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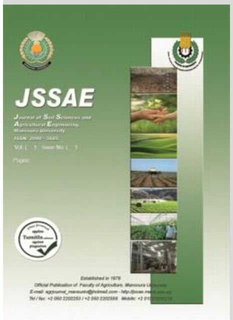
Effect of Applying Biochar on some Soil Chemical Properties, Pathogenic Fungi and Tomato Productivity in North Sinai

Sally A. Ismail [1]; Taghreed A.M.A. Badawi [2], A. A. ElSharawy [3]*

[1] Soil and Water Department., Faculty of Environmental Agricultural Science, Arish University, AlArish 45516,Egypt
[2] Plant Production Department., Faculty of Environmental Agricultural Science, Arish University, AlArish 45516,Egypt
[3] Plant Pathology Lab., Plant Production Department., Faculty of Environmental Agricultural Science, Arish University, AlArish 45516,Egypt



ABSTRACT

This study examined the effects of biochar on sandy loam soil at a private farm in EL-Sakska, North Sinai Governorate, Egypt, throughout two some chemical properties sequential summer seasons in 2020 and 2021 with three treatments. Results in both seasons indicated that, the highest values of soil properties (pH, EC, CEC) were recorded with biochar and control, respectively in both seasons. The lowest values (EC, CEC) were obtained with (Biochar + Recommended fertilization). While the highest value of the fresh and dry weight of tomato and NPK in leaves and fruits, fruit quality (TSS and vitamin C), and plant total marketable tomato fruit yield per fed, were recorded with the application of (Biochar + Recommended fertilization) in both seasons and the lowest value was obtained with control.Furthermore, biochar treatment and Biochar with recommended fertilization, were significantly effective in reducing incidences of root rot and wilt, with plant survival rates of 89.57% and 81.54 %, respectively. These findings provide an intriguing starting point for using complicated biochar formulations into plant systemic disease management techniques. Our findings show that biochar amendment causes tomato seedlings to successfully resist infection with certain important pathogenic fungi such as *Fusarium oxysporum* and *Rhizoctonia solani*. Thus, results obtained in this study may indicate that biochar could be safely used as an environmental-friendly method for disease control and crop yield enhancement.

keywords: Biochar, tomato, fertilization, and pathogenic fungi.

INTRODUCTION

Food insecurity is a result of inadequate fertilizer use and steadily deteriorating soil conditions, which continuously reduce agricultural productivity. The burden on agricultural systems was intensified by issues including global climate change, rising human population, and urbanization. To address the wide variety of issues influencing agricultural output, such as disconnects in nutrient supply, demand, recycling, and water consumption, agro-ecosystem planning and performance need to be revisited. Reusing organic nutrients in the soil can help maintain soil organic matter, which usually results in an improvement in the physical and chemical qualities of the soil. The organic matter will come from a variety of sources, such as crop residues, animal waste, human waste, and industrial waste. However, the choice of organic material to employ is crucial since certain sources, depending on the grade of organic material or the presence of contaminants, may have a negative impact on soils. One possible additive to improve soil qualities is biochar. Due to its well-established advantages, such as improving soil fertility and immobilising and modifying heavy metals and pollutants in agricultural soils, it is employed as a soil amendment. Biochar is typically referred to as "biomass-derived black carbon" or "charcoal," and it has the potential to operate as a long-term carbon sink (Singh *et al*., 2022a). The tomato is a significant economic crop that is consumed widely all over the world. The usage of organic fertilizer, sunlight, air, soil, and water conditions, as well as tomato growth, are the key limiting factors. One of the crucial soil supplements is biochar, which is also acknowledged as a potential technique for raising crop yields in agriculture. The impact of biochar on the characteristics of photosynthetic organisms and tomato yield under reduced nitrogen fertilizer application is still not well understood (Guo *et al*., 2021). Sinai soil is in general characterized as sandy soil, which is very poor soil in mineral nutrients, has low moisture holding capacity, has single grain structure, susceptibility to erosion in addition low quantities of organic matter content and microorganisms (El-Kassas *et al*., 2019). Concerns regarding the sustainability of agriculture are raised by the low fertility of highly worn soils, which has prompted the development of management strategies to improve or restore fertility. As a result, using biochar as a sustainable method of restoring deteriorated soils has garnered growing interest.(Tsai and Chang, 2020). Pyrolysis, the thermo-chemical breakdown of biomass under anaerobic or oxygen-limited conditions, results in the production of biochar. Because of its extent and porosity, bulk density, nutrient content, stability, cation exchange capacity (CEC), pH value, and carbon content, biochar is expected to improve water retention, nutrient retention, and plant uptake of nutrients. Biochar's physical, chemical, and nutritional properties depend on the chemical composition of the feedstock used, the pyrolysis system, and production conditions. A result of biomass pyrolysis that is C-rich and intended for use as a soil amendment is biochar. It has been discovered that adding biochar to soil increases its ability to store water and increase its availability of nutrients. (Mostafa

*** Corresponding author.**
E-mail address: Ahmed_Plantpathology@hotmail.com
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and Shaban, 2019). In order to increase the long-term ability of soils to retain and recycle nutrients and to reduce nutrient loss in agriculture, biochar application may offer a substitute management alternative. By lowering soil acidity, raising soil CEC and nutrient retention, and enhancing plant nutrient availability, the biochar addition has a significant potential to improve agricultural productivity and soil fertility. However, the improvement relies on the type of biochar, the rate of application, and the soil type. (Tsai and Chang, 2020). Due to recognised sensitivities of crops, for instance to changing pH or salt levels, some biochars may improve crop output while others may decrease crop productivity. The type of biomass or feedstock, the state of the pyrolysis, the application rate, and the conditions all play a role in the effects of applying biochar on the physical qualities of the soil. One of the most significant vegetable crops is the tomato. It is frequently grown in salty environments because of its modest salinity tolerance. High salt concentrations, however, severely hampered tomato crop development at all stages of growth and greatly decreased crop production. Global data on the impact of applying biochar on several soil physical, chemical, and microbiological properties as well as crop yield were statistically examined, according to (Singh *et al*., 2022a), 59 papers from the literature published between 2012 and 2021 were chosen for the meta-analysis based on supported selection criteria. There have been identified correlations between the use of biochar and several soil parameters, as well as crop productivity. With larger impacts in coarse and fine-textured soils, biochar application raised soil pH, cation exchange capacity (CEC), and organic carbon (OC) by 46%, 20%, and 27% (Singh *et al*., 2022a), respectively. The effects on the chemical characteristics of biochar produced from various feed supplies varied. Application of biochar changed the physical characteristics, reducing bulk densities by 29% and increasing porosity by 59% (Singh *et al*., 2022a). Applications of biochar boosted crop productivity. Biochar application has been proven in recent research to effectively prevent soilborne plant diseases caused by pathogenic fungi such as *Fusarium oxysporum*, *Rhizoctonia solani, and Ralstonia solanacearum* (Jaiswal *et al*., 2014; Jaiswal *et al*., 2015; Elmer, 2016; Liu *et al*., 2019; Huang *et al*., 2020).

Furthermore, published data indicates that biochar has the ability to improve plant resistance to a variety of airborne and soil-borne diseases, with evidence that disease severity is biochar dose-dependent (Graber *et al*., 2014; Jaiswal *et al*., 2015). In terms of soil-borne pathogens, biochar amendment has been shown to reduce disease incidence and severity in 22 pathosystems (Bonanomi *et al*., 2015). When compared to other controls, biochar soil treatment improved the plant root fresh weight of asparagus plants and significantly reduced the proportion of root lesions produced by *F. oxysporum f. sp. asparagi and F. proliferatum* (Elmer and Pignatello, 2011) . (Zwart and Kim, 2012) also discovered that adding biochar to red oak and red maple reduced the severity of stem canker induced by *Phytophthora sp* .

Biochar has been shown to improve plant growth by increasing the plant's response to biotic stressors. Its usage against airborne bacterial and soil borne fungal diseases has already demonstrated beneficial benefits due to interactions with soil microorganisms and plants rather than the direct production of fungi toxic chemicals (Bonanomi *et al*., 2015). Regarding the direct impacts on plants, it has been proposed that biochar can generate both systemic acquired resistance and initiating systemic resistance (Meller Harel *et al*., 2012; Luigi *et al*., 2022), even if the processes are not fully understood and the results reported thus far appear to be dosage dependent.

Biochar, on the other hand, has more compelling empirical evidence that it can enhance the formation and activity of plant growth promoting microorganisms (PGPMs) such as rhizobacteria, mycorrhizal fungi, and other endophytic fungi. These microorganisms successfully use the porous structure of biochar to seek sanctuary from predators such as mites, collembola, protozoa, and nematodes, while the organic carbon generated from biochar adds to their saprophytic growth (Bonanomi *et al*., 2018). The PGPMs, in turn, play an important role in pathogen protection through competition for nutrients and space, direct parasitism, and antagonism via secondary metabolite synthesis (Bonanomi *et al*., 2018; Luigi *et al*., 2022). *Trichoderma* spp., for example, are known to be excellent competitors for space and nutrients, as well as to swiftly penetrate plant roots.

The purpose of this study was to investigate the effect of biochar on some soil qualities while using some soil organic additions (application of biochar and organic addition) on tomato development, yield, and several soil borne diseases under a saline water irrigation system (North Sinai).

MATERIALS AND METHODS

In order to assess the impact of biochar on certain soil chemical parameters, tomato growth, and yield in sandy loam soil, this experiment was conducted in EL-Sakska farm, east of El-Arish city, North Sinai Governorate, Egypt, during the course of two succeeding summer seasons (2020 and 2021). Biochar obtained from the pruning of citrus trees after firing at 400 C^o /6 h Table 3. Treatments were as follow: 1) control (applying recommended fertilization), 2) application of biochar (3.5 ton/fed.) without application of fertilization at 20-30 m^3 /fed of chicken manure before planting, 100-120kg nitrogen, 30kg phosphor, 80-100kg potassium added with irrigation water after planting and 3) application of biochar (3.5 ton/fed.) + application of recommended fertilization. Three replications of a randomized full blocks design were used to randomly distribute the treatments. On March 16th, the "Gs12 F1" hybrid was seeded in plastic seedling trays, and transplanting was done in nurseries. The plants in the same row were 50 cm apart, while the distance between dripper lines centers was 1.2 m. The plot area was 14.4 m^2 (12 m length and 1.2 m width), planting density was 1.67plant/m^2. Tables 1 and 2 display chemical analyses of irrigation water as well as preliminary physical and chemical assessments of experimental soil. In order to determine some soil chemical characteristics (Cations, anions, pH, EC and CEC), soil samples were taken from all analysed treatments at a depth of 0 to 30 cm during growth period stages (at A. Vegetative growth stage (30 days), B. Flowering stage (60 days), and C. Maturity stage 90 days after transplantation). According to the procedure outlined by Allison *et al*., (1954), soil physical and chemical examination was completed. Biochar was mixed thoroughly with soil during soil preparation. The fertilization program and the traditional agricultural practices were carried out as commonly followed in El-Arish region according the recommendations of the Ministry of Agriculture and Soil

Reclamation. Data recorded were fresh and dry weight traits (root, stem and leaves), and NPK content of tomato leaves. Roots were taken out of the soil by collecting root system with the surrounding soil, washed with tap water, then air dried, fruit yield and its component as well as fruit quality (Vitamin C,TSS), and NPK content were determined.

Isolation and frequency of pathogenic fungi:

Infected portions, namely the root of diseased tomato plants (symptoms included leaf wilt and root rot on tomato), were collected from Al Arish and Bear Al Abd regions. in clean sterile plastic bags and sent to the Plant pathology lab for further processing. To remove adherent soil particles, the roots of sick plants were rinsed with water and surface-sterilized. The roots were cut into small pieces (1 cm), surface sterilized by dipping in 0.5% sodium hypochlorite solution for 2 minutes and then thoroughly washing with sterile distilled water multiple times. Root parts were dried between sterile filter sheets. The surface sterilized pieces were transferred to petri dishes containing Acidified Potato Dextrose Agar (APDA) media and cultured in the dark at 25°C for 7-10 days before being observed for fungal growth (Nelson *et al*., 1983; Agrios, 2005). The hyphal tips were then transplanted to another Petri dish with PDA medium and obtained isolates were identified based on cultural, morphological, and microscopical criteria given by Summerell (Leslie and Summerell, 2006) for *Fusarium* and Sneh *et al*(Sneh *et al*., 1991) for *Rhizoctonia*, respectively. Based on colony features and microscopic studies of hyphal and spore morphology (Jensen *et al*., 1991). The frequency pathogenic fungi was calculated.

The Pathogenicity tests:

These experiments were carried out under greenhouse settings at the Fac. of Environ. Agric. Sci., El-Arish. This experiment was conducted out to evaluate the pathogenicity of the isolated pathogenic fungi on susceptible cultivars in order to select highly pathogenic isolates, as well as to explore the effects of different biochar treatments on disease occurrence. In this investigation, Pots (25 cm in diameter) were disinfected by immersing them in a 5% formalin solution for 5 minutes and then drying them in the open air.

Soil sterilisation was performed by thoroughly mixing a 5% formalin solution into the soil. The treated soil was then covered with a plastic sheet for one week before the plastic sheet was removed to allow complete formalin evaporation (El-Sayed, 2011). The soil was infested with each particular fungus pathogen at a rate of 3% of soil weight (Metwally, 2004). Control treatment was amended with the same amount of sterilized sorghum grain.

Individual isolates of fungi were allowed to grow for 15 days in sterilized bottles containing sterilised sorghum grain at 25°C. Disinfested loamy sandy soil (clay:sand, 1:3 w/w) was placed in sterilised pots (25 cm diameter). At a rate of 3% (w/w), the soil mixture was combined with the inoculum of each fungal isolate. Tomato seeds (*Solanum. lycopersicum* cv. Super strain B) were surface-sterilized for 1 minute with a 1.5% NaOCl solution and washed three times with sterile water before planting into the pots at the rate of four seeds per pot, five pots were used for each treatment. This experiment was repeated twice.

Disease assessment:

The percentages of pre- and post-emergence plants, as well as healthy surviving plants, in each treatment were determined 15 and 30 days after sowing, respectively, using the El Helaly formula (El-Helaly *et al*., 1970). Disease evaluation and a visual examination was used to confirm tomato infection. For a total of five weeks following inoculation, disease incidence and severity were documented weekly. According to (Abdel-Razik *et al*., 2012) the percentage of disease incidence and the disease severity index (DSI) was calculated.To apply Koch's postulates, the final colony features were examined to ensure that the isolated fungus was identical to what had been utilized for the pathogenicity test.

Table 1. Some of the irrigation water's chemical properties

pH	EC dSm^{-1}	ions in solution (mel^{-1}) Cations: Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Anions: Cl^{-}	HCO_3^{-}	$CO_3^{=}$	$SO_4^{=}$
First season(2020)									
7.63	6. 50	23.05	20.57	20.71	0.67	50.94	5.86	-	8. 20
Second season (2021)									
7.79	6.75	24.05	20.89	21.81	0.75	52.17	6.39	-	8. 94

Table 2. Initial physical and chemical characteristics of the agricultural area's soil profile under investigation

	initial season (2020)	season two (2021)
Size distribution of the particles (%)		
Coarse sand (%)	59.5	59.6
Fine sand (%)	18.2	18.1
Silt (%)	11.1	12.2
Clay (%)	10.2	10.1
Soil texture	Sandy loam	Sandy loam
Bulk density (Mgm^{-1})	1660	1662
properties of chemicals (Ions that are soluble in a 1:5 soil water extract)		
Ca^{++} (mel^{-1})	3.40	3.42
Mg^{++}(me l^{-1})	2.54	2.57
Na^{+}(me l^{-1})	3.87	3.91
K^{+} (me l^{-1})	0.31	0.30
$CO_3^{=}$ (me l^{-1})	-	-
HCO_3^{-} (me l^{-1})	4.29	4.40
Cl^{-} (me l^{-1})	4.41	4.35
$SO_4^{=}$ (me l^{-1})	1.49	1.45
EC (dSm^{-1})	1.01	1.02
pH (in1:2.5 Soil water suspension extract)	8.12	8.10
Organic matter (%)	0.150	0.175
$CaCO_3$ (%)	22.32	22.40

Table 3. Chemical properties of Biochar using

pH (1:2.5)	EC (dSm^{-1}) (1:10)	O.M	N	P	K	Na	C
8.85	2.85	35.32	1.65	0.39	5.41	6.52	68.46

Statistic evaluation

The obtained data were statistically analysed using statistical analysis of variance (Snedecor and Cochran, 1980). To compare means, Duncan's multiple range tests were utilised (Duncan, 1958).

RESULTS AND DISCUSSION

1. Impact of biochar on the chemical composition of soil

Biochar's impact on soil pH

The influence of biochar on soil pH is demonstrated by the data in Table 4. After transplanting, the pH values of the soil declined over time. The highest value was 8.8 with biochar only but the lowest one was 7.5 with biochar + recommended fertilization in the first season. In the second season, the highest value was 8.8 with biochar only, wherease the lowest one was

7.1 with biochar + recommended fertilization in the second seasons. The soil pH reduction was 4.9, 10.22 and 10.70% with control, biochar and (biochar + recommended fertilization), respectively from 30 to 90 days after transplanting in the first season, but the soil pH reduction was 8.75, 14.77 and 11.25% with control, biochar and (biochar + recommended fertilization), respectively from 30 to 90 days after transplanting in the second season. El-Naggar *et al*., 2019 found that because biochar is alkaline, it has a minor influence on the pH of alkaline soil while having a significant impact on increasing the pH of acidic soil, which has been shown in other studies. Generally, the pH increased in the soil amended with biochar (Mostafa and shaban, 2019; Tsai and Chang, 2020; Singh *et al*., 2022a). These results agree with (Agbna *et al*., 2017,Tsai and Chang, 2020 and Dvořáčková *et al*., 2022). According to (Mostafa and Shaban, 2019), the addition of biochar may result in a rise in soil pH due to the mineral ashes included in the biochar, which have a favourable impact on soil microbial activity, and the surface's negative charge, which buffers soil acidity. One potential explanation for this rise in soil pH, according to (Singh *et al*., 2022b), is the reduction of exchangeable aluminum (Al) brought on by biochar. When applied to soil, biochar has the potential to reduce the amount of Al present by (I) adsorbing exchangeable Al onto negatively charged biochar particles, (ii) chelating soluble organic molecules from biochar to reduce the amount of Al in soil solution, and (iii) other means. Another explanation for the rise in soil pH following the application of biochar is that the cations (Ca2+, Mg2+, and K+) in biochars might be changed during pyrolysis into alkaline substances (such as oxides, hydroxides, and carbonates), and that the dissolution of these substances causes biochar to act as a liming substance. However, the type of feedstock and the temperature of the pyrolysis play crucial roles in deciding the outcome.

Biochar's impact on the electrical conductivity of soil (EC)

Table 4's findings demonstrate how biochar affects soil EC (dSm-1). After transplantation, the soil's EC values gradually increased. The highest value was 1.44 with control but the lowest one was 0.60 with biochar + recommended fertilization after 90 and 30days from transplanting, respectively, in the first seasons but the highest value was 1.51 with control and the lowest one was 0.75 with biochar + recommended fertilization after 90 and 30 days from transplanting, respectively, in the second seasons. The soil EC increased with time in all treatments: control, biochar and (biochar + recommended fertilization) from 30 to 90 days after transplanting in the first and second seasons. These findings concur with those of (Agbna *et al*., 2017, and Dvoáková *et al*., 2022), who discovered that adding biochar to soils significantly, changed their chemical properties, such as EC. This result may be due to the processes the EC soil results in slowly decreasing EC while one process salting inputs, followed by a relatively rapid decrease in EC when that process is exhausted and the next takes over. (El-Naggar *et al*., 2019) indicated that generally, the EC increase in the sandy loam soil may lead to high salinity compared with other treatments. Generally, the EC increase in the soil with biochar because of increased C mineralization in soil (Mostafa and shaban, 2019; Tsai and Chang, 2020; Singh *et al*., 2022a). This suggested that a high salinity environment would likely slow the biochar's rate of decomposition, which would slow the release of nutrients. Both the biochar's effects on salinity and the salinity water irrigation's effects on plant productivity would normally be detrimental. However, adding more biochar greatly improved the amount of soil organic matter, which is crucial for water retention and the availability of nutrients for plants, hence reducing the detrimental impacts of salt (Dongli She *et al*., 2018).

Biochar's impact on soil CEC

Table 4's data demonstrate how biochar affects soil CEC (meg 100 g-1). The soil CEC values were increased with time after transplanting. The highest value was 4.8 with biochar + recommended fertilization but the lowest one was 2.73 with control after 90 and 30days from transplanting, respectively, in the first seasons but the highest value was 5.3 with biochar + recommended fertilization but the lowest one was 3.9 with control after 90 and 30 days from transplanting, respectively, in the second seasons. The soil CEC increased with time in all treatments: control, biochar and (biochar + recommended fertilization) from 30 to 90 days after transplanting in the two seasons (statistical analysis is required to compare between treatments). These impacts of biochar, which improved soil's physical and chemical qualities, could be to blame for these outcomes. Additionally, these findings support those of (El-Kassas *et al*., 2019) and (Singh *et al*., 2022b), who claimed that applying biochar greatly boosted the soil's cations exchange capacity (CEC) The oxygen-containing functional groups (carboxyl, carbonyl, and hydroxyl) found in pyrolysis-recommended residues in biochars can improve CEC in soils. In general, biochars application significantly increased the soil cation exchange capacity in the soil.(Mostafa and shaban, 2019) shows that the soil that had been treated with biochar had the highest levels of nutrient availability (N, P, and K). This result may be due to biochar's ability to increase symbiotic N2 fixation, which is highly dependent on a number of mechanisms including immobilizing inorganic nitrogen and enhancing food availability. The aforementioned biochar addition had a favorable effect on the nutrients' availability. Increased nutrient availability and better nutrient bioavailability are possible with the usage of biochar. The addition of biochar to soils has a major impact on all of their chemical properties, including the amount of nutrients present.

Table 4. Effect of biochar **on CEC (meq 100 g^{-1}), pH and EC (dSm^{-1}) of soil after 30, 60 and 90 days from transplanting season 2020 and 2021**

	season 2020			season 2021		
	CEC	**pH**	**EC**	**CEC**	**pH**	**EC**
			At 30 days			
Control	2.73	8.1	1.00	3.9	8.0	1.10
Biochar	2.94	8.8	0.80	4.2	8.8	0.88
R+B	3.01	8.4	0.60	4.3	8.0	0.75
			At 60 days			
Control	4.0	8.0	1.25	4.1	7.9	1.29
Biochar	4.4	8.5	0.98	4.5	8.3	1.01
R+B	4.4	8.1	0.75	4.5	7.9	0.81
			At 90 days			
Control	4.4	7.7	1.44	4.9	7.3	1.51
Biochar	4.7	7.9	1.19	5.2	7.5	1.21
R+B	4.8	7.5	0.99	5.3	7.1	1.05

Biochar's impact on cations and anions

The results of soil cations and anions presented in Table 5 show that, all cations and anions decreased with application of soil additives in all periods of growth in both seasons. The highest cations and anion values were found in the control group, followed by biochar alone. The lowest values were found in the first and second seasons in (biochar + prescribed fertilizer) treatment. With the passing of time from transplantation, the values of cations and anions increased. These results are in agreement with those obtained by (El-Kassas *et al*., 2019) and (Singh *et al*., 2022b) who reported that biochar application significantly increased the soil cations and anions. This is mostly because of their surface buildup at biochar C, along with soil management techniques and microorganism activity, which positively impacted the availability of organic materials (Mostafa and shaban, 2019).

Table 5. Biochar's impact on cations and anions (meq l^{-1})of soil after 30, 60 and 90 days from transplanting season 2020 and 2021

Treatments	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
First season 2020								
At 30 days								
Control	3.11	2.06	4.50	0.33	0.00	4.19	5.21	0.60
Biochar	2.60	2.09	3.00	0.31	0.00	3.40	3.66	0.94
R+B	1.60	1.80	2.30	0.30	0.00	2.14	3.01	0.85
At 60 days								
Control	4.44	3.19	4.42	0.44	0.00	5.32	5.78	1.40
Biochar	3.27	2.91	2.92	0.70	0.00	3.99	3.36	2.45
R+B	2.11	2.21	2.73	0.46	0.00	2.88	2.93	1.69
At 90 days								
Control	4.46	4.68	4.70	0.56	0.00	6.07	5.69	2.65
Biochar	4.78	3.24	2.86	1.02	0.00	4.09	5.16	2.64
R+B	2.95	3.09	3.29	0.57	0.00	3.39	3.91	2.60
Second season 2021								
At 30 days								
Control	4.14	3.61	2.86	0.39	0.00	4.77	4.67	1.60
Biochar	3.27	3.12	2.13	0.29	0.00	3.60	3.40	1.80
R+B	2.83	2.77	1.67	0.23	0.00	3.20	2.80	1.50
At 60 days								
Control	4.62	4.50	3.23	0.54	0.00	5.20	5.00	2.70
Biochar	3.71	3.54	2.44	0.40	0.00	4.20	3.90	2.10
R+B	3.02	2.96	1.81	0.30	0.00	2.79	2.85	1.03
At 90 days								
Control	5.35	5.22	3.78	0.74	0.00	6.90	6.03	2.13
Biochar	4.40	4.20	2.93	0.57	0.00	5.50	4.90	1.70
R+B	3.88	3.81	2.36	0.45	0.00	4.30	3.90	2.30

Effect of biochar on growth and yield of tomato fresh and dry weight (g)

Results in Tables 6 and 7, show significant effects of application of biochar treatments on all studied traits of tomato in both seasons. The highest records of all studied traits were obtained by application of the biochar + recommended organic fertilizer that increased all mean values of weight (fresh and dry) of tomato plants and total weight at 30 and 60 days after transplanting.

Table 6 Effect of biochar on fresh weight (g) of tomato plant season 2020 and 2021

	Roots		Stems		Leaves		Total	
	Days of transplanting season (2020- 2021)							
	30	60	30	60	30	60	30	60
Season (2020)								
Control	24.15 c	30.16 c	21.11 c	33.16 c	104.43 c	187.11 c	151.29 c	252.03 c
Biochar	32.15 b	46.41 b	31.4 b	62.34 b	149.53 b	268.3 b	214.68 b	378.65 b
R + B	45.75 a	72.96 a	37.12 a	77.33 a	160.12 a	326.11 a	244.59 a	478.00 a
Season (2021)								
Control	24.95 c	30.96 c	21.91 c	33.96 c	105.23 c	187.91 c	152.09 c	252.83 c
Biochar	32.95 b	47.21 b	32.2 b	63.14 b	150.33 b	269.1 b	215.48 b	379.45 b
R + B	46.55 a	73.76 a	37.92 a	78.13 a	160.92 a	326.91 a	245.39 a	478.8 a

According to Duncan's multiple range test, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of probability.

Table 7. Effect of biochar on dry weight (g) of tomato plant season 2020 and 2021

	Roots		Stems		Leaves		Total	
	Days of transplanting season (2020-2021)							
	30	60	30	60	30	60	30	60
Season (2020)								
Control	6.98 c	8.68 c	6.07 c	9.68 c	30.97 c	56.13 c	45.22 c	75.69 c
Biochar	8.93 b	13.58 b	9.06 b	18.34 b	44.52 b	80.13 b	63.71 b	113.25 b
R + B	13.29 a	21.62 a	11.16 a	22.89 a	47.68 a	97.47 a	73.33 a	143.18 a
Season (2021)								
Control	7.58 c	9.28 c	6.67 c	10.28 c	31.57 c	56.73 c	45.82 c	76.29 c
Biochar	9.53 b	14.18 b	9.66 b	18.94 b	45.12 b	80.73 b	64.31 b	113.85 b
R + B	13.89 a	22.22 a	11.76 a	23.49 a	48.28 a	98.07 a	73.93 a	143.78 a

According to Duncan's multiple range test, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of probability.

The maximum mean values of total plant fresh weight at 30 and 60 were 244.59 g and 478.00 g respectively, and dry weight of plants were73.33 g and 143.18 g respectively at first season. Maximum mean values of total plant fresh weight at 30 and 60 (245.39 g and 478.8 g), respectively, and dry weight of plants (73.93 g and 143.78 g), respectively at second season. The lowest values were recorded with control treatment in both seasons. These results are in agreement with those reported by (El-Kassas et al., 2019) and (Singh et al., 2022a and Singh et al., 2022b). It could be concluded that all vegetative growth trails were enhanced due to application of biochar. This may be due to the fact that biochar as a soil additive had an important role in enhancing nutrient availability for plants which reflected positive effects on plant growth. Also, our results are in the same direction of results obtained by (El-Kassas et al., 2019) and (Singh et al., 2022b) who indicated that effects of biochar were due to processes that increase the availability of nutrients to plants

Effect of additions on yield and fruit qulity

Data in Table 8 show that, the highest marketable yield was recorded with application of (biochar + recommended fertilizer) in both seasons (20.6 ton and 20.8 ton) respectively and the lowest value was recorded with control. Concerning unmarketable yield, the highest unmarketable yield was recorded with control treatment in both seasons. These results are in agreement with those obtained by El-Kassas *et al*., (2019) and Singh *et al*., (2022b) who reported that biochar application significantly increased crop yield . This study and many previous studies illustrate that organic additions have the power to improve soil properties and plant development. This was typically caused by improving the soil environment by increasing the availability of nutrients and water. It increases the availability to the plant of the nutritional components that favour plant growth and the majority of physiological processes that directly influence yield and its constituent parts. According to Dongli *et al*. (2018), soils treated with biochar showed better vegetative growth they found that biochare enhanced tomato vegetative growth. Also organic additives may increase soil fertility, soil structure, water holding capacity, cation exchange capacity, soil pH and microbial community and activity (Ayeni *et al*., 2010 and Badawi 2012).

Table 8. Effect of biochar on yield (ton/fed) of tomato plant season 2020 and 2021

	Marketable yield				Un-Marketable yield			
	First (2020)		Season (2021)		First (2020)		Season (2021)	
	Number of fruits/m2	Yield/fed. (ton)	Number of fruits/m2	Yield/fed. (ton)	Number of fruits/m2	Yield/fed. (ton)	Number of fruits/m2	Yield/fed. (ton)
Control	58.78 c	14.8 c	58.96 c	14.9 c	14.8 a	1.85 a	12.01 a	1.55 a
Biochar	60.62 b	16.4 b	61.06 b	16.5 b	11.55 b	1.42 b	10.18 b	1.12 b
R + B	63.65 a	20.6 a	63.91 a	20.8 a	10.21 c	1.19 c	8.07 c	0.89 c

According to Duncan's multiple range test, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of probability.

fruit quality

Data in Table 9 show that, the highest values TSS and vitamin C were recorded with application of (biochar + recommended fertilizer) at 5.48 and 6.85 for TSS respectively in first and second season, while results were 17.49 and 21.86 for vitamin C respectively in first and second season and the lowest value was recorded with control in both seasons. These results are in agreement with the findings of El-Kassas *et al*., (2019) who reported that the effects of biochar was due to the soil pH, nutrient retention (owing to an increase in cation exchange capacity and surface area), or direct release of nutrients from the surfaces of the biochar are that all led to boosting plant nutrient availability. This was reflected on good photothyinthetic process that enhanced flowering and fruiting, then reflects on the quality of the fruits (Badawi 2020).

Table 9. Effect of biochar on tomato fruit quality, TSS (%) and Vitamin C (mg/100 g) season 2020 and 2021

	season (2020)		season (2021)	
	TSS	Vitamin C	TSS	Vitamin C
Control	4.73 b	13.94 c	5.91 b	17.43 c
Biochar	4.80 b	15.60 b	6.00 b	19.50 b
R + B	5.48 a	17.49 a	6.85 a	21.86 a

According to Duncan's multiple range test, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of probability.

Leaves and Fruit content of NPK

Data in Table 10 show that, the applied treatments had significant effect on all traits under study the highest values NPK in leaves and fruit were recorded with application of (biochar + recommended fertilizer) followed by biochar , and the lowest value was recorded with control in both seasons respectively. These results are in agreement with those obtained by El-Kassas *et al*., (2019) and Singh *et al*., (2022b).

Table 10. Effect of additions on tomato Leaves and fruit content of NPK (%) season 2020 and 2021

	Leaves			fruits		
	N	P	K	N	P	K
	season (2020)					
Control	4.07 b	0.59 a	2.60 a	3.30 b	0.58 a	3.05a
Biochar	4.23 b	0.68 a	2.64 a	3.37 b	0.63 a	3.16 a
R + B	4.70 a	0.73 a	2.65 a	3.69 a	0.65 a	3.14 a
	season (2021)					
Control	4.28 b	0.63 a	2.77 a	3.44 b	0.62 a	3.21 a
Biochar	4.45 b	0.72 a	2.78 a	3.55 b	0.66 a	3.33 a
R + B	4.95 a	0.77 a	2.79 a	3.88 a	0.68 a	3.31 a

According to Duncan's multiple range test, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of probability.

Isolation and identification soil borne fungi

Fungi were isolated from diseased tomato roots that showed wilt, drying, and yellow leaves. According to the results shown in (Table 11), the pathogens isolated represented seven species, namely *Rhizoctonia solani*, *Fusarium oxysporum* , *Fusarium moniliform* , *Alternaria solani* , *Fusarium semitictum* , *Macrophomina phasolena* and *Pythium sp*.

Table 11. Isolated and frequency fungi from rooted and wilted tomato plants

Number of samples	Associated fungi	Number of isolates	% Frequency
105	Alternaria solani	10	8.13
	Macrophomina phasolena	8	6.50
	Fusarium oxysporum	31	25.20
	Fusarium monilliform	12	9.76
	Fusarium semitictum	9	7.32
	Pythium sp	7	5.69
	Rhizoctonia solani	42	34.15
	Unknown fungi	4	3.25
	Total	123	100

These species were identified using morphological, cultural, and microscopical criteria provided by (Barnett and Hunter, 1972; Booth, 1977; Gerlach *et al*., 1982; Nelson *et al*., 1983). Table (11) show the frequency of fungi associated with damaged tomato roots during these experiments.

Rhizoctonia solani was the most commonly isolated fungus (34.15%), followed by *Fusarium oxysporum* (25.20%), *Fusarium moniliform* (9.76%), *Alternaria solani* (8.13%), *Fusarium semitictum* (7.32%), *Macrophomina phasolena* (6.50 %) and *Pythium sp* (5.69 %).

Rhizoctonia solani was detected in the highest frequencies (34.15%) *Fusarium oxysporum* (25.20%) Abo-Shady *et al*., (2007) isolated seven pathogenic fungi as well, while the *Pythium sp* showed the least number . These data are in agreement with Al-Askar *et al*., (2014).

Effect of treatments on disease incidence..

Five weeks after inoculation, the effects of biochar treatments on disease incidences of both *Rhizoctonia solani* anf *Fusarium oxysporum* were assessed. As presented in Table 12, biochar treatments resulted in reduction of both pre and post emergence damping off as compared with the untreated control in case of *R. solani* infestation. This has led to increase in the percentage survival of plants to 62 .8% in case of biochar treatment and 89.57% in the biochar with recommended mineral fertilization. In the control treatment, the percentage of survival plants was only 27.6%.

Similar results were obtained in case of *F. oxysporum* infestation. The biochar raised the percentage of survival plants to 51.7%, whereas the percentage of survival plants reached 81.5% in case of biochar and mineral fertilization treatment. The percentage of survival plants in this case was 32.86% for the untreated control.

Biochar soil application delayed the establishment of *F. oxysporum* and *R. solani*, reducing disease incidence by up to 80.68% and 71.07, respectively. Furthermore, the severity of fusarium wilt and root rot decreased with disease resistance (Graber *et al*., 2014).

Table 12. Effect of different treatments on disease incidence under artificial infection conditions.

Treatments	**Rhizoctonia solani (Root Rot %)**			
	Pre emergence [a]%	**Post emergence [b] %**	**Survival plants**	**Dead plants [c]%**
Control	[d]51.76	20.63	27.61	24.62
Biochar	22.45	14.70	62.85	16.18
R+B	7.62	2.81	89.57	5.45
Mean	27.28	12.71	60.01	15.42
LSD	3.19	3.85		4.04
	Fusarium oxysporum (Wilted Plant %)			
Treatments	Pre emergence %	Post emergence %	Survival plants	Dead plants
Control	46.15	22.99	33.86	26.64
Biochar	30.63	17.63	51.74	21.61
R+B	11.95	6.51	81.54	9.98
Mean	29.58	15.71	55.71	19.41
LSD	2.25	1.50		2.27

[a, b, c] Assessed 15, 30, 90 days after sawing, respectively; [c] Dead plants, % due to infection by root rot and/or stem rot; d Values are means of 3 replicates

Biochar incorporation into soil has been shown to improve plant growth, sequester carbon, and improve soil fertility, as well as protect plants from various soil-borne pathogens (Zimmerman, 2010; Lehmann and Joseph, 2015). They also reported that biochar soil application delayed the development of *F. oxysporum* and *R. solani*, significantly reducing disease incidences by up to 85% and 80%, respectively. Incorporating biochar into soil has been demonstrated to boost plant development, sequester carbon, and improve soil fertility, as well as protect plants from numerous soil-borne diseases. Biochar soil amendment not only improves plant development but also inhibits the growth of various soil-borne fungal infections (Graber *et al*., 2014; Jaiswal *et al*., 2015).

CONCLUSIONS

Biochar has long been known as a possible amendment to enhance soil characteristics and enhance agricultural production. In general, there are many effects for biochar applications on different soil physical and chemical properties as well as crop productivity. Biochar increased crop productivity in poor soils. The findings of this study support biochar's beneficial role in increasing plant disease resistance against soil-borne pathogens, and it is a step forward in its use as part of integrated disease management program for sustainable crop production. More research is needed to identify more biochar-enriched media microorganisms that contribute to disease suppression and to understand the role of each of these microorganisms in controlling soilborne diseases.

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تأثير اضافة البيوتشار على الخصائص الكيميائية للتربة، فطريات التربة وانتاجية الطماطم في شمال سيناء

سالي أحمد إسماعيل[1] ، تغريد على محمود احمد بدوى[2] و أحمد عبدالعليم الشعراوي[3]

[1] قسم الأراضي والمياه، كلية العلوم الزراعية البيئية، جامعة العريش، مصر.

[2] قسم الانتاج النباتى، كلية العلوم الزراعية البيئية، جامعة العريش، مصر.

[3] معمل امراض النبات، قسم الانتاج النباتى، كلية العلوم الزراعية البيئية، جامعة العريش، مصر.

الملخص

أجريت هذه التجربة في تربة طمية رملية بمنطقة السكاسكة بمحافظة شمال سيناء بمصر خلال موسمين صيفيين متتاليين 2020/2019 و 2021/202020 لدراسة تأثير البيوتشار المنتج من تقليم أشجار الحمضيات تحت ظروف التربة المالحة. كانت المعالجات على النحو التالي (التسميد الموصي به، التسميد الموصي به + فحم حيوي (بمعدل 3.5 طن / فدان) وفحم حيوي فقط). النتائج التي تم الحصول عليها في كلا الموسمين كانت اعلاها (البيوتشار + التسميد الموصي به) والأدنى كان الكونترول. كما تم تسجيل تأثيرات معنوية للمواد المضافة لمعظم صفات جودة الثمار المدروسة في كلا الموسمين. علاوة على ذلك ، كانت المعالجة بالفحم الحيوي والفحم الحيوي مع التسميد الموصى به فعالين بشكل كبير في حالات تعفن الجذور والذبول ، حيث بلغت معدلات بقاء النبات 96.37٪ و 90.52٪ على التوالي ، كما قللت من كثافة الفطريات المسببة للأمراض مقارنةً بالضوابط ذات الصلة الكنترول ، مما منح نسبة أعلى. مقاومة وبقاء نباتات الطماطم في ظل ظروف مقيدة ، ربما بسبب تأثير الفحم الحيوي التكاثري قصير المدى على فطريات المكافحة الحيوية. توفر هذه النتائج نقطة انطلاق مثيرة للاهتمام لاستخدام تركيبات الفحم الحيوي في تقنيات إدارة الأمراض النظامية النباتية. تظهر النتائج التي توصلنا إليها أن الفحم الحيوى يجعل الطماطم تقاوم بنجاح العدوى ببعض الفطريات المسببة للأمراض المهمة مثل *Fusarium oxysporum* و *Rhizoctonia solani*. وهكذا ، تم الإشارة إلى أنه يمكن استخدام البيوتشار بأمان للزراعة مع بعض الإضافة لتحسين بعض الخصائص مثل الحموضة و العناصر الغذائية لإعطاء نتائج أفضل.

الكلمات الدالة : البيوتشار - الطماطم - الاضافات العضوية ، فطريات التربة .