Egypt. J. Phytopathol., Vol. **43**, No. 1-2, pp. 25-39 (2015)

Impact of some Soil Amendments and Mycorrhiza on Cowpea Damping-Off Caused by *Rhizoctonia solani*

Nour El-Houda A. Reyad and M.F. Attia
Plant Pathol. Dept., Fac. Agric., Cairo Univ.

Addition of biochar to soil improves carbon sequestration, soil fertility and plant growth, especially when combined with organic compounds such as compost. This greenhouse study was carried out to examine the effects of soil amendments with biochar, compost and mycorrhiza as biofertilizer alone or in combinations on cowpea plant growth parameters and on suppression of damping-off disease caused by *Rhizoctonia solani*. *In vitro* experiment showed that biochar has no direct efficacy on the tested fungus even at the higher tested concentrations. A synergistic effect was noticed when cowpea plants were grown in soil amended with biochar in the presence of mycorrhiza. Also, results indicated that the tested soil amendments and mycorrhiza improved the growth parameters as well as macronutrient contents of cowpea.

Keywords: Compost, cowpea, mycorrhiza, rice straw biochar and macronutrients.

Seeking for new disease management strategies and improving agricultural systems has led to a number of creative ideas, including the pyrolysis of biomass residues (biochar) and their addition to the soil system (Paz-Ferreiro *et al*., 2015). The use of organic compounds such as biochar and compost might be a promising approach, as their suppressive effect has been shown for a wide range of soil borne diseases (Coventry *et al*., 2005 and Noble and Coventry, 2005).

Biochar is a carbon rich product of a heating process in an oxygen depleted environment known as pyrolysis (Sohi *et al.*, 2010; Elad *et al*., 2011 and Sparks, 2011). The type of organic material and heating temperature used for the production of biochar determine its nutrient contents and physicochemical properties (Antal and Gronli, 2003 and Gaskin *et al.*, 2008). A biochar addition to the soil may improve the physicochemical properties of soil like bulk density, water holding capacity, nutrient retention, soil pH and cation exchange capacity resulting into beneficial effects on plant growth (Glaser *et al.*, 2002; Steiner *et al.*, 2008 and Atkinson *et al.*, 2010). Biochar is very stable in soil with a half-life ranging up to thousands of years (Zimmerman, 2010). Recently, it has been reported that soil amended with biochar can influence the progress of plant diseases caused by both foliar and soil borne pathogens (Graber *et al.,* 2014).

Another soil amendment with known suppressive effects is compost. It is known to suppress a wide range of plant diseases caused by various soil-borne pathogens. This could be due to an enhanced competition and antagonism by the soil biota associated with increased microbial activity in soil (Pugliese *et al*., 2011).

Arbuscular mycorrhizal fungi (AMF) comprise a large portion of soil and rhizosphere microorganisms. AMF share symbiotic associations with many important plant species and affect soil borne pathogens (Whipps, 2004) as well as foliar necrotrophic pathogens like *Alternaria solani* (Fritz *et al.*, 2006).

Cowpea is the most important vegetable crop grown and consumed globally. Seeds of cowpea contain about 23% protein and 57% carbohydrate (Belane and Dakora, 2009). Cowpea plants are vulnerable to attack by damping-off and root-rot diseases caused by *Fusarium solani*, *Rhizoctonia solani*, *Macrophomina phaseolina*, *Sclerotium rolfsii* and *Pythium* sp. These diseases cause substantial losses to cowpea crop (Shihata and Gad El-Hak, 1989; Ushamalini *et al.*, 1993; Rauf, 2000; Satish *et al.,* 2000; El-Mohamedy *et al.,* 2006).

In the present study, the economically important pathosystem cowpea (*Vigna sinensis* Endl.) and *Rhizoctonia solani* were concerned. Thus, the effect of compost, biochar and mycorrhiza, either alone or in combinations, on the plant growth parameters and on disease suppression were studied.

Materials and Methods

1. Isolation, purification and identification of the fungi associated with cowpea damping-off:

Diseased cowpea seedlings, showing typical symptoms of damping-off, were collected from the Experimental Farm of the Fac. Agric., Cairo Univ.

For isolation, infected roots were washed thoroughly with tap water and cut into small fragments (0.5- 1.0 cm), superficially sterilized with 1% sodium hypochlorite for 3 min., then rinsed several times in sterilized water, blotted to dry between folds of sterilized filter papers. Small pieces were transferred onto PDA medium into Petri plates and incubated at 26±2°C for 7 days. Observations were daily recorded and emerged fungi were picked up and cultured on PDA medium slants and its frequencies were calculated. Fungal growth was microscopically examined and purified using the single spore and/or the hyphal tip techniques (Dhingra and Sinclair, 1985). Purified fungi were identified according to their morphological features, either to the generic or to the species level, according to Booth and Waterston (1964) and Barnett and Hunter (1972). The most frequent fungus was used *in vitro* and *in vivo* (pot experiments) after confirming its pathogenic capability.

2. Source of tested biochar, compost and AMF:

Rice straw biochar and Commercial compost were kindly obtained from Soil, Water and Environ. Res. Inst., Agric. Res. Centre, Giza, Egypt. The characteristics of compost and rice straw biochar are mentioned in Table (1). For AMF inoculation, mycorrhizen was utilized as a commercially available inoculum. This AMF inoculum was purchased from Soil, Water and Environ. Res. Inst., Agric. Res. Centre, Giza, Egypt.

3. Laboratory experiments:

3.1. Preparation of compost water extract (CWE):

The CWE was prepared by vigorously shaking of mature compost, at the ratio of 1 : 2 (w/v) of compost (500 g) to sterile water (1000 ml), for 20 min. To remove

Table 1. Selected characteristics of compost and rice straw biochar used in the present study

Tested compound	pH	Total carbon (%)	Total N (%)	Total P (%)	Total K (%)
Biochar	9.0	36.60	0.52	0.54	0.88
Compost	8.19	25.05	1.31	1.65	-

large particles from compost mixture, aliquot of 250 ml of the mixture were filtrated by passing through sterile 3 layers of cheese cloth and then the filtrate was centrifuged at 500 rpm for 10 min to obtain active supernatant as stock solution. Four different concentrations, *i.e*. 0, 5, 10 and 15%, were tested against the fungus.

3.1.1. Effect of biochar and compost on mycelium growth of Rhizoctonia solani:

The inhibitory effect of tested compost as water extract (CWE) was *in vitro* examined against the tested pathogenic fungus using the wells-cut diffusion method according to El-Masry *et al.* (2002). The CWE was filtered through 0.22 µm sterilized Millipore membrane filter. Fifteen ml of sterile PDA medium were used for each plate, one well was then punched out on one side of the plate using a sterile 0.5 cm cork borer, and the well bottom was sealed with two drops of sterile PDA medium. Hundred ml of each CWE concentration were separately transferred to each well. The sterile water was used as check. One disc (0.5 cm diameter) of 7-day-old culture of the tested fungus was placed on the other side of the plate against the well on the surface of PDA medium. Five Petri dishes were used as replicates for each treatment as well as the check. All plates were incubated at 25°C for 7 days and then the reduction in mycelium growth was recorded.

The direct toxicity of biochar was studied using an *in vitro* contact assay according to Jaiswal *et al.* (2015) to evaluate the reduction in *R. Solani* growth. PDA medium was amended with varying concentrations of biochar, *i.e*. 0, 0.5, 1, and 3 %, w:v, before autoclaving, and then dispensed into Petri dishes (9-cm-diam.). Agar plugs (5-mm-diam.), covered with actively growing mycelium, were transferred into the centre of Petri dishes amended with one of the four concentrations of biochar and then incubated at 25°C for 7 days, then the fungal mycelial growth was measured and the average diameter was calculated. The fungal growth inhibition was calculated using the following formula: I % = (C-T/C) x 100

Whereas; I= Reduction (%) in fungal growth; C= Fungal growth in the check and T= Fungal growth in the treatment.

4. Greenhouse experiments:

4.1. Effect of soil amendments (Compost, biochar and mycorrhiza) on disease suppression:

In order to determine the most effective concentrations of the tested compost and biochar, cowpea seeds (cv. Tiba), obtained from Agric, Res. Centre, Giza, Egypt, were surface disinfested in 2% sodium hypochlorite, rinsed in sterile distilled water and then 5 seeds were sown in each plastic pot (30-cm-diam.) filled with a sterilized mixture of sand and clay (2:1, v/v) containing compost at 0, 5, 10 and 15% w/w or biochar at 0, 0.5, 1 and 3%, w/w. One day later, the treated soil was individually infested with the tested fungal inoculum at the rate of 5% w/w, previously grown on sand barley medium (1/1, w/w and 40% water) at 25±2ºC for two weeks. Five randomly replicated pots were used for each treatment.

The most effective concentrations of the tested compost and biochar were selected to study their effect on the disease suppression when mixed together in the presence or absence of mycorrhiza. The sterilized cowpea seeds were coated with the AMF inoculum before sowing. The following treatments were used in the experimental setup:

1. Compost;
2. Biochar;
3. Mycorrhizen;
4. Compost + Biochar;
5. Compost + Mycorrhizen;
6. Biochar + Mycorrhizen;
7. Compost + Biochar + Mycorrhizen;
8. Rizolex-T;
9. Check.

Seeds were sown in April 15th, 2014 and 2015 seasons. All agricultural practices were carried out according to the recommendation of Ministry of Agric., Egypt. Complete randomized block design with five replicates was allocated.

4.1.2 Disease assessment.

Percentages of pre- and post- emergence damping-off as well as healthy survived plants were determined 15, 21 and 45 days after sowing, respectively, using the formula described by Mikhail *et al.* (2005) and Abd El-Moneim *et al.* (2012) as follows:

Pre-emergence (%)= Number of non-germinated seeds and/or dead seedlings before emergence/Total number of planted seeds x 100.

Post-emergence (%)= No. of dead seedlings after emergence/Total No. of planted seeds x 100

Survival efficacy (%)= 100 - (D2 / D1 X 100)

Whereas: D1= Damping-off (%) in check treatment.
D2= Damping-off (%) in treatment.

4.1.3 Effect of soil amendments (compost, biochar and mycorrhiza) on some parameters of cowpea plants:

The vegetative parameters of cowpea plants, *i.e*. plant height, root length, fresh and dry weights of leaves and roots, were determined 90 days after sowing. Random samples of cowpea plants representing each treatment were removed carefully from the pots, and then washed under running tap water to remove adhering particles.

Nitrogen and phosphorus contents were assayed according to Jackson (1973), where potassium content was determined using atomic absorption spectrophotometer (Barkin Elmer 3300) according to (Chapman and Pratt, 1961), the results were calculated as g/100g dry weight.

5. *Statistical analysis:*

Most of the data were statistically evaluated according to Snedecor and Cochran (1967). Averages were compared at 5% level of probability using the least significant differences (L.S.D.) as mentioned by Fisher (1948). On the other hand, percentages data were transformed to arcsines and then subjected to statistical analysis to determine the least significant differences (L.S.D.) to compare variance between treatments (Gomez and Gomez, 1984).

Results

1. Isolation, purification and identification of the fungi associated with cowpea damping-off:

Twenty five fungal isolates representing five species belonging to four genera, *i.e*. *Rhizoctonia solani* Kuhn (14 isolates), *Fusarium oxysporum* Schlecht (5 isolates), *F. solani* (Mart.) Appel & Wollenw (3 isolates), *Aspergillus niger* Tiegh (2 isolates) and *Pythium* sp. (1 isolate) were isolated from cowpea plants showing damping-off symptoms. Results in Table (2) indicate that the most dominant fungi were *R. solani* (56%) followed by *F. oxysporum* (20%) and *F. solani* (12%). Meanwhile, *A. niger* and *Pythium* sp. recorded less frequency.

Table 2. Frequency (%) of the isolated fungi from roots of cowpea seedlings showing damping-off symptoms

Isolated fungus	No. of isolates	Frequency (%)
Aspergillus niger	2	8
Fusarium oxysporum	5	20
Fusarium solani	3	12
Pythium sp.	1	4
Rhizoctonia solani	14	56
Total counts of fungi	25	-

2. Effect of biochar and compost on R. solani mycelium growth:

Data presented in Table (3) indicate that compost at 15% was the most effective on reducing mycelium growth of the tested fungus where it gave the highest mycelium reduction, being 54% compared to check. It is interesting to note that there were no significant differences among the biochar treatments at different tested concentrations and check treatment.

3. Effect of soil amendments (compost, biochar and mycorrhiza) on disease suppression:

This experiment was carried out to investigate the effect of compost and biochar at three different concentrations on the incidence of cowpea damping-off caused by *R. solani* under greenhouse conditions.

Table 3. Effect of different concentrations of compost and biochar on the radial growth of *R. solani* on PDA medium after 7 days incubation at 25°c

Treatment	Concentration (%)	Mycelium radial growth (mm.)	Reduction in the linear growth (%)
Compost	5	65.4	27.3
	10	58.8	34.7
	15	41.4	54.0
	Mean	55.2	38.7
Biochar	0.5	90.0	00.0
	1	90.0	00.0
	3	90.0	00.0
	Mean	90.0	00.0
Check		90.0	-
L.S.D $_{0.05}$		1.12	-

Data presented in Table (4) show that disease incidence (%) was significantly reduced by soil amendments with compost and biochar. Soil amended with compost at 15% was the most effective in reducing the percentage of pre- and post-emergence damping off, being 8 and 8%, respectively, compared to check treatment, being 32 and 24%, respectively. Biochar was more effective at concentrations of 1 and 3% without significant differences between them.

Table 4. Effect of different concentrations of compost and biochar on damping-off incidence caused by *R. solani* on cowpea plants (cv. Tiba) grown under greenhouse conditions

Treatment	Concentration (%)	Damping-off (%)		Survived plants (%)	Efficacy (%)
		Pre-	Post-		
Compost	5	24	16	60	28.6
	10	16	12	72	50.0
	15	8	8	84	71.4
	Mean	14.7	13.3	72	50.0
Biochar	0.5	32	24	44	00.0
	1	28	20	52	14.3
	3	28	20	52	14.3
	Mean	29.3	21.3	49.3	9.5
Check		32	24	44	-
L.S.D $_{0.05}$		0.44	0.34	-	-

Data presented in Table (5) show that all tested treatments significantly reduced the disease incidence compared to the check treatment. Rizolex-T showed the highest significant effect in decreasing the disease incidence (96% healthy survived plants and 93.3% efficacy in the first season as well as 88.0% healthy survived plants and 84.2% efficacy in the second season) followed by cowpea plants grown in soil amended with biochar in the presence of mycorrhizen (84% healthy survived

Table 5. Effect of compost, biochar and mycorrhiza alone or in combination on damping-off incidence caused by *R. solani* on cowpea plants (cv. Tiba) during 2014 and 2015 growing seasons under greenhouse conditions

Treatment	First season (2014) Damping-off (%)		Survived plants (%)	Efficacy (%)	Second season (2015) Damping-off (%)		Survived plants (%)	Efficacy (%)
	Pre-	Post-			Pre-	Post-		
Compost	24	8	68	46.7	20	20	60	47.4
Biochar	32	20	48	13.3	36	28	36	15.8
Mycorrhizen	16	12	72	53.3	20	12	68	57.9
Compost+ Biochar	24	16	60	33.3	32	16	52	36.8
Compost+ Mycorrhizen	20	4	76	60.6	20	12	68	57.9
Biochar+ Mycorrhizen	12	4	84	73.3	12	12	76	68.4
Compost+ Biochar+ Mycorrhizen	24	12	64	40.0	24	20	56	42.1
Rizolex-T	4	0	96	93.3	8	4	88	84.2
Check	36	24	40	-	44	32	24	-
L.S.D $_{0.05}$	2.21	2.31	-	-	1.81	2.04	-	-

plants and 73.3% efficacy in the first season as well as 76% healthy survived plants and 68.4% efficacy in the second season). Biochar alone was the least effective one, being 48.0% healthy survived plants and 13.3% efficacy in the first season as well as 36% healthy survived plants and 15.8% efficacy in the second season).

4. *Effect of soil amendments (compost, biochar and mycorrhiza) on some parameters of cowpea plants:*

Results presented in Tables (6 and 7) show significant enhancement of growth parameters of cowpea plants when soil was amended with compost, biochar and mycorrhizen, alone or in combinations, compared to the check treatment. Cowpea plants grown in soil amended with biochar in the presence of mycorrhizen showed the most positive effect on enhancement of plant growth parameters.

In both seasons, the best results of N, P, K values were obtained when soil was amended with biochar in the presence of mycorrhiza followed by mycorrhiza only as shown in Table (8). Biochar alone was the least effective one in comparison with check treatments.

Table 6. Agronomic characteristics of cowpea plants (cv. Tiba) as affected by compost, rice straw biochar and mycorrhizen alone or in combination during 2014 growing season, under greenhouse conditions

Treatment	Plant height (cm)	Root length (cm.)	Number/plant			Fresh weight (gm)		Dry weight (gm)	
			Leaves	Pods	Nodules	Leaves	Roots	Leaves	Roots
Compost	33.5	13.5	21.4	6.4	7.0	8.1	1.5	1.6	0.7
Biochar	29.7	12.0	18.8	6.2	5.4	6.4	1.4	1.0	0.6
Mycorrhizen	36.0	14.7	23.2	7.8	10.2	10.4	2.5	4.2	1.8
Compost+ Biochar	32.5	12.4	20.8	6.2	6.4	7.8	1.7	1.4	0.8
Compost+ Mycorrhizen	35.8	14.2	22.6	7.0	9.4	10.2	2.2	3.7	1.7
Biochar+ Mycorrhizen	38.5	16.5	24.6	8.8	10.2	11.8	3.2	4.2	1.8
Compost+ Biochar+ Mycorrhizen	34.0	13.0	22.2	7.0	7.2	8.2	2.1	3.2	1.6
Rizolex-T	27.2	10.7	17.4	5.2	4.2	5.7	1.4	0.4	0.6
Check	24.0	9.3	15.2	4.4	3.8	4.0	0.8	0.4	0.4
L.S.D. 0.05	5.4	3.5	3.3	1.8	4.0	1.3	1.7	0.6	0.4

Table 7. Agronomic characteristics of cowpea plants (cv. Tiba) as affected by compost, rice straw biochar and mycorrhizen alone or in combination during 2015 growing season, under greenhouse conditions

Treatment	Plant height (cm)	Root length (cm)	Number/plant			Fresh weight (gm)		Dry weight (gm)	
			Leaves	Pods	Nodules	Leaves	Roots	Leaves	Roots
Compost	33.5	13.5	21.4	6.4	7.0	8.1	1.5	1.6	0.7
Biochar	29.7	12.0	18.8	6.2	5.4	6.4	1.4	1.0	0.6
Mycorrhizen	36.0	14.7	23.2	7.8	10.2	10.4	2.5	4.2	1.8
Compost+ Biochar	32.5	12.4	20.8	6.2	6.4	7.8	1.7	1.4	0.8
Compost+ Mycorrhizen	35.8	14.2	22.6	7.0	9.4	10.2	2.2	3.7	1.7
Biochar+ Mycorrhizen	38.5	16.5	24.6	8.8	10.2	11.8	3.2	4.2	1.8
Compost+ Biochar+ Mycorrhizen	34.0	13.0	22.2	7.0	7.2	8.2	2.1	3.2	1.6
Rizolex-T	27.2	10.7	17.4	5.2	4.2	5.7	1.4	0.4	0.6
Check	24.0	9.3	15.2	4.4	3.8	4.0	0.8	0.4	0.4
L.S.D. 0.05	3.4	2.5	3.3	1.9	3.7	1.3	1.5	0.6	0.3

Table 8. Nitrogen, phosphorus and potassium uptake by cowpea plants cv. Tiba as affected by compost, biochar and mycorrhiza alone or in combination during 2014 and 2015 growing seasons under greenhouse conditions

Treatment	First season (2014)			Second season (2015)		
	N %	P %	K %	N %	P %	K %
Compost	2.4	0.5	1.6	2.3	0.6	1.6
Biochar	3.0	0.6	2.1	2.9	0.8	1.9
Mycorrhizen	2.1	0.4	1.5	1.9	0.5	1.4
Compost + Biochar	2.9	0.6	1.9	2.8	0.7	1.8
Compost + Mycorrhizen	2.6	0.5	1.8	2.2	0.5	1.5
Biochar + Mycorrhizen	3.3	0.7	2.1	3.1	0.8	2.1
Compost + Biochar + Mycorrhizen	2.7	0.6	1.8	2.4	0.7	1.8
Rizolex-T	1.7	0.3	1.5	1.8	0.4	1.3
Check	1.6	0.3	1.3	1.7	0.3	1.2
L.S.D.$_{0.05}$	0.14	0.03	0.05	0.08	0.05	0.05

D i s c u s s i o n

Biochar application not only affects the crop yield (Kloss *et al.*, 2014) but also has the ability to alter the plant response to disease stress (Graber *et al.*, 2014). It has been reported to affect the progress of different plant diseases caused by soil-borne pathogens, to now, in five distinct pathosystems: *Fusarium oxysporum* f.sp. *asparagi* on asparagus (Elmer and Pignatello, 2011 and Matsubara *et al.*, 2002), *Ralstonia solanacearum* on tomato (Nerome *et al.*, 2005), *Phytophthora* spp. on oak and maple (Zwart and Kim, 2012), *Rhizoctonia solani* on cucumber (Jaiswal *et al.*, 2014) and *F. oxysporum* f.sp. *lycopersici* on tomato (Akhter *et al.*, 2015), but there is no available information on the impact of biochar on the cowpea damping-off and root-rot diseases caused by *Rhizoctonia solani*. In comparison, many studies document a suppressive effect of organic amendments like compost and organic wastes against *R. solani* and other soil-borne pathogens (Borrero *et al.*, 2004; Bonanomi *et al.*, 2007 and Akhter *et al.*, 2015). This study is the first report on the effects of compost and biochar alone or in combination with an AMF application on cowpea plant growth and on the incidence and development of damping-off caused by *R. solani*.

In the presented investigation, *in vitro* study indicated that biochar has no direct toxicity effect on the tested fungus whereas compost extract had a greater effect on the reduction of the fungus mycelium growth. These results are, to somewhat, in harmony with those reported by Bonanomi *et al.* (2007); Elmer and Pignatello (2011); Jaiswal *et al.* (2014) and Gravel *et al.* (2015). Biochar amendments could also have an indirect effect on plant pathogen proliferation through stimulation of the naturally occurring microorganisms in the potting soil (Steinbeiss *et al.*, 2009; Atkinson *et al.*, 2010 and Elad *et al.*, 2010). In this regard, differences in plant response to soil amendment with biochar and/or compost in the presence of mycorrhizal fungi were noticed in the entire study. Soil amendment with biochar in the presence of mycorrhiza affected plant growth parameters as well as disease suppression. These results are in harmony with those obtained by Gravel *et al.* (2015) who reported that additional benefits could be observed if biochar amendments were used in combination with the beneficial microorganisms, such as mycorrhizae or other biological control agents. According to Warnock *et al.* (2007), the mechanisms in which biochar may influence the abundance and function of mycorrhizas included (a) alteration of soil physic-chemical properties; (b) indirect effects on mycorrhizae through effects on other soil microbes; (c) plant-fungus signalling interference and detoxification of allelochemicals on biochar; and (d) provision of refuge from fungal grazers. On the other hand Ogawa (1994) suggested that the porous structure of charcoal may create a favourable habitat for symbiotic microorganisms.

The efficacy of mycorrhiza - biochar complex on disease suppression was reduced when amended to soil containing compost. These results are in harmony with those obtained by Akhter *et al.* (2015) who observed a growth suppression of mycorrhizal plants in the biochar treatment already containing compost as an additional source of nitrogen. They revealed that this may be due to the carbon drainage to the fungal symbionts or a reduced availability of nutrients to the plants (Fitter, 1991; Johnson *et al.*, 1997 and Landis and Fraser, 2008).

The entire study showed an increase in plant parameters as well as macroelements, *i. e*. nitrogen, phosphorus, and potassium in cowpea plants grown in soil amended with biochar in the presence of mycorrhiza. This is might be due to alter the soil pH by addition of biochar and in turn affects the nutrient availability to plants. These results are not in agreement with those obtained by LeCroy *et al.* (2013) who demonstrated that the combined treatment of apple wood saw dust biochar and mycorrhizal fungi with additional nitrogen fertilizer decreased aboveground sorghum biomass even though biochar had a positive effect on the AMV root colonization in a greenhouse experiment. Moreover, they also noted a reduction in below ground sorghum biomass as well. Meanwhile, Yamato *et al.* (2006) reported an increase in the plant root amount after the application of charcoal. They revealed that to the amelioration of the soil chemical properties and the creation of an appropriate environment for root growth and AM fungal colonization. These different results might be due to the differences in the experimental conditions.

From the data of this study, it could be concluded that biochar alone has no suppression effect on cowpea damping-off diseases caused by *R. solani.* Meanwhile, it has a synergistic effect on mycorrhizal fungi and in turn in plant growth response and *R. solani* suppression. Future research must be focused in this direction.

References

Abd El-Moneim, Maisa, L.; Gad El-Mola, Manal M.H. and Gaafer, S.A.M. 2012. Effect of some bioagents on root-rot disease incidence on bean plants. *Egypt. J. Phytopathol.*, **40** (2): 113-129.

Akhter, A.; Ahmed, K.; Soja, G. and Steinkellner, S. 2015. Compost and biochar alter mycorrhization, tomato root exudation, and development of *Fusarium oxysporum* f.sp. *lycopersici*. Fron. *Plant Sci.*, **529** (6): 1-13.

Antal, M.J. and Gronli, M. 2003.Theart, science and technology of charcoal production. *Ind. Eng. Chem. Res*., **42**:1619-1640.

Atkinson, C.J.; Fitzgerald, J.D. and Hipps, N.A. 2010. Potential mechanisms for achieving agriculture benefits from biochar application to temperate soils: A review. *Plant Soil*, **337**: 1-18.

Barnett, H.L. and Hunter, B.B. 1972. *Illustrated Genera of Imperfect Fungi*. 3rd Ed. Burgess Publishing Co., Minneapolis, USA. 244pp.

Belane, A.K. and Dakora, F.D. 2009. Measurement of N_2 fixation in 30 cowpea (*Vigna unguiculata* (L) Walp.) genotypes under field conditions in Ghana using 15N natural abundance technique. *Symbiosis*, **48**: 47-57.

Bonanomi, G.; Antignani, V.; Pane, C. and Scala, F. 2007. Suppression of soil borne fungal diseases with organic amendments. *J. Plant Pathol*., **89**: 311-324.

Booth, C. and Waterston, J.M. 1964. *Fusarium solani*. C.M.I. Descriptions of Pathogenic Fungi and Bacteria N.29. CAB Internat. Commonwealth Mycol. Inst., Kew. Surrey, England.

Borrero, C.; Trillas, M.I.; Ordovas, J.; Tello, J.C. and Aviles, M. 2004. Predictive factors for the suppression of Fusarium wilt of tomato in plant growth media. *Phytopathology*, **94**: 1094-1101.

Chapman, H.D. and Pratt, F.P. 1961. *Methods of Analysis for Soils, Plants and Water*. Calif. Univ., USA. 309pp.

Coventry, E.; Noble, R.; Mead, A. and Whipps, J.M. 2005. Suppression of allium white rot (*Sclerotium cepivorum*) in different soils using vegetable waste. *Eur. J. Plant Pathol.*, **111**: 101-112.

Dhingra, O.D. and Sinclair, J.B. 1985. *Basic Plant Pathology Methods*. CRC Press, Inc., Florida, USA, 355pp.

Elad, Y.; Cytryn, E.; Harel, Y.M.; Lew, B. and Graber, E.R. 2011. The biochar effect: plant resistance to biotic stresses. *Phytopathol. Mediterr*., **50**: 335-349.

Elad, Y.; David, D.R.; Harel, Y.M.; Borenshtein, M.; Kalifa, H.B.; Silber, A. and Graber, E.R. 2010. Induction of systemic resistance in plants by biochar, a soil-applied carbon sequestering agent. *Phytopathology*, **100**: 913-921.

El-Masry, M.H.; Khalil, A.I.; Hassouna, M.S. and Ibrahim, H.A.H. 2002. *In situ* and *in vitro* suppressive effect of agricultural composts and their water extracts on some phytopathogenic fungi, *World J. Microbiol. and Biotechnol.*, **18** (6): 551-558.

Elmer, W.H. and Pignatello, J.J. 2011. Effect of biochar amendments on mycorrhizal associations and Fusarium crown and root-rot of asparagus in replant soils. *Plant Dis*., **95**: 960-966.

El-Mohamedy, R.S.R.; Abd Alla, M.A. and Badiaa, R.I. 2006. Soil amendment and seed bio-priming treatments as alternative fungicides for controlling root-rot diseases on cowpea plants in Nobaria Province. *Res. J. Agric. Biol. Sci*., **2** (6): 391-398.

Fisher, R.A. 1948. *Statistical Methods for Research Workers*. Oliver and Boyd. Edinburgh Tweeddale Court, London. 189pp.

Fitter, A.H. 1991. Costs and benefits of mycorrhizas: implications for functioning under natural conditions. *Experientia,* **47**: 350-355.

Fritz, M.; Jakobsen, I.; Lyngkjær, M.F.; Thordal-Christensen, H. and Pons-Kühnemann, J. 2006. Arbuscular mycorrhiza reduces susceptibility of tomato to *Alternaria solani*. *Mycorrhiza,* **16**: 413-419.

Gaskin, J.W.; Steiner, C.; Harris, K.; Das, K.C.; and Bibens, B. 2008. Effect of low-temperature pyrolysis conditions on biochar for agricultural use. *T. Asabe*., **51**: 2061-2069.

Glaser, B.; Lehmann, J. and Zech, W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal- a review. *Biol. Fertil. Soils,* **35**: 219-230.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley, Interscience Publication, NY, USA. 678pp.

Graber, E.R.; Frenkel, O.; Jaiswal, A.K. and Elad, Y. 2014. How may biochar influence severity of diseases caused by soil borne pathogens?. *Carbon Manag.,* **5**: 169-183.

Gravel, V.; Dorais, M. and Menard, C. 2015. Organic potted plants amended with biochar: Its effect on growth and Pythium colonization. *Can. J. Plant Sci*., **93**: 1227.

Jackson, M. 1973. *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi, India. 18pp.

Jaiswal, A.K.; Elad, Y.; Graber, E.R. and Frenkel, O. 2014. *Rhizoctonia solani* suppression and plant growth promotion in cucumber as affected by biochar pyrolysis temperature, feedstock and concentration. *Soil Biol. Biochem.,* **69**: 110-118.

Jaiswal, A.K.; Frenkel, O.; Elad, Y.; Lew, B. and Gra, B.L. 2015. Non-monotonic influence of biochar dose of bean seedling growth and susceptibility to *Rhizoctonia solani*: the “Shifted Rmax-effect”. *Plant and Soil,* 395 (1-2): 125-140.

Johnson, N.C.; Graham, J.H. and Smith, F.A. 1997. Functioning of mycorrhizal associations along the mutualism-parasitism continuum. *New Phytol*., **135**: 575-585.

Kloss, S.; Zehetner, F.; Wimmer, B.; Buecker, J.; Rempt, F. and Soja, G. 2014. Biochar application to temperate soils: effects on soil fertility and crop growth under greenhouse conditions. *J. Plant Nutr. Soil Sci.*, **177**: 3-15.

Landis, F.C. and Fraser, L.H. 2008. A new model of carbon and phosphorus transfers in arbuscular mycorrhizas. *New Phytol*., **177**: 466-479.

LeCroy, C.; Masiello, C.A.; Rudgers, J.A.; Hockaday, W.C. and Silberg, J.J. 2013. Nitrogen, biochar and mycorrhizae: alteration of the symbiosis and oxidation of the char surface. *Soil Biol. Biochem.*, **58**: 248-254.

Matsubara, Y.; Hasegawa, N. and Fukui, H. 2002. Incidence of Fusarium root-rot in asparagus seedlings infected with arbuscular mycorrhizal fungus as affected by several soil amendments. *J. Japan Soc. Hort. Sci*., **71**: 370-374.

Mikhail, H.K.; Sabet, K.K.; Mohamed, Maggie E.; Kenawy, Mona H.M. and Kasem, K.K. 2005. Effect of compost and macronutrients on some cotton seedling diseases. *Egypt. J. Phytopathol*., **33** (2): 41-52.

Nerome, M.; Toyota, K.; Islam, T.; Nishijima, T.; Matsuoka, T. and Sato, K. 2005. Suppression of bacterial wilt of tomato by incorporation of municipal biowaste charcoal into soil. *Soil Microorg*., **59**: 9-14.

Noble, R. and Coventry, E. 2005. Suppression of soil-borne plant diseases with composts: A review. *Biocontrol Sci. Technol*., **15**: 3-20.

Ogawa, M. 1994. Symbiosis of people and nature in the tropics. *Farming Japan*, **28**: 10-34.

Paz-Ferreiro, J.; Liang, C.; Fu, S.; Mendez, A. and Gasco, G. 2015. The effect of biochar and its interaction with the earthworm *Pontoscolex corethrurus* on soil microbial community structure in tropical soils. *Plos One*., **10** (4): e0124891. http//dx.doi.org/10.1371/journal. pone.0124891.

Pugliese, M.; Liu, B.; Gullino, M.L. and Garibaldi, A. 2011. Microbial enrichment of compost with biological control agents to enhance suppressiveness to four soil-borne diseases in greenhouse. *J. Plant Dis. Protect*., **118**: 45-50.

Rauf, B.A. 2000. Seed borne disease problems of legume crops in Pakistan. *Pak. J. Sci. and Indust. Res.*, **43**: 249-254.

Satish, L.; Uday, B.; Lodha, S. and Burman, U. 2000. Efficacy of composts on nitrogen fixation, dry root-rot (*Macrophomina phaseolina)* intensity and yield of Legumes. *Ind. Agric. Sci.*, **70**: 846-849.

Shihata, Z.A. and Gad El-Hak, A. 1989. Cowpea wilt and root-rot diseases in El-Minia, Egypt. *Assiut J. Agric. Sci*., **20**: 159-171.

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical Methods*. 6th Ed. The Iowa State University Press, Ames, Iowa, USA.

Sohi, S.; Krull, E.; Lopez-Capel, E. and Bol, R. 2010. A review of biochar and its use and function in soil. *Adv. Agron*., **105**: 47-82.

Sparks, D.L. 2011. *Advances in Agronomy*. Vol. **112**. San Diego, CA, Academic Press.

Steinbeiss, S.; Gleixner, G. and Antonietti, M. 2009. Effect of biochar amendment on soil carbon balance and soil microbial activity. *Soil Biol. Biochem*., **41**: 1301-1310.

Steiner, C.; Glaser, B.; Teixeira, W.G.; Lehmann, J.; Blum, W.E.H. and Zech, W. 2008. Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal. *J. Soil Sci. Plant Nutr*., **171**: 893-899.

Ushamalini, C.; K. Rajappan and Gangadhran, K. 1993. Management of charcoal rot of cowpea using bio-control agent and plant products. *Ind. Phytopathol*., **50** (4): 504-507.

Warnock, D.D.; Lehmann J.; Kuyper, T.W. and Rillig, M.C. 2007. Mycorrhizal responses to biochar in soil concepts and mechanisms. Pages: 9-20. In: *Plant and Soil*. http://www.springer.com/conte nt/qw2jg522346226t6/fulltext.pdf

Whipps, J.W. 2004. Prospects and limitations for mycorrhizas in biocontrol of root pathogens. *Can. J. Bot*., **82**: 1198-1227.

Yamato, M.; Yasuyki, O.; Irhas, F.W.; Saifuddin, A. and Makoto, O. 2006. Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. Masahide. *Soil Sci. and Plant Nutr.*, **52**: 489-495.

Zimmerman, A.R. 2010. Abiotic and microbial oxidation of laboratory-produced black carbon (biochar). *Environ. Sci. Technol*., **44**: 1295-1301.

Zwart, D.C. and Kim, S.H. 2012. Biochar amendment increases resistance to stem lesions caused by *Phytophthora* spp. in tree seedlings. *Hort. Sci*., **47**: 1736-1740.

(Received 01/03/2015;
in revised form 12/04/2015)

تأثير إضافة الكمبوست والبيوشار والميكوريزا إلي التربة الزراعية على مرض سقوط بادرات اللوبيا المتسبب عن الفطر *Rhizoctonia solani*

نورالهدى عبد التواب رياض و محمد فاروق عطية
قسم أمراض النبات - كلية الزراعة - جامعة القاهرة .

تؤدي إضافة البيوشار إلي التربة الزراعية إلي زيادة خصوبة التربة وتحسين صفات النمو بالنسبة للنبات ، خاصة عندما يخلط مع المواد العضوية والكائنات النافعة مثل الميكوريزا. هذه الدراسة نفذت داخل الصوبة الزجاجية بغرض دراسة تأثير إضافة كلا من الكمبوست و البيوشار والميكوريزا كمعاملات فردية وكذلك في مخاليط متبادلة علي الصفات المحصولية لنبات اللوبيا وكذلك علي خفض الإصابة بمرض سقوط البادرات الناتج عن الفطر ريزوكتونيا سولاني. ولقد أظهرت الدراسة أن البيوشار ليس له تأثير سام على الفطر باستخدام التركيزات العالية تحت ظروف المعمل ، في حين لوحظ تأثيره المشجع عند زراعة النباتات في أصص تحتوي علي البيوشار في وجود الميكوريزا. وأشارت النتائج أيضاً إلى أن الإضافات المختبرة والميكوريزا أدت إلى تحسين الصفات المحصولية لنبات اللوبيا وكذلك محتواه من العناصر الغذائية.