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Saving 45% of Irrigation Water of Date Palm Tree Plantations Using Soil Amendments in UAE

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Date palm (Phoenix dactylifera) tolerates relatively harsh climatic and soil condition in Arab countries. The annual total irrigation water requirements for Date palm trees in the Arab regions range from 73.0 to 95 (m^3/tree). Also, approximately 70-80% of global freshwater consumption is used in the agricultural sector, yet water use efficiency in many countries is below 50%. Today, some 2.8 billion people live in water-scarce areas, but by 2030, it is expected that about half of the world's population will live in water stressed areas. Water saving amendments, are natural soil mixes produced from recycled date palm fronds and farm wastes to produce Compost and Bio char in order to be used to reduce the amount of water needed in irrigation for date palms. When soil amendments mixed in the soil, the material can retain great amounts of water per kg of product which will be beneficial as water reservoir especially during periods of drought. In this experiment we used three natural different water conservative materials to study their effects on saving irrigation water under date palm plantations, the Three different water saving products e.g. Compost©, Bio Char (BC) and water saving (WS). Five different levels of water saving materials e.g. control, 5 kg/tree, 10 kg / tree, 15 kg / tree and 20 kg/tree were used. Our results recommend that, addition of 15 kg of water saving amendments per tree can reduce the water needed for irrigation by 45%. This research paper focuses mainly on introducing natural means of managing irrigation water through soil conditioning, using water saving amendments. Economic Values of water saved are evaluated, and we found that compost and bio char can save 6.35 m^3/tree and

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11.35 m^3/tree of water per year respectively, while water saver product can save 31.90 m^3 of water/tree per year. By calculating the cost saved, compost and bio char can save 5.40$ and 9.65$/tree/year respectively, while water saver product can save 27.13 $/tree/year. Therefore, soil conditioning using these materials can save huge amounts of water in agricultural sector including date palm as well as other plants in addition to improved soil properties. This study was undertaken to show how much water can be saved when farmers recycle farm wastes in the form of soil conditioners, and its impact on farm profitability and environmental protection.

Keywords: Compost; bio char; water saver; irrigation; and date palm trees.

1. INTRODUCTION

Today, some 2.8 billion people live in water-scarce areas, but by 2030, it is expected that about half of the world's population will live in water stressed areas. World agriculture is facing an enormous challenge over the next 40 years: to produce almost 50% more food up to 2030 and double production by 2050. This will probably have to be achieved with less water, mainly because of pressure from growing urbanization, industrialization and the negative impact of climate change [1,2].

An increase in C content of the soil increases aggregation, decreases bulk density and increases water holding capacity [3]. Date palm trees (DPT) in the UAE generate around 600000 tons of date fronds which is an abundantly available agricultural waste and small percentage is economically used and recycled, and the same problems exist in many date producing countries. DPT are cultivated in arid and semi-arid regions and can thrive in long and hot summers, low rainfall and very low relative humidity [4]. About 105 million trees are available around the Arab world covering over a million hectares. The UAE has the largest number of date palm trees in the Arab world, about 42 million date palm trees with an annual production rate of 770,000 tons of date fruits. Each tree generates about 15 kilograms (kg) of waste biomass annually, totaling 600 million kg of green waste. Converting date palm waste into soil amendments can reduce carbon dioxide (CO_2) and methane (CH_4) emissions generated by the natural decomposition or through burning of the waste [5-8].

The United Arab Emirates (UAE) has sandy soil with very low water and nutrient holding capacities. In these conditions, date palm is considered one of the most resilient crops in the region. Over the years, with rising temperatures and scarce precipitation, there have been calls for new ways to conserve water, improve soil properties and prevent nutrients loss to achieve future food and nutrition security.

Two major natural resource concerns of this century are climate change and water (quality and quantity). Soil texture and organic matter content are the key components that determine soil water holding capacity (WHC). Water holding capacity of soils is controlled primarily by: (i) the number of pores and pore-size distribution of soils; and (ii) the specific surface area soils. Because of increased aggregation, total pore space is increased [1,2,9,10,11]. Furthermore, as a result of decreased bulk density, the pore-size distribution is altered and the relative number of small pores increases, especially for coarse textured soils [9]. Sandy soils have much less surface area than clayey soils and, thus, retain much less water at higher tensions. However, with the addition of organic matter, specific surface area increases resulting in increased WHC at higher tensions [9,12]. Soil "holds" water available for crop use, retaining it against the pull of gravity, and this is one of the most important physical facts for agriculture. In one study, after 32 years, AWC increased by 23% in NT vs. CT where residue was retained under both systems. This increase was correlated to soil organic matter (SOM) increases. Soil organic matter (SOM) increased 102% under NT in the surface 20 centimeters (cm). In another study, "because of the changing nature of the soil matrix (mineral-dominated to organic carbon dominated surfaces), the change in AWC ranges from about 2.5 to 5% per 1.0% change in organic carbon in soils containing less than 2.5% organic carbon and less than 40% clay" [13]. The increase in amount of SOM in any soil is highly correlated to the increase in AWC. In all textural classes studied (sand, silt loam, silty clay loam), increasing SOM from 1-3% for the sand, and 2-4% for the silt loam and silty clay loam classes, increased AWC by 73, 45%, and 47% respectively.

This paper demonstrates that in a business-as-usual scenario, water consumption in agriculture would almost doubles. Current water use trends are not sustainable in the face of population growth and climate change [14]. Placing both economic development and security at risk due to poor water management. Groundwater has provided great benefits to agriculture irrigation in semi-arid countries, but its intensive use beyond recharge in certain regions has depleted resources and generated significant negative environmental externalities.

During seasons of drought and water scarcity, the other inefficiencies of irrigation and soil management make already difficult times for farmers even worse [5,15,16]. Since water is essential to grow food, a drought situation can pose major problems for agriculture. Hence, farmers often face extreme poverty in drought-prone areas. That is why efficient water use techniques are very important in the face of climate change [9-12,17].

In the Kingdom of Saudi Arabia KSA, [18] studied the irrigation water requirements for date palm trees in several areas. The annual total irrigation water requirements (m^3 /tree) in these regions are 95, 73.4, 73, 89, 86, 85.7, 80, 85 m^3 respectively as the radius of shaded area per tree is 3.5 m. Each soil type has a different capability to hold moisture based on soil depth, soil texture (ratios of various soil particle sizes), soil structure (soil porosity) and soil water tension. A combination of these elements determines the amount of water available to the plant. In addition to serving as water reservoir, soil is also a nutrient reservoir, and it mechanically supports and stabilizes plants. Soil type may vary within the root zone, so it is important to know crop root depth and the soil type throughout the root zone [19-22].

Bio char is a solid product produced from thermal conversion of unstable carbon-enriched materials into stable carbon-enriched charred materials that can be incorporated into the soils as a mean for agronomic or environmental management. It can be produced out of a long list of feed stock. The composition of bio char (content in carbon, nitrogen, potassium, calcium, etc.) is directly related on the feedstock used and the duration and temperature of pyrolysis.

Bio char has been produced with a range of pH values between 4 and 12, dependent upon the feedstock and pyrolysis temperature. Generally, low pyrolysis temperatures (< 400°C) yield acidic bio char, while increasing pyrolysis temperatures produce alkaline bio char. Once incorporated to the soil, surface oxidation occurs due to reactions of water, O_2 and various soil agents [23,24]. The cation exchange capacity (CEC) of fresh bio char is typically very low, but increases with time as the bio char ages in the presence of O_2 and water [23-25].

Previous analysis has shown that it is feasible to prepare bio char with relatively high BET surface areas from date palm fronds, which is favorable for microbial communities to grow and therefore enhancing fertility of the soils. We can boost food security, discourage deforestation and preserve cropland diversity by converting agricultural waste into a powerful soil enhancer that holds carbon and makes soils more fertile [15,26-28].

Biomass produced from date palm trees can't be composted easily in normal composting process due to its high content of lignocellulose compound, while the bio char production can be the option to generate both energy and soil conditioner for the improvement of sandy soil under the gulf countries severe climate. Compost, bio char and water saver are biologically produced stable carbon sources that can be added to soil. They process agricultural waste into a soil enhancer that improves soil fertility, saves water, helps to mitigate greenhouse gas (GHG) emissions and fight global warming.

2. MATERIALS AND METHODS

In this experiment we used the three different soil amendments, e.g. Compost, Bio char and Water saver products at five different levels to test water saving under date palm tree plantations in sandy soils under UAE climate conditions.

2.1 Materials

A. Soils, sandy soil used in this study, located in Al Ain, Abu Dhabi – UAE.

B. Irrigation water used was underground water wells. Analysis of soil and irrigation water, are presented in Table 1.

Table 1. Analysis of soil and irrigation water used in the experiment

Samples				Cations				Anions			
	pH	EC	$CaCO_3$	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4
Soil	7.30	2.12	26.95	27.6	58.3	124	3.8	146	0.0	2.5	42.9
Water	7.50	1.36	---	490	462	1393	46	3053	0.0	91.5	2640

C. Water Saving amendments were produced at Emirate Bio Fertilizer Factory from natural materials e.g. Composted animal manure and bio char from the pyrolysis of dry date palm trees frond treated at 350°C. While water saver product is produced at EBFF from clay minerals, organic matter, Gypsum and Amorphous Silica. Analysis of water saving amendments used are in Table 2.

D. Preparation of compost ©

Mixed cow manure and chicken manures collected from dairy and chicken farms in Al Ain, AD emirates are composted in windrow systems, with a proper condition of aeration, moisture and adjusting for one month till maturation, and heat treated properly. The analysis of end product is depicted in Table 2.

E. Preparation of bio char (BC)

Date palm tree leaves waste, collected from Al Ain City, UAE, was dried in air under sunshine and then chopped into small pieces. Pyrolysis of the processed date palm waste was carried out in a closed stainless-steel container 200 L capacity at 350 ^{o}C were maintained for 4h under a limited supply of air. Feedstock samples were hydrolyzed to the desired temperature at the rate of 5◦C min−1. The bio char produced (25% W/W) was left to cool inside the furnace overnight, analysis of bio char is in Table 2.

F. Preparation of water saver (WS)

Water saver product (WS) is a special mix of clay minerals, organic substances, gypsum and amorphous silica. Analysis of WS is in Table 2.

2.2 Methods

10 identical date palm trees of 7 years old are used in each treatment for this experiment of the month of October 2016/2017 and 2017/2018 at Al Salamat research station. Treatments were:

1- Control,
2- 5 kg/tree,
3- 10 kg/tree,
4- 15 kg/tree and
5- 20 kg/tree of materials,

Soil amendment materials were mixed in the tree bits around the trees. Irrigation was scheduled every 6 days in summer months and every 16 days in winter months and every 8 days in moderate months.

1- Irrigation water was monitored and water consumption was recorded, using water meter.
2- Soil samples were taken for analysis of water content, and samples dried at 105°C for 24 hours.
3- Chemical analysis of soil, water, compost, bio char and water saving amendments, followed the standard methods protocols [29,30].
4- Water holding capability for retention of water was measured in a separate experiment in 100 grams of materials and soil mix samples were saturated with water and incubated for 24 hours, then weight of water drained and water retained are recorded. The calculated WHC of the tested materials as in Table 3.

Cation exchange capacity, CEC, is an abbreviation for Cation Exchange Capacity, refers to the amount of negative charges available on the surface of soil particles. It gives an indication of the potential of the soil to hold plant nutrients, by estimating the capacity of the soil to retain Cations, which are positively-charged substances. The CEC was measured following [30]. Periodical samples were taken after one week, 30 days, 60 days, 90 days and at the end of experiment at 180 days. Soil samples were prepared and tested for total bacterial counts and Colony Forming Unit (CFU) were measured using nutrient agar media while potato dextrose media were used to measure the total fungi in respective order [31,32].

Each mixture used in this study was saturated with water by following the procedure found in [32] to establish sample's water holding capacity. Water was slowly applied to each mixture container, while gently agitating, until excess water was observed. The mixtures were then allowed to sit for 24 h to assure homogeneity of water content throughout the sample. After that, the mixtures were drained by gravity for another

Table 2. Analysis of water saving amendment products used in the experiment

Parameter	Values			
	Sandy soil	Compost	Bio char	Water saver
Moisture (%)	15.0	12.0	12.2	12.1
Organic matter (%)	0.22	42.0	75.0	40.0
pH value	7.73	7.2	6.8	7.0
EC mmoh/cm	0.51	9.2	6.4	4.5
Total nitrogen (%)	0.12	1.6	1.12	1.0
Total phosphorus (%)	0.09	1.2	0.9	0.5
Total potassium (%)	0.9	1.2	1.4	0.5
Total sulfur (%)	0.3	0.8	0.6	5.0
Water holding capacity L/Kg	0.160	0.8	1.5	25.0
Specific gravity, (kg / l)	2.65	0.6	0.3	0.4
Cation Exchange capacity (meq/100 gm)	7.6	36.0	48.2	120

Table 3. Values of water holding capacity and Cation exchange capacity of material used in the experiment

Material	Water holding capacity (WHC) l/kg of materials	Cation exchange capacity (CEC) Meq/100g
Sand	0.16	3.5
Compost	3.0	85.0
Bio char	5.0	120
Water saver	25.0	180.0

24 h through a coffee filter. Three 90-mL stainless steel containers were then tared, filled to two third full, and massed using a 0.01-g digital balance to determine wet mass. The samples were then dried at 110°C for 24 h using a convection oven and massed to determine the dry mass. The results yielded the amount of water being held by each mixture

2.3 Statistical Analysis

The study design was a randomized complete block design (RCBD). Least significant difference test was used to compare means using the statistical analysis software. For all statistical analyses carried out in this study, SAS Software version 9 was used (SAS Institute Inc., NC, United States, 2015). Values are means of five independent replicates. Mean values followed by different letters are significantly ($P < 0.05$) different from each other according to Fisher's Protected LSD Test.

3. RESULTS AND DISCUSSION

3.1 Water Holding Capacity and Water Saved During the Course of Experiment

The results obtained in this study showed that incremental increase in percent water holding capacity normalized to percent amendment added.

Addition of water saving amendments, e.g. Compost ©, Bio char BC and water saver product (WS) improved water holding capacity and reduced irrigation water requirements for date palm trees in all treatments against control. It gives an indication of the potential of the soil to hold plant nutrients, by estimating the capacity of the soil to retain cations, which are positively-charged substances. Evaluation of water holding capacity, WHC and water saving amendment in sandy soil over time as affected by addition of water saving amendments are depicted in Tables 4, 5, 6.

Increasing the ratio of water saving amendments reduced the water losses and increased the water retention to be used by date palm trees.

Table 4 showed the effect of adding compost to date palm trees grown in sandy soils. It is clear that irrigation water requirements decreased with increasing amount per tree from 5 kg/tree to 20 kg/tree. The irrigation water decreased from 70.5 m^3 to 63.4 m^3/tree per year.

While in Table 5 bio char addition to date palm trees grown in sandy soil improved soil properties and reduced irrigation water per tree from 70.49 m^3 /tree per year to 56.39 m^3/tree per year. All treatments showed that increasing bio char percentage improved soil water retention above control. Increasing the amounts of biochar increased the amounts of water saved and reduced the irrigation water requirements.

Table 6 depicts the effect of water saver product on reducing irrigation water for date palm tree grown in sandy soils. All treatments showed better results against control. Irrigation water required per tree as been reduced from 70.44 m^3/tree per year to 36.6 m^3/tree per year.

The results prove that water saver performed much better than bio char, and bio char was better than compost, WS > BC > C as in Tables 4, 5, 6.

It is very clear that cultivating sandy soil consume huge amounts of irrigation water, due to its physical properties e.g. open structure and less organic matter content [20,33]. Irrigation water requirements (m^3/ha) after taking into account the proportion of cultivated area of date palm for each year were found to be 7044 m^3 considering 100 trees per ha which means, date palm tree consumed 70.44 m^3/tree under control while the percent water saved is 10%, 20% and 48.0% when adding 20 kg/tree of compost, bio char and water saver respectively. The annual total irrigation water requirements (m^3/tree) in different regions in KSA were 95m3/tree and 85 m^3 /tree. [34] in UAE stated that mature trees require 69.7 m^3 per year. Similar results obtained by [5,18,35-38].

Table 4. Average irrigation water per date palm tree of 7 years old, during different seasons and water saved percent when using compost in Al Ain for two years

Treatment	Compost				
	Summer months (L)	**Winter months (L)**	**Moderate Months (L)**	**Average Per year (L)**	**Annual Requirement (L)**
Control	287.87^a	104.25^a	212.87^a	200.25^a	70511.00
5 kg/Tree	281.00^b	102.78^a	206.56^b	195.87^b	68395.67
10 kg/Tree	272.20^c	97.53^b	199.26^c	190.00^b	66280.34
15 kg/Tree	265.11^d	96.87^b	195.06^d	183.75^c	64165.01
20 kg/Tree	259.87^e	93.93^b	191.56^d	181.00^c	63459.9

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 5. Average irrigation water per date palm tree of 7 years old, during different seasons and water saved percent when using Bio char in Al Ain for two years

Treatment	Bio char				
	Summer months (L)	**Winter months (L)**	**Moderate Months (L)**	**Average Per year (L)**	**Annual Requirement (L)**
Control	280.00^a	103.25^a	213.37^a	199.25^a	70490.0
5 kg/Tree	261.96^b	96.63^b	203.10^b	185.09^b	66260.6
10 kg/Tree	257.05^b	94.77^b	197.55^b	179.15^b	64850.8
15 kg/Tree	237.05^c	90.45^c	181.60^c	166.04^c	59141.11
20 kg/Tree	231.63^c	83.12^d	169.87^d	162.88^c	56392

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 6. Average irrigation water per date palm tree of 7 years old, during different seasons and water saved percent in Al Ain for two years

Treatment	Water saver				
	Summer months (L)	**Winter months (L)**	**Moderate Months (L)**	**Average Per year (L)**	**Annual Requirement (L)**
Control	279.00^a	99.00^a	202.00^a	193.62^a	70440
5 kg/Tree	200.88^b	71.28^b	145.44^b	139.37^b	50716.8
10 kg/Tree	178.56^c	63.36^c	129.28^c	123.70^c	45081.6
15 kg/Tree	151.00^d	51.00^d	115.00^d	104.75^d	38540
20 kg/Tree	142.29^e	52.47^d	105.04^e	102.68^d	36628.8

Values followed by different letters in one column are significantly (P < 0.05) different from each other

The results recommend that for better management of irrigation water, farmers have to add soil amendments to reduce water loss and to improve the soil water retention and plant growth [33]. The reason for soil amendment is to provide a better environment for roots and plant growth, this includes the improvement of the soil structure and water holding capacity, the availability of nutrients, and the living conditions for soil organisms, which are important for the plants to grow [26,38,39].

Bio char is used as a soil amendment to improve soil nutrient status, carbon, (C) storage and/or filtration of percolating soil water [40]. Bio char from pyrolysis and charcoal produced through natural burning share key characteristics including long residence time in soils and a soil conditioning effect [41]. Research has claimed that application of bio char can increase soil organic carbon (SOC), improve the supply of nutrients to plants and therefor enhance plant growth and soil's physical, chemical, and biological properties [23,41].

Water saving amendments can alter soil physical properties such as structure, pore size distribution and density, with implications for soil aeration, water holding capacity, plant growth, and soil workability. Consequently, this may improve soil water and nutrient retention [42]. Also, an increase in C content of the soil increases aggregation, decreases bulk density and increases water holding capacity [3] Bio char may increase the overall net soil surface area [43]. Therefore, reducing soil bulk density which is generally desirable for most plant growth [44]. Water saving amendments have a higher surface area and greater porosity relative to other types of soil organic matter, and can therefore improve soil texture and aggregation, which improves water retention in soil. Improved water holding capacity with bio char addition is most commonly observed in coarse-textured or sandy soils [41,45]. Bio char has a higher sorption affinity for a range of organic and inorganic compounds, and higher nutrient retention ability compared to other forms of soil organic matter [46-49].

Table 7 showed the periodical changes of WHC of sandy soil amended with compost. Results revealed that addition of compost increased WHC in all treatments over control, in the same time increasing the amounts of compost from 5kg/tree till 20 kg/tree increased WHC for all treatments from 0.17 to 1.33. That means WHC increased more than 7 times over control. While in Tables 8 & 9 showed an increase in WHC in all treatments above control. WHC of sandy soil amended with bio char increased from 0.17 to 3.37, which means increased by 19 times Table 8. But for water saver product which is considered the highest water holding capacity material in this study Table 9, WHC increased from 0.17 to 8.73 which means increased by 51 times above control. Addition of compost organic fertilizer, bio char and water saver around the trees separately increased the WHC of the sandy soil. But the addition of bio char increased the WHC of the soil doubly than addition of compost organic fertilizer, while addition of 20 kg/tree of water saver increased WHC more than 50 times of control and 2.6 times than compost and more than 6.56 times the compost treatments. The reported results are in line with several studies [16,28].

Table 8 depicted the water holding capacity of soil treated with bio char in comparison to control. All treatments that received bio char showed water holding capacity improvement compared to control and increasing bio char content increased water holding content values [50,51].

Table 7. Periodical changes of Water holding capacity (%) in sandy soil amended with compost through 180 days

Treatment	Compost			
	7 Days	60 Days	120 Days	180 days
Control	0.17^{d}	0.16^{d}	0.16^{d}	0.16^{c}
5 kg/Tree	0.81^{c}	0.84^{c}	0.79^{c}	0.80^{b}
10 kg/Tree	0.90^{c}	0.94^{b}	0.91^{b}	0.89^{b}
15 kg/Tree	1.14^{b}	1.28^{a}	1.27^{a}	1.23^{a}
20 kg/Tree	1.35^{a}	1.33^{a}	1.30^{a}	1.17^{a}

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 8. Periodical changes of Water holding capacity (WHC%) in sandy soil amended with bio char through 180 days

Treatment	Bio char			
	7 Days	60 Days	120 Days	180 days
Control	0.168[d]	0.16[d]	0.16[d]	0.16[e]
5 kg/Tree	2.18[c]	2.03[c]	2.08[c]	2.20[d]
10 kg/Tree	2.59[b]	2.63[b]	2.52[b]	2.50[c]
15 kg/Tree	2.18[c]	2.73[b]	2.60[b]	2.68[b]
20 kg/Tree	3.40[a]	3.25[a]	3.23[a]	3.21[a]

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 9. Periodical changes of water holding capacity (WHC%) in sandy soil amended with water saver through 180 days

Treatment	Water saver			
	7 Days	60 Days	120 Days	180 days
Control	0.169[e]	0.159[e]	0.16[e]	0.16[e]
5 kg/Tree	5.12[d]	5.18[d]	5.13[d]	5.20[d]
10 kg/Tree	6.58[c]	6.69[c]	6.55[c]	6.54[c]
15 kg/Tree	7.81[b]	7.78[b]	7.75[b]	7.73[b]
20 kg/Tree	8.68[a]	8.36[a]	8.33[a]	8.18[a]

Values followed by different letters in one column are significantly (P < 0.05) different from each other

At higher tensions close to wilting range, nearly all pores are filled with air and the moisture content is determined largely by the specific surface area and the thickness of water films on these surfaces. Sandy soils have much less surface area than clayey soils and, thus, retain much less water at higher tensions. However, with the addition of organic matter, and water saving products specific surface area increases resulting in increased WHC at higher tensions [9,12].

The application of soil amendments to soil offers multiple benefits in a wide range of agricultural systems. Bio char have been evaluated in various field crops and pastures around the world. Studies have found that bio char can improve plant yields, enhance soil water holding capacity and reduce fertilizer requirements, and results vary widely between different bio char, soil types, climates and target crops. Compost, or decomposed organic matter, bio char and water saver have been found to enhance water-holding capacity and improve soil structure. It can retain more water in the soil during dry season. Farmers may also use water saving amendments to reduce evaporation, and infiltration of water [8,15,16,52]. The potential benefits of bio soil amendment are well identified in the literature. These include carbon sequestration, improved crop yields, and enhanced water retention. The conversion of biomass carbon to bio char leads to sequestration of about 50% of the initial carbon compared to 3% sequestration from burning and less than 20% from biological decomposition [43]. Bio char is resistant to decomposition and remains in the soil for centuries or millennia.

While many articles report on carbon sequestration potential and nutrient trapping, there have been only a few studies on the effect of bio char on water holding capacity. [53] reported an increase in the water holding capacity of a loamy sand soil with 2% mixtures of bio char made from various switch grass feed stocks. They were interested in understanding the different effects of temperature and feedstock on the water holding capacity of bio char but all values were calculated at a 2% mixture rate only. Another finding was an 11% increase in water holding capacity reported as an additional observation and was not validated through the use of control techniques [42]. The ability of bio char to increase water holding capacity could have profound effects on areas prone to drought [9,42]. Summarized the current state of bio char knowledge and concluded that soil water holding capacity was an area of significance that was lacking in research.

3.2 Sandy Soil Biological Activities and Microbial Counts as Affected by Addition of Soil Amendments

3.2.1 Counts of total bacteria

Tables 10, 11, 12 describe the total bacterial population measured by plate count technique in the soil amended with different rates of water saving products: Compost, bio char and water saver from 5 kg/tree till 20 kg/tree against control.

3.2.2 Counts of fungi in the soil

Numbers of CFU increased with increasing dose of compost, bio char and water saver applied in all treatments. All treatments showed high microbial counts over control. Bacterial population was in the range of 31 million bacteria in the control treatment while increased sharply in all treatments reaching 107 million of CFU/gram for compost treated sandy soil. In case of bio char, the numbers were in the range of 100 million CFU, while in water saver treatments, bacterial numbers reached 103 million microbes after 180 days.

Table 10. Periodical changes of total plate counts, TPC content in sandy soil amended with compost through 180 days, CFU/10^6

Treatment	Compost			
	7 Days	60 Days	120 Days	180 days
Control	32.31^e	33.06^d	35.75^e	32.56^e
5 kg/Tree	70.06^d	70.75^c	89.31^d	74.56^d
10 kg/Tree	84.00^c	90.87^b	92.56^c	89.62^c
15 kg/Tree	88.00^b	99.93^a	99.18^b	100.00^b
20 kg/Tree	94.56^a	102.25^a	106.50^a	108.00^a

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 11. Periodical changes of total plate counts, TPC content in sandy soil amended with biochar through 180 days, CFU/10^6

Treatment	Bio char			
	7 Days	60 Days	120 Days	180 days
Control	31.00^e	32.75e	32.62^d	32.25^d
5 kg/Tree	68.75^d	66.25^d	87.56^c	74543^c
10 kg/Tree	83.25^c	87.75^c	93.18^b	90.00^b
15 kg/Tree	87.00^b	96.48^b	97.18^a	100.37^a
20 kg/Tree	92.18^a	101.25^a	101.62^a	101.75^a

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 12. Periodical changes of total plate counts, TPC content in sandy soil amended with water saver through 180 days, CFU/106

Treatment	Water saver			
	7 Days	60 Days	120 Days	180 days
Control	32.87^e	33.00^d	32.97^e	32.37^d
5 kg/Tree	69.00^d	71.20^c	77.68^d	74.56^c
10 kg/Tree	85.12^c	98.00^a	94.01^c	89.25^b
15 kg/Tree	89.00^b	97.25^a	98.35^b	101.62^a
20 kg/Tree	91.73^a	91.73^b	104.87^a	103.25^a

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 13. Periodical changes of Total fungi colonies content in sandy soil amended with compost through 180 days, CFU/10^4

Treatment	Compost			
	7 Days	60 Days	120 Days	180 days
Control	7.20^e	7.34^e	7.20^e	7.12^e
5 kg/Tree	11.98^d	12.81^d	12.80^d	13.83^d
10 kg/Tree	14.26^c	15.96^c	15.97^c	16.900^c
15 kg/Tree	16.10^b	17.17^b	17.16^b	18.75^b
20 kg/Tree	18.26^a	19.10^a	19.10^a	19.72^a

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 14. Periodical changes of Total fungi colonies content in sandy soil amended with bio char through 180 days, CFU/10^{4}

Treatment	Bio char			
	7 Days	**60 Days**	**120 Days**	**180 days**
Control	7.20^{e}	7.34^{e}	7.21^{e}	7.12^{e}
5 kg/Tree	11.98^{d}	12.81^{d}	12.80^{d}	13.83^{d}
10 kg/Tree	14.26^{c}	15.96^{c}	15.97^{c}	16.90^{c}
15 kg/Tree	16.10^{b}	17.17^{b}	17.16^{b}	18.75^{b}
20 kg/Tree	18.26^{a}	19.10^{a}	19.10^{a}	19.72^{a}

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Table 15. Periodical changes of Total fungi colonies content in sandy soil amended with water saver through 180 days, CFU/10^{4}

Treatment	Water saver			
	7 Days	**60 Days**	**120 Days**	**180 days**
Control	7.16^{e}	7.26^{e}	7.30^{e}	7.28^{e}
5 kg/Tree	14.08^{b}	14.96^{d}	14.17^{d}	13.91^{d}
10 kg/Tree	16.26^{c}	16.76^{c}	17.21^{c}	17.08^{c}
15 kg/Tree	16.92^{b}	17.46^{b}	18.86^{b}	19.01^{b}
20 kg/Tree	18.20^{a}	19.97^{a}	19.33^{a}	21.37^{a}

Values followed by different letters in one column are significantly (P < 0.05) different from each other

Microbial biomass and total plate count in most cases increase in the presence of soil amendments. According to [28,54], notable exceptions are mycorrhizae in situations of abundant nutrient supply. No direct negative effects of bio char on roots have been detected.

Fungi population are depicted in Tables 13,14,15 the total fungi colonies showed less numbers, e.g. control treatments showed 7x10^{4} CFU/gram while for treatments received compost, bio char, and water saver the fungi numbers grown in the range of 20, 21, 21.4x10^{4} CFU/gram of soil received compost, bio char and water saver respectively. The significant differences in bacteria, and fungi population were observed between bio char and control [54-56].

The microscopic structure of compost, bio char and water saver is one of the primary determinants in its soil conditioning properties; the surface area of the pre-charred source material can be increased several thousand folds [38].

3.3 Discussion

The water retained in sandy soil by the water saver product was higher than Bio char and compost organic fertilizer. Therefore, addition of soil amendments in date palm tree sandy lands increases the WHC of the soil. This addition enhances soil frtility and improves water use efficiency, because surface area and organic matter percentage influences in the water-holding capacity and microbial populations. As the percentage increases, the water-holding capacity increases because organic matter has affinity for water [3,57,58].

Much of this interest is focused on water saving amendments. The claims for them are many: larger crop yields, decreased fertilizer requirements, greater microbial activity, reductions in greenhouse gas emissions from fields, greater soil water holding capacity, drought mitigation, and increased soil organic carbon content (SOC), which can improve the physical properties of soil. Further, carbon sequestration benefits of bio char soil amendment have been heavily studied [15,23,25], while [9] showed that soils with a high water holding capacity produce increased crop yields and a decreased need for irrigation. [41,59] suggested that the increased porosity of bio char increases water retention in soils, and the enhancement depends on bio char feedstock, soil type, and mixture rates. Nutrients dissolved in the water may also be retained in the soil so plants may access the nutrients better [57]. Also, Previous analysis has shown that it is feasible to prepare bio char with relatively high BET surface areas from date palm fronds, which is favorable for microbial communities to grow and therefore enhancing fertility of the soils. We can boost food security, discourage deforestation and preserve cropland diversity by converting agricultural waste into a powerful soil enhancer that holds carbon and makes soils more fertile [15,26-28].

Table 16. Evaluation of water saving amendments on economics of water consumption on date palm plantation, using 15kg per tree under UAE water tariff of 0.85$/m^3

Product	Material unit cost, ($/kg)	Material cost ($/15kg)	Water saved (M^3/tree/year)	Total money Saved in ($) / tree / year
Compost	0.110	1.65	6.35	5.40
Bio char	0.380	5.70	11.35	9.65
Water saver	1.600	24.00	31.90	27.13

3.4 Economics of Using Irrigation Water Saving Amendments

Table 16 depicts the economic profitability of using soil amendments for saving irrigation water under date palm plantations.

Water saving amendments were calculated at 15 kg/tree, because there was no significant difference between using 15 and 16 kg/tree in all treatments Tables 4,5,6 and water price as per UAE Agriculture tariff (50 % subsidized price of 2020).

When we add 15 kg/tree of different water saving amendments, we found that compost can save 6.35 m^3 / tree of water per year , while adding 15 kg of bio char can save 11.35 m^3 /tree of water per year, while using the water saver product, we can save 31.90 m^3 of water/tree per year, if we calculate how much money we can save when we use water saving amendments materials it can be as follow, compost can save 5.40 $, followed by bio char can save 9.65 $ per tree per year while water saver product can save 27.13 $ per tree per year.

To reflect these water saving we can save huge amounts of water on the global basis or at least for Arab countries which have 105 millions of date palm trees. Along with these irrigation water saving, soil physical, chemical and biological properties are improved which is considered value addition of using water saving amendments.

To promote the practice of agricultural soil water saving amendments, the full life cycle costs and benefits to soil amendment must be estimated. The effect of water holding capacity on crop growth due to water holding capacity, nutrient retention, and microbial growth must be understood, in addition to the benefits of the likely reduced need for irrigation and fertilizer and pesticide usage. Inclusion of traditionally externalized costs associated with carbon and environmental degradation, a side effect of current farming and irrigation techniques, will further improve the cost/benefit analysis of agricultural water saving amendments usage.

4. CONCLUSION

Farm wastes can be recycled to produce soil conditioners at the farm level e.g. compost, water saver and bio char products. Proper water management in sandy soil, require Farmers to use available organic matter in their farms to be serving as soil conditioner and to act for saving water for better plant growth and soil microbial activities in the soils.

Addition of water saving amendments improved water retention (WHC) and cation exchange capacity (CEC) which can contributes to produces uniform moisture at the root zone, reduces irrigation requirement by up to 45%, saving both water and money, reduces evapotranspiration, holding water and nutrients at the roots to produce strong, healthy plants and in soils to retain more water and nutrients. We can save up to 45% of irrigation water requested for date palm plantation. This water saved can be used for other eventual needs of water e.g. industry and other purposes.

To promote the use of compost, biochar and water saver as soil amendment, it is important to understand the mechanism of the amended water retention, to characterize the effects of feedstock, bio char production, soil types, and mixtures, and to quantify these effects on plant growth. The results obtained from this research should be used at the farm level for best agriculture practice.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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