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# Utilization of Biochar with Some Soil Amendments and evaluation of AquaCrop model under Saline Water and Soil Management at Ismailia Desert, Egypt

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Abstract

This investigation was carried out at Ismailia Desert in Egypt during two seasons 2019 and 2020 to evaluate the effect of biochar or/ and compost with reclamation amendments SGF (sulfur, gypsum, farmyard manure) on soil properties of saline loamy sand soil and olive water productivity of olive trees which irrigated with saline water under groundwater table fluctuation conditions. Simulated olive water productivities were calculated using by Aquacrop model. The results showed that soil organic carbon(SOC) and organic matter were markedly affected by biochar and compost with SGF reclamation amendments. Moreover the incorporation of biochar at 75 % and compost at 25 % led to enhancement in hydro-physical properties through decreasing soil bulk density and increasing soil total porosity, water holding capacity, and soil available water, and thus olive water productivity. According to obtained results, the studied treatments which attained the best observed and simulated olive fruit water productivities could be ranked in the following descending orders: with SGF reclamation amendments, biochar at 75 % and compost at 25 % > biochar at 100 % > compost at 100 %. According to obtained results, the studied treatments which attained the best observed and simulated olive fruit water productivities could be ranked in the following descending orders: with SGF reclamation amendments, biochar at 75 % and compost at 25 % > biochar at 100 % > compost at 100 %. For achieving sustainable saline soil and water management, it could be recommended that incorporation of biochar and compost with SGF reclamation amendments (sulfur, gypsum, farmyard manure) can accomplish reclamation and amelioration of saline loamy sand soil irrigated with saline water and increasing crop water productivity, an appropriate drainage system could be suggested.

Keywords:- Biochar, Compost, SGF-reclamation amendments, Soil organic carbon, Soil hydro-physical properties, Olive yield, crop water productivity

**Introduction**

Under negative growing impacts of population and climate change on fresh water availability and quality utilization of low quality water that were considered unsuitable for irrigation in the past became essintial and choosing salt-tolerant plants could be last resort for exploiting saline soils, so irrigation of olives with saline water may increase in the Mediterranean region (Bashir et al., 2021; Ezlit et al., 2010). Mismanagement of this water can lead to an increase in soil degradation and limit crop production in the long-term.. However, the management options depend on complex factors such as soil type and condition, water quality, irrigation practice and crop type. the problems related to salinity and sodicity in the soil-water-plant system are complex.. (Ezlit et al., 2010).

Over this century and beyond, with increasing concern about global climate change due to elevated anthropogenic CO2 emissions, soil has recently become part of the global carbon agenda; soil organic carbon (SOC) sequestration management could be effectively adopted if SOC is considered not just for mitigating climate change but also for contributing to soil health, increased food security, and other sustainable development goals (Amelung et al., 2020).

Soil salinization and water table fluctuations are considered strict environmental issues for future development in Ismailia governorate area in Egypt. The hypothetical salt accumulations change from north to south, the clay intercalations are generally existed towards south and north. The salinity increased in the groundwater of the eastern parts of this area(Ismail, 2015; Moheb et al., 2015). Aragüés et al., 2004 indicated that salinity and groundwater table fluctuation stresses are constraints 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.

To enhance the productivity of saline sandy loam soils, Sulfur, gypsum(CaSO4_2H2O) as well as bio-organic (combined use of organic materials, such as farmyard manure and compost were significantly improved the biological, physical and chemical (Bello et al., 2021; Hemdan et al., 2017; Makoi and Commission, 2014). Compost can alleviate soil salt stress owing to compost humic acids and their ability to chelate sodium on their carboxylic sites (Hasini et al., 2020). (Saifullah et al., 2018) mentioned that biochar can improve the soil organisms growth in salt-affected through enhance soil aggregate formation, water retention and also can serve as source releasing nutrients in soil for for microbial metabolism (Jatav et al., 2021).

Biochar has been produced under conditions that optimize certain characteristics considered valuable in agriculture, for instance large surface area and low residual resins and its characteristic ability to persist in soils with very little biological decay

(Hunt et al., 2010; Lehmann et al., 2006). Jindo et al., 2020, 2014 elucidated that biochar enhances physical, chemical and biological properties of soil and improves crop yields which could be owing to during pyrolysis contains a higher amount of supplements. Its positive influence was perceived on several fruit crops such as mango, banana, citrus and apple. Moreover biochar accomplished increased soil C mineralization under saline conditions and decreased the effect of salt stress on soil microorganisms (Zheng et al., 2022).

AquaCrop could be utilizing as a planning tool for managing the irrigated agriculture. The model is particular beneficial to evaluate the crop response to environmental changes, to compare achievable and actual yields in a field, farm, or a region, identify restrictions of crop production and water productivity and to study the impact of climate change on food production, by running AquaCrop with both historical and future weather conditions. Simulated crop water productivity by Aquacrop model relies on climate, plant, soil, and water of this studied area (Raes et al., 2018; Steduto et al., 2009)

It was hypothesized that the effect of studied treatments on the soil physical and chemical properties under saline water and soil condition (if any) will significant influence on olive fruit yield which in turn attains observed crop water productivity, and evaluates by AquaCrop model. For this objective, soil (soil organic carbon, bulk density, total porosity, pore size distribution and available water) and olive fruit water productivity of olive trees were investigated under saline water and soil condition during two growing seasons (2019& 2020) in a field experiment at Ismailia Desert, Egypt.

## Materials and methods

### Experimental conditions and trial design

Ismailia located at the Eastern Desert along the west bank of the Suez Canal, its area is approximated 4482.8 km$^2$ of Egypt's area, Ismailia map and weather are illustrated in fig. (1 and 2). This study was conducted 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>Silt</td><td>Clay</td><td colspan="3">Texture</td></tr>
<tr><td colspan="2">82.3</td><td>8.6</td><td>9.1</td><td colspan="3">loamy sand</td></tr>
<tr><td colspan="7">Chemical soil characteristics</td></tr>
<tr><td colspan="2">pH (1:2.5)</td><td>EC dS-1<br>(1:5)</td><td>N<br>ppm</td><td>P<br>ppm</td><td colspan="2">Organic matter %</td></tr>
<tr><td colspan="2">8.19</td><td>1.23</td><td>53.3</td><td>22.4</td><td colspan="2">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 (El-Sayed, 2018; Ismail, 2015; Moheb et al., 2015), 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 sulphate (20.6% N) and 0.75 Kg/tree of potassium sulphate (48% K2O) were added in three equal doses at February, April and August.

a) b)

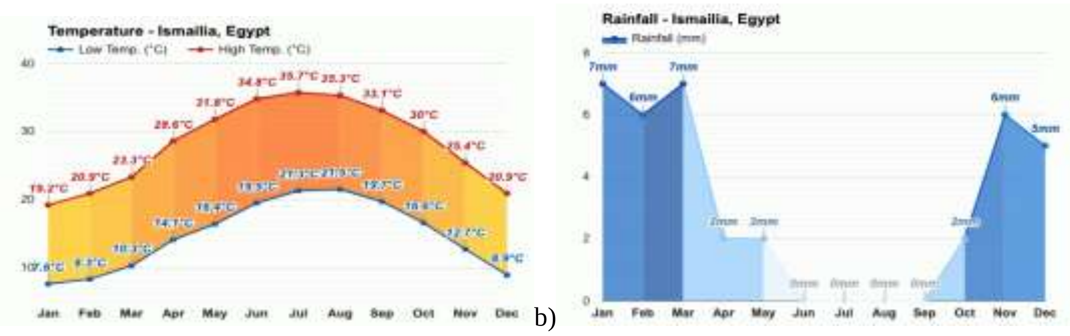


Fig. 2: (a and b) Temperature and rainfall at Ismailia, Egypt (Atlas, 2022)

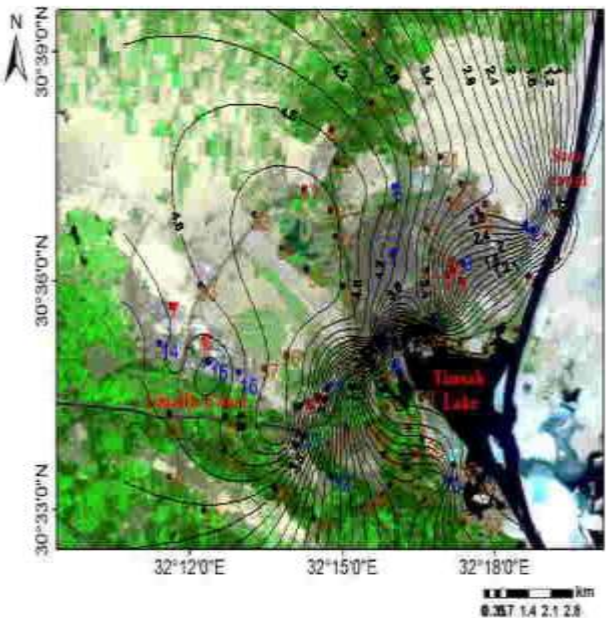


Figure.3. Water table map of Ismailia area in 2004 (Moheb et al., 2015)

**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 (SGF) where S: Sulfur, G: Gypsum, F: Farmyard manure with improvement process by Biochar (Bc) and/or compost (Com) as soil amendments were mixed and added in 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 compost and biochar.

| 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.

**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: soil bulk density, total porosity and void ratio were determined using the core methods (Vomocil, 1986). Moisture retention values over the range from 0.0 to 15 bars were carried out using the pressure membrane apparatus (Loveday, 1974). Pore size distribution was calculated according to (Loveday, 1974). Water transmitting properties:

**Olive Water Productivity**

Simulated water productivity was calculated by Aquacrop model version 6, FAO paper 66 (Steduto et al., 2012) as follows:

$$WP= (B/\sum (Tr/ET_o))_{(CO2)}$$

Where, B is the biomass produced cumulatively (kg per $m^2$) for most crops, Tr is the crop transpiration (m3 per unit surface), with the summation over the time period in which the biomass is produced, and WP is the water productivity parameter kg of biomass per $m^3$ of water transpired). The WP parameter is based on the atmospheric evaporative demand and the atmospheric CO2 concentration for the purpose of simulating future climate scenarios. All AquaCrop model parameters with their values for olive trees are shown in table (5).

Table 5. List of all AquaCrop model parameters with their values for olive trees

| Parameter | Description | Unit | Value |
|---|---|---|---|
| $CC_0$ | Initial green canopy cover | % | 3 |
| $CC_x$ | Maximum green canopy cover | $m^2\ m^{-2}$ | 0.94 |
| CDC | Canopy decline coefficient | fraction $GDD^{-1}$ | 0.004375 |
| CGC | Canopy growth coefficient | fraction $GDD^{-1}$ | 0.003131 |
| Cn | Curve number | | 44 |
| Eme | Period from sowing to emergence | GDDs | 0 |
| evardc | Effect of canopy cover in reducing soil evaporation in late season | % | 72 |
| HI | Harvest index ((AGB-leaves)/*B*) | % | 71 |
| HIGC | Growth coefficient for HI | $day^{-1}$ | |
| $HI_{length}$ | Period of harvest index build-up (% of the growing cycle) | % | 54 |
| $HI_{ini}$ | Initial value for harvest index | % | 0.02 |
| $K_{cTr,x}$ | Coefficient of maximum crop transpiration | | 0.99 |
| $K_s$ | Soil water stress coefficient | | 1 |
| $K_{sat}$ | Saturated hydraulic conductivity | mm $day^{-1}$ | 1189 |
| $K_{sb}$ | Cold stress coefficient | | 1.5 |
| Mat | Total length of crop cycle from sowing to maturity | GDDs | 3149 |
| mul | Reduction of evaporation by mulches during the growing season | % | 19 |
| $mul_a$ | Reduction in soil evaporation by mulches after growing season | % | 79 |
| $mul_b$ | Reduction in soil evaporation by mulches before growing season | % | 58 |
| Root | Period from sowing to maximum rooting depth | GDDs | 1679 |
| rtexlw | Maximum root water extraction in bottom quarter of root zone | $m^3\ m^{-3}$ soil $day^{-1}$ | 0.009 |
| rtexup | Maximum root water extraction in top quarter of root zone | $m^3\ m^{-3}$ soil $day^{-1}$ | 0.041 |
| $rt_n$ | Minimum effective rooting depth | m | 0.85 |
| $rt_x$ | Maximum effective rooting depth | m | 0.85 |
| Sen | Period from sowing to start senescence | GDDs | 2479 |
| $SWC_{fc}$ | Soil water content at field capacity | vol% | 22 |
| $SWC_{pwp}$ | Soil water content at wilting point | vol% | 10 |
| $SWC_{sat}$ | Soil water content at saturation | vol% | 41 |
| $T_b$ | Base temperature for crop development | °C | 0 |
| $T_u$ | Upper temperature for crop development | °C | 25 |
| WP | Water productivity normalized for $ET_0$ and $CO_2$ | g $m^{-3}$ | 10.4 |

- GDDs: growing degree days. (Allen et al., 1998)

**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**

Soil salinity is indeed a severe abiotic stress that affects crop production on global earth; causes deterioration in microbial activity, chemical and physical properties of soil and soil productivity because of salt toxicity and detrimental osmotic potential results in lower carbon storage into these soils. These soluble salts may be from those present in the original soil profile or accumulated from irrigation water (Amini et al., 2016; Saxton and Rawls, 2006; Wong et al., 2009). Salinity stresses seriously disrupt the growth, nutrient uptake and yield of plants (Guo et al., 2020).

Olive trees are considered moderately tolerant to salinity, using drip irrigation system with higher salinity water often attains better yield, this is attributed to the continuous high soil moisture in the root zone (Ayers and Westcot, 1985) (Melgar et al., 2012).

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

The soil salinity has been expanded at a broader scale and caused an adverse impact on soil structural stability, permeability and bulk density (Tejada and Gonzalez, 2005).

**Effects of biochar and compost with SGF reclamation amendments on soil organic carbon and some soil physical properties**

High water tables result in a layer of higher bulk density or restricted drainage in the soil which becomes anaerobic and reduced (Easton et al., 2016). The reclamation process SGF (sulfur, gypsum, farmyard manure) resulted in decline soil bulk density (BD) and increase in soil organic carbon(SOC), soil organic matter, soil total porosity and void ratio compared to untreated soil ( table 1) in both seasons.

The results in table (9) and in figures (4, 5 and 6) show that the effect of the reclamation process SGF (sulfur, gypsum, farmyard manure) and the improvement process (biochar and compost with or without combination); incorporating SGF with biochar and compost increased soil organic carbon (SOC), soil organic matter (SOM), soil total porosity and void ratio while decreased soil bulk density (BD) compared to soil treated with SGF soil amendments.

Biochar at 75% + compost at 25% + SGF gave the highest values of soil organic carbon, soil organic matter, soil total porosity and void ratio, and recorded the lowest value of BD during both seasons. These results are in agreement with (Razzaghi et al., 2020; Rehman et al., 2021). IR spectroscopic analyses of treated soils with compost and manure revealed a better concentration and polymerization of humic substances (Mbarek et al., 2019). Soil application of compost organic matter nutrients, and improves soil bulk density, total porosity, void ratio and aromatic structures in sandy soils (Hemdan, 2014). (Jain and Kalamdhad, 2020) point out that compost significantly amended the physical properties of alluvial and laterite soils for instance, bulk density considerably reduced by 38 and 37%, respectively.

Soil organic carbon increased from 0.93% (SGF) to 1.6% (biochar+ compost+ SGF), this result are in agreement with those reported by (Agegnehu et al., 2015; Mensah and Frimpong, 2018). Amendment of biochar-manure compost with pyroligneous acid increased the activities of urease and phosphatase in saline soils, which alleviated salinity stress on plants (Guo et al., 2020; Lu et al., 2015). On the other hand, (Meschewski et al., 2019) point out that adding biochar only to the soil slight effected on soil microbial activity, as soil microorganisms have low potential to mineralize carbon of biochar.

The low levels of respiration is attributed to the low SOC levels that result from decrement in carbon input into the soils whose the salinity and sodicity levels have increased with scarcity of vegetation (Wong et al., 2009). The lower levels of the soil microbial biomass and respiration rates are attributed to the low SOC levels, the addition of organic material to the sodic and saline soils, respiration rates increased despite adverse soil environmental conditions (Guo et al., 2020b; Wong et al., 2009). 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.

She et al., 2021 indicated that soil organic carbon decomposition negatively affected by soil salinity relied on soil texture, and in the coarse textured soil, increased salinity suppressed fungi and the Gram-positive bacterial populations to exploit the stable C pool and thus inhibited the C mineralization rate.

Biochar declines bulk density BD because of its lower bulk density (0.38 g $cm^{-3}$) compared to about 1.58 g $cm^{-3}$ for studied soil, and its ability to improve soil aggregation and stability, which in turn improves soil porosity, Cooper et al., 2020 detected that biochar significantly increased SOC storage and all aggregate fractions and pH, whereas compost significantly increased SOC, pH and CEC. (Blanco-Canqui, 2017; Razzaghi et al., 2020) showed that applying biochar decreased BD in the coarse-textured soil more than the fine-textured soils. However the inconsistency has been in results from (Omondi et al., 2016) who reported that biochar reduced BD in the fine textured soils more than both the medium- and coarse-textured soils.

Siedt et al., 2021 reviewed to which organic amendments (straw, compost, and biochar) is extent carbon-rich help to maintain nutrients in agricultural soils and to reduce the contamination of groundwater. Influence of compost and biochar can vary greatly relying on type of soil, application rate, and production procedure of the organic material. Biochar is most effective in increasing the sorption capacity of soils. However, design of biochar properties marks it as a promising material.

Table 9. Effect biochar and compost with reclamation process (SGF) on soil organic carbon and some soil physical properties

| Treatments | Total soil organic carbon | | Soil organic matter | | Soil bulk density g/cm3 | | Soil total porosity % | | Soil void ratio | |
|---|---|---|---|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season | First season | Second season | First season | Second season |
| SGF+100%Com* | 1.19d | 1.2c | 2.05d | 2.064c | 1.22d | 1.23c | 53.96b | 53.71c | 1.17b | 1.16c |
| SGF+100%B | 1.58a | 1.58a | 2.72a | 2.72a | 1.20d | 1.19d | 54.59b | 54.96b | 1.20b | 1.22b |
| SGF+25%Com+75%Bc | 1.62a | 1.63a | 2.78a | 2.79a | 1.14e | 1.14e | 56.85a | 56.98a | 1.32a | 1.32a |
| SGF+50%Com+50%Bc | 1.51b | 1.44b | 2.59b | 2.48b | 1.35a | 1.35 a | 48.93e | 49.18e | 0.96e | 0.96e |
| SGF+75%Com+25%Bc | 1.36c | 1.32b | 2.33c | 2.27b | 1.25c | 1.25c | 52.95c | 52.95c | 1.13c | 1.12c |
| (only Control(SGF | 0.72d | 0.93d | 1.21e | 1.59d | 1.3b | 1.29b | 50.94d | 51.32d | 1.04d | 1.05d |

*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).

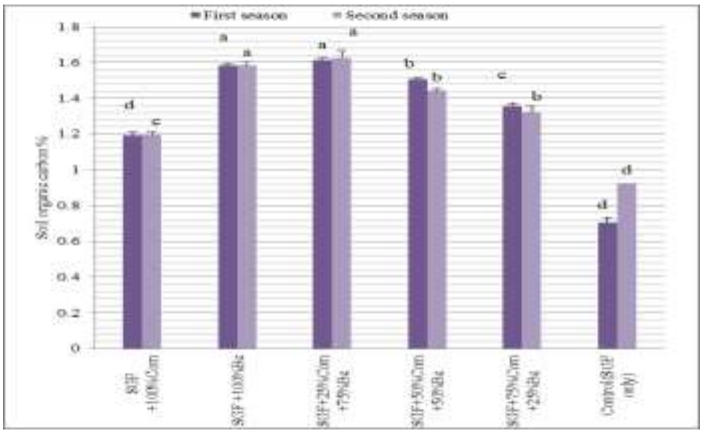


Figure 4. Effect biochar and compost with reclamation process (SGF) on soil organic carbon, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

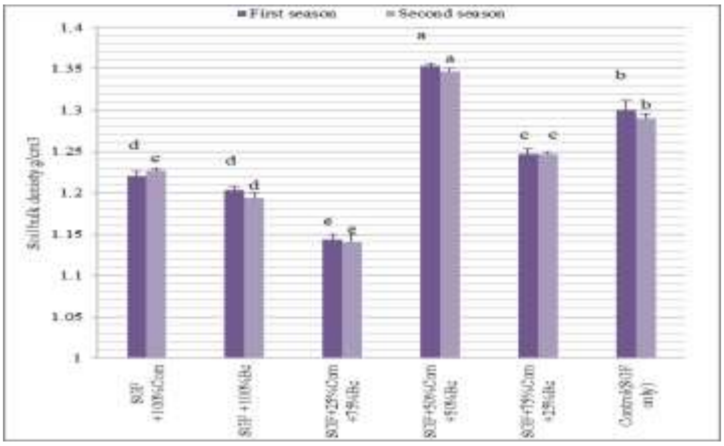


Figure 5. Effect biochar and compost with SGF reclamation amendments on soil bulk density, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

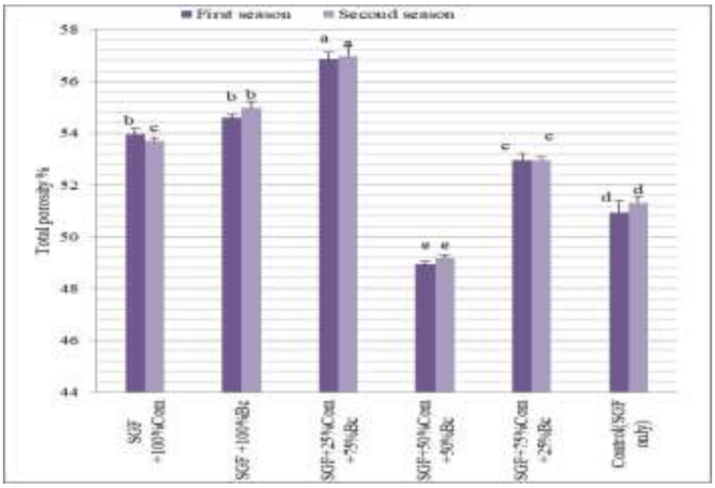


Figure 6. Effect biochar and compost with SGF reclamation amendments on soil total porosity, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

Biochar and compost have potential benefits, i.e. improving soil physical and chemical properties including higher cation exchange capacity, higher nutrient availability and water holding capacity and lower bulk density (Guo et al., 2020a; Khorram et al., 2016; Lehmann et al., 2011).

**Effects of biochar and compost with reclamation process (SGF) on soil hydrophysical properties**

Salinization can be rapid in irrigated areas in hot climates where portions of the land remain fallow for extended periods. 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).

Singh and Singh, 2020 indicated that biochar with organic fertilizer enhanced both physical and chemical properties of the soil, increased ion exchange capacity, soil nutrients and reduced amount of all sodium in the soil including the sodium absorption, the conductance of the soil, while increasing exchangeable magnesium and calcium which could exchange the sodium ions in the saline soil.

**Effects of biochar and compost with reclamation process (SGF) on soil pore size distribution**

Obtained results show that soil pores were positively influenced by applying biochar and compost combined SGF reclamation amendments. Drainable pores, water holding pores and non-useful pores were boosted. In other words, increments in drainable pores and water holding pores of the soil that treated with SGF amendments, 75% of biochar and 25 % of compost were (11.60 and 11.03) and ( 17.60 and 18.34) % during two seasons compared to the soil that treated with SGF amendments only, respectively. 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.

Cooper et al., 2020 detected a significant interaction effect of the factors biochar and compost on water holding capacity for the surface soil and a significantly higher water holding capacity for the high-rate versus low-rate compost treatments in the subsurface soil between the low and high addition rates. Biochar addition achieves higher soil porosity and water holding capacity, improves aeration water and nutrient retention, and enhances microbial activity. Porous structure of biochar creates a new colonization for soil microorganisms(Jatav et al., 2021).

Table 10. Effect biochar and compost with reclamation process (SGF) on soil pore size distribution

| Treatments | Drainable pores | | Water holding pores | | Non useful pores | | Micro/Macro pores | |
|---|---|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season | First season | Second season |
| SGF+100%Com* | 53.96b | 53.71c | 36.07b | 35.33b | 9.352ab | 9.79a | 0.84 | 0.84 |
| SGF+100%B | 54.59b | 54.96b | 36.70ab | 36.634a | 9.385ab | 9.31ab | 0.84 | 0.84 |
| SGF+25%Com+75%Bc | 56.85a | 56.98a | 37.5a | 37.35a | 9.41a | 9.576a | 0.83 | 0.82 |
| SGF+50%Com+50%Bc | 48.93d | 49.18d | 28.73e | 29.13e | 8.841c | 8.62b | 0.77 | 0.77 |
| SGF+75%Com+25%Bc | 52.95c | 52.95c | 33.16c | 33.04c | 8.97bc | 9.47a | 0.80 | 0.80 |
| Control (SGF only) | 50.94d | 51.32d | 31.89d | 31.56d | 9.27ab | 9.158ab | 0.81 | 0.79 |

*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).

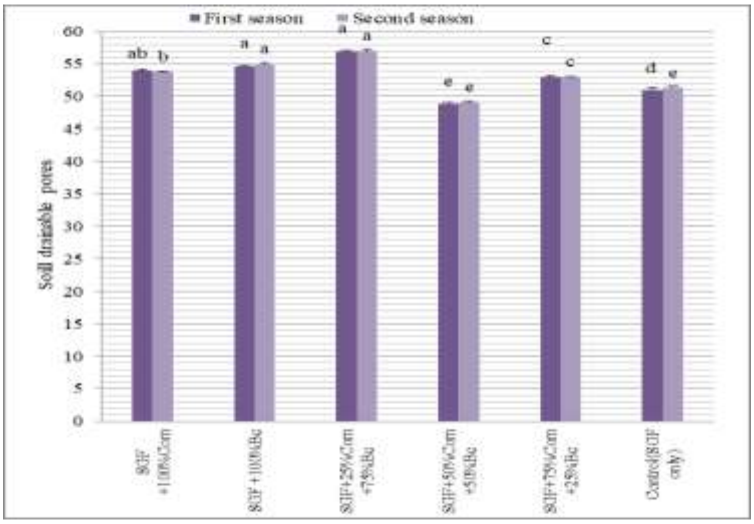


Fig 7. Effect biochar and compost with reclamation process (SGF) on soil drainable pores, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

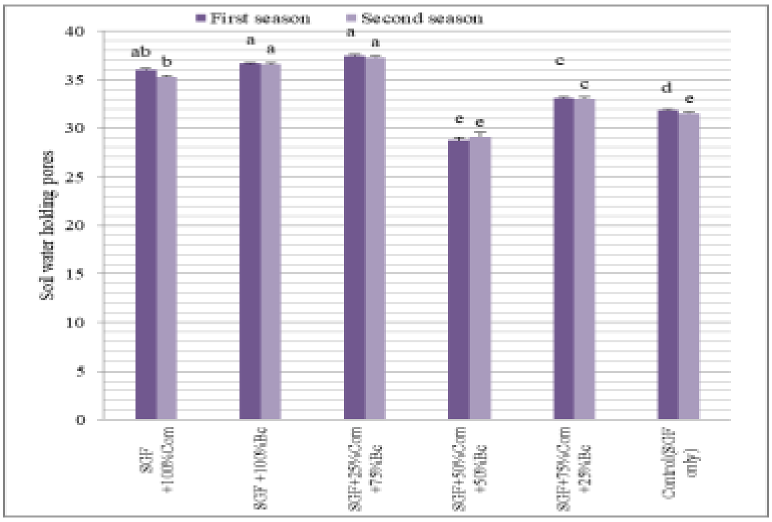


Fig 8. Effect biochar and compost with reclamation process (SGF) on soil water holding pores, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

Osmotic plus matric potentials increase the total energy required for plant water uptake at all moisture levels by making water less readily available. Secondary effects of ionic mineral nutrition may also be present creating additional plant stress beyond the water potentials (Saxton and Rawls, 2006). Biochar is important for sustainable good soil properties and salt affected soil reclamation. through decreasing in the salt and $Na^+$ in the soil, encouraging the water to flow down and leaching the salt out of the root zone ( Zhao et al., 2020).

**Effects of biochar and compost with reclamation amendments (SGF) on soil available water**

Figure (9) illustrates that incorporating biochar by 75 % and compost by 25 % with SGF amendments achieved the highest values of available water over other treatments. Similar patterns were detected by(Hunt et al., 2010; Jindo et al., 2020; Ulyett et al., 2014; Zhang et al., 2016) who explained that large surface area and porosity of biochar can adsorb nutrients and water, and increase the specific surface area of coarse-textured soils to increase water retention. (Yoo et al., 2020) The biochar itself also functioned as a macro aggregate and increased aeration under the excessive water condition. Under the changing water condition, the micropores of biochar may retain the available water for plant roots and soil microbes.

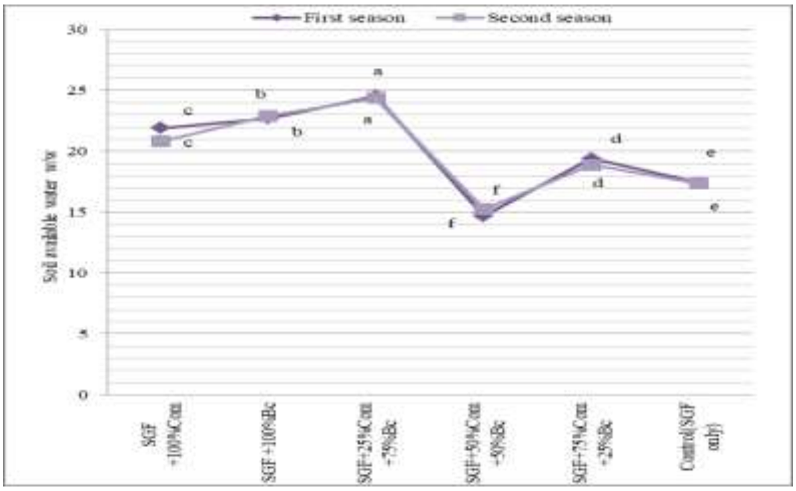


Fig 9. Effect biochar and compost with SGF reclamation amendments on soil available water, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

In this study, because of olive trees grown in the salt affected soil with saline water were irrigated by 100 % of calculated water requirement, accompanying with saline water ground water table fluctuation, the increase in compost amount at the expense of biochar amount with SGF reclamation amendments (sulfur, gypsum and farmyard manure) ascending causes anaerobic condition affect the availability of nutrients in the plant root zone; where The excess of irrigation water led water percolating below the root zone moves downward to the soil water and may cause the water table to rise. As the water table moves upward the root zone, poor soil aeration and/or high salinity in the root zone reduces crop yields.

During spring season with water table rising led to in turn partially unaerobic condition leading to unavailable important elements in the soil, excess of water and organic amendments in the soil environment with rising ground water table rather may be decrease aerobic bacteria, and increase anaerobic conditions in olive trees root zone with poor drainage network in the studied area may be cause water logging (Dwire et al., 2006). Soil porosity is an important indicator for O2 availability, but pore connectivity is probably more crucial for aerobic respiration rates (Moyano et al., 2013). Soil water-respiration dynamics i.e. soil respiration substantially increases with soil moisture and peaks at ~75% saturation(Patel et al., 2021; Yan et al., 2018). Beyond optimal moisture contents, the microbes become oxygen-limited, resulting in lower respiration rates in saturated or nearly saturated soils (Patel et al., 2021).

Shallow water table arises as a result of the presence of clay barrier below the soil surface with slowly permeable layer In most soils with a shallow water table, water rises into the active root zone by capillarity and, if the water table contains salts, it becomes a continual source of salts to the root zone as water is used by the crop or evaporates at the soil surface (Ayers and Westcot, 1985). (Dwire et al., 2006) observed that redox potential dynamic in the soil was related with the seasonal fluctuations in water-table depth and differed among the plant communities. Anaerobic conditions were during spring from March through July during the year while aerobic in summer as loss of nutrients by leaching could be as the result of water table receding down thus obvious decrease in olive fruit yield (Dwire et al., 2006).

Therefore, applying biochar with other soil amendments led to increase in aeration and improvement of soil chemical and physical properties, and enhance soil available water and nutrients for olive trees in root zone. the installation of subsurface drainage system and decrease the distance between drains could be a must for receding the ground water table level down and leaching the salts away from the plant root zone and increasing soil aeration (Bresler et al., 1982; Rafie, 2017)

**Effects of biochar and compost with reclamation amendments (SGF) on olive water productivity**

Using climate, soil, irrigation water, etc. as the inputs in the Aquacrop model sourced by FAO Paper 66 for simulating yield and water productivity, table (13) and figure (11) presented that biochar and compost with SGF amendments either separated or supplemented increased the olive fruit water productivity. applying biochar by 75 % and compost by 25 % with SGF amendments achieved the highest values; the measured water productivity values were 2.49 and 2.58 Kg/m$^3$ and the simulated water productivity were 3.98 and 4.12 Kg/m$^3$ during the first and the second seasons, respectively. Simulated data by the Aquacrop model under studied conditions are higher than the observed ones (Raes et al., 2018; Steduto et al., 2012).

Table 13. Effect of biochar and compost with reclamation process (SGF) on olive water productivity

| Treatments | Water requirement (m$^3$/fed) | Total olive fruit yield (Kg/Fed) | Observed water productivity (kg /m$^3$) | Simulated water productivity (kg /m$^3$) |
|---|---|---|---|---|
| First season | | | | |

| | | | | |
|---|---|---|---|---|
| SGF+100%Com* | 3333 | 6790b | 2.13b | 3.41b |
| SGF+100%B | 3333 | 6860b | 2.15b | 3.44b |
| SGF+25%Com+75%B | 3333 | 7980a | 2.49a | 3.98a |
| SGF+50%Com+50%B | 3333 | 3640d | 1.18d | 1.90d |
| SGF+75%Com+25%B | 3333 | 5810c | 1.83c | 2.93c |
| Control (SGF only) | 3333 | 5740c | 1.81c | 2.90c |
| Second season | | | | |
| SGF+100%Com | 3333 | 7175b | 2.20b | 3.53b |
| SGF+100%B | 3333 | 7560b | 2.30b | 3.69b |
| SGF+25%Com+75%B | 3333 | 8435a | 2.58a | 4.12a |
| SGF+50%Com+50%B | 3333 | 4410d | 1.36d | 2.17d |
| SGF+75%Com+25%B | 3333 | 6090c | 1.86c | 2.98c |
| Control (SGF only) | 3333 | 5600c | 1.74c | 2.77c |

*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).

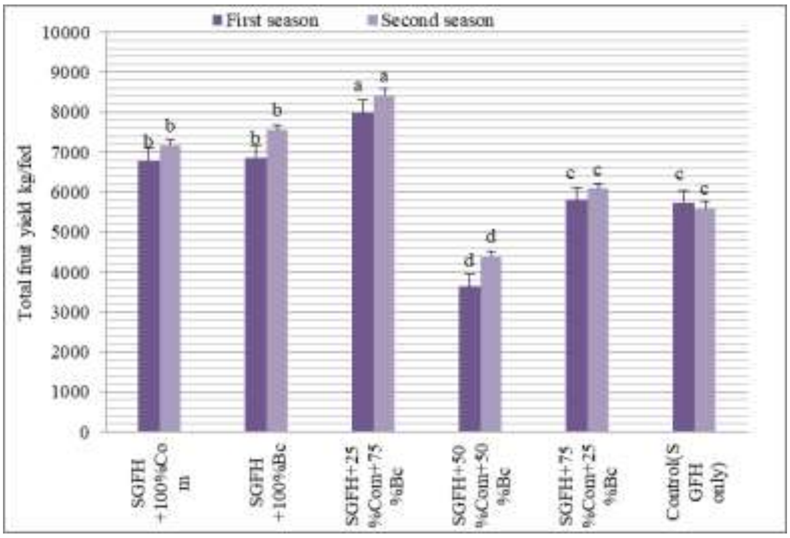


Figure 11. Biochar and compost with reclamation process (SGF) on total olive fruit yield, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

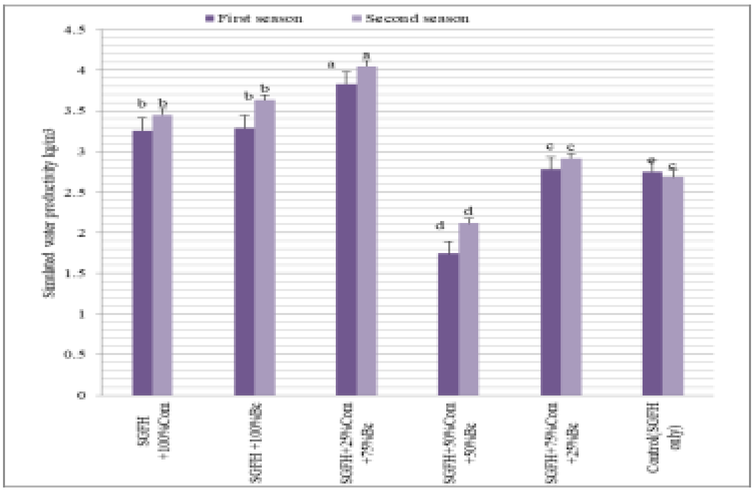

Figure 11. Biochar and compost with reclamation process (SGF) on simulated olive water productivity, where s: Sulfur, G: Gypsum, F: Farmyard manure, Com: Compost and B: Biochar. Different letters in the figure show significant differences according to LSD test (P= 0.05).

While the lowest values of observed water productivity and simulated olive fruit water productivity were 1.18 & 1.36 and 1.90 & 2.17 Kg/m3 by incorporating biochar by 50 % and compost by 50 % with SGF amendments in both seasons, respectively. This may be attributed to that biochar and compost with SGF amendments enhanced soil bulk density, soil total porosity, soil pore size distribution and soil available water as abovementioned. The results showed correspondence between values observed and those simulated by the Aquacrop model (Hemdan et al., 2021; Mansour et al., 2020; Mansour and Aljughaiman, 2020; Stricevic et al., 2011).

**Conclusion**

Under saline water and soil with ground water table fluctuation condition, application of biochar at 75 % and compost at 25 % with SGF reclamation amendments (sulfur, gypsum, farmyard manure) positively enhanced soil organic carbon and organic matter, decreased soil bulk density, and improved soil total porosity, water holding pores and available water, accordingly increased observed fruit water productivity of olive trees irrigated with saline water in orchard for two seasons at Ismailia Desert in Egypt. Obvious convergence has been detected between simulated olive fruit water productivity using Aquacrop simulation program and observed ones of olive trees. Aquacrop program depends on climate, plant, soil, and water as the inputs hence the simulated data as the output could find the suitable scenarios in case of changes in climate, water, plant nutrition or soil characteristics in the future. It could be concluded that the combinations of biochar at 75 % and compost at 25 % with SGF reclamation amendments (sulfur, gypsum, farmyard manure) could be attained proper saline soil and water management and olive orchard sustainability, and could be recommended for the region suffered from the same converse environmental condition. In addition, to achieve the best crop water productivity, it could be suggested to apply capable drainage system.

**Conflict of interest**

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

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