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ORIGINAL PAPER

Influence of Biochar on Growth of Eggplant and Pepper Plants and Incidence of Root Rot

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ABSTRACT

Eggplant (*Solanum melongena* L.) and pepper (*Capsicum annuum* L.) cultivars were evaluated for their reaction to *Rhizoctonia solani* and *Fusarium solani*, and their mixture to evaluate their tolerance to root rot and crown rot. The reaction of eggplant response to inoculation with the mixture of fungi was variable, six cultivars were highly susceptible, 18 intermediate and one was susceptible. Pepper cultivars under the same conditions were 18 highly susceptible, seven intermediate and two susceptible. The application of different concentrations (0.5, 1.0 and 2.0 g.) of non activated or activated biochar and inoculation with the tested pathogen of the pepper and eggplant reacted differently on disease expression on the two pepper cultivars (Gedeon X, Titanic), and on the two eggplant cultivars (F2N-29, Balady). The lower concentrations of biochar (0.5 and 1.0 g.) suppressed disease expression while at a higher dose (2.0g.), of non-activated and activated biochar showed acute disease expression on susceptible cultivars. Also, growth of cultivars planted in the biochar-treated soil was significantly promoted compared to the un-amended controls. While greater dose (2.0 g.) decreased growth habits of both pepper and eggplant cultivars. Meanwhile, amendment of different concentrations (0.5, 1.0 and 2.0 g.) of biochar treatments alone with pepper cv. Titanic and eggplant cv. Balady showed remarkable phytotoxic effects at four weeks growth stage than on Gedeon X pepper cultivar and F2N-29 eggplant cv. Counts of fungi and bacteria showed inconsistent differences between different treated soils at different seasons and various periods, 37,44,51 and 60 days.

Keyword: Biochar, soil amendment, soil-borne fungi, solanaceous, eggplant, pepper plants and control.

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INTRODUCTION

Solanaceous plants, especially pepper (*Capsicum annuum* L.) and eggplant (*Solanum melongena* L.), tomatoes (*Solanum lycopersicum* L.) are the most widely cultivated vegetables in the world. Pepper and Eggplant are considered the most important summer vegetable crops in Egypt and are cultivated under widely different environmental conditions. The area of production increased from year to year, the total area devoted for production was 38901 and 52013 fed., which produced about 381379 and 651374 tons, with an average yield of 9.804 and 12.523 ton/fed, in 2018 for pepper and eggplant, respectively (Ministry of Agriculture and Land Reclamation, Economic affairs Sector, Bulletin of The Agricultural Statistics, 2018, Egypt.).

Vegetable crops are highly susceptible to a number of root diseases caused by soil-borne fungi causing great losses in crop yield and quality (Chehri *et al.*, 2010). Eggplant is one of the most common and extensively grown variety and at the same time is subject to wilt complex caused by fungi belonging to several genera such as *Fusarium*, *Verticillium*, *Rhizoctonia*, *Sclerotium* and *Phytophthora* (Najar *et al.*, 2011).

Nonchemical methods as well as addition of organic amendments are considered as an effective method for controlling soil-borne diseases in different field crops (Zhou and Everts, 2004). Soil amended with biochar may have the potential to sequester carbon for thousands of years (Zimmerman, 2010).

Application of biochar improves crop productivity by modifying the soil structure, water holding capacity, pH, cation exchange power and increasing nutrient retention and their availability. Moreover, it stimulates the plant defense system through biochar-borne elicitor chemicals (Elad *et al*., 2010).

Adding biochar to the soil induces systemic resistance on pepper to grey mold (*Botrytis cinerea*), and on tomato against powdery mildew (*Leveillula taurica*) Elad *et al*., (2010). The mechanisms involved in the beneficial

effects conferred to plants that include impaired cell wall degrading enzymes and competition for nutrients Egamberdieva *et al*. (2011). Biochar is fine-grained charcoal rich in organic carbon, produced by heating biomass in a low oxygen and has been used in the world as a soil amendment to increase soil fertility (Schomberg *et al*., 2012).

Applying Biochar to agricultural soils can lead to resistance against several soil- and air-borne plant diseases such as potato rot, tomato seedling damping-off, pepper and strawberry fungal diseases, and carrot root-lesion nematode, through stimulation of several general defense pathways and promotion of defense-related gene expression (George *et al*., 2016). Biochar influences soil organisms. *i.e*., stimulating soil microbial processes by absorbing/detoxifying inhibitory components (Elad *et al.*, 2010), biochar is also an effective sorbent of heavy metals and organic pollutants (Jiang *et al*., 2012), changing in the availability of soil nutrients and shifts soil nutrients ratios: N, P, and others (Ojeda *et al*., 2015).

Biochar added before agricultural fast pyrolysis increases the risk of generating toxic compounds to seed germination and plant growth. Therefore, general phytotoxicity and eco toxicity tests are recommended (Domene *et al*., 2015).

The objective of this work was to screen up susceptibility of eggplant and pepper for *R. solani* and *F. solani*, selection of cultivars for studying the effect of different concentrations of biochar on either soil or plant growth of eggplant and pepper seedlings, along with the effect of biochar on the total microbial count.

MATERIALS AND METHODS

Isolation and Identification:

The present study was carried out in Vegetable Dep., Horticulture Research Institute, Agricultural Research Center. Naturally, infected eggplant and pepper plants showing root rot and wilt symptoms were collected from Kaha Research Station, Qaliobia Governorate for the isolation of the causal pathogen(s). Roots were washed thoroughly with tap water then surface sterilized with sodium hypochlorite 0.5 % for one minute then washed with sterilized water and dried. Infected sections were then placed on PDA, in Petri plates and incubated at 28°C for 5 days. The selected fungal colonies were purified using the hyphal tip or single spore technique (Dhingra and Sinclair, 1995). Identification of the isolated fungi was carried out as described by Nelson *et al*. (1983), Carling and Summer (1992). Cultures were kept on PDA medium at 4±1°C till use.

Preparation of inoculum:

The tested fungi were grown on PDA medium for seven days at 25°C. Two discs (5 mm) of agar medium bearing fungal growth were taken from seven days old culture of each fungus and transferred to the surface of autoclaved cornmeal sand medium (75 g ground corn meal, 25 g fine washed sand and 50 ml tap water) in glass bottles (500 ml) that were incubated at 28°C for 15 days.

Pathogenicity tests:

Eggplant and pepper seedlings representing the tested cultivars were obtained from Veg. Res. Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt. Soil infestation was made by mixing the fungal inoculum of each isolate alone with mixture of soil 2:1 (sand + peat moss) at the rate of 3% (w/w) active inoculum, in plastic pots (12.5 cm in diam.) each contains approximately 1.0 kg soil, before planting. Thirty days old pepper and eggplant seedlings were planted in pots (three plants/ pot) and three replicates were used for each treatment, *R. solani, F. solani* and the mixture of the two fungi. Pots used as control were considered and kept under the same conditions.

Disease readings:

Four weeks after planting, the seedlings were carefully removed from the soil and rated for disease severity on (0-5) scale (Galindo, 1982) and the percentage of diseased seedlings was also determined.

0= no symptom	Highly resistant	(HR)
1= 1-20	Resistant	(R)
2= more than 20-40	Moderately resistant	(MR)
3= more than 40-60	Intermediate	(I)
4= more than 60-80	Susceptible	(S)
5= more than 80-100	Highly susceptible	(HS)

Tested cultivars:

Twenty-five eggplant and twenty-seven pepper cultivars were tested. Seedlings of the tested plants were prepared in a greenhouse at Veg. Res. Dept., Hort. Res. Inst. Agric. Res. Center (Table, 1). In most cases, seedlings of pepper and eggplant used in this investigation were raised from seeds obtained from various authentic producers (Table, 1) under greenhouse conditions. For sowing pepper and eggplant seeds, trays were prepared for seed germination in the greenhouse, the cells were filled with

moist peat moss, 2-3 seeds/cell were planted, keeping the trays 6-8 days for germination, the stage was exposed to more sunlight for growth, then transplanted to pots after one month.

Table (1): Sources of Eggplant and Pepper seeds used in this work.

No.	Eggplant Cultivars	Sources	Pepper cultivars	Sources
1	Tream	Vilmoran	OTL	Italia
2	Tasco	Vilmoran	Rollarells	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
3	Larg marado	Italia	Gs.	USA
4	N-650	Takii	Zarco.	Syngenta
5	Milda	Sengenta	Orabell	Syngenta
6	Classic	Harris moran	Titanic	Peto-seed
7	White romy	Egypt	GK.	USA
8	Turki	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza	Ranain B	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
9	Topaz	Enza Zadin	Magno	Enz zedan
10	Trieam	Nunhems	Gedeon	Syngenta
11	N-29	Sakata	Falko	Vilmoran
12	Rozana	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza	Jupiter Sun	USA
13	Landrace-Long White	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza	Giant Aconcagua	USA
14	Nsx-787	Namdharise	Choco Pepper	USA
15	Anan	Namdharise	Ariane	USA
16	Falcon	Enza Zaden	Marcony	Fito
17	Black Beauty	Takii	Rida	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
18	China-line,1	Chine	China -Line 6	China
19	Barbara	Abandance Vil.	Balady-	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
20	Landrace-Long Black	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza	Marcata	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
21	Coury	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza	Naisa	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
22	Nsx-797	Namdharise	Maroni Rosso	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
23	Ramy	Sakata	Suptol	Hungary
24	Snow	Fito	Greygo	Hungary
25	Rondona	Aub. 132	Albaragia	Hungary
26	-----	-----	20 M	Veg. Res. Dept., Hort. Res. Inst., ARC., Giza
27	-----	-----	Sweet Banana	USA

Biochar preparation:

Biochar was pulverized into a powder of particles less than 0.5 mm using blender. Two biochar treatments were transferred to glass bottles, the first treatment was unsterilized, and the second treatment was sterilized by autoclaving at 121°C for 2h.

Plant response and tested concentrations of biochar:

Thirty days old Gedeon X & Titanic pepper cv. seedlings and F2N-29 & Balady eggplant cv. seedlings were used. Soil infestation was made by a mixture of the pathogens (*R. solani* and *F. solani*) at the rate of 3% (w/w) active mixed inoculum. Pots (12.5 cm in diam.) were filled with approximately 1.0 kg soil (sand + peat moss 2:1 w/w) and infested with the fungal inoculum, the desired seedlings were transplanted in the plastic pots (3 seedlings/pot). Three replicates were used for each treatment (Table, 2). Two biochar types were prepared and from each three concentrations (0.5, 1.0, and 2.0 g.) were prepared and mixed with the potted soil. Positive control using the fungicide Hymexazol 30% was undertaken. Seedlings grown in infested soil as well as control were grown under greenhouse conditions for 60 days, fertilized and irrigated with NPK fertilizers. At the end of the experiment, eggplant and pepper plant growth habits were evaluated after 60 days, dry plant weight (g) and dry root weight (g). Plant material was dried in an air circulated at 70°C oven for 72 hours for dry weight determinations.

Disease severity values were scored according to Abdou *et al*. (2001) using a scale from 0-5 based on the degree of root discoloration or leaf yellowing as follow:

0 = neither root discoloration nor leaf yellowing
1= 1-25% root discoloration or one leaf yellowing
2= more than 25-50% root discoloration or more than one leaf yellowing
3= more than 50-75% root discoloration with one wilted leaf
4= more than 75% root discoloration with more than one wilted leaf
5= dead seedlings.

$$\textbf{DSI \%} = \frac{\Sigma\ \textbf{(Number of plants} \times \textbf{degree of symptom)}}{\textbf{Total number of plants} \times 5} \times 100$$

Percentages of treatment efficacy in decreasing the disease infection were calculated as follows:

$$\textbf{\% Treatment efficiency} = \frac{\textbf{Control} - \textbf{Treatment}}{\textbf{Control}} \times 100$$

$$\textbf{\% Chemical inducer efficiency relative to fungicide efficacy} = \frac{\textbf{Chemical inducer efficiency}}{\textbf{fungicide efficacy}} \times 100$$

Microbial plate counts:

Soil samples were collected from the root zones of different treatments for the determination of microbial density, after experiment application (37, 44, 51 and 60 days) first year and samples were stored in refrigerator during the second year at 8°C. Counts of total microorganisms were made by adding 10 g of soil to 90 ml of sterile water and shacking on an orbital shaker (200 rpm) for 2 hrs. Soil extract agar medium was used (Allen,1957) to estimate bacteria population and Peptone dextrose agar medium (Martin, 1950) to estimate fungi population densities. Incubation was at 28-30°C for 5-7 days for fungi and bacteria. The average number of colonies per dish is multiplied by the dilution factor to obtain the number per gram in the original soil sample that was being calculated by using the following formula:

$$\textbf{CFU/g soil} = \frac{\textbf{number of colonies} \times \textbf{dilution factor}}{\textbf{volume of culture plat.}}$$

Table (2): Biochar treatments used in the study.

No	Treatments		Biochar conc. g.
1	Biochar (non-activated)	Cultivars + Pathogens	0.5
2		Cultivars + Pathogens	1.0
3		Cultivars + Pathogens	2.0
4	Biochar (activated)	Cultivars + Pathogens	0.5
5		Cultivars + Pathogens	1.0
6		Cultivars + Pathogens	2.0
7	Biochar (non-activated)	Cultivars	0.5
8		Cultivars	1.0
9		Cultivars	2.0
10	Biochar (activated)	Cultivars	0.5
11		Cultivars	1.0
12		Cultivars	2.0
13	Pathogens	Cultivars	0.0
14	Fungicide (Hymexazol 30%)	Cultivars +Pathogens	1.3ml/100
15	Control	Cultivars only	0.0
16	Soil + Pathogens + Biochar (non-activated)	(without cultivars)	0.5
17		(without cultivars)	1.0
18		(without cultivars)	2.0
19	Soil + Pathogens + Biochar (activated)	(without cultivars)	0.5
20		(without cultivars)	1.0
21		(without cultivars)	2.0
22	Soil + Pathogens	(without cultivars)	0.0
23	Soil only	(without cultivars)	0.0

Cultivars (Eggplant & Pepper), Pathogens (Mixture of *R. solani* and *F. solani*)

Statistical analysis:

The obtained data were statistically analyzed according to Snedecor and Cochran (1980).

RESULTS

Isolation and identification of fungi:

Several fungi were isolated from infected roots of pepper and eggplant plants collected from Qaliobia governorate (Table 3). The isolated fungi were identified as *R. solani* Kühn, and *F. solani* (Mart.) Sacc. and their frequency percentages were calculated. *F. solani* showed the highest percentage followed by *R. solani*, *Alternaria alternata*, *Aspergillus* sp. being, 53.89, 35.89, 5.5 and 3.0%, respectively. The very low frequency of minor fungi (1.72 %) was also scored and neglected.

Table (3): Frequency percentage of fungi isolated from the infected roots and wilted pepper and eggplant plants.

Isolated fungi	No of isolates	Frequency %
Rhizoctonia solani Kühn	22	35.89
F. solani (Mart.) Sacc.	32	53.89
Alternaria alternata (Fr.) Keissl	*3*	*5.5*
Aspergillus sp.	*2*	*3.0*
Other fungi (neglected)	1	1.72
Total no of isolates	60	---

Pathogenicity test and cultivars reactions:

Data presented in Table (4) show the pathogenicity of isolated fungi. Severity ratings of eggplant cultivars ranged from 26.6 to 90.0% when grown in soil infested with *F. solani* and ranged from 32.8 to72.1% when the soil was infested with *R. solani*. Moreover, the disease severity on eggplant ranged between 43.9 to 90.0% when the soil was infested with the mixture of the two fungi.

Furthermore, disease severity ranged between 31.9 to 90.0% for pepper cultivars infected with *F. solani* and ranged between 36.1 to 90.0% in case of *R. solani*. However, using the mixture of the two ungi showed the highest disease severity ranged between 47.4 to 90.0% (Table, 5).

The treatments using 25 eggplant cultivars revealed that six cvs. were highly susceptible to the mixture of the tested fungi, 18 rated intermediate and one cultivar was scored susceptible.

The treatments using 27 pepper cultivars were highly susceptible, 18 cvs., seven rated intermediate and two cultivars were scored susceptible.

Biochar concentrations in relation to root rot and survival of pepper plants:

Results in Table (6) clearly show the effect of growing pepper cultivars Gedeon X and Titanic in soils amended with both biochar types (non-activated and activated), amendment with different concentrations of biochar on root rot incidences compared to control with the mixture of pathogens (*R. solani* and *F. solani*).

The highest percentage of root rot incidence of Gedeon X cv. was found to be due to the pathogens and non-activated biochar (11.1%).

Meanwhile, in case of Titanic cv. the highest percentage of root rot was recorded (33.3%) with non-activated and activated treatments compared to control one.

However, both non activated and activated biochar with different concentrations without pathogen were significantly variable. The highest percentages of root rot incidence of Gedeon X cv. were 11.1 to 22.2% with non-activated treatment and (0.0%) with activated ones. The susceptible Titanic cv. showed the highest percentage of root rot ranged between (22.2 to 33.3%) with non-activated treatment and 11.1 to 22.2% for activated biochar treatment.

Fungicide treatment showed that root rot incidence percentage recorded 11.1% in Titanic cv. While Gedeon X cv. recorded 0.0% root rot incidence.

Non activated and activated biochar types and plants grown in soil infested with the mixed pathogens (*R. solani* and *F. solani*) significantly increased plant survival and showed root rot incidence percentages ranged between 88.9 to100.0% for non-activated, and (100.0%) for activated biochar on Gedeon X cv. compared to control (77.8%) and the susceptible Titanic cv. that ranged between (66.7 and 88.9%) for non-activated and activated treatments, respectively compared to control (100.0%).

However, both non-activated and activated biochar of different single concentrations varied significantly in plant survival, the non-activated biochar recorded 77.8 to 100.0% while activated biochar recorded 100%. Similar trend is shown in Table (6), the susceptible Titanic cv. ranged from 66.7 to 88.9% for non-activated, 77.8 to100% with activated biochar. While fungicide treatment recorded 100.0 and 88.9% on Gedeon X and Titanic cultivars, respectively.

Table (4): Disease severity and the reaction of eggplant cultivars to Rhizoctonia and Fusarium root and crown rots.

	Eggplant cultivars	Disease severity %			Scored reaction		
		F. solani	*R. solani*	Mixed fungi	*F. solani*	*R. solani*	Mixed fungi
1	Tream	26.6	32.8	44.6	MR	MR	I
2	Tasco	26.6	33.6	45.4	MR	MR	I
3	Larg marado	56.4	72.1	90.0	I	S	HS
4	N - 650	36.9	46.7	45.4	MR	I	I
5	Melida	34.4	37.6	46.9	MR	MR	I
6	Classic	38.5	43.9	50.8	MR	I	I
7	White romy	34.4	36.1	43.1	MR	MR	I
8	Turki	32.8	37.6	53.9	MR	MR	I
9	Topaz	35.2	37.6	43.9	MR	MR	I
10	Trieam	32.8	38.5	53.7	MR	MR	I
11	F2N - 29	31.1	50.8	51.5	MR	I	I
12	Rozana	31.9	35.2	50.7	MR	MR	I
13	Landrace-Long White	35.2	44.6	56.4	MR	I	I
14	Nsx - 787	39.2	50.8	50.8	MR	I	I
15	Anan	35.2	46.9	63.4	MR	I	S
16	Falcon	90.0	58.9	90.0	HS	I	HS
17	Black Beauty	39.2	43.1	50.8	MR	I	I
18	China-line,1	26.6	43.1	50.2	MR	I	I
19	Barbara	33.6	40.0	46.1	MR	I	I
20	Landrace-Long Black (Balady)	39.2	50.8	90.0	MR	I	HS
21	Koury	50.8	58.9	90.0	I	I	HS
22	Nsx - 797	31.0	50.8	54.8	MR	I	I
23	Ramy	35.2	50.8	58.9	MR	I	I
24	Snow	38.5	46.1	90.0	MR	I	HS
25	Rondona	43.1	56.4	90.0	I	I	HS
	LSD at 0.05	3.01	2.72	2.20			

Table (5): Disease severity and the reaction of pepper cultivars to Rhizoctonia and Fusarium root and crown rots.

	Pepper cultivars	Disease severity%			Scored reaction		
		F. solani	*R. solani*	Mixed fungi	*F. solani*	*R. solani*	Mixed fungi
1	OTL	45.3	52.4	68.6	I	I	S
2	Rollarells	31.9	36.1	58.9	MR	MR	I
3	Gs.	39.2	50.8	90.0	MR	I	HS
4	Zarco	40.4	51.5	90.0	MR	I	HS
5	Orabell	40.8	47.7	90.0	MR	I	HS
6	Titanic	42.3	52.2	90.0	I	I	HS
7	GK.	43.1	50.8	90.0	I	I	HS
8	Ranain B	43.9	56.4	90.0	I	I	HS
9	Magno	43.9	53.1	90.0	I	I	HS
10	Gedeon x	44.6	50.8	53.9	I	I	I
11	Falko	45.3	40.4	90.0	I	MR	HS
12	Jupiter Sun	45.4	43.1	47.4	I	I	I
13	Giant Aconcagua	45.4	63.4	90.0	I	S	HS
14	Choco Pepper	45.4	90.0	90.0	I	HS	HS
15	Ariane	45.4	90.0	90.0	I	HS	HS
16	Marcony	45.4	90.0	90.0	I	HS	HS
17	Rida	46.1	40.4	57.2	I	MR	I
18	China-Line 6	46.1	90.0	90.0	I	HS	HS
19	Balady-	46.9	50.8	90.0	I	I	HS
20	Marcata	49.2	50.0	57.2	I	I	I
21	Naisa	50.0	50.8	58.9	I	I	I
22	Maroni Rosso	50.8	57.2	90.0	I	I	HS
23	Suptol	50.8	50.8	57.2	I	I	I
24	Greygo	50.8	52.3	63.4	I	I	S
25	Albaragia	56.4	90.0	90.0	I	HS	HS
26	20 M	58.1	56.4	90,0	I	I	HS
27	Sweet Banana	90,0	56.4	90.0	HS	I	HS
	LSD at 0.05	1.23	1.32	1.43			

Table (6): Effect of biochar dosage(s) on root rot and survival of pepper plants.

No.	Treatment component	Dose (g)	Pepper cultivars			
			Root rot disease %		Plant survivals %	
			Gedeon X	Titanic	Gedeon X	Titanic
1	Pathogens + Biochar (non-activated)	0.5	11.1	22.2	88.9	77.8
2		1.0	0.0	11.1	100.0	88.9
3		2.0	0.0	33.3	100.0	66.7
4	Pathogens + Biochar (Activated)	0.5	0.0	22.2	100.0	77.8
5		1.0	0.0	11.1	100.0	88.9
6		2.0	0.0	33.3	100.0	66.7
7	Biochar (non-activated)	0.5	0.0	33.3	100.0	66.7
8		1.0	11.1	22.2	88.9	88.9
9		2.0	22.2	22.2	77.8	77.8
10	Biochar (Activated)	0.5	0.0	11.1	100.0	88.9
11		1.0	0.0	22.2	100.0	77.8
12		2.0	0.0	0.0	100.0	100.0
13	Pathogens	---	22.2	33.3	77.8	66.7
14	Pathogen + Fungicide	1.3 ml/100	0.0	11.1	100.0	88.9
15	Cultivars only (control)	---	0.0	0.0	100.0	100.0
LSD at 0.05			T = 0.66	D = 0.51	T = 9.01	D = 6.98
Treatments (T)			C = 0.42	T×D = 1.15	C = 5.70	T×D = 15.6
Doses (D)			T×C = 0.94	D×C= 0.73	T×C = 12.8	D×C= 9.87
Cultivars (C)			T×D×C = 1.62		T×D×C = 22.1	

Pathogens= Mixture of pathogens (*R. solani* and *F. solani*)

Biochar dosage in concern to root rot and plant survival of Eggplant:

Results in Table (7) show the root rot disease incidence values of eggplant cvs. F2N-29 and Balady. Both biochar, non-activated and activated treatments with the amended concentrations positively reduced root rot incidence compared to the inoculated control. The effect of both non activated and activated biochar in the presence of mixed *R. solani* and *F. solani* on F2N-29 cultivar showed that the highest percentage was obtained from mixed pathogens with non-activated biochar, being 11.1 to 33.3% and (11.1%) with activated biochar.

Meanwhile, in case of Balady cultivar the highest percentage of root rot was recorded with non-activated and activated biochar, being 22.2 to 55.5% and 44.4 to 66.6%, respectively.

However, both biochar (non-activated and activated) types with amendment of different doses (without pathogens) were significantly different in the incidence of root rot. The highest percentage of root rotted plants of cultivar F2N-29 was 11.1% with activated, and (0.0%) with non-activated biochar treatments.

Meanwhile, the susceptible cv. Balady showed the highest percentage of root rot (11.1 to 22.2 %) with non-activated and activated biochar.

The fungicide treatment was significantly effective against root rot of the two cultivars of eggplant that recorded (11.1%) for Balady cv. and (0.0%) with F2N-29 cv.

The survived plants due to using both biochar (non-activated and activated) treatments and different concentrations in the presence of the pathogen's mixture (*R. solani* and *F. solani*) were significantly variable and ranged from 66.7-100.0% with non-activated and 88.8 to 100.0% with activated biochar on F2N-29 cv. eggplant and the susceptible Balady ranged from 44.5 to 77.8% with non-activated and 33.4 to 55.6% with activated biochar compared to the control (33.6%).

However, both biochar treatments with the amendment of different single concentrations, each alone, without pathogens were significantly different, survived plants ranged from 88.9 to100.0% with activated biochar and (100%) with non-activated ones on F2N-29, and for the susceptible cultivar Balady ranged between 77.8 to 88.9% with non-activated and activated biochar. The treatment with fungicide was significantly effective on cvs.F2N-29 and Balady eggplant that showed 100.0 and 88.9% plant survival, respectively.

Table (7): Effect of biochar dosage(s) on the incidence of root rot and survival of eggplant.

No.	Treatment component	Dose (g)	Eggplant cultivars			
			Root rot disease %		Survivals %	
			F2N-29	Balady	F2N-29	Balady
1	Pathogens + Biochar (non-ctivated)	0.5	11.1	22.2	88.9	77.8
2		1.0	33.3	44.4	66.7	55.6
3		2.0	0.0	55.5	100.0	44.5
4	Pathogens + Biochar (Activated)	0.5	11.1	44.4	88.9	55.6
5		1.0	0.0	66.6	100.0	33.4
6		2.0	11.1	55.5	88.9	44.5
7	Biochar (non-activated)	0.5	0.0	11.1	100.0	88.9
8		1.0	0.0	22.2	100.0	77.8
9		2.0	0.0	11.1	100.0	88.9
10	Biochar (Activated)	0.5	11.1	22.2	88.9	77.8
11		1.0	0.0	11.1	100.0	88.9
12		2.0	0.0	22.2	100.0	77.8
13	Pathogens	---	44.4	66.6	55.6	33.3
14	Pathogens + Fungicide	1.3ml /100	0.0	11.1	100.0	88.9
15	Cultivars only (control)	---	0.0	33.3	100.0	88.9
LSD at 0.05			T = 14.7	D = 11.4	T = 0.84	D = 0.65
	Treatments (T)		C = 9.26	T×D = 25.4	C = 0.53	T×D = 1.45
	Doses (D)		T×C = 20.7	D×C = 16.0	T×C = 1.19	D×C = 0.92
	Cultivars (C)		T×D×C = 35.9		T×D×C = 2.06	

Pathogens= Mixture of pathogens (*R. solani* and *F. solani*)

Effect of biochar concentrations on disease severity of pepper plant:

Different concentrations (0.5, 1.0, and 2.0 g.) of non-activated and activated biochar have shown significant positive effects on disease severity on pepper and eggplant cultivars. Data in Table (8) and Fig (1) show that biochar amendment of different concentrations had an efficient effect on disease severity compared to the plants grown in infested soil with the mixed pathogens (*R. solani* and *F. solani*) on pepper cultivars.

Both biochar amendments and soil infestation with the mixture of pathogens showed significant differences and disease severity ranged between 44.4 to 55.6% with non-activated and 36.5 to 42.2% with activated biochar on Gedeon X pepper cultivar compared with control (60.0%). While the disease severity on the susceptible Titanic cultivar ranged from 60.0 to 73.3% with non-activated and 55.5 to 71.1% with activated biochar compared to the control (80.0%).

However, both biochar treatments without pathogens trials at different concentrations of biochar gave symptoms similar to disease diagnostic and symptoms ranged from 14.8 to 17.0% with non-activated, and 12.6 to 16.3% with activated biochar on the cultivar Gedeon X. While on the Titanic susceptible cultivar,

disease severity ranged from 19.3 to 24.2% with non-activated and 17.0 to 20.0% with activated biochar. Isolation trials from such affected plants did not show the involvement of any fungal pathogen.

The fungicide Hymexazol 30% significantly decreased disease severity on pepper cultivars Gedeon X and Titanic and recorded 31.1 and 42.2%, respectively.

Efficiency percentage for both biochar types decreased disease severity with the pathogens mixture (*R. solani* + *F. solani*) at 1.0 g of activated and non-activated treatments on Gedeon X pepper cultivar. Meanwhile, Titanic pepper showed the highest reaction to non-activated biochar at 0.5g., then activated one at 1.0g., and showed the lowest effect with 2.0g., treatment.

However, both biochar treatments, each alone, gave the highest negative effect at 0.5g., while the lowest one was at 1.0g., non-activated and activated biochar on Gedeon X cultivar. Meanwhile, Titanic pepper cultivar showed the highest negative effect at 2.0g. and showed the lowest negative effect at 1.0g., treatment.

Table (8): Effect of biochar treatment on pepper cultivars and their interactions.

No	Treatment component	Dose (g)	Pepper cultivars			
			% Disease severity		% Efficiency	
			Gedeon X	Titanic	Gedeon X	Titanic
1	Pathogens + Biochar (non-activated)	0.5	55.6	60.0	7.33	25.0
2		1.0	44.4	64.4	26.0	19.5
3		2.0	48.9	73.0	18.5	8.75
4	Pathogens + Biochar (Activated)	0.5	42.2	62.2	29.7	22.3
5		1.0	36.5	55.5	39.2	30.6
6		2.0	37.7	71.1	37.2	11.1
7	Biochar (non-activated)	0.5	17.0*	20.7*	-104.8*	-33.5*
8		1.0	14.8*	19.3*	-78.3*	-24.2*
9		2.0	15.6*	24.2*	-87.9*	-56.1*
10	Biochar (Activated)	0.5	16.3*	20.0*	-96.4*	-29.0*
11		1.0	12.6*	17.0*	-51.8*	-9.67*
12		2.0	13.3*	18.5*	-60.2*	-19.4*
13	Pathogens	---	60.0	80.0	0.0	0.0
14	Pathogens + Fungicide	----	31.1	42.2	48.2	47.8
15	Cultivars only (control)	----	8.30	15.5	0.0	0.0
	LSD at 0.05		Treatments (T) = 0.79		Doses (D) = 0.61	
			Cultivars (C) = 0.49		T × D =1.36	
			T × C = 1.11		D × C = 0.86	
			T × D × C = 1.93			

* Physiological disorders, similar to disease reaction.

Effect of Biochar concentrations on disease severity of Eggplant:

Data in Table (9) show that all treatments significantly decreased the percentages of disease severity. Both biochar treatments significantly decreased the disease severity with non-activated biochar, being 40.0 to 51.1% and 40.0 to 55.6% with activated ones on eggplant F2N-29 cv. The susceptible Balady cultivar showed disease severity ranged from 64.4 to 75.6% with non-activated and 66.6 to 82.2% with activated biochar.

However, both biochar applications at different concentrations with pathogen free

treatments gave symptoms similar to the disease ranged from 11.9 to 14.8% with non-activated and 13.3 to 20.7% with activated biochar on the cultivar F2N-29 and on the susceptible cultivar Balady ranged from 20.7 to23.7% with non-activated and 22.2 to 23.7% with activated one.

Isolation trials from such physiologically affected plants did not show any fungal pathogens.

Moreover, treatment with the fungicide Hymexazol 30% significantly decreased the disease severity on the two eggplant cultivars (F2N-29 and Balady), being 37.8 and 62.2%, respectively.

The efficiency percentage for both biochar types significantly decreased the root rot severity caused by the mixture of pathogens (*R. solani* and *F. solani*). They gave the best control results at 0.5 g with non-activated and 1.0 g. with activated biochar treatments on F2N-29 eggplant cultivar. Meanwhile, Balady eggplant cultivar showed better reaction with biochar treatments at 1.0 g. and the lowest reactions were noticed on plants received 2.0 g., biochar.

However, the two types of biochar (treatments) gave the highest negative effect at 0.5g. with non-activated biochar and the lowest one was at 1.0g., activated biochar on Eggplant cv. F2N-29. Meanwhile, Balady eggplant cultivar showed the highest negative effect at 2.0 g. activated and the lowest negative treatment at 1.0 g. non-activated compared to activated treatment of biochar.

Table (9): Effect of biochar treatment on Eggplant cultivars and their interactions.

No	Treatment component	Dose (g)	Eggplant cultivars			
			% Disease severity		% Efficiency	
			F2N-29	Balady	F2N-29	Balady
1	Pathogens + Biochar (non-activated)	0.5	40.0	75.6	45.4	14.9
2		1.0	51.1	64.4	30.3	27.6
3		2.0	46.7	75.6	36.3	14.9
4	Pathogens + Biochar (Activated)	0.5	55.6	68.9	24.1	22.5
5		1.0	44.4	66.6	39.4	25.1
6		2.0	40.0	82.0	45.4	7.76
7	Biochar (non-activated)	0.5	14.8*	22.2*	-120.9*	-42.3*
8		1.0	11.9*	20.7*	-77.6*	-32.6*
9		2.0	13.3*	23.7*	-98.5*	-51.9*
10	Biochar (Activated)	0.5	20.7*	22.2*	-208.9*	-42.3*
11		1.0	14.1*	22.2*	-110.4*	-42.3*
12		2.0	13.3*	23.7*	-98.5*	-51.9*
13	Pathogens	---	73.3	88.9	0.0	0.0
14	Pathogens + Fungicide	----	37.8	62.2	48.4	38.3
15	Cultivars only (control)	----	6.7	15.6	0.0	0.0
	LSD at 0.05		Treatments (T) = 0.61		Doses (D) = 0.47	
			Cultivars (C) = 0.38		T × D = 1.05	
			T × C = 0.86		D × C = 0.66	
			T × D × C = 1.49			

* Physiological disorders, similar to disease reaction.

Effect of biochar concentrations on plant growth habits of the tested cultivars:

All treatments caused a significant effect on growth habits of plants treated with biochars. In the absence of the disease-causing pathogens, both two types of biochar had positive effects on growth habits as plant height and dry weight (Tables 10 &11) and (Figs.1 &2).

Effect of biochar concentrations on growth of (Gedeon X and Titanic) Pepper cvs.:

Both biochar treatments at various concentrations had promoted plant growth even under the stress conditions of the pathogens (Table10). Both biochar treatments caused significant promotion on plant height even under the mixture of pathogens stress, ranged from 11.4 to11.9 cm., for non-activated and activated biochar, respectively on Gedeon X cultivar. While the susceptible Titanic cultivar recorded 6.3 to10.6 cm., with non-activated and 9.6 to 10.8cm. due to using activated biochar (Fig.1).

The root length ranged from 3.9 to 4.6 cm., with non-activated, and 4.1 to 4.9cm. with activated biochar, while root length of the susceptible Titanic cultivar recorded 1.9 to 3.7cm. with non-activated and 1.8 to 4.4cm. with activated biochar compared to control (4.5 cm.).

However, both biochar treatments showed significant differences on the above ground plant parts due to the used concentrations of the plants grown in uninfested soil that ranged from 12.3 to 13.6 cm., with non-activated and 12.4 to 13.8cm. with activated biochar treatments, respectively on Gedeon X cultivar compared to control (13.0 cm.). The susceptible Titanic cultivar recorded 10.2 to 10.8cm. with non-activated and 9.2-11.3cm. with biochar activated treatments compared to control, being 10.6 cm. (Fig.1).

Meanwhile, significant differences were recorded for the underground parts of cultivar Gedeon X that was ranging from 5.7 to 6.4 cm. with non-activated and 5.1 to 5.6 cm. with activated biochar compared to control (6.0 cm.). The susceptible Titanic cultivar, on the other hand, recorded 3.2 to 4.8cm. and 2.6 to3.4cm, respectively compared to control (3.2 cm.).

Shoot/root ratio (Table 10) of pepper cultivars ranged from (2.5 to 3.1 cm.) with non-activated and 2.3 to 2.8 cm. with activated ones compared to control (2.4cm.) in cv. Gedeon X, while the susceptible Titanic cultivar showed 2.9 to 3.3 cm. with non-activated and 2.3 to 5.3 cm. with activated treatments compared to control (1.9cm.).

However, both biochar amended treatments without pathogens had affected the shoot/root ratios in pepper cultivar that ranged from 2.1 to2.4 cm. with non-activated and 2.3 to 2.6 cm. with activated ones compared to control (2.2 cm.) in Gedeon X, while, for Titanic the susceptible cultivar these figures ranged from 2.1 to 3.4 cm. with non-activated and 3.2 to 4.2 cm. with activated biochar compared to control (3.3 cm.).

The fungicide treated cultivars of pepper recorded 2.3 cm. for Gedeon X and 2.5 cm. for Titanic. Also, a significant effect was reported for the above ground plant parts. Dry weight of Gedeon X cultivar ranged from 0.16 to 0.23g with non-activated and 0.21 to 0.25g. with activated biochar compared with control (0.20g.), while the susceptible Titanic cultivar ranged from 0.09 to 0.16g with non-activated and 0.09 to 0.15g with activated biochar treatments compared with control (0.10g).

However, root dry weight of cv. Gedeon X ranged from 0.05 - 0.06g with non-activated and activated biochar compared with control (0.05g). The susceptible Titanic cv. ranged from 0.02 to 0.04g with non-activated biochar, 0.02 to 0.05g with activated biochar compared to control (0.04g).

However, both biochar treatments without pathogens improved plant growth compared to the control as expressed by the recorded significant differences. Shoot dry weight of Gedeon X cultivar ranged from 0.23 to 0.28g with non-activated and 0.24 to 0.43g with activated biochar compared to control (0.27g.), while the susceptible Titanic ranged from 0.14 to 0.19g with non-activated and 0.15 to 0.18g with activated biochar compared to control (0.11g). Also, significant difference for root dry weight of Gedeon X cultivar was detected ranged from 0.06 to 0.07g with non-activated and 0.08 to 0.09g with activated biochar treatments, compared to control (0.06g), while susceptible cultivar Titanic recorded 0.05 to 0.06g with non-activated and 0.05 to 0.07g with activated biochar compared to control (0.06g).

Effect of biochar concentrations on growth habits of (F2N-29, Balady) Eggplant cvs.:

Data presented in Table (11) and Fig (2) show the interaction with biochar (non-activated and activated) treatments, different concentrations and their effect on plant growth habits as compared to plants grown in infested soil (control). Both biochar types of significantly increased plant height even under mixture of pathogens stress, being 11.9 to 14.3 cm. with non-activated biochar and 11.6 to 12.3 cm. with activated ones on F2N-29 cultivar compared to control (12.0 cm.), while the susceptible Balady cultivar recorded 8.8 to 9.8cm. with non-activated and 8.2 to 9.8 cm. with activated biochar compared to control (8.0 cm.) (Fig.2).

Moreover, the treatment significantly increased root length that recorded 5.1 to 6.5cm. with non-activated biochar and 4.8 to 5.7 cm. with activated treatments. The susceptible Balady cultivar under these conditions of the experiment showed an increase in root length, being 4.1 to 4.2cm. with non-activated treatment and 2.0 to3.3cm. with activated biochar.

However, both biochar treatments without pathogens significantly improved plant height due to application with different concentrations of biochar that recorded 12.8 to14.4 cm. for non-activated treatment and 12.7 to 15.0 cm. for activated biochar on cultivar F2N-29 compared to control (12.8 cm.). The susceptible Balady cultivar plant height was estimated, being 10.8 to 12.6 cm. with non-activated biochar and 10.0 to11.5 cm. with activated ones (Fig.2). Also, the root length ranged from 5.4 to 7.1 cm. with non-activated treatments and 5.5 to 6.2 cm. with activated biochar compared to control (5.5 cm.). Root length of the susceptible Balady cultivar ranged from 3.2 to 4.2 cm. with non-activated and 3.1 to3.6cm. with activated biochar.

The shoot / root ratio for F2N-29 eggplant cultivar (Table, 11) ranged from 1.9 to 2.4cm. with non-activated biochar treatment and 2.2 to 2.4 cm. for activated ones and in the susceptible Balady cultivar, this ratio ranged from 2.1 to 2.3 cm. with non-activated and 2.8 to 4.1 cm. due to activated biochar.

However, in the absence of the pathogens, biochar treatments showed a tendency of shoot/root ratio decrease in eggplant cultivar that ranged from 1.9 to 2.6 cm. with non-activated and 2.0 to 2.7 cm. with activated biochar compared to control (2.3cm.) with cv. F2N-29 and for susceptible Balady cultivar, these figures were 2.8 to 3.4cm. with non-activated and 3.2 to 3.3cm. with activated ones compared to control (4.1cm.).

The treatment with fungicide on the two eggplant cultivars, F2N-29, and Balady showed 2.6 cm. and 3.2 cm., respectively for shoot/root ratio.

Shoot dry weight of F2N-29 cultivar showed significant effect where the values ranged from 0.17 to 0.24 g with non-activated and 0.18 to 0.29g with activated biochar. The corresponding figures of dry weight of shoot of the susceptible Balady ranged from 0.05 to 0.09g with non-activated and 0.07 to 0.08g with activated ones. F2N-29 cultivar root dry weight recorded 0.04 to 0.05g with non-activated and ,0.03 to 0.06g. with activated biochar. Meanwhile, the susceptible Balady cv. recorded 0.01g with non-activated and activated biochar treatments.

However, both biochar types of amendment concentrations without mixture of pathogens significantly improved plant growth compared to the control. They also significantly affected shoot dry weight of F2N-29 cv. that ranged from 0.24 to 0.31g with non-activated and 0.25 to 0.32g. with activated compared to control (0.3g.). The susceptible Balady cultivar ranged from 0.09 to 0.11g with non-activated and 0.07 to 0.08g with activated biochar compared to control (0.2g).

Meanwhile, root dry weight of F2N-29 cultivar without mixture of pathogens was significant ranged from 0.03 to 0.06g with non-activated and 0.04 to 0.05g with activated biochar and the susceptible Balady was ranging from 0.01 to 0.02g with non-activated and (0.01g) with activated biochar compared to control (0.03g).

Table (10): Effect of different biochar concentrations on plant growth habits of pepper cultivars.

No.	Treatment component.	Cvs.	Dose (g)	Pepper cultivars				
				Plant height (cm)		Shoot /Root ratio	Dry weight (g)	
				Shoot	Root		Shoot	Root
1	Pathogens + Biochar (non-activated)	A	0.5	11.6	4.4	2.6	0.23	0.05
2		B		10.6	3.7	2.9	0.16	0.02
3		A	1.0	11.4	4.6	2.5	0.22	0.05
4		B		10.5	3.2	3.3	0.09	0.03
5		A	2.0	11.9	3.9	3.1	0.16	0.06
6		B		6.3	1.9	3.3	0.12	0.04
7	Pathogens + Biochar (activated)	A	0.5	11.5	4.1	2.8	0.21	0.05
8		B		10.8	4.2	2.3	0.15	0.04
9		A	1.0	11.4	4.9	2.3	0.22	0.06
10		B		10.0	4.4	2.3	0.11	0.05
11		A	2.0	11.9	4.9	2.4	0.25	0.06
12		B		9.6	1.8	5.3	0.09	0.02
13	Biochar (non-activated)	A	0.5	12.3	5.7	2.2	0.23	0.07
14		B		10.2	4.8	2.1	0.14	0.05
15		A	1.0	13.4	6.4	2.1	0.28	0.06
16		B		10.4	3.3	3.2	0.16	0.05
17		A	2.0	13.6	5.7	2.4	0.26	0.07
18		B		10.8	3.2	3.4	0.19	0.06
19	Biochar (activated)	A	0.5	13.1	5.1	2.6	0.24	0.09
20		B		11.3	3.4	3.3	0.15	0.07
21		A	1.0	13.8	5.6	2.5	0.27	0.08
22		B		9.2	2.9	3.2	0.18	0.06
23		A	2.0	12.4	5.5	2.3	0.43	0.08
24		B		11.1	2.6	4.2	0.18	0.05
25	Pathogens	A	-------	11.1	4.7	2.4	0.20	0.05
26		B		8.9	4.5	1.9	0.10	0.04
27	Pathogens + Fungicide	A	1.3 ml	12.9	5.7	2.3	0.27	0.08
28		B		10.8	4.3	2.5	0.14	0.06
29	Cultivars only (control)	A	-----	13.0	6.0	2.2	0.27	0.06
30		B		10.6	3.2	3.3	0.11	0.06
	LSD at 0.05							
	Treatments (T)			0.32	0.33	----	0.01	0.01
	Doses (D)			0.25	0.25	----	0.01	0.01
	Cultivars (C)			0.20	0.21	----	0.01	0.01
	T × D			0.55	0.57	----	0.01	0.02
	T × C			0.45	0.46	----	0.01	0.01
	D × C			0.35	0.36	----	0.01	0.01
	T × D × C			0.78	0.80	----	0.02	0.02

Pepper cultivars; A= Gedeon X, B= Titanic

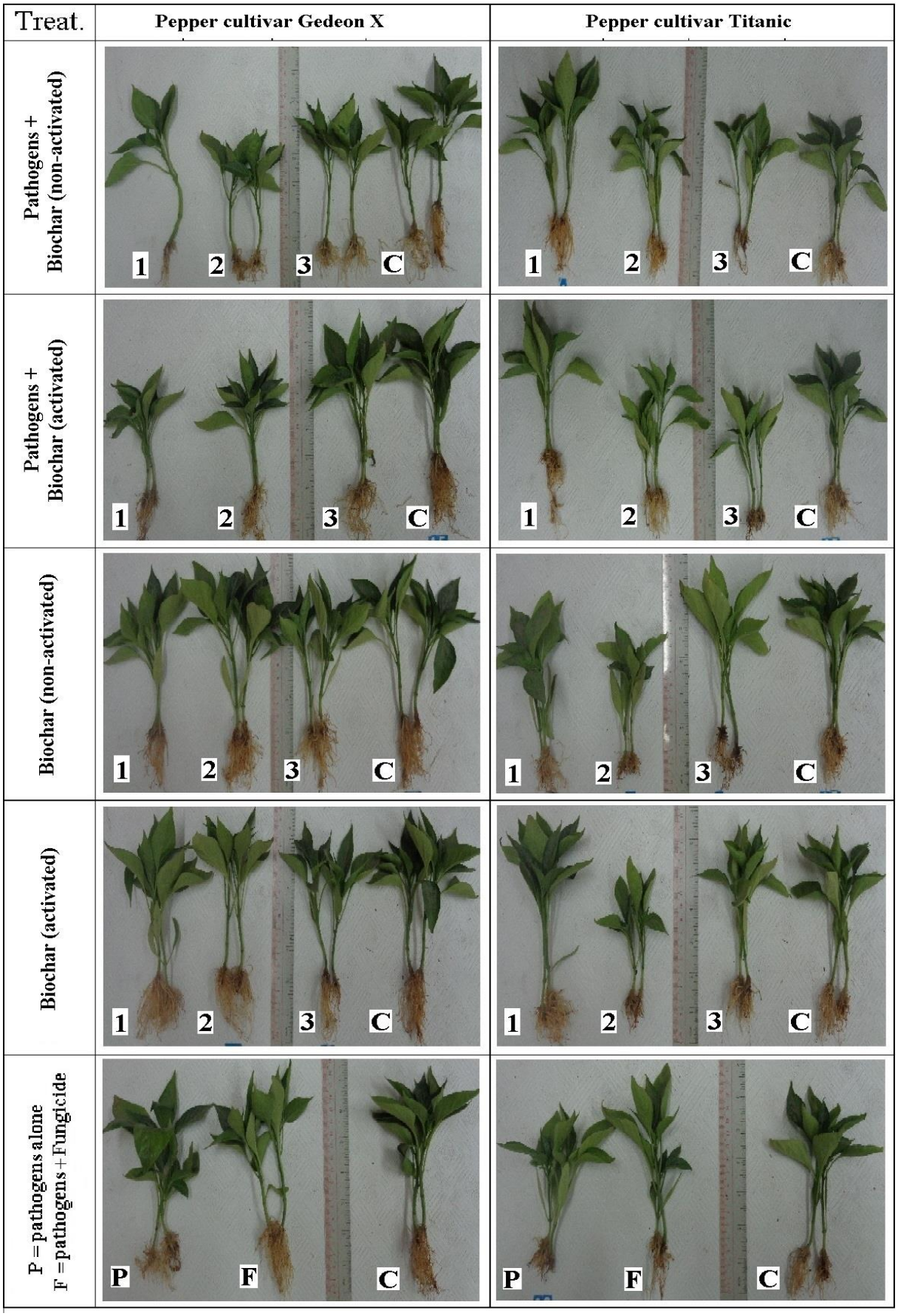

Fig. (1): Influence of two types of biochar amendment (0.5, 1.0, and 2.0g.) on pepper cultivars. 1, 2, and 3 = Concentrations of biochar (0.5, 1.0, and 2.0 g), P = mixture of pathogens (*R. solani* and *F. solani*), F = Pathogens + Fungicide, C = control

Table (11): Effect of biochar concentrations on plant growth habits of eggplant cultivars.

No.	Treatment component.	Cvs.	Dose (g)	Eggplant cultivars				
				Plant height (cm)		Shoot /Roo ratio	Dry weight (g)	
				Shoot	Root		Shoot	Root
1	Pathogens + Biochar (non-activated)	A	0.5	14.3	6.5	2.2	0.24	0.05
2		B		9.8	4.2	2.3	0.06	0.01
3		A	1.0	12.4	5.1	2.4	0.22	0.04
4		B		8.8	4.1	2.1	0.05	0.01
5		A	2.0	11.9	6.0	1.9	0.17	0.04
6		B		9.6	4.1	2.3	0.09	0.01
7	Pathogens + Biochar (activated)	A	0.5	11.6	4.8	2.4	0.18	0.03
8		B		8.2	2.0	4.1	0.08	0.01
9		A	1.0	12.3	5.7	2.2	0.24	0.04
10		B		9.3	3.3	2.8	0.08	0.01
11		A	2.0	12.1	5.2	2.3	0.29	0.06
12		B		9.8	2.6	3.8	0.07	0.01
13	Biochar (non-activated)	A	0.5	13.9	7.1	1.9	0.24	0.03
14		B		10.8	3.2	3.4	0.09	0.01
15		A	1.0	14.4	5.6	2.6	0.27	0.06
16		B		12.6	4.1	3.1	0.11	0.01
17		A	2.0	12.8	5.4	2.3	0.31	0.05
18		B		11.8	4.2	2.8	0.10	0.02
19	Biochar (activated)	A	0.5	12.7	6.2	2.0	0.25	0.05
20		B		11.5	3.6	3.2	0.08	0.01
21		A	1.0	13.7	5.7	2.4	0.29	0.05
22		B		10.0	3.1	3.2	0.07	0.01
23		A	2.0	15.0	5.5	2.7	0.32	0.04
24		B		10.1	3.1	3.3	0.08	0.01
25	Pathogens	A	----	12.0	2.8	4.3	0.19	0.02
26		B		8.0	2.0	4.0	0.07	0.01
27	Pathogens + Fungicide	A	1.3 ml	15.6	5.9	2.6	0.29	0.05
28		B		12.3	3.9	3.2	0.03	0.01
29	Cultivars only (control)	A	----	12.8	5.5	2.3	0.30	0.06
30		B		10.3	2.5	4.1	0.20	0.03
LSD at 0.05								
Treatments (T)				0.46	0.29	----	0.01	0.01
Doses (D)				0.36	0.23	----	0.01	0.01
Cultivars (C)				0.29	0.18	----	0.01	0.01
T × D				0.79	0.51	----	0.01	0.01
T × C				0.65	0.41	----	0.01	0.01
D × C				0.50	0.32	----	0.01	0.01
T × D × C				1.12	0.72	----	0.02	0.02

Eggplant cultivars; A= F2N-29, B= Balady.

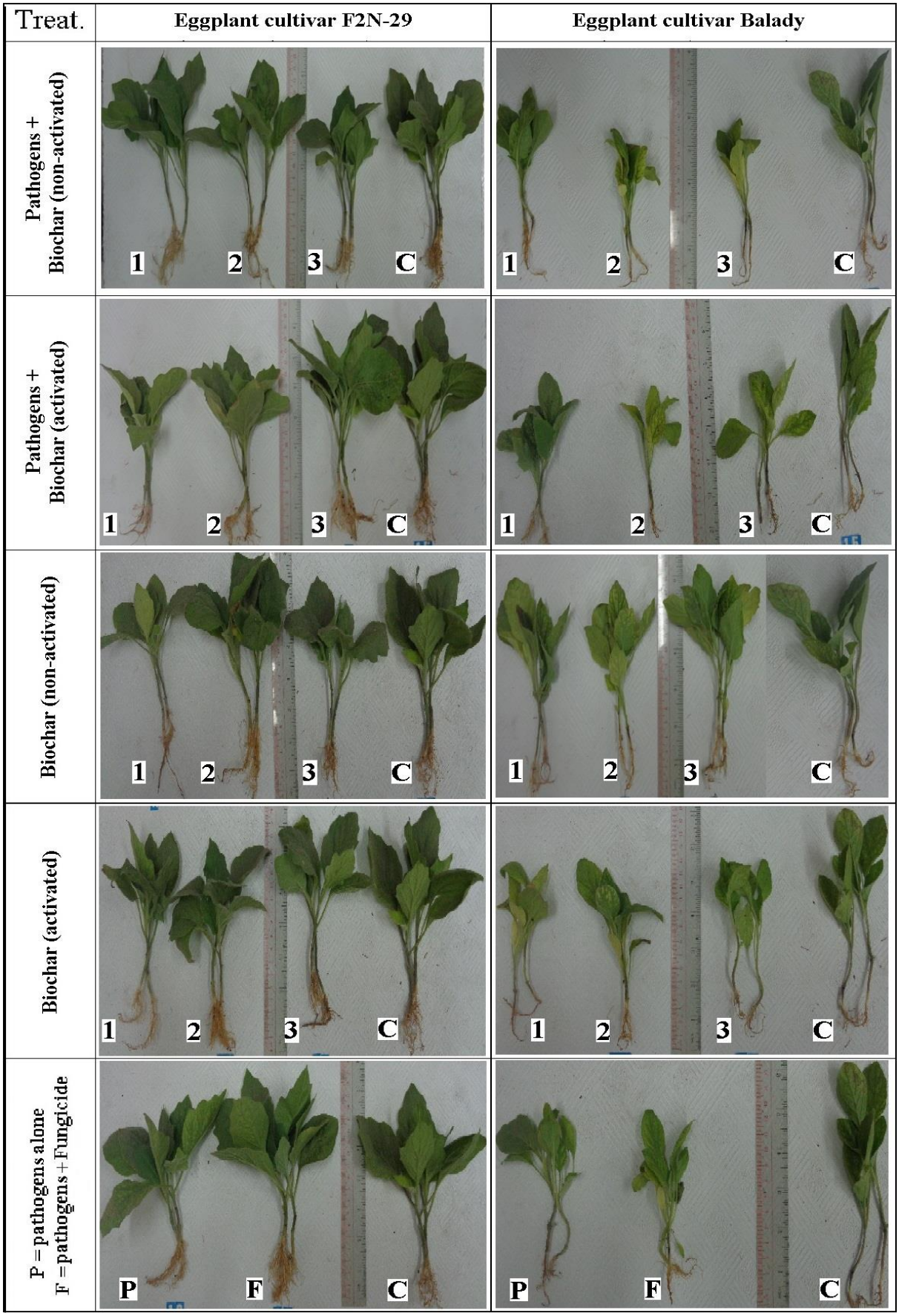

Fig. (2): The influence of two types of biochar amendment (0.5, 1, and 2g) on eggplant cultivars 1, 2, and 3 = Concentrations of biochar (0.5, 1.0, and 2.0 g), P = mixture of pathogens (*R. solani* and *F. solani*), F = Pathogens + Fungicide, C = control.

Plate counts of soil microorganisms:

Both biochar treatments under investigation at different concentrations 0.5, 1.0, 2.0 g. were effective on total counts of fungi and bacteria during different periods 37, 44, 51 and 60 days in the first and the second year (Tables, 12 and 13) and (Fig. 3).

Table (12): Effect of biochar treatments on periodic total counts of fungi and bacteria in the first year.

No.	Treatment Component.	Dose (g)	Count x 10^6 / g soil							
			37 days		44 days		51 days		60 days	
			F	B	F	B	F	B	F	B
1	Pepper +Pathogens + Biochar (non-activated)	0.5	0.0	0.0	1.7	5.2	0.5	1.4	1.0	3.1
2		1.0	0.0	0.0	1.7	4.9	0.2	0.5	2.7	8.2
3		2.0	0.9	2.9	0.0	0.0	0.4	1.1	0.6	1.9
4	Pepper +Pathogens + Biochar (activated)	0.5	0.0	0.0	1.2	3.7	0.03	0.1	0.3	0.9
5		1.0	0.03	0.1	0.0	0.0	0.03	0.1	0.5	1.6
6		2.0	0.0	0.0	0.9	2.6	0.3	0.9	1.1	3.3
7	Pepper + Biochar (non-activated)	0.5	0.0	0.0	1.3	3.9	0.3	0.9	1.2	3.5
8		1.0	0.0	0.0	0.0	0.0	0.5	1.4	0.8	2.3
9		2.0	3.8	11.3	1.4	4.3	0.3	0.9	0.8	2.5
10	Pepper + Biochar (activated)	0.5	2.1	6.4	1.5	4.4	0.5	1.4	0.2	0.7
11		1.0	1.7	4.9	0.6	1.7	0.2	0.5	0.3	0.9
12		2.0	1.1	3.2	0.3	0.9	0.1	0.8	0.8	2.3
13	Pepper + Pathogens	0.0	2.5	7.4	0.4	1.1	0.7	0.3	1.2	3.6
14	Pepper + Pathogens+ Fungicide	1.3ml	0.5	1.4	0.2	0.7	0.01	2.0	0.9	2.6
15	Pepper only (control)	0.0	0.5	1.4	0.5	1.4	0.5	0.02	0.7	2.0
16	Soil + Pathogens+ Biochar (non-activated) (without plant)	0.5	0.1	0.4	0.0	0.0	0.1	0.9	0.9	2.6
17		1.0	0.1	0.2	0.0	0.0	0.9	0.3	0.3	0.9
18		2.0	0.7	2.1	1.6	4.7	0.1	0.1	0.1	0.4
19	Soil +Pathogens + Biochar (activated) (without plant)	0.5	0.6	1.9	0.0	0.0	0.1	0.5	0.5	1.6
20		1.0	0.03	0.1	0.2	0.7	0.2	0.8	0.8	2.5
21		2.0	0.8	2.4	0.01	0.04	0.3	2.3	2.3	6.9
22	Soil + Pathogens (without plant)	0.0	1.4	4.1	1.0	3.1	0.8	0.2	0.2	0.7
23	Soil only (without plant)	0.0	0.9	2.6	0.0	0.0	0.1	0.3	0.1	0.2
	LSD at 0.05									
	Treatments (T)		0.12	0.17	0.10	0.11	0.07	0.11	0.13	0.13
	Doses (D)		0.07	0.11	0.06	0.07	0.04	0.06	0.08	0.08
	T × D		0.21	0.29	0.18	0.21	0.13	0.17	0.23	0.23

F= fungi; B= bacteria.

Table (13): Effect of biochar treatments on periodic total counts of fungi and bacteria in the second year.

No.	Treatment Component.	Dose (g)	Count x 10^6/ g soil							
			37 days		44 days		51 days		60 days	
			F	B	F	B	F	B	F	B
1	Pepper + Pathogens + Biochar (non-activated)	0.5	1.3	3.9	2.1	6.3	0.4	1.2	0.3	0.8
2		1.0	2.4	7.1	0.8	2.3	0.5	1.4	0.6	1.7
3		2.0	2.2	6.6	1.2	3.6	0.1	0.2	0.9	2.8
4	Pepper + Pathogens + Biochar (activated)	0.5	1.8	5.4	0.5	1.4	0.7	2.0	1.1	3.4
5		1.0	1.2	3.5	0.4	1.3	0.4	1.1	0.7	1.9
6		2.0	1.2	3.6	0.3	0.8	0.6	1.7	0.8	2.5
7	Pepper + Biochar (non-activated)	0.5	1.1	3.2	0.7	2.1	0.7	2.2	1.0	3.0
8		1.0	1.1	3.1	1.8	5.3	1.1	3.3	1.3	3.8
9		2.0	2.0	6.1	0.6	1.9	0.6	1.9	2.1	6.4
10	Pepper + Biochar (activated)	0.5	0.1	0.3	1.4	4.2	0.8	2.3	0.3	0.8
11		1.0	0.3	0.8	0.9	2.9	0.1	0.2	0.7	1.9
12		2.0	1.1	3.4	1.2	3.5	0.6	1.9	1.6	4.9
13	Pepper + Pathogens	0.0	1.8	5.3	1.4	4.1	1.8	5.3	0.8	2.3
14	Pepper + Pathogens + Fungicide	1.3ml	1.3	3.8	0.5	1.6	0.7	2.1	0.6	1.7
15	Pepper only (control)	0.0	0.6	1.7	0.7	2.2	0.5	1.5	0.3	1.1
16	Soil + Pathogens + Biochar (non-activated) (without plant)	0.5	1.6	4.8	1.5	4.5	0.7	1.9	0.5	1.6
17		1.0	1.7	5.2	1.5	4.6	0.6	1.8	0.6	1.7
18		2.0	0.8	2.3	0.5	1.5	0.5	1.5	0.9	2.6
19	Soil + Pathogens + Biochar (activated) (without plant)	0.5	1.1	3.2	0.9	2.9	0.9	2.8	0.9	2.8
20		1.0	0.5	1.4	0.2	0.5	1.3	3.8	0.8	2.4
21		2.0	0.5	1.5	0.1	0.2	0.4	1.1	0.5	1.5
22	Soil + Pathogens (without plant)	0.0	0.5	1.5	1.4	5.8	0.5	1.4	1.6	4.7
23	Soil only (without plant)	0.0	0.5	1.5	0.3	0.9	0.1	0.2	0.5	1.5
	LSD at 0.05									
	Treatments (T)		0.19	0.28	0.13	0.24	0.11	0.23	0.11	0.12
	Doses (D)		0.11	0.16	0.07	0.14	0.06	0.13	0.06	0.07
	T × D		0.32	0.49	0.22	0.42	0.19	0.41	0.17	0.20

F = fungi; B = bacteria.

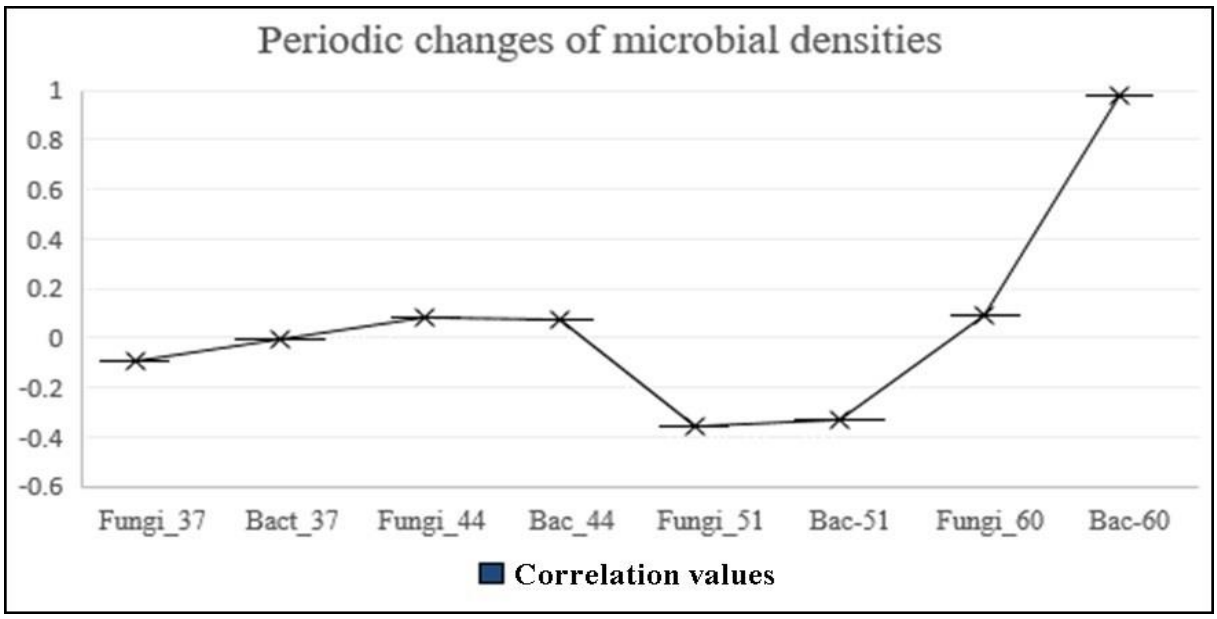

Fig (3): Two years microbial count in soil after biochar application.

It is clear from studying the correlation between counts determined at both years of study that negative correlation between the total counts of bacteria and fungi counted in 51 days. This was followed by a positive one for bacteria at the second interval at 60 days in both years. However, the correlation between the total counts of fungi and bacteria on 37 and 44 days in both years was poor or weak positive.

DISCUSSION:

The present study was carried out to compare the susceptibility of the tested eggplant and pepper cultivars which expressed a range of (intermediate - susceptible - highly susceptible) response to infection with *R. solani, F. solani* and a mixture of both fungi tested.

The eggplant cultivars were grouped as 18 cultivars were intermediate to infection with a mixture of fungi, six cultivars were highly susceptible, and one was susceptible.

Pepper cultivars were seven intermediate susceptible to a mixture of fungi, 18 cultivars were highly susceptible, and two cultivars were susceptible.

It could be concluded that susceptibility or resistance of the tested cultivars is depending basically on the genetic constitution(s) that varies greatly in resistance along with increased soil moisture at a long time. Moreover, several fungi are able to cause decay and seedling rot, including pathogenic species belonging to genera Rhizoctonia and Fusarium.

Nieman and Baayen (1988) reported that the difference in resistance between vegetable hosts might be due to the inhibition of the conversion of phenolic precursors into phytoalexins in susceptible hosts.

Results of the present study showed that effect of different concentrations (0.5, 1.0, 2.0 g.) of the two biochar types of treatments (non-activated and activated) were reacted positively on disease severity, plant growth (plant height, root length, % shoot/root, dry weight (shoot, root) of pepper Gedeon X, Titanic, and eggplant F2N-29, Balady cultivars.

The two cultivars of each eggplant and pepper were variably different in response to the reaction. The highest percentage of root rot characterized the most susceptible pepper Titanic cultivar, and the susceptible cultivar eggplant (Balady) showed greater root rot.

Non activated and activated biochar treatments under pathogen(s) stress reacted significantly in disease severity for Gedeon X pepper cultivar. The maximum suppressive effect of biochar at the moderate concentration (1.0g.) either non activated or activated biochar was reported, respectively, and the disease severity was low on Titanic cultivar at the low concentration (0.5g.).

However, both two types of biochar treatments without pathogen gave the highest negative efficiency at low 0.5g. and the lowest one at 1.0g. concentration on Gedeon X pepper cultivar. Meanwhile, the Titanic pepper cultivar showed the greatest negative effect at 2.0 g. and showed low negative effect at1.0 g. of both types of biochar.

With regard to F2N-29 eggplant cv, the maximum suppressive disease severity was

reported at 0.5g. of non-activated and 2.0 g. of activated biochar. The Balady eggplant cv showed the maximum suppressive severity at 1.0 g. on both biochar treatments.

However, both biochar un-inoculated treatments gave the highest negative efficiency at 0.5g. on F2N-29 eggplant cultivar. Meanwhile, the Balady eggplant cultivar showed the greatest negative effect at 2.0g. of both biochar treatments.

The disease known symptoms may be confused with the physiological disorders produced by biochar application on plant parameters in absence of any pathogenic involvement. These morphological – physiological effects were similar to symptoms caused by the pathogen and abide strictly with the early definition of disease.

Calabrese and Blain (2009) reported that biochar applied to soil as low concentration stimulate / high dose inhibition by chemicals, operates in a variety of plants. Chemicals from many classes, including phenols, carboxylic and fatty acids, aromatic compounds, hydrocarbons, and others, have been reported to be inverted U-shaped hermetic dose-response curves in plants.

Zimmerman (2010) recorded that the interaction between biochar and soil organisms and biochar addition to soils may influence native soil organic matter mineralization.

Cross and Sohi (2011) suggested that biochar toxicity that inhibited microorganisms were due to decreased substrate availability in the biochar-amended plots compared to the control or micropores adsorbed in the biochar's.

Jaiswal *et al*. (2014) mentioned that biochar's suppressive diseases caused by soil-borne pathogens *i.e*., *F. oxysporum* f. sp. *asparagi*, *F. oxysporum* f. sp. *radicis-lycopersici*, *F. proliferatum*, *Pythium aphanidermatum*, *Phytophthora cactorum*, *P. cinnamomi*, and *R. solani*) and found that phyto-toxic compounds in biochar, *i.e*., ethylene glycol and propylene glycol, hydroxy-propionic and butyric acids, benzoic acid, and o-cresol, quinones and 2 phenoxyethanol) may have direct damage in plant rots.

In the present study, the treatments had a significant effect on all plant growth parameters produced by biochars (non-activated and activated) at different concentrations (0.5, 1.0 and 2.0 g.).

Plant growth produced in presence of both biochar types (non-activated and activated) treatments under pathogen(s) stress increased shoot and root parameters at different concentrations applied (0.5 and 1.0 g.), while the higher concentration (2.0g.) decreased growth performance of both pepper and eggplant cultivars. Both biochar treatments, in the absence of mixture of pathogens have increased shoot and root length at different concentrations (0.5, 1.0, and 2.0 g.) of both pepper and eggplant cultivars compared to control.

Dry weight of shoot and root was increased significantly at different concentrations (0.5, and 1.0 g.), while the larger (2.0 g.) decreased dry weight, with both biochar treatments, under mixture of pathogen stress of both cultivars of pepper and eggplant candidates compared with control. Also, both biochar treatments alone have increased significantly dry weight (shoot and root) at different concentrations used (0.5, 1.0 and 2.0g.), with both pepper and eggplant cultivars.

Graber *et al*. (2010) found that biochar amendment increased plant height and leaf size of tomato and biomass and fruit yields of pepper, with low concentration of biochar. Changes in microbial community composition or activity induced by biochar application may not only affect nutrient availability and plant growth, but also the cycling of soil organic matter. Jeffery *et al*. (2015 a, b) observed that amending the soil with biochar increased crop productivity, soil fertility, interaction between crop with biochar types. Compared to other amendments, biochar is thought to be C-negative because it is derived from atmospheric CO_2 captured by plants, which is then diverted to the soil in a very stable form where it can remain for several years (Smith, 2016).

Kolb *et al*. (2009) recorded that increased concentrations of charcoal increase the populations of soil microbes as measured by their respiration activity. In addition, Liang *et al*. (2010) found that methane oxidation, C mineralization and nutrient transformations may increase or decrease in the presence of biochar. Also, Wang *et al.* (2014) reported that mechanism of biochar protective properties is absorption and detoxification of xenobiotics, phenolic compounds. Shigenaga and Argueso, (2016) observed that effect added of different kinds of biochar into soil increased microbial count in relative from genera such as *Pseudomonas*, *Bacillus* and *Trichoderma* whose produce compounds that inhibit pathogens and elicit phytohormones systemic plant resistance, *i.e*., indol-3-acetic acid (IAA, auxin), cytokinin, gibberellins, jasmonic acid (JA), salicylic acid (SA) and ethylene (ET).

Smith *et al*. (2010) reported that initial stage of fast mineralization has been noticed between 6 to 60 days, which depends on the biochar type, biochar application rate, and soil characteristics. Dempster *et al*. (2012) found that the limitation of N may have inhibited soil microorganisms to mineralize native soil organic matter substrates. Clough *et al*. (2013) mentioned that NO_3- adsorption only occurred in biochars produced at a temperature of at least 600°C, However, NH_4 + adsorption was dependent less of high pyrolysis temperatures.

CONCLUSION

In general, the low concentrations of biochar (0.5 and1.0 g.) either activated or non-activated improved percentage of plant growth and suppressed disease were stimulated directly by the concentrations of chemicals in the biochar and the possibility that the biochar stimulated the development of microorganisms which promoted plant growth negative or little. Meanwhile, large dosages of biochar (2.0g.), had effect on susceptible plants to the disease. Biochar applied to soil to determine suppression of soil-borne fungi and changes related to changes in soil microbial communities and densities must be studied as pilot experimentation under field conditions. The promotion of biochar application on soil antagonistic flora must be seriously considered.

CONFLICTS OF INTEREST

The authors declare no conflict of interest exists.

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