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EFFECT OF USING BIOCHAR AND ITS AQUEOUS EXTRACT ON SEEDLING PRODUCTION OF SOME VEGETABLE CROPS AND REFLECT THAT ON THE YIELD

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ABSTRACT

This study was carried out during the two successive seasons of 2018 and 2019 at the Experimental Farm, Kaha station, Qulubia Governorate to confirm the effect of different rates of biochar (0% biochar (control), 20% biochar, 40% biochar and 60% biochar) mixture with commercial media (peat moss and vermiculite (1:1 volume basis) and two concentration from aqueous extract of biochar (2% and 4%) as foliar spray on seed germination period and seedling growth parameters of tomato, sweet pepper, cucumber and lettuce and behavior of seedlings growth under the irrigation daily or every two days and study effect of that on the vegetative growth and total yield of sweet pepper plants. Biochar produced from gazwarina trees wood. Generally, it is clear that adding the low rate of biochar (20%) to growing media significantly affected positively on germination percentage, germination rate and coefficient germination velocity for all previous crops this was true in both growing season. Regarding to tomato, cucumber and lettuce seedling, the results showed that adding the low rate of biochar (20%) to growing media and irrigation daily or two days significantly affected positively on all vegetative growth and root growth characters followed by using aqueous extract of biochar at 2% as foliar spray and irrigation daily or two day treatments. While, the best treatments were foliar spray by aqueous extract of biochar at 4%, 2% followed by 40% and 20% biochar addition to growing media, respectively according to sweet pepper seedling. Generally, the effect of used different rates of biochar under two periods of irrigation induced significant effect on all vegetative growth, root growth parameters and leaf chlorophyll concentration of all previous crops seedling as grown in the nursery. It can be observed that with all biochar rates except addition the high rate of biochar (60%) to growing media which significantly negative affected on all vegetative growth and root growth characters, this was true in both growing season.

The data reveal also that, generally, all studied plant growth parameters and total yield of sweet pepper plant, were significantly increased by using all different biochar rates especially the plants obtained from seedlings sprayed by aqueous extract of biochar at 2% or at 4% in both growing seasons.

In general these results demonstrate that in nursery plant propagation, biochar may be a beneficial amendment for standard growing media, potentially bringing benefits to plant productivity and reducing reliance on non-renewable media components or the higher coast.

INTRODUCTION

Few studies were conducted to assess the impact of biochar on seed germination as well as enhancing the agriculture soil and plant growth which due to the specificity of the interaction between biochars and plants.

Tomato, sweet pepper, cucumber and lettuce are four of the most popular and versatile vegetables in the world. Tomato (***Solanum Lycopersicon***) and sweet pepper (***Capsicum annuum*** L.) are an excellent source of vitamins, minerals (Potassium, Calcium, Magnesium and Phosphor) and antioxidants such as lycopin pigment which conceder anti prostate cancer and contain salicylate compound. Cucumber (***Cucumis sativus*** L.) is very high in water content and very low in calories. It has potential ant diabetic, lipid lowering and antioxidant activity. Lettuce (***Lactuca sativa*** L.*)* contains Vitamin A, Vitamin C, Minerals, Water and Fibber. Pepper seed germination is considered a critical step in the development cycle of the plant, germination rate and seedling growth in pepper plants are very low comparing with the other vegetable seedlings. (**Korkmaz and Korkmaz, 2009**). Different pretreatments have been investigated to improving rate of pepper seeds germination and seedling growth, some of these treatments are chemical and others are natural product such as biochar.

Local alternatives for some inorganic components of growing media, such as vermiculite or perlite that are mined and often shipped great distances, are also being sought, especially given that the costs of some commonly used amendments, such as vermiculite, continue to climb **Landis and Morgan (2008)**. Peat is still available in large quantities and modern horticulture depends on quality-assured growing media (**Schmilewski, 2008** and **Michel, 2010**). Biochar has emerged as one such material that shows promise as a partial replacement of those media components, including perlite (**Northup 2013**), vermiculite (**Headlee *et al* 2014** and **Nemati *et al*. 2015)** and peat (**Vaughn *et al.* 2015 and Matt *et al.* 2018)**, one alternative to inorganic and organic constituents in growing media for plants is biochar.

Biochar is a product of pyrolysis which is rich in carbon content and produced by heating biomass such as wood, manure or leaves in a closed container with little or no available air. In other words, it is produced by the thermal decomposition of organic material under a limited supply of (O2) oxygen, and at relatively low temperatures (< 700 Cº) (**Lehmann and Joseph 2009** and **Sohi *et al*. 2010**). Biochar has the potential to become a new technology employed in agricultural systems, since it has the capacity to increase nutrient availability in many soil types but there was little evidence to support the hypothesis of increased seed germination with the addition of biochar. Researchers observed species-dependent effects of biochar on the germination (**Keller *et al.*, 2010, Kwapinski *et al*., 2010, Van Zwieten *et al*., 2010, Solaiman *et al*., 2012, Dumroese *et al* 2011, Robertson *et al*., 2012, Kamara *et al*., 2014 and Soni, *et al.*, 2014**).Biochar application significantly increases the early growth of seedlings (**Thomas and Gale 2015**). So it is crucial to study the impact of biochar on early growth of seedlings. Generally, biochar has the ability to enhance crop productivity. Moreover, biochar contains a high concentration of stable organic carbon (C) as well as eluted carbon and ash. Several macro and microelements can be stored in the mineral fraction of biochar which may act as a source of mineral substances for microorganisms in soil (**Saletnik *et al.* 2016**)

On the other side, biochar could be one of the solutions as it improves soil physical properties and aids in improving soil hydrology. Biochar is a finely divided pyrolysed material prepared for soil improvement. Due to negatively charged surfaces and high surface area, biochar soil amendments improved water holding capacity of soil and thus protected the crops against drought, while minimized the soil hardening and hence reduced soil bulk density (**Ernsting, 2011**). Successful seed germination is crucial for both plant growth and development; therefore, germination rate and early growth characteristics can be an early indicator of the effects of biochar on plant productivity (**Rogovska *et al.*, 2011**). In this regard **Northup (2013**) showed that, plants grown in media containing biochar at 30% blended with 70% sphagnum peat were the best compared to plants grown in a commercial substrate that contained sphagnum peat, perlite, and limestone. Many biochar based substrates produced plants with shoot dry mass greater than the control. These results demonstrate the potential for biochar to replace perlite and eliminate the limestone amendment needed for commercial greenhouse soilless substrates based on sphagnum peat. **Carter *et al.*(2013**) studied the effect of rice-husk char (potentially biochar) application on the growth of transplanted lettuce (***Lactuca sativa***) and cabbage they indicated that, the biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments. Biochar had an effect on water relations , increasing relative water content and leaf osmotic potential, decreasing stomatal resistance and stimulating foliar (transpiration) gas exchange, and on photosynthesis by increasing the electron transport rate of photo system and the relation between effective photochemical quantum yield and non-photochemical quenching(**Haider, *et al.*, 2015**).

Hafeez *et al*. (2017) indicated that under water stress seed vigor, germination percentage, shoot length, membrane stability index, chlorophyll contents of soybean seedlings decreased significantly compared to control. However biochar applied proved to be more effective in mitigating the drought stress impacts in all these parameters. Moreover, **Khan *et al* (2019)** reported that, biochar significantly improved shoot and root dry weights, biomass and altered chlorophyll contents of tomato seedlings. Also, **Uslu *et al*. (2020)** demonstrated that biochar could increase seed germination percentage and seedling growth as well as vigor index with appropriate application rates.

Produce healthy seedlings under good nursery management is an important part of successful vegetable production. Major research interests have been directed to study biochar effects on soil quality and crop response, but little information is available about their possible effects on seed germination and seedling growth of vegetables crops.

The purpose of this study was to evaluate the effect of biochar rates on seed germination and seedling growth of tomato, sweet pepper, cucumber and lettuce as well as reflect of that on growth and yield of sweet pepper plants.

MATERIALS AND METHODS

The First study

I.The nursery experiment

The present study were conduct at the experimental Farm of Kaha vegetable research Station, Qalubia Governorate, Egypt, seeds of tomato (***Solanum Lycopersicon*** **L. cv.** Super Strain B) sweet pepper (***Capsicum annum*** **L. cv.** California Wonder), cucumber (***Cucumis sativus*** L.Hybrid Mayson) and lettuce (***Lactuca sativa*** L. **cv.**Landrace Lettuce) were sown under plastic house in the nursery during both 2018 and 2019seasons. The first part of nursery experiment aim to study the effect of adding different rates of biochar mixture with commercial media (peat moss and vermiculite (1:1 volume basis) as nursery substrate on seed germination parameters. Seeds of the previous plants were sown in the nursery, on the first week of January 2018and 2019 for both seasons, in foam trays (84 eyes for cucumber and lettuce) and (209 eyes for tomato and sweet pepper) filled with a mixture of commercial media and biochar were adequate amounts of fertilizers and fungicide, calcium carbonate was added to modify the mixture pH. This experiment was distributed in randomized complete design with three replicates and included four treatments as follows (0% biochar +100% commercial media (control), 20% biochar +80%commercial media, 40% biochar +60%commercial media and 60% biochar +40%commercial media).The seeds were considered germinated when the radical was at least 2 mm long (**Al Harbi *et al*., 2008).**

The purpose of the second part of nursery experiment was to study the response of tomato, sweet pepper, cucumber and lettuce seedlings to the different rates of biochar mixture with commercial media(peat moss and vermiculite (1:1 volume basis) and two concentration of aqueous extract of biochar as foliar spray under two periods of irrigation (daily and every two days). Seedling trays were kept under green-house conditions with all agriculture managements required for the production of whole seedlings except the irrigation periods. This experiment was distributed in randomized complete design with three replicates and included twelve treatments as follows**.**

1-0% biochar (100% commercial media) + daily irrigation (control)
2-20% biochar adding to 80%commercial media + daily irrigation
3-40% biochar adding to 60%commercial media + daily irrigation
4-60% biochar adding to 40%commercial media + daily irrigation
5-2% biochar extract as foliar spray+ daily irrigation
6-4 % biochar extract as foliar spray+ daily irrigation
7-0% biochar (100% commercial media)+ irrigation every two days
8-20% biochar adding to 80% commercial media + irrigation every two days
9-40% biochar adding to 60%commercial media + irrigation every two days
10-60% biochar adding to 40%commercial media + irrigation every two days
11-2 % biochar extract as foliar spray+ irrigation every two days
12-4 % biochar extract as foliar spray+ irrigation every two days.

Table (1): Cost of treatments used in this study

Treatments	Cost of growing media (£E /ton)
0% biochar (100% commercial media)	6000
20% biochar	5250
40% biochar	4500
60% biochar	3750

Commercial media (peat moss and vermiculite (1:1 volume basis) = 6000 (£E /ton), Biochar = 1400 (£E /ton)

Preparation of biochar extract:

The effect of the aqueous extractsin this study was examined at two concentrations of 2 and 4%.Twenty grams for 2% or forty grams for 4% of dried powder from biochar were placed in a Erlenmeyer flask and then 1000mL of distilled water was added and boiled for half hour. After shaking for 2 hours at 120 rev min^{-1} in the dark, the mixtures were filtered through Whatman No. 2 filter paper and then through a membrane filter with 0.45µM pore–size **Taek–Keun *et al* (2012)**. The pH and EC were measured with a pH meter (Orion 3–star, Thermo Scientific, USA) and an EC meter (Orion 3–star, Thermo Scientific, USA), respectively.

Table (2) Aqueous pH and EC values of different biochar rates

Biochar rates	pH		EC(dS m^{-1})	
	Before sowing	Before transplanting	Before sowing	Before transplanting
0% biochar (100% commercial media)	7.13	7.79	0.81	0.88
20% biochar adding to 80%commercial media	7.14	7.85	1.00	0.95
40% biochar adding to 60%commercial media	7.18	7.89	1.04	0.97
60% biochar adding to 40%commercial media	7.21	8.17	1.13	1.06
2 % biochar extract	7.64		1.23	
4 % biochar extract	7.66		1.35	

Table (3): Chemical and physical characteristics of biochar produced from gazwarina trees wood.

Characters	Concentration
Moisture content %	3.5
Ash content %	3.3
Bulk density kg m^{-3}.	560
EC(dS m^{-1})	1.3
pH	7.6
Total organic carbon%	94
Total Nitrogen%	1.12
C:N Ratio	83.9
Total Phosphorus%	0.106
Total Potassium%	2.9
Calcium%	1.1
Magnesium%	0.36
Cation exchangeable capacity mmolc kg^{-1}	16

Data recorded:

-The germination percentage (number of germinated seeds was recorded each day during the period of the germination).

-The germination rate (number of days required for maximum germination), according to **Ranal and Santana (2006).** Germination rate = (G1T1 + G2T2 +...+ GnTn) / (G1 +G2 +...+ Gn), Where G: number of germination seeds per day and T: time.

-Coefficient germination velocity: Σ Ni / Σ NiTX 100

Ni: number of germination seeds per day and T: number of days from the start of count until the end according to **Ranal and Santana (2006)**.

Ten seedlings were chosen randomly from each treatment in the three replicates after 35, 35, 45 and 55 day (age of seedling transplanting) from sowing for cucumber, lettuce, tomato and sweet pepper, respectively in order to determine the following:

-Seedlings length (the length of stem cm) -Number of leaves/ seedling- Stem diameter cm - Seedlings fresh weight (g) - Total leaf chlorophyll concentration was measured using Minolta chlorophyll Meter SPAD- 501 as SPAD units- Root volume (cm^3) by using graduated cylinder – Root length (cm) - Root fresh weight (g).

The second study

II-Field experiment for planting the sweet pepper seedlings in the field:

The experiment was conducted at the Experimental Farm of Kaha vegetable research Station, Qalubia Governorate, Egypt. Soil was clay in texture with 7.6 ph, 1.43% organic matters, 3.3 Ec, 121 ppm N, 52 ppm P and 109 ppm K. The present investigation was conducted during two successive summer seasons of 2018 and 2019.

After 55 day from sowing healthy sweet pepper seedlings obtained from the first study were selected and transplanted on the field plot. The experiment was arranged in randomized complete block with three replicates and included twelve treatments asshowed in the nursery experiment. The plot area was 8.4 m^2 and includes 3 ridges each of 0.7 m width and 4.0 m length

All agricultural practices were followed according to the recommendation for sweet pepper plantation. The following data were recorded as follows:

Data recorded:

Three plants were chosen randomly from each treatment in the three replicates after 75days from transplanting in order to determine the following:

-Plant length (the length of main stem cm) -Stem diameter (cm) - No. of. leaves/ plant - No. of. brunches/ plant and The leaf area was calculated according to the following formula of **Wallace and Munger (1965):**

-Leaf area (cm^2) = Leaves dry weight (gm) x disk area / Disk dry weight (gm)

- Total fruit yield (ton/fed) after finishing the fruit pickings

Statistical Analysis: The experimental design of this trial was randomized complete design for nursery experiment and randomized complete block for field experiment with three replicates. The obtained data were statistically analyzed using Duncan's multiple range tests at P≤0.05 level to verify differences among treatment means according to **Snedecor and Cochran (1982).**

RESULTS AND DISCUSSION

The first study:

I-The nursery experiment

I.1. Germination percentage, germination rate and coefficient germination velocity of tomato, sweet pepper, cucumber and lettuce seeds.

Data in **Table (4)** revealed that, seeds of tomato, cucumber and lettuce grown in commercial media without biochar (control) or those media supplemented with lowest levels of biochar at 20% resulted the best values of germination percentage and reduced the time requirement for germination(germination rate).While the opposite was happened with the high level (60%) of biochar which recorded significant reductions in germination percentage and coefficient of germination velocity occurred, while the time required for seed germination (germination rate) was increased, this results may be due to the high rates of biochar which lead to increase in pH in growing media as shown in **Table (2)**.In this regard A dose-dependent negative effect on germination and seedling growth was found by **(Solaiman *et al.* 2012)**.The inhibition of seedlings may be attributed to the reduced rate of cell division and cell elongation**.** Concerning the coefficient germination velocity of the same three crops data cleared that, there is no significant differences between the commercial added with biochar at 20 or 40 % and without addition (control) while the level 60% gave negative effect. Regarding to sweet pepper seeds in the nursery showed that, all different rates of biochar led to increase in germination percentage and coefficient of germination velocity especially adding biochar at 20% or 40% rates to growing media comparing with control treatment (0% biochar), this was true in both growing season .Generally, it is clear that adding the low rate of biochar (20%) to growing media significantly positive affected on germination parameters , this was true in both growing season. The researchers observed species-dependent effects of biochar on the germination which they found that there is no negative impact of biochar on the germination (**Keller *et al.*, 2010, Kwapinski *et al.*, 2010, Van Zwieten *et al.*, 2010, Solaiman *et al.*, 2012, Dumroese *et al* 2011, Robertson *et al.*, 2012, Kamara *et al.*, 2014 and Soni, *et al.*, 2014**). Moreover, Biochar application significantly increases the early growth of seedlings (**Thomas and Gale 2015**). Also, **Uslu *et al.* (2020)** demonstrated that biochar could increase seed germination percentage and seedling growth as well as vigor index with appropriate application rates.

Table (4): Effect of different biochar rates on germination percentage, germination rate and coefficient germination velocity of tomato, sweet pepper, cucumber and lettuce in 2018 and 2019 seasons.

Treatments	Tomato					
	Germination %		Germination rate day		Coefficient germination velocity %	
	2018	2019	2018	2019	2018	2019
0% biochar (control)	84.50 c	83.00 b	11.94c	11.67 c	8.38 a	8.58 a
20% biochar	92.00 a	90.00 a	12.27 b	12.55 b	8.14 a	8.09 a
40% biochar	85.83 b	80.67 c	12.41 b	12.60 b	8.08 a	8.02 a
60% biochar	82.33 d	76.50 d	16.31 a	16.55 a	6.20 b	6.14 b
	Sweet pepper					
0% biochar (control)	56.81 c	61.36 d	11.96 a	12.37 a	8.35 b	7.90 b
20% biochar	85.63 a	86.36 b	10.60 b	10.71 b	9.43 a	9.34 a
40% biochar	86.33 a	88.63 a	10.74 b	10.75 ab	9.31 a	9.30 a
60% biochar	63.63 b	64.77 c	11.09 a	11.10 ab	9.02 a	9.01 a
	Cucumber					
0% biochar (control)	97.63 a	95.27 a	6.58 c	6.32 b	15.27 a	15.83 a
20% biochar	97.62 a	95.24 a	6.51 c	6.27 b	15.38 a	15.95 a
40% biochar	88.89 b	88.10 b	6.84 b	7.07ab	14.67 ab	14.17 ab
60% biochar	74.26 c	70.67 c	7.76 a	7.68 a	13.24 b	13.02 b
	Lettuce					
0% biochar (control)	84.29 b	81.90 a	6.21c	5.83 c	16.61 a	17.16 a
20% biochar	86.67 a	81.51 a	5.95 c	5.74 c	16.93 a	17.56 a
40% biochar	47.78 c	46.19 b	8.33 b	6.90 b	12.80 b	14.74 b
60% biochar	42.22 d	40.83 c	11.57 a	10.71 a	8.92 c	9.33c

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

I.2. Vegetative growth, roots growth characters and leaf chlorophyll concentration of tomato, sweet pepper, cucumber and lettuce seedlings.

I.2.1-Tomato

Vegetative growth and root growth characters determined at seedling transplanting stage of tomato as grown in the nursery are shown in **Tables (5 and 6)**the data revealed that, the seedlings growing in media with 20% biochar addition and irrigated daily or two days registered the highest values of seedling length, stem diameter, fresh weight/ seedling followed by using aqueous extract of biochar at 2% as foliar spray and irrigation daily or two days treatments in both growing seasons. It is clear that adding the low rate of biochar (20%) to growing media and irrigation daily or two days significantly positive affected on all abovious vegetative growth and root growth characters, this was true in both growing season except seedling leaf chlorophyll concentration, which the plants growing in media with 60% biochar addition and irrigated daily or two days gave the highest values. Regarding to number of leaves, it is noticed that, all treatments gave not significant value in both growing season.

Table (5): Effect of different biochar rates on some vegetative growth characters and leaf chlorophyll concentration of tomato seedling during 2018 and 2019 seasons

Treatments	Seedling length (cm)		Stem diameter (cm)		No. of. leaves / Seedling		Fresh weight g / Seedling		leaf chlorophyll concentration SPAD	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Daily irrigation										
0% biochar (control)	13.48 d	14.75 c	2.54 e	2.48 e	3.74 abc	3.83 b	1.80 d	1.99 f	28.60 cdef	28.20 de
20% biochar	18.32 a	19.66 a	2.99 a	3.17 a	4.66 a	5.33 a	3.22 a	4.14 a	29.30 cd	29.00 bcde
40% biochar	14.55 cd	15.33 c	2.65 cde	2.86 c	4.41 ab	4.71 ab	2.17 cd	2.86 d	27.30 f	28.00 e
60% biochar	5.80 f	11.25 d	2.15 g	2.28 f	3.33 c	3.66 b	0.99 f	1.48 h	31.95 a	31.70 a
2 % biochar extract	16.70 ab	17.13 b	2.79 bc	2.90 c	4.33 abc	4.83 ab	2.81 ab	2.95 c	28.15 def	28.16 de
4 % biochar extract	13.22 d	14.71 c	2.60de	2.59 de	3.82 abc	4.16 ab	1.87 d	2.03 f	29.00 cde	28.90 bcde
Irrigation every two days										
0% biochar	15.95 bc	17.70 b	2.74 cd	2.89 c	4.37 abc	4.80 ab	2.43 bc	3.01 c	27.06 f	28.10 e
20% biochar	16.75 b	18.40 ab	2.97 a	3.05 ab	4.35 abc	4.80 ab	2.88 ab	3.49 b	27.40 ef	28.40 de
40% biochar	13.70 d	14.00 c	2.59 e	2.71 f	4.15 abc	4.80 ab	1.96 cd	2.24 e	29.90 bc	29.60 bcd
60% biochar	9.22 e	11.55 d	2.30 f	2.24 d	3.38 bc	3.77 b	1.22 ef	1.64 g	31.40 ab	30.20 abc
2 % biochar extract	16.55 b	17.84 b	2.92 ab	3.03 b	4.22 abc	4.30 ab	2.74 ab	2.83 d	28.70 cdef	28.70 cde
4 % biochar extract	14.80 cd	15.30 c	2.58 e	2.68 d	3.83 abc	4.00 ab	1.72 de	2.16 e	31.10 ab	30.40 ab

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

Table (6): Effect of different biochar rates on some root growth characters of tomato seedling during 2018 and 2019 seasons

treatments	Root length (cm)		Root volume (cm^3)		Fresh weight g /root	
	2018	2019	2018	2019	2018	2019
Daily irrigation						
0% biochar (control)	7.60 de	6.88 cd	0.62 de	0.58 d	0.44 d	0.38 e
20% biochar	9.27 b	8.74 b	0.92 a	0.96 a	0.57 b	0.69 b
40% biochar	7.00 ef	7.94 bc	0.62 de	0.58 d	0.46 d	0.48 d
60% biochar	4.03 g	6.81 cd	0.24 g	0.33 e	0.13 f	0.23 f
2 % biochar extract	8.31 cd	7.96 bc	0.83 bc	0.89 b	0.51 bcd	0.55 cd
4 % biochar extract	7.95 d	7.79 cd	0.33 f	0.33 e	0.32 e	0.36 e
Irrigation every two days						
0% biochar	6.90 ef	6.80 cd	0.66 d	0.66 c	0.47 cd	0.51 d
20% biochar	10.32 a	10.90 a	0.89 ab	0.91 ab	0.66 a	0.78 a
40% biochar	6.69 f	7.08 cd	0.60 de	0.62 cd	0.43 d	0.50 d
60% biochar	4.00 g	5.45 d	0.16 h	0.16 f	0.16 f	0.23 f
2 % biochar extract	8.94 bc	8.71 b	0.78 c	0.66 c	0.55 bc	0.59 c
4 % biochar extract	7.02 ef	7.25 bc	0.58 e	0.58 d	0.47 cd	0.54 cd

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

I.2.2. Sweet pepper

The data in **Table (7)** registered that, the effect of used different rates of biochar under two periods of irrigation induced significant effect on all vegetative growth, root growth parameters and leaf chlorophyll concentration except stem diameter of sweet pepper seedling as grown in the nursery. It can be observed that with all biochar rates except addition the high rate of biochar (60%) to growing media which induced significantly negative affected on all obvious vegetative growth and root growth characters, this was true in both growing season.In other word it can be said that, the best treatments were under foliar spray by aqueous extract of biochar at 4%, 2% followed by 40% and 20% biochar addition to growing media, respectively.

I.2.3.Cucumber

The data recorded in **Table (8)** showed that, the effect of used different rates of biochar under two periods every one or two days of irrigation induced significant effect on all vegetative growth. It is quite clear from the data presented that, the seedlings growing in media with 20% biochar addition and irrigated daily followed by seedlings sprayed by aqueous extract of biochar at 4% and irrigated daily gave the highest values of seedling length in both growing seasons. According to stem diameter, number of leaves/ seedling, fresh weight/ seedling, data showed that, the best treatments were with 20% biochar addition to growing media with daily irrigation or spraying seedling by aqueous extract of biochar at 2% or at 4% and daily irrigation or two days in both growing seasons.

Regarding to root growth parameter and leaf chlorophyll concentration the data in **Table (9)** showed that, the seedlings growing in media with 20% biochar addition and irrigated daily gave the highest values of root volume, fresh weight / root. In addition, the best treatments were addition 20% or 40% biochar to growing media and irrigation every two days as well as leaf chlorophyll concentration. While, it is clear that, the best treatments were at addition 40% biochar to growing media and irrigation every two day or spraying seedling by aqueous extract of biochar at 4% and irrigation daily, whereas the two treatments gave the highest values ofroot length. These results were true in both growing seasons.

Table (7): Effect of different biochar rates on some vegetative and root growth characters as well as leaf chlorophyll concentration of sweet pepper seedling during 2018 and 2019 seasons

Treatments	Seedling length (cm)		Stem diameter (cm)		No. of. leaves / Seedling		Fresh weight g / Seedling		Root volume (cm³)		Fresh weight g /Root		leaf chlorophyll concentration SPAD	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
<u>Daily irrigation</u> 0% biochar (control)	9.40 h	9.80 g	0.17 b	0.15 b	4.75 d	5.25 efg	1.40 de	1.50 ef	0.33 c	0.33 b	0.32 de	0.43 de	32.40 l	31.00 i
20% biochar	10.70 e	11.10 d	0.28 ab	0.25 ab	5.14 cd	5.40 def	1.60 c	1.80 d	0.66 a	0.66 a	0.47 bcd	0.56 bc	35.10 j	35.50 gh
40% biochar	11.50 c	11.50 c	0.20 ab	0.19ab	5.00 cd	5.55 cde	1.50 cd	1.60 e	0.67 a	0.67 a	0.51 bc	0.61 b	35.50 i	35.90 g
60% biochar	10.20 f	10.80 e	0.20 ab	0.20 ab	4.75 d	5.50 cde	1.60 c	1.90 d	0.66 a	0.66 a	0.49 bc	0.53 bcd	34.50 k	35.30 h
2 % biochar extract	12.50 b	14.30 a	0.24 ab	0.22 ab	5.12 cd	5.75 bcd	2.30 b	2.80 a	0.58 ab	0.66 a	0.86 a	1.14 a	36.60 h	37.90 f
4 % biochar extract	13.60 a	14.40 a	0.30 a	0.29 a	5.33 bc	5.80 bc	2.70 a	2.90 a	0.67 a	0.67 a	0.94 a	1.17 a	38.10 g	39.00 e
<u>Irrigation every two days</u> 0% biochar	9.30 h	9.40 h	0.20 ab	0.20 ab	4.73 d	5.11 fg	1.10 f	1.20 g	0.33 c	0.33 b	0.30 e	0.45 de	38.90 f	37.60 f
20% biochar	9.60 g	10.00 fg	0.20 ab	0.20 ab	4.90 cd	5.37efg	1.50 cd	1.95 d	0.53 ab	0.66 a	0.40 cde	0.51 bcd	42.20 d	41.40 d
40% biochar	9.70 g	10.10 f	0.20 ab	0.20 ab	5.00 cd	5.44 cdef	1.30 e	1.40 f	0.54 ab	0.66 a	0.45 bcd	0.53 bcd	48.30 a	47.50 b
60% biochar	9.30 h	9.50 h	0.19 ab	0.18 b	4.93 cd	5.00 g	1.30 e	1.50 ef	0.33 c	0.33 b	0.42bcde	0.49 de	40.80 e	41.50 d
2 % biochar extract	10.90 d	11.10 d	0.21 ab	0.20 ab	6.00 a	6.44 a	2.20 b	2.40 c	0.49 bc	0.58 a	0.49 bc	0.55 bc	46.20 c	47.00 c
4 % biochar extract	11.40 c	12.20 b	0.22 ab	0.21 ab	5.75 ab	6.00 b	2.20 b	2.60 b	0.66 a	0.66 a	0.56 b	0.62 b	46.70 b	48.40 a

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

Table (8): Effect of different biochar rates on some vegetative growth characters of cucumber seedling during 2018 and 2019 seasons

Treatments	Seedling length (cm)		Stem diameter (cm)		No. of. leaves / Seedling		Fresh weight g / Seedling	
	2018	2019	2018	2019	2018	2019	2018	2019
<u>Daily irrigation</u>								
0% biochar (control)	16.67 cd	16.70 d	0.39 de	0.38 e	3.57 ab	3.00 ab	3.92 e	3.76 c
20% biochar	20.80 a	20.73 a	0.43 a	0.42 b	4.00 a	3.83 a	4.83 a	4.80 a
40% biochar	17.10 c	17.40 c	0.43 a	0.39 de	3.17 ab	3.33 a	4.08 d	4.30 b
60% biochar	11.30 i	13.48 g	0.29 h	0.39 de	2.00 c	2.00 b	1.22 i	1.03 f
2 % biochar extract	16.40 d	16.90 d	0.41 bc	0.38 e	4.00 a	3.83 a	4.78 a	4.69 a
4 % biochar extract	19.60 b	18.40 b	0.42 ab	0.41 bc	4.00 a	3.83 a	4.76 a	4.69 a
<u>Irrigation every two days</u>								
0% biochar	15.71 e	15.20 f	0.39 de	0.38 e	3.65 ab	3.33 a	4.40 b	3.71 c
20% biochar	14.20 g	15.90 e	0.40 cd	0.40 cd	3.15 ab	3.33 a	3.45 de	4.20 b
40% biochar	12.08 h	13.70 f	0.37 f	0.40 cd	3.17 ab	3.00 ab	3.25 g	3.68 c
60% biochar	11.42 i	9.21 h	0.33 g	0.31 f	2.66 bc	2.00 b	2.78 h	1.89 e
2 % biochar extract	16.33 d	16.92 d	0.43 a	0.44 a	4.00 a	3.50 a	4.62 c	4.66 a
4 % biochar extract	15.06 f	15.30 f	0.38 ef	0.39 de	4.00 a	3.66 a	3.72 f	3.40 d

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

Table (9): Effect of different biochar rates on some root growth characters and leaf chlorophyll concentration of cucumber seedling during 2018 and 2019 seasons.

Treatments	Root length (cm)		Root volume (cm^3)		Fresh weight g /Root		leaf chlorophyll concentration (SPAD)	
	2018	2019	2018	2019	2018	2019	2018	2019
Daily irrigation								
0% biochar (control)	7.00 c	7.00 cd	1.67 a	1.50 b	0.65 cd	0.73 cde	32.90 h	34.60 g
20% biochar	8.09 ab	8.17 a	1.67 a	1.67 a	1.20 a	1.10 a	36.98 d	39.40 b
40% biochar	7.33 bc	7.33 bc	1.00 d	1.00 e	0.80 b	0.87 b	38.30 c	38.43 c
60% biochar	5.50 f	4.50 f	0.78 e	0.50 g	0.75 bc	0.80 bcd	36.10	37.90 d
2 % biochar extract	7.50 bc	7.60 b	1.00 d	1.00 e	0.70 bcd	0.65 ef	33.80 g	35.50 f
4 % biochar extract	8.70 a	8.33 a	1.09 cd	1.17 d	0.70 bcd	0.67 e	36.60 de	35.30 f
Irrigation every two days								
0% biochar	6.17 de	6.50 de	1.00 d	1.00 e	0.50 e	0.53 f	32.00 i	35.20 f
20% biochar	6.83 cd	6.50 de	1.25 b	1.33 c	0.78 b	0.83 bc	40.30 a	40.00 a
40% biochar	8.50 a	8.50 a	1.00 d	1.00 e	0.77 bc	0.70 de	39.25 b	40.01 a
60% biochar	6.00 e	6.00 e	0.75 e	0.73 f	0.70 bcd	0.70 de	35.16 f	36.30 e
2 % biochar extract	7.34 bc	7.34 bc	1.09 cd	1.17 d	0.65 cd	0.70 de	36.30 e	35.30 f
4 % biochar extract	7.42 bc	7.42 bc	1.17 bc	1.33 c	0.58 de	0.63 ef	32.70 h	31.40 h

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

I.2.4.Lettuce

Data illustrated in **Tables (10 and11)** showed that, the seedlings growing in media with 20% biochar addition and irrigated daily followed by seedlings sprayed by aqueous extract of biochar at 4% and irrigated daily gave the highest values of seedling length in both growing seasons. While, it is clear that, the best treatments were addition 20% biochar to growing media and daily irrigation or spraying seedling by aqueous extract of biochar at 4% and irrigation every two days, whereas the two treatments gave the highest values of number of leaves. These results were true in both growing seasons. According to fresh weight/ seedling, data showed that, the best treatments were with 20% biochar addition to growing media or spraying seedling by aqueous extract of biochar at 2% or at 4% and daily irrigation in both growing seasons. Moreover, it is clear that, foliar spray by aqueous extract of biochar at 2% or at 4% and irrigation every two days gave leaf chlorophyll concentration higher than those obtained from daily irrigation. Regarding to stem diameter, it is noticed that, all treatments gave not significant value in both growing season. Data also reported that, adding the low rate of biochar (20%) to growing media and daily irrigation significantly positive affected on root volume, fresh weight/ root, this was true in both growing season while the plants growing in media with 0% biochar addition and irrigated every two days gave the highest values of root length.

These results may be due to biochar addition can improve plant growth directly as a result of its nutrient content and release characteristics or indirectly, through improved nutrient retention (**Rogovska *et al.,* 2011**). Moreover, Biochar contains a high concentration of stable organic carbon (C) as well as eluted carbon some macro, micro elements and ash as shown in **Table (3)**. In this regard A dose-dependent negative effect on germination and seedling growth was found by **(Solaiman *et al*. 2012)**.The inhibition of seedlings may be attributed to the reduced rate of cell division and cell elongation**.** On the other hand **Northup (2013**) showed that, plants grown in biochar containing substrates 30% [biochar] blended with 70% sphagnum peat were the best compared to plants grown in a commercial substrate that contained sphagnum peat, perlite, and limestone. Moreover, **Haider, *et al.,* (2015)** reported that, biochar had an effect on water relations , increasing relative water content and leaf osmotic potential, decreasing stomatal resistance and stimulating foliar (transpiration) gas exchange, and on photosynthesis by increasing the electron transport rate of photosystem and the relation between effective photochemical quantum yield and non-photochemical quenching .In this regard, Several macro and micro elements can be stored in the mineral fraction of biochar which may act as a source of mineral substances for microorganisms in the soil (**Saletnik *et al.* 2016**). **Also, Hafeez *et al*. (2017)** indicated that under water stress, shoot length, chlorophyll contents of soybean seedlings decreased significantly compared to control. However biochar applied proved to be more effective in mitigating the drought stress impacts in all these parameters. **Khan *et al* (2019)** reported that, biochar significantly improved shoot and root dry weights, biomass and altered chlorophyll contents of tomato seedlings. Also, Uslu ***et al*. (2020)** demonstrated that biochar could increase seedling growth with appropriate application rates.

The second study:

II- Field experiment for planting the sweet pepper seedlings in the field

II.1. Vegetative growth parameters and total yield of sweet pepper plants, whereas obtained from seedlings treated with biochar in the nursery

The vegetative growth parameters of sweet pepper plants and total yield as affected by obvious nursery treatments as shown in the first study are shown in **Table (12)**. The data revealed that, all treatments under investigation gave significantly positive effect on previous characters than the control especially the plants obtained from seedlings sprayed by aqueous extract of biochar at 2% or at 4% in both growing seasons. These results may be due to biochar addition can improve plant growth directly as a result of its nutrient content and release characteristics or indirectly, through improved nutrient retention (**Rogovska *et al.*, 2011**). Moreover, Biochar contains a high concentration of stable organic carbon (C) as well as eluted carbon macro and microelements as shown in **Table (3)** since it has the capacity to increase nutrient availability in the soil. Generally, biochar has the ability to enhance crop productivity and significantly increases the early growth of seedlings (**Thomas and Gale 2015**). Several macro and microelements can be stored in the mineral fraction of biochar which may act as a source of mineral substances for microorganisms in soil (**Saletnik *et al.* 2016**).Moreover; biochar contains a high concentration of stable organic carbon (C) as well as eluted carbon and ash. Several macro and microelements can be stored in the mineral fraction of biochar which may act as a source of mineral substances for microorganisms in soil (**Saletnik *et al.* 2016**).

Table (10): Effect of different biochar rates on some vegetative growth characters of lettuce seedling during 2018 and 2019 seasons

Treatments	Seedling length (cm)		Stem diameter (cm)		No. of. leaves / Seedling		Fresh weight g / Seedling	
	2018	2019	2018	2019	2018	2019	2018	2019
<u>Daily irrigation</u> 0% biochar (control)	16.00 bc	14.75 de	0.40 abc	0.39 bc	6.67 abc	7.50 ab	3.52 b	3.05 abc
20% biochar	17.73 a	18.80 a	0.40 abc	0.50 a	7.50 a	8.40 a	3.62 a	3.57 a
40% biochar	15.50 c	14.00 e	0.40 abc	0.48 ab	7.30 ab	6.50 cd	3.10 d	3.10 abc
60% biochar	12.80 e	11.90 g	0.20 d	0.23 d	6.00 cd	5.00 e	1.23 g	1.89 d
2 % biochar extract	15.50 c	15.00 d	0.50 a	0.50 a	6.67 abc	7.00 bc	3.52 b	3.52 ab
4 % biochar extract	17.30 a	17.85 b	0.50 a	0.50 a	7.00 abc	7.40 bc	3.52 b	3.52 ab
<u>Irrigation every two days</u> 0% biochar	13.75 d	13.00 f	0.39 bc	0.38 c	6.33 bcd	6.50 cd	2.65 e	2.88 bc
20% biochar	14.08 d	15.50 d	0.38 bc	0.45 abc	7.00 abc	7.40 bc	3.30 c	3.30 ab
40% biochar	13.75 d	13.00 f	0.36 c	0.40 bc	7.00 abc	6.00 d	2.50 f	2.50 cd
60% biochar	11.00 f	9.30 h	0.18 d	0.20 d	5.50 d	5.00 e	1.10 h	1.10 e
2 % biochar extract	16.33 b	16.83 c	0.48 ab	0.46 abc	7.17 ab	7.40 bc	3.28 c	3.28 ab
4 % biochar extract	17.20 a	17.50 bc	0.47 ab	0.47 abc	7.33 ab	7.50 ab	3.30 c	3.30 ab

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

Table (11): Effect of different biochar rates on some root growth characters and leaf chlorophyll concentration of lettuce seedling during 2018 and 2019 seasons

Treatments	Root length (cm)		Root volume (cm³)		Fresh weight g /Root		leaf chlorophyll concentration SPAD	
	2018	2019	2018	2019	2018	2019	2018	2019
<u>Daily irrigation</u>								
0% biochar (control)	6.52 cd	6.90 ab	1.33 b	1.40 b	1.04 b	0.97 cd	31.13 h	34.50 bc
20% biochar	6.83 bcd	6.80 abc	1.50 a	1.50 a	1.60 a	1.40 a	34.30 e	35.00 bc
40% biochar	6.50 cd	6.00 abc	1.00 d	0.96 d	0.90 c	1.10 b	38.60 c	36.90 ab
60% biochar	5.33 e	5.67 bc	0.32 f	0.30 g	0.42 g	0.39 i	33.50 g	34.90 bc
2 % biochar extract	7.50 ab	5.02 c	1.00 d	0.98 d	0.85 cd	0.90 de	28.50 j	27.90 e
4 % biochar extract	7.17 abc	6.92 ab	1.25 c	1.17 c	1.13 b	1.00 c	28.60 j	26.53 e
<u>Irrigation every two days</u>								
0% biochar	7.53 ab	7.59 a	1.00 d	0.88 ef	0.60 f	0.70 gh	33.90 f	31.20 d
20% biochar	6.42 cd	6.83 abc	1.33 b	1.10 c	0.77 de	0.77 fg	36.50 c	38.40 a
40% biochar	6.00 de	6.25 abc	0.92 e	0.84 f	0.66 ef	0.66 h	39.70 a	38.00 a
60% biochar	4.00 f	3.20 d	0.28 f	0.28 g	0.30 g	0.30 i	39.10 b	36.30 abc
2 % biochar extract	7.83 a	7.50 a	1.00 d	0.92 de	0.80 cd	0.85 ef	30.70 i	33.80 c
4 % biochar extract	7.00 abc	6.50 abc	1.00 d	0.99 d	0.90 c	0.85 ef	31.20 h	33.90 c

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

Table (12): Effect of using different biochar rates in nursery on some vegetative growth characters and total yield of sweet pepper plant grown in the field during 2018 and 2019 seasons

Treatments	Plant length (cm)		Stem diameter (cm)		No. of. branches/plant		No. of. leaves / plant		Leaf area (cm^2)		Total yield ton / fed	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Daily irrigation												
0% biochar (control)	39.00 e	40.00 e	1.00 c	1.00 c	16.50 de	19.00 de	92.00 j	94.00 k	326.23 l	328.55 l	23.52 e	24.01 e
20% biochar	40.30 de	43.00 bc	1.20 ab	1.30 ab	17.30 de	19.00 de	108.50 h	117.20 g	511.31 e	556.87 e	24.18 de	25.25 de
40% biochar	41.40 cd	42.50 bcd	1.22 ab	1.30 ab	19.80 b	20.90 cd	111.80 fg	114.00 hi	434.60 f	485.10 f	25.21 cd	24.23 e
60% biochar	40.00 de	42.00 cd	1.20 ab	1.30 ab	19.30 bc	20.70 bc	110.50 g	113.00 i	405.16 i	424.14 i	24.24 de	23.71 e
2 % biochar extract	42.50 c	44.00 b	1.30 a	1.40 a	22.00 a	25.50 a	158.00 d	170.00 d	525.26 d	602.91 c	27.57 ab	26.91 bc
4 % biochar extract	42.50 c	44.00 b	1.30 a	1.40 a	22.40 a	23.00 b	169.00 b	181.0 b	542.05 c	626.91 b	27.70 ab	28.09 ab
Irrigation every two days												
0% biochar	40.00 de	41.10 de	1.10 bc	1.20 ab	17.00 de	19.00 de	102.00 i	107.00 j	339.31 k	360.30 k	23.18 e	23.96 e
20% biochar	41.50 cd	43.00bc	1.20 ab	1.30 ab	17.50 de	19.00 de	110.70 g	115.30 h	425.09 g	480.44 g	24.53 de	25.05 de
40% biochar	40.00 ed	42.00 cd	1.20ab	1.20 b	16.00 e	18.00 e	123.50 e	135.50 e	409.35 h	434.60 h	23.73 de	25.98cd
60% biochar	42.50 c	43.00 bc	1.10 bc	1.20 b	18.00 cd	19.00 de	112.80 f	131.30 f	395.72 j	414.95 j	23.71 de	24.15 e
2 % biochar extract	45.30 b	48.50 a	1.15 abc	1.30 ab	19.50 bc	21.00 c	160.50 c	172.50 c	557.87 b	588.14 d	26.13 bc	26.30 cd
4 % biochar extract	48.00 a	49.00 a	1.30 a	1.30 ab	23.00 a	24.00 ab	184.50 a	188.00 a	574.59 a	629.25 a	27.76 a	28.56 a

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level

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تأثير استخدام الفحم النباتى والمستخلص المائى له على انتاج شتلات بعض محاصيل الخضر وانعكاس ذلك على المحصول.

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أقسام بحوث الخضر – معهد بحوث البساتين–مركز البحوث الزراعية– الجيزة–مصر" "

أجريت هذه الدراسة خلال موسمى الزراعة 2018 و 2019 بمحطة بحوث التجارب بقها– محافظة القليوبية بهدف دراسة تأثير إستخدام معدلات مختلفة من الفحم النباتى على إنبات البذور و نمو الشتلات لبعض محاصيل الخضر (الطماطم والفلفل الحلو والخيار والخس). وسلوك نمو الشتلات المروية كل يوم أو كل يومين ودراسة تأثير ذلك على النمو الخضرى والمحصول الكلى لنبات الفلفل الحلو. وقد كان الفحم المستخدم ناتج من خشب اشجار الجازورريناوأوضحت النتائج أن إستخدام المعدل المنخفض من الفحم النباتى 20 % أدى الى إرتفاع نسبة الإنبات وكفاءة الإنبات وقلل عدد الأيام اللازمه للإنبات (معدل الإنبات) لجميع المحاصيل السابقة، فيما يتعلق بشتلات الطماطم والخيار والخس أوضحت النتائج أن إضافة

المعدل المنخفض من الفحم النباتى (20٪) إلى بيئة النمو والرى كل يوم أوكل يومين أثر تأثير إيجابى على جميع خصائص النمو الخضرى ونمو الجذور للشتلة يليها معاملة الرش الورقى بالمستخلص المائى للفحم النباتى بتركيز 2٪ والرى كل يوم أو يومين. بينما كانت أفضل المعاملات هى الرش الورقى بالمستخلص المائى للفحم النباتى بنسبة 4٪ و 2٪ تليها إضافة الفحم الى بيئة النمو بمعدل40٪ و 20٪ على التوالى بالنسبة لشتلة الفلفل الحلو. بشكل عام ، أثر إستخدام المعدلات المختلفة للفحم النباتى تحت فترتين من الرى فى إحداث تأثير معنوى على قياسات النمو الخضرى ، و النمو الجذرى وتركيز الكلوروفيل بالأوراق لجميع شتلات المحاصيل السابقة النامية بالمشتل. كما يمكن ملاحظة أنه من الممكن إضافة جميع معدلات الفحم النباتى إلى وسط النمو ب

إستثناء المعدل المرتفع (60٪) الذي أثر سلبيًا بشكل كبير على جميع خصائص النمو الخضري ونمو الجذر.

وقد أظهرت البيانات أيضًا أنه ، بشكل عام ، زادت جميع قياسات النمو الخضرى والمحصول لنبات الفلفل الحلو زيادة معنوية باستخدام جميع معدلات الفحم النباتى المختلفة خاصة النباتات التى تم الحصول عليها من الشتلات التى تم رشها بواسطة المستخلص المائي للفحم النباتى بتركيز 2 ٪ أو 4 ٪ فى كلا موسمى الزراعة.

بشكل عام ، توضح هذه النتائج أنه بالنسبة لنباتات المشتل ، قد يكون اضافة الفحم النباتى بمعدل 40% او 20% لبيئة المشتل له تأثير ايجابى على نمو الشتلات وبالتالى تحسين انتاجية النباتات الناتجة كما يقلل من الإعتماد على مكونات بيئات النموغير المتجددة أو مرتفعة التكاليف.