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Impact of Biochar Mixed with Compost on Olive and Some Soil Properties under Saline Water and Soil Management

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Abstract

This study was conducted at Ismailia Desert in Egypt during two seasons 2019 and 2020 to investigate the effect of biochar or/ and compost with SGF reclamation amendments (sulfur, gypsum, farmyard manure) on soil properties of saline loamy sand soil irrigated with saline water and yield of Picual olive trees. The results showed that soil hydro-physical properties were markedly affected by biochar and compost with SGF reclamation amendments, the incorporation of biochar and compost with SGF reclamation amendments led to enhancement in soil water retention and soil water transmission through increasing soil field capacity and available water and improving saturated hydraulic conductivity and mean diameter of soil pore. Consequently olive fruit yield and yield components. Both biochar or/ and compost with SGF reclamation amendments had valuable influences on growth, nutrients content, yield, fruit quality, and oil percentage in olive fruits, especially application of biochar at 75% plus compost at 25% with SGF reclamation amendment. In conclusion, it could be recommended that mixing biochar with compost with SGF reclamation amendments (sulfur, gypsum, farmyard manure) can managing saline soil irrigated with saline water.

Keywords:- Biochar, Compost, SGF reclamation amendments, Soil water retention, Soil water transmission, Olive yield

Introduction

Soil salinization is a severe issue that globally threatens food security. It's a dynamic process influenced by natural and anthropological factors, and socioeconomic and political aspects frequently play a role in hastening the process of soil salinization. Such problems are often beyond the farmers' control and require the policymakers 'attention (Kumar and Sharma, 2020).

Inadequate drainage causes soil salinity, as the groundwater rises, depending upon texture, structure, and other factors, the water reaching the surface evaporates, leaving a salt-deposit typical of saline soils, it brings salt to the surface through capillary rise and subsequent evaporation, leading to clearance of vegetation and general lack of deep rooted trees plants consequently reducing yields. These soils need attention for their management and reclamation (Shahid and Rahman, 2016).

Application of organic matter (such as manures, compost can both ameliorate and increase the carbon stocks and fertility of saline soils, Research interest on biochar as a Carbon-rich organic soil amendment has been shown to alter and improve physical, chemical, and biological properties of soils and as a result increase plant productivity and enriching the soil microbial community (Woolf et al., 2010; Lehmann and Joseph, 2012; Schulz et al., 2013; Khorram et al., 2016). Yang et al., 2018 revealed that organic soil amendments decline soil pH, enrich soil with organic matter, alter soil enzyme activities of coastal saline soil.

Biochar is gaining interest as a sustainable approach for improving the physicochemical properties of non-saline and non-alkali soils. Moreover, biochar and compost could positively affect the soil quality, leading to possible higher plant growth and crop yields, especially for poor soils with low organic carbon and high nutrient leaching (Baronti et al., 2010, 2014; Velli et al., 2021). The benefits of biochar incorporation on reclamation of degraded lands especially salt-affected soils is scant, and to date, most studies have evaluated biochar use only in none salt-affected soils (Amini et al., 2016). short-term beneficial effects of residual sulfur-enhanced biochar combined with effective microorganisms on peppers can be attained in high salinity soil (Abd El-Mageed et al., 2020). Biochar can adsorb Na^+ by increasing soil cation (e.g., Na^+) exchange capacity leading to declining Na^+ taken up by plants and alleviating the effect of soil salinity on plant growth and physiology. Biochar and compost can improve the soil physio-chemical and biological properties, considerably increased available phosphorus, mineral nitrogen and cation exchange capacity in the soils and microbial activities (Mensah and Frimpong, 2018; Liang et al., 2021). Mixture of gypsum and sulfur in the percentage proportion 50:50 with Acidithiobacillus were attained the best results on crop growth and nutrient uptake (Stamford et al., 2015).

Soil salinization and land degradation are the most serious and extensive environmental problems in Ismailia governorate area in Egypt. The underflow and agricultural drainage water drain upward towards low wetlands and surface water. Soil types, level of water table, waterlogging, salinization and underground water flow are considered a crucial environmental factors for future development strategy in this area (Moheb et al., 2015).

The olive tree, has moderately salt tolerance, could be irrigated with water containing 3200 mg/L of salt (ECw of 5 dS/m) (Chartzoulakis, 2011). (Aragüés et al., 2004) indicated that salinity and waterlogging (hypoxia) stresses are detrimental to the growth of olive trees, decline its salinity tolerance. Low soil infiltration rate, high penetration resistance and shallow water table result in restricted salt leaching.

It was hypothesized that the observed increases in olive yield (if any) would be related to (1) the significant soil reclamation and improvement of soil physical and chemical properties, (2) higher vegetative growth and nutritional state of trees. For this purpose, soil hydrophysical characteristics (soil water retention and soil water transmission) and plant growth (shoot extension, number of leaves/shoot and leaf nutrients), and fruit yield (fruit weight, length, width, volume, pulp/seed ratio, and oil content) were studied during two growing seasons (2019 & 2020) in a field experiment at a private orchard located at Ismailia Desert, Egypt.

Materials and methods

Experimental conditions and trial design

This study was conducted at a private orchard located at Ismailia Desert 30°39'13.4"N 32°18'36.5"E (Northeastern about 16 Km from Ismailia), Egypt during two successive seasons 2019 and 2020 on 10-year-old "Picual" olive (*Olea europaea* L.) trees planted at 4 x 5 m (210 trees/ fed) grown in loamy sand soil under drip irrigation. The chemical and mechanical properties of soil are presented in Table (1).

Fig.1 Ismailia location and studied area maps in Egypt (Google earth, 2021)

Table 1. Soil physical and chemical properties of the olive farm before applying studied treatments.

<table>
<tr><td colspan="7">Particle size distribution (%)</td></tr>
<tr><td colspan="2">Sand</td><td colspan="2">Silt</td><td>Clay</td><td colspan="2">Texture</td></tr>
<tr><td colspan="2">82.3</td><td colspan="2">8.6</td><td>9.1</td><td colspan="2">loamy sand</td></tr>
<tr><td colspan="7">Chemical soil characteristics</td></tr>
<tr><td colspan="2">pH (1:2.5)</td><td colspan="2">EC dS-1
(1:5)</td><td>N
ppm</td><td>P
ppm</td><td>Organic matter %</td></tr>
<tr><td colspan="2">8.19</td><td colspan="2">1.23</td><td>53.3</td><td>22.4</td><td>0.60</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td colspan="4">Soluble cations (me/l)</td><td colspan="3">Soluble anions (me/l)</td></tr>
<tr><td>Ca++</td><td>Mg++</td><td>Na+</td><td>K+</td><td>CO3--+HCO3-</td><td>Cl-</td><td>So4--</td></tr>
<tr><td>2.7</td><td>1.3</td><td>7.5</td><td>1.0</td><td>1.0</td><td>10.0</td><td>1.5</td></tr>
<tr><td colspan="7">Hydro-physical characteristics</td></tr>
<tr><td>Bulk density g cm-3</td><td>Total porosity %</td><td>Saturation %</td><td>Field capacity %</td><td>Wilting percentage %</td><td>Available water %</td><td>Hydraulic conductivity m day-1</td></tr>
<tr><td>1.58</td><td>40.27</td><td>21.8</td><td>14.5</td><td>5.4</td><td>9.1</td><td>4.08</td></tr>
</table>

Irrigation water

The source of irrigation is an aquifer well in the studied area. Regarding its water quality, it was classified as acute problem water (Ayers and Westcot, 1985).

Table 2. Irrigation water analysis.

Properties	pH	EC dSm-1	SAR	Soluble cations (me/l)				Soluble anions (me/l)			
				Ca+2	Mg+2	Na+	K+	CO3-2	HCO-3	Cl -	SO4-2
Value	7.84	6.27	11	15.0	10.5	42.6	0.20	-	1.9	43.5	22.9

Soil reclamation and olive tree Fertilization

Because studied area was conducted in salt affected soil using saline ground water for irrigation under shallow water table condition (0.5-2.0 m soil depth) according to (Ismail, 2015; Moheb et al., 2015; El-Sayed, 2018), the reclamation process (SGF) is a must for all treatment to avoid hazard of salinity of water and soil, therefore sulfur (S) at 250 g/ tree, gypsum at 250 g/ tree and 10 kg/tree of farmyard manure (Table 3) (F) were added to all treatments in December (Hemdan et al., 2017). The trees were annually fertilized in different rates as 50 % of recommended doses by the Ministry of Agriculture and Land Reclamation in Egypt for the new reclaimed sandy soils; 1.0 Kg/ tree calcium superphosphate (15.5% P2O2). Also, 1.75 Kg/ tree ammonium sulfate (20.6% N) and 0.75 Kg/tree of potassium sulfate (48% K2O) were added in three equal doses at February, April and August.

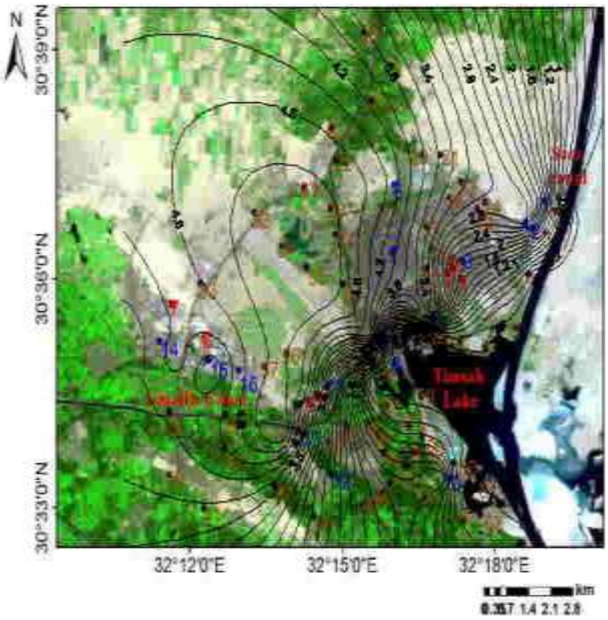

Figure.2. Water table map of Ismailia area in 2004 (Moheb et al., 2015)

Design of experiment and Treatments

The experiment followed a complete randomized block design on 24 trees as 6 treatments were applied. Each tree was considered a replicate, four replicates trees per each treatment as follow:

1- SGF+100% compost (Com) (5 Kg/tree).

2- SGF+100% biochar (Bc) (5 Kg/tree).

3- SGF+25% compost +75% biochar.

4- SGF+50% compost +50% biochar.

5- SGF+75% compost +25% biochar.

6- Control (SGF+ none biochar or compost).

The reclamation process were by SGF amendments where S: Sulfur, G: Gypsum and F: Farmyard manure, and improvement process were by biochar (Bc) and/or compost (Com) as soil amendments were mixed and incorporating in the soil trenches close to the root system under the tree canopy in December of both seasons; soil amendments were applied up to 40 cm depth of soil layer and in a 0.5m radius of each olive tree and followed by irrigation. The physical and chemical properties of compost and biochar are shown in Table (4).

Table 3. Farmyard manure analysis

Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)	Organic matter (%)	Organic carbon (%)	C:N soils (%)	pH (1: 2.5)	E.C (ds / m^{-1})
0.45	0.315	1.065	42.505	24.155	24.25:1	7.835	4.985

Table 4. Physical and chemical properties of the compost.

Properties	Compost	Biochar
Bulk density (kg m-3)	539	380
Moisture content (%)	35.4	10.63
Porosity (%)	69.85	63.5
pH	7.2	8.86
EC (dS m-1)	2.9	2.175
Total organic carbon (%)	21.35	85.5
Total organic matter (%)	38.5	2.04
Total nitrogen (%)	1.25	1.1
Total phosphorus (%)	0.54	0.11
Total potassium (%)	0.78	0.75

Irrigation Water Requirements

Olive trees are irrigated using the drip irrigation system as 4 emitters per tree, emitter charge is 4 litre/hour , reference evapotranspiration (ET_o) was calculated using meteorological data at Ismailia in Egypt according FAO Penman Monteith equation (Allen et al., 1998) for both seasons 2019 and 2020.

The irrigation water applied 3333 m^3/ fed calculated according to the following equation (Doorenbos, 1992):

$$IW= ((ET_O*K_C*K_r*I)/Ea* (1-LR))*4.2$$

Where IW is irrigation water requirement m^3/ fed., ET_o is reference evapotranspiration, Kc is crop coefficient = 0.7,, K_r is reduction factor= 0.70, I = irrigation interval, Ea is irrigation efficiency = 90%, LR is leaching requirement = 20% of the total water amount.

Plant growth parameters

At mid-July of every season shoot extension (cm) was determined as the average of twenty shoots per replicate tree at the beginning of the experimental season and at maximum growing spring cycle. The average number of leaves was counted in ten shoots per replicate from the applied treatments.

Leaf nutrient contents

Twenty leaves were taken in late August from ten shoots randomly distributed around the tree/ replicate. Samples were dried at 70°C till constant weight and finely ground and digested in a mixture of perchloric: sulphuric acid (1:3 v/v) for determination of the following nutrient elements: total nitrogen (%) using the modified micro – kjeldahl method as lined by (Cottenie et al., 1982), phosphorus (%) was estimated as described by (Chapman and Pratt, 1961), potassium, magnesium, and calcium were measured photometrically as (%) using flame photometer outlined by (Cottenie et al., 1982). Iron, zinc, and manganese as ppm were spectrophotometrically determined using atomic absorption spectrophotometer (PerkinEl-mer 100 B).

Yield (Kg/tree), fruit characteristics and fruit oil content (%)

At maturity stage (early October), fruits of each replicate tree were separately harvested, then weighted and yield as Kg/tree was estimated. For characterizing olive fruit, samples of 10 fruits from each replicate tree i.e. 40 fruits from each of the applied treatments were picked randomly to determine: average fruit weight (g), length (mm), width (mm) volume (cm^3), seed weight (g), and pulp/seed ratio. Fruit oil content as a dry weight was determined according to (AOAC, 1995) method by extracting the oil from the dried flesh fruit with soxhlet for extraction apparatus using petroleum ether (40/60 °C) of boiling point.

Determination of Studied Soil Properties

After harvesting of each growing season, soil samples (30 cm depth) were taken from each plot to determine the following soil physical and hydrophysical properties: Moisture retention values over the range from 0.0 to 15 bars were carried out using the pressure membrane apparatus (Loveday, 1974). Water transmitting properties: Saturated hydraulic conductivity was determined under constant head (m day^{-1}) as describing by(Singh, 1980):

K= HAT/QL

Where; K: hydraulic conductivity coefficient, Q: volume of water being passed through the soil column at time (T), L: length of soil column, H: hydraulic head, A: cross section area. Mean diameter of soil pores (μm) was calculated using the equation described by (Dielman and De Ridder, 1972) as follows:

d= (6.177637√K

Where; d: soil mean pore diameter in microns (μ), K: hydraulic conductivity in m day^{-1}(for water at 20°C).

Statistical analysis

The collected data on various parameters were statistically analyzed using variance (One-Way ANOVA) according to Gomez and Gomez (1984), using CoStat Software Program Version 6.303 (2004) and LSD at 0.05 level of significance was used for the comparison between means.

Results and Discussion

Olive trees are considered moderately tolerant to salinity; irrigation saline water has not the negative effects on olive tree growth and yield, proper management under drip irrigation system allows using saline irrigation water for a long time denied influence on growth and yield of olive trees (Melgar et al., 2012).

Using drip irrigation system with higher salinity water often attains better yield than other irrigation methods, attributed to the continuous high soil moisture in the root zone maintained by irrigation replenishing the plant water consumption (Ayers and Westcot, 1985) .

Effects of biochar and compost with SGF reclamation amendments on olive tree growth parameters, yield components and yield

Application of reclamation process SGF (sulfur, gypsum, farmyard manure) with biochar and compost, alone or in combination showed the obvious effects on tree growth and yield components and yield during the two seasons.

Shoot extension and number of leaves

The results revealed that the shoot extension and number of leaves/ shoot were significantly affected by the application of all treatments during the two seasons (Table 6). The application of compost at 25% + biochar at 75% achieved the maximum shoot extension in both seasons (27.67and 30.00 cm), respectively. While, the application of compost at 100% achieved the minimum shoot extension (21.57 and 23cm), which was not significantly different from the control treatment in both seasons (22.33 and 23.50 cm), respectively.

With respect to number of leaves per shoot, the results showed that application of biochar at 100% recorded the larger number of leaves/shoot followed by compost at 25% + biochar at 75% in both seasons (50 & 51and 44.67 & 45.22 leaves/shoot), respectively whereas the control treatment recorded the lowest number of leaves/shoot in both seasons (36 and 37 leaves/shoot), respectively (Vaccari et al., 2015). (Mensah and Frimpong, 2018) found that application biochar and/or compost improved soil quality and increased the plant height, stem girth, dry matter and maize yield.

Table 6. Effect biochar and compost with reclamation process (SGF) on shoot extension, number of leaves

Treatments	Shoot extension (cm)		No. of leaves/shoot	
	First season	Second season	First season	Second season
SGF+100%Com	21.57b	23.00c	36.33b	37.11e
SGF+100%Bc	24.0ab	26.00b	50.00a	51.00a
SGF+25%Com+75%Bc	27.67a	30.00a	44.67ab	45.22b
SGF+50%Com+50%Bc	27.17a	26.72b	37.33b	38.11d
SGF+75%Com+25%Bc	23.5ab	23.11c	40.33ab	41.11c
Control(SGF)	22.33b	23.50c	36.00b	37.00e

*Where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and Bc: Biochar

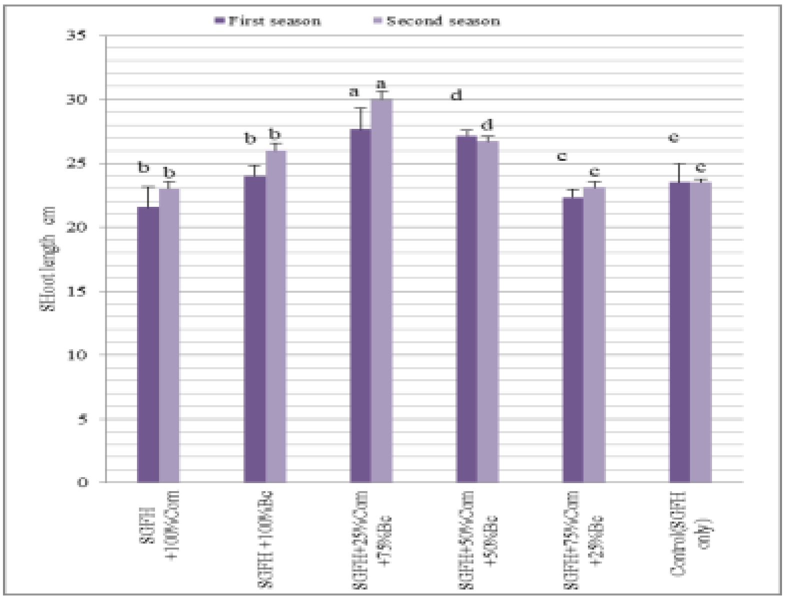

Figure 3. Effect biochar and compost with reclamation process (SGF) on shoot length of olive tree, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar, Different letters in the figure show significant differences according to LSD test (P= 0.05).

Plant Nutrients Analysis

The content of olive leaves of macro and micro nutrients was affected as a result of adding SGF, compost and biochar during the two seasons of the study. Based on Table 7, it observed that the plant nutrients content in olive leaf samples (N, P, K, Ca, Mg, Fe, Cu, Zn and Mn) was differed in their response to different applications and there was no clear trend among biochar and compost, alone or in combination during the two seasons of study.

The nitrogen content was significantly affected by the different treatments; application of SGF + compost at 25% + biochar at 75% recorded the high significant values (2.9 and 2.87%) respectively in both seasons. While the compost at 75% + biochar at 25% during the first season and the control treatment during the second season recorded the less significant for nitrogen content.

With regard to the phosphorous content of leaves, in the first season treatment with SGF + compost at 50% + biochar at 50% recorded the highest significant value followed by compost at 25% + biochar at 75% (0.53 and 0.45 %) respectively, on the contrary treatment with SGF + biochar at 100% recorded the lowest significant values (0.36%). While in the second season, no significant differences were observed between the different treatments in the phosphorous content of leaves (Table 7).

Potassium content of leaves was not significantly affected by different treatments in the first season, while during the second season application of SGF + compost at 100% recorded the highest significant value followed by (SGF + compost at 25% + biochar at 75%) and (SGF + compost at 50% + biochar at 50%) by 1.20, 0.99 and 0.90%, respectively without significant difference between them. On the contrary, the control (SGF only) treatment recorded the least significant values (0.49%) in the potassium content of the leaves.

As for the calcium content of leaves, treatment with SGF + compost at 75% + biochar at 25% recorded the highest significant value (2.15 and 2.18%) in the first season and the second season, respectively. While the treatment with SGF + biochar at 100% recorded the lowest significant values (1.45 and 1.50%), respectively during the two studies seasons (Table 7).

This may be due to that soil nutrient status is improved after combined application of biochar and compost Biochar contains essential macronutrients and micronutrients, including N, P, K and Ca, can recycle C and P, whilst composting can recycle C, N, P, and K, so a blend of both resulted in the recycling of plant macro and micronutrients, accordingly, the biochar-compost mixture, which is capable of increase C, N, P, K and CEC in soils, can apply the same role as chemical fertilizers (Guo et al., 2020). As revealed by (Oldfield et al., 2018) biochar contains essential macronutrients and micronutrients, including N, P, K and Ca, which can be used by plants as a result of its higher nutrient retention and sorption capacity (Manolikaki and Diamadopoulos, 2016 (Mensah and Frimpong, 2018)

Table 7. Effect of biochar and compost with reclamation process (SGF) on leaf macro and micro nutrients content

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
First season									
SGF+100%Com	2.4b	0.40c	1.15a	1.55c	0.21b	138.00a	6.00a	18.90d	29.00c
SGF+100%Bc	2.1c	0.36d	0.68a	1.45d	0.24a	102.60c	6.00a	21.20b	46.00a

SGF+25%Com+75%Bc*	2.9a	0.45b	0.98a	1.55c	0.24a	121.50b	3.00b	20.30c	49.00a
SGF+50%Com+50%Bc	2.4b	0.53a	0.80a	1.65b	0.21b	102.60c	6.00a	21.60a	49.00a
SGF+75%Com+25%Bc	1.8d	0.42c	0.55a	2.15a	0.25a	121.50b	7.50a	15.70e	46.00a
Control(SGF)	1.9cd	0.41c	0.47a	1.55c	0.20b	97.00d	6.00a	21.20b	39.00b
Second season									
SGF+100%Com	2.63ab	0.52a	1.20a	1.57c	0.25abc	141.00a	8.40a	19.27b	31.33c
SGF+100%Bc	2.3b	0.37a	0.72c	1.50d	0.26ab	111.00c	8.60a	22.47a	52.33ab
SGF+25%Com+75%Bc	2.87a	0.59a	0.99b	1.60c	0.26ab	125.00b	8.30a	20.87ab	54.67ab
SGF+50%Com+50%Bc	2.67ab	0.55a	0.90b	1.67b	0.22bc	106.67c	7.27a	22.07a	48.67abc
SGF+75%Com+25%Bc	1.9c	0.45a	0.65cd	2.18a	0.27a	126.67b	8.83a	16.80c	65.67a
Control(SGF)	1.8c	0.41a	0.49d	1.56c	0.21c	98.67d	6.60a	22.47a	41.67bc

*Where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters within each column indicate significant differences according to LSD test (P= 0.05).

Magnesium content of leaves was significantly affected during the two seasons, treatment with SGF + compost at 75% + biochar at 25% recorded the highest significant value (0.25 and 0.27%), respectively. While the control treatment recorded the lowest significant values (0.20 and 0.21%), respectively during the two study seasons. Iron content of leaves was significantly affected by different treatments during the two seasons. Application of compost at 100% recorded the highest significant value (138 and 141 ppm) in the first and the second season, respectively. While the control treatment recorded the lowest significant values (97 and 98.67 ppm) during 2019 and 2020 seasons, respectively.

Table (7) shows that biochar with compost improved leaves content from copper, zinc and manganese while SGF amendments with compost increased the iron in the first and second seasons. Regarding the copper content of leaves, the statistical analysis showed a slightly significant difference between treatments during the first season of the study, whereas in the second season there were no significant between treatments. Concerning the zinc content of leaves, treatment with SGF + compost at 75% + biochar at 25% recorded the lowest significant values (15.70 and 16.80 ppm) during the first and the second seasons of the study, respectively. At the same time, there were slightly significant differences between other treatments including the control treatment. For the manganese content of leaves, treatment with SGF + compost at 100% recorded the lowest significant values (29 and 31.33 ppm) during the two seasons, respectively. In the second season, treatment with SGF + compost at 75% + biochar at 25% recorded the highest significant value of manganese (65.67 ppm).

Addition of biochar to the loamy sand soil increased gross nitrification rates, improved soil N transformations in the short term, in so increasing soil N bio-availability (Nelissen et al., 2012). Wu et al., 2020 showed that applying biochar to dairy manure and corn straw composting changed the diazotroph (N fixing) community structure, moreover, boosted the relations between temperature, ammonium and nitrate and diazotroph community and their influence on nitrogen transformation. Biochar short-term addition to the sandy soils increased soil nutrient availability and uptake bean plant where increased soil available Fe, Mg, Zn, also soil available ammonium by 45–54% in the rooting zone over mid-season, mineral N by 48–110%, and citrate extractable P by 29% and thus enhanced soil ammonium and nitrate, and P retention by 33%, 53% and 39% respectively (Gao et al., 2016).

Yield, fruit quality and oil content

The total fruit yield affected significantly by the all application treatments including the control in the two seasons of the study (Table 8, Fig. 4). The fruit yield ranged from (17.33 kg/tree to 40.17 kg/tree) and the maximum yield (38 and 40.17 kg/tree) was obtained from the treatment of SGF + compost at 25% + biochar at 75% during the both seasons, respectively. While, the minimum yield (17.33 and 21 kg/tree) was obtained from the application of SGF + compost at 50% + biochar at 50% in 2019 and 2020 seasons, respectively. The fruit weight, width, pulp/seed ratio and oil content were also influenced significantly as a result of all treatments during both seasons (Table 8, Fig. 5). The application of SGF + compost at 25% + biochar at 75% showed the highest values (8.26 g, 2.31 cm, 89.83 and 21.18 %, respectively) in the first season and (8.07g, 2.35 cm, 89.22 and 21.67%, respectively) in the second season. While, both the fruit volume and length was not influenced significantly, and the application of SGF + compost at 75% + biochar at 25% recorded the lowest seed weight in the two seasons (0.74 and 0.79 g) in the first and second seasons, respectively.

Table 8. Effect of biochar and/or compost biochar and compost with SGF soil amendments on yield, fruit characteristics

Treatments	Yield (Kg/tree)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit volume (cm^3)	Seed weight (g)	Pulp/seed ratio	Fruit oil (%)
First season								
SGF+100%Com	32.33b	7.31abc	2.72a	2.24ab	2.54a	0.89ab	87.82ab	16.24c
SGF+100%B	32.67b	6.45c	2.58b	2.17b	2.29a	0.88ab	86.36b	19.39ab
SGF+25%Com+75%B	38.00a	8.26a	2.74a	2.31a	2.64a	0.84ab	89.83a	21.18a
SGF+50%Com+50%B	17.33d	7.82ab	2.75a	2.26ab	2.64a	0.94a	87.98ab	16.29c
SGF+75%Com+25%B	27.33c	6.8bc	2.56b	2.19b	2.35a	0.74b	89.12ab	18.26bc
Control(SGF)	27.67c	7.61ab	2.73a	2.20b	2.65a	0.85ab	88.83ab	18.18bc
Second season								
SGF+100%Com	34.17b	8.00ab	3.50a	2.25b	3.50a	0.92a	88.5b	17.88bc
SGF+100%B	36.00b	7.37ab	2.67b	2.19c	2.67b	0.90a	87.79bc	20.49ab
SGF+25%Com+75%B	40.17a	8.07a	2.87b	2.35a	2.87b	0.87ab	89.22a	21.67a
SGF+50%Com+50%B	21.00d	7.83ab	2.80b	2.28b	2.80b	0.97a	87.61bc	17.29c
SGF+75%Com+25%B	26.67c	6.77ab	2.76b	2.20c	2.77b	0.79b	88.33bc	18.71bc
Control(SGF)	29.00c	6.37b	2.60b	2.22bc	2.60b	0.87ab	86.34c	17.79bc

*Where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters within each column indicate significant differences according to LSD test (P= 0.05).

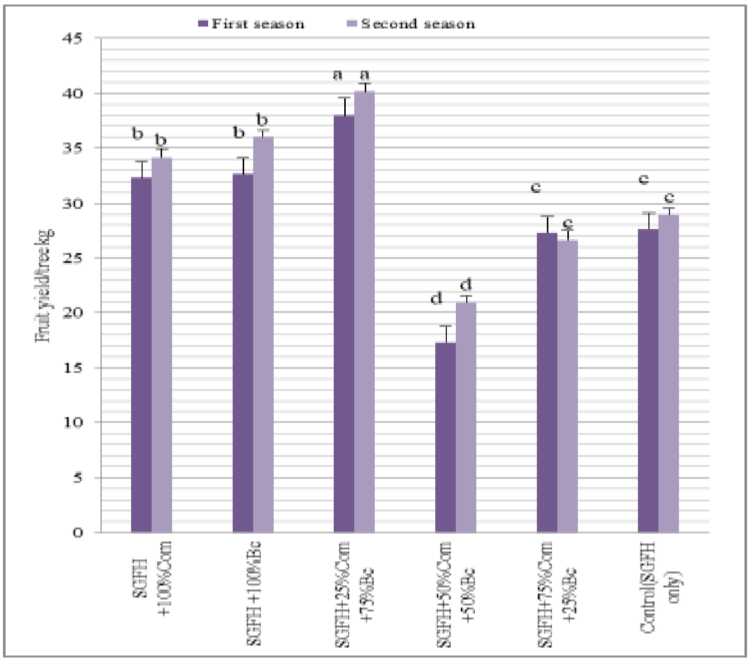

Figure 4. Effect of biochar and/or compost with reclamation process (SGF) on fruit yield/ tree, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

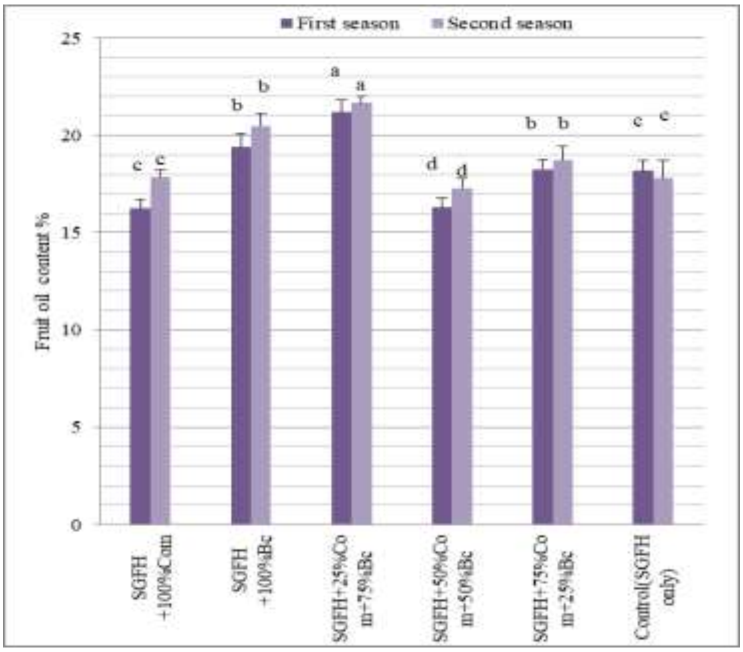

Figure 5. Effect of biochar and/or compost with reclamation process (SGF) on olive oil content, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

Paoletti et al., 2021 observed that the fruit presence has effects on photosynthesis and on vegetative growth as a result of the functional relationship between photosynthesis in the leaves and carbohydrate partitioning for fruits and shoots growth. (Rosati et al., 2018) showed that competition for resources i.e. nutrient, water or other stress played a major role in determining tree growth, photosynthesis was enhanced at increasing fruit load, fruit partition is associated with tree vegetative growth.

Erel et al., 2008 found that each of the macronutrients plays a fundamental role in processes affecting tree productivity. A higher plant N and P concentration is higher fruit load by boosting flowering level and fruit set. While plant K concentration has positive effect on flowering, but not on fruit set. (Proietti et al., 2006) when treatments were applied at the initial stage of fruit development fruit growth increased as the leaf/fruit ratio increased. Oil content and a dry matter were not markedly influenced by the leaf/fruit ratio. The plentiful availability of assimilates could be cause earlier fruit ripening parallel retard fruit senescence.

Applying biochar to soils alleviated salt stress and augmented crop yields (Lashari et al., 2013; Guo et al., 2020). Bashir et al., 2021 revealed that the role of the S assimilation pathway plays a key role in olive plants in alleviating the adverse effects of salt stress conditions. Overexpressing osmotin gene was coped with increasing salt stress by the stimulation of S metabolism; predominantly increase in O-acetyl serinelyase (the last enzyme of the s assimilation pathway) activity.

Effects of biochar and compost with SGF soil amendments on soil properties

Salinity distribution is well consequent on the water table, where salinity increases. Also, the hypothetical salt accumulations change from north to south Ismailia in Egypt according to metasomatic processes. The clay intercalations are generally existed towards south and north. In the narrow strip adjacent to the Ismailia canal in Egypt, the depth to the groundwater is highly affected by the surface water running in the canal (Ismail, 2015). The high salinity is more noticeable in the groundwater of the eastern parts. Chloride water type is 86%, while the bicarbonate is 14% only. Increasing salinity and the change of water detected that the groundwater has been affected by cation exchange processes with mixing of Nile water and locally infiltrated fossil water during the Holocene periods(Ismail, 2015).

Soil and water management is a must to combat soil salinity as water flow governs the salt transfer from the saline water table towards the surface. Water flow in soil mainly depends on soil hydraulic conductivity. The rate of soil salinity accumulation from an uncontrolled shallow water table will depend upon irrigation management, salt concentration and depth of the groundwater, soil type, and climatic conditions (Ayers and Westcot, 1985).

Effects of biochar and compost with SGF reclamation amedments on soil water retention

Data shown in table (9) and illustrated in figures (6 and 7) indicated that saturation percent, field capacity, wilting point and available water of the studied soil were simultaneously enhanced by saline soil reclamation and improvement processes including SGF amendments (sulfur, gypsum and farmyard manure) and compost and/or biochar application. Increasing biochar to 75 % and decreasing compost to 25% with SGF amendments (sulfur, gypsum and farmyard manure) improved the field capacity and soil available water for plant and achieved the best olive fruit yield. Similar patterns were observed by Razzaghi et al., 2020 who showed that soil field capacity, wilting point and available water significantly increased using biochar for the coarse-textured soils over than the medium-textured.

Obtained results could be explained that biochar and compost as soil amendments increased the micro pores i.e. water holding pores and none useful pores in the expense of macro ones i.e. drainable pores. The increments in water storage pores are the increments in water retention in sandy soil under arid conditions.

The soil moisture at soil saturation for applying SGF amendments only was 39.19 and 39.78 % for both of seasons, whereas adding biochar at 75 % and compost to 25% with SGF amendments were between and 49.73 and 49.99 %. This improvement in the soil saturation may be due to an increase in the amount of macropores and thus soil total porosity (Arthur et al., 2011; Suliman et al., 2017). This finding indicates that biochar and compost application attained obvious difference in the soil moisture retention. However, higher in soil saturation percentages is compatible with higher values for soil field capacity and soil wilting point will benefit crops capacity.

Organic matter i.e. farmyard manure and compost inputs particularly in the sandy soil may hold water moisture, thus affects directly on soil water retention, indirectly on soil structure. The higher in organic matter is almost the double higher in soil available water (Hemdan, 2014).

The increment in soil field capacity by adding biochar at 75 % and compost to 25% with SGF amendments summed to 32.8 and 32.76 %, the same is true for the available water, relevant values are 24.57and 24.37% during both of seasons. This may be due to that biochar acts as a catalyst, increasing nutrient uptake and water consumption by plant. In comparison to other soil amendments, biochar's large surface area and porosity allow it to adsorb or retain nutrients and water while also supplying a habitat for beneficial microbes to thrive (Hunt et al., 2010; Jindo et al., 2020).

Table 9. Effect biochar and compost with reclamation process (SGF) on soil water retention

Treatments	Saturation %	Field capacity w/w	Wilting point w/w	Available water w/w
First season				
SGF%100+ Com	44.23b	29.56c	7.66b	21.9c
SGF%100+ Bc	45.37b	30.5b	7.8b	22.7b
SGF+25%Com+75%Bc	49.73a	32.8a	8.23a	24.57a
SGF+50%Com+50%Bc	36.15e	21.23f	6.53d	14.7f
SGF+75%Com+25%Bc	42.48c	26.6d	7.2c	19.4d
Control(SGF only(	39.19 d	24.53e	7.13c	17.4e
Second season				
SGF +100%Com	43.78c	28.8c	7.98ab	20.82c
SGF +100%Bc	46.07b	30.7b	7.8ab	22.9b
SGF+25%Com+75%Bc	49.99a	32.76a	8.4a	24.37a
SGF+50%Com+50%Bc	36.52e	21.63f	6.4d	15.23f
SGF+75%Com+25%Bc	42.47c	26.5d	7.6bc	18.9d
Control(SGF only)	39.78d	24.46e	7.1c	17.37e

*Where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters within each column indicate significant differences according to LSD test (P= 0.05).

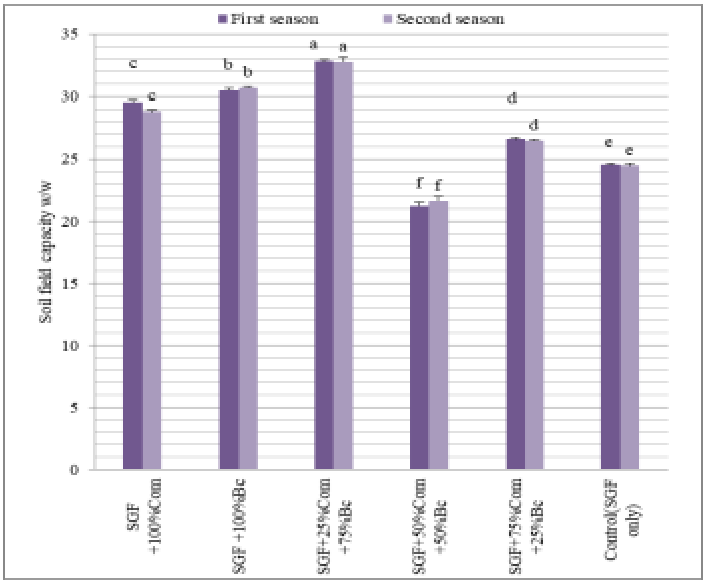

Figure 6. Effect biochar and compost with reclamation process (SGF) on soil field capacity (w/w), where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

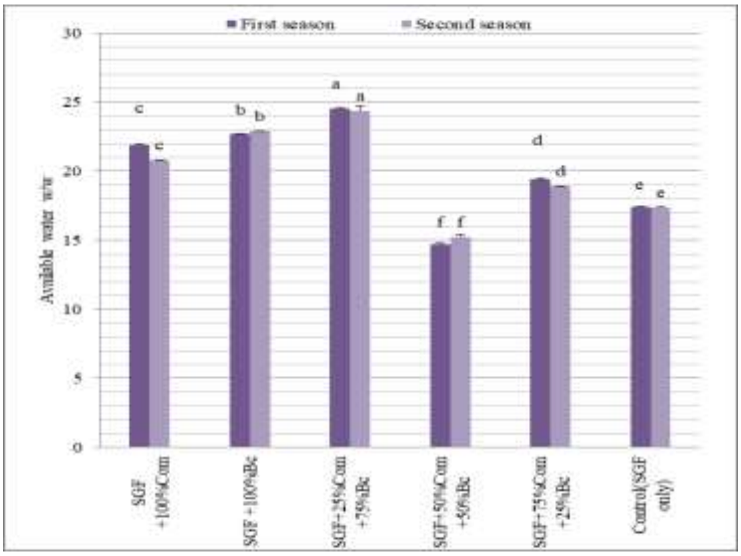

Figure 7. Effect biochar and compost with SGF soil amendments on soil available water (w/w), where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

Increase in field capacity in coarse- and medium-textured soils may be explained as biochar increasing soil micropores owing to the high internal microporosity of biochars and because smaller biochar particles size can fill interpores between coarse soil particles, which decreases the average pore size (Liu et al., 2017; Razzaghi et al., 2020). Small soil pores are able to hold more water against gravity than large soil pores (Blanco-Canqui, 2017; Rehman et al., 2021). Suliman et al., 2017 noticed that the total acidic functional groups of biochar surface significant correlated with water contents which in turn correlated with bulk densities of amended soil with biochar at different matric potentials.

Biochar incorporation in soil can alter soil hydrological properties, including these water retention variables (Peake et al., 2014) and increased the average field capacity and wilting point in the coarse- and medium-textured soil, but not in the fine-textured soils. The increased WP in the coarse- and medium-textured soil may be ascribed to increased specific surface area with biochar application. The large surface area of smaller biochar particle size can increase the specific surface area of coarse-textured soils to increase water retention (Zhang et al., 2016). (Ulyett et al., 2014) showed that biochar increased water retention for the soil treated with compost and the soil treated with mineral nitrogen fertilizer and this is attributed to its porous structure.

Effects of biochar and compost with SGF reclamation amendments on soil water transmission

Although saline sandy soils having low content clay, the clay fraction is dispersed or flocculated attributing the soil solution composition. Therefore irrigation water quality affects soil structure, hydraulic conductivity of soil and hence water flow over the soil profile. The inherent saturated hydraulic conductivity measured was low compared to the values usually observed for sandy soils. (Hammecker et al., 2005). swelling of the clay particles mainly causes a decrease of hydraulic conductivity; dispersion and migration of clay particles into the accompanying pores are the mechanisms responsible for plugging the soil pores through Sodium (Na^{+}) dominated soils reduce saturated hydraulic conductivity by clay dispersion and plugging pores, in dispersion and particles translocation to the deeper layer might have blocked the pores without an electrolyte or Ca^{2+} source that decreased saturated hydraulic conductivity (Pupisky and Shainberg, 1979)

Taking in the account the saturated hydraulic conductivity was determined at the laboratory using tape fresh water. Notable effect was detected in all treatments on the saturated hydraulic conductivity of the saline soil. In detail, increasing the percentage of biochar 75% to 25% compost with SGF amendments significantly changed the saturated hydraulic conductivity by 60.59, 30.31 % and mean diameter of soil pore by 24.40, 14.17 % for the percentage over using SGF amendments only, respectively (table 12 and fig. 8).

Biochar and/or compost treatments with SGF amendments (sulfur, gypsum, farmyard manure) continue to have significantly effect on saturated hydraulic conductivity and mean diameter of soil pores than SGF soil amendments only during both seasons. Saturated hydraulic conductivity and mean diameter of soil pore measured in the studied treatments. The lowest values were obtained using SGF soil amendments only, while the highest values were recorded with the combination of SGF amendments, 50% of biochar and 50 % of compost with receding ground water table down through the summer season, this might be led to loss both of nutrients and salts by leaching away from plant root zone and clearly decreased olive fuit yield. While the best values of saturated hydraulic conductivity (15.61 and 16.98) which attained the highest olive fruit yield were 75% of biochar and 25% of compost treatment with SGF amendments. This might be owing to biochar have hydrophilic surfaces allowing water to infiltrate into the biochar intrapores, biochar hydrophilicity may be attributable to increase in the number of oxygen containing functional groups on biochar surfaces (Liu et al., 2017; Razzaghi et al., 2020).

Table 12. Effect biochar and compost with SGF amendments on soil water transmission

Treatments	Saturated hydraulic conductivity m/day		Mean diameter µm	
	First season	Second season	First season	Second season
Com%100+ SGF*	13.19d	14.15d	22.44d	23.24d
Bc%100+ SGF	14.33cd	15.77c	23.38cd	24.54c
SGF+25%Com+75%Bc	15.61c	16.98b	24.40bc	25.45b
SGF+50%Com+50%Bc	23.49a	21.92a	27.40b	28.92a
SGF+75%Com+25%Bc	19.68b	18.78b	29.94a	26.77b
Control(SGF only)	9.72e	13.03d	19.25e	22.29e

*Where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters within each column indicate significant differences according to LSD test (P= 0.05).

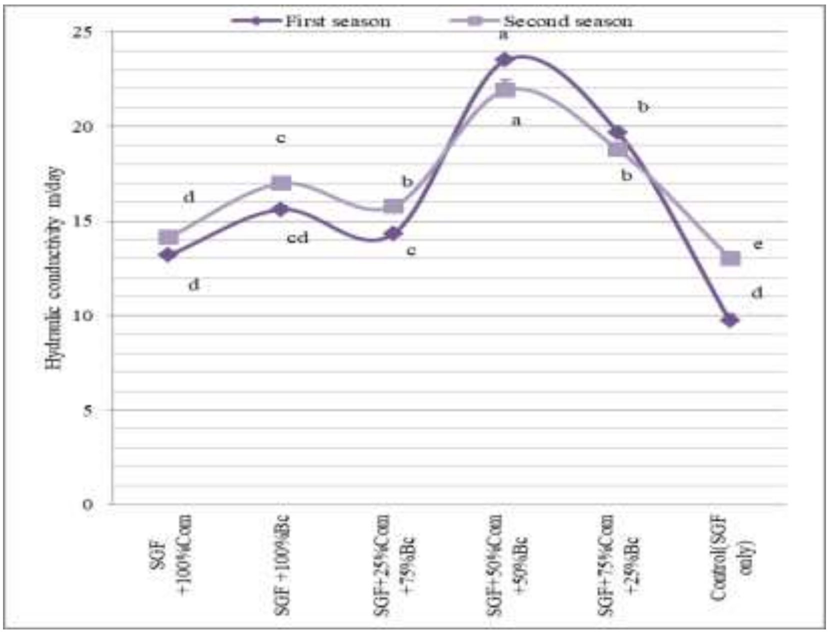

Figure 8. Effect biochar and compost with SGF soil amendments on soil hydraulic conductivity, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

In this investigation, because of olive trees grown in the salt affected soil with saline water were irrigated by 100 % of calculated water requirement, accompanying with gradually saline water ground water table rising to the plant root zone during the winter season and receding down in the soil during the summer season, increasing compost amount at the expense of biochar amount with SGF reclamation amendments (sulfur, gypsum and farmyard manure) causes the following problems:-

a) Saline water irrigation with applying compost with SGF amendments in saline soil result in organic element mineralization, This water would be lost from the soil either by evaporation or by transpiration, gradually salt and nutrient accumulated in the root zone and thus increased in osmotic potential, insufficiency in nutrient availability for plant, this is amplifying the energy of nutrient uptake of plant and hence deficiency in olive fruit yield. Salinity largely affects the plant water uptake through increased water potentials; however it also can affect the hydrologic processes of soil infiltration and redistribution through chemical induced changes of soil structure and aggregation(Zhang and Dawes, 1998; Saxton and Rawls, 2006).

b) Saline water irrigation with applying SGF amendments with 50 % compost and 50 % biochar or with 75 % compost and 25 % biochar in saline soil improved vegetative growth and plant nutrient uptake during the vegetative stages of olive trees during winter season through the soil mineralization of the organic elements. Excess irrigation water with organic amendments led to increasing vegetative growth stage of olive trees at the expense of the flowering stage and fruit maturity thus decrease fruit yield. During spring season with water table escalating led to in turn partially redox condition leading to loss of important elements from the soil, excess of water and organic amendments in the soil environment with rising ground water table somewhat is mostly threatening to aerobic bacteria, and may be cause waterlogging in olive root zone accompanied by anaerobic conditions with poor drainage network in the studied area (Dwire et al., 2006). Under waterlogged conditions damage through lack of oxygen and fungal diseases increases sharply (FAO, 2020). On the contrary during summer season, loss of nutrients by leaching with water table receding down thus obvious decrease in olive fruit yield (Dwire et al., 2006) and therefore saturation hydraulic conductivity increased. (Borowik and Wyszkowska, 2016) unequivocally demonstrated that the soil moisture content is an exceptionally significant factor that changes the biological activity of soil. Li et al., 1997 noted that applying compost and N or P fertilizers at high rates may cause nitrate, ammonium, and phosphate leaching into the groundwater especially in sandy soils and shallow water table.

c) Inadequate drainage causes soil salinity, during summer season, groundwater brings salt to the surface through capillary rise and subsequent evaporation and hence saturation hydraulic conductivity decreased, leading to clearance of vegetation and shortage of tree root consequently reducing yields (Shahid and Rahman, 2016).

Conserving appropriate leaching and preventing soil structure degradation can control soil salinity. However, complex issues the saline soil management depends on soil condition, water quality, irrigation system and crop type. the soil salinity and sodicity problems in the soil-water-plant system are complex (Ezlit et al., 2010).

Jain and Kalamdhad, 2020 depicted that compost have significant effect on soil organic carbon, total nitrogen, and available phosphorus. In laterite soil, the total nitrogen increased more (94%) when applying compost by 30% but more 86% in the alluvial soil adding 20% compost over other treated soils. Ulyett et al., 2014 determined that the increment in cation exchange capacity retained ammonium and reduced nitrification in the soil treated with green-waste compost. Carbon dioxide increased with small contents of ammonium and nitrate when biochar was added. Whereas biochar enhanced nitrification without increased respiration in the soil treated with mineral nitrogen fertilizer. Also, (Jain et al., 2018) noted that adding biochar in composting mixture increased nitrogen transformation and total nitrogen by 45% compared to the other treatments.

In highly managing soil with organic amendments, the infiltration properties are higher than in the low managed soil. Moreover, gypsum (CaSO4.2H2O) application confronts these properties, improves Ks, leach Na^+ and salts by controlling its dispersion through Na^+-Ca^{2+} exchange, hydrolysis of Na^+ through ionic strength (Ahmad et al., 2016; Hammecker et al., 2005; McNeal and Coleman, 1966; Pupisky and Shainberg, 1979). Under soil salinity condition, biochar can increase plant salt tolerance by decreasing plant sodium uptake and increasing plant potassium uptake. This is allied with improving soil properties, accordingly increasing plant water status, nutrient availability, regulating stomatal conductance and phytohormones (Ali et al., 2017). Kanwal et al., 2018 observed that biochar mitigated the negative effects of salinity through increasing leaf water potential and osmotic potential decreasing proline content and superoxide dismutase activity, thus improving crop productivity. Application of different organic amendments to the soil improved its physicochemical properties; mineralized of the important organic elements by soil enzymatic and biological activity (Frankenberger and Dick, 1983; Yuan et al., 2020; Vahedi et al., 2021).

Conclusion

The results reveal the possibility to achieve the best fruit yield of olive trees as an important food oil crop grown in the salt affected soil and irrigated with saline water. Incorporating biochar at 75 % and compost at 25 % with SGF reclamation amendments (sulfur, gypsum, farmyard manure) in the salt affected soil increased soil water retention i.e. field capacity and soil available water, and improved soil water transmission i.e. saturated hydraulic conductivity and mean diameter of soil pore. Therefore using biochar at 75 % and compost at 25 % with SGF amendments enhanced concentration of the plant leaf nutrients, plant growth and olive fruit yield. The combinations of 75 % biochar and 25 % compost with SGF amendments can attain proper saline soil and water management and olive orchard sustainability, and may be suggested for the same condition. Under saline irrigation water and salt affected soil conditions with seasonal ground water table rising, determination the best drip water regime, applicable drainage system accompanied with soil amendments could be recommended.

Conflict of interest

The authors hereby declare that there is no conflict of interest.

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