**	**27.50**
S_5	20-40	7.81	7.94^{MN}	27.66^{S}	7.63	8.95^{GHI}	31.18^{L}	7.41	10.31^{BC}	37.27^{D}	**7.62**	**9.07**	**32.04**
	40-60	7.95	8.70^{IJK}	30.29^{O}	7.87	9.85^{DE}	34.30^{G}	7.99	11.06^{A}	39.98^{B}	**7.94**	**9.87**	**34.86**
	0-20	7.71	6.21^{QR}	21.68^{W}	7.47	7.44^{OP}	25.94^{T}	7.28	8.42^{JKL}	30.44^{NO}	**7.49**	**7.36**	**26.02**
S_{10}	20-40	7.84	8.05^{LM}	28.05^{R}	7.66	9.16^{GHI}	31.89^{K}	7.40	10.26^{BCD}	37.11^{D}	**7.63**	**9.16**	**32.35**
	40-60	7.98	8.96^{GHI}	31.21^{L}	7.85	10.00^{BCDE}	34.82^{F}	7.91	11.13^{A}	40.25^{A}	**7.91**	**10.03**	**35.43**
	0-20	7.64	5.83^{R}	20.37^{X}	7.44	7.11^{P}	24.78^{U}	7.25	8.06^{LM}	29.14^{P}	**7.44**	**7.00**	**24.76**
S_{15}	20-40	7.80	7.50^{NOP}	26.13^{T}	7.62	8.80^{HIJ}	30.66^{MN}	7.36	9.91^{CDE}	35.82^{E}	**7.59**	**8.74**	**30.87**
	40-60	7.94	8.74^{IJK}	30.45^{NO}	7.95	9.69^{EF}	33.72^{H}	7.88	11.09^{A}	40.10^{AB}	**7.92**	**9.84**	**34.76**
	0-20	**7.69**	**6.45**	**22.50**	**7.49**	**7.67**	**26.73**	**7.29**	**8.64**	**31.24**			
Mean	**20-40**	**7.83**	**7.95**	**27.68**	**7.65**	**9.07**	**31.57**	**7.40**	**10.23**	**37.00**			
	40-60	**7.95**	**8.81**	**30.69**	**7.88**	**9.86**	**34.34**	**7.92**	**11.07**	**40.04**			
LSD at 0.05			**EC**	**0.48**		**Ca^{+2}**		**0.27**		**pH**		**ns**	

Means having the same letter (s) within the same column are not significantly different according to LSD for all-pairwise comparisons test at 5% level of probability.

Table 10. Regression equations between the studied soil properties.

Wheat season		Corn season	
Surface layer (0 – 20 cm)			
Equations	**R^2**	**Equations**	**R^2**
$CaCO_3$ = 35.281 – 5.0238 SOM	0.7096	$CaCO_3$ = 34.55 – 5.0022 SOM	0.6915
EC = 4.404 + 1.4527 SOM	0.8803	EC = 4.8666 + 1.6512 SOM	0.9029
EC = 11.633 – 0.1807 $CaCO_3$	0.4846	EC = 14.529 – 0.2639 $CaCO_3$	0.8344
Ca^{+2} = 15.42 + 5.0305 SOM	0.8789	Ca^{+2} = 15.795 + 6.656 SOM	0.9484
Ca^{+2} = 40.435 – 0.6252 $CaCO_3$	0.4829	Ca^{+2} = 53.383 – 1.0119 $CaCO_3$	0.7931
pH = 7.7172 – 0.1611 SOM	0.3669	pH = 7.8939 – 0.2453 SOM	0.7098
pH = 7.2566 + 0.0076 $CaCO_3$	0.029	pH = 6.8596 + 0.024 $CaCO_3$	0.245
Subsurface layer (20 – 40 cm)			
$CaCO_3$ = 38.471 – 13.134 SOM	0.8024	$CaCO_3$ = 36.402 – 13.456 SOM	0.863
EC = 4.2801 + 5.1263 SOM	0.724	EC = 5.7035 + 4.8497 SOM	0.7546
EC = 19.021 – 0.3804 $CaCO_3$	0.8571	EC = 18.53 – 0.3496 $CaCO_3$	0.8226
Ca^{+2} = 14.949 + 17.775 SOM	0.7158	Ca^{+2} = 18.586 + 19.38 SOM	0.7318
Ca^{+2} = 66.134 – 1.3216 $CaCO_3$	0.8506	Ca^{+2} = 69.826 – 1.3964 $CaCO_3$	0.7971
pH = 8.3281 – 0.8508 SOM	0.5634	pH = 8.1104 – 0.697 SOM	0.4671
pH = 5.8763 + 0.0633 $CaCO_3$	0.6711	pH = 6.1906 + 0.0531 $CaCO_3$	0.5681

Table 11. Simple correlations (r) among the studied characters, (N= 36).

(r) values after wheat season in the 1st layer						**(r) values after maize season in the 1st layer**					
Properties	SOM	$CaCO_3$	pH	EC	Ca^{+2}	Properties	SOM	$CaCO_3$	pH	EC	Ca^{+2}
SOM	1					SOM	1				
$CaCO_3$	-.842**	1				$CaCO_3$	-.832**	1			
pH	-.606**	0.17	1			pH	-.842**	.495**	1		
EC	.938**	-.696**	-.810**	1		EC	.950**	-.914**	-.793**	1	
Ca^{+2}	.938**	-.695**	-.811**	1.000**	1	Ca^{+2}	.974**	-.891**	-.821**	.993**	1
(r) values after wheat season in the 2nd layer						**(r) values after maize season in the 2nd layer**					
Properties	SOM	$CaCO_3$	pH	EC	Ca^{+2}	Properties	SOM	$CaCO_3$	pH	EC	Ca^{+2}
SOM	1					SOM	1				
$CaCO_3$	-.896**	1				$CaCO_3$	-.929**	1			
pH	-.750**	.819**	1			pH	-.683**	.754**	1		
EC	.851**	-.926**	-.939**	1		EC	.869**	-.907**	-.923**	1	
Ca^{+2}	.846**	-.922**	-.941**	0.999**	1	Ca^{+2}	.855**	-.893**	-.938**	.996**	1

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

6. References

Abou Hussien E, Elbaalawy A M, Hamad M (2019). Chemical properties of compost in relation to calcareous soil properties and its productivity of Wheat. Egyptian Journal of Soil Science, 59(1), 85-97. https://doi.org/10.21608/ejss.2019.7945.1248

Abou Hussien E, Nada W, Elgezery M (2020). Influence of sulphur compost application on some chemical properties of calcareous soil and consequent responses of Hordeum Vulgare L. plants. Egyptian Journal of Soil Science, 60(1), 67-82. https://doi.org/10.21608/ejss.2019.18503.1318.

Al-Badran Y M (2020). Effect of Adding Sand on Clayey Soil Compressibility. In Key Engineering Materials (857), 328-333). Trans Tech Publications Ltd.http://dx.doi.org/10.4028/www.scientific.net/KEM.857.328.

Al-Turki A I (2010). Quality assessment of commercially produced composts in Saudi Arabia market. International Journal of Agricultural Research, 5(2), 70-79. Al-Turki, A. (2010). Quality Assessment of Commercially Produced Composts in

Saudi Arabia Market. International Journal of Agricultural Research. https://doi.org/10.3923/ijar.2010.70.79.

Al-Turki A, El-Hadidy Y, Al-Romian F, (2013). Assessment of chemical properties of locally composts produced in Saudi Arabia composts locally produced. Int. J. Curr. Res, 5, 3571-3578.

Amer M M, Hashem I M (2018). Impact of Some Soil Amendments on Properties and Productivity of Salt Affected Soils at Kafr El-Sheikh Governorate. Egypt. J. Soil Sci., 58 (2), 177 – 191.

Amri S, Akchiche M, Bennabi A, Hamzaoui R (2019). Geotechnical and mineralogical properties of treated clayey soil with dune sand. J Afr Earth Sc 152:140–150. https:// doi. org/ 10. 1016/j. jafre arsci. 2019. 01. 010.

Analytical software, Statistix Version 9 (2008). Analytical Software, Tallahassee, Florida, USA.

Awadalla S Y, Khalil K Y, Bothaina F A (2002). Field composts as a way to combat salinization of cultivated desert soils. 1st Int. Symp. Des. Res. Cent. Cairo.

Bernal M P, Albuquerque J A, Moral R (2008). Composting of animal manures and chemical criteria for compost maturity assessment: A review. Bioresour. Technol., 100: 5444-5453. Bernal, M. P., Alburquerque, J. A., & Moral, R. (2009). Composting of animal manures and chemical criteria for compost maturity assessment. A review. Bioresource Technology, 100(22), 5444–5453. https://doi.org/10.1016/j.biortech.2008.11.027.

Corwin D L (2003). Soil salinity measurement. Encyclopedia of Water Science. Marcel Dekker, New York, NY, USA, 852-860.

El-Ramady H R, Alshaal T A, Amer M, Domokos-Szabolcsy É, Elhawat N, Prokisch J, Fári M (2014). Soil quality and plant nutrition. Sustainable Agriculture Reviews 14: Agroecology and Global Change, 345-447. http://dx.doi.org/10.1007/978-3-319-06016-3_11.

Elsheikh A E (2015). Mitigation of groundwater level deterioration of the Nubian Sandstone aquifer in Farafra Oasis, Western Desert, Egypt. Environ. Earth Sci. 74, 2351–2367. http://dx.doi.org/10.1007/s12665-015-4236-7.

El-Zemrany H M, El-Shinnawi M M, Naglaa E E A (2016) Micronutrients and Diazotrophs affecting maize plant growth in alluvial and calcareous soils. Egypt. J. Soil Sci., 56 (4), 386-366.

EU (2006). Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Off. J. Eur. Union, 364, 5-24. http://data.europa.eu/eli/reg/2006/1881/oj.

FAO (2006). Guidelines for soil description. 4th edition. FAO, Rome, Italy.

Ganzour SK, Tharwat K G, Nadia M H, Khatab A (2020). Impact of Biofertilizers on Maize (Zea mays L.) Growth and Yield under Calcareous Soil Conditions. Egypt. J. Soil. Sci. 60 (4), 469-482.

Gondek M, Weindorf D C, Thiel C, Kleinheinz G (2020). Soluble salts in compost and their effects on soil and plants: A Review, Compost Science & Utilization, 28:2, 59-75, https://doi.org/10.1080/1065657X.2020.1772906.

Goufi A E, Harichane K, Harichane Z, Ghrici M, Driss A A E (2022). Improvement of the geotechnical properties of a clay–sand mixture treated with lime. Innovative Infrastructure Solutions, 7(1), 114. http://dx.doi.org/10.1007/s41062-021-00705-8.

Helmi M Y, (2018). Impact of using some chemical and biological treatments on ameliorating salt affected soil and its productivity. Ph. D. Thesis, Fac. of Agric., Benha Univ., Egypt.

Ilyas M, Ayub G, Hussain Z (2014). Response of tomato to different levels of calcium and magnesium concentration. World Applied Sciences Journal, 31(9), 1560-1564. DOI: 10.5829/idosi.wasj.2014.31.09.1994.

Imas P (2000). Integrated nutrient management for sustaining crop yields in calcareous soils. In GAU-PRII-IPI Nat. Symposium balanced nutrition of ground nut and other field crops grown in calcareous soils of India, Junagadh, India.

Jokubauskaitė I, Karčauskienė D, Antanaitis Š, Mažvila J, Šlepetiene A, Koncius D, Piaulokaite-Motuziene L (2015). The distribution of phosphorus forms and fractions in Retisol under different soil liming management. Zemdirbyste-agriculture, 102(3), (3), 251–256. https://doi.org/10.13080/z-a.2015.102.032.

Kolay P K, Ramesh K C (2015). Reduction of expansive index, swelling and compression behavior of kaolinite and bentonite clay with sand and class C fly ash. Geotech Geol Eng 34(1):87– 101. https:// doi. org/ 10. 1007/ s10706- 015- 9930-4.

Kovačević V, Andric L, Banaj D, Jambrovic A (2010). Impacts of liming on maize and soil status. Növénytermelés, 59 (Supplement), 61-64.

Laekemariam F, Gidago G. (2012). Response of Maize (Zea mays L.) to integrated fertilizer application in Wolaita, South Ethiopia. Advances in Life Science and Technology, 5, 21-30.

Mohamed W S, Sherif M A, Youssef I A (2008). Effect of some natural organic and inorganic materials on some soil properties and growth in sandy calcareous soil. Minia J. of Agric., Res., 28 (2), 331-349.

Mahmoud E, Ibrahim M, Ali N, Ali H (2020). Effect of Biochar and Compost Amendments on Soil Biochemical Properties and Dry Weight of Canola Plant Grown in Soil Contaminated with Heavy Metals. Communications in Soil Science and Plant Analysis, 51(12), 1561-1571.

Muzan A H (2021). Enhancement of physical properties of clay soils by adding sand. Indian Journal of Ecology, 48 Special Issue (15): 135-138.

Nada W M, Abou Hussien E, Elbaalawy A M (2023). Biochemical Properties of Calcareous Soil Affected by the Source of Sulphur-Organo Fertilizers. Egypt. J. Soil Sci. 63 (2), 255-265.

Ouda K A (2012). “Final report results of new geological & underground water witness at the great sand sea in the western desert – Egypt, a push that leads to agricultural development & architectural societies at the western part of the western desert-Egypt,”.

Pansu M, Gautheyrou J (2006). Organic and total c, n (h, o, s) analysis. Handbook of Soil Analysis: Mineralogical, Organic and Inorganic methods, 327-370.

Radwan S A, Abou Hussien E A, & Ahmed B M (2019). Effect of compost on properties and selectivity coefficient of salt affected soils I. On pH, ec and soluble cations and anions. Menoufia Journal of Soil Science, 4(5), 237-247. https://dx.doi.org/10.21608/mjss.2019.174962.

Rastijia D, Semialjac Z, Rastija M, Gulisija A (2012). Residual effect of liming on soil properties and maize grain yield. In Third International Scientific Symposium (pp. 87-91).

Saber A A, Ichihara K, Cantonati M (2017). Molecular phylogeny and detailed morphological analysis of two freshwater Rhizoclonium strains from contrasting spring types in Egypt and Italy. Plant Biosyst. 151, 800–812. https://doi.org/10.1080/11263504.2016.1211195.

Said R (Ed.). (2017). The geology of Egypt. Routledge.

Salman A M, A W S A M, Wale A, T J P R C (2018). Effect of Addition of Coarse Sand Particles on Engineering Properties of Clay Soil. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development, 8(4), 23–30. https://doi.org/10.24247/IJCSEIERDAUG20183.

Scrimgeour C, (2007). Handbook of Soil Analysis. Mineralogical, Organic and Inorganic Methods. By M. Pansu and J. Gautheyrou. Berlin, Heidelberg, New York: Springer (2006), pp. 993, £ 191.50. ISBN 978 – 3 – 540 – 31210 – 9. Experimental Agriculture, 43(3), 1 – 993.

Soil Survey Staff. (2014). Kellogg soil survey laboratory methods manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Sullivan D M, Miller R O, (2001). Compost quality attributes, measurements and variability. In: Compost Utilization in Horticultural Cropping Systems, Stofella P J and Kahn B A (Eds.). CRC Press, Boca Raton, Florida, ISBN10:156670460X, 95-120. http://dx.doi.org/10.1201/9781420026221.ch4.