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Evaluation of Date Palm Biochar as Oasis Soil Amendment under Saline Irrigation in Morocco

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ABSTRACT

Background and Objective: Salinity is a growing problem worldwide that affects agricultural production. Biochar is considered an alternative organic amendment to improve soil physicochemical properties and fertility and mitigate salinity's effects in Morocco's Oases. The objective of this study was to evaluate the potential of date palm leaves biochar to mitigate the damaging effects of salinity on local lettuce seeds (*Lactuca sativa*). **Materials and Methods:** Biochar produced from date palm leaves were characterized and incorporated at different doses (1, 2, 4, 8, 16 and 32%) into an oasis soil (Ternata Oasis in Zagora, EC: 1.82 dS m^{-1} 1:5 soil-water-extract). Phytotoxicity of biochar amendments was evaluated by a germination test performed on local lettuce seeds in Petri dishes irrigated with the water used by local farmers with an EC of 6.96 dS m^{-1}. Statistical analysis was performed to evaluate the effects. **Results:** Biochar improved the soil that was initially poor in nutrients. Organic matter and minerals (N, K, Mg and Na) increased depending on biochar doses. Water holding capacity also increased from 21.75% (without biochar) to 49.83% (32% biochar). Concentrations of 1 and 2% biochar stimulated the germination parameters of lettuce seeds while doses of 4 to 32% negatively affected them. The addition of 2% biochar increased root and hypocotyl lengths. **Conclusion:** The amending oasis soil by 2% of date palm biochar leads to an improvement of its properties without having any phytotoxic effect.

KEYWORDS

Date palm, biochar, oasis soil, lettuce, germination, saline irrigation

INTRODUCTION

For decades, soils have been exposed to several threats worldwide such as structural degradation, contamination, salinization and insufficient fertility[1]. This has led to edaphic and economic constraints such as reduced water retention, reduced land productivity and consequently food security. Soil reclamation by mineral fertilization is quite common but does not offer a permanent solution to maintain crop yields[2]. The soil can be degraded by the excessive use of mineral fertilizers which cause induced salinization. This salinization affects the biocenosis and biogeochemical processes of the environment leading to a decrease

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in agricultural production[3]. Instead, organic amendments such as the application of biochar could be an interesting alternative for the sustainable conservation or increase of soil organic matter and the preservation of soil fertility and crop yield improvement[4].

Biochar is obtained from the pyrolysis of biological residues under oxygen-limited conditions leading to a stable, highly aromatic and carbon-rich product[5]. Its chemical composition and pH depend on the feedstock used for its production[6]. The use of biochar as an organic soil amendment has several assets. These include the improvement of nutrient supply, waterholding capacity[7], soil fertility and agricultural production[8] and the reduction of greenhouse gas emissions[9]. In addition, microbial biomass was shown to increase following the addition of biochar to the soil[10]. According to Anderson *et al.*[11], certain groups of soil microorganisms that have a role in the cycles of nitrogen, carbon and phosphorus are likely to be affected by biochar addition as it can potentially reduce their growth.

Date palm production occupies an important part of Moroccan agriculture and contributes to the preservation of oasis ecosystems threatened by desertification. The date production ranks first among fruit oases and contributes 20-60% of the income of oasis farmers, With an average of around 100,000 mt annually[12]. Therefore, it is advisable to check the properties of the little-used leaves of this common palm for biochar production.

The main objective of this study was to characterize this biochar and the evaluation of its effect on oasis soil physicochemical parameters and the germination of local lettuce seeds (*Lactuca sativa*) used as an indicator of phytotoxicity.

MATERIALS AND METHODS

Study area: The study was conducted from March to September, 2022 in the Oasis of Ternata, located in Zagora Province (Drâa-Tafilalet Region), South-Eastern Morocco.

Biochar preparation: The 4 kg of date palm dried leaves collected from the Oasis of Ternata (Zagora, Morocco) were used as a source of biomass for the production of biochar. For this purpose, a pyrolytic stove was made from locally available materials according to the model described by Kammann *et al.*[13]. It is a cylindrical stainless steel stove 68 cm high with ventilation holes at the top and bottom of the cylinder. The plant material intended to be transformed into biochar was placed in a combustion cylindrical stainless steel chamber placed inside the first cylinder. It has a row of small holes at the base and covers with a lid to ensure combustion in the absence of oxygen. The outer cylinder is closed by a cover fitted with a flue (Fig. 1). The process for biochar production consisted of filling the outer chamber with combustible materials. Air-dried date palm leaves cut into small pieces were placed in the combustion chamber located inside the stove and closed to prevent the entry of air. Once the plant material around the combustion chamber began to burn, the outer cylinder cover was placed on the stove. Pyrolysis of date palm leaves arranged in the central cylinder was achieved 5 hrs later when the exhaustion of the smoke indicated that the content of the stove was completely charred. Biochar resulting from this pyrolysis was then ground, sifted through a 2 mm mesh sieve and then retained for chemical characterization and used as soil amendment using doses of 1, 2, 4, 8, 16 and 32% as suggested by Bouqbis *et al.*[14].

Soil/biochar mixtures: The soil used in this experiment was taken from a farm in the oasis of Ternata. A mixture of several samples was taken at a depth of 30 cm. After drying at room temperature, the soil was homogenized shifted through a 2 mm mesh sieve. Analyses were performed on soil without amendments, biochar alone and soil/biochar mixtures.

Characterization of date palm leaves and soil/biochar mixtures: Chemical analyses of date palm leaves, soil, biochar as well as soil-biochar mixtures were carried out at the Soil Sciences Laboratory of

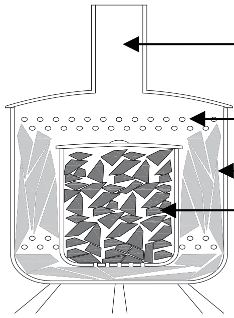

Fig. 1: Schematic cross section of the biochar stove

Hassan II Institute of Agronomy and Veterinary Medicine, Agadir Campus (Morocco). Physicochemical parameters relating to soil fertility were determined using methods described by Chapman and Pratt[15]. The organic matter content was determined using the method of Walkley and Black[16]. The electrical conductivity (EC) and pH were measured using 1:5 soil-water extract. The EC was measured by an Adwa AD3000 EC-meter made in Romania. The pH was measured by a Jenway pH-meter made in Essex, United Kingdom. Total nitrogen content was quantified using the method described by Krom[17]. Mineral composition of biochar alone and samples of date palm leaves were obtained after complete calcination at 500°C in a Naber muffle furnace made in Bremen, Germany. Sodium and potassium contents were determined by flame spectrophotometry[15] using a Wagtech spectrophotometer made in Berkshire, United Kingdom. Calcium, magnesium, iron, manganese, zinc and copper were measured as described by Chapman and Pratt[15] using an iCE3300 Thermo Scientific atomic absorption spectrophotometer, designed in the United Kingdom and made in China[15].

For the measurement of water holding capacity, 100 g samples from each treatment were placed in metal cylinders having an internal diameter of 5.8 cm and a height of 4.3 cm, closed at the bottom by a paper filter. These cylinders filled with substrate were placed on a grid plate and then placed in a plastic basin filled with water. After 24 hrs of soaking, the cylinders were drained for 15 min. The weight of the water-saturated samples was measured and then their dry weight was determined after drying for 24 hrs in an oven at 105°C. The waterholding capacity was calculated according to the formula[18]:

$$\text{Water holding capacity (\%)} = \frac{\text{Saturated soil weight - Soil dry weight}}{\text{Soil dry weight}} \times 100$$

Evaluation of date palm biocharphytotoxicity: The possible phytotoxic effect of date palm biochar was studied by a germination test with lettuce seeds[14,19]. This is a widespread test to study the toxicity of biochars. It was carried out with Petri dishes containing the different soil-biochar mixtures. For each mixture, three replicates were performed at a rate of 20 seeds per dish. Local lettuce seeds were obtained from a local farmer in the oasis. They were harvested in 2019 and stored in sealed plastic bags for use in 2020. Before application, the seeds were disinfected for 5 min with bleach (5%) and subsequently rinsed 3 times with distilled water. They were then soaked in water to remove any floating seeds, considered non-viable. The seeds that remained at the bottom were germinated in Petri dishes containing the different soil-biochar treatments. Moisture was kept constant by daily watering with underground (well) water (EC: 6.96 dS m^{-1}). This water came from the same source as that used for irrigation of the farm from which the soil was sampled. After eighteen days of germination and monitoring at room temperature (35 to 40°C), the germinated seeds were gently washed with cold distilled water (ca 4°C) to remove substrate particles. Subsequently, germination parameters (germination rate and velocity, length of hypocotyls and radicals and their dry weights) were determined.

Statistical analysis: The results were subjected to analysis of variance (Fisher Test at α = 5%) using Excel, 2016 software and mean values were compared using Newman and Keuls method[20] with Statistica software, Version 8.

RESULTS AND DISCUSSION

Oasis soil characteristics

Soil texture: The results of particle size analysis revealed that the soil contains 44 and 26.3% coarse and fine sand, respectively 12.3 and 12.4% coarse and fine silt, respectively and 1.60% clay, giving it a sandy-loam texture. The sandy texture of this soil enables easy penetration of the roots. However, the low clay content can be a constraint for agricultural production because of the low retention of water and mineral elements and the rapid drying of the soil due to rapid percolation.

Soil chemical properties: Chemical analyses of the soil show that its pH is alkaline (7.9) with a high electrical conductivity (1.82 dS m^{-1}), according to standards considering that soils with an EC above 0.5 dS m^{-1} are saline (measured using 1: 5 soil: Water extract)[21], a low organic matter content (0.94%) according to standards[22]. Saharan soils are known to be generally low in organic matter and mineral nutrients. The organic matter content of these soils is often less than 0.1%[23]. The low organic matter content can be explained by the influence of the saharan climate where high temperatures and low rainfall lead to poor organic matter production and rapid mineralization[24].

Soil is low in nutrients: Total nitrogen (300), K (57.1), Mg (202.0) and P (16.6 ppm) were very low compared to standards[22]. Calcium content (1130.0 ppm) is considered within the average range[22]. Analysis of soil trace elements concentrations revealed very low concentrations of copper (0.8), iron (1.2), manganese (1.9) and zinc (0.6 ppm). These results show low intrinsic fertility. Similar results have been reported in other studies such as Sawadogo *et al.*[25], who showed that soils in Sub-Saharan Africa are characterized by low organic matter content and low cation exchangeable capacity. In these conditions, soils require amendments to allow suitable levels of productivity.

Chemical characterization of date palm leaves: The chemical analysis of date palm leaves showed that they contained high levels of potassium (5,800), phosphorus (1,100), sodium (240) and magnesium (6,000 ppm). Except for calcium (1100 ppm), these contents were well above levels found in the tested soil. The levels of trace elements in palm leaves were 275, 5.7, 55.2 and 5.2 ppm for iron, zinc, manganese and copper, respectively and thus much higher than in the tested soil. These results fit with a study reported by Chaira *et al.*[26], who showed that potassium was most abundant in date pits followed by phosphorus, magnesium and calcium, with sodium coming last. Regarding trace elements, they reported that iron had the highest content followed by zinc. It is important to note that date palm leaves contain quite significant amounts of manganese. Contrary to the results of the present work, a study conducted by Titiladunayo *et al.*[27] showed that apa wood and palm kernel shells could contain up to 17.32 and 13.25 mg kg^{-1} of manganese, respectively.

Characteristics of date palm leaves biochar (DPLB): Biochar produced from date palm leaves was characterized by high pH (9.01) and EC (5.29 dS m^{-1}). Singh *et al.*[28] reported similar results for *Eucalyptus saligna* wood biochar produced at temperatures between 400 and 550°C.

The DPLB is rich in several nutrients with levels of 6.09% for organic matter, 100 for mineral nitrogen, 58,600 for magnesium, 22,000 for potassium, 2,600 for phosphorus, 178,300 for calcium and 1,000 ppm for sodium. The low total nitrogen content (860 ppm) of DPLB could be explained by the elimination of this element during pyrolysis. Usman *et al.*[29] and Gaskin *et al.*[30] found that pyrolysis temperature of date palm waste had an effect on the total nitrogen rate during the production process.

This rate was 0.54% when the pyrolysis temperature was 300°C and decreased to 0.31% if the temperature reached 800°C. They concluded that during pyrolysis, nitrogen evaporation is significantly reduced if the temperature is below 550°C. They emphasized that the temperature of date palm leaves biochar pyrolysis should be optimized to minimize nitrogen loss. Unfortunately, during this experiment, temperature during pyrolysis can not measured.

On the other hand, levels of trace elements are very low in date palm leaves biochar (copper (0.062), iron (0.385), manganese (35) and zinc (0.56 ppm). In spite of this, the use of this biochar as an amendment of oasis soil will contribute to the increase of fertility due to its high concentrations of major nutrients. Glaser *et al.*[31] reported that biochar has a high fertilization potential, especially in tropical soils. Laird *et al.*[32] also observed a significant increase in phosphorus, potassium and calcium even 500 days after the addition of biochar.

The contents of major nutrients such as calcium, magnesium, sodium, potassium and phosphorus were higher in biochar compared to samples of non-charred date palm leaves. They were respectively 16.2, 9.7, 4.16, 3.79 and 2.36 times higher in the biochar compared to date palm leaves indicating that the pyrolysis process results in an enrichment of these nutrients in the biochar. A similar enrichment of Mg, Ca, P, Na and K was reported by Yuan *et al.*[33]. The increase in phosphorus content in the biochar could be attributed to the fact that in date palm leaves this element is associated with phosphate minerals, which are difficult to break down unless there is a very high increase in temperature[34]. However, it should be noted that the contents of trace elements such as copper, iron, manganese and zinc are lower in the biochar compared to non-charred date palm leaves, indicating that the pyrolysis process could suppress the release of these elements. The contents were respectively 714.2, 83.87, 10.77 and 1.5 times higher in date palm leaves compared to their biochar. The adsorption of trace elements on the surface of the biochar and the formation of organometallic complexes could explain their low content[5,35].

Characteristics of soil/biochar mixtures: Characterization of the soil amended with date palm leaves biochar in the proportions of 1, 2, 4, 8, 16 and 32% showed that the pH increased from 7.9 (at 0% biochar) to 8.56 (at 32% biochar, Table 1). Similar results were reported by Novak *et al.*[36] for biochar derived from pecan nut tree residues and by Usman *et al.*[29] for biochar derived from date palm wastes including finlets, rachis and trunks. The alkaline nature of biochar plays an important role in increasing acidic soil pH[36]. The increase in pH leads to an increase in the cation exchange capacity of the soil because an increase in pH leads to a greater negative charge on soil particles[37].

Electrical conductivity increased from 1.8 dS m^{-1} in oasis soil to 4 dS m^{-1} with 32% biochar (Table 1). The EC is a parameter that indirectly indicates the total concentration of soluble salts. It depends on mineral composition which in turn depends on the type of raw material and pyrolysis conditions[28]. The EC of a soil solution increases with increasing ion concentration[38]. It is mainly affected by the potassium content of biochars due to the higher solubility of salts and carbonates containing K^+ in water[39]. Results showed that the EC increased with increasing biochar concentration. However, it did not exceed the critical limit of 4.0 dS m^{-1} [40]. Similar results have been reported in the dedicated literature[41-43]. This limit was established based on the appearance of a negative impact on soil properties, soil-water relations and plant growth[44].

The rate of organic matter increased in the soils treated with biochar according to the proportion applied (Table 1). Similar results were obtained by Schulz *et al.*[45], who showed that wood biochar had a positive effect on the amount of soil organic matter. The cation exchange capacity (CEC) of soil-biochar mixtures varied depending on the dose of biochar added. It increased from 34.87 meq/100 g in soil without amendment to 323.50 meq/100 g in soil amended by 32% biochar. This increase can be explained by the

Table 1: Physicochemical characteristics of the soil amended with date palm biochar

Biochar rates (%)	pH	EC ($dS\ m^{-1}$)	Organic matter (%)	CEC meq/100 g	Ca ($g\ kg^{-1}$)	Total nitrogen	NO_3^- ppm	Na ppm	K ppm	P ppm	Mg ppm	Fe ppm	Zn ppm	Mn ppm	Cu ppm
1	8.10	1.80	1.21	118.89	1.40	500	9.0	312	133.3	26.3	1140	1.2	0.5	3	0.8
2	8.30	2.16	1.38	134.28	1.45	700	11.0	360	200.0	31.5	1275	1.1	0.5	5	0.7
4	8.40	2.48	2.18	174.01	1.50	800	13.0	448	352.4	47.3	1656	0.8	0.4	6	0.5
8	8.44	3.04	2.93	218.78	1.58	900	14.0	600	600.0	60.5	2033	0.8	0.5	8	0.5
16	8.50	3.80	3.51	263.27	1.80	1000	14.4	808	990.5	65.7	2325	0.7	0.5	11	0.4
32	8.56	4.00	4.16	323.50	2.00	1100	15.0	1192	1752.4	71.0	2601	0.4	0.5	12	0.5

EC: Electrical conductivity, CEC: Cation exchange capacity, Ca: Calcium, NO_3^-: Nitrate, Na: Sodium, K: Potassium, P: Phosphorus, Mg: Magnesium, Fe: Iron, Zn: Zinc, Manganese and Cu: Copper high cation levels in date palm biochar. High biochar CEC may have a beneficial effect on soil nutrient retention[32,46,47]. Laird *et al.*[32] reported an increased soil CEC after the application of biochar obtained from oak and pecan nut trees wood. Changes in nutrient availability by the addition of biochar can influence microbial community structure and biogeochemical functions of the soil[11]. Indeed, biochar can stimulate the activity of microorganisms, mycorrhizae and their symbioses in the soil[48,49]. It also favors the enzymatic activity and the proliferation of microorganisms by its large specific surface and its high density in macro and micropores[50].

Despite its low nitrogen content, the addition of biochar increased total nitrogen and mineral nitrogen (NO_3^-) in amended soils. Total nitrogen increased from 300 ppm in the soil without amendment to 1,100 ppm after 32% biochar addition. At the same time, mineral nitrogen increased from 7 ppm in oasis soil to 15 ppm after the addition of 32% biochar. Karbout *et al.*[51] showed that biochar derived from date palm waste increased total nitrogen content from 0.37% in sandy soil without amendment to 0.53% 3 months after the application of 20 tons of biochar per hectare. The retention of total nitrogen in soils amended with biochar may be due to a nitrate recycling mechanism favoured by the high availability of carbon[52].

Major elements and particularly exchangeable cations increased with the addition of biochar. The supply of biochar at different concentrations had a positive effect on phosphorus, potassium, sodium, calcium and magnesium contents. A study on *Prosopis* wood biochar also showed that its application to soil increased phosphorus, potassium, calcium and magnesium levels[52]. The promotion of plant growth could be facilitated by soil nutrients provided by biochar[52].

In contrast, the addition of biochar to the soil led to a decrease in trace elements, particularly iron, zinc and copper since their levels were lower in the biochar than in the soil. The concentration of iron (Fe) decreased from 1.2 ppm in the soil without amendment to 0.4 ppm in 32% biochar. Copper (Cu) also decreased with the increase in biochar concentration from 0.8 ppm in soil without amendment to 0.5 ppm with 32% biochar. The content of zinc (Zn) did not change since its presence was almost the same in the soil and biochar. Some studies found that heavy metals (copper and zinc) contents decreased significantly in the presence of 5% of rice straw biochar in soil polluted by these metals[53]. Manganese (Mn) level increased from 1.9 ppm in oasis soil to 12 ppm with 32% biochar. Contrasting results were reported in the literature by Fseha *et al.*[54], who showed that biochar derived from date palm waste, including fruits and leaves, was used to remove and adsorb manganese with efficiencies increasing to 85.57% at pH 8 and 98.77% at pH 10.

The addition of biochar led to an increase in the water-holding capacity of the soil. This increase had a positive trend with the amount of biochar added. The water holding capacity of the sandy-silty soil increased from 21.75% in the control (without amendment) to 49.83 for the 32% biochar mixture, more than double.

Several studies showed that the incorporation of biochar into the soil can alter its hydrological properties[55]. The improvement in water retention can be explained by the increase in soil micropores due to the high internal microporosity of biochar and the availability of hydrophilic surfaces that favour water penetration in micropores of the soil[56].

Evaluation of date palm biocharphytotoxicity

Effect of biochar on germination kinetics of lettuce (*Lactucasativa*): The evolution of the germination of lettuce seeds as a function of time in different concentrations of biochar (0, 1, 2, 4, 8, 16 and 32%) is shown in Fig. 2. The results show that lettuce germination rate and kinetics vary with biochar

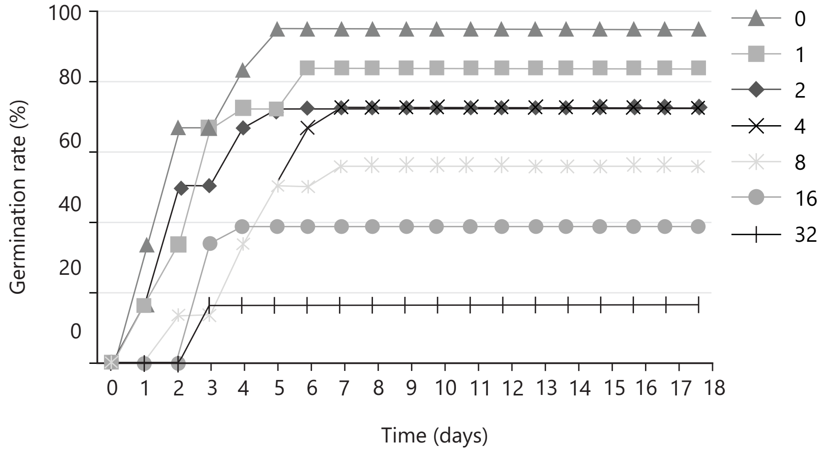

Fig. 2: Effect of different concentrations of date palm biochar on lettuce germination kinetics

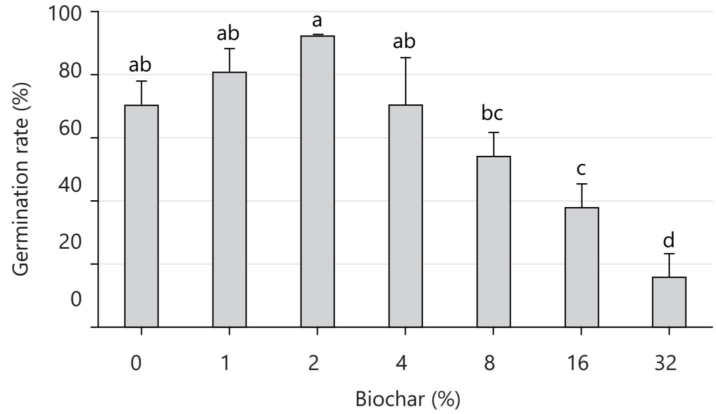

Fig. 3: Effect of different concentrations of date palm biochar on the germination rate of lettuce
Bars sharing the same letter do not differ significantly at p<5%

concentrations. The curves are characterized by the presence of three phases. A phase of latency during which no germination could be observed. The duration of this phase was variable depending on the concentration of biochar. It was short to non-existent in control seeds and those treated with low biochar concentrations (1 and 2%). However, it became longer, especially for seeds subjected to high concentrations of biochar for which it extended up to 48 hrs (16 and 32%). The absence of germination during this phase may be due to the delay in seed imbibition and enzyme synthesis, essential to the basic metabolism of germination[57]. These enzymes are necessary for the hydrolysis of the reserves contained in the semen[57]. The second phase is exponential, characterized by an increased germination rate. The 2% dose of biochar stands out compared to the others, followed by 1%. After that, there is a stationary phase, during which the rate of germination hardly changed (Fig. 2).

Effect of biochar on lettuce germination rate: In the present study, it appears that the supply of biochar amendment affects the germination of lettuce in a highly significant way ($p<0.001$) (Fig. 3). The optimum germination was achieved at the dose of 2%. This concentration makes it possible to obtain a germination rate 30% higher compared to control seeds. It seems that the physicochemical characteristics of the soil/biochar mixture at 2%, the optimal conditions for lettuce seed germination. In the soil amended with 4% biochar, the germination rate dropped slightly but not significantly compared to the control and 1% treatment.

However, higher biochar concentrations (8, 16 and 32%) negatively affected the germination rate which was reduced by more than 77 in 32% biochar compared to the control treatment. Excessive concentrations

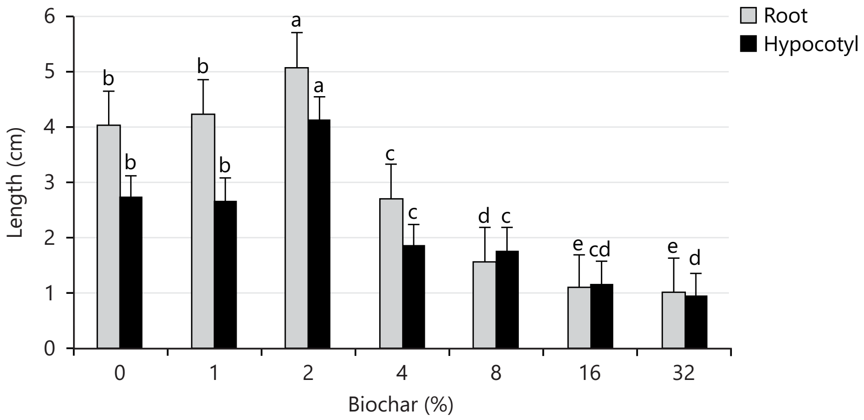

Fig. 4: Effect of different concentrations of date palm biochar on the length of lettuce root and hypocotyl, 18 days after germination

Bars sharing the same letter do not differ significantly at p<5%

of K in the soil amended with high biochar concentrations can limit the uptake of Ca and Mg due to their antagonistic effects[58]. The results showed that the addition of 2% biocharhada significant positive effect on the germination rate of lettuce. The antagonism between mineral elements in addition to their excess in the soil amended by high concentrations of biochar could explain the reduction of germination. These results showed that, at high doses, the biochar of date palm leaves reduceslettuceseeds' germination. It was found that a high concentration of carbonaceous matter inhibits seed germination of several plant species[59,60]. A decreased germination rate can also be related to high electrical conductivity in high doses of biochar. Deshmukh[61] figured out that electrical conductivity above 2 dS m^{-1} is critical for the growth of salt-sensitive crops. If it is higher than 3 dS m^{-1}, it becomes harmful to these crops.

Effect of biocharoninitialgrowth of lettuce: The effect of biochar addition on the growth of the shoot and root parts of lettuce 18 days after germination was shown in Fig. 4.

In general, the contribution of biochar led to an increase in the length of the shoot and root parts, especially in moderate treatments. Figure 4 clearly showed that maximum elongation of shoot and root parts was observed with a 2% dose. Statistical analysis of single-factor variance showed a highly significant effect ($p \leq 0.001$) on the lengths of shoot and root parts. These results agree with those of Indawan *et al.*[62], who showed that the addition of 5 t of biocharper hectare had positive effects on the length and volume of sweet potato roots.

Effect of biochar on shoot and root dry biomass: The dry weight of the roots of lettuce increased in treatments 1 and 2% biochar compared to the control, although without statistical significance (Fig. 5). The dry weight of the hypocotyl also increased with 2% biochar application but not ignificantly compared to the control. Beyond this concentration, the biomass was reduced in a very highly significant way as the dose of biochar increased, for both shoot and root parts. The lowest values were obtained in the soil amended with 32% biochar. Viger *et al.*[63] showed that the biomass of lettuce plants increased by 111% after the addition of 50 and 100 t/ha of poplar wood biochar although they have not expressed these amounts in percentages.

This study showed that biochar can be made from date palm entire leaves that are abundant in Moroccan Oases. Applied to oasis soil as an alternative to manure, this biochar improved its properties. At concentrations of 1 and 2%, it improved lettuce seed germination. Its incorporation into oasis soils at appropriate doses will lead to the improvement of crop productivity, thus enhancing the socio-economic level of oasis populations subjected to environmental constraints exacerbated by climate change. However, given its low levels of trace elements, it should be applied in combination with another organic fertilizer.

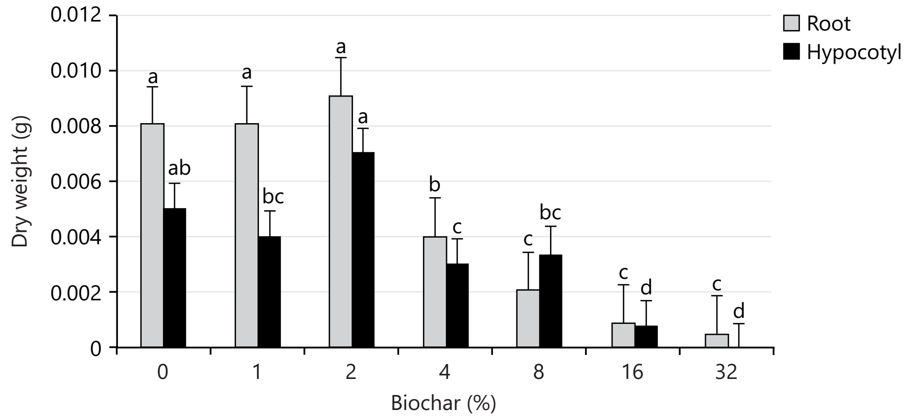

Fig. 5: Effect of different concentrations of date palm leaf biochar on dry biomass of lettuce root and hypocotyl, 18 days after germination

Bars sharing the same letter do not differ significantly at p<5%

This work is an attempt to make a valuable use of date palm residues through pyrolysis. It aims at encouraging local farmers to adopt this affordable technology to improve soil properties for better crop production. It is important to state that this study was conducted at a laboratory scale and needs to be applied at field level. Therefore, more extensive field trials with other crops should be conducted to better understand the agronomic value of adding biochar under saline conditions.

CONCLUSION

Biochar produced from date palm leaves is rich in organic matter and exchangeable cations. Its addition to oasis soil improved its physical and chemical properties. The addition of 2% biochar to the soil significantly increased lettuce seed germination velocity and rate by 15 and 30%, respectively. The recovery of date palm residues to produce organic amendments will certainly contribute to improving crop productivity in oases. However, more extensive field trials with other oases crops should be conducted to better understand the agronomic value of adding biochar under saline conditions.

SIGNIFICANCE STATEMENT

Biochar is an amendment that can be easily made from available organic matter, it is still little known in Morocco. The purpose of the work was to make biochar from date palm leaves and use it as an amendment to improve soil properties. The study showed that biochar was not phytotoxic at low concentrations (1 and 2%) and improved lettuce seed germination. It is suggested that biochar from date palm leaves can be a valuable amendment to improve oases soil and crop production but more trials are needed to investigate its effect on other crops, especially under saline conditions.

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