Egypt. J. Hort. Vol. **46,** No. 1, pp. 83- 93 (2019)

Effect of Gypsum and Compost on Growth and Yield of Washington Navel Orange under Saline-Sodic Soils

A.M. Abo-Ogiala* **and Naglaa E. Khalafallah****
**Horticulture Department, Faculty of Agriculture, Tanta University and* ***Soil and Water Department, Faculty of Agriculture, Tanta University, Tanta, Egypt.*

INCREASING saline-sodic soils area as a result of climatic change, wrong agriculture practices and unsuitable of nutrition sources were lead to malnutrition and caused low productivity and quality of citrus. The study focused on gypsum and compost application in the proper rates for coping with such variable parameters. The trial carried out during 2017 and 2018 seasons on Washington navel orange trees (*Citrus sinensis* L., Osbek) grafted on sour orange (*Citrus aurantium* L.). Six application treatments were examined for the purpose of the study, *i.e.*, T1: control, T2: compost at 10 tons/ fed, T3: compost at 15 tons/ fed, T4: gypsum at 10 tons/ fed, T5: T4+T2 and T6: T4+T3. Field capacity (FC), Permanent wilting point (PWP), available water (AW), soil moisture and soil total content of NPK as indicators of soil parameter for application treatments were looked up. Growth parameters such shoot length, number of shoots/branch, number of leaves/shoot and leaf area, yield attributes such fruit set, fruit cracking, peel thickness, total tree yield (Kg), fruit juice volume, TSS, acidity, total sugars and vitamin C and leaf nutritional content of N, P, K, Ca and Mg were also determined. Results showed that T6 gave the highest results followed by T5, T4, T3 and T2 whereas T1 was the lowest ones for all parameters under investigations. The study aimed and recommends gypsum at 10 tons/ fed + compost at 15 tons/ fed for ameliorating saline-sodic soil and improving growth, yield and quality of Washington navel orange under such conditions.

Keywords: Saline soil, Moisture, Gypsum, Compost, Vegetative growth, Yield, Fruit quality, Washington navel orange.

Introduction

Citrus is the first Egyptian fruit crops for exporting worldwide. The citrus cultivated area is occupies around 485940 fed with a total area including (418415) feddans as a fruitful area with a total annual production about (427886) tons of fruits with an average of 10.21 tons/ fed as reported by Ministry of Agriculture and Land Reclamation (2016). Citrus in Delta Nile of Egypt suffer low productivity due to several reasons, *i.e*, increasing salinity and sodicity are the main reasons which related to malnutrition due to climate changing, wrong practices and unsuitable fertilizers. Therefore it was necessary developing agriculture practices that deal with those problems together and improve citrus production in that region. Gypsum as fascinating soil reclamation is totally neglected in the meantime. Gypsum considers the main source of calcium (Ca^{2+}) that exchange with Na^+ which can be leached or uptake by crops (Qadir and Oster, 2002). The sulfate in gypsum is not a problem for crops but improve dissolves calcium-rich at high pH (Horneck et al, 2007). Gypsum application followed by irrigation improves the efficiency than application on dry soil surface (Choudhary et al., 2008). Gypsum at higher rates to saline-sodic soils following by irrigation results an increase in sodium, chloride, potassium, manganese and zinc in leached water but decrease pH, exchangeable sodium (Alva et al., 1991, Sahin et al., 2003 and Makoi & Ndakidemi, 2007). Furthermore, gypsum lead to aggregation which happened due to similarly charged ions accumulate at the same site and connect to each other in stable aggregates such Ca^{2+} and Mg^{2+} (Fisher, 2011). Therefore, improving soil aggregation resulting salt leaching as a result of gypsum application and this lead to enhancing infiltration rate (IR) (Ahmad et al., 2006

Corresponding author: Atef Mostafa Abo-Ogiala, e-mail: atef_aboogiala@yahoo.com
DOI: 10.21608/ejoh.2019.7170.1093

and Zia et al., 2007). Increasing soil aggregation leads to increasing soil porosity, subsequently increasing bulk density (BD) (Chaudhry, 2001). Increasing IR and BD combined with deep tillage are breaking the compacted soil subsequently increasing water storage in deeper rooting area which means enhancing water use efficiency, *i.e.*, increasing tolerance to drought stress (Shainberg et al., 1989). Furthermore, sulphur in gypsum increases the availability of plant nutrient in root area such as P, Mn, Ca and SO_4 via decreasing pH (Lindemann et al., 1991, Neilsen et al., 1993 and Chien et al., 2011). The following model (Fig. 1) explains the previous described gypsum effect on chemical and physical properties:

However, limited literature were found in the effect of gypsum on fruit trees, some of them stated that gypsum had direct relation in increasing growth and leaf mineral content of some fruit trees such as persimmon, grapevine and orange trees (Abdel- Nasser and El-Shazly, 2000). Other studies found that gypsum improve the quality of horticultural crops in general (Shear, 1979, Scott et al., 1993 and Sumner 2007). Moreover, it was found that gypsum controlling many symptoms coming from soil desieses such citrus glue, avocado root rot, apples bitter pit and blossom-end rot of watermelon and tomatoes (Scott et al., 1993 and Shear, 1979). Xu (2006) found that 1, 5 and 10 tons/fed as low, medium and high, respectively were suggested as gypsum rate for sodic or sodium affected soil. On the other hand, the application of compost to sodic soils was found to reduce pH and ESP values (Rao and Pathak, 1996). Also, soil aggregates was enhanced via organic matter of compost (Six et al., 2004 and Abbas et al., 2012) and soil structure showed higher stability with improving plant growth under application of compost (Avnimelech et al., 1994 and Puget et al., 2000). Furthermore, compost was found to be a crucial organic mulching material that showed positive effects on soil physical properties by decreasing soil evaporation and increasing soil water moisture (García-Moreno, 2013, López et al., 2014 and Zribi et al., 2015). The study aimed to figure out the effect of optimal gypsum rate combined with compost on growth, leaf mineral content, yield and quality of Washington navel orange under saline-sodic soil condition.

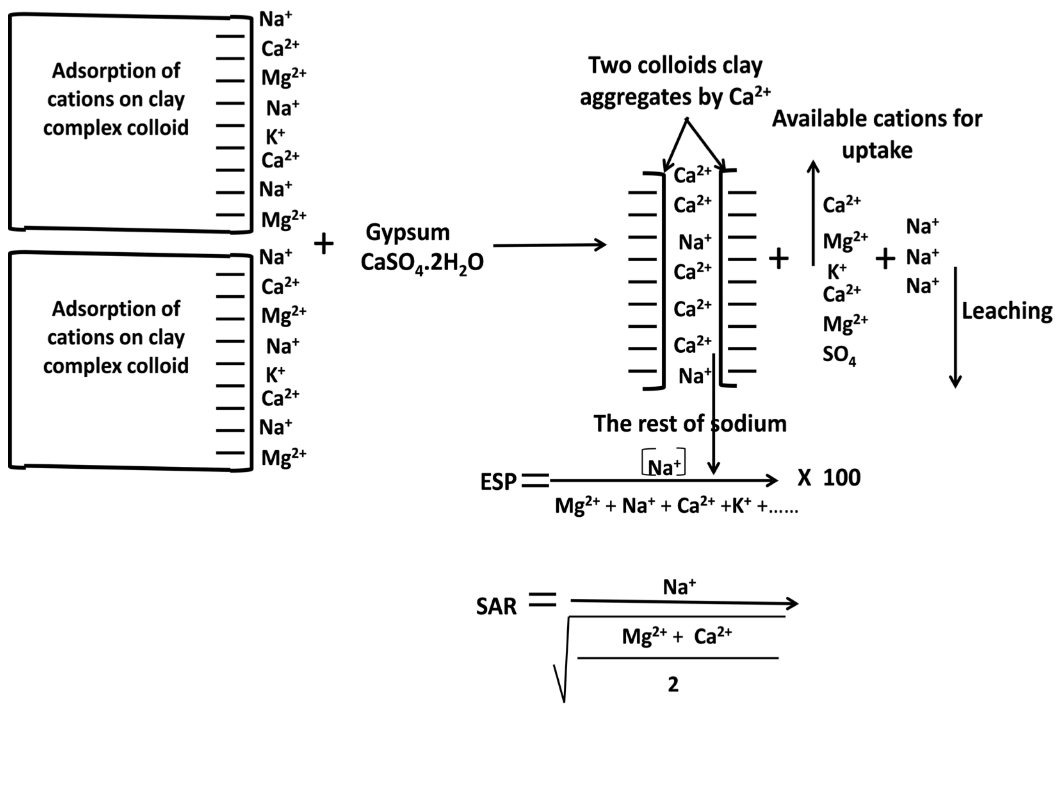

Fig. 1. Model explains gypsum effect on soil chemical and physical properties.

Materials and Methods

Experimental design

The experiment was carried out during 2017 and 2018 seasons on eight years old Washington navel orange trees (*Citrus sinensis* L., Osbek) budded on sour orange (*Citrus aurantium* L.) with planting space of 5 x 5 meters resulting density 168 trees/ fed. The trees grown on saline-sodic soil in a private orchard located at Akwa El Hessa village, Kafr El-Zayat, El- Gharbyia Governorate, Egypt.

The amount of gypsum needed to reclaim a sodic soil was according to Schoonover (1952) where a weighed quantity of sodic soil (5 g) is shaken with 100 ml of a saturated gypsum solution of known calcium concentration, Ca^{2+} and Mg^{2+} were calculated to determine gypsum requirements as follow:

$$\text{The Gypsum requirement} = \frac{(C_1 - C_2) \times 100 \times 100}{1000 \times 5}$$

The Gypsum requirement = $(C_1 - C_2) \times 2$ meq L^{-1} of Ca^{2+} per 100 g soil.

Where : C_1 is the concentration (meq L^{-1}) of Ca^{2+} in gypsum solution.

C_2 is the concentration of Ca^{2+} and Mg^{2+} in filtrate.

Since it was found that 1.70 ton of gypsum reduce one meq L^{-1} of Na per ha (USDA, 1954). The dose of gypsum needed for the experimental soil to reduce ESP from 35.2% to 20.0%, *i.e.*, 6 meq L^{-1} was found 10 tons/fed. Compost was used at normal agriculture practices at two rates which were 10 and 15 tons/fed as alternative material for mulching benefits plus its advantages as organic matter. The experiment was arranged in spilt-plot based on randomized complete blocks design with six treatments (control and gypsum) placed in two main plots while compost was placed in four sub-plots (with rates of 10 and 15 tons/ fed) as follows: T1: untreated soil (control), T2: compost at 10 tons/ fed, T3: compost at 15 tons/ fed, T4: gypsum at 10 tons/ fed, T5: gypsum at 10 tons/ fed + compost at 10 tons/ fed, T6: gypsum at 10 tons/ fed + compost at 15 tons/ fed. The application of the treatments starts in first of January each season. Prior gypsum application, soil samples were analyzed for background characteristics as shown in (Table 1).

The result analysis of compost used for the experimental treatments was shown Table 2 as well:

Soil characteristics analysis

Soil samples from depths 0-30, 30-60 and 60-90 cm and at harvest from 0-30 cm were collected and divided into two subsamples, the first was for physical and chemical soil properties, while second was for chemical soil composition. Soil characteristics analysis was done according to Bouyoucos (1962). Bulk density (BD, g cm^{-3}) was measured using the core method (Grossman and Reinsch, 2002). A portable EC and pH meters were used for electrical conductivity (EC, 1:5) and $pH_{1:5}$. Flame photometer (Chintala et al.,

TABLE 1. Soil characteristics of Washington navel orange orchard at the start of the treatments

parameter	Physical properties			Chemical properties										
Depth	Clay	Silt	Sand	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	Cl^{-}	ESP	SAR	OM%	P%	K%
0-30	47.2	24.1	28.6	8.21	9.51	7.53	12.6	77.2	59.2	36.51	23.15	1.35	3.94	201.06
30-60	45.1	22.1	32.7	8.01	8.15	5.11	11.7	66.3	45.3	32.33	21.01	1.16	3.75	194.13
60-90	43.1	21.7	35.0	8.26	8.33	4.63	10.8	63.5	41.0	31.91	22.12	0.85	3.59	198.45

Note: Acidity ($pH_{1:5}$), Electrical conductivity ($EC_{1:5}$ dS m^{-1}), SAR = Sodium Adsorption ratio, ESP= Exchangeable sodium%, OM refer to organic matter, Meq L^{-1} is the concentration of Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-}

TABLE 2. compost characteristics used for the experimental treatments

Prosperities	EC	pH	BD	OM	C:N	Total N	Total P	Total K
Unit	dS m^{-1}	(1:10)	Mg m^{-3}	g kg^{-1}	ratio	%	%	%
Value	4.44	7.85	0.59	330.12	15.15	1.88	0.79	1.83

2014 and USDA 1954) was used for Na^+ and K^+ determination. Calcium was measured using atomic absorption spectrophotometer Perkin Elmer-3300 according Chapman and Pratt (1961). Magnesium (Mg) was determined according to Wilde et al., (1985). Chloride was analyzed using silver nitrate (0.025 M) with potassium chloride (0.1 M) according to Mohr's titration method (Rhoades, 1982). Organic matter of compost was calculated using the method of (AFNOR, 1991).

Infiltration rate (IR) was measured using double ring with applying 15 cm depth of water. Infiltration time was recorded for each plot then, average of these values was calculated using the equation of Kostiakov (1932): $IR = KT^n$, Where, IR is the cumulative infiltration after time T, T= Time after infiltration starts, K and n are constants that depend on the soil and initial conditions (evaluated from measured infiltration data. K and n values range between zeros to one. Soil organic carbon was determined according (Nelson and Sommers, 1982) and used for calculation of organic matter (%) = organic carbon (%) × 1.72.

The available water (AW) was calculated according Klute (1986) by subtracting permanent wilting point (-1500 kpa) from field capacity (-33kpa): AW = FC – PWP, Where, FC is the water content at field capacity, WP is the water content at permanent wilting point. Then soil moisture % as a percent of field capacity were calculated. Exchangeable cations capacity (CEC) was estimated according (Bower *et al.,* 1952) and use to calculate exchangeable Na^+ percentage (ESP) according Richards (1954). Sodium adsorption ratio (SAR) as described in USDA (1954) as follow:

Vegetative Growth parameters

Developed twigs from spring bud sprouting at end of May were used to calculate shoot length (cm), number of shoots/branch, number of leaves/shoot and leaf area (cm^2) using model CL-203 area meter CID, Inc. USA.

Yield and Fruit quality attributes

Fruit set % a month after full bloom and Fruit cracking% at harvest time was calculated according to the following equations:

In December average fruit weight multiplied by numbers of fruit /tree was used to calculated yield (Kg/tree). Peel thickness, fruit juice volume and total soluble solids (TSS) as Brix Harvest using Hand refractometer were measured. Total sugars %, acidity % and vitamin c (mg/100 juice) were determined according A.O.A.C., (2000).

Leaf nutritional status

The fourth leaves from the top of the spring twigs were labeled in April and collected in September for analysis. Nitrogen was determined using Micro-kjeldehl as described by (page, 1982). Cotteine et al. (1982) method was followed for Phosphorus determination. Flame photometer was used for Potassium (K) determination according Jackson (1958). Calcium was measured using atomic absorption spectrophotometer Perkin Elmer-3300 according Chapman and Pratt (1961). Magnesium (Mg) was measured according to Wilde et al., (1985).

Statistical analysis

Data were analyzed by Statistical Graphics Corporation, STATGRAPHICS Plus (St. Louis, MO, USA) for one way analysis of variance and employing Duncan's multiple range tests (Duncan, 1955) at the 0.05 confidence level and for principle component analysis (PCA).

Results and Discussions

Effect of gypsum and compost on soil attributes

The mean results of soil moisture as a percentage of field capacity are shown in (Fig. 2) which illustrated that gypsum application alone or combined with compost significantly improved soil moisture % especially after long distance of water irrigation. T6 that introduce gypsum with higher compost rate showed the best results followed by T5, T4, T3 and T2, respectively, compared to control treatment. It is clear that both of gypsum and compost play together an important role in amelioration saline-sodic soils which reflect in decreasing surface soil evaporation and increasing the ability of soil holding water, subsequently increasing soil moisture percentage.

In the same trend where results of field capacity (FC), permanent wilt point (PWP) and available water (AW) showed similar results to that obtained in soil moisture % after gypsum and compost applications (Table 3). In that concern T6 revealed the highest results followed by T5, T4, T3 and T2, respectively, compared to control treatment. Increasing water content at the higher rates of gypsum and compost refer to increasing soil potential in holding capacity subsequently, increasing available water to plants. These results come in the same line with other findings (Shainberg et al., 1989) who found that increasing soil aggregates due to gypsum application lead to increasing water storage in deeper rooting area.

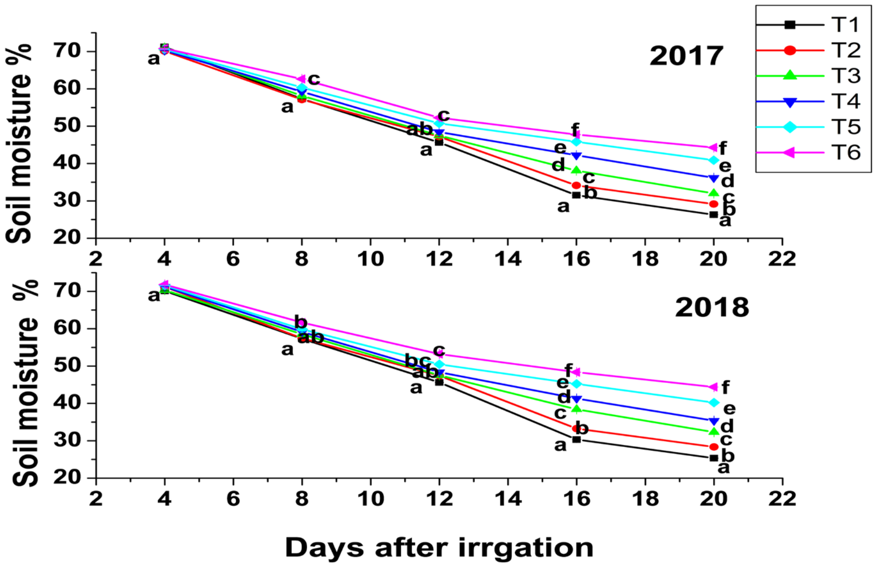

Fig. 2. Is ... ıtrol), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange trees under saline –sodic soil during 2017 and 2018 seasons. Data indicated means (*n* =5 ± SE). Different letters indicated significant differences at $p < 0.05$.

TABLE 3. The effect of gypsum and compost on field capacity (FC), permanent wilt point (PWP), available water (AW) and soil total content of NPK in the trail field of Washington navel orange trees under saline – sodic soil during 2017 and 2018 seasons.

Parameters	FC		PWP		AW		N mg Kg^{-1}		P mg Kg^{-1}		K mg Kg^{-1}	
Treatments	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
T1	37.62**e**	37.58**e**	19.48**b**	19.35**b**	18.14**d**	18.23**d**	44.35**d**	44.23**d**	4.41**c**	4.42**c**	201.32**d**	201.33**d**
T2	39.18**d**	39.09**d**	19.51**a**	19.44**a**	19.67**cd**	19.65**cd**	44.43**d**	44.68**d**	4.50**c**	4.51**c**	202.42**d**	202.44**d**
T3	39.98**c**	39.86**c**	19.77**a**	19.64**a**	20.21**c**	20.22**c**	45.65**c**	45.61**c**	4.60**c**	4.61**c**	207.71**c**	207.74**c**
T4	39.82**c**	39.82**c**	19.61**a**	19.60**a**	20.21**c**	20.22**c**	47.75**b**	47.77**b**	4.79**b**	4.78**b**	210.07**b**	210.04**b**
T5	42.08**b**	42.18**b**	19.57**a**	19.65**a**	22.51**b**	20.53**b**	49.12**a**	49.15**a**	5.25**a**	5.29**a**	211.11**b**	211.17**b**
T5	45.21**a**	45.31**a**	21.24**a**	21.37**a**	23.97**a**	23.94**a**	49.29**a**	49.28**a**	5.33 **a**	5.37**a**	215.24 **a**	215.36 **a**

T1: untreated soil (control), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange under saline –sodic soil during 2017 and 2018 seasons. Means followed by the same letter are not statistically different by Duncan at 0.05 levels.

Other supporting results on compost as mulching material were found by (Mubarak et al., 2009, García-Moreno, 2013, López et al., 2014 and Zribi et al., 2015) which stated that increasing water moisture as a correlation of improving soil physical properties was markedly noted after compost application. Soil total content of NPK showed the same direction as well as the previous introduced soil parameters. These findings are in harmony with the previous results of (Alva et al., 1991, Sahin et al., 2003, Makoi and Ndakidemi, 2007) who found that gypsum and compost applications were lead to the increase of nutrient release, subsequently increasing soil content of total NPK.

Effect of gypsum and compost on vegetative growth parameters

Results in Table 4 showed that all vegetative growth parameters, *i.e.,* shoot length, number of shoots/branch, number of leaves/shoot and leaf area were slightly increased after gypsum and compost application compared to control treatment. The first rate of compost (T2) not significantly differed with control (T1), bust showed significantly differences with other treatments (T3, T4, T5 and T6). Moreover, there were no significant differences between T3 compared to T4 and T5 compared to T6, whereas T5 and T6 showed significantly higher results compared to T3 and T4. These results are in the same line with (Abdel- Nasser and El-Shazly, 2000) who found that gypsum application showed growth increasing of some fruit trees such as persimmon, grapevine and orange tree. Other studies were found that improving growth parameter was related to improving soil structure under application of compost (Avnimelech et al., 1994 and Puget et al., 2000).

Effect of gypsum and compost on yield indicators and Fruit quality attributes

Fruit set as the most important yield parameter which reflects the stability of flowers and fruitlets against abscission zone that occurs between branch and peduncle during blooming stage and June drop. Table 5 showed that gypsum and compost application at all rates increased the fruit set percentage compared to untreated soils (control, T1). The increasing of fruit set was probably due to the improving nutritional status and this come in agreements with many previous studies such (Goldschmidt & Koch, 1996, Iglesias et al., 2003 & 2006 and Syvertsen et al., 2003) who was found a link between creating the abscission zone and nutritional status. Fruit cracking and peel thickness were found related to each other and affected by gypsum and compost treatments. All gypsum and compost rates may increase the availability and the uptake of Ca^{2+} subsequently reduced the fruit cracking % and increased peel thickness compared to T1. these results was found in agreements with the previous studies who stated that increasing available water leads to increasing absorption of Ca^{2+}, subsequently reduce the fruit cracking rate (Fan et al., 2012). This can be happen via increasing cell-wall Ca^{2+} content and inhibit the degradation of pectin, cellulose and hemicellulose in the peel cell wall (Alvaro et al., 2010). Wen and Shi (2012) also found the lower leaves Ca^{2+} content was in the cracking peel and pulp in ‘Jincheng’ sweet orange compared to normal fruit. Results of yield, *i.e.*, fruit weight and number of fruits/tree showed that gypsum and compost treatments were better than control (Table 5). T6 gave the greatest yield value followed by T5, T4, T3 and T2.

Table 6 showed that fruit quality, *i.e.*, fruit juice volume, TSS, acidity, total sugars and vitamin C had significantly higher values compared to control (T1) due to gypsum and compost applications. It was logically to note the improved fruit quality attributes due to gypsum and compost applications as a reflection of improvement of soil physical and chemical properties subsequently their relates such increasing availability of water

TABLE 4. The effect of gypsum and compost on shoot length (cm), number of shoots/ branch, number of leaves/ shoot and leaf area (cm²) in the trail field of Washington navel orange trees under saline –sodic soil during 2017 and 2018 seasons.

Parameters	Shoot length(cm)		No. shoots/ branch		No. leaves/shoot		Leaf area (cm²)	
Treatments	2017	2018	2017	2018	2017	2018	2017	2018
T1	24.24**c**	24.53**c**	18.12**c**	18.23**c**	5.15**c**	5.13**c**	14.12**c**	14.17**c**
T2	24.32**c**	24.55**c**	18.24**c**	18.51**c**	5.24**c**	5.25**c**	14.22**c**	14.21**c**
T3	26.19**b**	26.15**b**	20.74**b**	20.70**b**	5.87**b**	5.77**b**	16.14**b**	16.17**b**
T4	26.98**b**	26.78**b**	21.41**b**	21.31**b**	6.07**b**	6.09**b**	16.23**b**	16.26**b**
T5	28.17**a**	28.15**a**	22.95**a**	22.91**a**	6.95**a**	6.89**a**	17.91**a**	17.85**a**
T6	29.06**a**	29.07**a**	23.21**a**	23.24**a**	7.11**a**	7.13**a**	18.11**a**	18.14**a**

T1: untreated soil (control), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange under saline –sodic soil during 2017 and 2018 seasons. Means followed by the same letter are not statistically different by Duncan at 0.05 levels.

TABLE 5. The effect of gypsum and compost on fruit set %, fruit cracking %, Peel thickness (mm), fruit weight (g), number of fruits /tree and tree yield (kg) in the trail field of Washington navel orange trees under saline –sodic soil during 2017 and 2018 seasons.

Parameters	Fruit set %		No. fruits /tree		Tree Yield (Kg)		Fruit weight (g)		Fruit cracking %		Peel thickness (mm)	
Treatments	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
T1	14.25**c**	14.21**c**	65.53**e**	65.74**e**	65.75**e**	75.65**e**	235.23**e**	235.78**e**	5.64**a**	5.61**a**	3.11**a**	3.15**a**
T2	14.25**bc**	14.22**bc**	66.75**de**	66.41**de**	66.68**de**	66.78**de**	236.35**de**	236.74**de**	5.32**a**	5.31**a**	3.12**ab**	3.14**ab**
T3	16.18**b**	16.17**b**	67.71**cd**	67.54**cd**	68.68**cd**	68.89**cd**	237.43**cd**	237.54**cd**	4.11**b**	4.12**b**	2.97**bc**	2. 9**bc**
T4	17.18**b**	17.18**b**	68.45**c**	68.87**c**	70.74**c**	70.85**c**	238.87**c**	238.89**c**	3.81**b**	3.85**b**	2.74**c**	2.71**c**
T5	18.85**a**	18.81**a**	70.51**b**	70.87**b**	72.36**b**	72.74**b**	240.31**b**	240.29**b**	2.51**cd**	2.53**cd**	2.75**d**	2.71**d**
T6	19.03**a**	19.06**a**	72.13**a**	72.11**a**	74.05**a**	74.03**a**	241.17**a**	241.11**a**	2.10**d**	2.11**d**	2.51**e**	2.49**e**

T1: untreated soil (control), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange under saline –sodic soil during 2017 and 2018 seasons. Means followed by the same letter are not statistically different by Duncan at 0.05 levels.

TABLE 6. **The effect of gypsum and compost on fruit juice volume (ml), TSS, acidity %, total sugars % and vitamin C (mg/100 juice) in the trail field of Washington navel orange trees under saline –sodic soil during 2017 and 2018 seasons.**

Parameters	Fruit juice volume (ml)		TSS%		Acidity %		Total sugars%		Vitamin C (mg/100 juice)	
Treatments	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
T1	68.34**e**	68.54**e**	10.11**c**	10.12**c**	0.97**d**	0.97**d**	6.11**d**	6.13**d**	53.55**e**	53.51**e**
T2	68.53**de**	68.51**de**	10.35**c**	10.33**c**	1.03**cd**	1.05**cd**	6.36**d**	6.35**d**	53.61**de**	53.65**de**
T3	69.63**cd**	69.74**cd**	11.15**b**	11.17**b**	1.09**bc**	1.07bc	7.36**c**	7.37c	54.22**d**	54.19**d**
T4	70.89**c**	70.83**c**	11.74**b**	11.81**b**	1.15**b**	1.13**b**	7.78**c**	7.79**c**	56.65**c**	56.68**c**
T5	72.47**b**	72.41**b**	12.52**a**	12.54**a**	1.24**a**	1.22**a**	8.15**b**	8.12**b**	58.24**b**	58.21**b**
T6	73.13**a**	73.11**a**	12.98**a**	12.97**a**	1.30**a**	1.31**a**	9.22**a**	9.23**a**	59.69**a**	59.67**a**

T1: untreated soil (control), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange under saline –sodic soil during 2017 and 2018 seasons. Means followed by the same letter are not statistically different by Duncan at 0.05 levels.

and nutrients to plans which showed the direct effect on fruit quality as stated in previous studied (Shainberg et al., 1989, Sahin et al., 2003, Makoi & Ndakidemi, 2007, Sumner 2007, López et al., 2014 and Zribi et al., 2015).

Effect of gypsum and compost on leaf mineral content

As expected gypsum with the higher rate of compost showed the highest value of all measured nutrients compared to other treatments (Table 7). There were no significant differences between T1 compared to T2 and T3 compared to T2 for measured leaf mineral. Whereas, T5 showed higher significant differences compared to T4. These results come in harmony with the previous studies (Lindemann et al., 1991, Abdel- Nasser and El-Shazly, 2000, Neilsen et al., 1993 and Chien et al., 2011) who stated that application of gypsum or compost resulted to the increase of plant nutrient in root area, subsequently increasing the uptake of it.

Conclusion

Gypsum 10 tons/ fed and compost at 15 tons/ fed (T6) showed the best results followed by T5, T4, T3 and T2 whereas T1 was the lowest ones for all parameters under investigations. Gypsum combined compost at T6 treatment was found to be promising agriculture practices for ameliorating saline-sodic soil and improving growth parameter, yield level and enhancing quality of Washington navel orange.

TABLE 7. The effect of gypsum and compost on the uptake of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in the trail field of Washington navel orange trees under saline –sodic soil during 2017 and 2018 seasons.

Parameters	N %		P %		K %		Ca %		Mg%	
Treatments	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
T1	2.14d	2.15d	0.121d	0.124d	1.33e	1.35e	4.01e	4.03e	0.31d	0.32d
T2	2.21cd	2.19cd	0.129cd	0.128cd	1.43de	1.44de	4.14de	4.17de	0.41cd	0.43cd
T3	2.38bc	2.37bc	0.136bc	0.137bc	1.55cd	1.54cd	4.29d	4.28d	0.46c	0.47c
T4	2.48b	2.47b	0.156b	0.158b	1.59bc	1.57bc	4.89c	4.86c	0.56b	0.57b
T5	2.69a	2.68a	0.177a	0.178a	1.68ab	1.65ab	5.23b	5.26b	0.63ab	0.65ab
T6	2.88a	2.87a	0.191a	0.192a	1.89a	1.87a	5.87a	5.88a	0.69a	0.68a

T1: untreated soil (control), T2: compost at 10 tons/ fed., T3: compost at 15 tons/ fed., T4: gypsum at 10 tons/ fed., T5: gypsum at 10 tons/ fed. + compost at 10 tons/ fed., T6: gypsum at 10 tons/ fed. + compost at 15 tons/ fed., on soil moisture % for the orchard of Washington navel orange under saline –sodic soil during 2017 and 2018 seasons. Means followed by the same letter are not statistically different by Duncan at 0.05 levels.

Acknowledgment

The authors wish to acknowledge Tanta University, Egypt for introducing all facilities needed for this study. We also thank all kind of help supported by all members of Citrus Department, Horticulture Research center, Ministry of Agriculture and all members of Soil and water Department, Faculty of Agriculture, Tanta University.

Funding statement

Partial funding of this work was provided by the Faculty of Agriculture, Tanta University, Egypt and there was no external funding received for this study.

Conflicts of interest

The authors declare that there are no conflicts of interest related to the publication of this work.

References

A.O.A.C. (2000) *Official Methods of Analysis* 16th Ed. A.O.A.C. Benjamin Franklin Station

Abbas, M.H.H., Ismael, A.O.A., El-Gamal, M.A.H. and Salem, H.M. (2012) Integrated effect of mineral nitrogen, bio and organic fertilization on soybean productivity *Egypt J Biotechnol*, **39**, 43-63.

Abdel-Nasser, G. and El-Shazly, S.M. (2000) Effect of sulphur application on soil properties, nutrient status, yield and fruit quality of Balady orange trees. *J. Agric. Res., Tanta Univ.,* **26**, 72-92.

AFNOR. (1991) Matières fertilisantes et supports de culture, Recueil des normes Françaises. AFNOR, Paris, 713 p.

Ahmad, S., Ghafoor, A., Qadir, M. and Aziz, M.A. (2006) Amelioration of a calcareous saline sodic soil by gypsum application and different crop rotations. *Int. J. Agric. Biol*., **8**, 142–146.

Alva, A.K. and Gascho, G.J. (1991) Differential leaching of cations and sulfate in gypsum amended soils. Commun. *Soil Sci. Plant Anal*., **22**, 1195-1206

Alvaro, B., Victoria, F. and Jesús, V. (2010) Improving the performance of calcium-containing spray formulations to limit the incidence of bitter pit in apple (Malus × domestica Borkh). *Sci Hortic*, **127**, 23–28

Avnimelech, Y., Shkedy, D., Kochva, M. and Yotal, Y. (1994) The Use of Compost for the Reclamation of Saline nd Alkaline Soils. *Compost Science & Utilization*, **2**, 6-11

Bouyoucos, G. J. (1962) Hydrometer method improved for making particle size analysis of soils. *Agron. J.*, **54**, 464-465.

Bower C. A., Reitemeier, R. F. and Fireman, M. (1952) Exchangeable Cation Analysis of Saline and Alkali Soils. *Soil Sci*., **73**, 251-261.

Chapman, H.D. and Pratt, P.F. (1961) *Methods of Analysis for Soils*, Plants and Waters Div. Agric. Sci. Univ. Calif. USA, 309 p.

Chaudhry, M.R. (2001) Gypsum efficiency in the amelioration of saline-sodic/sodic soils. *Int. J. Agri. Biol.*, **3**, 276-280.

Chien, S.H., Gearhart, M.M. and Villagarcía, S. (2011) Comparison of ammonium sulfate with other nitrogen and sulfur fertilizers in increasing crop production and minimizing environmental impact, a review. *Soil Science*, **176** (7), 327-335.

Chintala, R., Mollinedo, J., Schumacher, T. E., Malo, D. D., and Julson, J. L. (2014) Effect of biochars on chemical properties of acidic soil. *Arch. Agron. Soil Sci.*, **60** (3), 393-404.

Choudhary, M. R., Munir, A. and Mahmood, S. (2008) Field soil salinity distribution under furrow-bed and furrow-ridge during wheat production in irrigated environment. *Pak. J. Water Res.*, **12** (2), 33–40.

Cottenie, A., Verloo, M., Kiekens, L., Velgle, G. and amerlynuck, R. (1982) Chemical Analysis of Plant and Soil, 43- 51. Laboratory of Analytical and Agroch. State Univ. of Belgium,Gent.

Duncan, D. B. (1955) Multiple ranges and multiple F. test. *Biometrics*, **11**, 1-42.

Fan, W.G., Li, Q.H. and Wu, S.F. (2012) Effect of perennial drought environments on Citrus tangerina Hort. cv. 'Chuanju' growth, nutrient absorption and physiology. Chin. J. Eco. Agric., **20**, 1484–1493.

Fisher, M. (2011) Amending soils with gypsum. *Crops & Soils Magazine*, November-December 2011, American Society of Agronomy.

García-Moreno, J., Gordillo-Rivero, Á.J., Zavala, L.M., Jordán, A. and Pereira, P. (2013) Mulch application in fruit orchards increases the persistence of soil water repellency during a 15-years period. *Soil Till Res*, **130**, 62-68.

Goldschmidt, E.E. and Koch, K.E. (1996) Citrus. In: *Photoassimilate Distribution in Plants and Crops*: Source-Sink Relations, Zaminski E, Schaffer AA (Ed.), pp.797-823. Marcel Dekker, New York.

Grossman, R.B. and T.G. Reinsch (2002) Bulk density and linear extensibility. In*: Methods of soil Analysis*. Part 4. J.H. Dane and G.C. Topp (Ed.) p. 201-228, SSSA Book Ser. 5. SSSA, Madison, WI.

Horneck, D. A., Ellsworth, J. W., Hopkins, B. G., Sullivan, D. M. and Slevens, R.G. (2007) managing salt-affected soils for crop production. Oregon State University Extension Service.

Iglesias, D.J., Calatayud, A., Barreno, E., Primo-Millo, E. and Talon, M. (2006) Responses of citrus plants to ozone: growth, antioxidant mechanisms and lipidperoxidation. *Plant Physiol. Biochem*., **44**, 125-131.

Iglesias, D.J., Tadeo, F.R., Primo-Millo, E. and Talón, M. (2003) Fruit set dependence on carbohydrate availability in citrus trees. *Tree Physiol*., **23**, 199-204.

Jackson, M.L. (1967) *Soil Chemical Analysis*. Printice-Hall Inc. Englewood Cliffs-N.S.

Klute, A. (1986) *Methods of Soil Analysis* : Part 1,2nd ed. Agron. Monogr.Q.ASA, Madison, WI.

Kostiakov, A. N. (1932) On the Dynamics of the Confinement of Water Percolation in Soils and on the Necessity of Studying it from a Dynamic Point of View for Purpose of Amelioration. *Society of Soil Science, Russia*, **14**, 17-21.

Lindemann, W.C., Aburtto, J.J., Haffner, W.M. and Bono, A.A. (1991) Effect of sulfur source on sulfur oxidation. *Soil Sci. Soc. Am. J.*, **55**, 85-90.

López, R., Burgos, P., Hermoso, J.M., Hormaza, J.I. and GonzálezFernández, J.J. (2014) Long term changes in soil properties and enzyme activities after almond shell mulching in avocado organic production. *Soil Till Res.*, **143**, 155-163.

Makoi, H. J. R. and Ndakidemi, P. A. (2007) Reclamation of sodic soils in northern Tanzania, using locally available organic and inorganic resources. *African Journal of Biotechnology*, **6** (16), 1926–1931.

Ministry of Agriculture and Land Reclamation (2016) *Bulletin of the Agricultural Statistics*, part (2) Summer & Nile crops, 2013/2014, Cairo, Egypt.

Moran, E.F., Brondizio, E.S., Tucker, J.M., Silva-Forsberg, M.C.D. and Mc Cracken, S.D. (2000) Effects of soil fertility and land-use on forest succession in Amazonia. *Forest Ecol. Manage*., **139**, 93-108.

Neilsen, D., Hogue, E. J., Hoyt, P.B. and Drought, B.G. (1993) Oxidation of elemental sulfur and acidifcation of calcareous orchard soils in southern British Columbia. *Can. J. Soil Sci*., **73**, 103-114.

Nelson, D.W. and L.E. Sommers (1982) Total carbon, organic carbon and organic matter. In : *Methods of Soil Analysis,* Page A.L., Miller R.H., Keeney D.R. (Ed.), pp. 539–549, .American Society of Agronomy, Madison.

Page, A. L., (ed) (1982) *Method of Soil Analysis*, Part 2, *Chemical and Microbiological Properties*, Second edition, American Society of Agronomy, Inc and Soil Science Society of America, Inc., Publisher, Madison, Wisconsin USA.

Puget, P., Chenu, C. and Balesdent, J. (2000) Dynamics of soil organic matter associated with particle-size fractions of water-stable aggregates. *European Journal of Soil Science*, **51**, 595-605.

Qadir, M. and Oster, J. D. (2002) Vegetative bioremediation of calcareous sodic soils: history, mechanisms, and evaluation. *Irrigation Sci*., **21**, 91-101.

Rao, D.L.N. and Pathak, H. (1996) Ameliorative influence of organic matter on biological activity of salt affected soils. *Arid Soil Research and Rehabilitation*, **10**, 311- 319.

Rhoades, J. D. (1982) Soluble Salts in Methods of Soil Analysis (Part 2). In: *Agronomy Monograph*, A.L. Page, R.H. Miller & D.R. Keeney (Ed.) (No. 9, 2nd ed., p. 168). American Soil Science Society, Madison WI.

Richards, L.A. (1954) *Diagnosis and Improvement of Saline and Alkali Soils*. USDA Handb. 60. U.S. Gov. Print. Office, Washington, DC.

Sahin, U., Oztas, T. and Anapali, O. (2003) Effects of consecutive applications of gypsum in equal, increasing and decreasing quantities on soil hydraulic conductivity of a saline-sodic soil. *J. Plant Nut. Soil Sci*., **166** (5), 621-624.

Schoonover, W.R. (1952) Examinations of soils for alkali. University of California Extension Service, Berkeley, California, USA. (Mimeographed).

Scott, W. D., Mc Craw, B. D., Motes, J. E. and Smith, M. W. (1993) Application of calcium to soil and cultivar affect elemental concentration of watermelon leaf and rind tissue. *Journal of the American Society of Horticultural Science*, **118**, 201–206.

Shainberg, I., Sumner, M.E., Miller, W.P., Farina, M.P.W., Pavan, M.A. and Fey, M.V. (1989) Use of gypsum on soils: A review, pp. 1-1 I 1. IN: B.A. Stewart (Ed.), Advances in Soil Science, Vol. 9, Springer-Verlag New York.

Shear, C.B. (1979) Calcium nutrition of economic crops (Special Issue). *Communications in Soil Science and Plant Analysis*, **10**, 1–501.

Six, J., Bossuyt, H., Degryze, S. and Denef, K. (2004) History of research on the link between (micro) aggregates, soil biota, and soil organic matter dynamics. *Soil and Tillage Research*, **79**, 7-31

Sumner, M.E. (2007) Soil chemical responses to FGD gypsum and their impact on crop yields. Presented at the workshop on Agricultural and Industrial Uses of FGD Gypsum. October 2007, Atlanta, Ga.

Syvertsen, J.P., Goñi, C. and Otero, A. (2003) Fruit load and canopy shading affect leaf characteristics and net gas exchange of “Spring” navel orange trees. *Tree Physiol.*, **23**, 899-906.

USDA. (1954) *Diagnosis and improvement of saline and alkali soils*. U.S. Department of Agriculture (USDA). Handbook no. 60. U.S. Govt. Printing Office, Washington, USA.

Wen, M.X. and Shi, X.J. (2012) Influence of calcium on fruit cracking of Jincheng orange and its physiological mechanism. *Scientia Agricultura Sinica*, **45**, 1127–1134.

Wilde, A.A., Corey, R.B., Lyer, J.G. and Voigt, G.K. (1985) *Soil and Plant Analysis for Tree Culture*, 3rd ed., Oxford IBH Publishing Co., New Delhi, pp, 64-115.

Xu, X. (2006) Soil reclamation using FGD byproduct in China. Presented at the workshop on Research and Demonstration of Agricultural Uses of Gypsum and Other FGD Materials. September 2006, St. Louis, Mo. http://www.oardc.ohio-state.edu/agriculturalfgdnetwork/workshop_fles/

Zia, M.H., Saifullah, M. Sabir, Ghafoor, A. and Murtaza, G. (2007) Effectiveness of sulphuric acid and gypsum for the reclamation of a calcareous saline-sodic soil under four crop rotations. *Journal of Agronomy and Crop Science*, **193**, 262–269.

Zribi, W., Aragüés, R., Medina, E. and Faci, J.M. (2015) Efficiency of inorganic and organic mulching materials for soil evaporation control. *Soil Till. Res.*, **148**, 40-45.

(*Received* 12/01/2019;

accepted 17/02/2019)

تأثير الجبس مع الكمبوست على النمو والمحصول للبرتقال بسرة تحت ظروف الأراضى الملحية الصودية

عاطف مصطفى أبو عجيلة * و نجلاء إبراهيم خلف الله**
*قسم البساتين- كلية الزراعة - جامعة طنطا و** قسم الأراضى والمياه- كلية الزراعة - جامعة طنطا- مصر.

زادت مساحة الأراضى الملحية الصودية كنتيجة لتغيرات المناخ والممارسات الزراعية الخاطئة والأسمدة الغير مناسبة مما أدى إلى خلل فى تغذية أشجار الموالح والذى إنعكس بدوره على إنخفاض الإنتاج والجوده. ولذلك تهدف الدراسة على التركيز على إضافة الجبس والكمبوست بالمعدلات المناسبة والتى تغطى سلبيات هذه المتغيرات. أجريت الدراسة خلال عامى ٢٠١٧ و٢٠١٨ بمزرعة خاصة بقرية أكوة الحصة – مركز كفر الزيات – محافظة الغربية- مصر وذلك على أشجار برتقال بسرة مطعومة على النارنج البلدى عمره ثمانية سنوات منزرعة على مسافات ٥X٥ بكثافة زراعية ١٦٨ شجرة للفدان. إشتملت الدراسة على ٦ معاملات هى ١- الكنترول , ٢- الكمبوست بمعدل ١٠ طن/فدان , ٣- الكمبوست بمعدل ١٥ طن/فدان , ٤- الجبس بمعدل ١٠ طن/فدان , ٥- الجبس بمعدل ١٠ طن/فدان+ الكمبوست بمعدل ١٠ طن/فدان ، 6- - الجبس بمعدل ١٠ طن/ فدان+ الكمبوست بمعدل ١٥ طن/فدان. لمعرفة تاثير تلك المعاملات على التربة حيث تم تقدير نسبة الرطوبة عند السعة الحقلية ونقطة الذبول المستديم ثم قدرت الرطوبة كنسبة مئوية من السعة الحقلية بالإضافة إلى تقدير محتوى التربة من النتروجين والفوسفور والبوتاسيوم. كما تم إختبار تأثير تلك المعاملات على قياسات النمو مثل طول أفرخ نموات الربيع وعددها ومساحة الأوراق , دلائل المحصول مثل نسبة الثمار العاقدة وأوزان الثمار و المحصول للشجرة الواحدة. أما بالنسبة لصفات الجودة فقد تم تقدير نسبة الثمار المشقوقة ونسبة سمك القشرة ، كمية العصير فى الثمرة ونسبة المواد الذائبة الكلية والحموضة والسكر وفيتامين ج. كما تم قياس نسبة العناصر المعدنية فى الأوراق مثل النتروجين والفوسفور والبوتاسيوم والكالسيوم والماغنسيوم. وقد أظهرت المعاملة رقم ٦ الخاصة بالجبس والكمبوست بمعدل ١٥ طن/فدان اعلى النتائج لكل الصفات تحت الدراسة تلتها المعاملة رقم ٥ ثم رقم ٤ ثم ٣ ثم ٢ بينما أظهرت المعاملة رقم ١ (الكنترول) أقل القيم للصفات المدروسه. ولذلك يمكن التوصية بإضافة الجبس مع الكمبوست بمعدل ١٥ طن/فدان لمزارع البرتقال بسرة لمعالجة ظروف الأراضى الملحية الصودية والتى أعطت أفضل نتائج للنمو والمحصول والجودة تحت نفس ظروف التجربة.