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Non-chemical Control Method for Management of Tomato Leafminer *Tuta absoluta* (Lep.: Gelechiidae) Using Biochar and Vermicompost Extracts

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ABSTRACT

This research was aimed of investigating the effect of vermicompost tea and biochar, as plant growth enhancers, in reducing the population and damage of tomato leafminer. The experiment was performed in completely randomized design with five treatments (vermicompost tea 50/1000, vermicompost tea 75/1000, biochar 2/1000, biochar 4/1000 and control-normal water) in four replications on tomato plants. After three days of spraying the treatments, the number of larval tunnels on each pot was counted to check the effect of the treatments on the activity of the larvae. Then the second foliar spraying was done and twenty days later, active larval tunnels and adult insects were counted. The results showed that the average number of *T. absoluta* adults observed in the vermicompost tea treatment 50/1000 with 21.75, in the biochar treatment 2/1000 with 9, in the biochar treatment 4/1000 with 13.75, in the vermicompost tea treatment 75/1000 is 26 and and 31.5 in the control. In this study, after the first foliar spraying, tomatoes treated with biochar 2/1000 and biochar 4/1000 had the lowest number of mature moths. In the second foliar spraying of the treatments, biochar 2/1000 showed the best effect in reducing the active larval tunnels. Also, vermicompost tea 50/1000 and 70/1000 had similar effects. The results of the total number of larval tunnels also showed that the number of larval tunnels is very different in each treatment. The average number of tunnels after the first stage of foliar spraying of treatments in vermicompost tea 50/1000 is 43.75, in biochar 2/1000 is 19.5, in biochar 4/1000 is 26.75, in vermicompost tea 70/1000 is 55 and in the control is equal to sixty-nine.

Keywords: Induced systemic resistance, Biochar, Non chemical control, Tomato, Biological control.

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is considered a valuable vegetable crop in the Middle East. The cultivated area of this crop in Iraq is approximately 67 thousand hectares, with the provinces of Karbala, Basra, and Najaf having the largest area under cultivation and production. Furthermore, according to statistics from the Food and Agriculture Organization

(FAO, 2019), the total production of tomatoes, including both open-field and greenhouse cultivation, in Iraq was 771 thousand tons. Tomato is attacked by numerous pests, one of which is the tomato leafminer. The tomato leafminer attacks all growth stages of the host plant and causes 50-100% damage to the host (EPPO, 2005). Larvae penetrate the leaves, buds, and both unripe and ripe tomato fruits, forming distinct mines. The mines created in the fruit can be attacked by secondary microorganisms, leading to fruit rot and decay. This pest has a high reproductive potential and produces 10 to 12 generations per year (EPPO, 2005).

The tomato leafminer pest, with the scientific name *Tuta absoluta* (Meyrick), is an extremely dangerous moth, particularly on tomatoes. This pest also appears on eggplant, bell pepper, potato, and various other cultivated plants. The tomato leafminer moth belongs to the family Gelechiidae and primarily damages plants of the Solanaceae family. This pest is native to South America. It was reported in Spain in 2006 and rapidly spread to other European and Mediterranean countries, becoming a serious pest for both open-field and greenhouse tomato cultivations. It was a quarantine pest for Iraq and was observed and reported in the country for the first time in 2010 (Abdul Razzak *et al.,* 2010). Similar to other quarantine pests in the initial stages of introduction to a new region, which, in the absence of biocontrol agents, have a high capacity for causing damage, this insect also became a key and damaging pest in Iranian tomato fields upon its arrival (EPPO, 2005). The tomato leafminer moth is a polyvoltine (multivoltine) insect lacking obligatory diapause. Its development period varies depending on environmental conditions and temperature. The average lower threshold temperature for the development of this pest is 14.8°C; this temperature is 9.6°C for eggs, 6.7°C for larvae, and 2.9°C for pupae (Robredo and Cardeoso, 2008).

The term "biochar" refers to a substance with a high carbon concentration, derived from the process of decomposing organic materials and their pyrolysis under low-oxygen conditions and at high temperatures (Tian *et al.,* 2021). This process takes place in a reactor and converts organic matter into varying quantities of solid, liquid, and volatile products. The solid portion, which contains fixed carbon and other minerals, is known as biochar (Jaiswal *et al.,* 2020). The positive effects of adding high-carbon-concentration materials to soil were first described in the 1870s in the soils of Brazil (Wang *et al.,* 2019). In the Amazon region of Brazil, *Terra Preta* refers to soils with a thick black or dark grey top layer, characterized by a high percentage of organic matter and high fertility. Furthermore, these soils contain higher concentrations of nutrient elements such as Calcium (Ca), Nitrogen (N), Phosphorus (P), and Potassium (K) compared to the surrounding low-fertility soils, and they have a higher pH and water-holding capacity.

Adding biochar as a soil amendment has several positive environmental effects, such as high carbon sequestration, reduction of greenhouse gases, energy production (Arshad *et al.,* 2021), soil improvement, immobilization of organic and inorganic pollutants (Rasool *et al.,* 2021), and assistance in waste management. Only a limited number of studies exist regarding the effects of biochar application for controlling arthropod pests and weeds. In most cases, the mechanism of action is presumed to be the induction of plant defense responses against insects. For example, the use of biochar derived from deciduous trees, dolomite, and beet molasses at a 10% concentration (w/w) was effective in controlling *Sogatella furcifera* (the white-backed planthopper; Hemiptera: Delphacidae), a major herbivorous pest of rice in Asia (Wang *et al.*, 2019). This was achieved by inducing the accumulation of jasmonic acid in the leaves, which enhanced the resistance of rice plants against *S. furcifera*.

Similarly, biochar derived from citrus wood induced systemic resistance in pepper plants against the broad mite, *Polyphagotarsonemus latus* (Acari: Tarsonemidae), an economically important pest in many agricultural and horticultural crops (Chen *et al.*, 2019). Given the high commercial importance of tomato and the significance of the tomato leafminer moth on this crop, the use of new control methods that firstly have no adverse effects on product health and the environment, and secondly possess high efficacy and ease of application, has led researchers to focus their studies on the use of organic compounds with plant growth-promoting and defense system-enhancing properties to control plant pests and diseases.

Among these, vermicompost and biochar, in addition to their plant growth-stimulating properties, have significant potential in limiting the growth and feeding of pests. By being incorporated into plant nutrition programs, they can play an important role in protecting plants against pests and diseases.

MATERIALS AND METHODS

Research Location and Rearing Conditions for Tuta absoluta

To conduct this experiment, 100 seedlings of the 'Heda' hybrid tomato cultivar were initially prepared. The characteristics of this cultivar are as follows: hybrid type, round fruit shape, fruit weight between 180 and 230 grams, vigorous plant, suitable for autumn cultivation, and relatively resistant to various wilts. The seedlings were then planted in pots with a 25 cm mouth diameter containing a mixture of coco peat, perlite, and regular soil in a 35-30-35 percent ratio. The experiment was conducted in a research greenhouse maintained at 25.5°C and 55% relative humidity. Initially, a section of the greenhouse measuring 2 x 2.5 meters and 3 meters in height was isolated from other parts using a fabric mesh (30 mesh) such that all six sides of this space were enclosed by the net. A number of adult tomato leafminer moths, which had been randomly collected from a tomato greenhouse infested with the said pest, were then released underneath the net onto the pots containing eight-leaf tomato plants. This was done by placing 20 tomato pots inside the net-enclosed chamber and then releasing the captured adult insects inside. Based on studies conducted on the life cycle of the tomato leafminer moth, a period of approximately 40 days was considered for the pest to complete its life cycle. After this period, the required number of adult insects for conducting the experiment was obtained.

Experimental Treatments and Methodology

The experimental treatments were as follows: vermicompost tea at 50/1000, vermicompost tea at 75/1000, biochar at 2/1000, biochar at 4/1000 and water as the control. Tomato plants in pots were arranged in a Completely Randomized Design (CRD) at the research site. Irrigation and nutrition were uniform for all pots. To prevent the infiltration of pest insects from other greenhouse areas and to contain the experiment, a 280-cubic-meter enclosure was constructed using a fabric mesh. All treatments were tested inside this isolated structure. Each replication consisted of two pots, which were housed within an individual netting chamber to prevent the migration of tomato leafminer moths between adjacent replications. Following the observation of the first signs of first-instar larvae on tomato plants across all replications, the treatments were applied. For this purpose, one liter of each treatment solution at the specified concentrations was poured around the base of each plant. The first count of larval mines on each pot was conducted three days after the application of the treatments to determine the effect of the applied treatments on larval activity. Thirty days after the larval mine count, the adult insects were counted. Counting emerged adult insects is an accurate and straightforward method for determining larval mortality. The insects were counted upon their emergence and appearance in each replication. Eight days after the adult insect count, the second application of the experimental treatments to the pots was carried out. In this second stage, all treatments were applied identically to the first stage. Three days after the second solution application, the number of larval mines on each pot was again counted to determine the effect of the treatments on larval activity. Finally, similar to the first stage, adult insects were counted thirty days later.

Data analysis was performed using SAS software, version 16, and means were compared using Duncan's Multiple Range Test.

RESULTS

The Impact of Treatments on Adult Tuta absoluta

Analysis of variance of the data indicated a significant difference in the number of adult tomato leafminer moths (*Tuta absoluta*) among the different treatment groups during both application stages. Furthermore, the comparison of treatment means revealed that after the first application stage, tomatoes treated with Biochar 2/1000 and Biochar 4/1000 had the lowest number of adult moths. The effect of these two treatments was not significantly different from each other at the 1% probability level. Following these, Vermicompost Tea 75/1000 showed the best performance. The performance of Vermicompost Tea 50/1000 and the Control group was not significantly different at the 1% level. In the second application stage, Biochar 2/1000 and Biochar 4/1000 again showed no significant difference between them at the 1% level. Similarly, Vermicompost Tea 75/1000 and Vermicompost Tea 50/1000 exhibited comparable performance (Table 1).

Table 1. The effects of experimental treatments on the mean number of *Tuta absoluta* adults

Treatments	first experiment			second experiment		
	homogeneous groups			homogeneous groups		
	1	2	3	1	2	3
Biochar 2/1000	9c			1.75c		
Biochar 4/1000	13.75c			5.75c		
Vermicompost tea 75/1000		21.75b			19.5b	
Vermicompost tea 50/1000		26ab	26ab		24.5b	
control			31.5a			47.25a
Significance level	0.026	0.043	0.012	0.188	0.105	1

Means followed by same letters in each column are NOT significantly different (P<0.05, Duncan)

The impact of treatments on the number of larval mines

According to Table 2, the total number of active larval mines counted differed considerably among the various treatment groups. The mean number of mines counted after the first application stage were as follows: Vermicompost Tea 75/1000: 42.75, Biochar 2/1000: 19.5, Biochar 4/1000: 26.75, Vermicompost Tea 50/1000: 55 and Control: 69. A notable observation is that for all four treatment solutions, the mean number of larval mines was lower after the second application compared to the first. Conversely, this trend was reversed in the control group, where the number increased.

Comparison of the mean number of larval mines across different treatment groups during the two application stages showed a significant difference (Table 3). After the first application stage, tomatoes treated with biochar 2/1000 and biochar 4/1000 had the lowest number of active larval mines. Furthermore, the effect of these two treatments was not significantly different from each other at the 1% level. Subsequently, 75/1000 vermicompost tea and 50/1000 vermicompost tea, in that order, were the next most effective treatments in reducing the number of leaf miner larval mines on tomato plants. During the second application stage, the treatments with the best performance, in descending order, were biochar 2/1000, biochar 4/1000, vermicompost tea 75/1000, and vermicompost tea 50/1000. The lowest numbers of active larval mines were recorded in these treatments.

Table 2. Number of active larval mines counted for tomato leafminer moth *Tuta absoluta*

Treatments	First step of experiment				Second step of experiment			
	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation
Vermicompost tea 75/1000	38	50	42.75	2.25	33	38	35.5	1.08
Biochar 2/1000	16	23	19.5	1.11	7	11	9.25	1.71
Biochar 4/1000	22	31	26.75	2.03	13	17	15.25	0.75
Vermicompost tea 50/1000	50	60	4.76	1.76	51	59	54	1.41
Control	60	77	69.8	2.98	90	99	95.25	2.86

Table 3. The effects of experimental treatments on the mean number of *Tuta absoluta* mines

Treatments	first experiment					second experiment				
	homogeneous groups					homogeneous groups				
	1	2	3	4	5	1	2	3	4	5
Biochar 2/1000	19.5d					9.25e				
Biochar 4/1000	26.75d						15.25d			
Vermicompost tea 75/1000		42.75c						35.5c		
Vermicompost tea 50/1000			55.25b						54.65b	
control				69.5a						95.25a
Significance level	0.058	1	1	1	1	1	1	1	1	1

Means followed by same letters in each column are NOT significantly different (P<0.05, Duncan)

DISCUSSION

The extensive effects of biochar on controlling root and foliar fungal pathogens have been investigated through alterations in root exudates, soil properties, and nutrient availability, which influence the growth of antagonistic microorganisms. The induction of plant systemic resistance by biochar in the roots to reduce foliar fungal pathogens, the activation of hormonal stress responses, and changes in reactive oxygen species indicate a coordinated hormonal signaling within the plant (Wang *et al.,* 2019). Although limited data exist for oomycete and bacterial pathogens, reports indicate that biochar induces changes in the soil microbiota—affecting pathogen motility and establishment—along with inducing plant systemic resistance; both mechanisms contribute to disease control. Biochar also suppresses soil nematodes and insect pests. For plant-parasitic nematodes, the primary mechanisms of action for biochar are the modification of soil microbial diversity, the release of nematicidal compounds, and induced systemic resistance. The use of biochar as a soil amendment is a reliable and environmentally friendly strategy and serves as a component of integrated pest and disease management. Many studies have demonstrated the efficacy of biochar against soilborne bacteria, particularly against *Ralstonia solanacearum*, the causal agent of bacterial wilt of tomato (Tian *et al.,* 2021).

Fungi have also shown varied responses in terms of disease control. In studies on airborne fungal pathogens, the use of wood-derived biochars controlled diseases caused by *Alternaria solani* and *Botrytis cinerea* on tomato and strawberry (Rasool et al., 2021). Biochars derived from green waste, rice straw, and rice husks also effectively controlled *A. solani*, *B. cinerea*, *Leveillula taurica*, *Magnaporthe oryzae*, *Phyllactinia corylea*, and *Pseudocercospora mori* (De Tender *et al.*, 2016).

The results showed that the highest number of adult moths counted during both application stages was recorded in the control treatment, while the lowest number of adult moths was recorded in the treatment with 2 per thousand biochar. Furthermore, the results of the one-way analysis of variance (ANOVA) test indicated a significant difference between the mean numbers of adult moths in the different groups, both in the first and second application stages. Based on the results obtained after the first application stage, tomatoes treated with 2 and 4 per thousand biochar had the lowest number of adult moths. Additionally, the effect of these two treatments did not show a significant difference at the 1% level. The performance of the 50 per thousand vermicompost tea and the control treatment also showed no significant difference at the 1% level. In the second application stage, the 2 and 4 per thousand biochar teas showed no significant difference at the 1% level. Similarly, the 75 and 50 per thousand vermicompost teas performed comparably. Chen *et al.* (2019) investigated the effect of biochar on the growth and reproductive performance of *Cnaphalocrocis medinalis* on rice and examined the population size of *C. medinalis*. Their study demonstrated that biochar can affect its growth and have negative impacts on its population.

The results of the total larval mine count also show that the total number of mines counted varies greatly between the different groups. The average number of mines counted after the first application stage was 43.75 in the 75 per thousand vermicompost tea group, 19.5 in the 2 per thousand biochar group, 26.75 in the 4 per thousand biochar group, 55 in the 50 per thousand vermicompost tea group, and 69 in the control group. Another noteworthy point is that in all four treatment types, the average number of larvae was lower in the second stage compared to the first stage; however, the opposite trend was observed in the control group.

Najafabadi (2014) concluded that the reduction in pest populations and their damage on plants treated with vermicompost and compost tea, under both greenhouse and field conditions, could be due to a lesser change in nitrogen forms and a slower release of minerals, particularly through the production of phenolics from vermicomposts. The application of 20 to 40 percent vermicompost reduced the damage caused by the striped cucumber beetle (*Acalymma vittatum*) and the spotted cucumber beetle (*Diabotrica undecimpunctata*) on cucumbers and tomatoes. In a study investigating the effect of vermicompost on the growth and development of cabbage, *Brassica oleracea* L., and the sucking pest *Brevicoryne brassicae* L., it was reported that the number of pest-free plants, cabbage leaves, and the cabbage heads themselves showed a significant difference at the 5% probability level compared to the control plants (Eche and Okafor, 2020). These researchers concluded that vermicompost had a significant effect on promoting cabbage growth and significantly reduced the pests of this plant, particularly aphids.

The described results from previous research indicate that the effects of biochar stem from changes in the soil environment, which involve a combination of three-way or higher-degree interactions among pests, plants, and soil microorganisms. Coordinated plant hormonal responses play a significant role in this process. Furthermore, several studies demonstrate that biochar helps reduce the emission of pollutants from applied chemicals, such as nematicides, thereby mitigating their potential adverse effects on agricultural systems. Available information suggests that the gradual adoption of biochar is feasible within integrated pest management strategies. It is compatible with current chemical-based practices, with the key distinction of having minimal negative impacts on agricultural systems.

Therefore, biochar, as a product derived from biomass, particularly agricultural waste, represents an advanced strategy that requires dedicated study and optimization. It operates through complex mechanisms to control plant pathogens. Furthermore, another aspect of biochar that has not been fully investigated is the potential of using its water-based extracts for pathogen control. In this context, fundamental research is essential in the near future to understand the mechanisms of action of biochar, whether it acts directly on the pathogen or indirectly through the plant.

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