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Rice Straw and Peanut Residues Biochars as Eco-Friendly Approaches for Controlling Root-Knot Nematode, *Meloidogyne incognita* Infecting Eggplant

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ABSTRACT

Biochar is a vital carbon complex and can improve plant growth and suppress of soil-borne pathogens. Root-knot nematode, *Meloidogyne incognita* is identified as one of the most demoralizing pests blighting roots of many crops and lead to notable decrease in their productivities. So, the present study was carried out with a hypothesis that the application of biochar from various feed-stocks may cause significant enhancements in the tolerance of eggplant for *M. incognita* infection. Two types of biochars were manufactured by the slow pyrolysis process of rice straw and peanut residues. A pot experiment was conducted to explore the effects of rice straw biochar (RSB) and peanut residues biochar (PRB) on *M. incognita* and the growth and yield performances of eggplant in loamy soil. Eight treatments were achieved in the current experiment, resulted from the combination between RSB and PRB at four applied rates [zero =no addition, 5.25, 10.5 and 21 g/pot, which were equated to 0, 5, 10 and 20 t/ha, respectively]. Treatments were arranged in a randomized complete block design (RCBD) and with five replicates. The individual incorporation of RSB and PRB at rates of 5.25, 10.5, and 21 g/pot exhibited significant enhancements in growth parameters (length, fresh and dry weight of shoots and roots), and productivity of eggplant. Application of RSB or PRS at 21 g/pot caused superior impacts in enhancing the fresh fruit yield of eggplant (946 and 1012 g/pot). Soil pH increased after applications of RSB and PRB from 5.85 in the control treatment to 6.12-6.39 and 6.28-6.75, respectively. Both RSB and PRB revealed variable degrees in lessening numbers of egg masses and galls/root system and J2/250 g soil of *M. incognita* and this caused marked improvements in eggplant growth parameters in comparison to the control. The use of high doses of RSB and PRB was responsible for larger efficiency in declining the above-mentioned *M. incognita* parameters than their low rates. The largest declines in galls/ root system (80 and 93%), egg-masses/ root system (90 and 96%), egg/egg-mass (76 and 90%) and J2/250g soil (83 and 92%) at 50 and 90 days after transplanting (DAT) were shown after application of PRB at a rate of 21 g/pot. This study indicated that RSB and PRB can be used as effective materials in dropping the harmful effects of *M. incognita* and also can be recommended as eco-friendly alternatives to synthetic pesticides with marked nematicidal activity to control *M. incognita* infection.

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INTRODUCTION

The phyto-parasitic nematode is one of the main harmful diseases and a threat to numerous agricultural crops (Mostafa *et al.*, 2018; Eche and Okafor2020). Generally, root-knot nematodes (RKNS) are responsible for enormous qualitative and quantitative harm to these crops. The infection of crops with RKNS causes about 125-157 billion dollars losses every year in the world, especially under subtropical and tropical regions (Ali et al. 2015 and 2017; Ibrahim *et al.*, 2018 a; Arshad *et al.*, 2020; Eche and Okafor 2020). RKNS, (*Meloidogyne spp*.) are intensively dispersed in developing countries and lead to noticeable decreases in growth and productivity (yield) of different crops. Among all RKNS, *Meloidogyne incognita* is the most precarious and damaging species of nematodes with great losses reach about 80% in greatly infected fields (Kshetrimayum and Das 2015; Arya 2016; Xiao *et al.,* 2016; Asif *et al.,* 2017; Karuri *et al.,* 2017). Moreover, it can parasitize most of the crops under greenhouses and field conditions (El-Sherif *et al.*, 2016; Radwan *et al.*, 2017).

The chemical management for *M. incognita* is the most sought and effective method till the latest years because of its immediate and rapid effects. There is an increasing awareness noticed due to the use of nematicides and they have commonly inhibited from the market as a result of their harmful effects on beneficial soil microorganisms, environment, human health and non-target organisms (Gad and Sergany 2017; Wang *et al.,* 2019). So, the enactment of ecological and harmless approaches, which are safe through decreasing the usage of nematicides against *M. incognita* is highly and urgently requested. Organic amendments are safe and ecofriendly materials with promoted effects on soil chemical and physical properties such as structure and fertility and also on plant growth. Moreover, these materials can be used as a good strategy to manage different plant diseases in soils, and they have direct or indirect impacts in declining of the plant-parasitic nematode residents to levels below damage thresholds and in the same time enhance the evolution of microbial antagonists of nematodes (El-Sherif et al. 2105; Xiao et al. 2016; Gad and Sergany, 2017; Jothi and Poornima 2017; Radwan *et al.,* 2017; Wang *et al.,* 2019).

Biochar is a dissimilar material produced through the pyrolysis process (thermal process) of organic biomass at high temperatures reaching 200 to 900°C in the presence of low (limited) oxygen content or under zero oxygen accessibility in a special type of furnace. Biochar contains huge quantities of carbon with an important role in the global carbon cycle and can improve soil functions and plant growth (Gao *et al.,* 2016; Usman *et al.,* 2016; Hussain *et al.,* 2017; El-Naggar *et al.,* 2019; Moahmed *et al.,* 2019; Sashidhar *et al.,* 2020). Moreover, the Incorporation of biochar into the soils has significant effects on soil chemical and physical properties and its application is recommended as a long-term technique for carbon impounding in soils, which is markedly reduced carbon emission and losses. Furthermore, it can enhance water holding capacity, pore size, aeration, and microbial activities. Biochar application improves organic matter contents in the soils and this leads to noteworthy promotion and accumulation in soil microbes, which may cause antagonistic influences on parasitic nematodes (Onkendi *et al.,* 2014; Graber *et al.,*2014; Bonanomi *et al.,* 2015; Huang *et al.,* 2015; George et al. 2016; Frenkel et al. 2017; Cao et al. 2018; Arshad et al. 2020; Liu *et al.,* 2020). Many studies have been conducted to determine the influence of biochar as an amendment to improve soil properties and crops production but limited investigations have studied its effect on plant-parasitic nematodes (Ibrahim *et al.,* 2018 a; Arshad et al. 2020; Eche and Okafor 2020). Therefore, the objective of the present study aims to evaluate the potential impacts of two types of biochar (rice straw and peanut residues) as soil amendments for the management of *M. incognita* infecting eggplant.

MATERIALS AND METHODS

Experimental Site:

The study was carried out at the experimental greenhouse of Wuhan Botanical Garden (WBG), Wuchang District, Wuhan City (Latitude 30°32’ 23.99’’ N, Longitude 114°24’ 26.99’’ E), Hubei Providence, China. The location had a subtropical moist monsoon climate zoon with four distinct seasons. The annual rainfall in Wuhan was 1485 mm and the average temperature ranged between 20 to 30°C with 78%.

Soil Samples Collection:

Soil samples at a depth of 0-30 cm were collected from the experimental farm of WBG. The soil was loamy (sand=45.23%, silt=37.03% and clay=18.74%) and characterized with pH of 5.89, EC of 1.56 dS m^{-1}, organic matter (OM) of 21.87 g kg^{-1}, available N of 41.91 mg kg^{-1}, P of 15.62 mg kg^{-1} and K of 147.35 mg kg^{-1}. The obtained soil samples were mixed well and air-dried for a week and kept for further use.

Collection of Feed Stocks (Plant Residues):

Two plant residues (rice straw and peanut wastes) were collected from an agricultural farm near Wuhan Botanical Garden, Wuhan, Hubei, China. These residues were cut into small parts (1-2 cm), arranged to air (sun) drying process for seven days and then dried at 60-70 °C in an electric oven for two days. Consequently, dried plant materials were grind, sieved and finally kept in a plastic container to produce the biochars later.

Biochars production:

The dried plant wastes (rice straw=RSB and peanut residues= PRB) were slow pyrolyzed at 400-450 °C under low oxygen in a laboratory setup Muffle furnace according to the protocol designated by Xie et al. (2010). The produced biochar was cooled and manually crushed into powder and then passed through a 2 mm sieve. The sieved samples of biochar were saved for chemical analysis and experimental use.

Growing of eggplant seeds:

Eggplant seeds were collected from a commercial seeds market and then sterilized by soaking them under aseptic conditions in ethanol (70%) and sodium hypochlorite (0.2% v/v) for 1-2 min and 5-10 min, respectively. The sterilized seeds were sowed in peat moss media enriched with nutrients solutions to get the required seedlings for the pot experiment.

Soil and Biochar Analysis:

Soil pH was measured in a soil-water suspension (1:2.5, soil: water ratio), while the electrical conductivity was determined in the soil paste. Also, soil organic carbon, available nitrogen (AN), phosphorus (AP) and potassium (AK) were determined according to the methods of page et al. (1982). The values of soil pH, EC, OM, AN, AP and AK were 5.89, 1.98 dS m^{-1}, 21.8 g kg^{-1}, 32.5 mg kg^{-1}, 16.3 mg kg^{-1} and 124.7 mg kg^{-1}, respectively. The Chemical properties of the produced biochar in this study (RSB and PRB) were estimated according to methods described by van Zwieten et al. (2010). Values of pH, EC, organic carbon, total N, P and K were 8.87, 3.28 dS m^{-1}, 58%, 0.84%, 0.31% and 1.29% in RSB, were 9.16, 2.74 dS m^{-1}, 49%, 1.57%, 0.45% and 2.36%, respectively.

Nematode Inoculum:

Root-knot nematode (RKN), *Meloidogyne incognita* was isolated from infected roots of eggplant (*Solanum melongena* L.) obtained from a farm near to the experimental greenhouse of WBG. The chosen species of RKN in this study was recognized by the female perineal patterns as described by the method of Taylor and Netscher (1974). The galled roots were carefully separated from the collected plants and washed by a slow stream of tap water to remove the soil particles through a 90 µm sieve. The infected roots were cut into small pieces and placed in 1.5 % sodium hypochlorite (NaOCl) solution and stunned for 3 minutes to disband the gelatinous matrix and then getting eggs of *M. incognita* from the mass matrices (Hussey and Barker, 1973) on a 25 µm (500-mesh) sieve. The collected eggs were quietly washed with distilled water before the infection process of eggplant seedlings in the experimental pots. The number of *M. incognita* eggs in the infection solution was determined by a Doncaster counting dish under a stereomicroscope.

Pot Experiment:

Rice straw and peanut residues biochars were used as soil amendments in this study to evaluate their effects against *M. incognita* on eggplant under greenhouse conditions. Each biochar type was incorporated into a loamy soil at four rates (0, 5.25, 10.5 and 21 g/pot) and left for three weeks before transplanting to ensure the proper decomposition of the additives. All treatments were replicated five times and organized in a complete randomized block design. Two eggplant seedlings (30 days old) were transformed on 25th March 2015 to be cultivated in each experimental pot that contained 5 kg sterilized soil. After that, 20 ml contained 5000 eggs of *M. incognita* were inoculated in each pot after seven days from the transplanting process of eggplant seedlings by making three holes with a glass rod in the soil near the root zone without damaging the root system. Plants were regularly irrigated and received the recommended dose of N, P and K fertilizers in the form of urea, calcium superphosphate and potassium sulfate. The temperature degrees of the greenhouse during the experiment were ranged from 20-35 °C. Numbers of galls and egg-mass /root system were recorded according to Barker (1985). The number of eggs/egg masses was counted after setting the egg masses in NaOCl solution (1%) and reserved for 7-10 minutes (Hussey and barker, 1973). The 2nd phase juveniles (J2)/250 g soil were extracted through Cobb's sieving followed by Baermann's funnel technique and counted under a stereomicroscope. Nematoda parameters were recorded two times at 50 and 90 days after transplanting (DAT). At the end of the experiment (25th June 2015), the plants were removed gently from the pots and the roots were separated carefully and washed with tap water to isolate soil particles. Also, soil pH, plant length, fresh weight and dry weight of shoots and roots of eggplant, number of eggplant fruits per plant, and fresh and dry weight of eggplant fruit were recorded.

Statistics Analysis:

The statistical analysis was performed according to the SAS program (SAS Institute, 1998). Results of the present work were subjected to the analysis of variance test (ANOVA) as a completely randomized block design (RCBD) followed by the least significant difference (LSD) test to determine the significant differences among means at the probability level of 0.05.

RESULTS AND DISCUSSION

Effect of Different Biochars on Growth and Yield of Eggplant:

The growth (fresh and dry weight of shoots and roots) and yield (fresh and dry weight of fruits) parameters of eggplant were determined after application of different types and rates of biochars in an acidic soil infected with *M. incognita*. The impact of PRS was higher than that of RSB and the use of 21 g/pot of RSB or PRB was more efficient in increasing the shoot length of eggplant than other rates (5.25 and 10.5 g/pot). Significant increases were recorded in the shoot length of eggplant by 24.89, 53.39 and 78.45% after application of rice straw biochar (RSB) and by 36.43, 66.36 and 100.19% when the soil was treated with peanut residues biochar (PRB) at rates of 5.25, 10.5 and 21 g/pot (**Table 1**). The effect of RSB and PRB on fresh and dry weights of eggplant shoots was presented in **Table 2**. Fresh and dry weights of the shoots significantly increased from 102.4 and 22.84 g/pot in the control (no biochar application) to 128.5 and 29.81 g/pot and to 165.7 and 37.12 g/pot as a result of 5.25 and 10.5 g RSB/pot applications, while in the case of 5.25 and 10.5 g PRB/pot applications, they enhanced to 142.1 and 31.97 g/pot, and to 186.9 and 43.17 g/pot, respectively. The highest fresh weights (194.2 and 224.3 g/pot) and dry weights (47.19 and 51.14 g/pot) of eggplant were recorded when the soil received the highest rate of RSB and PRB (21 g/pot).

Table 1: Effect of RSB and PRB on shoot length (cm) of eggplant grown in a loamy soil infected with *M. incognita*

Treatments	Shoot length
Zero Biochar	50.81 e
5.25 g/pot RSB	63.46 d
10.5 g/pot RSB	77.94 c
21.0 g/pot RSB	90.67 b
5.25 g/pot PRB	69.32 d
10.5 g/pot PRB	84.53 b
21.0 g/pot PRB	101.7 a

DAT= Day after transplanting. RSB= Rice straw biochar and PRB= Peanut residues biochar. Different letters within the same column indicated significant differences between treatments.

Data demonstrated in Table 2 indicated that all RSB and PRB treatments at their applied rates (5.25, 10.5 and 21 g/pot) were effective in increasing fresh and dry weights of eggplant roots. The lowest values (49.81 and 13.55 g/pot) of fresh and dry weights of eggplant roots were noticed in the control treatment. On the other hand, their maximum values (95.67 and 28.22 g/pot, and 103.4 and 30.91 g/pot) were found in soil incorporated with 10.5 g/pot RSB and 10.5 g/pot PRB, respectively. The effect of different rates of RSB and PRB on the yield of eggplant (fresh and dry weights of the fruits) was presented in Table 3. The outcomes of our study verified that the yield of eggplant was considerably improved in all RSB and PRB treatments, including 5.25, 10.5 and 21 g of each biochar type/pot. Fresh and dry yields of eggplant fruits were 359 and 55.29 g/pot and then prominently increased to 724 and 112.2 g/pot, and to 765 and 121.6 g/pot as results of RSB or PRB applications at a rate of 5.25 g/pot. While at the rate of 10.5 g/pot for RSB and PRB, fresh and dry yields of eggplant fruits reached 873 and 140.6 g/pot, and 927 and 147.4 g/pot, respectively. The use of the highest rates of RSB and PRB (21 g/pot) was significantly responsible for the greatest fresh yield (946 and 1012 g/pot) dry yield (149.5 and 163.9 g/pot) for eggplant fruits.

Table 2: Effect of RSB and PRB on fresh and dry weights (g) of shoots and roots of eggplant grown in a loamy soil infected with *M. incognita*

Treatments	Shoot		Root	
	Fresh weight	Dry weight	Fresh weight	Dry weight
Zero Biochar	102.4 g	22.84 e	49.81 f	13.55 e
5.25 g/pot RSB	128.5 f	29.81 d	63.75 e	17.98 d
10.5 g/pot RSB	165.7 d	37.12 c	83.63 c	22.57 bc
21.0 g/pot RSB	194.2 b	47.19 ab	95.67 b	28.22 a
5.25 g/pot PRB	142.1 e	31.97 d	70.18 d	20.77 cd
10.5 g/pot PRB	186.9 c	43.17 b	88.92 c	24.99 b
21.0 g/pot PRB	224.3 a	51.14 a	103.4 a	30.91 a

DAT= Day after transplanting. RSB= Rice straw biochar and PRB= Peanut residues biochar.
Different letters within the same column indicated significant differences between treatments.

Table 3: Yield (g) of eggplant as affected by RSB and PRB in a loamy soil infected with *M. incognita*

Treatments	Fresh	Dry
Zero Biochar	359 f	55.29 f
5.25 g/pot RSB	724 e	112.2 e
10.5 g/pot RSB	873 c	140.6 c
21.0 g/pot RSB	946 b	149.5 b
5.25 g/pot PRB	765 d	121.6 d
10.5 g/pot PRB	927 b	147.4 b
21.0 g/pot PRB	1012 a	163.9 a

DAT= Day after transplanting. RSB= Rice straw biochar and PRB= Peanut residues biochar.
Different letters within the same column indicated significant differences between treatments.

Effect of Different Biochars on *M. incognita* Indicators:

Both RSB and PRB at their different applied rates had a significant perspective in dropping eggmasses/root system and egg/egg-mass as compared to untreated pots (control) after 50 and 90 days from the transplanting process (DAT) of eggplant seedlings (**Table 4**). The effect of PRB was more efficient than that of RSB and increasing their applied rates from 5.25 to 21 g/pot showed noticeable influences in suppressing the above-mentioned items. Data indicated that the highest treatments, which diminished egg-masses/root system, were 21 g RSB /pot or 21 g PRB /pot with marked decline percentages of 71.01 and 89.86% at 50 DAT and 88.57 and 96% at 90 DAT. On the other hand, the treatments of 5.25 g/pot RSB or 5.25 g/pot PRB recorded the less decrease percentage of egg-masses/root system by 38.41 and 66.66% at 50 DAT, and 66.86 and 82.29% at 90 DAT. The treatments of 10.5 g RSB /pot or 10.5 g PRB /pot were ordered between the highest and the lowest treatments, and they decreased the numbers of egg-masses/root system in eggplant roots by 57.25-78.98% and 81.71-91.43% at 50 and 90 DAT, respectively. Significant reductions in egg/egg-mass of *M. incognita* by 37.07-61.25%, 54.42-76.71% and 65.81-82.78% were recorded in soil treated with 5.25, 10.5 and 21 g RSB/pot, and by 63.58-81.41%, 72.36-88.65% and 76.35-90.22% were noticed when the soil mixed with 5.25, 10.5 and 21 g PRB/pot, respectively.

Table 4: Effect of different biochar treatments on egg/egg-mass and egg-masses/root system of *M.incognita* infecting eggplant

Treatments	Egg-masses /root system		Egg/egg-mass	
	50 DAT	90 DAT	50 DAT	90 DAT
Zero Biochar	138 a	175 a	351 a	511a
5.25 g/pot RSB	85 b	58 b	221 b	198 b
10.5 g/pot RSB	59 c	32 c	160 c	119 c
21.0 g/pot RSB	40 e	20 d	120 d	88 d
5.25 g/pot PRB	46 d	31 c	128 d	95 d
10.5 g/pot PRB	29 f	15 d	97 e	58 e
21.0 g/pot PRB	14 g	7 e	83 f	50 f

DAT= Day after transplanting. RSB= Rice straw biochar and PRB= Peanut residues biochar.
Different letters within the same column indicated significant differences between treatments.

Numbers of gall/root system gall/root and J2/250 soil were also significantly ($p \leq 0.05$) affected by RSB and PRB and their different applied rates in comparison to the control treatment (Table 5). Gall numbers in eggplant roots declined at 50 and 90 DAT from 195-287 in the control treatment to 99-86, 64-51, and 46-38 due to the application of RSB at rates of 5.25, 10.5 and 21 g/pot, while they reduced to 69-55, 51-40 and 39-20 as results of 5.25, 10.5 and 21 g PRB additions/pot, respectively. Pots mixed with 21 g RSB /pot or 21 g PRB /pot showed the highest diminutions in J2/250 g soil of *M. incognita* (59.38-66.21% and 79.25-83.92%), whereas the lowest decreases (41.17-66.78% and 49.18-74.13%) were found in 5.25 g RSB/pot and 5.25 g PRB/pot PRB at 50 and 90 DAT, consistently. Moreover, these reductions in J2 numbers of *M. incognita*/250 g soil were 53.37-62.84% at 50 DAT and 75.41-80.65% at 90 DAT after treating the experimental containers with 10.5 g RSB/pot or 10.5 g PRB/pot, correspondingly.

Table 5: Effect of different biochar treatments on gall/root system and J2/250 g soil of *M. incognita* infecting eggplant

Treatments	Gall/root system		J2/250 g soil	
	50 DAT	90 DAT	50 DAT	90 DAT
Zero Biochar	195 a	287 a	549 a	858 a
5.25 g/pot RSB	99 b	86 b	323 b	285 b
10.5 g/pot RSB	64 c	51 c	256 d	211 c
21.0 g/pot RSB	46 d	38 d	223 e	178 d
5.25 g/pot PRB	69 c	55 c	279 c	222 c
10.5 g/pot PRB	51 d	40 d	204 f	166 d
21.0 g/pot PRB	39 e	20 e	186 g	138 e

DAT= Day after transplanting. RSB= Rice straw biochar and PRB= Peanut residues biochar.
Different letters within the same column indicated significant differences between treatments.

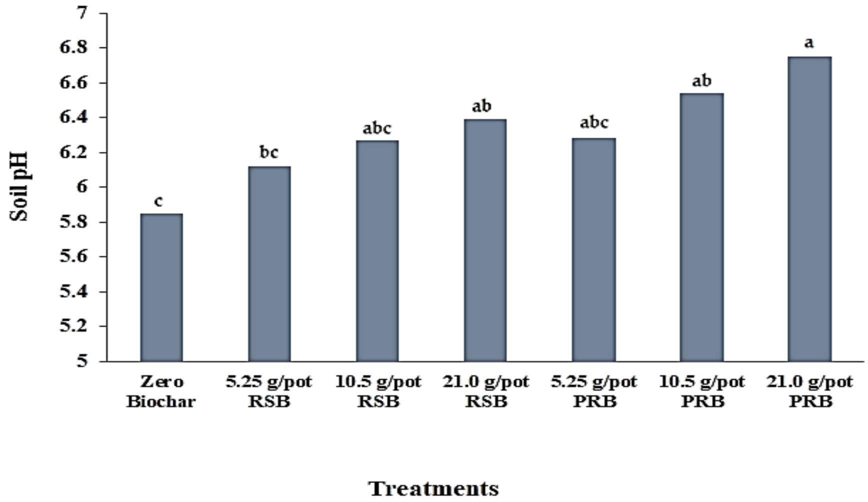

Fig. 1: Soil pH at the end of the experiment as affected by different biochar treatments RSB= Rice straw biochar and PRB= Peanut residues biochar. Different letters indicated significant differences between treatments.

Incorporation of some indigenous organic amendments in the soil caused significant suppression in *M. incognita* and promoted the plant growth due to releasing of available nutrients and some certain phytochemical ingredients such as ammonia, organic acids and fatty acids from their decomposition process in the soil (Arshad *et al.*, 2020). These materials encouraged the tolerance of plants to nematodes by forming inappropriate conditions around the roots. Moreover, they had nematicidal and toxic impacts and could inhabit the infection of plants with nematodes (Ibrahim *et al.,* 2018 a, b). The application of organic amendments or wheat straw biochar could be used as a logical reason to explain their negative effects on parasitic nematodes due to the increase of free-living (useful) nematodes (Bacterivores and Fungivores) (Oka, 2010; Zhang *et al.*, 2013). Also, it was mentioned by Elad *et al.* (2010) and Bonanomi et al. (2015) that biochar mixing with the soil under field or pot experiments might motivate the resistance system in the plants against different nematodes through modification soil quality by enhancing populations of the beneficial microbes (bacteria, fungi, actinomycetes and yeasts). The marked reductions in numbers of galls, egg masses and J2 of *M. incognita* might also result from the increase of soil pH after application of RSB and PRB (Fig. 1). Our results are in agreement with many investigations such as Ibrahim *et al.* (2018 a) who demonstrated the influence of biochar produced from shea nutshell on root-knot nematodes and the performance of tomato in Alfisol soil. They showed that shea nutshell biochar increased soil pH, diminished galls and egg masses and then declined the adversarial impacts of *Meloidogyne spp.* on the growth and yield of tomatoes. Moreover, Ansari *et al.* (2020) found in pots experiment that application of 45 g woody biomass biochar could be used to control suppressed *M. incognita* infection in terms of eggs and egg masses by 52.7 and 56.0% and improved the growth of lentils, which presented in length and dry weight by 74.1 and 63.8%, respectively. The effect of biochars from three different feedstocks (wheat straw, rice husk and sugarcane bagasse) against *M. incognita* was evaluated by Arshad et al. (2020) in a pot trial. They found the use of rice husk biochar at a rate of 3% exhibited significant improvements in tomato plant parameters, including shoot length, shoot fresh weight and dry weight (35.3 cm, 56.7 g and 22.4 g), which could be resulted from the highest reductions in the number of galls, egg masses and females by 83.1, 77.5 and 62.1%, respectively under this type of biochar. Also, they confirmed the significance of biochar using in governing *M. incognita* in tomatoes. Eche and Okafor (2020) studied the effects of different types of biochars such as on *M. incognita* and overall growth and yield of tomato, which infected with 5000 infective juveniles of *M. incognita* under the screen-house condition in 2016 and 2017 and they found that bush mango and neem biochars significantly suppressed root galls by 64.05 and 66.52%, infective juveniles by 42.7 and 35.02, respectively, while neam biochar caused the highest increases in tomato yield by 57.5%.

CONCLUSION

The findings of this study deliver clear evidence that biochars produced from indigenous rice straw and peanut residues (RSB and PRB) are promising materials in suppressing *M. incognita*, which was positively reflected on the growth and yield of eggplant due to altering of soil acidity. These plant wastes are excitedly available and changing them to biochars is comparatively inexpensive and can be applied as ecological substitutes to synthetic nematicides. However further short or long-term studies are needed for better understanding to evaluate the effect of these biochars alone or in combination with other amendments against plant-parasitic nematodes on different crops under field conditions.

REFERENCES

Ali, MA; A Abbas, F Azeem, N Javed, H Bohlmann (2015). Plant-Nematode Interactions: From Genomics to Metabolomics. *International Journal of Agriculture and Biology*, 17:1071-1082

Ali MA, F Azeem, A Abbas, FA Joiya, H Li, AA Dababat (2017). Transgenic strategies for enhancement of nematode resistance in plants. *Frontiers in Plant Science,* 8, Article 750

Arshad U, M Naveed, N Javed, MD Gogi, MA Ali (2020). Biochar Application from Different Feedstocks Enhances Plant Growth and Resistance against *Meloidogyne incognita* in Tomato. *International Journal of Agriculture*, 24:961-968

Arya R (2016). Combined effect of Trichoderma harzianum and Vermicompost in the management of root knot nematode (*Meloidogyne incognita*) in tomato cv Pusa Ruby. *Indian Phytopathology,* 69:464-467

Asif M, F Ahmad, M Tariq, A Khan, T Ansari, F Khan, AM Siddiqui (2017). Potential of chitosan alone and in combination with agricultural wastes against the root-knot nematode, *Meloidogyne incognita* infesting eggplant. *Journal of Plant Protection Research,* 57: 288-295

Barker KR (1985). Nematode extractios and bioassays. Pp. 19-35 in Barker, K.R., C.C. Carter, N. Sasser, Eds. An advanced Treatise on *Meloidogyne,* Methodology, (Vol II). Raleigh, North Carolina State University Graphics, USA.

Bonanomi G, F Ippolito, F Scala (2015). A “black” future for plant pathology? Biochar as a new soil amendment for controlling plant diseases. *Journal of Plant Pathology,* 97:223-234.

Cao Y, Y Gao, Y Qi, J Li (2018). Biochar-enhanced composts reduce the potential leaching of nutrients and heavy metals and suppress plant-parasitic nematodes in excessively fertilized cucumber soils. *Environmental Science and Pollution Research, 25*: 7589-7599.

Eche CO, OE Okafor (2020). Control potential of some indigenous biochars against *Meloidogyne incognita* [(Kofoid and White) Chitwood] in tomato (Solanum lycopersicum L.). *Journal of Entomology and Nematology,* 12: 32-38.

Elad Y, DR David, YM Harel, M Borenshtein, HB Kalifa, A Silber, ER Graber (2010). Induction of systemic resistance in plants by biochar, a soil-applied carbon sequestering agent. *Phytopathology Journal*, 100:913-921.

El-Naggar A, SS Lee, J Rinklebed, M Farooq, AK Sarmah, AR Zimmerman, M Ahmad, SM Shaheen, YS Ok (2019) Biochar application to low fertility soils: A review of current status, and future prospects. *Geoderma*, 337:536-554

El-Sherif AG, SB Gad, AM Khalil, RHE Mohamedy (2015). Impact of Four Organic Acids on *Meloidogyne Incognita* Infecting Tomato Plants under Greenhouse Conditions. *Global Journal of Biology, Agriculture & Health Sciences*, 4: 94-100

El-Sherif AG, SB Gad, SM Saadoon (2016). Impact of Potassium Silicate Application on *Meloidogyne incognita* Infecting Cucumber Plant under Greenhouse Conditions. *Asian Journal of Nematology*, 5:1-7

Frenkel O, AM Jaiswal, Y Elad, B Lew, C Kammann, ER Graber (2017). The effect of biochar on plant diseases: What should we learn which designing biochar substrates. *Journal Enviromental Engineering and Landscape Management*, 25:105-113

Gad SB, MI Sergany (2017). Influence of five plant dried leaf powders on eggplant plants infected with *Meloidogyne incognita* under greenhouse conditions. *Egyptian Journal of Agronematology* ,16: 1-10.

Gao S, K Hoffman-Krull, AL Bidwell, TH DeLuca (2016). Locally produced wood biochar increases nutrient retention and availability in agricultural soils of the San Juan Islands, USA. *Agriculture Ecosystems & Environment ,233*:43-54.

George C, J Kohler, MC Rillig (2016). Biochars reduce infection rates of the root-lesion nematode Pratylenchus penetrans and associated biomass loss in carrot. *Soil Biology and Biochemistry*, 95: 11-18

Graber ER, O Frenkel, AK Jaiswal, Y Elad (2014). How may biochar influence severity of diseases caused by soil-borne pathogens? *Carbon Management*, 5:169-183

Huang W, H Ji, G Gheysen, J Debode, T Kyndt (2015). Biochar-amended potting medium reduces the susceptibility of rice to root-knot nematode infections. *BMC Plant Biology*, 15:267

Hussain M, M Farooq, A Nawaz, AM Al-Sadi, ZM Solaiman, SS Alghamdi, U Ammara, YS Ok, KHM Siddique (2017). Biochar for crop production: Potential benefits and risks. *Journal of Soils Sediments*, 17:685-716

Hussey RS, KR Barker (1973). A comparison of methods of collecting inocula for *Meloidogyne spp.* including a new technique. *Plant Disease Representatives*, 57:1025-1028

Ibrahim F, KQ Albert, K Frederick (2018 a). Effect of shea nut shell biochar on root knot nematodes (Meloidogyne spp.) of tomato (*Solanum lycopersicum* L.). *Annual Research & Review in Biology*, 2:1-7

Ibrahim HS, MA Radwan, ASA Saad, HA Mesbah, MS Khalil (2018 b). Assessing the potential of some Egyptian plants as soil amendments in *Meloidogyne incognita* management on tomato. *Journal of Biopesticides*, 11:154-160

Jothi G, K Poornima (2017). Potassium humate for the management of root knot nematode in tomato (*Lycopersicon esculentum*). *Journal of Entomology and Zoology Studies*, 5:646-648

Karuri HW, D Olago, R Neilson, E Mararo, J Villinger (2017). A survey of root knot nematodes and resistance to *Meloidogyne incognita* in sweet potato varieties from Kenyan fields. *Crop Protection Journal*, 92:114-121

Kshetrimayum S, D Das (2015). Management of root-knot nematode, *Meloidogyne incognita* on green gram through bioagents. *Indian Journal of Nematology,* 44:247-248

Liu X, D Zhang, H Li, X Qi, Y Gao, Y Zhang, Y Han, Y Jiang, H Li (2020). Soil nematode community and crop productivity in response to 5-year biochar and manure addition to yellow cinnamon soil. *BMC Ecology,* 20:39

Mostafa FAM, AE Khalil, AH Nour El-Deen, DS Ibrahim (2018). The role of Bacillus megaterium and other bio-agents in controlling root-knot nematodes infecting sugar beet under field conditions. *Egyptian Journal of Biological Pest Control*, 28:66

Oka Y (2010). Mechanisms of nematode suppression by organic soil amendments—a review. *Applied Soil Ecology,* 44:101-115

Onkendi EM, GM Kariuki, M Marais, LN Moleleki (2014). The Threat of root-knot nematodes (*Meloidogyne spp*.) in Africa: A review. *Journal of Plant Pathology,* 63:727-737

Page AL, RH Miller, DR Keeney (1982) Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. ASA-SSSA, Madison

Radwan, MA, MM Abu-Elamayem, SAA Farrag, NS Ahmed (2017). Comparative suppressive effect of some organic acids against *Meloidogyne incognita* infecting tomato. *Pakistan Journal of Nematology,* 35:197-208

Sanchez ME, E Lindao, D Margaleff, O Martinez, A Moran (2009). Pyrolysis of agricultural residues from rape and sunflower: Production and characterization of bio-fuel and biochar soil management. *Journal of Analytical and Applied Pyrolysis,* 85:142-144.

Sashidhar P, M Kochar, B Singh, M Gupta, D Cahill, A Adholeya, M Dubey (2020). Biochar for delivery of agri-inputs: current status and future perspectives. *Science of the Total Environment,* https ://doi. org/10.1016/j.scito tenv.2019.13489 2

Taylor DP, C Netscher (1974). An improved technique for preparing perinral patterns of Meloidogyne spp. *Nematologica,* 20:268-269

Usman ARA, MI Al-Wabel, AH Abdulaziz, WA Mahmoud, AH El-Naggar, M Ahmad, AF Abdulelah, AO Abdulrasoul (2016). Conocarpus biochar induces changes in soil nutrient availability and tomato growth under saline irrigation. *Pedosphere,* 26:27-38

van Zwieten L, S Kimber, A Downie, S Morris, S Petty, J Rust, KY Chan (2010). A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. *Australian Journal of Soil Research,* 48:569-576

Wang Y, S Chikamatsu, T Gegen, K Sawada, K Toyota, S Riya, M Hosomi (2019). Application of biogas digestate with rice straw mitigates nitrate leaching potential and suppresses Root-Knot Nematode (*Meloidogyne incognita*). *Agronomy,* 9:227; doi:10.3390/agronomy9050227

Xiao Z, M Liu, L Jiang, X Chen, BS Griffiths, H Li, F Hu (2016). Vermicompost increases defense against root-knot nematode (*Meloidogyne incognita*) in tomato plants. *Applied Soil Ecology,* 105:177-186

Xie ZB, QC Bei, G Liu, JG Zhu (2010). A device for biochar production from straws. China, Patent No. 200920232191.9. June 16, 2010. Available online at http: //search.cnipr.com (Verified on 12 November, 2012)

Zhang XK, Q Li, WJ Liang, M Zhang, XL Bao, ZB Xie (2013). Soil Nematode Response to Biochar Addition in a Chinese Wheat Field. *Pedosphere* ,23:98-103

ARABIC SUMMARY

الفحم الحيوي المنتج من قش الأرز ومخلفات الفول السوداني كطرق صديقة للبيئة لمقاومة نيمانودا تعقد الجذور التي تصيب الباذنجان*Meloidogyne incognita*

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يعتبر البيوشار (الفحم الحيوي) معقد كربوني حيوي ويعمل علي تحسين نمو النبات وقمع مسببات الامراض التي تعيش في التربة. نيماتودا تعقد الجذور *Meloidogyne incognita* تعرف علي أنها واحدة من أكثر الافات ضررا بجذور العديد من المحاصيل وتؤدي إلي إنخفاضات ملحوظة في إنتاجها. لذلك اجريت الدراسه الحاليه لتطبيق إستخدام أنواع مختلفة من البيوشار مع إفتراض إن إضافة البيوشار مصادر مختلفة يمكن أن تسبب تحسن في تحمل نبات الباذنجان للعدوي بالنيماتودا. تم إنتاج نوعين من الفحم الحيوي بإتباع طريقة التحلل الحراري لقش الأرز ومخلفات الفول السوداني. وقد تم تنفيذ تجربة أصص لدراسة تأثير الفحم الحيوي لقش الأرز والفحم الحيوي لمخلفات الفول السوداني علي *M. incognita* ونمو ومحصول نبات الباذنجان في أرض لومية. وقد تم تصميم 8 معاملات نتجو من التفاعل بين نوعين البيوشار المستخدمين وأربعة مستويات منهم (صفر و 5.25 و 10.5 و 21 جم/اصيص) والذي يعادل (صفر و 5 و10 و20 طن/هكتار) علي التوالي. وقد رتبت المعاملات في نظام قطاعات كاملة العشوائية بخمسة مكررات. أظهرت النتائج أن الأضافات الفردية لكل من بيوشار قش الأرز و بيوشار محلفات الفول السوداني عند 5.25 و 10.5 و 21 جم/اصيص تحسنات معنوية في مؤشرات النمو (الطول والوزن الجاف والطازج للسيقان والجذور) وكذلك إنتاجية نبات الباذنجان. وقد تسببت إضافة بيوشار قش الأرز أو بيوشار محلفات الفول السوداني عند معدل 21 جم/أصيص في الحصول علي تأثيرات علي محصول الثمار الطازجة لنبات الباذنجان (946 و 1012 جم/أصيص). أيضا أظهرت النتائج أن رقم حموضة التربة قد ارتفع بعد إضافات بيوشار قش الأرز وبيوشار مخلفات الفول السوداني من 5.85 في معاملة الكنترول إلي 6.12-6.39 و 6.28-6.75 علي التوالي. إضافة كل من بيوشار قش الأرز وبيوشار مخلفات الفول السوداني أظهر درجات مختلفة في خفض أعداد كتل البيض والعقد المتواجدة علي الجذر وكذلك الطور اليرقي الثاني لكل 250 جم تربة لل *M. incognita* وقد أدي ذلك إلي تحسنات ملحوظة في مؤشرات النمو لنبات الباذنجان بالمقارنة بمعاملة الكنترول. إستخدام المعدلات العالية من بيوشار قش الأرز وبيوشار مخلفات الفول السوداني كان مسؤلا عن الكفاءة العالية في خفض المؤشرات السابق ذكرها لل *M. incognita* مقارنة بمعدلاتهم المنخفضة. إن أعلي إنخفاضات في العقد علي الجذر (80-93%) وكتل البيض (90-96%) وعدد البيض في كتل البيض (76-90%) و الطور اليرقي الثاني (83-92%) عند 50 و 90 يوم من نقل الشتلات قد ظهرت بعد إضافة بيوشار مخلفات الفول السوداني عند معدل 21 جم/اصيص. وقد أشارت هذة الدراسة أنه يمكن إستخدام بيوشار قش الأرز وبيوشار مخلفات الفول السوداني كمواد فعالة في خفض التأثيرات الضارة لل *M. incognita* وأيضا يمكن أن يوصي بهم كبدائل صديقة للبيئة عن مبيدات الأفات المصنعة لمكافحة العدوي بنيماتودا تعقد الجذور *M. incognita*.