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(Original Article)

Biochar Addition to Soil as Eco-Friendly Approach for Controlling Peanut Root-lesion Infecting Nematode

Alaa G. H. El-Ladgha[1*]; Abd-El-Moneim M. H. Amein[1]; Aida M. El-Zawahry[1]; Ameer E. Elfarash[2] and Hadeel M. M. K. Bagy[1].

[1]Department of Plant Pathology, Faculty of Agriculture, Assiut University, Assiut, Egypt.
[2]Department of Genetics, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Corresponding author e-mail: alaa.g.hassan@agr.aun.edu.eg
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Abstract

Biochar, produced through pyrolysis of organic materials, has shown potential in improving soil properties and reducing population density of plant parasitic nematodes. Biochar prepared from rice straw, moringa wood and mango bushes were applied *in vitro* at various concentrations (1, 3 and 5%) against *Pratylenchus penetrans*. Results indicated that biochar types had significant effect on nematode mortality, the mortality rate increased with increasing the concentration and exposure period. Rice straw biochar had the highest effect on suppressing *P. penetrans* at concentration 5% for 72h (%90), followed by moringa wood (%86.33) then mango bush (%65.67). *In vivo*, the highest concentration of biochar was used. Rice straw biochar had the highest effect. It reduced the root lesion and population density of *P. penetrans* infecting peanut seedlings (%39.50) and (418.88), followed by moringa wood (%59.25) and (497.77) mango bushes came last with (%77.77) and (543.33). The use of biochar also led to an increase in plant height and root weight compared to the control infected (only nematode) and control healthy (without nematode). These findings suggest that biochar from these plant sources could serve as an eco-friendly alternative for nematode management in peanut cultivation. Future research should focus on optimizing biochar and application techniques to enhance its efficiency in sustainable peanut production.

Keywords: *Biochar rice, Mango, Moringa, Nematode infection scale, Pratylenchus penetrants.*

Introduction

Peanut (*Arachis hypogaea* L.) is an important food and fodder crop in the agricultural systems in developing countries (Farid and Toma, 2013). Peanut is an annual legume, also known as groundnut, earthnut, monkey-nut and goobers. It ranks as the world's 13th most important food crop and 4th most significant oilseed crop. Peanut seeds are a rich source of nutrients, including vitamin E, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium. Peanuts are considered an excellent cash crop, serving both domestic markets and foreign trade in many developing and developed countries (Reddy *et al.*, 2011). Recently,

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significant attention has been given to peanuts due to their suitability for growth in newly reclaimed sandy areas in Egypt. Egypt new reclaimed areas primarily consist of sandy soils, which are often low in organic matter and lacking in essential plant nutrients (Mahmoud *et al.,* 2020).

Plant-parasitic Nematodes (PPNs) are considered major pathogens in agricultural production, as they cause serious damage by increasing both direct and indirect symptoms in infected plants (Gamalero and Glick, 2020). PPNs impact peanut crops in all production regions worldwide. The most common nematodes affecting peanuts are *Pratylenchus* spp. and *Meloidogyne* spp. (Singh *et al.*, 2013; Ebone *et al*., 2019).

With the revision of European Union (EU) legislation on pesticides use in agriculture, there is a growing need for control strategies with minimal environmental impact (Migunova and Sasanelli, 2021). Recently, Biochar has been promoted as an eco-friendly alternative for controlling plant-parasitic nematodes instead of using synthetic chemicals (Eche and Okafor, 2020).

Biochar is produced from various feedstocks, including animal and agricultural waste, such as rice straw, maize cobs, moringa wood, mango bush, wheat residues, sewage sludge, municipal solid waste, and biogas byproducts (Kumar *et al*., 2023). When incorporated into soil, biochar enhances agricultural productivity and promotes systemic plant resistance. It is widely used as a soil amendment to improve crop yield and soil fertility (Ikram *et al*., 2024).

Biochar has been shown to suppress populations of PPNs, making it a promising eco-friendly alternative for nematode management (Eche and Okafor, 2020). Additionally, biochar produced from various feedstocks has been found to reduce the infection rate of *Pratylenchus penetrans* (George *et al*., 2016).

The aim of this study is to investigate whether biochar derived from plant sources can serve as an environmental friendly alternative for nematode management in peanut cultivation.

Materials and Methods

Pyrolysis of feedstocks for biochar production

Three feedstocks (rice straw, moringa wood and mango bushes) were used to produce biochar. Feedstocks were sun dried to retain moisture up to 15% before biochar preparation.

Biochar was prepared in Soil and Water Department, Faculty of Agriculture, Assiut University. Feedstocks were pyrolyzed at temperature 450°C with retention time of 30 min after a gradual rise of 10°C for production of biochar following the protocol described by (Sanchez *et al*., 2009).

In vitro experiment

Rice straw, moringa wood and mango bushes biochar were used to suppress root lesion nematode, *P. penetrans* at three concentrations (1%, 3% and 5%). 5 ml of each concentration were placed in a petri dish with 100 juveniles, the control had distilled water. Three replicates of each concentration were made. Petri dishes were incubated at 25 ± 2°C. The nematode mortality was assessed at 24, 48 and 72 hours.

Greenhouse experiment

The site of this experiment is the greenhouse of Plant Pathology Department, Faculty of Agriculture, Assiut University. Peanut seedlings were grown in clay pots (20 cm diam) containing 2 kg of sterilized soil (silt 1:1 clay). Each pot contained three peanut plants. Fifteen days later, plants were inoculated with 1000 juveniles per plant from stock cultures. Fifteen days later, 50 ml at 5% concentration of the three biochar types (rice straw, moringa wood, and mango bushes) were added around the roots of each plant. In addition to the control healthy (without nematode) and the control infected (only nematode), each treatment was performed three times. The experimental design was randomized complete block design (RCBD).

Three months later, data was recorded for plant and nematode parameters. Plants were uprooted and water was used to remove the soil that was sticking to the roots. Population density of nematodes in 100g soil was measured in the soil samples. The scale 1-9 was used to evaluate disease severity of lesion due to root lesion nematode, which was measured in the root samples

where 1 represented no symptoms, 2 = 1-5, 3 = 6-10, 4 = 11-20, 5 = 21-30, 6 = 31-50, 7 = 51-70, 8 = 71-100 and 9 represented more than 100, described by Bridge and Page (1980).

Disease Severity (DS) % = $\left(\frac{\Sigma\,(\boldsymbol{n}\,.\,\boldsymbol{v})}{\boldsymbol{X}\,.\,\boldsymbol{N}}\right)X100$

Where:

n = Number of plants in each category.

v = Category number from the following scale.

X = The highest determined from the scale.

N = Total number of all inspected.

The root plant weight (g) and plant length (cm) were noted

Statistical analysis

Using ANOVA (Gomez and Gomez, 1984) and means were compared with Duncan's test (Duncan, 1955).

Results

1-Effect of biochar types on *Pratylenchus penetrans* mortality *in vitro*

Effect of biochar types (rice straw, moringa wood, and mango bushes) at three concentrations (1, 3, and %5) against *P. penetrans*, data was recorded after 24, 48 and 72 hours.

Data in Table (1) and Figure (1) show that different biochar types had significant effect on nematode mortality, where each type had a different effect. The mortality rate increased as concentration and exposure duration increased.

The effect of rice straw biochar on suppressing *P. penetrans* was highest at concentration 5% after 72h (%90) followed by moringa wood (%86.33) and then mango bush (%65.67).

Table 1. Effect of Biochar types on *Pratylenchus penetrans* mortality *in vitro*.

Biochar types	Concentration (%)	Nematode mortality (%)		
		24h	48h	72h
Rice straw	1	47.00 h	51.67 g	57.67 ef
	3	54.33 fg	62.00 de	74.33 c
	5	76.33 c	83.33 b	90.00 a
Moringa wood	1	27.33 j	33.67 i	43.33 h
	3	34.67 i	46.33 h	58.67 ef
	5	65.00 d	76.00 c	86.33 ab
Mango bushes	1	12.00 l	19.33 k	36.67 i
	3	19.67 k	36.00 i	54.00 fg
	5	27.00 j	46.33 h	65.67 d
Control	0	0 m	0 m	0 m

* Means column followed by the same letter are not significantly different by Duncan multiple range test at P < 0.05.

2-Effect of biochar types on *Pratylenchus penetrans* under greenhouse conductions:

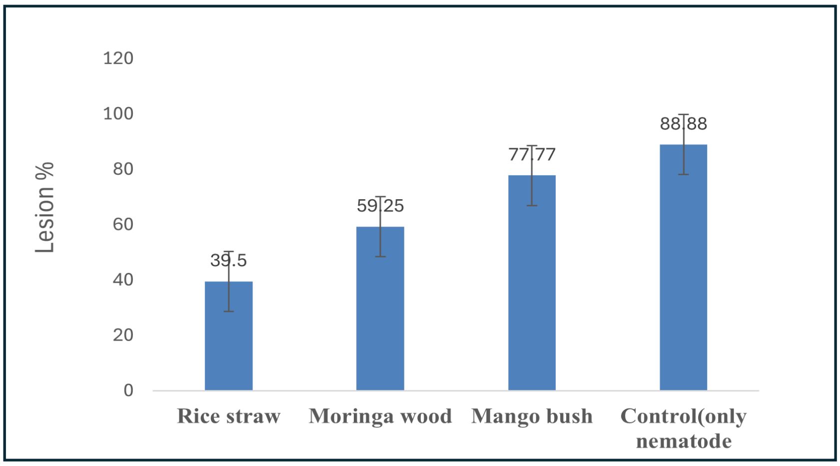
The highest effective concentration was used in this experiment. Data was collected after three months. Results show that biochar can reduce the nematode population density and lesion addition to improved root weight and plant height.

Table (2) and Figure (2) indicate that rice straw biochar was the highest effective, as it reduced the root lesion and population density to (%39.50 and 418.88), followed by moringa wood (%59.25 and 497.77) and then mango bush (%77.77 and 543.33), compared with control (only nematode) was (%88.88 and 783.33), respectively.

Table 2. Effect of biochar types on *Pratylenchus penetrans* under greenhouse conditions

Biochar types	Lesion (%)	Population (J2/ 100 gm soil)
Rice straw	39.50 d	418.88 c
Moringa wood	59.25 c	497.77 bc
Mango bush	77.77 b	543.33 b
Control (only Nematode)	88.88 a	783.33 a

* Means within each column followed by the same letter are not significantly different by Duncan multiple range test at P < 0.05.



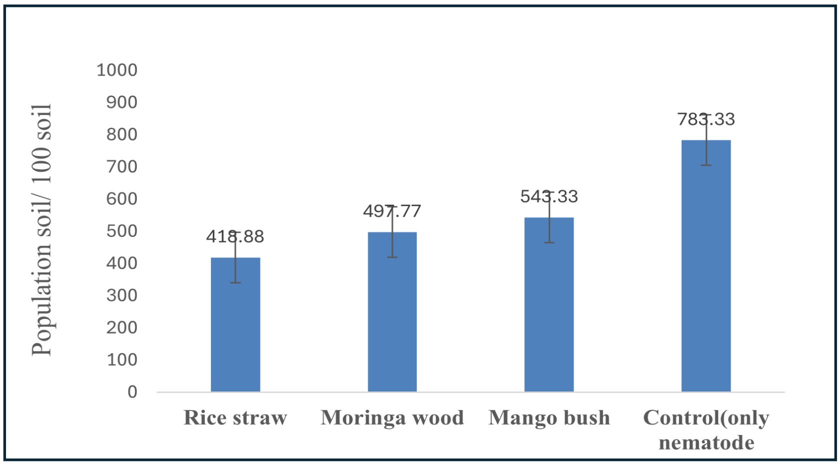


Fig 2. Effect of biochar types on *Pratylenchus penetrans* under greenhouse conductions.

Table (3) and Figure (3) explain the effect of biochar types on both plant height and root weight. The use of biochar led to an increase in plant height and root weight compared to the infected control (only nematode) and healthy control. Rice straw biochar give the highest increase in plant height and root weight (16.67g and 37.33cm), followed by moringa wood (13.33g and 35.44cm) and then mango bush (10.00g and 34.11cm) respectively.

Table 3. Effect of biochar types on plant height and root weight under greenhouse conditions.

Biochar types	Root weight (g)	Plant height (cm)
Rice straw	16.67 b	37.44 b
Moringa wood	13.33 c	35.44 c
Mango bush	10.00 d	34.11 c
Control (only nematode)	6.67 e	27.00 d
Control healthy	21.67 a	39.00 a

* Means within each column followed by the same letter are not significantly different by Duncan

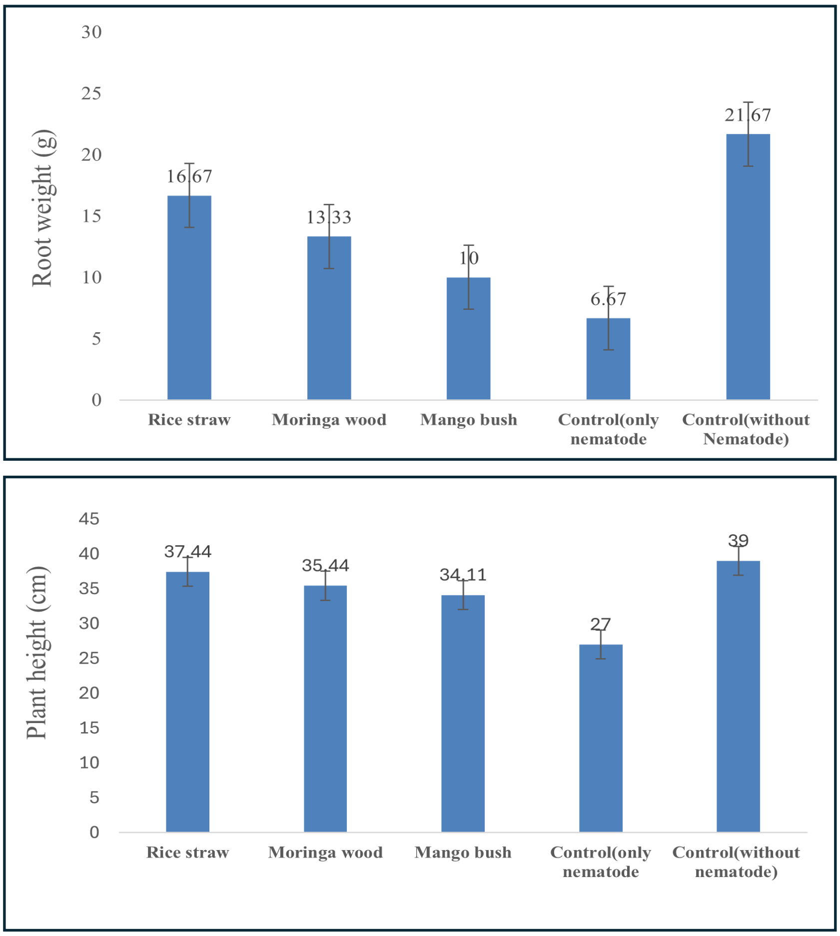


Fig 3. Effect of biochar types on both plant height and root weight under greenhouse conditions.

Discussion

Biochar as eco-friendly approaches for controlling root-lesion nematode infecting peanut. This study indicates that the use of three types of biochar (rice straw biochar, moringa wood biochar and mango bushes biochar) has effectively reduce the population density and root lesion caused by *Pratylenchus penetrans*, additionally, they effectively improve plant growth.

Biochar plays a significant role in improving soil quality and reducing population density of nematodes. As noted by Poveda *et al*., (2021), biochar can be effectively used as a soil amendment. Its various effects include modifying root exudates, enhancing soil properties and increasing nutrient availability, which collectively promote the growth of antagonistic microorganisms. Biochar also induces systemic defenses in plant roots, which help to reduce pathogens by activating stress-hormone responses and altering reactive oxygen species. For plant parasitic nematodes, biochar's main modes of action include changing the diversity of soil microbial communities and release nematocidal compounds. Using biochar as a soil amendment is a promising, sustainable strategy that aligns with zero-waste principles and supports integrated pathogen and pest management.

The use of biochar is a sustainable method and an effective strategy for improving soil quality and addressing heavy metal pollution in soil. Incorporating biochar into the soil presents a valuable opportunity to enhance soil quality and promote plant growth. The effectiveness of biochar in boosting nutrients cycles on agricultural lands is demonstrated by its positive effects on plant growth and soil health, making it a practical tool for mitigating nutrient deficiencies (Samal *et al*., 2024).

Biochar derived from burned log wood has proven effective in reducing populations of *Pratylenchus coffeae*, a migratory endo-parasitic nematode and a major cause of root lesion nematode (Rahayu and Sari 2017; Muthusamy *et al*. 2019; Vieira *et al*. 2019). In grapevines, biochar produced from poultry litters significantly lowered populations of plant-parasitic nematodes in soils, such as *Pratylenchus* spp., *Meloidogyne javanica*, *Tylenchulus* spp., *Helicotylenchus* spp., and *Criconemoid* spp., by increasing the diversity of plant-beneficial organisms (Rahman *et al*. 2014).

Edussuriya *et al*. (2023) investigated the use of biochar and biochar-based soil amendments, examining their potential applications in enhancing growth, yield, and control of plant-parasitic nematodes across various root crops. Most studies have focused on the effects of biochar on crops like cassava, sweet potatoes, as well as minor root crops such as ginger and turmeric. Biochar application rates between 5 and 20 t ha^{-1} have been observed to increase length, the number of leaves and tubers, and tuber weight.

In conclusion, this study recommends that the use of alternative environmentally friendly methods is effective in reducing the number of nematodes that infect peanut, such as biochar produced from plants at 5% concentration.

References

Bridge, J., and Page, S. L. J. (1980). Estimation of root knot nematode infestation levels on roots using aerating chart. Trop Pest Manage. 26: 296-298.

Ebone, L. A., Kovaleski, M., and Deuner, C. C. (2019). Nematicides: History, mode, and mechanism action. Plant Science Today. 6(2): 91-97.

Eche, C. O., and Okafor, O. E. (2020). Control potential of some indigenous biochar against *Meloidogyne incognita* [(Kofoid and White) Chitwood] in tomato (*Solanum lycopersicum* L.). Journal of Entomology and Nematology. 12(2): 32-38.

Edussuriya, R., Rajapaksha, A. U., Jayasinghe, C., Pathirana, C., and Vithanage, M. (2023). Influence of biochar on growth performances, yield of root and tuber crops and controlling plant-parasitic nematodes. Biochar. 5(1): 68. https://doi.org/10.1007/s42773-023-00261-7.

Duncan, D. B. (1955). Multiple range and multiple, F-test. Biometrics. 11: 1-4.

Farid, M., and Toma N. Q. (2013). Isolation and identification of fungi from spices and medicinal plants. Research Journal of Environmental and Earth Sciences. 5: 131-138.

Gamalero, E., and Glick, B. R. (2020). The use of plant growth-promoting bacteria to prevent nematode damage to plants. Biology. 9:381. DOI: 10.3390/biology9110381.

George, C., Kohler, J., and Rillig, M. C. (2016). Biochars reduce infection rates of the root-lesion nematode *Pratylenchus penetrans* and associated biomass loss in carrot. Soil Biol. Biochem. 95: 11-18. http://dx.doi.org/10.1016/j.soilbio.2015.12.003.

Gomez, K. A., and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed., Jon Wiley and Sons: Inc., New York.

Ikram, M., Singh, S., Bano, N., Alahmadi, T. A., Shariq, M., Siddiqui, M. A., and Islam, J. (2024). Biochar and oil cakes act as antagonists towards *Meloidogyne incognita* in tomato: A sustainable approach. Plant Stress. 11: 1-8.

Kumar, A., Bhattacharya, T., Shaikh, W. A., Roy, A., Chakraborty, S., Vithanage, M., and Biswas, J. K. (2023). Multifaceted applications of biochar in environmental management: A bibliometric profile. Biochar. 5(1): 11. 1 https://doi.org/10.1007/s42773-023-00207-z.

Mahmoud, M. W. S., Hussein, E. M.A., and Ashour, K. R. (2020). Sequential path analysis for determining the interrelationships between yield and its components in peanuts. Egypt. J. Agron. 42(1): 79-91.

Migunova, V. D., and Sasanelli, N. (2021). Bacteria as biocontrol tool against phyto-parasitic nematodes. Plants, 10(2): 389. https://doi.org/10.3390/plants10020389.

Muthusamy, M., Uma, S., Suthanthiram, B., Saraswathi, M. S., and Chandrasekar, A. (2019). Genome-wide identification of novel, long non-coding RNAs responsive to *Mycosphaerella eumusae* and *Pratylenchus coffeae* infections and their differential expression patterns in disease-resistant and sensitive banana cultivars. Plant Biotechnol. Rep. 13: 73-83.

Poveda, J., Martínez-Gómez, Á., Fenoll, C., and Escobar, C. (2021). The use of biochar for plant pathogen control. Phytopathology. 111(9): 1490-1499.

https://doi.org/10.1094/PHYTO-06-20-0248-RVW.

Rahayu, D. S., and Sari, N. P. (2017). Development of *Pratylenchus coffeae* in biochar applied soil, coffee roots and its effect on plant growth. Pelita Perkebunan. 33: 24-32.

Rahman, L., Whitelaw-Weckert, M. A., and Orchard, B. (2014). Impact of organic soil amendments, including poultry-litter biochar, on nematodes in a Riverina, New South Wales, vineyard. Soil Res. 52: 604-619.

Reddy, E. C. S., Sudhakar, C., and Reddy, E. N. P. (2011). Aflatoxin contamination in groundnut induced by *Aspergillus flavus* fungi. International Journal of Applied Biology and Pharmaceutical Technology. 2: 180-192.

Samal, I., Mahanta, D. K., Bhoi, T. K., Komal, J., Jatav, H. S., Jatav, S. S., and Sathyanarayana, E. (2024). Approaches of Biochar in Ecosystem Management: Current Scenario and Future Perspectives. DOI: 10.5772/intechopen.1004288.

Sanchez, M. E., Lindao, E., Margaleff, D., Martinez, O., and Moran, A. (2009). Pyrolysis of agricultural residues from rape and sunflower: Production and characterization of biofuel and biochar soil management. J Anal Appl Pyrol. 85: 142-144.

Singh, S. K., Mike, H., and Ash, G. J. (2013). Plant-parasitic nematodes of potential phytosanitary importance, their main hosts and reported yield losses. EPPO Bull. 43: 334-374.

Vieira, P., Mowery, J., Shao, J., Eisenback, J. D., and Nemchinov, L. G. (2019). Cellular and transcriptional responses of resistant and susceptible cultivars of alfalfa to the root lesion nematode, *Pratylenchus penetrans*. Front. Plant Sci. 10: 971. https://doi.org/10.3389/fpls.2019.00971.

اضـــافة الفحم الحيوي للتربة كنهج صـــديق للبيئة لمكافحة نيماتودا تقرح الجذور التي تصـــيب الفول السوداني

الاء جمـال حســـن اللدغة[1*]، عبد المنعم محمود امين[1]، عايدة محمد ابراهيم الظواهري[1]، امير عفت الفراش[2]، هديل مجدي محمد خليل باجي[1]

[1]قسم امراض النبات ، كلية الزراعة، جامعة اسيوط، اسيوط، مصر.
[2]قسم الوراثة، كلية الزراعة، جامعة اسيوط، اسيوط، مصر.

الملخص

أظهر الفحم الحيوي المُنتج من خلال التحلل الحراري للمواد العضـوية، إمكانية في تحسـين خصـائص التربة وتقليل كثافة أعداد النيماتودا الممرضـة للنبات. وقد تم تحضـير الفحم الحيوي من ثلاث مصادر نباتية هي قش الأرز وخشب المورينجا وأغصـان المانجو، وتمت تجربته بتركيزات مختلفة (3،1 ،5%) ضد نيماتودا تقرح الجذور (*Pratylenchus penetrans*) في المختبر. أشارت النتائج إلى أن أنواع الفحم الحيوي كان لها تأثير ملحوظ على معدل الموت ليرقات نيماتودا التقرح، حيث زاد المعدل بزيادة التركيز وفترة التعرض. وقد أظهر الفحم الحيوي الناتج من قش الأرز أعلى تأثير في نسـبة الموت عند تركيز 5% لمدة 72 سـاعة بنسـبة (90%)، تلاه خشـب المورينجا بنسبة (86.33%) ثم شجيرات المانجو بنسبة (65.67%).

في تجربة الصـوبة تم استخدام التركيز الأعلى وكان الفحم الحيوي من قش الأرز هو الأكثر فعـاليـة، حيـث أدى إلى الخفض من تقرحـات الجـذور وكثـافـة أعـداد نيمـاتودا *Pratylenchus penetrans* في شتلات الفول السوداني المعدية بنسبة (39.50%)، (418.88) تلاه خشب المورينجا بنسبة (59.25%)، (497.77) ثم أغصـان المانجو بنسبة (77.77%)، (543.33) على التوالي. كما أدى اسـتخدام الفحم الحيوي إلى زيادة في طول النبات ووزن الجذور مقارنةً بالنباتات المعدية فقط والنباتات السـليمة. تشـير هذه النتائج إلى أن الفحم الحيوي المسـتخرج من هذه المصـادر النباتية يمكن أن يكون بديلاً صـديقاً للبيئة لمكافحة النيماتودا في زراعة الفول السـوداني. ويجب أن تركز الأبحاث المسـتقبلية على تحسـين إنتاج الفحم الحيوي وتقنيات تطبيقه لتعزيز كفاءته في تحقيق زراعة فول سوداني مستدامة.

الكلمات المفتاحية: *نيماتودا تقرح الجذور، مقياس الاصـابة، فحم قش ألارز، خشـب المورينجا، أغصـان المانجو*