EFFECT OF CERTAIN PSEUDOMONAS FLUORESCENS ISOLATES ON THE INFECTION OF ROOT-KNOT NEMATODE, MELOIDOGYNE INCognITA IN TOMATO AND EGGPLANT AND THE PLANT GROWTH

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ABSTRACT

Under screen house conditions, two experiments were carried out to evaluate certain bacterium, Pseudomonas fluorescens isolates regarding reproductive potential of root-knot nematode, Meloidogyne incognita, infecting tomato or eggplant. Results on tomato revealed that, on the basis of average total percentages nematode reduction, the over topped results were gained with P. fluorescens (Pf2) which recorded the highest significant (P≤0.05) average nematode reduction (61.3%) and higher percentage reduction of females (77%) per plant. The second rank was obtained by Pf3 which reduced all nematode numbers as an average of 56.9%. On the basis of average total percentages plant growth and weight of fruit increases, four bacterial treatments can be ranked in a descending order as follows: Pf9 > Pf4 > Pf1 and Pf7, as they achieved the highest average total percentages increases of 96.0, 47.3, 38.2 and 29.8%, respectively compared to other treatments and untreated check. Regarding to eggplant, the over topped results observed was achieved by P. fluorescens (Pf10) which recorded the highest average total nematode reduction (66.2%) with higher reduction of (J2s) in roots (89.9%) per plant and in soil (78.8%) per pot. The second rank was obtained by Pf9 and Pf2 where they reduced all nematode numbers as averages of 55.9% and 54.9%, respectively. Also Pseudomonas isolates enhanced the plant growth of eggplant, averages were found in a descending order as follows: Pf1 (20.0%), Pf9 (18.7%) and Pf10 (18.3%). It is worthy to note that the most distinct growth criteria was fresh weight of roots as it achieved higher percentage increase (58.1%) by using Pf6 followed by Pf1 as it caused 40.6% increase compared to untreated check. The highest average percentage of fresh weight of shoot were recorded for Pf10 (26.4%) and Pf8 (22.1%). Whereas for dry weight Pf3 (29.8%) and Pf2 (19.1%). In conclusion, the tested biocontrol agent was efficient in controlling the root-knot nematode on tested plants.

Keywords: Pseudomonas fluorescens isolates, Tomato, Eggplant, Meloidogyne incognita.

INTRODUCTION

Root-knot nematodes belonging to the genus of Meloidogyne known as an endoparasite cause root-knot symptoms and serious plant damage (Trudgill and Blok 2001). Plant parasitic nematodes reducing production by 12–20% worldwide were studied widely (Oka et al 2000), moreover losses can reach 30–60% (Talavera et al 2012) in protected cultivation. Efforts were directed to use the biological control as environmental friendly management of root-knot nematodes (Timper 2011). Plant growth-promoting rhizobacteria (PGPR) can protect plants against nematodes (El-Hadad et al 2010 and
Oliveira et al. (2007). Approximately, 7–10% of all rhizobacteria act as antagonistic agents against nematodes by more than mode of action, including competition, antibiosis and induced resistance (Burkett-Cadena et al. 2008). Under pot experiments, several Pseudomonas species were effective in managing root-knot nematode (Siddiqui et al. 2009, Singh and Siddiqui 2010). Kavitha et al. (2011) mentioned that soil application by the native isolates Pft 20 (P. fluorescens) at 2.5 kg/ha significantly reduced the infestation of root-knot nematode, M. incognita in the treated tomato both in soil and roots as indicated by the reduction in number of the studied nematode criteria and increasing in the plant growth. Mokbel and Alharbi (2014) evaluated the efficacy of certain bacterial genera against M. javanica on eggplant as egg-hatch inhibition and reduction in 2nd stage juveniles percentages ranged from 50.5–90.3% were obtained by using Bacillus subtilis, B. thuringiensis, P. fluorescens and Serratia marcescens. Also, they observed that 56.5–86.8% reductions in the number of galls, egg-masses/root system, and number of J2s. Subsequently, 50.9-73.7% increases in the root and shoot dry weights of eggplant occurred. The information about the efficacy of biocontrol agents in controlling root-knot nematodes needs more expanded researches. Therefore, this research was designed to evaluate certain Pseudomonas fluorescens isolates for their nematicidal efficacy on root-knot nematode, M. incognita infecting tomato and eggplant and subsequently on their plant growth.

2. Bacterial isolates

2.1. Source of Pseudomonas fluorescens isolates

Twelve soil samples (200g soil) were taken from the rhizospheres of eggplant and tomato plants cultivated in El-Beheira and Monufiya Governorates, Egypt. In addition, 3 soil samples of pepper plant only were collected from El-Beheira Governorate. All samples were free from root-knot nematode infestation; the samples were transferred to the laboratory of PPD-NRC for isolation and identification of Pseudomonas fluorescens.

2.2. Isolation and identification of P. fluorescens

For isolation of P. fluorescens, the total plate counts technique and dilution method were carried out according to (Ghini et al. 2007). Each collective sample (Ten gram) was transferred into 250 ml conical flask containing 90-ml of sterile distilled water to prepare serial dilutions ranging from 10⁻¹ to 10⁻⁷. One ml of each sample dilution was pipetted onto the surface of sterile Petri-dish (9 cm diam.) containing KB (King’s medium B) [Peptone 20.0g; Glycrol 15.0 ml; K₂HPO₄ (anhydrous) 1.5g; MgSO₄ x 7H₂O; Agar 15.0g in 1.0 liter of distilled water at pH 7.2 ± 0.2]. The soil suspension was spread on the surface of medium using glass rod (L-shape). The inoculated plates were incubated at 28°C for 48h. The growing bacterial colonies were examined with UV light for detection fluorescent pigment production. Subsequently, the bacterial colonies, which showed fluorescent pigment, were picked on slant of nutrient glucose 2% agar medium (NGA) [Beef extract 3.0g; Peptone 5.0g; Glucose 20.0g; Agar 15.0g in 1.0 liter of distilled water at pH 7.2 ± 0.2].

Nine P. fluorescens isolates were isolated from the collected rhizosphere samples (Table 1 and 2). The isolates were identified according to cultural characters on NGA medium and LOPAT test (Levan production, Oxidase test, pectolytic enzymes, arginine dihydrolase and hyper sensitivity reaction) using standard bacteriological methods (Schaad 1980, Leliiot and Stead 1987 and Goszczyńska et al. 2000).

Justification of bacterial inoculums for each isolate reached 10⁷-10⁹ colony forming unit (CFU)/ml by turbidity method (Baid et al. 2000) and was applied as mixture of bacterial cells and cultural filtrate.

MATERIALS AND METHODS

1. Preparation of root-knot nematode pure culture and inoculum

The tested species of root-knot nematode was Meloidogyne incognita, identified from nematode adult female according to the morphological characteristics of the female perineal pattern (Taylor and Sasser 1978). Pure culture of M. incognita was reared on eggplant cv. Ice under screen house conditions at 30 ± 5°C by using a single egg-mass of this nematode. Newly hatched second stage juveniles (J2s) were used as inoculum.

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Table 1. Location, source and name of the tested bacterial isolates

| Governorate | Source plant  | No. of samples | Bacterial isolate |
|-------------|---------------|----------------|------------------|
| El-Beheira  | Egg plant     | 3              | Pf1, Pf2         |
|             | Pepper        | 3              | Pf3, Pf4, Pf5, Pf6, Pf7 |
|             | Tomato        | 3              | Pf8, Pf9         |
| El-Monoufyia| Egg plant     | 3              |                  |
|             | Tomato        | 3              |                  |

Table 2. Identification of some green fluorescent *Pseudomonas* by the LOPAT scheme

| *P. fluorescens* Isolates (Ivb) | LOPAT Test                  |
|---------------------------------|-----------------------------|
|                                 | Levan Production | Oxidase Test | Potato Soft Rot | Arginin Dihydrolase | Tobacco Hyper Sensitive Reaction |
| P11                             | -              | +            | +               | +                   | -                               |
| P12                             | -              | +            | +               | +                   | -                               |
| P13                             | -              | +            | +               | +                   | -                               |
| P14                             | -              | +            | +               | +                   | -                               |
| P15                             | -              | +            | +               | +                   | -                               |
| P16                             | -              | +            | +               | +                   | -                               |
| P17                             | -              | +            | +               | +                   | -                               |
| P18                             | -              | +            | +               | +                   | -                               |
| P19                             | -              | +            | +               | +                   | -                               |

3. Source of standard *P. fluorescens* isolate

A standard *P. fluorescens* Pf10 (NRC isolate) was obtained from (PPD-NRC). The inoculum of this isolate was prepared as mentioned previously.

4. Source of Micronema®

The commercial bio-nematicide, Micronema® (mixture of certain beneficial bacteria) was obtained from the Agricultural Research Center (Giza, Egypt) and used with the recommended dose.

5. Tested plants

Seeds of tomato (*Lycopersicum esculentum*) cv. Castle Rock and eggplant (*Solanum melongena*) cv. Ice. were obtained from Agricultural Research Center, Giza, Egypt. Seeds were sown in a nursery for germination and maintained till the seedling reached one-month old.

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6. In vivo evaluation of the *P. fluorescens* isolates against *M. incognita*

Under screen house conditions, two experiments were conducted in PPD-NRC, in order to differentiate the potential of *P. fluorescens* isolates infecting tomato and eggplant.

6.1. Tomato experiment

One-month-old of tomato seedlings were transplanted into 20-cm diameter plastic pots (one seeding/pot) containing 2 kg of solarized sandy loamy soil (1:1) in August 2-2015. A week later, second stage juveniles of *M. incognita* at the rate of 1000 individuals per pot were inoculated around the vicinity of each seedling. At the same time, the inoculation of each tested *P. fluorescens* isolates, inoculated to each seedling with a rate of 30 ml/pot (10^4-10^8 colony forming unit (CFU)/ml). The commercial product, Micronema® was used at the recommended rate (0.5 ml/pot) as comparison. Nematodes only in 30-ml distilled water were used as untreated check.

6.2. Eggplant experiment

The same procedures in tomato were carried out except that; eggplant seedlings were transplanted into May 15, 2016. A week later, each pot was inoculated with 500 newly hatched juveniles (Jjs) of *M. incognita*. Simultaneously, seedlings of eggplant were treated with 9 isolates of *P. fluorescens*. Also, the standard *P. fluorescens* Pf10 (NRC isolate) isolate was used as comparison. In both experiments, pots were arranged in a completely randomized design with 6 replicates for each treatment on a bench and maintained, plants were irrigated as needed.

7. Determination of *M. incognita* and plant growth parameters

7.1. *M. incognita* parameters

Plants of tomato and eggplant were harvested after three months from inoculation with nematodes and carefully uprooted. Roots were washed thoroughly with running tap water to get rid of soil aggregation and debris. Then, roots were cut into two halves. In one half, acid fuchsin in cold lacto-phenol was used to stain and store roots for not less than 24 hr. After that, stained roots were put in water and cut into pieces to enable counting of galls, females, and egg masses. Incubation method described by (Young 1954) was used for the remaining half of roots by incubating in tap water for obtaining Jjs from egg masses. The number of (Jjs) in the soil was extracted using a sieving and decanting technique (Barker 1985) and counted. Numbers of nematodes (Jjs) were counted under a light microscope. Average total percentages nematode reduction was calculated to compare among treatments. Rate of nematode reproduction (Rr) was calculated by dividing final nematode population (Pf) by the initial population (Pi).

7.2. Plant growth parameters

Plant growth criteria including shoot length (cm), fresh and dry shoot weights (g) and fresh root weight (g) of tomato and eggplant were recorded. Also, weight of fruits (g) was registered.

8. Statistical analysis

Statistically data of the present experiment were subjected to analysis by (ANOVA) procedures. Comparison was made for treatment at 5% probability by Duncan’s Multiple Range Test as reported by Snedecor and Cochran (1989). This was carried out by Computerized Statistical Package (COSTAT) User Manual Version 3.03, Barkley Co.

RESULTS

1. Influence of certain *P. fluorescens* isolates on root-knot nematode, *Meloidogyne incognita* infecting tomato

Under screen house conditions, nine bacterial isolates were tested, for their nematicidal efficacy to control *M. incognita* infecting tomato as indicated by number of nematode juveniles (Jjs) in soil and roots, females, galls and egg masses compared to a commercial product namely, Micronema® and untreated check. Table (3) illustrates mean numbers of treatments and untreated check. In general, all bacterial isolates had suppressive effect on *M. incognita*, when number of the studied nematode reproductive criteria and galls were significantly (P≤0.05) reduced at various degrees on the basis of average total percentages nematode reduction. The over topped results gained were achieved by *P. fluorescens* (Pf2) which recorded the highest average total percentages nematode reduction (61.3%) and high percentage reduction of females (77%) per plant. The second rank was obtained by Pf5, where it reduced all reproductive nematode numbers as an...
average total percentages reduction (56.9%) with the highest percentage reduction of females (84.7%) and 78.3% for number of second stage juveniles in roots. This was followed by Micronema® which caused 56% and was as effective as some treatments in reducing number of females by 58.1%. However, the percentages reduction of galls behaved an independent pattern, as they recorded the highest reduction (48.1%) caused by Pf1 followed by Pf4 (43.8%). On the other hand, control treatment (untreated infected plants) showed the highest numbers and galls of root knot nematode. Obviously, the isolates of Pf2 and Pf3 recorded the lowest reproduction rates (2.9 and 2.4), respectively followed by Micronema®. The reproduction rate of the other isolates ranged from 3.7-4.8.

2- Effect of certain P. fluorescens isolates on tomato growth and yield infected by Meloidogyne incognita

Concerning tomato growth, a significant (Ps0.05) augmentation of shoot length, fresh and dry weights, root fresh weight and weight of fruits as influenced by the tested isolates of P. fluorescens are illustrated in Table (4). On the basis of average total percentages of plant growth, Pf5 isolate was superior in increasing shoot length, shoot and root fresh weights as four bacterial treatments can be ranked in a descending order as follows: Pf9 >Pf5>Pf1 and Pf7 achieved the highest percentages increase (96.0, 47.3, 38.2and 29.8%), respectively compared to other treatments and untreated check. As for weight of fruits, Pf9 achieved the highest percentage increase (194.6%) followed by Pf2 (95.7%) and Pf4 (80.4%), whereas Micronema® caused 66.3% only.

3- Influence of certain P. fluorescens isolates on root-knot-nematode, Meloidogyne incognita infecting eggplant

Also, the nine bacterial isolates in addition the standard isolate (Pf10) were tested, for their efficacy on M. incognita infecting eggplant. Averages number of nematode juveniles in soil and roots, females, egg masses per root system as well as number of galls were used as indicators. In general, on the basis of these indicators, data in Table (5), indicated that all tested bacterial isolates had significantly (Ps0.05) suppressed M. incognita (J2S) in the above mentioned nematode criteria compared to the untreated check. The over topped results gained was achieved by P. fluorescens (Pf10) which recorded the highest average total nematode reduction (66.2%) with higher reduction of (J2S) in roots (89.9%) and in soil (78.8%) per plant. The second rank was obtained by Pf7 and Pf3 as they reduced all nematode numbers with averages 55.9% and 54.9%, respectively. The highest reductions of J2S in soil (77.1%) and female (72.4%) in root were recorded by Pf1. However, the percentages reduction of galls behaved an independent pattern, as they were reduced by 71.9 % caused by Pf5 followed by Pf6 (69.2%). On the other hand, the lowest reproduction rates (Rr) were recorded by the isolates Pf10 (3.4), Pf2 (5.8), Pf6 (6.97) and Pf1 (9.1). In contrast, control treatment (untreated infected plants) registered the highest numbers in all nematode parameters.

4- Effect of certain Pseudomonas fluorescens isolates on eggplant growth parameters infected by Meloidogyne incognita

Concerning eggplant growth as influenced by the tested bacterial isolates, mean numbers of shoot length, fresh and dry weights and root fresh weight and untreated check are illustrated in Table (6). Results indicated that, three treatments significantly (Ps0.05) promoted plant growth criteria than the other treatments and un-infected untreated plants as follows: averages total percentages plant growth increase of Pf1 (20.0%), Pf9 (18.7%) and Pf10 (18.3%) were found in a descending order. It is worthy to note that the most distinct growth criteria was fresh weight of roots, as it achieved higher percentage increase (58.1%) by using Pf9 followed by Pf1 caused increase 40.6% compared to untreated check. The highest average percentages increase recorded for fresh weight of shoot were achieved by Pf10 (26.4%) and Pf6 (22.1%), while for dry weight, the most effective isolates were Pf3 (29.8%) and Pf2 (19.1%).
Table 3. Effects of certain *Pseudomonas fluorescens* isolates on reproduction potential of *Meloidogyne incognita* infecting tomato plants

| Treatments | J2s in soil | % Red. | J2s in roots | % Red. | Females | % Red. | Egg-masses | % Red. | Galls | % Red. | % Average total percentages reduction | Reproduction rate (Rr) |
|------------|-------------|--------|--------------|--------|---------|--------|------------|--------|-------|--------|-------------------------------------|---------------------|
| Pf1        | 1451b       | 53.3   | 2970ab       | 10.0   | 330ab   | 29.0   | 74c        | 63.0   | 166c  | 48.1   | 38.8                                | 4.8                 |
| Pf2        | 1358 b      | 56.3   | 1430cd       | 56.7   | 107c    | 77.0   | 90c        | 55.0   | 219bc | 31.6   | 61.3                                | 2.9                 |
| Pf3        | 1599 b      | 48.5   | 715d         | 78.3   | 71 c    | 84.7   | 168ab      | 16.0   | 350a  | -      | 56.9                                | 2.4                 |
| Pf4        | 1958ab      | 37.0   | 2236abc      | 32.2   | 167bc   | 64.1   | 80c        | 60.0   | 180c  | 43.8   | 48.3                                | 4.4                 |
| Pf5        | 1708b       | 45.0   | 2310abc      | 30.0   | 167 bc  | 64.1   | 117bc      | 41.5   | 258abc| 19.4   | 45.2                                | 4.2                 |
| Pf6        | 1466b       | 52.8   | 2786ab       | 15.5   | 174 bc  | 62.6   | 117bc      | 41.5   | 260abc| 18.8   | 43.1                                | 4.4                 |
| Pf7        | 2325ab      | 25.1   | 2255abc      | 31.7   | 243 bc  | 47.7   | 73c        | 63.5   | 220abc| 31.3   | 42.0                                | 4.8                 |
| Pf8        | 1769 b      | 43.0   | 2035bc       | 38.3   | 212 bc  | 54.4   | 161ab      | 19.5   | 329abc| -      | 38.8                                | 4.0                 |
| Pf9        | 1588b       | 49.8   | 1925bc       | 41.7   | 235 bc  | 49.5   | 127bc      | 36.5   | 202c  | 36.9   | 44.4                                | 3.7                 |
| Micronema® | 1371 b      | 55.9   | 1393cd       | 57.8   | 195 bc  | 58.1   | 96c        | 52.0   | 245abc| 23.4   | 56.0                                | 3.0                 |
| Nematode only | 3106a     | 0      | 3300a        | 0      | 465a   | 0      | 200a       | 0      | 320ab | 0      | 6.9                                 |                     |

Averages followed by same letter(s) within each column are not significantly (P ≤ 0.05) different according to Duncan’s Multiple Range Test. Reproduction rate (Rr) = Final population (Pf)/Initial population (Pi).
Table 4. Effects of certain *Pseudomonas fluorescens* isolates on growth and yield parameters of tomato infected with *Meloidogyne incognita*

| Treatments   | Shoot length (cm) | Shoot weight (g) | Root weight (g) | Fruit weight (g) | % Average total percentages inc. |
|--------------|-------------------|------------------|-----------------|-----------------|---------------------------------|
|              | Length | % inc. | Fresh | % inc. | Dry | % inc. | Fresh | % inc. | Weight | % inc. |
| Pf1          | 29.7d   | -      | 19.2bc | 26.3 | 3.9cd | 25.8 | 21.3ab | 67.7 | 15.8bcd | 71.1 | 38.2 |
| Pf2          | 31.3cd  | -      | 16.3c  | 7.2  | 3.8cd | 22.6 | 15.2bc | 19.7 | 18.0b   | 95.7 | 29.0 |
| Pf3          | 30.5cd  | -      | 17.2bc | 13.2 | 3.6cd | 16.1 | 15.8bc | 24.4 | 13.3bcde | 44.6 | 19.6 |
| Pf4          | 35.7ab  | 11.5   | 20.9bc | 37.5 | 5.2ab | 67.7 | 17.7bc | 39.4 | 16.6bc  | 80.4 | 47.3 |
| Pf5          | 33.7abc | 5.3    | 16.6c  | 9.2  | 2.9d  | -    | 13.8c  | 8.7  | 13.2bcde | 43.5 | 13.3 |
| Pf6          | 32.0bcd | 0      | 16.0c  | 5.3  | 3.3de | 6.5  | 13.6c  | 7.1  | 11.5cde | 25.0 | 11.0 |
| Pf7          | 37.5a   | 17.2   | 23.0ab | 51.3 | 4.3bc | 38.7 | 16.6bc | 30.7 | 10.2de  | 10.9 | 29.8 |
| Pf8          | 34.5abc | 7.8    | 18.9bc | 24.3 | 4.4bc | 41.9 | 15.0bc | 18.1 | 13.1bcde | 42.4 | 26.9 |
| Micronema®   | 36.2ab  | 13.1   | 27.4a  | 80.3 | 6.1a  | 96.8 | 25.3a  | 99.2 | 27.1a   | 194.6 | 96.8 |
| Nematode only (control) | 34.3abc | 7.2    | 16.7c  | 10   | 3.8cd | 22.6 | 14.6bc | 15.0 | 15.3bcde | 66.3 | 24.2 |

Averages followed by same letter(s) within each column are not significantly (P ≤ 0.05) different according to Duncan's Multiple Range Test. -Decrease less than control.
Table 5. Effects of certain Pseudomonas fluorescens isolates on reproduction potential of Meloidogyne incognita infecting eggplant

| Treatments | J2s in soil | % Red. | J2s in roots | % Red. | Females | % Red. | Egg masses | % Red. | % Average total percentages Red. | Galls | % Red. | Reproduction rate (Rr) |
|------------|-------------|--------|-------------|--------|---------|--------|------------|--------|---------------------------------|-------|--------|----------------------|
| Pf1        | 1179b       | 77.1   | 3311ab      | 31.2   | 85b     | 72.4   | 114ab      | 21.9   | 50.7                            | 221ab | 33.2   | 9.1                  |
| Pf2        | 1540b       | 70.1   | 1205b       | 75.0   | 171ab   | 44.5   | 104ab      | 28.8   | 54.6                            | 110b  | 66.8   | 5.8                  |
| Pf3        | 1907b       | 63.0   | 2662ab      | 44.7   | 118b    | 61.7   | 98ab       | 32.9   | 50.6                            | 228ab | 31.1   | 9.4                  |
| Pf4        | 6914a       | -      | 2340ab      | 51.4   | 190ab   | 38.3   | 81b        | 44.5   | 33.6                            | 115b  | 56.3   | 18.9                 |
| Pf5        | 1987b       | 61.4   | 2420ab      | 49.7   | 201ab   | 34.7   | 125ab      | 14.4   | 40.1                            | 213ab | 35.6   | 9.3                  |
| Pf6        | 2472b       | 52.0   | 2960ab      | 38.5   | 130b    | 57.8   | 75b        | 48.6   | 49.2                            | 93b   | 71.9   | 11.1                 |
| Pf7        | 5164a       | -      | 1819b       | 62.2   | 146ab   | 52.6   | 74b        | 49.3   | 41.0                            | 127b  | 61.6   | 14.3                 |
| Pf8        | 2070b       | 59.8   | 2314ab      | 51.9   | 235ab   | 23.7   | 96ab       | 34.2   | 45.4                            | 166b  | 49.8   | 9.2                  |
| Pf9        | 1535b       | 70.2   | 1764b       | 63.3   | 189ab   | 38.6   | 71b        | 51.4   | 55.9                            | 102b  | 69.2   | 6.97                 |
| Pf10 (Standard) | 1093b | 78.8   | 487b        | 89.9   | 135b    | 56.2   | 88b        | 39.7   | 66.2                            | 104b  | 68.6   | 3.4                  |
| Nematode only (control) | 5150a | 0      | 4811a       | 0      | 308a    | 0      | 146a       | 0      | 0                               | 331a  | 0      | 20.5                 |

Averages followed by same letter(s) within each column are not significantly (P ≤ 0.05) different according to Duncan’s Multiple Range Test. Reproduction rate (Rr) = Final population (Pf)/Initial population (Pi).
Table 6. Effects of certain *Pseudomonas fluorescens* isolates on growth parameters of eggplant infected with *Meloidogyne incognita*

| Treatments          | Shoot Length | Shoot weight (g.) | Root weight (g.) | %Average total percentages inc. |
|---------------------|--------------|-------------------|------------------|-------------------------------|
|                     | Length (cm)  | % inc. | Fresh weight (g) | % inc. | Dry | % inc. | Fresh | % inc. |
| Pf1                 | 46.3abc      | 7.7    | 26.8a | 16.0 | 5.5ab | 17.0 | 22.5ab | 40.6 | 20.3 |
| Pf2                 | 45abc        | 4.7    | 23.3ab | 0.9 | 5.6ab | 19.1 | 19.1ab | 19.4 | 11.0 |
| Pf3                 | 44.0bc       | 2.3    | 27.2a | 17.7 | 6.1a | 29.8 | 17.0b | 6.3 | 14.0 |
| Pf4                 | 48.0ab       | 11.6   | 25.4a | 10.0 | 3.7bc | -   | 20.1ab | 25.6 | 11.8 |
| Pf5                 | 41.0c        | -      | 19.6ab | - | 5.2ab | 10.6 | 19.6ab | 22.5 | 8.3 |
| Pf6                 | 47.5ab       | 10.4   | 28.3a | 13.9 | 4.9abc | 4.3 | 17.0b | 6.3 | 8.7 |
| Pf7                 | 31.0d        | -      | 13.3b | - | 3.0c | -   | 22.0ab | 37.5 | 9.4 |
| Pf8                 | 47.0ab       | 9.3    | 28.2a | 22.1 | 5.2ab | 10.6 | 18.6ab | 16.3 | 14.6 |
| Pf9                 | 43bc         | 0      | 23.5ab | 1.7 | 5.4ab | 14.9 | 25.3a | 58.1 | 18.7 |
| Pf10 (Standard)     | 50.0a        | 16.3   | 29.2a | 26.4 | 5.4ab | 14.9 | 18.5ab | 15.6 | 18.3 |
| Nematode only (control) | 43.0bc   | 0      | 23.1ab | 0 | 4.7abc | 0 | 16b | 0 | 0 |

Averages followed by same letter(s) within each column are not significantly (P ≤ 0.05) different according to Duncan's Multiple Range Test. = Decrease less than control
DISCUSSION

As a result of cellular metabolism, fluorescent pseudomonad isolates can produce exotoxic compounds and also can affect nematode juveniles as reported by Wescott and Kluepfel (1993) which conform to the present study regarding efficacy of certain P. fluorescens isolates for controlling M. incognita on tomato or eggplant. This effect may refer to the selective permeability changes of juveniles’ cuticle and this effect is more pronounced with molting inside eggs. These results are similar to those obtained by Ashoub and Amara (2010). Plant growth promoting pseudomonads, antibiotic production, and competition with pathogens for essential nutrients such as iron and more, may act to induce direct antagonism against pathogens (Gamliel and Katan1993). The efficacy of Micronema® against M. incognita may refer to that it contains some beneficial bacterial isolates which are well known to suppress nematodes as follows: El-Hadad et al (2010) stated that the nematode numbers were significantly reduced particularly, 60 days after inoculation by nitrogen fixing bacterium, Azotobacter sp. and the potassium solubilizing bacterium, Bacillus circulans. Zavaleta-Mejia and Van Gundy (1989) reported that Serratia marcescens reduced juveniles of M. incognita which may be due to volatile materials produced during its metabolic activity (Ali 1996 and El-Sherif et al 1999). Eklund (1970) showed that some Pseudomonads convert amino acids present in root exudates to ammonia suppressive to pathogens. Also, El-Nagdi and Youssef (2015) clarified that gall reduction reached 69.3% by Micronema® on sugar beet infected by M. incognita. The same percentages nematode gall reduction occurred when Micronema treated on date palm which may be due to that juveniles were unable to penetrate the host root as reported by Youssef et al (2014). The obtained present results conform with those reported by Stirling and Sharma (1990) and El-Nagar et al (1998) who showed that, Pasteurea penetrans reduced number of root-knot nematodes which led to decreased infectivity of the juveniles. In accordance, the product, agerin which contains Bacillus thuringiensis reduced the number of root knot nematode (Noweer and Hasabo 2005) by releasing toxins that suppressed synthesis of proteins and nucleic acids in nematode (Sebesta et al 1969). Coinciding with these results, Sohrabi et al (2018) reported that tomato growth criteria infected by M. javanica was affected by four plant growth-promoting rhizobacteria (PGPR) and indicated that the PGPR significantly affected the reproductive factor of the nematode by P. fluorescens which was reduced from 112.15 to 24.94 and significantly improved the plant growth parameters. Also, El-Nagdi et al (2019) reported that P. fluorescens caused the highest percentage nematode reduction (89%) of M. incognita on cowpea and caused average increase of 55.6% in the studied plant growth parameters which conform to the present study. Finally, the different effects of the tested bacterial isolates on M. incognita as affected by eggplant and tomato may be due to the differences in genetic composition and degree of host susceptibility against root-knot nematode between these plants.

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تأثير بعض عزلات سيدوموناس فلوريسنس على نيماتودا تعقد الجذور ميلويدوجين انكوجنيتا

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الموجز

أجريت تجربتان تحت ظروف الصوبه على نباتي الطماطم والباذنجان لتقييم قدرة عزلات سيدوموناس فلوريسنس التي تم عزلها من بعض نباتات الفصيلة الباذنجانية على القدرة المرضية للنيماتودا تعقد الجذور ميلويدوجين انكوجنيتا (Meloidogyne incognita).

أوضحت النتائج في هذا البحث على أن جميع العزلات المستخدمة أدت إلى خفض أعداد نيماتودا تعقد الجذور. وتم التوالي عزلة P.f1 سجلت أعلى نسبة مئوية لموت أعداد النيماتودا (61.3%)، ونسبة نسبة ازدياد في وزن الجذور (Pf2) ونسبة نسبة زيادة في وزن الجذور (Pf3) بقدر (29.8%) ونسبة نسبة زيادة في وزن الجذور (Pf4) بقدر (19.1%). وتستنتج من ذلك أن سيدوموناس فلوريسنس فعاله في مكافحة نيماتودا تعقد الجذور.

الكلمات المفتاحية: عزلات سيدوموناس فلوريسنس، الطماطم، الباذنجان، ميلويدوجين انكوجنيتا

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