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THE INTEGRATED CONTROL OF EGGPLANT ROOT ROT DISEASE CAUSED BY *FUSARIUM SOLANI* IN THE GREENHOUSE

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ABSTRACT

The study aimed to evaluate the efficacy of the fungicide Topsin-M , Copper sulfate ($CuSO_4.5H_2O$) and the bioagents *Trichoderma harzianum* and *T. longibrachiatumin* for controlling eggplant root rot disease caused by *Fusarium solani* under greenhouse conditions in Basrah Province. The results of the pathogenicity test showed that the fungus *F. solani* reduced the germination of eggplant seeds with apercentage of 20% compared to the control treatment in which the germination rate reached 93.3% . The results also showed that the use of the fungicide Topsin-M at a concentration of 1 $g.L^{-1}$ led to inhibit *F. solani* growth on PDA, completely while it inhibited the growth of bioagents *T.harzianum* and *T.longibrachiatum*, with percentages of 16.63 and 26.80% respectively. Both bioagents *T.harzianum* and *T.longibrachiatum* also achieved a high antagonistic ability against the pathogenic fungus *F. solani* on PDA, where a degree of antagonism amounted 2 and 1 respectively, according to the Bell scale. The results of the experiment also showed that the treatment of Topsin-M with bioagents *T.harzianum* and *T.longibrachiatum* separately and Copper sulfate ($CuSO_4.5H_2O$) in the presence of the pathogenic fungus achieved a highest percentage in reducing the infection severity 10.67 and 16.67%, followed by the treatment of the pathogenic fungus and Topsin-M with one bioagents *T. harzianum* and *T.longibrachiatum* each separately, where the infection severity amounted to 16.67 and 27.67% compared to the treatment of the pathogenic fungus *F. solani* alone, in which the infection severity amounted to 71.67% . These result reflected on eggplant growth indicators positively.

Keywords: Copper sulfate, Topsin-M, *Trichoderma harzianum*, *Trichoderma longibrachiatum*, *Fusarium solani*.

1. INTRODUCTION

Eggplant (*Solanum melongena* L.) is considered as one of the important vegetable crops in Iraq. This plant belongs to the family: Solanaceae, which includes more than 75 genera and 2000 species spread all over the world, India and China are consideredas their original homeland, where it has been grown in the wild type since ancient times (Boras *et al*, 2011). The crop is cultivated for its fruits that are eaten after cooking, and it is also used in making pickles and kept frozen or canned for the purpose of export (DGCIS, 2008).

Eggplant is affected by many pests and diseases, including root rot disease, which is considered as one of the most important diseases under greenhouse condition and is widespread throughout the world. The amount of loss resulting from infection with this disease is largely related to the density of the pathogen inoculum available in the soil, the cultivation season and the presence of

bio-agents (Shenashen *et al*, 2017; Wanjohi *et al*, 2018). The principle of integrated pest management has become the ideal alternative to reduce the damage of agricultural pests of all kinds, where many researchers have indicated that the combination of fungicides and bioagents such as *Trichoderma* spp. increase and enhance the rates of disease control and provide better management of diseases transmitted by soil and seeds, thus accessing a practical and safe solution to control root rot diseases, because of the problems and damage they cause (Jaafar, 2015; Wedajo, 2015). The use of integrated control in controlling root rot disease has been successfully achieved in many studies, where it was found that the use of the combination of the *T. harzianum* fungus and some fungicides such as Topsin-M and Carbendazim led to reduce root rot disease caused by *F. solani* in several crops (Elshahawya *et al*, 2016; Abd-El-Khair *et al*, 2019; Salih and Mansoor, 2019; Jamil and Kumar, 2021). Nutrients such as copper have also received a great deal of studies due to their various role and effectiveness, and their environmental and economic importance (Keller *et al*, 2017). Mahanty (2000) indicated that the monthly treatment of soil with bioagent *T.harzianum* and copper sulfate was the best solution to eliminate soil borne fungi. Peciulyte and Volodkiene (2012) also found that the addition of copper sulfate to the soil led to eliminate many genera of pathogenic fungi such as *Fusarium*, *Pythium*, *Verticillium* and *Rhizoctonia*. Also, it found that the strains of *Trichoderma* that are tolerant to fungicides and copper were very important in the integrated pest management, which proved ahigh effective in elimination of soil fungi (Kredis *et al*, 2004).

There are many studies conducted in Basrah Province that dealt with the study of root rot diseases on some crops such as beans (Fayyad *et al*, 2008), cucumber (Al-Maliki, 2009) and okra (Al-Maliki, 2016 and Salih and Mansoor, 2019), but there is no study that deals with eggplant roots rot disease, so this study dealt with this disease.

2. MATERIALS AND METHODS

Isolation and identification

Samples were taken from the roots of eggplant plants that showed symptoms of root rot disease from several areas in Basrah Province including Al-Qurna, Al-Madina, Al-Haritha, Shatt Al-Arab, Al-Zubayr, Al-Lhais, Abu Al-Khasib, Safwan and Al-Karma - the field of the College of Agriculture, Basrah University. The roots of the affected plants were washed carfully with tap water to remove the soil attached to them. The parts of the affected roots were cut to a length of 1 cm, they were then sterilized with 10% sodium hypochlorite (NaOCl) solution from the commercial formulations for 2-3 minutes, washed with sterile distilled water and dried on filter paper. Four pieces were cultured in each Petri dish containing PDA with the antibiotic Chloramphenicol (250 $mg.L^{-1}$). The dishes were incubated at 25±2°C for seven days, the pathogenic fungi isolates were then purified and incubated at 25°C for seven days. The fungi isolates were identified based on Lesslei and Summurel(2006). Molecular diagnosis was performed to confirm the phenotypic diagnosis for the isolate of the pathogenic fungus *F. solani* by extracting DNA from the fungus using Mini Kit Fungus Protocol (Geneaid Company).

Pathogenicity test

Water Ager (W.A) was prepared and sterilized with an autoclave at a temperature of 121°C and a pressure of 15 pounds/inch^2 and the antibiotic Cholramphenacol (250 mg.L^{-1}) was added to it. The medium was poured in Petri dishes (9 cm diameter) at a rate of 15-20 ml / dish . The dishes were inoculated with disk (0.5 cm diameter) by using a sterile cork borer from near the edges of seven days colony of pathogenic fungus *F. solani*. Three dishes were used for the pathogenic fungi. As for the control treatment, three dishes were left containing the WA medium only. All dishes were incubated at a temperature of 25±2°C for three days. After confirming the growth of the pathogenic fungus, the seeds of the eggplant (Barcelona cultivar) which superficially sterilized in a solution of sodium hypochlorite (NaOCl) 10% of the commercial formulation for 2-3 minutes were cultivated in the dishes circularly at a distance of 1 cm from the dish edge, at a rate of 10 seeds/dish .All dishes were placed in the incubator at 25±2°C. The percentage of germination after seven days of planting the seeds were calculated according to the following equation:

Percentage of germination = Number of germinated seeds / Total number of seeds x 100

Testing the efficiency of antagonism among the two bioagents *T.harzianum* and *T.longibrachiatum* and the pathogenic fungus *F. solani*

The dual culture method was used to test the ability of the bioagents *T.harzianum* and *T.longibrachiatum* of antagonism with pathogenic fungus *F. solani*. A petri dish containing sterile PDA was divided into two equal parts and the center of the first part was inoculated with a 0.5 cm diameter disc taken from the seven days colony of each bioagents *T.harzianum* and *T.longibrachiatum* at the and the second part was inoculated with a 0.5 cm diameter disc of seven days colony of pathogenic fungus *F. solani*, while the control treatment was inoculated with the pathogen alone. The dishes were incubated at a temperature of 25±2°C, and after the growth of pathogenic fungi in the control treatment reached the edge of the plate, the degree of antagonism was calculated according to the scale of Bell *et al* (1982) which consisting of five degrees as follows:

Degree	The description
1	Bioagent covers the whole dish.
2	Bioagent covers two-thirds of the dish.
3	The bioagent and the pathogenic fungus each cover half of the dish
4	Pathogenic fungus cover two thirds of the dish.
5	Pathogenic fungus cover the entire dish.

A bioagent is effective when the degree of antagonism is 1 or 2.

Testing the effect of fungicide Topsin-M in inhibiting the growth of *F. solani* and the bioagents *T. harzianum* and *T. longibrachiatum* on PDA

The PDA culture medium was prepared and poured in a 250 ml flask at a rate of 100 ml for each one and sterilized by autoclave at a temperature of 121°C and a pressure of 15 pounds/inch^2 for 30 minutes. After accessing the medium's temperature an appropriate degree, Topsin-M was added at a concentration of 1 g.L^{-1}, the medium was poured in sterile Petri dishes with three replicates

for each treatment. After the solidification of the medium, the center of each dish was inoculated by a disk (0.5 cm diameter)taken from the edge of the seven days colonies for *F.solani* and the bioagents *T. harzianum* and *T. longibrachiatum* at separately, while the control treatment was free of fungicide for all fungi. All dishes were incubated in the incubator at a temperature of 25±2°C.After the growth in the control treatment reached the edge of the dish, the diametrical growth of the fungal colonies was measured by taking the average of two perpendicular diameters passing through the center of the dish from the back. The percentage of inhibition was calculated according to Abbott's equation (Shaaban and Al-Mallah, 1993) as follows:

$$\text{The percentage of inhibition} = \frac{\textit{The average fungal growt in the control} - \textit{The average fungal growth in the treatment}}{\textit{The average fungal growth in the control}} \times 100$$

Preparation of the fungal inoculum for the pathogenic fungus *Fusarium solani* and the bioagents *T. harzianum* and *T. longibrachiatum*

The inoculum of the pathogenic fungus *F. solani* which was isolated from the roots of infected eggplant plants and the two bioagents *T. harzianum* and *T .longibrachiatum* which were obtained from Basil Y. Mehdi, Department of Plant Protection, College of Agriculture, University of Basrah was prepared according to method of Dewan (1989), using seeds of local local millet *Panicum miliaceum* L., where the seeds were soaked in water for 6 hours and then washed well to remove impurities from them. The seeds were distributed in 250ml flasks at a rate of 150 g/ flask, then sterilized with an autoclave at a temperature of 121°C and a pressure of 15 pounds/in^2 for one hour, then the flasks were cooled and inoculated with 5 disks par each flask of pathogenic fungi and bio agents, taken from the edge of seven days the colony for each of them. The flasks were incubated at 25±2°C for 14 days, the flasks were shaken well every 2-3 days for distributing the fungal inoculum on all the seeds and preventing the seeds.

Field experiment

Testing the efficiency of the bioagents *T. harzianum* and *T.longibrachiatum* , the fungicide Topsin-M and aqueous copper sulfate and their interaction in controlling the pathogenic fungus *F. solani*

The field experiment was conducted in the Department of Horticulture and Forestry, Directorate of Basrah Agriculture in a greenhouse with a dimension of 32 x 9 m. The soil was tilled and leveled and then divided into three rows with a height of 30 cm and a distance of 1 m between one row and another, and a distance of 50 cm between one pit and another. The drip irrigation system was used and service operations were conducted for the soil and plant. Each treatment was conducted with three replicates, and the experiment included thirteen treatments, the following :

1- Control treatment (Control)
2- Treatment of pathogenic fungus *F. solani* alone (Fs)
3- Treatment of pathogenic fungus + bioagent *T.harzianum* (Fs+Th)
4- Treatment of pathogenic fungus + bioagent *T. longibrachiatum* (Fs+Tl)
5- Treatment of pathogenic fungus + fungicide Topsin-M (Fs+TM)
6- Treatment of pathogenic fungus + aqueous copper sulfate $CuSO_4.5H_2O$ (Fs+Cu)
7- Treatment of pathogenic fungus + *T. harzianum* + Topsin-M (Fs+ Th+TM)

8- Treatment of pathogenic fungus + *T. longibrachiatum* + Topsin-M (Fs+Tl+TM)
9- Treatment of pathogenic fungus + Topsin-M + $CuSO_4.5H_2O$ (Fs+TM+Cu)
10- Treatment of pathogenic fungus + *T. harzianum* + $CuSO_4.5H_2O$ (Fs+Th+Cu)
11- Treatment of pathogenic fungus + *T. longibrachiatum* + $CuSO_4.5H_2O$ (Fs+Tl+Cu)
12- Treatment of pathogenic fungus + *T. harzianum* + Topsin-M + $CuSO_4.5H_2O$ (Fs+Th+TM+Cu)
13- Treatment of pathogenic fungus + *T. longibrachiatum* + Topsin-M + $CuSO_4.5H_2O$ (Fs+Tl+TM+Cu)

The inoculum of the bioagents *T. harzianum* and *T. longibrachiatum* was added to the treatments in which it was present at a rate of 1% w/w per pit, after three days, the pathogenic *F. solani* inoculum was added at the same rate and after a day of adding the pathogenic fungus, Topsin-M was added to the soil at the recommended concentration by irrigation (Radi *et al*, 2016). The eggplant seedlings (Barcelona cultivar) with one month age were cultivated at a rate of two seedlings per pit, then copper sulfate was added at a concentration of 200 $mg.L^{-1}$ by irrigation. The results were recorded after four months of planting, and the infection severity was calculated according to the following disease index:

0 = the roots are healthy
1 = discoloration of root system with a light brown color at a percentage of 1-25%
2 = discoloration of root system with a dark brown color at a percentage of 25-50%
3 = discoloration of root system with a dark brown color at a percentage of 50-75%.
4 = discoloration of root system with a dark brown color at a percentage of 75-100% with the death of the plant

The severity of infection for each treatment was calculated according to the equation of Mckinney(1923) which found in Al-Waely(2004) as follows:

$$\text{The severity of infection} = \frac{(Number\ of\ plants\ in\ grade\ 0\ x\ 0) + - - - + (Number\ of\ plants\ in\ grade\ 4\ x\ 4)}{Number\ of\ examined\ plants \times the\ highest\ degree\ of\ infection} \times 100$$

The studied growth indicators

After four months of planting measurements of growth indicators were taken, which included plant height (cm), fresh and dry weight of the shoot and root systems (g), leaf area (cm^2) and total plant yield ($g.plant^{-1}$).

Statistical analysis

The laboratory results were analyzed by using a Completely Randomized Design (CRD), whereas the field experiment was based on The Randomized Complete Block Design (RCBD). All averages were compared by using the least significant difference test(LSD) at the probability level of 1% for laboratorial experiments and 5% for field experiment (Al-Rawi and Khalaf Allah, 1980).All statistical analyses were conducted by using Genstat discovery edition program .

3. RESULTS AND DISCUSSION

Isolation and identification pathogenic fungus *F. solani*

The isolation results showed the presence of the fungus *F. solani* in all infected samples collected from the studied areas(Figure 1). The morphological features were represented by the formation of a creamy white mycelium. Microscopic examination revealed the formation of three types of spores: Macroconidia which be a fusiform or cylindrical and slightly curved, with 3-5 septa , the second type is microconidia which be an abundant, oval or elongated, one-celled or two-celled, and present on long phialides and the third type is chlamydospores, which are hyaline by being transparent with a rough or smooth wall, spherical or oval shaped and terminal. The characteristics of the pathogenic fungus are consistent with Lesslei and Summurel(2006). The results of the molecular diagnosis also showed that the isolate of *F. solani* matched with the global isolates recorded according to the available information in the National Center for Biotechnology Information (NCBI) and the Gen Bank, with rates ranging between 97.50 - 98.24% as shown in Figure (2).

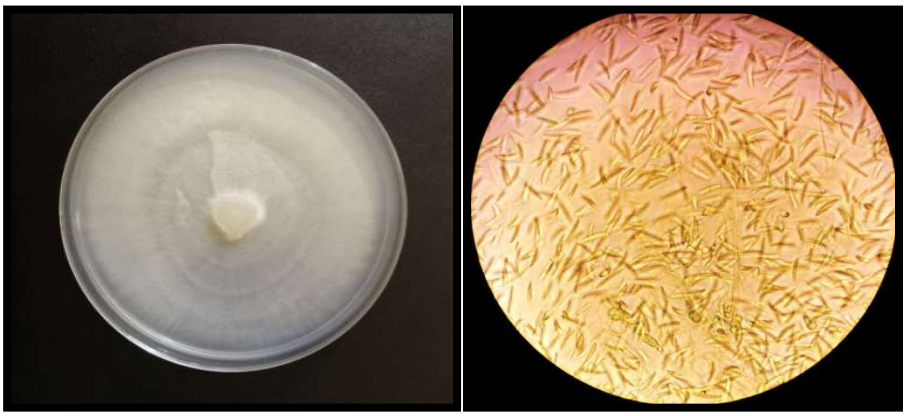

Figure 1: The colony and the conidid of the fungus *Fusarium solani* isolated from the roots of eggplant infected with root rot disease in Basrah Province

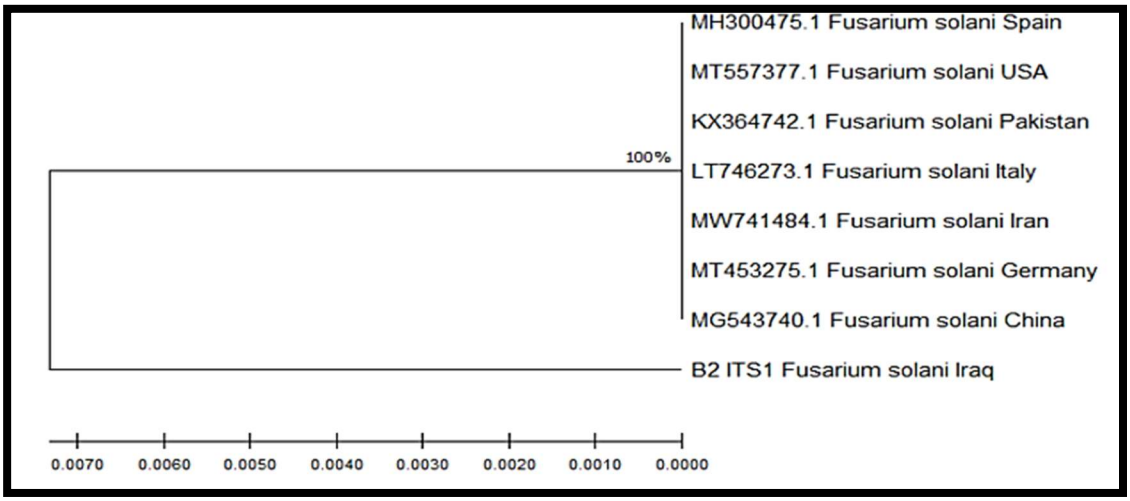

Figure 2: Phylogenetic tree of the pathogenic fungus *F. solani* isolated from the roots of the eggplant infected with root rot disease in Basrah Province

Pathogenicity test of the pathogenic fungus *F.solani*

Table (1) showed that the pathogenic fungus *F.solani* led to reduce the percentage of germination of eggplant seeds to 20% with significant difference compared to the control treatment in which the percentage of germination amounted to 93.3%. This result agree with Almammory and Matloob(2020), who found that the pathogenic fungus *F.solani* significantly reduced the germination of eggplant seeds. The low percentage of eggplant seed germination is may be due to the ability of some isolates of *Fusarium* spp. For producing pectin and cellulose degrading enzymes such as Polygalactoronase enzyme, in addition to produc toxic substances such as Fusaric acid, Lycomarasmine and Dehydrofusaric acid (Kumari *et al*, 2011).

The results of this experiment also showed that the treatment with bioagents *T.harzianum* and *T. longibrachiatum* led to increase the percntage of germination up to 96.7 and 86.7% respectively, with a significant differences from the treatment of pathogenic fungi which amounted to 20%, These results were compatible with several studies that showed to the effectiveness of the bio agent in increasing the percentage of germination for many vegetable crops, including eggplant and reducing the infection with root rot disease (Hossain and Naznin, 2005; Woo and Pape, 2018; Salih and Mansoor and 2019; Al-Abbad, 2020).

Table 1: Effect of fungi on the percentage of eggplant seed germination in the plates.

Treatment	% Germination
F. solani	20
T. harzianum	96.7
T. longibrachiatum	86.7
Control	93.3
L.S.D. 0.01	27.4

* Each number represents the average of three replicates.

Testing the efficiency of antagonism among the two bioagents *T. harzianum* and *T. longibrachiatum* and the pathogenic fungus *F. solani*

Figure (3) revealed that the two bioagents *T. harzianum* and *T. longibrachiatum* achieved a high antagonistic capability against the pathogenic fungus *F. solani* , where the antagonism degree reached 1 when *T. longibrachiatum* was used and degree 2 when *T. harzianum* was used, according to on the scale of Bell *et al* (1982). This result was in agreement with Basco *etal*(2017); Salih and Mansoor(2019); Kareem and Matloob(2019)and Al-Abbad(2020). The reason of the high antagonism of *Trichoderma* against pathogens is due to the direct parasitism on the mycelium of the pathogen and the production of cell wall-degrading enzymes such as Chitinase and B-1,3 glucanase or competition (Behzad *et al*, 2008; Hernández-Melchor *et al*, 2019).

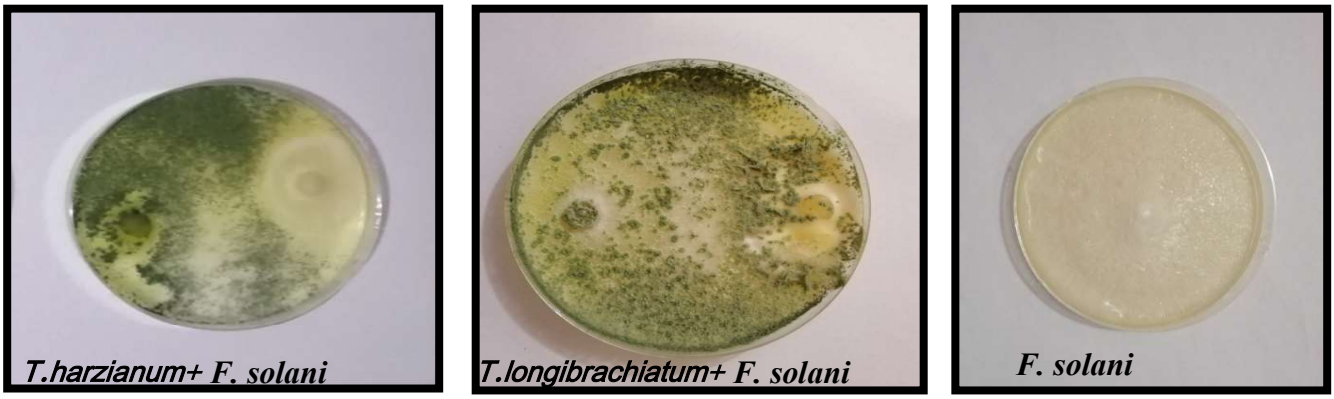

Figure 3: The antagonism among the two bioagents *T.harzianum* and *T.longibrachiatum* and the pathogenic fungus *F. solani* on PDA medium.

Testing the effect of the fungicide Topsin-M on the growth of pathogenic fungus *F. solani* and the bioagents *T. harzianum* and *T.longibrachiatum* on PDA medium

Figure (4) and Table(2) explained that using the fungicide Topsin-M at a concentration of 1 $g.L^{-1}$ led to inhibit the growth of *F. solani* with a percentage of 100% compared to the control treatment in which the percentage of inhibition amounted to 0%. This result agreed with several studies that demonstrated the efficiency of Topsin-M in inhibiting pathogenic fungi on PDA medium (Al-Hujazy, 2010; Salih and Mansoor, 2019 and Abdel-Wahed, 2020). While the fungicide Topsin-M inhibited the growth of the bioagents *T.harzianum* and *T. longibrachiatum* slightly when using the same concentration, where the percentage of inhibition amounted to 16.63 and 26.80% respectively. This result was in agreement with Khan *et al*(2013) and Salih and Mansoor(2019) who elucidated that Topsin-M did not significantly inhibited *T.harzianum* on PDA medium.

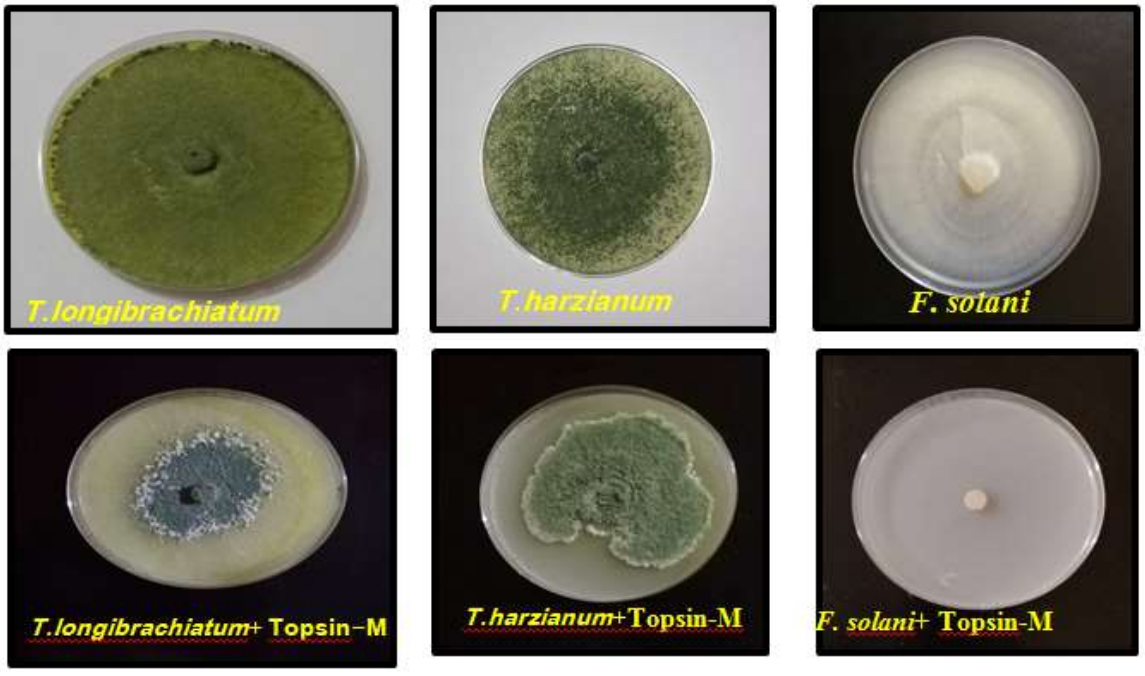

Figure 4: Effect of Topsin-M on the growth of the pathogenic fungus *F. solani* and the bioagents *T.harzianum* and *T.longibrachiatum* on PDA medium.

Table 2: Effect of the fungicide Topsin-M on the growth of pathogenic fungus *F. solani* and the bioagents *T. harzianum* and *T. longibrachiatum* on PDA medium.

% Inhibition	Treatments	Fungicide
100	*F. solani*	Topsin-M
16.6	*T. harzianum*	
26.8	*T. longibrachiatum*	
0.0	Control	
30.95	L.S.D.0.01	

Evaluating the efficiency of the bioagents *T. harzianum*, *T.longibrachiatum*, Topsin-M, and aqueous copper sulfate in the percentage of infection severity with pathogenic fungus *F. solani* and some growth indicators of eggplant in greenhouses.

The field experiment results revealed (Table3) the efficiency of all treatments in reducing the percentage of infection severity for eggplant plants with the *F. solani* fungus significantly compared to the pathogenic fungus *F. solani*. Fs+Th+TM+Cu treatment has achieved the lowest infection severity amounted to 10.67% , followed by the treatments Fs+Tl+ TM+Cu, Fs+Th+TM and Fs+Tl+TM, wich reduced the infection severity to 16.67, 21.67and 27.67% respectively, with a significant difference from the treatment of pathogenic fungus, in which the severity of infection amounted to 71.67% . This study was compatible with Salih and Mansoor (2019), who indicated that the interaction of the bioagent *T.harzianum* and the fungicide Topsin-M with the pathogenic fungus *F. solani* reduced the severity of infection with the *F. solani* which causes okra root rot to 46.2% compared to the treatment of pathogenic fungus which amounted to 66.8%. Peciulyte and Volodkiene (2012) found that the soil to which copper sulfate was added led to eliminate many species of pathogenic fungi, including *Fusarium*. This may be due to the fact that the elements directly enter into the defense processes of cells, whether in terms of their direct effect on the work of enzymes or coenzyme, which participate in the electronic transport chain of respiration and in the regulation of bio-metabolic processes (Rai *et al*, 2018).

The same table indicated that the two treatments Fs+Th+TM+Cu and Fs+Tl+ TM+Cu achieved a significant increase in plant height amounted to 80.67 and 79.67 cm respectively. These two treatments were significantly differed from the control treatment without pathogenic fungus and the pathogenic fungus treatment which amounted to 68.67 and 48.67 cm respectively. These results agree with Salih and Mansoor(2019), who explained that the interaction of the bioagent *T.harzianum* and the fungicide Topsin-M with the pathogenic fungus *F. solani* led to increase the height of okra plant which amounted to 31.87 cm compared to the treatment of the pathogenic fungus which amounted to 17.67 cm. The reason of the increasing in plant height in the presence of the bioagent *T. harzianum* may be due to the ability of this fungus to produce salicylic acid, carbohydrates, fatty acids, amino acids, and glycoproteins which induce the resistance by increasing the activity of the enzyme Peroxidase (Saravanakumar *et al*, 2016). It was also observed from the same table that these two treatments led to increase the leaf area up to 791 and 745 cm^2 respectively, with a significant difference from the control treatment (without pathogenic fungi)

and the pathogenic fungus treatment, which had leaf area amounted to 624 and 373.5 cm^2 respectively. This result was in agreement with Almammory and Matloob(2019), who indicated that the pathogenic fungus *F. solani* caused a loss in leaf area, which amounted to 18.67 cm^2 compared to the control treatment which amounted to 23.33 cm^2. The reason of the superiority of the treatments of which have more than one factor in increasing the leaf area is attributed to the synergistic effect among the factors used in the experiment, where they work together and cooperatively in stimulating the systemic resistance of the plant against pathogens and improving the plant growth (Shoresh *et al*, 2010; Wedajo, 2015).

Table (4) showed that the highest average of the fresh and dry weight of the shoot system of the plant at the end of the season was recorded in the treatment Fs+Th+TM+Cu which reached 564.3 and 88.2 g respectively, followed by the treatments Fs+Tl+ TM+Cu , Fs+Th +TM and Fs+Tl+ TM which amounted to 543.3, 520, 506.7, 82.9, 77.1 and 73.8g respectively. All these treatments were significantly differed from the control treatment (without pathogenic fungus), which amounted to 484.7 and 68.2 g, respectively, and the pathogenic fungus treatment, which amounted to 354.7 and 35.9 g respectively. It was also clear from the same table that the highest average of fresh and dry weight of the root system of the plant at the end of the growing season was observed in the treatment Fs+Th+TM+Cu which amounted to 64.33 and 16.42 g respectively, followed by the treatments Fs+Tl+ TM+Cu , Fs+ Th+TM and Fs+Tl+ TM which amounted to 61.67, 60.33, 55, 15.42, 15.08 and 13.75 g respectively.

Table 3: Effect of the bioagents *T. harzianum*, *T. longibrachiatum*, Topsin-M, and aqueous copper sulfate on the percentage of infection severity the height of the eggplant plant and the leaf area in the greenhouse.

Treatments	% Infection severity	Plant height (cm)*	Leaf area (cm^2)*
Control	0.00	68.67	624
Fs	71.67	48.67	373.5
Fs+TM	36.67	62.67	547.6
Fs+Cu	50.00	61.33	510.6
Fs+TM+Cu	29.33	67.50	547.4
Fs+Th	38.33	69.17	652.5
Fs+Tl	41.67	68.17	591.5
Fs+Th+Cu	28.33	71	661.3
Fs+Tl+Cu	31.67	69	643.8
Fs+Th+TM	21.67	74.83	737.1
Fs+Tl+TM	27.67	74.83	680.7
Fs+Th+TM+Cu	10.67	80.67	791
Fs+Tl+ TM+Cu	16.67	79.67	745.8
L.S.D. 0.05	**4.75**	**6.46**	**69.7**

*Each number represents an average of three replicates.

Th=*Trichoderma harzianum*, Tl= *Trichoderma longibrachiatum*, Fs=*Fusarium solani* Cu=$CuSO_4.5H_2O$, TM=Topsin-M

These treatments were significantly differed from the control treatment (without pathogenic fungus), which amounted to 43.33 and 10.83 g respectively. The increase in fresh and dry weights in treatments that included the bioagents , Topsin-M and aqueous copper sulfate may be due to the ability of the bioagent to induce plant growth through the exudation of plant growth regulators that work in compatible with other mechanisms, including increasing the availability and absorption of plant nutrients (Harman, 2000; Harmosa *et al*, 2012). The increase in weights in the treatments that included aqueous copper sulfate may be due to the effect of this element on the pathogenic fungus and reflected positively on the plant health or to increase the absorption of some nutrients such as phosphorous (Al-Nuaimi, 2000; Aravind and Prasad, 2004). As for the treatments containing the fungicide Topsin-M, the increase in weight may be due to its effect on pathogenic fungi, as it prevents the germination and sporulation and inhibit RNA synthesis, then it negatively affects on the indirect division process (Gisi *et al*, 2002).

It was found from the same table that the highest average of production per plant at the end of the growing season was recorded in the two treatments Fs+Th+TM+Cu and Fs+Tl+ TM+Cu, which amounted to 2276 and 2108 g/plant respectively, with highly significant differences from the control treatment which was 1451 g /plant and the pathogenic fungus treatment, which amounted to 876 g/plant. Whereas all other treatments were significantly differed from the pathogenic fungus treatment, which gave the lowest average of production per plant, which amounted to 876 g/plant. The reason of the increasing in plant production indicators is attributed to the cooperation among the mechanisms of the bioagents used in the experiment against pathogens, which mechanisms include fungal parasitism, competition of nutrients and place, production of antibiotics and secondary metabolites, induction of the defense system in the plant and production of enzymes such as cellulases, hemicellulases, proteases and B-1, 3-glucanase in addition to induce the plant growth (Shoresh, 2010; Kowsari *et al*, 2014and Jamal Uddin *et al*, 2020). It is also noted from the results the role of the copper in inducing the increase in yield compared to the treatment of pathogenic fungus. Aravind and Prasad (2004) indicated the importance of the copper in the production of agricultural crops and it had a positive effect in improving plant growth and increasing its productivity in quantity and quality, and activates the plant biosynthesis processes.

Table 4: Effect of the bioagents *T.harzianum*, *T.longibrachiatum*, the fungicide Topsin-M and aqueous copper sulfate on the fresh and dry weight of shoot and root systems and plant yield of eggplant in the greenhouse

Treatments	Average of Fresh Weight (g)*		Average of dry weight (g)*		Plant yield (g/plant)*
	Shoot system	Root system	Shoot system	Root system	
Control	484.7	43.33	68.2	10.83	1451
Fs	354.7	23.33	35.9	6	876
Fs+TM	436.7	35	56.2	8.75	1203
Fs+Cu	396.7	33.33	46.2	8.33	1178

Fs+TM+Cu	470	40.67	64.6	10.17	1248
Fs+Th	489	50	70	12.50	1461
Fs+Tl	483.3	41.33	67.9	10.33	1339
Fs+Th+Cu	498.3	52.33	71.7	13.42	1740
Fs+Tl+Cu	493.3	50	70.4	12.50	1528
Fs+Th+TM	520	60.33	77.1	15.08	1813
Fs+Tl+TM	506.7	55	73.8	13.75	1758
Fs+Th+TM+Cu	564.3	64.33	88.2	16.42	2276
Fs+Tl+ TM+Cu	543.3	61.67	82.9	15.42	2108
L.S.D. 0.05	**42.9**	**8.25**	**10.6**	**2.10**	**133.3**

*Each number represents an average of three replicates.
Th=*Trichoderma harzianum*, Tl= *Trichoderma longibrachiatum*, Fs=*Fusarium solani*
Cu=$CuSO_4.5H_2O$ TM=Topsin-M

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