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Biochar as a Possible New Alternative in the Propagation Medium of Olive Cuttings

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WITHIN the framework of using organic waste in line with sustainable development, which helps reduce carbon emissions and overcome pollution resulting from burning these wastes while also lowering the cost of purchasing peat moss imported from abroad, this investigation aimed to study the possibility of using biochar as a good alternative to peat moss in the olive propagation medium, which helps in achieving the previous goals. Therefore, during the 2021 and 2022 seasons, cuttings of Coratina, Manzanillo, and Picual cultivars were used to find out the success of their propagation in biochar media. Where 5 ratios of biochar to sand were used to achieve the following ratios, which are 1:3, 1:4, 1:5, 1:6, and 1:7. In addition to the use of compost-sand in a ratio of 1: 7 and peat-sand in a ratio of 1:3 as a control medium.

The results indicated that the media containing biochar-sand at a ratio of 1:5 achieved results similar or close to those achieved with the comparison treatments for all root growth and then vegetative growth characteristics. In terms of leaf nutrient content, biochar treatments, particularly at high rates, showed superiority in leaves K and Ca content, while the use of biochar-sand at a rate of 1:4 to 1:6 in addition to the comparison treatment containing peat resulted in the highest content of P, while the maximum carbohydrate content and C/N ratio were also achieved when using the media containing biochar-sand at a ratio of 1:3 to 1:6, which was equal to that achieved by the control containing peat.

Keywords: Biochar, Olive, Propagation media, Rooting percentage, Root characteristics, Shoot characteristics and Leaf nutrient content.

Introduction

Egypt has an advantage over other nations in the production of olives and olive oil, due to its relatively stable climate and distinctive commercial location for the areas where the crop is grown. It ranks eighth globally among nations that produce olive oil and third among those that produce table olives, contributing about 11.5% of the global total (Mansour et al., 2019). This continuous expansion of cultivated areas needs an increased production of olive transplants. One of the most critical inputs for efficient rooting with improved root quality of cuttings is propagation media (PM) (Dolor et al., 2009). The cost and accessibility of medium components should be considered when selecting a rooting medium (Hartmann et al., 2007), quality (particle size, freedom from salt, weed and diseases and that pH), physical structure (ability to support the cutting, easy sticking of the cuttings), adequate aeration, mixing - the ability to be easily mixed, and standardization (FAO TECA, 2011). Since peat moss is regarded as one of the primary components in the medium of propagation of olive cuttings, in addition to the use of compost as an alternative to it (Abdel-Mohsen, 2015).

One of the biggest challenges in propagation media (PM) is obtaining components that are readily available, inexpensive, high quality, and environmentally friendly. Several media are used

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in various combinations to form PM, including peat moss and aggregates (vermiculite and perlite). Due to rising increasing environmental concerns, decreasing availability, and the increasing horticultural substrates cost (particularly those made of peat and aggregate), many renewable and economical alternatives are being pursued, of which biochar (BC) could be one of them. More focus has been placed on BC in recent decades due to its possible applications in agriculture, the environment, energy, and other fields. The "biochar revolution" has been dubbed as a result of this latter interest (Maddox, 2013). Although there has been a tremendous effort at the research level regarding how BC helps to store carbon and improve the fertility of the soil it is placed on, it has not been generally explored in the PM (Sohi et al., 2013). Whereas BC is a sustainable alternative to peat that reduces peat-derived carbon dioxide emissions. BC in potting soil combinations is said to boost water storage, nutrient supply, microbial life, and disease control (Blok et al., 2017). BC, on the other side, is seen to be one of the greatest potential long-term options for soil quality improvement, providing an optimal environment for microbial immobilization (Vlajkov et al., 2023). So as a replacement element for popular substrates such as vermiculite, peat moss, bark, perlite, and compost, which are both environmentally and economically costly (Huang, 2019, Banitalebi et al., 2021).

Biochar (BC) is created by pyrolysis, which is the thermal breakdown of organic substances without the presence of air. Pyrolysis is the process of heating biomass in a partially or entirely oxygen-free environment (Reed, 2009). Due to a lack of oxygen, the substance cannot burn entirely. Biochar ashes are rich in nutrients that can enhance plant nutrition and decrease the requirement for fertilizer (Dumroese et al., 2011). In addition to adding organic matter to soils, Additionally, BC increases such soils' capacity to hold onto water., which lessens the requirement for irrigation (Maddox, 2013). In terms of biology, it has been shown that BC encourages mycorrhizal association (Elad et al., 2011), raises bacterial flora (Yin et al., 2021), and makes atmospheric nitrogen fixation easier (Sohi et al., 2010). Due to its high porosity, BC promotes the growth of microorganisms (Yamato et al., 2006). Additional advantages for the environment include biochar, it is a carbon-negative chemical that has the potential to remove CO_2 from the atmosphere on a net basis. Similar to coal, BC can trap carbon in the soil for hundreds to thousands of years, slowing the rate of global warming (Maddox, 2013). Additionally, it may lessen fertilizer leaching in agricultural fields and greenhouse gas emissions (Prendergast-Miller et al., 2011 and Case et al., 2014). Despite these advantages, it is unknown how BC affects propagation media. Surface area, density, porosity, pore size and volume, hydrophobicity, and water-holding capacity are some of the physical characteristics of BC. Greater pyrolysis temperature increases surface area, porosity, and pore volume. The surface area and porosity of biochar vary from 100 to 800 m2/g and 50% to 70%, respectively. 0.6 g/cm3 is a rather low bulk density (Yu et al., 2019). The ability to hold water is dependent on porosity, and hydrophobicity is related to surface function groups. pH, cation exchange capacity, composition of elements, and surface functionality are some of the chemical characteristics of BC. The pH and capacity for cation exchange of BC rise as pyrolysis temperature rises. pH was 8.9 on average. According to Yang et al. (2019), BC's functional groups such as acyl, amido, acyl, carbonyl, carboxyl, ether, ester, hydroxyl, and sulfonic play important roles in controlling pH, cation exchange capacity, nutrient and gas adsorption, pollutant degradation, and interactions amongst soil microbial communities.

Therefore, three different olive cultivars (Coratina - Manzanillo - Picual) were used to study the possibility of using biochar as a good alternative to the propagation media.

Materials and Methods

This study was done in the Pomology Department nursery of the Faculty of Agriculture, Cairo University, during the seasons of 2021 and 2022 to study the possibility of using biochar as a good alternative to peat moss in the olive propagation media. The use of biochar, resulting from the thermal decomposition of organic matter without the presence of air, undoubtedly supports the non-waste of resources resulting from burning these materials, which is in line with sustainable development and overcoming pollution resulting from burning these wastes while at the same time reducing the cost of purchasing peat moss imported from abroad.

Olive material

Cutting of 3 olive cultivars were used to eliminate the effect of varietal differences on the results and the results are more comprehensive.

The cultivars used were Coratina, Manzanillo and Picual. The semi-hardwood shoots cuttings were made from 1-year-old shoots of the Pomology department nursery fruitful olive mother's trees. The cuttings were about 15-20 cm in length with four leaves. Cuttings were prepared during August then the basal part of cuttings was immersed for about 5 seconds in an aqueous freshly prepared IBA (indole 3- butyric acid) solution at 4000 ppm (Mura et al., 1995; Mancuso et al., 1997) just before planting.

Olive propagation media

Biochar was used in olive propagation media in 5 ratios to sand, these ratios were 1:3, 1:4, 1:5, 1:6 and 1:7. Besides using the plant composting: sand in ratio 1:7 and peat moss: sand in ratio 1:3 as a control olive propagation media. The physical and chemical properties of the employed biochar are shown in Table (1).

Olive cutting planting

The cuttings were cultivated after treating their bases with indole 3- butyric acid, in olive cutting boxes filled with the previous planting media. Where each box for a replicate included 60 cuttings of the cultivar. Then, the boxes were placed under the mist irrigation system during the experiment period (75 days).

Assessments

After 75 days, transplants were removed from the olive propagation media and rooting percentage was calculated from the number of cuttings with at least one root. 10 transplants per replicate were taken to determine the root growth and shoot growth parameters. Where average root number and root weight and shoot number and weight were determined. Also, the leave chemical content was measured. Whereas leaf samples were taken and cleaned with tap water then dried at 70 C to constant weight and finally ground as a powder to determine macro elements (N, P, K and Ca) and carbohydrates. Total carbohydrates are determined according to Herbert *et al.* (1971). While 0.2 g of dried samples were digested with a mixture of sulfuric acid and perchloric to estimate N % by the macro-Kjeldahl method as described by (AOAC, 1995) and P% was determined by spectrophotometer model: CT- 2200 (Page *et al.,* 1982). While K% was determined by Flame photometer (Model: Jenway PFP7) (Chapman and Pratt, 1961).

Statistical analysis

The experiment design was a randomized complete block design with three replicates in each treatment. Tabulated and subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1989), using the general linear models "GLM" procedure of the SAS software (SAS Institute, 2002). Significant differences between treatments were assessed by Multiple Range Test (Duncan, 1955).

Results and Discussions

Rooting percentage

The results shown in Table (2) clearly that, it was statistically achieved using peat-sand or compost-sand as an olive propagation media in addition to 1:5 biochar-sand during the second propagation season for the highest rates of rooting of cuttings, while this was achieved in the first season with peat-sand or compost-sand only and 1:5 biochar-sand propagation media came in the next position for them. In the same context, it cleared the superiority of the Manzanillo olive cultivar in the rates of rooting over the two cultivars Coratina and Picual during both seasons. While the effect of the interaction between the propagation medium and the olive cultivars showed that, in the first season, the Manzanillo propagated in peat-sand or compost-sand media achieved the highest rate of rooting, Coratina propagated in peat-sand achieved the same statistical rate. Also, the Manzanillo propagated in the 1:5 biochar-sand media came in second place. While in the second season, this was achieved with the biochar-sand and compost-sand media only in the second season.

TABLE 1. Physical and chemical analysis of the biochar employed in the study.

Parameter	Value	Parameter	Value
Total surface area (m/g)	170.135	P%	0.15
Moisture%	7.34	K%	0.52
C	44.94	Ca%	1.91
pH	8.74	Mg%	0.96
EC (ds/m)	0.58	Fe (ppm)	990
CEC	29.03	Mn (ppm)	56.1
N%	0.72	Zn (ppm)	150.71

TABLE 2. Rooting percentage as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	23.73^{i}	28.33^{hi}	17.26^{j}	**23.10^{d}**	23.66^{h}	28.70^{g}	17.46^{j}	**23.27^{c}**
1:4 BC: sand	38.06^{ef}	46.08^{cd}	23.17^{i}	**35.77^{c}**	31.00^{g}	50.22^{c}	19.24^{ij}	**33.48^{b}**
1:5 BC: sand	46.10^{cd}	50.49^{bc}	32.58^{fgh}	**43.11^{b}**	42.57^{de}	57.80^{a}	36.63^{f}	**45.66^{a}**
1:6 BC: sand	32.33^{f-h}	40.79^{de}	27.70^{hi}	**33.61^{c}**	30.01^{g}	45.22^{d}	23.70^{h}	**32.98^{b}**
1:7 BC: sand	23.28^{i}	29.57^{gh}	16.10^{j}	**22.98^{d}**	22.24^{hi}	29.33^{g}	11.87^{k}	**21.15^{c}**
1:7 Com.: sand	50.59^{bc}	56.35^{a}	35.59^{ef}	**47.51^{a}**	42.20^{de}	54.70^{ab}	37.45^{f}	**44.78^{a}**
1:3 Peat: sand	54.43^{ab}	57.11^{a}	34.56^{fg}	**48.70^{a}**	49.07^{c}	53.94^{b}	39.49^{ef}	**47.50^{a}**
Mean	**38.36^{b}**	**44.10^{a}**	**26.73^{b}**		**34.39^{b}**	**45.70^{a}**	**26.55^{c}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

Number of roots / cutting

Regarding the effect of the propagation medium and cultivar on the rooting of cuttings, the results showed (Table 3) that the use of the propagation medium of biochar: sand at a ratio of 1:5 had a significant superiority in achieving the highest results for the number of roots/cutting and was significantly equal to the use of the peat: sand medium in the first season, while in the second season, the results showed that the average number of roots on the cuttings was equal when using the propagation medium of biochar: sand at a ratio of 1:4 and 1:5 with both the peat: sand and compost: sand. In addition, the Manzanillo olive cultivar was significantly superior in giving the highest number of roots per cutting, while the Coratina and Picual cultivars came in second place in both years of the study. And that during the first season, only the three cultivars achieved a significantly higher rate of rooting on the cuttings when using the propagation medium of biochar: sand at a ratio of 1:5 and equal to them only the Manzanillo cultivar propagated in the compost: sand and peat moss: sand, while in the second season, only the Manzanillo cultivar achieved the highest rate of root formation on the cuttings when propagated in biochar: sand in ratio of 1:4, 1:5, 1:6 and also when propagated in the compost: sand, and the peat: sand media.

Root length (cm)

In terms of average root length, propagation with peat moss: sand medium showed a statistical advantage, and it was equal to compost: sand medium and biochar: sand at a 1:5 ratio in the second season. Similarly, the Manzanillo cultivar was much superior in both years, with the longest average root length. Furthermore, Manzanillo cuttings propagated in peat-sand and compost-sand media achieved the highest average root length in the first season. While in the second season, the three cultivars were equal in achieving the highest average root length when using biochar: sand propagation medium at a ratio of 1:5 and equal to Manzanillo and Coratina propagated in peat-sand medium (Table 4).

Root dry weight (gm)

Continuing the superiority of the Manzanillo cultivar, it achieved a significantly higher mean dry weight of the roots in both years of the study. The peat-sand medium achieved a significantly higher mean of the dry weight of the roots in both years and was equal to it in the first season using the propagation medium of biochar-sand with a ratio of 1:4 up to 1:6, as well as when using the compost: sand medium, while they are coming second after the peat-sand medium in the second season. The results also show that Manzanillo cuttings grown in peat moss-sand, compost-sand, or biochar-sand (1:5) achieved the highest average roots dry weight in both years and equaled with it the Coratina cultivar propagated by compost-sand propagation medium and peat-sand in the first season and propagated in the second season by peat-sand propagation medium only (Table 5).

Number of shoots / cutting

The propagation medium of biochar: sand at a 1:4 or 1:5 ratio was statistically equal to the comparator treatments of compost: sand (1:7) or peat: sand (1:3) in terms of the number of shoots produced in the first season. In the second season,

TABLE 3. Root number as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	5.11^{j}	8.11^{hi}	6.44^{ij}	**6.55^{e}**	6.41^{h}	10.53^{fg}	9.55^{g}	**8.83^{c}**
1:4 BC: sand	9.33^{fgh}	14.00^{b-d}	8.57^{gh}	**10.63^{dc}**	12.89^{de}	16.11^{ab}	10.83^{fg}	**13.27^{ab}**
1:5 BC: sand	14.29^{a-d}	16.24^{a}	14.52^{a-d}	**15.02^{a}**	13.44^{d}	17.21^{a}	13.67^{d}	**14.77^{a}**
1:6 BC: sand	9.61^{fgh}	9.62^{fgh}	10.63^{fg}	**9.95^{d}**	9.42^{g}	15.89^{ab}	10.33^{fg}	**11.88^{b}**
1:7 BC: sand	7.94^{hi}	14.17^{b-d}	8.18^{hi}	**10.10^{dc}**	7.60^{h}	15.33^{bc}	10.50^{fg}	**11.15^{bc}**
1:7 Com.: sand	13.00^{cde}	15.74^{ab}	8.58^{gh}	**12.44^{bc}**	14.00^{cd}	15.67^{ab}	10.96^{fg}	**13.54^{ab}**
1:3 Peat: sand	12.89^{de}	15.08^{a-c}	11.17^{ef}	**13.04^{ab}**	13.11^{d}	15.75^{ab}	11.58^{ef}	**13.48^{ab}**
Mean	**10.31^{b}**	**13.28^{a}**	**9.73^{b}**		**10.98^{b}**	**15.21^{a}**	**11.06^{b}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

TABLE 4. Root length (cm) as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	30.85^{h}	66.00^{ef}	48.70^{g}	**48.52^{e}**	33.96^{k}	67.85^{ij}	65.55^{j}	**55.79^{e}**
1:4 BC: sand	69.78^{def}	91.33^{bc}	55.55^{fg}	**72.22^{d}**	88.22^{c-g}	86.33^{e-h}	78.37^{gh}	**84.30^{cd}**
1:5 BC: sand	83.55^{b-e}	95.33^{b}	79.53^{b-e}	**86.14^{bc}**	92.52^{a-e}	100.81^{a}	98.08^{a-d}	**97.14^{a}**
1:6 BC: sand	74.74^{cde}	85.15^{bcd}	89.88^{bc}	**83.25^{cd}**	79.15^{fgh}	89.41^{b-f}	93.20^{a-e}	**87.25^{bc}**
1:7 BC: sand	74.23^{cde}	89.45^{bc}	78.19^{b-e}	**80.62^{cd}**	61.93^{j}	93.44^{a-e}	76.33^{hi}	**77.24^{d}**
1:7 Com.: sand	92.08^{bc}	121.00^{a}	80.08^{b-e}	**97.72^{b}**	99.36^{ab}	98.28^{a-d}	87.29^{d-g}	**94.98^{ab}**
1:3 Peat: sand	112.36^{a}	123.04^{a}	67.97^{def}	**101.12^{a}**	90.66^{a-e}	98.78^{abc}	93.34^{a-e}	**94.26^{ab}**
Mean	**76.80^{b}**	**95.90^{a}**	**71.41^{b}**		**77.97^{c}**	**90.70^{a}**	**84.60^{b}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

TABLE 5. Root dry weight (gm) as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	0.240^{ef}	0.340^{bcd}	0.283^{de}	**0.288^{b}**	0.187^{ijk}	0.247^{f-i}	0.203^{h-k}	**0.212^{c}**
1:4 BC: sand	0.293^{de}	0.363^{abc}	0.297^{de}	**0.317^{ab}**	0.237^{f-j}	0.263^{e-h}	0.223^{g-k}	**0.241^{c}**
1:5 BC: sand	0.323^{cd}	0.373^{abc}	0.340^{bcd}	**0.346^{a}**	0.283^{c-g}	0.347^{abc}	0.270^{efg}	**0.300^{b}**
1:6 BC: sand	0.287^{de}	0.347^{bcd}	0.300^{de}	**0.311^{ab}**	0.300^{c-f}	0.277^{d-g}	0.253^{e-h}	**0.277^{b}**
1:7 BC: sand	0.207^{f}	0.283^{de}	0.200^{f}	**0.230^{c}**	0.177^{jk}	0.273^{d-g}	0.167^{k}	**0.206^{c}**
1:7 Com.: sand	0.367^{abc}	0.403^{ab}	0.297^{de}	**0.356^{a}**	0.317^{b-e}	0.337^{a-d}	0.267^{e-h}	**0.307^{b}**
1:3 Peat: sand	0.390^{ab}	0.413^{a}	0.287^{de}	**0.363^{a}**	0.367^{ab}	0.387^{a}	0.290^{c-g}	**0.348^{a}**
Mean	**0.30^{b}**	**0.36^{a}**	**0.29^{b}**		**0.267^{b}**	**0.304^{a}**	**0.239^{c}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

the two treatments of 1:5 biochar: sand and 1:7 compost: sand came in second place after the 1:3 peat: sand treatment. Furthermore, in both research years, the Manzanillo and Coratina olive cultivars were statistically comparable in providing the new shoots, with the Picual cultivar coming in last (Table 6).

Shoot length / cutting (cm)

Table (7) shows the effect of propagation media (PM) and cultivar on shoot length during the two-year trial. The type of PM had a significant effect on the average shoot length/ cutting, with the use of biochar: sand in a 1: 5 ratio obtaining statistically the same average shoot length as the comparison treatment peat: sand in both seasons of the study. In addition, the Manzanillo cultivar had the longest average shoot length. Whereas the Manzanillo cultivar propagated in a 1:5 biochar: sand ratio acquired the highest values for shoot length and was statistically equal to that obtained in the comparative PM of peat to sand in both years.

Number of leaves / cutting

In both years of the study, the propagation medium peat: sand produced the largest average number of leaves and was considerably equal to the propagation medium biochar: sand at a rate of 1:5. In terms of cultivar influence, Manzanillo had the highest average number of leaves / cutting , followed by Coratina, and Picual had the lowest number of leaves across the two years of the study (Table 8).

TABLE 6. Shoot numbers as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	0.70^{i}	2.78^{ab}	1.19^{hi}	**1.56^{d}**	0.68^{i}	1.88^{efg}	1.11^{hi}	**1.22^{e}**
1:4 BC: sand	2.56^{a-e}	2.78^{ab}	2.18^{b-g}	**2.50^{ab}**	2.78^{c}	2.11^{def}	1.58^{fgh}	**2.16^{c}**
1:5 BC: sand	2.78^{ab}	2.86^{a}	2.77^{ab}	**2.80^{a}**	2.89^{c}	2.89^{c}	2.56^{cd}	**2.78^{b}**
1:6 BC: sand	2.59^{a-d}	1.97^{efg}	2.15^{c-g}	**2.24^{bc}**	1.78^{fg}	1.56^{fgh}	1.78^{fg}	**1.70^{d}**
1:7 BC: sand	1.95^{fg}	2.05^{d-g}	1.61^{gh}	**1.87^{cd}**	1.67^{fg}	2.33^{cde}	1.50^{gh}	**1.83^{cd}**
1:7 Com.: sand	2.93^{a}	2.78^{ab}	2.33^{a-f}	**2.68^{ab}**	2.39^{cde}	2.72^{c}	2.72^{c}	**2.61^{b}**
1:3 Peat: sand	2.54^{a-e}	2.67^{abc}	1.83^{fg}	**2.35^{ab}**	3.69^{ab}	4.00^{a}	3.48^{b}	**3.73^{a}**
Mean	**2.29^{a}**	**2.56^{a}**	**2.01^{b}**		**2.27^{ab}**	**2.5^{a}**	**2.10^{b}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

TABLE 7. Shoot length as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	2.30^{j}	9.30^{cde}	3.13^{j}	**4.91^{d}**	2.42^{h}	8.92^{de}	4.41^{g}	**5.25^{d}**
1:4 BC: sand	6.97^{f-i}	9.22^{cde}	5.15^{i}	**7.11^{c}**	8.81^{de}	9.93^{cd}	4.69^{g}	**7.81^{c}**
1:5 BC: sand	9.52^{cde}	13.51^{a}	9.26^{cde}	**10.67^{ab}**	8.37^{e}	12.48^{a}	10.19^{bcd}	**10.34^{ab}**
1:6 BC: sand	7.42^{e-h}	8.33^{def}	6.45^{f-i}	**7.40^{c}**	4.61^{g}	10.04^{cd}	6.22^{f}	**7.08^{cd}**
1:7 BC: sand	5.82^{hi}	9.45^{cde}	6.24^{ghi}	**7.17^{c}**	4.72^{g}	7.85^{e}	4.08^{g}	**5.55^{d}**
1:7 Com.: sand	9.75^{cd}	14.39^{a}	7.92^{d-g}	**10.69^{ab}**	8.19^{e}	9.03^{de}	6.22^{f}	**7.81^{c}**
1:3 Peat: sand	11.19^{bc}	13.00^{ab}	9.12^{cde}	**11.10^{a}**	11.50^{ab}	11.55^{ab}	10.96^{bc}	**11.34^{a}**
Mean	**7.56^{b}**	**11.03^{a}**	**6.75^{b}**		**6.95^{b}**	**9.97^{a}**	**6.68^{b}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

Shoot dry weight (gm)

During the two years of the study, the propagation medium peat-sand attained a much higher average dry weight of the shoots per cutting and was equal to that propagation in the compost-sand medium in the first season. While propagation using a biochar-sand medium at a 1:5 ratio came in second place. During the two study years, the Manzanillo cultivar had the highest average dry weight of shoots (Table 9).

Leaf minerals content %

Concerning the elemental content of the leaves, Table (10) showed that the leaves of the two cultivars Coratina and Manzanillo surpassed Picual in their nitrogen content. Also, the use of the propagation medium of biochar-sand at a ratio of 1:3 and compost-sand significantly achieved the highest nitrogen content. Likewise, the Coratina cultivar grown in the compost sand achieved the highest nitrogen content.

Also, the results in the same table show that there were no significant differences between the three cultivars in their phosphorus content, while the use of peat-sand medium and biochar-sand at ratios of 1:4 up to 1:6 gave the highest phosphorus content.

As for the leaves potassium content, the results presented in Table (11) showed that the use of biochar-sand propagation medium at any ratio achieved a significant increase in the potassium content of the leaves compared

TABLE 9. Shoot dry weight (gm) as influenced by propagation media and olive cultivars.

Treatments	Season 2020				Season 2021			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	0.197^{hi}	0.270^{def}	0.167^{i}	**0.211^{d}**	0.187^{hi}	0.273^{cde}	0.117^{k}	**0.192^{c}**
1:4 BC: sand	0.253^{efg}	0.293^{cde}	0.190^{hi}	**0.246^{c}**	0.273^{cde}	0.260^{c-f}	0.147^{jk}	**0.227^{bc}**
1:5 BC: sand	0.293^{cde}	0.337^{bc}	0.253^{efg}	**0.294^{b}**	0.240^{efg}	0.270^{cde}	0.293^{c}	**0.268^{b}**
1:6 BC: sand	0.233^{fgh}	0.207^{ghi}	0.223^{fgh}	**0.221^{dc}**	0.220^{fgh}	0.283^{cd}	0.200^{ghi}	**0.234^{bc}**
1:7 BC: sand	0.167^{i}	0.247^{efg}	0.170^{i}	**0.194^{d}**	0.207^{ghi}	0.260^{c-f}	0.177^{ij}	**0.214^{c}**
1:7 Com.: sand	0.343^{bc}	0.393^{a}	0.310^{dc}	**0.349^{a}**	0.277^{cde}	0.283^{cd}	0.250^{def}	**0.270^{b}**
1:3 Peat: sand	0.377^{ab}	0.397^{a}	0.333^{bc}	**0.369^{a}**	0.360^{ab}	0.383^{a}	0.337^{b}	**0.360^{a}**
Mean	**0.27^{b}**	**0.31^{a}**	**0.24^{c}**		**0.25^{b}**	**0.29^{a}**	**0.22^{c}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

TABLE 10. Leaf N% and P% content as influenced by propagation media and olive cultivars.

Treatments	N%				P%			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	1.85^{b}	1.82^{bc}	1.82^{bc}	**1.83^{a}**	0.263^{cde}	0.253^{def}	0.220^{g}	**0.246^{b}**
1:4 BC: sand	1.75^{bcd}	1.64^{d-g}	1.61^{fg}	**1.66^{c}**	0.263^{cde}	0.260^{cde}	0.313^{ab}	**0.279^{a}**
1:5 BC: sand	1.78^{bc}	1.75^{bcd}	1.73^{b-e}	**1.75^{b}**	0.277^{cd}	0.280^{cd}	0.243^{efg}	**0.267^{ab}**
1:6 BC: sand	1.72^{c-f}	1.80^{bc}	1.75^{bcd}	**1.76^{b}**	0.287^{bc}	0.250^{def}	0.290^{bc}	**0.276^{a}**
1:7 BC: sand	1.62^{efg}	1.64^{d-g}	1.62^{efg}	**1.62^{c}**	0.227^{fg}	0.233^{efg}	0.183^{h}	**0.214^{c}**
1:7 Com.: sand	1.99^{a}	1.82^{bc}	1.80^{bc}	**1.87^{a}**	0.187^{h}	0.160^{h}	0.240^{efg}	**0.196^{c}**
1:3 Peat: sand	1.47^{h}	1.55^{gh}	1.45^{h}	**1.49^{d}**	0.253^{def}	0.330^{a}	0.260^{cde}	**0.281^{a}**
Mean	**1.74^{a}**	**1.72^{ab}**	**1.68^{b}**		**0.251^{a}**	**0.252^{a}**	**0.250^{a}**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

to using either the peat-sand or compost-sand media and that the highest potassium content was achieved with biochar-sand at a ratio of 1:3. Also, the two cultivars Coratina and Manzanillo were significantly superior to Picual in their potassium content.

As for the leaf's calcium content, the propagation medium peat-sand achieved significantly the lowest content of calcium in the leaves, while the medium of biochar-sand at a ratio of 1:3 achieved the highest content of calcium in the leaves. Also, the two cultivars Coratina and Manzanillo had superiority in the content of calcium in their leaves compared to the Picual cultivar (Table 11).

Leaf carbohydrates content and C/N ratio

The results tabulated in Table (12), showed that both the carbohydrate content of the leaves and the C/N ratio had the same behavior. The use of biochar-sand propagation medium at ratios from 1:3 up to 1:6 and peat-sand medium had superiority in the content of the leaves of both carbohydrates and the ratio C/N, while the two cultivars of Coratina and Manzanillo were superior in both traits compared to Picual. The Coratina cultivar achieved the highest values of both traits when propagated by the biochar-sand medium at a ratio of 1:3 in both years of the study.

Discussions

Positive results of the use of biochar in the propagation environment of olive cuttings (especially when used at a one-to-five ratio to sand) on rooting and root characteristics such as number, length, and weight of the roots, which were similar to those obtained by the two control treatments that included peat or compost (Tables

TABLE 11. Leaf K% and Ca% content as influenced by propagation media and olive cultivars.

Treatments	K %				Ca %			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	1.09[a]	1.03[ab]	0.977[bc]	**1.03[a]**	1.25[a]	1.27[a]	1.09[c]	**1.21[a]**
1:4 BC: sand	0.950[bc]	0.957[bc]	0.930[c]	**0.946[b]**	1.09[c]	1.16[b]	0.950[d]	**1.07[b]**
1:5 BC: sand	0.940[c]	0.950[bc]	0.973[bc]	**0.954[b]**	1.03[cd]	1.02[cd]	0.977[d]	**1.01[bc]**
1:6 BC: sand	0.983[bc]	0.920[cd]	0.973[bc]	**0.959[b]**	0.993[d]	0.847[e]	0.800[ef]	**0.880[d]**
1:7 BC: sand	0.970[bc]	0.963[bc]	0.927[c]	**0.953[b]**	1.01[d]	0.843[e]	0.807[ef]	**0.888[d]**
1:7 Com.: sand	0.847[de]	0.840[e]	0.800[e]	**0.829[c]**	0.867[e]	1.00[d]	0.983[d]	**0.950[cd]**
1:3 Peat: sand	0.820[e]	0.803[e]	0.810[e]	**0.811[c]**	0.767[fg]	0.713[g]	0.817[ef]	**0.766[e]**
Mean	**0.942[a]**	**0.923[ab]**	**0.913[b]**		**1.00[a]**	**0.98[a]**	**0.92[b]**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

TABLE 12. Leaf carbohydrate content and C/N ratio as influenced by propagation media and olive cultivars.

Treatments	Carbohydrates				C/N ratio			
	Corat.	Manz.	Picual	Mean	Corat.	Manz.	Picual	Mean
1:3 BC: sand	1.83[a]	1.33[de]	1.04[f]	**1.40[a]**	0.993[a]	0.733[c]	0.570[de]	**0.766[a]**
1:4 BC: sand	1.47[b]	1.25[e]	0.89[g]	**1.20[ab]**	0.837[b]	0.767[bc]	0.550[ef]	**0.718[ab]**
1:5 BC: sand	1.45[bc]	1.36[dc]	0.75[i]	**1.89[ab]**	0.817[bc]	0.777[bc]	0.433[ghi]	**0.676[abc]**
1:6 BC: sand	1.36[dc]	1.32[de]	0.85[gh]	**1.17[abc]**	0.793[bc]	0.733[c]	0.480[fgh]	**0.669[abc]**
1:7 BC: sand	0.93[g]	1.05[f]	0.63[j]	**0.869[c]**	0.577[de]	0.637[d]	0.390[i]	**0.534[c]**
1:7 Com.: sand	1.03[f]	1.43[bc]	0.77[hi]	**1.07[bc]**	0.513[efg]	0.787[bc]	0.423[hi]	**0.574[bc]**
1:3 Peat: sand	1.45[bc]	1.27[de]	0.70[ij]	**1.14[abc]**	0.967[a]	0.813[bc]	0.483[fgh]	**0.754[ab]**
Mean	**1.36[a]**	**1.29[a]**	**0.80[b]**		**0.79[a]**	**0.75[a]**	**0.48[b]**	

* The values provided are the average and standard deviation; different letters within each column indicate significant differences based on repeated Duncan range tests (P 0.05).

2, 3, 4, 5) as a result of biochar (BC) application likely improved soil environments and, as a result, significantly promoted root growth mainly by increasing root length. Where Di Lonardo et al. (2013) noted that BC decreases the concentration of ethylene and raises the number of roots in tissue-grown poplars, demonstrating that BC has a major effect on the root phenotype. According to Xiang et al. (2017), the use of BC enhanced root volume (+29%), root biomass (+32%), and surface area (39%). The BC-induced enhancement in root length (+52%) and number of root tips (+17%) were significantly greater than the rise in the diameter of the root (+9.9%). Furthermore, Zou et al. (2021) found that the BC amendment had a favorable influence on root growth in 81.3% of 203 data from 47 published investigations, with an average relative rise of 32%. Trees had the greatest increase in root biomass following biochar amendment (+101.6%), which was followed by grasses (+66.0%), vegetables (+26.9%), and grains (+12.7%).

The good effect of using biochar on the vegetative growth characteristics shown in Tables (6) to (9) can be attributed to the effect of biochar (BC) is expected to improve soil characteristics and enable plant growth. BC is recognized to increase soil fertility and therefore enhance plant growth (Shetty and Prakash, 2020). According to Simiele et al. (2022), BC enhanced substrate characteristics, which promoted root, shoot, and leaf morphology. The BC-treated plants had more leaves compared to untreated plants. The addition of 1% and 2% BC greatly boosted both the root and shoot biomass of seedlings. The shoot›s dry weight was also found to be substantially related to soil available-P. According to the experiments, adding 12%- BC improved the growth of roots and shoots in Robinia pseudoacacia L. (Bu et al., 2020).

The elemental content of the leaves and carbohydrates, as shown in Tables 10 to 12, demonstrates that cuttings propagated in biochar excelled in this, which can be linked to the biochar (BC) is high in nutrients like N, P, K, Ca, and Mg (Wang et al. 2014), and also it can be used to enhance soil nutrients, encourage growth of roots and absorption of nutrients, and raise the biomass of plants and yield (Taghizadeh-Toosi et al., 2012; Born et al., 2018). Whereas BC treatment level affects soil nutrition and plant roots phenotype (Fouladidorhani et al., 2020). Whereas the addition of biochar changes root shape to enhance N uptake (increased specific root length, smaller root diameter, and lower root tissue mass density), showing good root proliferation regardless of fertilization amount (Zaitun et al., 2020; Rafique et al., 2020). Di Lonardo et al. (2013) discovered that BC treatment is an efficient method for boosting N consumption efficiency. It promotes N assimilation by modulating root shape as well as associated physiologic and metabolic functions (Abbasifar et al., 2020; Liang et al., 2020). Furthermore, research indicates that biochar improves crop N use efficiency and boosts rhizosphere microbial variety (Wu et al., 2020). In addition, because of its skeletal-sponge structure (Craswell et al., 2021), it increases rhizosphere microbial populations and activities, especially cellulose-degrading and nitrogen-fixing bacteria (Pokharel et al., 2020). Many studies also show that biochar has a good influence on P availability (Parvage et al., 2013, Chintala et al., 2014). Furthermore, raising the application of biochar increased the concentration of leaf minerals (N, P and K) (Abo-Ogiala, 2018). Also, some BC boosted nutritional concentrations in the leaf, particularly K (Olszyk et al., 2020). Furthermore, Agegnehu et al. (2016) discovered that applying BC was successful at boosting the leaves chlorophyll content, implying that BC might be used as a possible soil modifier to increase plant fitness. Furthermore, BC has been shown to improve soil carbon and water content, in addition to macroaggregates, electrical conductivity, pH, total nitrates/nitrites, ammonia, N (Polzella et al., 2019; Craswell et al., 2021), extractable P, and cation-exchange capacity (Yaashikaa et al., 2020). Also, BC had a beneficial influence on the net photosynthesis rate of the leaf, chlorophyll index, N-balance index, and sucrose synthase activities, and leaf sucrose, soluble sugar, and starch contents (Qian et al., 2019).

In general, all the results show the superiority of the Manzanillo and Coratina cultivars over the Picual cultivar in the success of the cuttings in rooting and the characteristics of the roots, and thus the characteristics of the vegetative growth and its chemical content. This can be attributed to the difference in cultivar. Where exogenous and endogenous and factors such as genotype, mother tree age, cutting type, and post-planting care influence the rooting response of different cuttings (Hechmi et al., 2013; Rashedy et al., 2021). Whereas Hechmi et al. (2013) indicated that cuttings from Koroneiki and Arbequina cultivars generated longer roots, more roots per cutting, and greater rooting percentages than Picual cv. Ozkaya and Celik (1999) explained that cultivar differences in olive-cutting rooting ability relate to endogenous carbohydrate status. In addition, Picual cuttings, for example, had a lower rooting percentage than Manzanillo, which was accompanied by a substantial decrease in vascular bundle percentage, total phenol, phenol/indole ratio, IAA, and IAA/GA ratio. Picual› cuttings also had more GA, GA/IAA ratio, and pith than Manzanillo› cuttings (Abdel-Mohsen and Rashedy, 2023). This is in addition to the genetic differences between the cultivars due to their responses to the propagation media (Awan et al., 2001). Whereas Qian et al. (2019) discovered that variances in genetic responses to biochar underscore the importance of taking specific cultivars and biochar rates into account when analyzing possible crop responses to biochar.

Conclusion

According to the findings of this study, biochar can be used in the propagation media of olive cuttings at a rate of 1 to 5 sand within the framework of using organic waste in line with sustainable development and replacing peat moss, which helps reduce carbon emissions and pollution caused by burning these wastes while also lowering the cost of purchasing imported peat moss. Whereas the results showed that the propagation media with biochar: sand at a 1:5 ratio generated results similar to or close to those obtained with the comparative treatments for all root growth characteristics and then for vegetative growth characteristics.

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الفحم الحيوى (Biochar) كبديل جديد محتمل فى وسط إكثار عقل الزيتون

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في إطار استخدام النفايات العضوية بما يتماشى مع التنمية المستدامة، مما يساعد على تقليل انبعاثات الكربون والتغلب على التلوث الناتج عن حرق هذه النفايات وفي الوقت نفسه تقليل تكلفة شراء البيت موس المستورد من الخارج، فأن هذه الدراسة هدفت إلى دراسة إمكانية استخدام الفحم الحيوى (Biochar) كبديل جيد للبيت موس في وسط إكثار الزيتون، مما يساعد في تحقيق الأهداف السابقة. لذلك وخلال عامي 2021 و 2022 تم استخدام عقل 3 أصناف من الزيتون (كوراتينا ومانزانيلو وبيكوال) لمعرفة مدى نجاح إكثارها في الوسائط التي تحتوي على الفحم الحيوي. حيث تم استخدام 5 معدلات من الفحم الحيوي إلى الرمل لتحقيق النسب التالية وهى 1: 3 ، 1: 4 ، 1: 5 ، 1: 6 و 1: 7. بالإضافة إلى استخدام الكمبوست : الرمل بنسبة 1: 7 و البيت موس: الرمل بنسبة 1: 3 كوسطين كنترول للمقارنة.

وقد أظهرت النتائج التي تم الحصول عليها أن وسط الإكثار المحتويةعلى الفحم الحيوي: الرمل بنسبة 1: 5 حقق نتائج مماثلة أو قريبة من تلك التي تحققت مع معاملات المقارنة لجميع الخصائص المتعلقة بنمو الجذر ومن ثم المتعلقة بخصائص النمو الخضري. أما بالنسبة للمحتوى الغذائي للأوراق ، أظهرت معاملات الفحم الحيوى، خاصة للمعدلات العالية منه، تفوقًا في محتوى الأوراق K و Ca ، بينما استخدام الفحم الحيوى: رمل بمعدل 1: 4 إلى 1: 6 بالاضافة لمعاملة المقارنة المحتوية على البيت موس عمل على إعطاء أعلى محتوى من الفسفور، بينما تم تحقيق أعلى محتوى من الكربوهيدرات ونسبة C / N أيضًا عند استخدام وسائط الإكثار التي تحتوي على الفحم الحيوي: الرمل بنسبة 1: 3 إلى 1: 6 ، والتي كانت مساوية للمتحقق بمعاملة الكنترول التى تحتوى على البيت موس. ومن ناحية أخرى، أظهر صنف مانزانيلو تفوقًا ملحوظًا في معظم الصفات قيد الدراسة بينما حقق صنف البيكوال أقل القيم.

الكلمات الدالة: الفحم الحيوي ، الزيتون ، وسط الإكثار ، نسبة التجذير ، الخصائص الجذرية ، الخصائص الخضرية ومحتوى المغذيات بالأوراق.