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Optimization the Impact of Fluopyram and Abamectin against the Root-Knot Nematode (*Meloidogyne incognita*) on Tomato Plants by Using *Trichoderma album*

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ABSTRACT

The root-knot nematodes (*Meloidogyne* spp.), cause great losses in tomato crops. The available measures for managing root-knot nematodes are limited. The growers are mostly depending on synthetic nematicides which have environmental and healthy defects. Thus, alternative approaches are needed to manage plant parasitic nematodes and reduce the adverse impacts of synthetic nematicides. In this study, two pot trials were conducted to evaluate the potential of fluopyram, abamectin and *Trichoderma album*, as well as their mixtures on the reproduction of the root-knot nematode, *Meloidogyne incognita* on tomato plants. The obtained results showed that all applied treatments significantly suppressed soil population, mature females, root-galls/root systems, eggs/egg mass and egg masses/root system significantly during both experiments. The co-toxicity factor for the combinations of either fluopyram or abamectin with *T. album* recorded additive interaction impacts on the reduction of soil population. However, the growth of tomato plants such as total fresh weight, shoot height and root length were increased significantly.

Keywords: fluopyram, abamectin, *Trichoderma album*, root-knot nematodes, biological control and tomato plants

INTRODUCTION

Tomato crop is one of the most popular and consumed vegetable in Egypt or around the world (Abd El-Ghany, 2011). Globally, the biggest tomato producers were Brazil, Mexico, Spain, Iran, Italy, Egypt, USA, Turkey, India and China (FAOSTAT, 2020). The total area of cultivated tomato crops in Egypt reached up to 170.862 acre and the total production estimate by 6.8 million metric tons (FAOSTAT, 2020). Various biotic and/or a biotic stress reported to reduce quality and quantity of tomato production. plant-parasitic nematodes (PPNs) are one of the most important biotic stresses that cause deterioration in tomato crop (Abd-Elgawad, 2014).

Lately, the infection with plant parasitic nematodes was increased and cause unprecedented injuries. The root-knot nematodes, *Meloidogyne* spp., are the most catastrophic genus in plant parasitic nematodes on tomato roots (Moens et al., 2009). *Meloidogyne* species causes plant yield suppression, chlorosis, spreading wilting, root galling and leaf nutritional deficiencies (Abd-Elgawad, 2021). Millions of $ dollars annually are spent to stop the attacks of plant parasitic nematodes which cost the global about $215.77 billion annually (Abd-Elgawad and Askary, 2015). Based on 2011- 2112 statistics, the plant parasitic nematodes caused losses $2.30 billion annually in Egyptian production (Abd-Elgawad, 2014).

The management measures of *Meloidogyne* spp. are aimed to improve plant growth, quality and yield by keeping the nematode population below the economical threshold level. One of the new bio-nematicides is abamectin which registered during the last few years in Egypt. Abamectin has been used as an insecticide, acaricide, and nematicide in vegetables, fruits and crop fields (El-Marzoky et al., 2022). Moreover, abamectin produced by the fermentation process of the bacteria of *Streptomyces avermitilis*, and belongs to avermectins that follow the mother group macrocyclic lactone (Khalil, 2013).

Fluopyram is a fungicide product, which developed by Bayer Crop Science and used as nematicide (Ji et al., 2019). Recent investigations showed that fluopyram exhibited a potential for managing root-knot nematode (*M. incognita*) on guava (Massoud et al., 2021), cyst nematode (*Heterodera glycines*) on soybean (Beeman et al., 2019), cotton nematode *(Rotylenchus reniformis*) on tomato (Storelli et al., 2020) and the stem and bulb nematode (*Ditylenchus dipsaci*) on sugar beet (Storelli et al., 2020).

Soil rhizosphere are one of the most important sources of antagonistic microorganisms that could be use as radical solution for pest and disease problems. *Trichoderma* species are beneficial fungi that commonly found in soil. The abundance of *Trichoderma* species in soil are form protective barriers from root pathogens (Nederhoff, 2001). The nematicidal effect of *Trichoderma album* has been described by several authors (Massoud et al., 2021; Raddy et al., 2013 and Radwan et al., 2011).

Therefore, this study is an attempt to estimate the potent of fluopyram, abamectin and *Trichoderma album*, as well as their combinations on the reproduction of *Meloidogyne incognita*, and on morphogenesis of tomato plants.

MATERIALS AND METHODS

The extraction and identification of the root-knot nematode (*Meloidogyne incognita*).

The eggs of the root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, were isolated from infected roots of eggplant (*Solanum melongena*) with sodium hypochlorite (NaOCl) according to the method of Hussey and Barker (1973). The eggs suspension was passed through a 200-mesh sieve and collected on a 400-mesh sieve to obtain free eggs before carrying out the experiments. The species of the root-knot nematode (*Meloidogyne incognita*) was identified by using the perineal pattern method according to Taylor and Nelscher (1974).

1.1. Tested materials and their rates of applications

1) Tervigo® 2% SC (Abamectin) applied in the recommended dose 2.5 L / feddan equivalent 0.005 ml /pot.
2) Velum prime®40% SC (Fluopyram) applied at the recommended dose of 250 ml/ feddan which equivalent 0.0005 ml /pot.
3) Bio Zeid® 2.5% WP (*Trichoderma album*, 1 x 10^7cell/g) at suggested dose of 3kg/100L water (El-Zawahry et al., 2015) which equivalent 3g/ 100 ml of water/pot.
4) The combinations of either fluopyram or abamectin + *Trichoderma album* were mixed in the half dose of each.

1.2. Experimental design

Two pot experiments were carried out using tomato plants (cv. Peto 86), each pot was17.5 cm diameter filled with approximately 2kg of autoclaved loamy sand soil. Tomato seedlings of five weeks old were transplanted and infested with the eggs suspension of *M. incognita* which applied at the rate of 5000 eggs / pot by making holes around the root system at uniform distance. Six treatments were applied and each treatment was replicated five times. Each replicate contains one plantlet. The treatments were applied after infection by two days as soil drench as follow;

1) Fluopyram + *M. incognita*
2) Abamectin + *M. incognita*
3) *T. album* + *M. incognita*
4) Fluopyram + *T. album* + *M. incognita*
5) Abamectin + *T. album*+ *M. incognita*
6) Untreated check (*M. incognita* only)

Fifty-five days after infestation, the seedlings were removed and assessed for the shoot system height and root system length, as well as total fresh weight. Meanwhile, the soil populations of the root-knot nematode (*M. incognita*) were evaluated in 250 g soil using the sieving and Baermann plates' technique (Ayoub, 1980), in addition to, galls number on plant roots. To count egg masses, the plant roots were stained for 15 minutes in an aqueous solution of Phloxine B stain (0.15 g/l water), then roots were washed to remove residual stain (Holbrook et al., 1983). To determine the average number of eggs; 10 egg masses were collected randomly from root system of each replicate and treated with 1% sodium hypochlorite (NaOCl), for three minutes and then obtained by rinsing the egg suspensions with sterile water in a sieve with 25-um according to the method of Hussey and Barker (1973), then the released eggs were collected and counted under light microscope (40X) and their average numbers were recorded .However, to count mature females, the roots were cut into small pieces and blended in a blender for 10 seconds to smooth out the roots, then the females were collected and counted.

1.3. Analysis of interaction data of mixtures

Interaction data for mixtures were estimated by using Limpel´s formula reported by Richer (1987) as follows:

E = X + Y – (XY /100)
Where:
E = the expected additive effect of the mixture
X = the effect due to component A alone
Y = the effect due to component B alone

The expected effect was compared with the actual effect obtained experimentally for mixture to determine the additive or synergistic and antagonistic effect according to the equation given by Mansour et al. (1966) as follows:

$$\text{Co}-\text{toxicity factor}=\frac{\text{Observed effect \%}-\text{ Expected effect \%}}{\text{Expected effect \%}}\times 100$$

This factor was used to classify results into three categories. A positive factor 20 or more considered potentiation, a negative factor 20 or more means antagonism and intermediate values between – 20 and + 20 indicate only additive effect.

1.4. Statistical analysis

The statistical analysis of data was carried out using a computer Costat program (2005) version 6.303. The used experimental design was complete randomized (CRD). Statistically significant differences between the means were compared using analysis of variance (ANOVA) with the least significant differences (LSD) and *P*-values at 0.05 probabilities.

RESULTS

In the 1st experiment, the obtained data in Table (1) indicted that all applied treatments resulted in variable significant decreases in *Meloidogyne incognita* populations in soil and root of tomato plants compared to the untreated control. For single treatments, soil populations were decreased by 91.00, 82.28 and 78.00% with fluopyram, abamectin and *T. album*, respectively. The binary mixtures of *T. album* with either fluopyram or abamectin recorded 84.34 and 79.39 % reduction, respectively. The adult females were minimized significantly with fluopyram (73.27%), abamectin (66.31%) and *T. album* (53.75%). While the combined treatments of *T. album* with fluopyram or abamectin gave 62.02 and 57.68%, respectively. The number of laid eggs by *M. incognita* was reduced significantly by 53.58, 76.90 and 30.21% with fluopyram, abamectin and *T. album*, consecutively. The binary mixtures of *T. album* with fluopyram and abamectin recorded reductions by 56.16 and 38.34%, respectively. The single treatments, i.e., fluopyram, abamectin and *T. album* exhibited reduction in nematode galls by 78.58, 68.41 and 57.21%, respectively. However, the combined treatments recorded reductions by 65.31 and 60.18% with fluopyram + *T. album* and abamectin + *T. album*, respectively. High reductions in egg masses were recorded with fluopyram (75.42%), abamectin (72.79%) and *T. album* (64.11%), while the mixtures of *T. album* with fluopyram or abamectin recorded 70.79 and 66.95%, respectively.

During the 2nd experiment, the same trend was recorded where the single treatments, i.e., fluopyram, abamectin and *T. album* suppressed the soil population significantly by 87.39, 85.03 and 75.09%, respectively (Table 1). The combinations of either fluopyram or abamectin with *T. album* decreased the soil population (J_2/250g soil) by 86.64 and 83.73%, respectively. The numbers of females were reduced up to 71.82, 65.94 and 59.27% with fluopyram, abamectin and *T. album*, respectively. In the same time, the mixtures of fluopyram + *T. album* or abamectin + *T. album* decreased females by 63.47 and 60.06%, respectively. The number of eggs were decreased by 44.93, 72.68 and 31.86% with fluopyram, abamectin and *T. album*, consecutively. The mixtures of *T. album* with either fluopyram or abamectin diminished eggs/egg mass by 51.47 and 35.52 %, consecutively. For root galling, single treatments such as fluopyram, abamectin and *T. album* reduced number of galls by 74.61, 70.9 and 59.77%, respectively. While, the combined treatments of *T. album* with either fluopyram or abamectin exhibited galls reduction by 68.23 and 64.52 %, respectively. The percentage reductions in egg masses of *M. incognita* were decreased by 71.92, 67.98 and 56.54% by using fluopyram, abamectin and *T. album*, respectively. Meanwhile, the combined treatments of *T. album* with fluopyram or abamectin exhibited reductions in egg masses estimated by 64.34 and 58.97%, respectively.

The affected growth parameters such as; total fresh weight, shoot system height and root system length of tomato plants were recorded during both experiments (Table 2 and Fig.1a&b). Application of fluopyram, abamectin and *T. album* showed increment in total fresh weight of tomato plants by 70.15, 36.85 and 71.10%, respectively during the 1st experiment (Table 2 and Fig.1a). While, *T. album* incorporate with either fluopyram or abamectin exhibited increment in the fresh weight by 53.00 and 9.61%, respectively. The shoot height was increased with fluopyram (66.52%), abamectin (30.00%) and *T. album* (66.09%) significantly over control. Meanwhile, *T. album* combined with either fluopyram or abamectin showed enhancement estimated by 42.61 and 16.52%, respectively. Furthermore, the root length was increased with single treatments of *T. album* (67.86%), fluopyram (49.11%) and abamectin (45.54%).

Table 1: The potential of fluopyram, abamectin and *Trichoderma album* alone and in combinations against *Meloidogyne incognita* on tomato plants during two experiments**.**

Treatments	No. of J2 / 250g soil		No. of females /plant root system		No. of eggs / egg mass		No. of galls /plant root system		No. of egg masses /plant root system	
	Mean*	Red%	Mean	Red%	Mean	Red%	Mean	Red%	Mean	Red%
The 1st experiment										
Fluopyram	148.8e	91.00	89.8e	73.27	374.6c	53.58	96.8d	78.58	93.4d	75.42
Abamectin	291.4cd	82.38	113.2de	66.31	186.4d	76.90	142.8c	68.41	103.4cd	72.79
Trichoderma album	364.0b	78.00	155.4b	53.75	563.2b	30.21	193.4b	57.21	136.4b	64.11
Fluopyram + *T. album*	259.0d	84.34	127.6cd	62.02	353.8c	56.16	156.8bc	65.31	111.0cd	70.79
Abamectin + *T. album*	341.0bc	79.39	142.2bc	57.68	497.6b	38.34	180.0b	60.18	125.6bc	66.95
Untreated Check	1654.2a	-----	336a	-----	807.0a	-----	452a	-----	380a	-----
Treatments	**The 2nd experiment**									
Fluopyram	147.2c	87.39	100.6c	71.82	493.0c	44.93	267.0d	74.61	129.6e	71.92
Abamectin	174.8c	85.03	121.6bc	65.94	244.6d	72.68	305.0cd	70.99	147.8de	67.98
Trichoderma album	290.8b	75.09	145.4b	59.27	610.0b	31.86	423.0b	59.77	200.6b	56.54
Fluopyram + *T. album*	156.0c	86.64	130.4bc	63.47	434.4c	51.47	334.0cd	68.23	164.6cd	64.34
Abamectin + *T. album*	190.0c	83.73	142.6b	60.06	577.2b	35.52	373.0bc	64.52	189.4bc	58.97
Untreated Check	1167.6a	0.00	357.0a	-----	895.2a	-----	1051.4a	-----	461.6a	-----

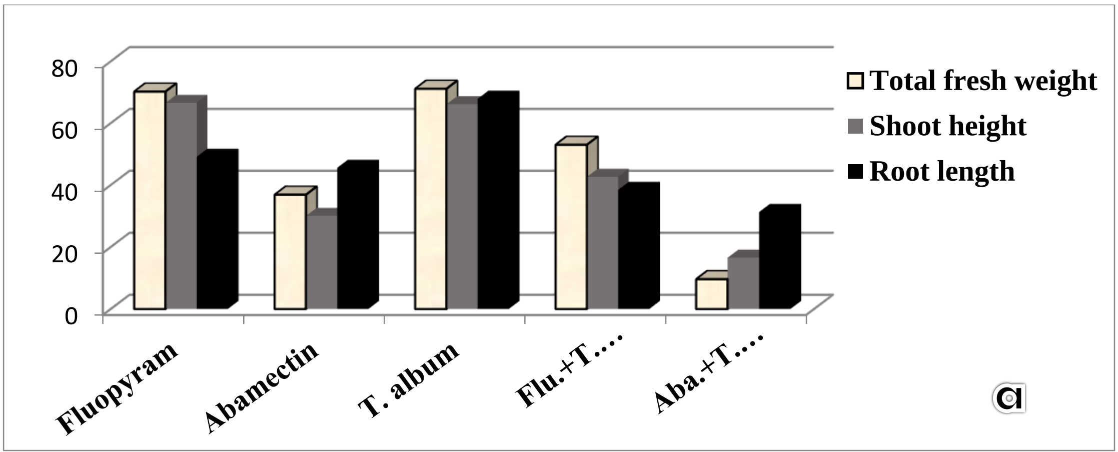
*Each number is a mean of five replicates.

Within a column, numbers followed by different letter(s) are significantly different using LSD at p = 0.05. Red% = Percent reduction.

Table 2: Effect of fluopyram, abamectin and *Trichoderma album* alone and in combinations on the growth of tomato plants infected with *Meloidogyne incognita*.

Treatments	1st experiment			2nd experiment		
	Total fresh weight (g)	**Shoot height (cm)**	**Root length (cm)**	**Total fresh weight (g)**	**Shoot height (cm)**	**Root length (cm)**
	Mean	Mean	Mean	Mean	Mean	Mean
Fluopyram	45.81a	38.30a	16.70ab	43.71a	38.50a	21.00ab
Abamectin	36.84c	29.90b	16.30ab	33.48c	29.80b	20.40ab
Trichoderma album	46.06a	38.20a	18.80a	42.41a	37.50a	22.70a
Fluopyram+ *T. album*	41.19b	32.80ab	15.50b	37.75b	32.80ab	19.90ab
Abamectin+ *T. album*	29.51d	26.80bc	14.70b	26.07d	28.80b	19.00b
Untreated Check	26.92d	23.00c	11.20c	23.88d	21.50c	15.60c

Each number is a mean of five replicates.
Within a column, numbers followed by different letter(s) are significantly different using LSD at P = 0.05.



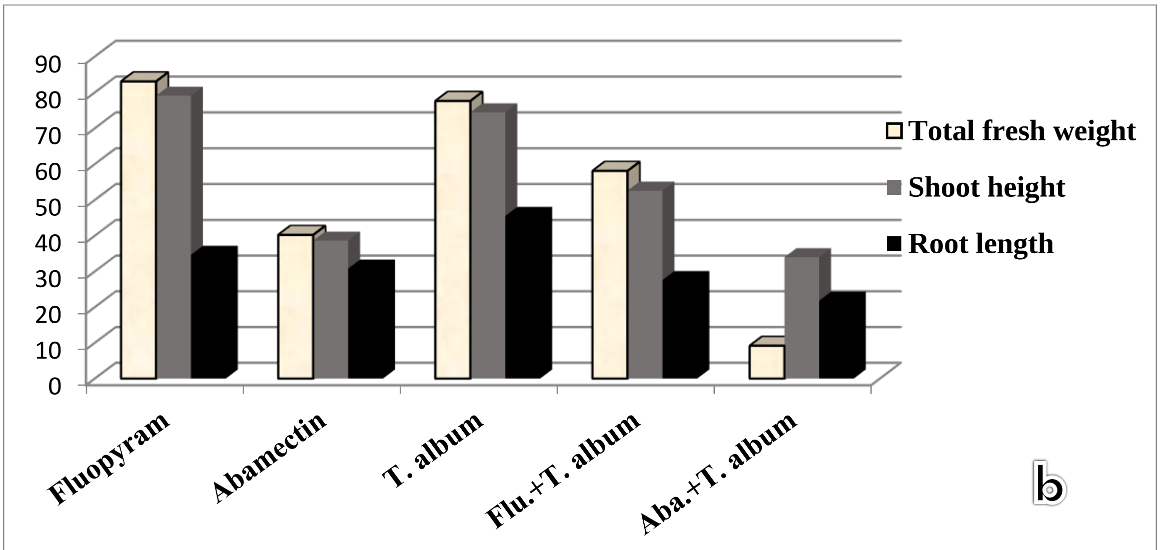


Figure 1: Efficacy (%) of fluopyram, abamectin and *Trichoderma album* singly or in combination on the growth indices of tomato plants infected with *Meloidogyne incognita* during 1st experiment (a) and 2nd experiment (b).

The binary mixtures of *T. album* with either fluopyram or abamectin recorded increment by 38.39 and 31.25%, respectively.

On the other hand, in the 2nd experiment, fluopyram, *T. album* and abamectin were found to increase the fresh weight of tomato plants by 83.05, 77.61 and 40.21%, respectively (Table 2 and Fig.1b). However, the combination between *T. album* with either fluopyram or abamectin recorded increasing by 58.09 and 9.16%, respectively. The tomato shoot height was increased with fluopyram (79.07%), *T. album* (74.42%) and abamectin (38.60%) significantly. The mixtures of *T. album* with either fluopyram or abamectin gave enhancement estimated by 52.56 and 33.5%, consecutively. In the same context, *T. album,* fluopyram and abamectin increased the root length by 45.51, 34.62 and 30.77%, respectively. While, *T. album* combined with fluopyram or abamectin recorded increment estimated by 27.56 and 21.79%, respectively.

Regarding the co-toxicity factor for the binary mixtures of fluopyram +*T. album* or abamectin +*T. album* recorded additive interaction effects on the reduction of soil population by -13.96 and -17.41, respectively, during the 1st experiment (Table 3). However, during the 2nd experiment, the mixtures of fluopyram +*T. album* or abamectin +*T. album* also showed additive interaction effects on the reduction of soil population by -10.55 and -13.03, respectively.

Table 3: Type of interaction between binary mixtures of fluopyram and abamectin admixed with *Trichoderma album.*

Treatments	**Effectiveness (%) on soil populations (1st Experiment)**			
	Observed (%)	Expected (%)	Co-toxicity factor	Type of interaction
Fluopyram +*T. album*	84.34	98.02	-13.96	Additive
Abamectin +*T. album*	79.39	96.12	-17.41	Additive
	Effectiveness (%) on soil populations (2nd Experiment)			
Fluopyram +*T. album*	86.64	96.86	-10.55	Additive
Abamectin +*T. album*	83.73	96.27	-13.03	Additive

DISCUSSION

The most of farmers are likely continue to use non-fumigant nematicides either solely or as part of integrated nematode management programs. In a recent study in Egypt, fluopyram (Velum prime® 40% SC) which is a new registered nematicide found to be effective against the root-knot nematodes (*Meloidogyne* spp.) compared with biocontrol agents on guava trees under field conditions (Massoud et al., 2021). The obtained results showed that fluopyram significantly reduced the soil population, galls and eggs ranged from 71.75 to 77.85%, 57.90 to 62.84% and 67.13 to 88.45%, respectively. Fluopyram suppress the population soil density of the root-knot nematodes (*Meloidogyne* spp.) at planting and protecting the roots of plantlets from the initial penetration and significant root damage (Dahlin et al., 2019). In our study fluopyram recorded relative decrease in the egg hatching of *M. incognita* which may be due to the limited permeability of fluopyram in egg shell (Heiken, 2017). Also, exposure the larvae of root-knot nematode (*M. incognita*) to fluopyram causes paralysis and stop feeding during 2 hours (Faske and Hurd, 2015). Fluopyram is one of the most and quick effective nematicides because of its action against succinate dehydrogenase inhibitor (SDHI) through the mitochondrial blocking of electron transport in the tricarboxylic acid of respiration cycle (Abad-Feuntes et al., 2015 and Hua et al., 2020).

Abamectin has nematicidal efficacy against root-knot nematodes (*Meloidogyne* spp.,) on various crops (Huang et al., 2014; El-Nagdi et al., 2015 and El-Ashry et al., 2021). The nematostatic activity of Tervigo® (abamectin 2% SC), as well as two prepared formulations of abamectin (EW and SC), were tested against *M. incognita* juveniles *in vitro*. The exposed larvae were immobilized and subsequently resumed mobility over time following a recovery test (d'Errico et al., 2017). In the same context, Radwan et al. (2019) compared the nematicidal activity of abamectin, emamectin, spinosad and spintoram against *M. incognita* infected tomato plants *in vitro* and *in vivo*. Results elucidated that abamectin and emamectin were the most toxic against the J_2 of *M. incognita in vitro*. Meanwhile, emamectin and abamectin were succeeded in decreasing galls, egg masses, eggs and soil population density significantly. Also, the plant growth characters were improved. The potential of abamectin is attributed to its act as blocker of the transmittance of electrical activity in nerves and muscle cells by stimulating the release and binding of γ-aminobutyric acid (GABA) at nerve endings. This causes an influx of chloride ion into the cells and lead to hyper polarization and subsequent paralysis of the neuromuscular systems (Bloomquist, 2003; Burkhart, 2000 and Cully et al., 1994).

The commercial bio-products are alternative approach to synthetic nematicides in management of the root-knot nematodes. Ahmed et al. (2022) confirmed that the bio-products included; Anti-Nema (*Serratia marcescens*) Bio-Arc (*Bacillus megaterium*), Bio-Zeid (*Trichoderma album*) and Bio-Nematon (*Purpureocillium lilacinum*) were effective against *M. incognita* and improved pepper growth indices. Also, El-Zawahry et al. (2015) reported that *T. album* at 20, 25 and 30g/l suppressed the soil populations of citrus nematode (*Tylenchulus semipenetrans*) by 76.50 up to 88.30% and females by 45.90 up to 72.00% on orange trees under greenhouse conditions. Also, El-Nagdi et al. (2011) recorded that *T. album* decreased galls (68.42%), females (73.33%) and egg masses (78.31%) of *M. incognita*, in addition to the root-rot disease (*Fusarium solani*) on sugar beet (*Beta vulgaris* L.) significantly. *Trichoderma* fungi have different proposed mechanisms of action such as contest with the pathogen for space and nutrients, inhibition of pathogen multiplication by secreting volatile and nonvolatile toxic metabolites, antibiotics, antibiosis, production of fungal cell wall and nematode cuticle degrading enzymes (proteases and chitinases), reduction of pathogen population through mycoparasitism, plant growth improvement and induction of the resistance in plants toward pathogen (Harman, 2006; Vey et al., 2001).

Very few studies clarified the effect of binary mixtures interaction against the root-knot nematodes (*Meloidogyne* spp.). Numerous attempts have been made to use antagonistic fungi, rhizobacteria, or botanicals to control RKNs, but biocontrol agents displayed lower efficacies when used alone than chemical nematicides (Ding et al., 2020). In a study, the efficacy of bi-combinations of sawdust, poultry manure and sesame cake with *B. thuringiensis* to control *M. incognita* on tomato plants were estimated. The results indicated that sesame cake + *B. thuringiensis* recorded the potential effect for nematode control (Radwan et al., 2004). While, treatments of chicken litter +*B. thuringiensis*, grape marc + *B. thuringiensis* and azadirachtin + *B. thuringiensis* recorded additive effect (Radwan, 2007). The combinations of *Matricaria chamomilla* dried seed + *T. album*, chitosan + *T. album* and *Ascophyllum nodosum* + chitosan recorded antagonistic interaction, while *M. chamomilla* + *B. megaterium*, chitosan + *B. megaterium*, oxamyl + *B. megaterium*, *Ascophyllum nodosum* + *B. megaterium* and Algaefol® + *M. chamomilla* recorded additive interaction also (Radwan et al., 2011). However, Dahlin et al. (2019) reported that Velum® (fluopyram) downregulated the *M. incognita* nematode population at-planting and reinforced the biological efficacy of *P. lilacinum* throughout the tomato growing season.

CONCLUSION

The results of this study reveal that using the bio-fungicide *Trichoderma album* was significantly effective and considered an alternative tool to non-fumigant nematicides.

In spite of the binary mixtures of *T. album* with fluopyram or abamectin didn't achieve the expectations of the authors and recorded additive effects, but economically the combinations were less cost than single treatments.

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الملخص العربي

تحسين فاعلية الفلوبيرام و الأبامكتين ضد نيماتودا تعقد الجذور *Meloidogyne incognita* علي نباتات الطماطم باستخدام *Trichoderma album*

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تسبب النيماتودا تعقد الجذور خسائر ضخمة في محصول الطماطم. وتعتبر الوسائل المتاحة لأداره نيماتودا تعقد الجذور محدودة للغاية. هذا و يعتمد المزارعون في الغالب على مبيدات النيماتودا المخلقة والتي لها أضرار بيئية وصحية. لذا، فإنه هناك حاجة إلى نهج بديلة لأداره النيماتودا المتطفلة علي النباتات و الحد من الآثار السلبية للمبيدات النيماتودا المخلقة. في هذه الدراسة، تم إجراء تجربتين في الأصص البلاستيكية لتقييم فاعلية الفلوبيرام، الأبامكتين و فطر ***Trichoderma album***، بالإضافة إلى مخاليطهم ضد نيماتودا تعقد الجذور (***Meloidogyne incognita***) على نباتات الطماطم. بينت النتائج المتحصل عليها أن كل المعاملات التي تم تطبيقها قد خفضت معنويا من تعداد النيماتودا بالتربة و الإناث الناضجة و عدد التعقدات الجذرية/ للمجموع الجذري، و عدد البيض / كتلة بيض وكتل البيض / للمجموع الجذري خلال كلا التجربتين. سجل عامل السمية المشتركة للخليط الثنائي بين كلا من الفلوبيرام أو الأبامكتين مع فطر الترايكوديرما ألبوم تأثير أضافة على انخفاض كثافة عشيرة النيماتودا بالتربة. ومع ذلك، فقد أدت جميع المعاملات إلى زيادة معنوية في مؤشرات نباتات الطماطم مثل الوزن الرطب الكلي وطول المجموع الخضري وطول الجذر.