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Remediation of Sandy Soil Irrigated with Treated Wastewater by Using Biochar and Organic Fertilizers for Jojoba Production

Alashram M.G.[1], Azab A.E.[2], Abdelmohsen Kh. H[2], Khater A.E.[3] and Abdelraouf R.E.[1]

[1]Water Relation and Field Irrigation Dept., National Research Centre, 33 EL Buhouth St., Dokki, Giza, Egypt, Postal Code: 12622.
[2]Biological Engineering Dept., [3]Agricultural Mechanization Operations Systems Dept., Agricultural Engineering Research Institute, Agricultural Research Center (ARC), Ministry of Agriculture, Giza, Egypt.

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ABSTRACT

To ensure global food security, there is an urgent need to extend agricultural production into semi-arid and arid regions. Soil amendments and restricted irrigation techniques are effective water-saving methods for crop yield in semi-arid and arid environments. Compost and biochar are examples of soil amendments that can enhance agricultural production, soil fertility, nitrogen absorption, and soil water relations. Consequently, an experiment was conducted combining four biochar rates (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed, respectively) with four rates of compost (C0, C5, C10, C15: 0, 5, 10, 15 ton/fed, respectively) as sustainable materials produced from agricultural waste to improve the productivity of jojoba trees by treating irrigated sandy soil with treated sewage water and studying their impact on application efficiency of irrigation water, chlorophyll content, yield of seeds and wax (oil) and water productivity of seeds and wax (oil) for jojoba. To meet the study's objective, two field experiments had been done at Al-Gabal Al-Asfar Region, El-Qalyubia Governorate, Egypt, during seasons 2021 and 2022. The higher soil organic matter content and micro-organism activity observed in B3+C15 compared with the other treatments. According to this study, biochar and compost had improved the yield and water productivity of seeds and wax (oil) over the two seasons. The highest seeds yield values were (1353.1 and 1440.5 kg/fed), and water productivity of jojoba seeds were (0.67 and 0.74 kg m^{-3}) using B3 with C15 for 2021 and 2022, respectively. Limited irrigation strategies and soil amendments that maintain or improve crop productivity in ever-changing climatic scenarios are among the most promising solutions.

Keywords: compost, drip irrigation system, water productivity of jojoba, water application efficiency, wax (oil).

1. Introduction

Sandy soil is widespread, predestined to encompass 900 million hectares. This soil is frequently infertile in spite of farming, and its yield relies on the levels of moisture and organic carbon. Limited ability to retain or exchange nutrients, high porosity, and low water-holding capacity are regular characteristics of sandy soil (Yost and Hartemink, 2019). In sandy soil, organic amendments have to be applied often to sustain yield. Under dry and sandy soil cases, manure had already been observed to be important in reducing water stress (Abdelraouf *et al.,* 2012). Chemical application of fertilizer is essential for the development of crops and grains. The process of fertilizer involves adding nutrients using irrigation water. For irrigation-based cultivating of sandy soil, fertilizer administration is particularly crucial because, if improperly handled, profound filtering to groundwater can result in the loss of significant quantities of nutrients. Significant effects of soil moisture motion characteristics and nutrients dynamics on plant yield and growth (Abdelraouf and Ragab, 2018).

Corresponding Author: Abdelraouf R.E., Water Relation and Field Irrigation Dept., National Research Centre, 33 EL Buhouth St., Dokki, Giza, Egypt, Postal Code: 12622.
E-mail: abdelrouf2000@yahoo.com

An efficient technique to cycle both water and minerals is by reusing wastewater for agricultural irrigation, which helps to achieve the sustainable economy (Chojnacka *et al.,* 2020). Reusing treated wastewater is regarded as an efficient cost-cutting method in Egypt. In Egypt, irrigation of parks and gardens (landscapes evolution) and non-food cultivation is the prime application of treated wastewater (Abdel-Shafy and Mansour, 2013). The potential benefits of irrigation by wastewater include efficient waste product disposal and the addition of good source of organic matter and nutrient to both crop and soil (Hashim *et al.,* 2010).

Among the most pressing existential defiance of our century are climate variability and food security. The recurrence of abrupt and intense occurrences is rising, as is climatic changes. Drought will persist, and agrarian sectors will face increased competition for water supplies (She *et al.,* 2018). Due to climate changes and rising temperatures, Egypt is experiencing significant irrigation water shortages and restricted water supplies. The level of suffering grows as the number of people rise. Thus, the use of contemporary irrigation techniques and technology aims to enhance and raise quality and yield of crop while also increasing water productivity (Marwa *et al.,* 2017). In several populous areas of the world, agrarian production under irrigation is required. Consequently, whether we want to face the issue of food security, semi-arid and arid cultivation requires explore options that better control water consumption (Abbas *et al.,* 2018; Pressler *et al.,* 2017).

Inorganic fertilizer had played a significant part in raising farm productivity and preserving yield during the last 50 years since the "green revolution" by supplying easily soluble nutrient. Nevertheless, fertilizer is costly and sometimes out of reach for many people, especially small-scale cultivators (Phares *et al.,* 2020). The effectiveness of soil conservation and agronomic production methods depends on maintaining enough amounts of soil organic matter and making sure that biological nutrient cycle is successful. With the ultimate aim of improving agricultural outcome of fertilizer application and, consequently, crop yield, these procedures consist of application of both inorganic and organic fertilizer in conjunction with knowledge of how to adjust these procedures to local conditions (Vanlauwe *et al.,* 2010). Nevertheless, depending only on such inorganic fertilizer to maintain agricultural productivity and improve fertility of soil is not a long-term solution. Instead, it is commonly known that excessive application of inorganic fertilizer, especially nitrogen, would result in degradation of soil or some environment troubles as organic matter of soil is mineralized more quickly, which in turn results in a huge drop in soil carbon stores (Foley *et al.,* 2005).

Particularly in poor soil like sandy soil, biochar has ability for successfully increasing agricultural yield. Additionally, biochar had been regarded as a viable option for carbon capture in soil and could significantly help to moderate climatic changes on a worldwide scale (Oni *et al.,* 2019; Smith, 2016). Agronomic systems had used biochar like a soil amendment to improve water productivity, growth and productivity of crop (Akhtar *et al.,* 2014; Jeffery *et al.,* 2011), increasing nutrient uptake, fertility and organic content of soil (Abou Hussien *et al.,* 2020), Improving porosity and reducing bulk density of soil (Liang *et al.,* 2021), and enhancing available of soil water retention and nutrients (Hammer *et al.,* 2014). The carbon-rich, solid substance is called biochar. It is created by pyrolysis process of biomass at temperatures between 350 and 800 °C with minimal to no oxygen present (Alves *et al.,* 2021). Crop production benefit from biochar has varied, based on raw material, application rate of biochar, texture of soil and region (Martí *et al.,* 2021; Akhtar *et al.,* 2014; Jeffery *et al.,* 2011). It has been extensively researched for its ability to enhance fertility of soil, reduce climatic changes, reduce the bioavailability of a variety of pollutants, and enhance soil water relationships (Abbas *et al.,* 2018; Jiang *et al.,* 2016; Bamminger *et al.,* 2014).

The biological, chemical, and physical characteristics of soil are enhanced by the application of biochar (He *et al.,* 2016). Because of the high temperatures and little precipitation, the degradation of organic matter for soil is very large, particularly in semiarid and arid regions. As a result, biochar offers an extra option for soil conditioner and can stay in soil for a long time (Jien and Wang, 2013). For several types of crops, biochar had been used to increase growth and production such as wheat (Abbas *et al.,* 2018; Akhtar *et al.,* 2015; Alburquerque *et al.,* 2013), maize (Pressler *et al.,* 2017; Arif *et al.,* 2016), corn (Aguirre *et al.,* 2021; Andreev *et al.,* 2016), sorghum (Laghari *et al.,* 2015), rice (MacCarthy *et al.,* 2020), cowpea (Phares *et al.,* 2020; Rafael *et al.,* 2019), sugar beet (Li *et al.,* 2022; Alves *et al.,* 2021), peanut (Agegnehu *et al.,* 2015a), sweet pepper (El-Shawadfy and Abdelraouf, 2019) and tomato (Gu *et al.,* 2021; She *et al.,* 2018; Akhtar *et al.,* 2014; Hossain *et al.,* 2010).

A favorable soil conditioner for crop productivity is compost, a microbially stabilized biomass product. Similarly to biochar, adding compost to soil can increase water-holding capacity, production, and growth of crop (Paradelo *et al.,* 2019). For the majority of cultivated soil, both inorganic and organic nutrients have been the main origins of nutrients supplies. Compost as an organic fertilizer improves productivity of crop and fertility of soil (Kranz *et al.,* 2020) further aids in reducing water and soil contamination (Ventorino *et al.,* 2019). It is important to regularly apply organic conditioner to sand soil for preserving yield. Compost addition is crucial to reducing water stress in conditions of dry and sand regions (Abdelraouf *et al.,* 2013). Compost could perfect water-holding capacity, microbial activity, fertility and structure of soil. It is widely applied for increasing yield and quality of crops (Aminifard *et al.,* 2013). For several types of crops, compost had been used to increase growth and production such as wheat (Abdelraouf *et al.,* 2013) and sweet pepper (Aminifard *et al.,* 2013).

Compost and biochar are examples of organic conditioners that are commonly produced from commercially viable resources of secondary waste sources. Consequently, their application as a soil conditioner is regarded as a "green" strategy (Gunarathne *et al.,* 2020). The practical use of organic fertilizer is regarded to be significantly constrained by the typically quick mineralization of soil organic matter. Consequently, a new strategy is required to aid in maximizing yield, reducing adverse effects and enhancing sustainability (Sohi *et al.,* 2010). Generally, it has been demonstrated that combining biochar with compost has significant potential for enhancing yield (Bonanomi *et al.,* 2017). In order to investigate the possible advantages of these kind of organic conditioners on water holding capacity and nutrients content of soil, evidence shows that a combination of compost and biochar is an effective method (Liu *et al.,* 2012). Due to its encouraging outcomes for both field and laboratory studies, the use of biochar in combined with compost, has lately attracted interest (Schmidt *et al.,* 2015). As consequence for this reason, great progress had been achieved in the study of compost-biochar combinations as soil conditioners, and take action to improve fertility, quality of soil, greenhouse gas emissions and carbon capture. The quality of the compost and biochar, the rates of usage, the kind of soil, and the weather conditions are only a few examples of the variables that might influence these beneficial benefits (Lehmann *et al.,* 2003). For several types of crops, biochar and compost had been used to increase growth and production such as maize (Manolikaki and Diamadopoulos, 2019) and peanut (Agegnehu *et al.,* 2015a).

A shrub called the jojoba (Simmondsia chinensis) produces wax (commercially oil). The majority (97%) of jojoba oil is made up of wax esters made from alcohols, straight-chain acids and monounsaturated. This oil resists oxidation and maintains its chemical purity for many years. When cooked repeatedly to temperature exceeding 285°C, it also basically keeps true. Thus, it is employed in the manufacturing of biofuel as well as the greasing of heavy machinery and aircraft motors (Arafat and Basuny, 2018). The remaining jojoba seed is made up of protein-rich feed (32%), which can be employed as livestock feed when the defatted seed is removed (Al-Soqeer *et al.,* 2012). Additionally, the residue from jojoba oil is wealthy in antioxidants and minerals. It appears in a number of medicinal outputs (Nasr *et al.,* 2018). Weak productivity of sandy and poor soil in organic and biological content, low water capacity and high prices of chemical fertilizers with the presence and availability of various forms of agricultural waste that threaten the environment if not transformed into sustainable products that can be used in a sustainable and environmentally friendly manner. Therefore, the aim of this study was improving the productivity of jojoba trees by treating irrigated sandy soil with treated sewage water using biochar and organic fertilizers as sustainable materials produced from agricultural waste and studying their impact on application efficiency of irrigation water, chlorophyll content, yield of seeds and wax (oil) and water productivity of seeds and wax (oil) for jojoba.

2. Materials and Methods

Location and climate of experimental site:

Field experiments were carried out on jojoba trees on sandy soil and the farm was located at Al-Gabal Al-Asfar Region, ($30^{o}\ 26^{`}\ 28^{``}$ N- $30^{o}\ 58^{`}\ 30^{``}$N and $31^{o}\ 8^{`}\ 0^{``}$E – $32^{o}\ 0^{`}\ 0^{``}$ E), El-Qalyubia governorate, Egypt as shown in Figure (1). The chosen region has a dry climate with cool winters and hot dry summers. The average air temperatures were 18.98 and 19.03, with average air relative humidity of 65.77 and 67.17%, for two seasons 2021 and 2022, respectively.

Fig. 1: The location of study site in the Al-Gabal Al-Asfar farm of the treatment plant, Qalyubia Governorate, Egypt.

Physical & chemical properties of soil, compost and treated sewage water used for irrigation of jojoba trees:

Physical & chemical characteristics of soil, compost and treated sewage water used to irrigate the experimental area in details were determined on-site and in a lab as shown in Tables 1, 2 and 3, respectively.

Table 1: Physical and chemical characteristics of soil for experimental area.

Soil Characteristics	**Soil depth (cm)** 0–30	**30-60**	**60-90**
	Physical parameters		
Texture	**Sandy**	**Sandy**	**Sandy**
Course sand (%)	40.45	51.24	50.75
Fine sand (%)	42.49	44.60	45.59
Silt + clay (%)	17.06	4.16	3.66
Bulk density (g cm^{-3})	1.69	1.65	1.68
Organic matter (%)	1.4	0.98	0.70
	Chemical parameters		
EC (dS m^{-1})	0.63	0.57	0.53
pH (1:2.5)	7.8	7.7	7.6
Total CaCO3 (%)	4.9	4.18	4.36

Table 2: Chemical analysis of organic fertilizer "compost".

Item		**Compost, 2021**	**Compost, 2022**
pH		5.95	5.84
EC, (ds/m)		0.73	0.69
	HCO_3^-&CO_3^{--}	1.25	1.29
Anions	**Cl^-**	3.51	3.47
(meq./L)	**SO_4^{2-}**	2.92	2.93
	Ca^{++}	2.01	1.92
Cation (meq./L)	**K^+**	2.25	2.18
	Mg^+	1.04	1.15
	Na^+	2.38	2.44
Organic Matter (%)		95.6	96.6
Moisture Content (%)		20	21
Nitrogen (%)		0.92	0.92
C/N ratio		25:1	26:1
Phosphorus (%)		0.87	0.88
Potassium (%)		0.91	0.92

EC: Electrical Conductivity, and C/N ratio: The ratio between carbon and Nitrogen in compost

Table 3: Chemical properties of treated sewage water used for irrigation of jojoba trees

Characteristics		Mean
pH		7.4
$N\text{-}NH_4^+$	**(mgL^{-1})**	41.31
P	**(mgL^{-1})**	2.18
K^+	**(mgL^{-1})**	17.82
Ca^{2+}	**(mgL^{-1})**	7.13
Mg^{2+}	**(mgL^{-1})**	6.12
S	**(mgL^{-1})**	6.59
Na^+	**(mgL^{-1})**	67.81
Fe^{2+}	**(mgL^{-1})**	0.42
Cu^{2+}	**(mgL^{-1})**	0.08
Zn^{2+}	**(mgL^{-1})**	0.05
Mn^{2+}	**(mgL^{-1})**	0.03
EC	**($dS\ m^{-1}$)**	0.825
TS	**(mgL^{-1})**	396
COD	**(mgL^{-1})**	169

EC: Electrical Conductivity, TS: Total Solids and COD: Chemical Oxygen Demand

Experimental design:

The experimental layout was arranged in a split-plot design using three replicates. Four biochar rates (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed, respectively) were assigned as main plots. Each main plot was then divided into sub main plots subjected to four rates of compost (C0, C5, C10, C15: 0, 5, 10, 15 ton/fed, respectively). Each treatment was replicated three times with two trees per replicate and the means of these two trees were used for statistical analysis.

Preparation of biochar and compost:

The used biochar in this experiment was made from post-harvest corn straw (as a feed stock), including stems and leaves, which was produced using pyrolysis treatment by simple reactors at a final temperature of 450 ℃ using metal scrap drums with a retention time of 2 hours. The feed stock (corn straw) was placed in the reactor to pyrolysis at low-temperatures. After pyrolysis, the reactor was left inside the furnace to cool to room temperature. The biochar and ash obtained were weighted. Commercially available compost was prepared from post-harvest corn straw. The amounts of biochar and compost required for the experimental treatment were distributed with the maximum wet surface area under the drippers by mixing these with the upper 30 cm of the soil profile and these were added each year during the preparation of the soil. The biochar properties were pH (H_2O) 9.2; ash content 112.4 g kg^{-1} ; CEC 40.5 cmol kg^{-1}; and the total C,N,P,K, Ca and Mg contents were 898.6, 7.4, 4.5, 15.4, 3.3 and 1.18 g kg^{-1} respectively]

Irrigation system description:

Irrigation system consisted of pumping, filtration unit and control head. It consists of centrifugal pump with 100 m^3/h discharge driven by electrical engine, control valves, screen filter, flow-meter, pressure gauges, pressure regulator and back flow prevention device. Manifold lines was made from Polyethylene pipes with a diameter of 63 mm were connected to the laterals through control valve 2" and discharge gauge. Emitters was built in the laterals with a diameter of 16 mm and a length of 50 m and the emitter discharge was 8 liters per hour at an operating pressure of 1.0 bar. Lateral drips were placed at the centers of adjacent trees rows in the experimental plots.

Irrigation requirements for jojoba:

Equation (1) was used for measuring daily irrigation water and the seasonal irrigation water were 2000 and 1960 m^3/fed/season during seasons 2021 and 2022, respectively, using drip irrigation system following Savva and Frenken (2002). Because the volume of rainfall was so small and the duration was only a few minutes, there was no rainfall that was included across the two seasons. The timing and amount of irrigation followed according to the local commercial practice.

$$\mathrm{IRg} = \left[\frac{\mathrm{ETO \times Kc \times Kr}}{\mathrm{Ei}}\right] - \mathrm{R} + \mathrm{LR} \qquad (1)$$

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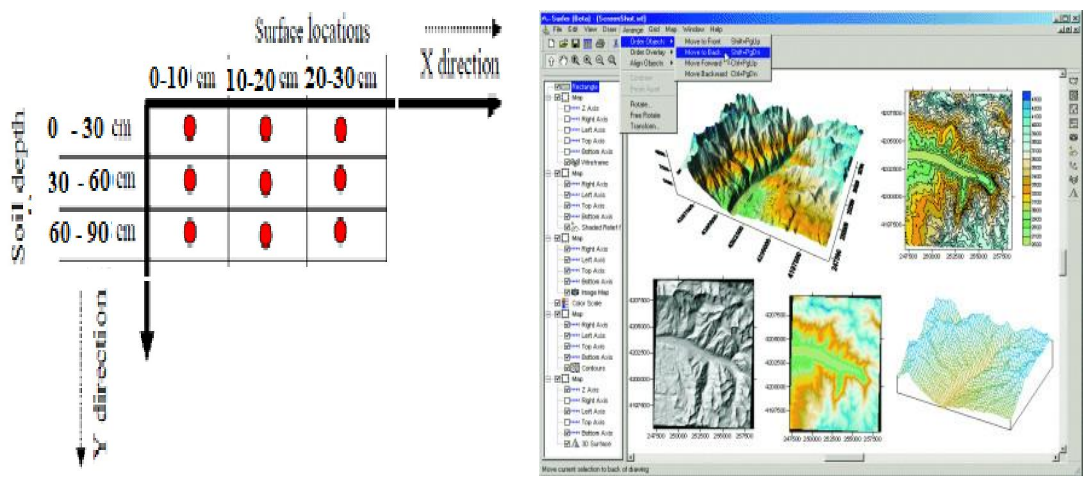
Where, IRg is the gross irrigation requirements (mm/day); ET_O is reference evapotranspiration (mm/day); Kc is crop factor "FAO-56"; Kr is factor of ground cover reduction; Ei is the irrigation efficiency (%); R is water received by plant from sources other than irrigation (mm) "for example rainfall"; and LR is amount of the water needed for leaching of salts (mm).

Jojoba trees:

Regardless of the experimental treatments, all experimental plots were treated by the normal and recommended jojoba growing requirements as recommended by the instructions of the official agricultural bulletins. The study was carried out using 10 years old jojoba trees (*Simmondsia chinensis*) and spaced at 4x2 m, with an average of 300 trees per fed. Plants drip irrigation procedure is totally depending on primary treated wastewater resulted from sewage treatment station in Al-Gabal Al-Asfar Region. All field practices were done according to recommended practices in the area. All field practices were done as usually recommended for jojoba cultivation in sandy soil.

Soil moisture distribution:

Soil moisture distribution was determined by measuring soil moisture content by profile probe device at maximum actual water requirements at 2 hours after irrigation and at different locations. The locations were measured from 0-10, 10-20 and 20-30 cm on the X- direction and the locations were measured from 0-30, 30-60 and 60-90 cm on the Y- direction. By using Surfer 13 Golden software program, the contouring map for different soil moisture levels with the depths for all treatments can be obtained as shown in Figure (2).



Soil moisture content measurement sites Surfer 13 Golden software program

Fig. 2: Contouring map for different moisture levels with depths for all treatments under study.

Soil organic matter content:

Measuring the soil organic matter content in the root zone in response to the various rates of biochar and compost were investigated as an indicator of nutritional status for jojoba trees. Soil organic matter percentage was estimated using Walkley and Black method outlined by Jackson (1958).

Water application efficiency "AE_{IW}":

In order to meet water requirements of jojoba trees in relation to water applied to the area; application efficiency refers to the actual storage of water inside root zone. According to El-Meseery (2003), application efficiency "AE_{IW}" was calculated with the following Equation (2):

$$\mathrm{AEIW} = \frac{\mathrm{Ds}}{\mathrm{Da}} \quad \ldots\ldots (2)$$

Where, AE_{IW} is application efficiency of the irrigation water (%); Ds is depth of stored water in root zone (cm); and Da is depth of the applied water (cm). Ds was determined using equation (3)

$$Ds = (\theta_1 - \theta_2) * d * \rho \quad (3)$$

Where, d is soil layer depth (cm), θ_1 is average of soil moisture content after irrigation (%); θ_2 is average of soil moisture content before irrigation (%); and ρ is relative bulk density of soil (dimensionless).

Micro-organisms activity :

Representative samples of surface soil (0–20 cm) were randomly chosen from each treatment to determine total bacterial count using chloroform fumigation extraction followed by UV persulphate oxidation according to the method described by Wu *et al.,* (1990).

Total chlorophyll content:

Leaf chlorophyll content was calculated by Spad device as spad unit according to the methods mentioned by von Wettstein (1957).

Yield of jojoba:

Numbers of seeds per tree in each treatment were collected and weighed and then seeds yield was calculated as kg per tree. The total yield as kg/fed was determined after converted. Percentage of wax (oil) content in each treatment were measured by extracting the oil from the dried and crushed seed samples using petroleum ether (60–80°C) as solvent, then wax (oil) yield as kg/fed was determined after converted.

Water productivity of jojoba "WP_{jojoba}":

According to James (1988), WP_{jojoba} was determined by Equation (4) as follows:

$$WP_{jojoba} = \frac{Ey}{Ir} \quad (4)$$

Where, WP_{jojoba} is water productivity of the jojoba (kg_{jojoba}/m^3_{water}); Ey is economical yield (kg/fed); and Ir is applied volume of the irrigation water (m^3_{water} /fed/season). The same equation was used to determine water productivity of jojoba wax (oil).

Statistical Analysis:

All the obtained data in the two seasons of study were statistically analyzed using the standard analysis of variance procedure (ANOVA) of split plot design using three replications according to Snedecor and Cochran (1980). All data were processed with the assistance of statistical program CoStat (Version 6.303, CoHort, USA, 1998–2004). Differences were considered significant at $p \leq 0.05$ using least significant differences (LSD) tests to compare treatment means of the measured parameters.

3. Results and Discussion

3.1. Soil moisture distribution

The effect of biochar and compost on the shape and distribution of moisture within the root zone of jojoba trees had been studied. Figure (3) demonstrates that with an increase in the rate of adding biochar without adding compost, the size of the wet area inside the root spreading area increases, which resulted in a decrease in water stress. It might potentially come into contact with tree roots, and it has been demonstrated that the additional biochar components have the capacity to keep irrigation water inside the root zone. Figure (4) shows that by increasing the rate of adding biochar with the addition of the highest amount of compost (15 ton/fed), amongst all the parameters that were tested, the optimal moisture distribution was attained. Figure (4) demonstrated the beneficial effects of both adding biochar and compost on enhancing and raising the amount of wet water inside the jojoba tree root spread region, which in turn will inevitably have a favorable impact on the state of water absorption and the availability of nutrient. The Figures of soil moisture distribution for the biochar effect with adding compost at 5 and 10 ton/fed were not shown because the forms obtained are a medium condition between the lowest and the highest rate of compost addition, so there is no need for unhelpful repetition.

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3.2. Soil organic matter content

The nutritional status of the soil was tested by measuring the soil organic matter content for all treatments under study during the two seasons. Figure (5) illustrates the importance of both factors (biochar and compost) for increasing soil organic matter content for the two seasons. For the first factor "biochar", the use of biochar led to a positive effect on soil organic matter content with or without using compost rates for the two seasons. The highest soil organic matter content values were under B3 followed by B2 and then B1, while the lowest values were under B0 for the two seasons. Application of biochar improved soil's nutritional, organic, ion, and salt contents (Arif *et al.,* 2016; Bouqbis *et al.,* 2021; Liang *et al.,* 2021). The application of biochar to soil can increase soil aeration, warmth, and moisture, which may encourage nitrification. The combination of biochar with organic or inorganic fertilizer favorably affects nitrifying activities (Prommer *et al.,* 2014) because the organic fertilizer enhanced the amount of organic matter and the availability of substrate (Song *et al.,* 2014; Zhao *et al.,* 2014).

For the second factor "compost", the use of compost led to a positive effect on soil organic matter content with or without using biochar rates for the two seasons. The highest soil organic matter content values were under C15 followed by C10 and then C5, while the lowest values were under C0 for the two seasons. The ability of the root zone to store water is improved by increasing the compost rate. In fact, adding organic matter to the soil enhances its structure, which has an impact on how much water is stored in the soil. Therefore, conserving soil organic matter is a crucial part of managing land use for sustainability. According to Adekiya *et al.,* (2019) findings, the compost's high organic matter content may have enhanced and maintained soil structure, resulting in a decrease in soil bulk density.

The interaction between the two factors also had a positive effect on soil organic matter content for the two seasons. The highest values of soil organic matter content were occurred using B3+C15, while the lowest values were occurred without both biochar and compost for the two seasons.

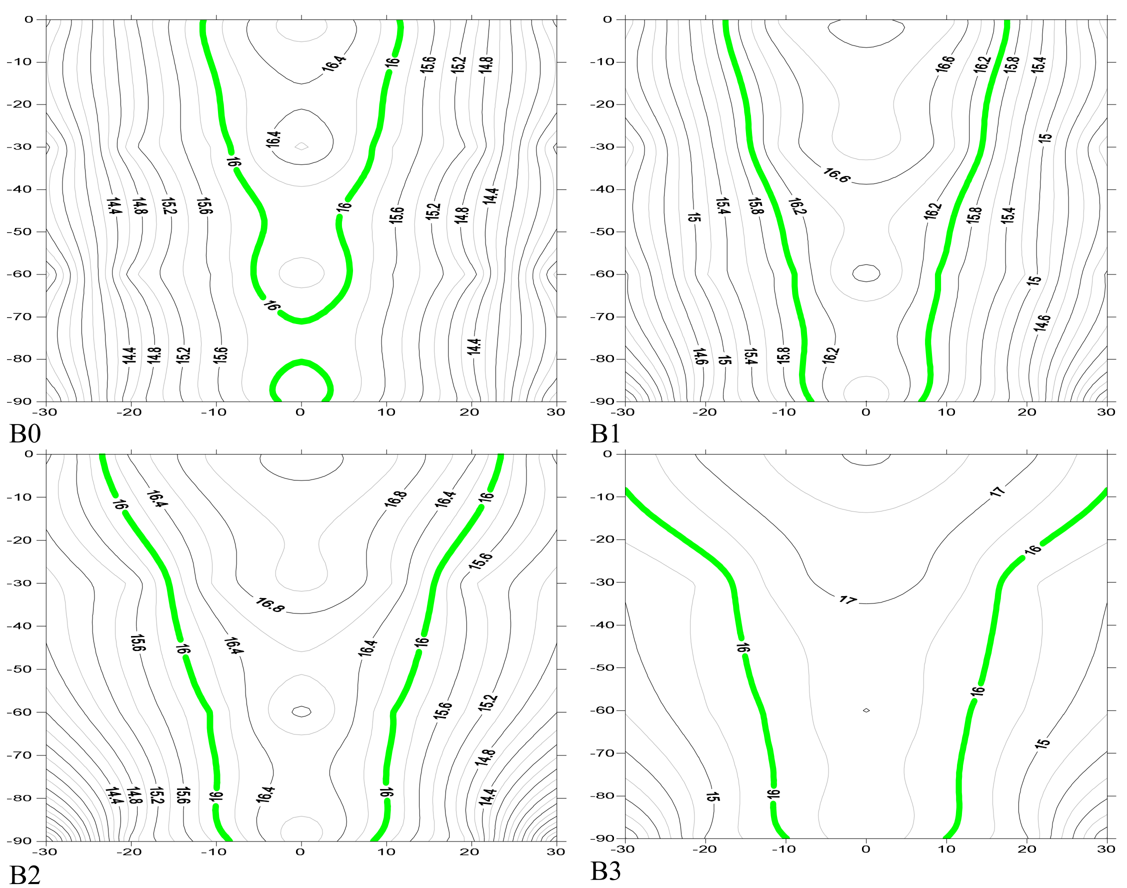

Fig. 3: Effect of biochar and compost on soil moisture distribution during season 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar under C0 "0 ton/fed of compost")

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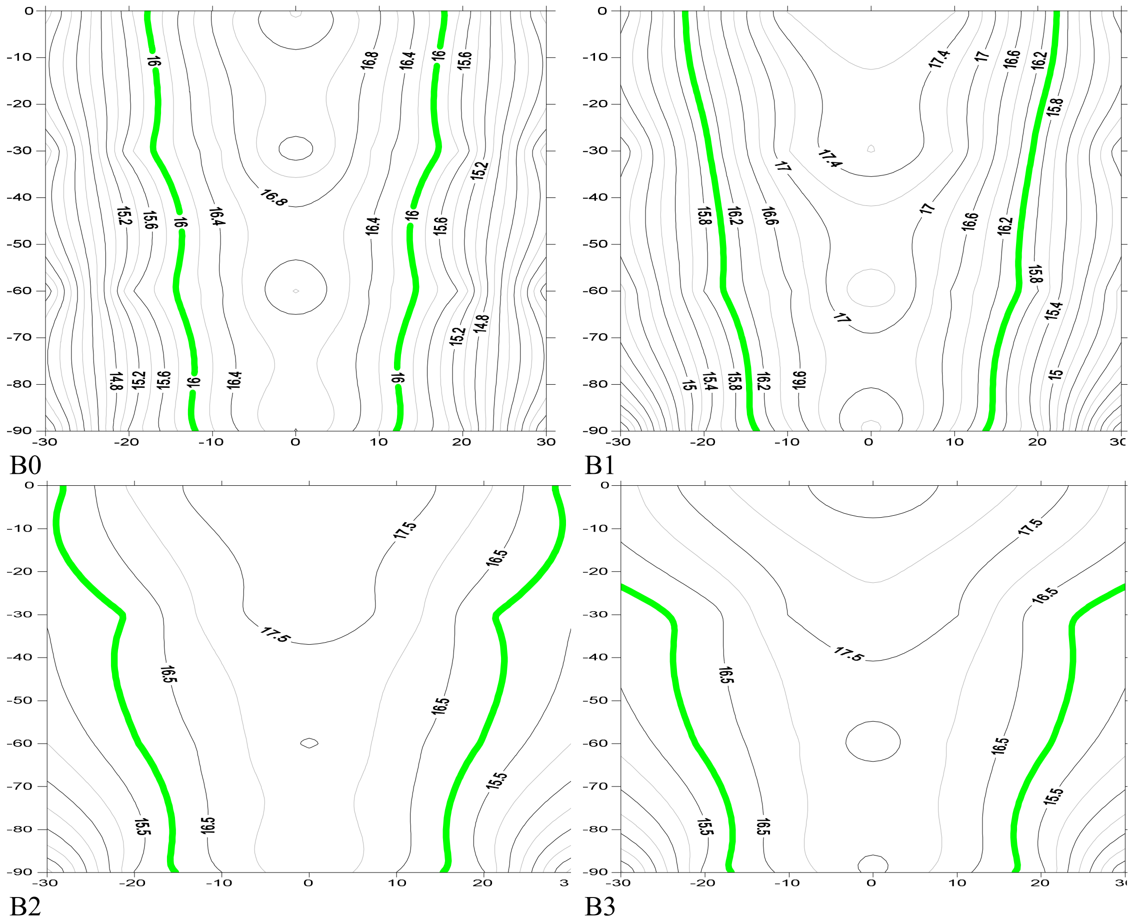

Fig. 4: Effect of biochar on soil moisture distribution during season 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar under C15 "15 ton/fed of compost").

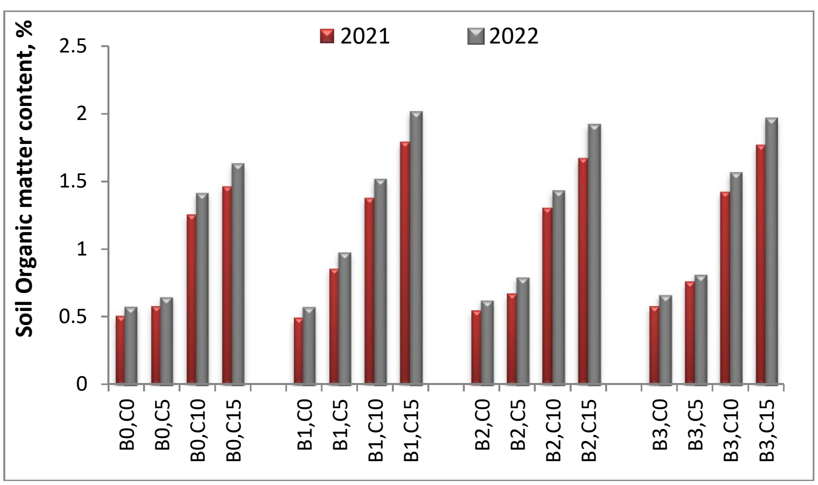

Fig. 5: Effect of biochar and compost on soil organic matter content during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

3.3. Water application efficiency

Figure (6) illustrates the importance of biochar and compost for increasing water application efficiency for the two seasons. The highest values of water application efficiency were occurred using B3+C15, while the lowest values were occurred without both biochar and compost for the two seasons.

The use of biochar led to a positive effect on water application efficiency with or without using compost rates for the two seasons. The highest water application efficiency values were under B3 followed by B2 and then B1, while the lowest values were under B0 for the two seasons. The use of compost led to a positive effect on water application efficiency with or without using biochar rates for the two seasons. The highest water application efficiency values were under C15 followed by C10 and then C5, while the lowest values were under C0 for the two seasons. Two possible explanations for the increased efficiency of water application when the biochar rate is increased; By improving sandy soil's capacity to hold water in the root zone, jojoba trees' roots experienced less water stress. The growing medium was also enriched with readily available nutrients as a result of the mechanical retention of moisture and the addition of mineral fertilizer to the biochar's pores and pockets. By increasing the rate at which biochar is applied, the capacity of the root zone to store water has increased. These findings supported El-Shawadfy and Abdelraouf (2019). Biochar had higher porosity than compost and probably produced a beneficial synergy (Githinji, 2014).

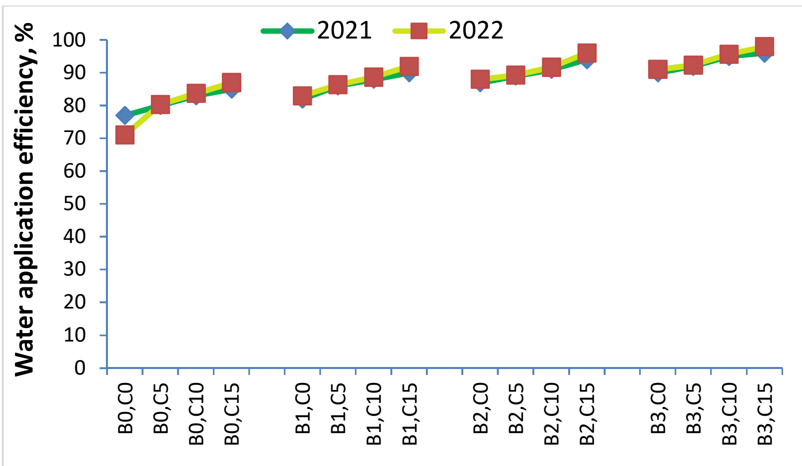

Fig. 6: Effect of biochar and compost on water application efficiency during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

3.4. Micro-organisms activity

Figure (7) represented the effect of biochar and compost on total bacterial count for the two seasons. In general, the use of biochar and compost led to a positive effect on total bacterial count for the two seasons. Total bacterial count was increased due to increasing compost rates at all biochar rates for the two seasons. The highest total bacterial count was under C15 followed by C10 and then C5, while the lowest values were under C0 for the two seasons. However, the biochar don't have clear effect on total bacterial count. Therefore, the rise in bacterial and fungal populations might be ascribed to the use of compost, which has improved the soil's chemical and physical characteristics.

3.5. Total chlorophyll content

Figure (8) showed the effect of biochar and compost on total chlorophyll content for the two seasons. The highest values of total chlorophyll content were occurred using B3+C15, while the lowest values were occurred without both biochar and compost for the two seasons. The use of biochar led to a positive effect on total chlorophyll content with or without using compost rates for the two seasons. The highest total chlorophyll content values were under B3 followed by B2 and then B1, while the lowest values were under B0 for the two seasons. The use of compost led to a positive effect on total chlorophyll content with or without using biochar rates for the two seasons. The highest total chlorophyll content values were under C15 followed by C10 and then C5, while the lowest values were under C0 for the two seasons. Chlorophyll content, which is connected to the N concentration in green plants and measures how crops respond to N fertigation and the condition of the soil's nutrients, is a useful predictor of both prospective photosynthetic production and general plant vigor. (Martínez and Guiamet, 2004). By applying biochar, chlorophyll contents of ryegrass improved by 20–32% (Hua *et* *al.,* 2012), and maize by 8–12% due to the usage of biochar and compost together with the same NPK levels as the control (Agegnehu *et al.,* 2015b).

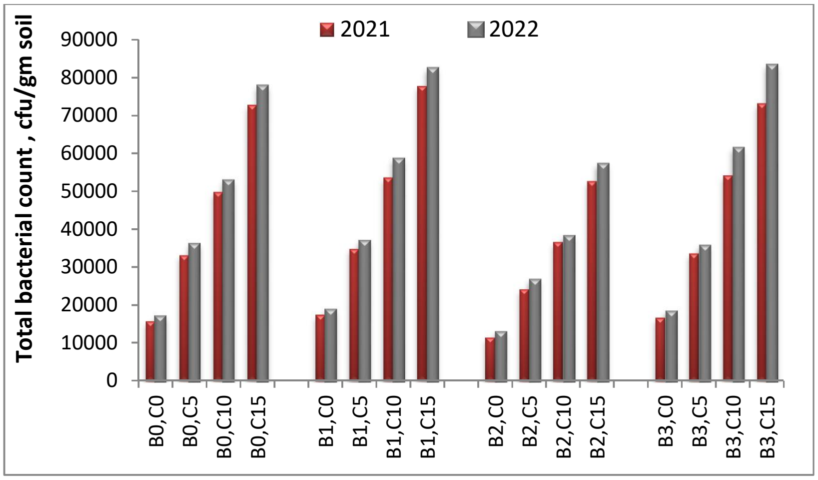

Fig. 7: Effect of biochar and compost on total bacterial count during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

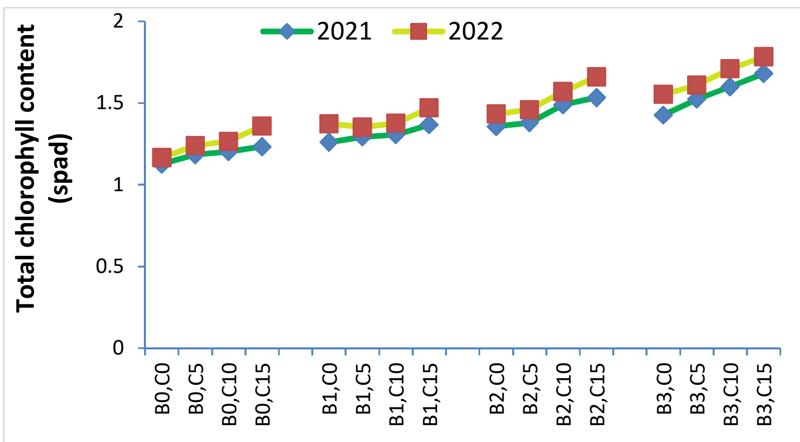

Fig. 8: Effect of biochar and compost on total chlorophyll content during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

3.6. Jojoba Productivity

When analyzing the factors separately, the first factor (biochar) had a positive and significant effect on the yield of jojoba seeds and wax (oil), which was also significantly affected by the second factor (compost) for the two seasons as represented in Table (4).

Among the biochar treatments, the highest yield values of jojoba seeds and wax (oil) were under B3 followed by B2 and then B1, while the lowest values were under B0 for the two seasons. The highest values of seeds yield were 1040.8 and 1192 ton/fed occurred by using B3 for 2021 and 2022, respectively and there are significant deference between using B3 and other rates, while the lowest values of seeds yield were 776 and 821.4 ton/fed occurred without using biochar for 2021 and 2022, respectively. Also, the highest values of wax (oil) yield were 541.9 and 643.1 ton/fed occurred by using B3 for 2021 and 2022, respectively and there are significant deference between using B3 and other rates, while the lowest values of wax (oil) yield were 352.6 and 387.1 ton/fed occurred without using biochar for 2021 and 2022, respectively. Increasing of yield of seeds and wax (oil) by increasing the biochar rate might be due to two reasons; improving the root zone's ability to store water, which will improve AE_{IW} and reduce plant water stress. As a result of the application of the biochar, nutrient availability will be increased in the growing area. The same results were found by Xu *et al.,* (2016) and Pereira *et al.,* (2015). Crop growth and yield were enhanced by the physicochemical improvements made by adding biochar to the soil (Arif *et al.,* 2016; Saxena *et al.,* 2013). The accompanying nutrient intake into the soil, which was gradually released to plants over time, can be attributed for this (Bouqbis *et al.,* 2021; Karer *et al.,* 2015). Additionally, the use of biochar had increased the productivity of crops including wheat, sorghum, and maize (Laghari *et al.,* 2015; Alburquerque *et al.,* 2013). Moreover, the use of biochar enhanced the water status of crops, which may have contributed to increasing total production (Akhtar *et al.,* 2014). According to Hossain *et al.,* (2010), applying wastewater to cherry tomatoes with 10 ton/ha of biochar enhanced production by 64.0% compared to the control soil conditions.

For compost treatments, more seeds yield (1162.6 and 1288.2 ton/fed) were recorded in C15 rate followed by using C10 rate (1012.5 and 11.31 ton/fed), and using C5 rate (908.7 and 1026.1 ton/fed), there are significant deference between using C15 and other rates, while the minimum seeds yield (760.8 and 858.7 ton/fed) were recorded without using compost for 2021 and 2022, respectively. Also, more wax (oil) yield (594.5 and 690.5 ton/fed) were recorded in C15 rate followed by using C10 rate (503.5 and 579.6 ton/fed), and using C5 rate (440.1 and 512.7 ton/fed), there are significant deference between using C15 and other rates, while the minimum seeds yield (356.8 and 419.7 ton/fed) were recorded without using compost for 2021 and 2022, respectively. Increasing of yield of seeds and wax (oil) by increasing the compost rate might be due to three reasons; improving the root zone's ability to store water while also improving the AEIW, reducing water stress in the root zone while also increasing fertigation effectiveness, and replenishing the growth medium with readily accessible nutrients as a consequence of compost application.

Among the interaction between the two factors, the interaction also had a statistically significant effect on the yield of jojoba seeds and wax (oil) for the two seasons as indicated in Figures (9) and (10), respectively. The highest values of seeds yield were 1353.1 and 1440.5 ton/fed occurred under applying B3 with using C15 during 2021 and 2022, respectively, there are no-significant deference between applying B3+C15 and B1+C15, but there are significant deference between using these conditions and other treatments, while the lowest values of seeds yield were 611.8 and 642.9 ton/fed occurred without applying biochar or compost for 2021 and 2022, respectively. Also, the highest values of wax (oil) yield were 722.6 and 805.7 ton/fed occurred under applying B3 with using C15 during 2021 and 2022, respectively, there are significant deference between applying B3+C15 and other treatments, while the lowest values of seeds yield were 261.1 and 288 ton/fed occurred without applying biochar or compost for 2021 and 2022, respectively. The increased jojoba seed and wax (oil) output might be attributed to the soil's better physico-chemical and microbiological qualities as a result of the application of compost along with biochar. By having beneficial additive effects on the soil's physical, chemical, and biological characteristics, conditioners were applied, which improved the soil environment by promoting root growth and nutrients availability and absorption. Potentially slowing soil decomposition by the use of biochar in combination with compost is advantageous for maintaining soil fertility and production. This result supports earlier research that found that biochar enhanced soil quality and yield during numerous crop seasons as a result of the delayed microbial degradation of its resistant carbon (Kätterer *et al.,* 2019). Generally, soil improvements addressing crucial parameters of nutrient availability, water content, nitrogen and carbon sequestration, and soil pH have been ascribed to better yield as a result of the application of biochar and compost together (Akca and Namli, 2015; Sun *et al.,* 2014).

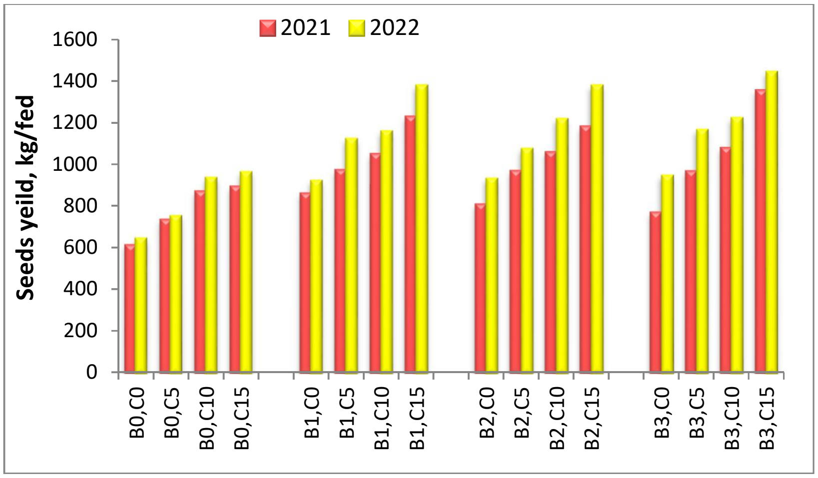

Fig. 9: Effect of biochar and compost on seeds yield of jojoba during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

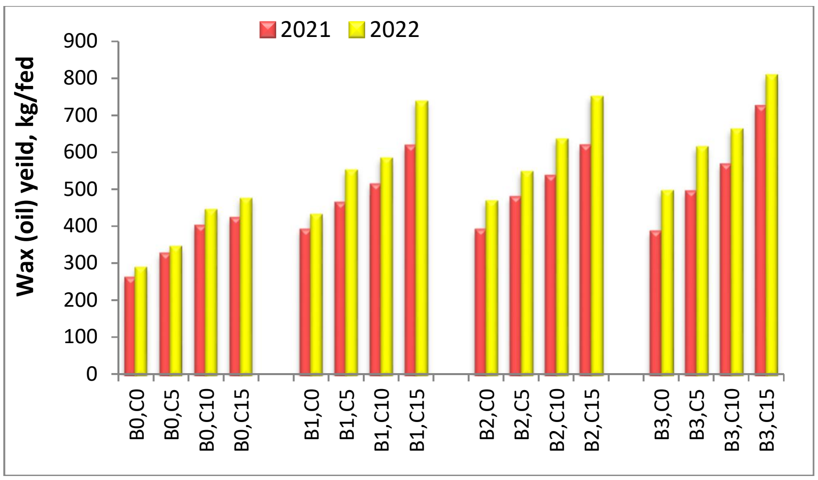

Fig. 10: Effect of biochar and compost on wax (oil) yield of jojoba during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

3.7. Water productivity of jojoba

Both factors (biochar and compost) had a statistically significant effect on water productivity (WP) of jojoba seeds and wax (oil) for the two seasons as indicated in Table (4). The first factor (biochar) had a positive and significant effect on WP. The highest WP values of jojoba seeds and wax (oil) were under B3 followed by B2 and then B1, while the lowest values were under B0 for the two seasons. The highest values of WP of jojoba seeds were 0.52 and 0.61 kg m^{-3} occurred by using B3 for 2021 and 2022, respectively and there are significant deference between using B3 and other treatments, while the lowest values of WP of jojoba seeds were 0.39 and 0.42 kg m^{-3} occurred without using biochar for 2021 and 2022, respectively. Also, the highest values of WP of wax (oil) were 0.27 and 0.33 kg m^{-3} occurred by using B3 for 2021 and 2022, respectively and there are significant deference between using B3 and other treatments, while the lowest values of WP of wax (oil) were 0.18 and 0.2 kg m^{-3} occurred without using biochar for 2021 and 2022, respectively. By increasing crop water availability, soil water storage, and soil water content by the application of biochar to soils, it may be possible to increase agricultural yield and water productivity (Liang *et al.,* 2021).

The second factor (compost) also had clearly significant effect on WP of jojoba seeds and wax (oil). More WP of jojoba seeds and wax (oil) were recorded in C15 followed by C10 and then C5, while the lowest values were under C0 for the two seasons. The highest values of WP of jojoba seeds were

0.58 and 0.66 kg m^{-3} occurred by using C15 for 2021 and 2022, respectively and there are significant deference between using C15 and other treatments, while the lowest values of WP of jojoba seeds were 0.38 and 0.44 kg m^{-3} occurred without using compost for 2021 and 2022, respectively. Also, the highest values of WP of wax (oil) were 0.3 and 0.35 kg m^{-3} occurred by using C15 for 2021 and 2022, respectively and there are significant deference between using C15 and other treatments, while the lowest values of WP of wax (oil) were 0.18 and 0.21 kg m^{-3} occurred without using compost for 2021 and 2022, respectively.

Table 4: Effect of biochar and compost on the yield and water productivity of jojoba seeds and wax (oil) during seasons 2021 and 2022.

Biochar, ton/fed	Compost, ton/fed	Seeds yield, ton/fed		Wax (oil) yield, ton/fed		Water productivity of jojoba seeds, kg m^{-3}		Water productivity of jojoba wax, kg m^{-3}	
		2021	2022	2021	2022	2021	2022	2021	2022
B0		776 b	821.4 c	352.6 c	387.1 d	0.39 b	0.42 c	0.18 c	0.2 d
B1		1025.7 a	1142.8 b	495.3 b	574 c	0.51 a	0.58 b	0.25 b	0.29 c
B2		1002.1 a	1148.1 b	505.1 b	598.2 b	0.5 a	0.59 b	0.25 b	0.31 b
B3		1040.8 a	1192 a	541.9 a	643.1 a	0.52 a	0.61 a	0.27 a	0.33 a
LSD at 5%		72.37	37.22	35.77	19.1	0.038	0.019	0.018	0.01
	C0	760.8 d	858.7 d	356.8 d	419.7 d	0.38 d	0.44 d	0.18 d	0.21 d
	C5	908.7 c	1026.1 c	440.1 c	512.7 c	0.46 c	0.53 c	0.22 c	0.26 c
	C10	1012.5 b	1131.3 b	503.5 b	579.6 b	0.51 b	0.58 b	0.25 b	0.3 b
	C15	1162.6 a	1288.2 a	594.5 a	690.5 a	0.58 a	0.66 a	0.3 a	0.35 a
LSD at 5%		67.29	34.12	34.11	18.08	0.033	0.018	0.018	0.01
B0	**C0**	611.8 h	642.9 g	261.1 j	288 l	0.31 h	0.33 h	0.13 i	0.15 k
	C5	732.3 gh	749.4 f	326.1 ij	343.7 k	0.37 gh	0.38 g	0.16 hi	0.17 j
	C10	868.4 ef	933.1 e	401.2 gh	443.2 ij	0.44 ef	0.48 f	0.2 gh	0.23 hi
	C15	891.3 ef	960.2 e	422.2 fgh	473.4 hi	0.44 ef	0.49 f	0.21 efg	0.24 gh
B1	**C0**	857.6 efg	918.6 e	390.2 hi	429.9 j	0.43 efg	0.47 f	0.2 gh	0.22 i
	C5	970.3 de	1120.2 cd	462.2 efg	549.3 fg	0.49 de	0.57 de	0.23 def	0.28 f
	C10	1048.1 cd	1156.6 bc	512.6 cde	581.8 ef	0.52 d	0.59 cd	0.26 cd	0.3 ef
	C15	1226.9 ab	1376 a	616.4 b	734.9 b	0.61 ab	0.7 b	0.31 b	0.37 b
B2	**C0**	806.4 fg	929.2 e	390.6 hi	466.5 hi	0.4 fg	0.47 f	0.2 gh	0.24 gh
	C5	966.4 de	1071.8 d	478.4 def	545.5 g	0.48 de	0.55 e	0.24 de	0.28 f
	C10	1056.3 cd	1215.2 b	534.5 cd	633.1 cd	0.53 cd	0.62 c	0.27 cd	0.32 cd
	C15	1179.1 bc	1376.2 a	616.7 b	747.8 b	0.59 bc	0.71 ab	0.31 b	0.38 b
B3	**C0**	767.4 fg	944.2 e	385.3 hi	494.5 h	0.38 fg	0.48 f	0.19 gh	0.25 g
	C5	965.7 de	1163.2 bc	493.8 de	612.2 de	0.48 de	0.59 cd	0.25 cd	0.31 de
	C10	1077 cd	1220.1 b	565.8 bc	660.1 c	0.54 cd	0.62 c	0.28 bc	0.34 c
	C15	1353.1 a	1440.5 a	722.6 a	805.7 a	0.67 a	0.74 a	0.36 a	0.41 a
LSD at 5%		134.59	68.24	68.21	36.15	0.066	0.035	0.035	0.02

B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost.

The interaction between the two factors also had a statistically significant effect on WP of jojoba seeds and wax (oil) for the two seasons as shown in Figures (11) and (12), respectively. The highest values of WP of jojoba seeds were 0.67 and 0.74 kg m^{-3} occurred using B3+C15 for 2021 and 2022, respectively and there are significant deference between using these conditions and other treatments, while the lowest values of WP of jojoba seeds were 0.31 and 0.33 kg m^{-3} occurred without using biochar or compost for 2021 and 2022, respectively. Also, the highest values of WP of wax (oil) were 0.36 and 0.41 kg m^{-3} occurred using B3+C15 for 2021 and 2022, respectively and there are significant deference between using these conditions and other treatments, while the lowest values of WP of wax (oil) were 0.13 and 0.15 kg m^{-3} occurred without using biochar or compost for 2021 and 2022, respectively.

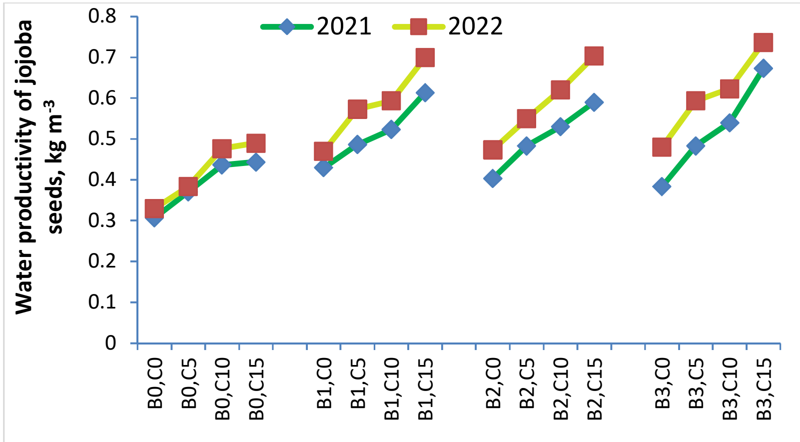

Fig. 11: Effect of biochar and compost on water productivity of jojoba seeds during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

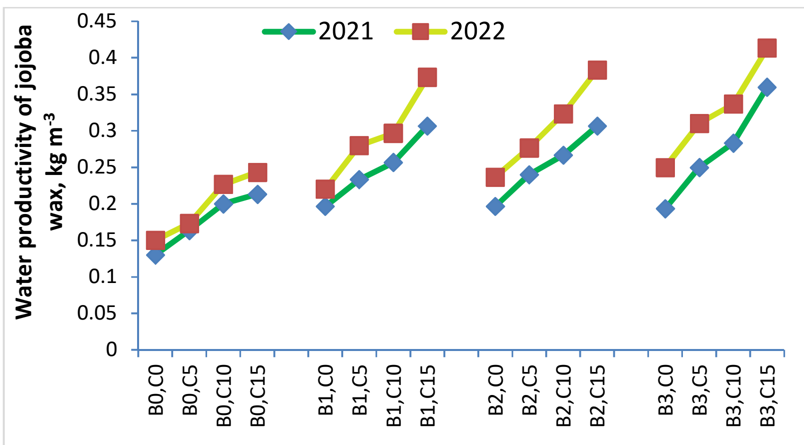

Fig. 12: Effect of biochar and compost on water productivity of jojoba wax (oil) during seasons 2021 and 2022. (B0, B1, B2, B3: 0, 1, 2, 3 ton/fed of biochar; C0, C5, C10, C15: 0, 5, 10, 15 ton/fed of compost)

4. Conclusions

Sandy soils have a high rate of infiltration, minimum water holding capacity, and a limited amount of accessible water as a result. This is explained by a large proportion of sand and a very limited range of organic matter. Sand soil's physical characteristics can be enhanced by using biochar and compost, sources of organic carbon with a high cation exchange capacity. Applied 3 ton/fed of biochar with 15 ton/fed compost have showed greater improvement of soil quality, yield, and water productivity for seed and wax (oil) of jojoba trees than other treatments, and farmers involved in upland jojoba production are encouraged to consider applying compost + biochar as a means of soil fertility management. According to this study, adding biochar and compost to sandy soil is a beneficial amendment for improving and raising plant production here.

References

Abbas, T., M. Rizwan, S. Ali, M. Adrees, A. Mahmood, M. Zia-ur-Rehman, M. Ibrahim, M. Arshad, and M.F. Qayyum, 2018. Biochar application increased the growth and yield and reduced cadmium in drought stressed wheat grown in an aged contaminated soil. Ecotoxicol. Environ. Saf., 148: 825-833. [https://doi.org/10.1016/j.ecoenv.2017.11.063]

Abdelraouf, R.E., S.D. Abou-Hussein, K.M. Refaie, and I.M. El-Metwally, 2012. Effect of pulse irrigation on clogging emitters, application efficiency and water productivity of potato crop under organic agriculture conditions. Australian Journal of Basic and Applied Sciences, 6(3): 807-816.

Abdelraouf, R.E. and R. Ragab, 2018. Effect of fertigation frequency and duration on yield and water productivity of wheat: field and modelling study using the saltmed model. Irrig. and Drain., 67(3): 414-428. [https://doi.org/10.1002/ird.2232]

Abdelraouf, R.E., K.M. Refaie, and I.A. Hegab, 2013. Effect of drip lines spacing and adding compost on the yield and irrigation water use efficiency of wheat grown under sandy soil conditions. Journal of Applied Sciences Research, 9(2): 1116-1125.

Abdel-Shafy, H. and M. Mansour, 2013. Overview on water reuse in Egypt: Present and Future. J. Sustainable Sanitation Practice, 14: 17-25.

Abou Hussien, E.A., M.H. Shalaby, and B.S. Alshahri, 2020. Utilizing compost and biochar in enhancing phytoremediation of contaminated soil. Menoufia J. Soil Sci., 5(8): 201-213. [https://doi.org/10.21608/MJSS.2020.172119]

Adekiya, A.O., T.M. Agbede, C.M. Aboyeji, O. Dunsin, and V.T. Simeon, 2019. Biochar and poultry manure effects on soil properties and radish (*Raphanus sativus* L.) yield. Biological Agriculture & Horticulture, 35(1): 33-45. [https://doi.org/10.1080/01448765.2018.1500306]

Agegnehu, G., A.M. Bass, P.N. Nelson, B. Muirhead, G. Wright, and M.I. Bird, 2015a. Biochar and biochar-compost as soil amendments: Effects on peanut yield, soil properties and greenhouse gas emissions in tropical North Queensland, Australia. Ecosyst. Environ., 213: 72-85. [https://doi.org/10.1016/j.agee.2015.07.027]

Agegnehu, G., M.I. Bird, P.N. Nelson, and A.M. Bass, 2015b. The ameliorating effects of biochar and compost on soil quality and plant growth on a Ferralsol. Soil Res., 53(1): 1-12. [https://doi.org/10.1071/SR14118]

Aguirre, J.L., M.T. Martín, S. González, and M. Peinado, 2021. Effects and economic sustainability of biochar application on corn production in a Mediterranean climate. Molecules, 26(11): 3313. [https://doi.org/10.3390/molecules26113313]

Akca, M.O. and A. Namli, 2015. Effects of poultry litter biochar on soil enzyme activities and tomato, pepper and lettuce plants growth. Eurasian J. Soil Sci., 4(3):161-168. [https://doi.org/10.18393/ejss.2015.3.161-168]

Akhtar, S.S., M.N. Andersen, and F. Liu, 2015. Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress. Agric. Water Manage., 158: 61-68. [https://doi.org/10.1016/j.agwat.2015.04.010]

Akhtar, S.S., G. Li, M.N. Andersen, and F. Liu, 2014. Biochar enhances yield and quality of tomato under reduced irrigation. Agric. Water Manage., 138: 37-44. [https://doi.org/10.1016/j.agwat.2014.02.016]

Alburquerque, J.A., P. Salazar, V. Barrón, J. Torrent, M.D. del Campillo, A. Gallardo, and R. Villar, 2013. Enhanced wheat yield by biochar addition under different mineral fertilization levels. Agron. Sustain. Dev., 33: 475-484. [https://doi.org/10.1007/s13593-012-0128-3]

Al-Soqeer, A., M.I. Motawei, M. Al-Dakhil, R. El-Mergawi, and N. Al-Khalifah, 2012. Genetic Variation and Chemical Traits of Selected New Jojoba (Simmondsiachinensis (Link) Schneider) Genotypes. J. Am. Oil. Chem. Soc., 89(8): 1455-1461. [https://doi.org/10.1007/s11746-012-2034-x]

Alves, B.S.Q., K.P.S. Zelaya, F. Colen, L.A. Frazão, A. Napoli, S.J. Parikh, and L.A. Fernandes, 2021. Effect of sewage sludge and sugarcane bagasse biochar on soil properties and sugar beet production. Pedosphere, 31(4): 572-582. [https://doi.org/10.1016/S1002-0160(21)60003-6]

Aminifard, M.H., H. Aroiee, M. Azizi, H. Nemati, and H.Z.E. Jaafar, 2013. Effect of compost on antioxidant component sand fruit quality of sweet pepper (*Capsicum annuum* L.). J. Cent. Europ. Agric., 14(2): 525-534. [https://doi.org/10.5513/jcea.v14i2.2180]

Andreev, N., M. Ronteltap, P.N. Lens, B. Boincean, L. Bulat, and E. Zubcov, 2016. Lacto-fermented mix of faeces and bio-waste supplemented by biochar improves the growth and yield of corn (*Zea mays* L.). Agric., Ecosyst. Environ., 232: 263-272.

[https://doi.org/10.1016/j.agee.2016.08.012]

Arafat, S.M. and A.M. Basuny, 2018. Jojoba oil: A new media for frying process. Curr. Trends Biomedical Eng. & Biosci., 17(1): 555952. [https://doi.org/10.19080/CTBEB.2018.17.555952]

Arif, M., K. Ali, M.T. Jan, Z. Shah, D.L. Jones, and R.S. Quilliam, 2016. Integration of biochar with animal manure and nitrogen for improving maize yields and soil properties in calcareous semi-arid agroecosystems. Field Crops Res., 195: 28-35. [https://doi.org/10.1016/j.fcr.2016.05.011]

Bamminger, C., N. Zaiser, P. Zinsser, M. Lamers, C. Kammann, and S. Marhan, 2014. Effects of biochar, earthworms, and litter addition on soil microbial activity and abundance in a temperate agricultural soil. Biol. Fertil. Soils, 50: 1189-1200. [https://doi.org/10.1007/s00374-014-0968-x]

Bonanomi, G., F. Ippolito, G. Cesarano, B. Nanni, N. Lombardi, A. Rita, A. Saracino, and F. Scala, 2017. Biochar as plant growth promoter: better off alone or mixed with organic amendments? Front. Plant Sci., 8: 1570. [https://doi.org/10.3389/fpls.2017.01570]

Bouqbis, L., S. Daoud, and M.C. Harrouni, 2021. Positive effect of biochar derived from argan waste on soil nutrients and growth of three plants. J. Ecol. Eng., 22(7): 28-34. [https://doi.org/10.12911/22998993/137920]

Chojnacka, K., A. Witek-Krowiak, K. Moustakas, D. Skrzypczak, K. Mikula, and M. Loizidou, 2020. A transition from conventional irrigation to fertigation with reclaimed wastewater: Prospects and challenges. Renew. Sustain. Energy Rev., 130: 109959. [https://doi.org/10.1016/j.rser.2020.109959]

El-Meseery, A.A., 2003. Effect of different drip irrigation systems on maize yield in sandy soil. The 11th Annual Conference of Misr Society of Agric. Eng., 576-594.

El-Shawadfy, M.A. and R.E. Abdelraouf, 2019. Deficit irrigation management in arid regions by adding biochar to sandy soils: Sweet pepper cultivation. Current Science International, 8(4): 667-677. [https://doi.org/10.36632/csi/2019.8.4.7]

Foley, J.A., R. Defries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, J.H. Helkowski, T. Holloway, E.A. Howard, C.J. Kucharik, C. Monfreda, J.A. Patz, I.C. Prentice, N. Ramankutty, and P.K. Snyder, 2005. Global consequences of land use. Science, 309: 570-574. [https://doi.org/10.1126/science.1111772]

Githinji, L., 2014. Effect of biochar application rate on soil physical and hydraulic properties of a sandy loam. Archives of Agronomy and Soil Science, 60(4): 457-470. [https://doi.org/10.1080/03650340.2013.821698]

Gu, S., F. Lian, H. Yang, Y. Han, W. Zhang, F. Yang, and J. Gao, 2021. Synergic effect of microorganism and colloidal biochar-based organic fertilizer on the growth and fruit quality of tomato. Coatings, 11(12): 1453. [https://doi.org/10.3390/coatings11121453]

Gunarathne, V., A. Senadeera, U. Gunarathne, J.K. Biswas, Y.A. Almaroai, and M. Vithanage, 2020. Potential of biochar and organic amendments for reclamation of coastal acidic-salt affected soil. Biochar, 2(1): 107-120. [https://doi.org/10.1007/s42773-020-00036-4]

Hammer, E.C., Z. Balogh-Brunstad, I. Jakobsen, P.A. Olsson, S.L. Stipp, and M.C. Rillig, 2014. A mycorrhizal fungus grows on biochar and captures phosphorus from its surfaces. Soil Biol. Biochem., 77: 252-260. [https://doi.org/10.1016/j.soilbio.2014.06.012]

Hashim, M.N., O. Abd Razak, K. Rosdi, and M.K. Soliman, 2010. Wastewater-irrigated industrial woody plantations for rehabilitation of arid areas in Egypt. In the Proceedings of the 2010 International Symposium on Forestry and Forest Products, Kuala Lumpur, Malaysia, 30-41. [https://doi.org/10.13140/2.1.4490.6563]

He, X., Z. Du, Y. Wang, N. Lu, and Q. Zhang, 2016. Sensitivity of soil respiration to soil temperature decreased under deep biochar amended soils in temperate croplands. Appl. Soil Ecol., 108: 204-210. [https://doi.org/10.1016/j.apsoil.2016.08.018]

Hossain, M.K., V. Strezov, K.Y. Chan, and P.F. Nelson, 2010. Agronomic properties of wastewater sludge biochar and bioavailability of metals in production of cherry tomato (*Lycopersicon esculentum*). Chemosphere, 78(9): 1167-1171. [https://doi.org/10.1016/j.chemosphere.2010.01.009]

Hua, L., Y. Chen, and W. Wu, 2012. Impacts upon soil quality and plant growth of bamboo charcoal addition to composted sludge. Environ. Technol., 33(1): 61-68. [https://doi.org/10.1080/09593330.2010.549845]

Jackson, M.L., 1958. Soil Chemical Analysis. Prentic-Hall, Inc. Englewood Cliffs, N.J. Library of Congress, USA, 498.

James, L.G., 1988. Principles of farm irrigation system design. John Willey & sons. Inc., Washington State University.

Jeffery, S., F.G. Verheijen, M. van der Velde, and A.C. Bastos, 2011. A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agric. Ecosyst. Environ., 144(1): 175-187. [https://doi.org/10.1016/j.agee.2011.08.015]

Jiang, X., M.L. Haddix, and M.F. Cotrufo, 2016. Interactions between biochar and soil organic carbon decomposition: effects of nitrogen and low molecular weight carbon compound addition. Soil Biol. Biochem., 100: 92-101. [https://doi.org/10.1016/j.soilbio.2016.05.020]

Jien, S.H. and C.S. Wang, 2013. Effects of biochar on soil properties and erosion potential in a highly weathered soil. Catena, 110: 225-233. [https://doi.org/10.1016/j.catena.2013.06.021]

Karer, J., A. Wawra, F. Zehetner, G. Dunst, M. Wagner, P. Pavel, M. Puschenreiter, W. Friesl-Hanl, and G. Soja, 2015. Effects of biochars and compost mixtures and inorganic additives on immobilisation of heavy metals in contaminated soils. Water Air Soil Pollut., 226: 342. [https://doi.org/10.1007/s11270-015-2584-2]

Kätterer, T., D. Roobroeck, O. Andrén, G. Kimutai, E. Karltun, H. Kirchmann, G. Nyberg, B. Vanlauwe, and K.R. de Nowina, 2019. Biochar addition persistently increased soil fertility and yields in maize soybean rotations over 10 years in sub-humid regions of Kenya. Field Crops Research, 235: 18-26. [https://doi.org/10.1016/j.fcr.2019.02.015]

Kranz, C.N., R.A. McLaughlin, A. Johnson, G. Miller, and J.L. Heitman, 2020. The effects of compost incorporation on soil physical properties in urban soils - A concise review. J. Environ. Manage., 261: 110209. [https://doi.org/10.1016/j.jenvman.2020.110209]

Laghari, M., M.S. Mirjat, Z. Hu, S. Fazal, B. Xiao, M. Hu, Z. Chen, and D. Guo, 2015. Effects of biochar application rate on sandy desert soil properties and sorghum growth. Catena, 135: 313-320. [https://doi.org/10.1016/j.catena.2015.08.013]

Lehmann, J., J. Pereira da Silva, C. Steiner, T. Nehls, W. Zech, and B. Glaser, 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. Plant and Soil, 249: 343-357. [https://doi.org/10.1023/A:1022833116184]

Li, Y., N. Yao, J. Liang, X. Wang, Y. Jia, F. Jiang, D.L. Liu, W. Hu, H. He, and T. Javed, 2022. Optimum biochar application rate for peak economic benefit of sugar beet in Xinjiang, China. Agric. Water Manage., 272: 107880. [https://doi.org/10.1016/j.agwat.2022.107880]

Liang, J., Y. Li, B. Si, Y. Wang, X. Chen, X. Wang, H. Chen, H. Wang, F. Zhang, Y. Bai, and A. Biswas, 2021. Optimizing biochar application to improve soil physical and hydraulic properties in saline-alkali soils. Sci. Total Environ., 771: 144802. [https://doi.org/10.1016/j.scitotenv.2020.144802]

Liu, P.M., W.J. Liu, H. Jiang, J.J. Chen, W.W. Li, and H.Q. Yu, 2012. Modification of biochar derived from fast pyrolysis of biomass and its application in removal of tetracycline from aqueous solution. Bioresour. Technol., 121: 235-240. [https://doi.org/10.1016/j.biortech.2012.06.085]

MacCarthy, D.S., E. Darko, E.K. Nartey, S.G. Adiku, and A. Tettey, 2020. Integrating biochar and inorganic fertilizer improves productivity and profitability of irrigated rice in Ghana, West Africa. Agronomy, 10(6): 904. [https://doi.org/10.3390/agronomy10060904]

Manolikaki, L. and E. Diamadopoulos, 2019. Positive effects of biochar and biochar-compost on maize growth and nutrient availability in two agricultural soils. Communications in Soil Science and Plant Analysis, 50(5): 512-526. [https://doi.org/10.1080/00103624.2019.1566468]

Martí, E., J. Sierra, X. Domene, M. Mumbrú, R. Cruañas, and M.A. Garau, 2021. One-year monitoring of nitrogen forms after the application of various types of biochar on different soils. Geoderma, 402: 115178. [https://doi.org/10.1016/j.geoderma.2021.115178]

Martínez, D.E. and J.J. Guiamet, 2004. Distortion of the SPAD 502 chlorophyll meter readings by changes in irradiance and leaf water status. Agronomie, 24(1): 41-46. [https://doi.org/10.1051/agro:2003060]

Marwa, M.A., R.E. Abdelraouf, S.W. Wahba, K.F. El-Bagouri, and A.G. El-Gindy, 2017. Scheduling irrigation using automatic tensiometers for pea crop. Agricultural Engineering International: CIGR Journal, Special issue: 174-183.

Nasr, F.A., S.A. El-Shafai, A.S. Abdelfadil, H.S. Ibrahim, and B.A. Hemdan, 2018. Potential use of treated domestic sewage for cultivation of biofuel crops in Egypt. Int. J. Environ. Sci. Technol., 16: 7433-7442. [https://doi.org/10.1007/s13762-018-2101-4]

Oni, B.A., O. Oziegbe, and O.O. Olawole, 2019. Significance of biochar application to the environment and economy. Ann. Agric. Sci., 64(2): 222-236. [https://doi.org/10.1016/j.aoas.2019.12.006]

Paradelo, R., R. Basanta, and M.T. Barral, 2019. Water-holding capacity and plant growth in compost-based substrates modified with polyacrylamide, guar gum or bentonite. Sci. Hortic., 243: 344-349. [https://doi.org/10.1016/j.scienta.2018.08.046]

Pereira, E.I.P., E.C. Suddick, I. Mansour, F.N. Mukome, S.J. Parikh, K. Scow, and J. Six, 2015. Biochar alters nitrogen transformations but has minimal effects on nitrous oxide emissions in an organically managed lettuce mesocosm. Biol. Fertil. Soils. 51(5): 573-582. [https://doi.org/10.1007/s00374-015-1004-5]

Phares, C.A., A. Kofi, K.A. Frimpong, A. Danquah, A. Asare, and S. Aggor-Woananu, 2020. Application of biochar and inorganic phosphorus fertilizer influenced rhizosphere soil characteristics, nodule formation and phytoconstituents of cowpea grown on tropical soil. Heliyon, 6(10): e05255. [https://doi.org/10.1016/j.heliyon.2020.e05255]

Pressler, Y., E.J. Foster, J.C. Moore, and M.F. Cotrufo, 2017. Coupled biochar amendment and limited irrigation strategies do not affect a degraded soil food web in a maize agroecosystem, compared to the native grassland. GCB Bioenergy, 9(8): 1344-1355. [https://doi.org/10.1111/gcbb.12429]

Prommer, J., W. Wanek, F. Hofhansl, D. Trojan, P. Offre, T. Urich, C. Schleper, S. Sassmann, B. Kitzler, G. Soja, and R.C. Hood-Nowotny, 2014. Biochar decelerates soil organic nitrogen cycling but stimulates soil nitrification in a temperate arable field trial. PLoS ONE 9(1): e86388. [https://doi.org/10.1371/journal.pone.0086388]

Rafael, R.B.A., M.L. Fernández-Marcos, S. Cocco, M.L. Ruello, F. Fornasier, and G. Corti, 2019. Benefits of biochars and NPK fertilizers for soil quality and growth of cowpea (Vigna unguiculata L. Walp.) in an acid Arenosol. Pedosphere, 29(3): 311-333. [https://doi.org/10.1016/S1002-0160(19)60805-2]

Saxena, J., G. Rana, and M. Pandey, 2013. Impact of addition of biochar along with Bacillus sp. on growth and yield of French beans. Sci. Hortic., 162: 351-356. [https://doi.org/10.1016/j.scienta.2013.08.002]

Savva, A.P. and K. Frenken, 2002. Irrigation manual, planning, development monitoring and evaluation of irrigated agriculture with farmer participation. Volume IV, FAO, SAFR, Harare. [http://www.fao.org/docrep/pdf/010/ai596e/ai596e.pdf]

Schmidt, H.P., B.H. Pandit, V. Martinsen, G. Cornelissen, P. Conte, and C.I. Kammann, 2015. Fourfold increase in pumpkin yield in response to low-dosage root zone application of urine-enhanced biochar to a fertile tropical soil. Agriculture, 5(3): 723-741. [https://doi.org/10.3390/agriculture5030723]

She, D., X. Sun, A. Gamareldawla, E.A. Nazar, W. Hu, K. Edith, and S. Yu, 2018. Benefits of soil biochar amendments to tomato growth under saline water irrigation. Sci. Rep., 8(1): 14743. [https://doi.org/10.1038/s41598-018-33040-7]

Smith, P., 2016. Soil carbon sequestration and biochar as negative emission technologies. Glob. Change Biol., 22(3): 1315-1324. [https://doi.org/10.1111/gcb.13178]

Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. Oxford and J.B.H. publishing com. 7th edition, 593.

Sohi, S., E. Krull, E. Lopez-Capel, and R. Bol, 2010. A review of biochar and its use and function in soil. Adv. Agron., 105: 47-82. [https://doi.org/10.1016/S0065-2113(10)05002-9]

Song, Y., X. Zhang, B. Ma, S.X. Chang, and J. Gong, 2014. Biochar addition affected the dynamics of ammonia oxidizers and nitrification in microcosms of a coastal alkaline soil. Biol. Fertil. Soils, 50(2): 321-332. [https://doi.org/10.1007/s00374-013-0857-8]

Sun, Z., E.W. Bruun, E.L.W. Arthur, J.P. Moldrup, H. Hauggaard-Nielsen, and H. Elsgaar, 2014. Effect of biochar on aerobic processes, enzyme activity, and crop yields in two sandy loam soils. Biol. Fert. Soils, 50: 1087-1097. [https://doi.org/10.1007/s00374-014-0928-5]

Vanlauwe, B., A. Bationo, J. Chianu, J.E. Giller, R. Merckx, U. Mokwunye, O. Ohiokpehai, P. Pypers, R. Tabo, K.D. Shepherd, E.M.A. Smaling, P.L. Woomer, and N. Sanginga, 2010. Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. Outlook Agric., 39(1): 17-24. [https://doi.org/10.5367/000000010791169998]

Ventorino, V., A. Pascale, M. Fagnano, P. Adamo, V. Faraco, C. Rocco, N. Fiorentino, and O. Pepe, 2019. Soil tillage and compost amendment promote bioremediation and biofertility of polluted area. Journal of Cleaner Production, 239: 118087. [https://doi.org/10.1016/j.jclepro.2019.118087]

Von Wettstein, D., 1957. Chlorophyll latalfaktoren und der submikroskopische formuechsel der plastidenn. Exper. Cell Res., 12: 327-433.

Wu, J., R.G. Joergensen, B. Pommerening, R. Chaussod, and P.C. Brookes, 1990. Measurement of soil microbial biomass C by fumigation-extraction: An automated procedure. Soil Biol. Biochem., 22: 1167-1169.

Xu, N., G. Tan, H. Wang, and X. Gai, 2016. Effect of biochar additions to soil on nitrogen leaching, microbial biomass and bacterial community structure. Eur. J. Soil Biol., 74: 1-8. [https://doi.org/10.1016/j.ejsobi.2016.02.004]

Yost, J.L. and A.E. Hartemink, 2019. Chapter Four-Soil organic carbon in sandy soils: A review. In: Sparks, D.L. (eds.), Advances in Agronomy, 1st edition, Academic Press, Newark, DE, USA: 217-230.

Zhao, X., S. Wang, and G. Xing, 2014. Nitrification, acidification, and nitrogen leaching from subtropical cropland soils as affected by rice straw-based biochar: laboratory incubation and column leaching studies. J. Soils Sediments, 14(3): 471-482. [https://doi.org/10.1007/s11368-013-0803-2]