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**Potency of Integrated Gamma Radiation With Nematodes Compared With *Trichogramma Evanescens* West And Some Insecticides For Controlling Tomato Leaf Miner *Tuta absoluta* On Tomato Plants In Egypt.**

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**ABSTRACT**

Different control agents were carried out in Baltiem District, Kafrelsheikh Governorate during October and November, 2016. Two applications were implemented at interval of 15-days between each. The potency of the tested control methods was recorded at 3, 5, 10 and 15-days from each application as reduction percentages in the larval infestation caused by tomato leaf miner, *Tuta absoluta* larvae on tomato vegetable plants. Nowadays, finding a safe control program is the objective of all researchers. The goal of this work is to investigate the effect of gamma radiation on the entomopathogenic nematodes, *Steinernema carpocapsae* BA2, the egg parasitoid, *Trichogramma evanescens* in comparable with the insecticidal applications for controlling the pest infesting tomato fruits under field conditions. Results showed that 2 Gy irradiated *S. carpocapsae* BA2 was substantially more effective in controlling the insect larvae compared with normal nematodes. Based on the general mean reduction in infestation rates caused by the larvae of the pest as mean average of two successive applications, the efficiency of these agents could be descendingly arranged in order as follows: irradiated nematode at rate of 80 IJ's+2Gy /ml, irradiated nematode at rate of 40 IJ's+2Gy/ml, normal nematode at rate of 80 IJ's /ml, , The insecticide proclain, irradiated nematode at rate of 20 IJ's+2Gy/ml, normal nematode at rate of 40 IJ's/ml, the insecticide, match, irradiated nematode at rate of 10 IJ's+2Gy/ml, the egg parasitoid, *T. evanescens*, normal nematodes at rates of 20 IJ's/ml, 10 IJ's/ml and the insecticide, chlorfan. The corresponding general mean reduction in the larval infestation rates were 89.20, 85.81, 83.73, 83.17, 82.38, 80.67, 79.66, 78.70, 77.64, 77.12, 74.77 and 74.74 %; respectively. The highest healthy yield production recorded 13.40 tons/feddan in case of treatment with irradiated nematode at rate of 80 IJ's +2Gy/ml; whereas the lowest healthy yield production reached 9.75 tons/feddan for the insecticide, chlorfan. The corresponding relative price benefit percentages recorded 230.86 and 140.74%; respectively as compared with the untreated plot.

**INTRODUCTION**

Egypt is considered one of the important tomato producer in the world (WPTC, 2011). Tomato leaf miner, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera), is an invasive pest causing severe damage and loss for tomato production in many countries either in open fields or green houses. Severely attacked tomato fruits lose their commercial value (EPPO, 2008). The tomato leaf miner, *T. absoluta* invaded Egypt in the nearest Governorate to Libya (Marsa Matrooh) in 2009.

By 2010 it had reached Giza, coming well established in all Governorates of Egypt and reaching the border and north part of Sudan on June, 2011 (Tamerk, 2011 and Khidr *et al.*, 2013). The entomopathogenic nematodes (EPNs) that belong to the family; Steinernematidae, associated with their symbiotic bacteria *Xenorhabdus*, have been used commercially as bio- control agents of economic insect pests (Gaugler & Kaya, 1990). So, EPNs seemed to be one of weapons for controlling this serious pest. Insect possess a well-developed innate immune system for protection against pathogens, which exhibited both as cellular and humoral reactions. In cellular response, the pathogens are phagocytosed, modulated or encapsulated by haemocytes. The humoral response including melanisation, clotting and the production of antimicrobial peptides, either induced (e.g. cecropins) or constitutive (e.g. lysozyme) (Lavine & Strand, 2002). The use of irradiation technique as a physical control method is cheaper, safe and can integrate with other best control methods. Many studies were done on the activation of entomopathogenic nematodes by gamma radiation (Sayed, 2011; Salem *et al.* 2014; Sayed *et al.* 2015 and Khidr *et al.*, 2017). Biological control has been developed and widely applied in different countries such as several South American states, using the egg parasitoids, *Trichogramma evanescens*. Three different species of *Trichogramma* were evaluated for controlling, *T. absoluta* eggs in Fayoum Governorate, Egypt (Gaffar, 2012). Insecticides are still one of the most powerful weapons in our never ending battle against insects including *T. Absoluta* (Khidr *et al.* 2013).

The objective of this study was to evaluate the virulence of gamma irradiated *Steinernema carpocapsae* as well as the egg parasitoid, *Trichogramma evanescens*, and three convenient insecticides against tomato leaf miner *Tuta absoluta* in Baltiem District, Kafrel-Sheikh Governorate, Egypt.

## MATERIALS AND METHODS

### Materials used:

#### Entomopathogenic nematodes:

The entomopathogenic nematodes (EPN) were originally obtained from the National Research Center, Pests & Plant Protection Department. *Steinernema carpocapsae* BA2, used in the experimental trials which was isolated from the Egyptian soil and identified by Hussein and Abou El Soud (2006). The nematodes used in this study were reared *in vivo* according to Glazer and Lewis (2000). Newly emerged infective juveniles (IJ's) were harvested and stored at 15° C for two weeks prior the experimentation. Their virulence was tested before starting up the experiments.

#### Radiation:

Irradiation of *S. carpocapsae* BA2 was conducted using Gamma Cell Irradiation Unit (cesium, Cs<sup>137</sup> source) located at the National Center for Radiation Research and Technology. The dose rate was 0.83084 Rad / sec.. In the present study, all results were calculated as a Gray unit (Gy); where Gy = 100 rad. Normal and gamma nematodes were tested at rates of 10 IJ's / ml, 10 IJ's + 2 Gy / ml, 20 IJ's / ml, 20 IJ's + 2 Gy / ml, 40 IJ's / ml, 40 IJ's + 2 Gy / ml, 80 IJ's / ml and 80 IJ's + 2 Gy/ ml.

#### Egg parasitoid, *Trichogramma evanescens* west:

The egg parasitoid, *T. evanescens* were obtained from the mass rearing at Department of Biological Control Research, Plant Protection Research Institute, Sakha Agricultural Research Station, Kafrel-Sheikh Governorate. The paper cards of

the egg parasitoid were attached to the tomato plants by using pieces of wire. Each card contained parasitoid eggs at three ages, so, adults of *T. evanescens* were emerged mostly in three waves, one day after attaching the plants. The rate of release was 150000 individuals/ feddan divided into 60 paper cards, each containing 2500 individuals, approximately.

**Insecticides used:**

Chlorpyrifos (chlorfan 48 % EC at a rate of 1liter / feddan.

Leufenuron ( match 5 % EC at a rate of 160 ml / feddan.

Emamectin benzoate (proclaim 5 % SG at a rate of 80 g / feddan).

**Field experiments:**

According to complete randomized block design, the experimental area (2.5 feddans) at Baltiem district, Kfrel-Sieikh governorate was divided into four main blocks. The normal and gamma irradiated nematodes, *S. carpocapsae* as well as the egg parasitoid and the chemical insecticides besides untreated check plots (1/2 feddan of each) were distributed randomly in each block. Spraying was implemented when the insect population density reached 5 larvae / 100 tomato fruits. Twenty - liters volume motor sprayer was used for insecticidal application; whereas 2- liter hand sprayer was used in case of nematodes used. The 1<sup>st</sup> and 2<sup>nd</sup> applications were carried out on 5<sup>th</sup> and 17<sup>th</sup> of March, 2017; respectively. Four counting periods; 3, 5, 10 and 15 days post treatments were achieved. At each count, samples of 100 tomato fruits (25 fruits /replicate) for each application were inspected. Mortality percentages as well as reduction rates in infestation caused by each treatment was determined according to the equation adopted by Henderson and Tilton (1955).

The results were statistically evaluated by analysis of variance to explain the significant differences between treatments. The 5 % level of probability was used in all statistical tests. The statistical software program CoStat (1995) was used for all analysis.

## RESULTS AND DISCUSSION

Comparisons between the different control methods were implemented on basis of the reduction percentages in tomato leaf miner, *Tuta absoluta* larvae infested tomato vegetable plants, *Lycopersicon esculentum* Mill. The control methods used in the current, study included normal as well as gamma irradiated nematodes, *Steinernema carpocapsae* BA2 compared with the egg parasitoid, *Trichogramma evanescens* and insecticidal applications.

**Biological control agents included entomopathogenic normal and gamma irradiated nematodes, *S. carpocapsae* BA2 compared with the egg parasitoid, *Trichogramma evanescens*:**

**Comparison on basis of reduction percentages in larval infestation:**

Results were recorded as reduction percentages in infestation at four periods after each treatment. The obtained results are presented in Table (1). All the treatments reduced the number of larvae over 66 % at three days post the 1<sup>st</sup> application and 68 % for the 2<sup>nd</sup> treatment. After 5 and 10- days from the two applications with all normal and gamma irradiated nematodes as well as the egg parasitoid *T. evanescens* increased reduction in infestation had been noticed in tomato fruits caused by the larvae. The obtained data showed that the reduction in infestation was significantly affected with juveniles' irradiation. The highest reduction percentages in the larval infestation were recorded at ten days post the two treatments, where the reduction values ranged from 82.50 and 94.95% for the 1<sup>st</sup> treatment with nematodes at rates of 10 IJ's / ml and 80 IJ's + 2 Gy / ml; respectively.

The corresponding values for the 2<sup>nd</sup> treatments ranged between 82.19 and 97.89 %; respectively. On the other hand, the lowest reduction percentages in infestation with the larvae were occurred at 3 days after the experimental applications.

Table 1: Effectiveness of biological control agents included normal and gamma irradiated nematodes, *Steinernema carpocapsae* BA2, and *T. evanescens* against tomato leaf miner, *T. absoluta* larvae on tomatoplants.

% Reduction in infestation at indicated nematodes treatment									
1 <sup>st</sup> Application									
Periods (days)	10	10 + 2 GY	20	20 + 2 GY	40	40 + 2 GY	80	80 + 2 GY	<i>T. evanescens</i>
3	66.50	68.75	68.25	71.11	70.02	74.56	73.09	76.98	70.25
5	72.75	76.50	72.67	80.19	76.28	83.36	79.91	87.54	74.22
10	82.50	86.67	84.36	90.25	89.13	94.55	93.17	94.95	83.94
15	74.67	80.25	79.21	85.10	82.46	88.79	85.26	94.37	75.39
Mean	74.11	78.04	76.12	81.66	79.47	85.32	82.86	88.46	75.95
2 <sup>nd</sup> Application									
3	68.16	70.25	70.05	71.79	72.78	74.97	73.98	80.12	72.93
5	74.52	79.95	77.09	83.79	79.13	86.17	82.19	90.13	77.98
10	82.19	85.27	84.37	90.76	90.45	95.12	95.05	97.89	87.49
15	76.79	81.96	80.12	86.05	85.11	88.91	87.14	91.57	78.91
Mean	75.42	79.36	78.12	83.10	81.87	86.29	84.59	89.93	79.32
General mean	74.77 <sup>e</sup>	78.70 <sup>de</sup>	77.12 <sup>de</sup>	82.38 <sup>c</sup>	80.67 <sup>cd</sup>	85.81 <sup>b</sup>	83.73 <sup>bc</sup>	89.20 <sup>a</sup>	77.64 <sup>de</sup>
L.S.D.	3.1067								

Values having the same letters vertically are non-significant for different treatments

The reduction percentages in the larval infestation ranged between 66.50 and 76.98 % in case of the 1<sup>st</sup> treatment and between 68.16 and 80.12 % in case of the 2<sup>nd</sup> treatment. Based on the mean reduction rates in larval infestations, the most promising treatment was using with nematodes at a rate of 80 IJ's + 2 Gy/ml, where the corresponding mean reduction values were 88.46 and 89.93 % associated to the 1<sup>st</sup> and 2<sup>nd</sup> experimental applications; respectively. The lowest reduction rates in the larval infestation were noticed with the treatment of nematodes at a rate of 10 IJ's / ml, where the corresponding mean values were 74.11 and 75.42 %, for the 1<sup>st</sup> and 2<sup>nd</sup> applications; respectively. Mean reduction in infestation with *T. absoluta* larvae infesting tomato fruits resulting from treatments with the normal as well irradiated nematodes, i.e. 10 IJ's / ml, 10 IJ's + 2 Gy / ml, 20 IJ's / ml, 20 IJ's + 2 Gy/ml, 40 IJ's/ml, 40 IJ's + 2 Gy / ml, 80 IJ's / ml and 80 IJ's + 2 Gy / ml, were 74.11, 78.04, 76.12, 81.66, 79.47, 85.32, 82.86 and 88.46 % after the 1<sup>st</sup> application and 75.42, 79.36, 78.12, 83.10, 81.87, 86.29, 84.59 and 89.93 % after the 2<sup>nd</sup> application; respectively. Concerning the egg parasitoid, *T. evanescens*, the reduction percentages in the larvae infesting tomato fruits after, 3, 5, 10 and 15- days were 70.25, 74.22, 83.94 and 75.39% with mean reduction percentage of 75.95% for the 1<sup>st</sup> release compared with 72.93, 77.98, 87.49 and 78.91% with mean reduction of 79.32% in case of the 2<sup>nd</sup> release; respectively.

#### Comparisons on basis of the controlling index and relative potency levels:

According to comparisons on basis of the controlling index and relative potency levels, the obtained results are represented in Table (2). It seems always convenient to consider the efficacy on the degree of toxicity of different products by comparing them with a standard material. In the present work, comparisons among the tested products are based on controlling index methods developed by Khidr *et al.* (2004) and the relative potency levels expressed as number of folds frequently used in this respect. The control index was obtained by comparing different control agents with the product having highest mean reduction in the larval infestation.

The potency levels expressed as number of folds were determined by dividing the values of the tested agents by the least effective material.

Table 2: Relative comparison between normal and gamma irradiated nematodes, *Steinernema carpocapsae* and the egg parasitoid, *T. evanescens* for controlling *T. absoluta* larvae on basis of controlling index and relative potency levels.

Nematodes conc. IJ's	Mean		Control index based on			Potency levels based on		
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	Mean	1 <sup>st</sup>	2 <sup>nd</sup>	Mean
10	74.11	75.42	83.73	83.87	83.80	1.00	1.00	1.00
10 + 2 G Y	78.04	79.36	88.22	88.25	88.24	1.05	1.05	1.05
20	76.12	78.12	86.05	86.87	86.46	1.03	1.04	1.035
20 + 2 G Y	81.66	83.10	92.31	92.41	92.36	1.10	1.10	1.10
40	79.47	81.87	89.84	91.04	90.44	1.07	1.09	1.08
40 + 2 G Y	85.32	86.29	96.45	95.95	96.20	1.15	1.16	1.155
80	82.86	84.59	93.67	94.06	93.87	1.12	1.12	1.12
80 + 2 G Y	88.46	89.93	100.00	100.00	100.00	1.19	1.19	1.19
<i>T. evanescens</i>	75.95	79.32	85.86	88.20	87.03	1.02	1.05	1.035

On the ground of controlling index, the treatment with entomopathogenic gamma irradiated nematodes at rate of 80 IJ's + 2 Gy / ml based on the reduction percentages in the pest larval numbers infesting tomato fruits was taken as standard control method and given arbitrary 100 units. The mean effectiveness of normal and gamma irradiated nematodes at rates of 10 IJ's / ml, 10 IJ's +2 Gy / ml, 20 IJ's / ml, 20 IJ's + 2 Gy / ml, 40 IJ's / ml, 40 IJ's + 2 Gy/ ml, 80 IJ's / ml and *T. evanescens* released at rate of 150000 individuals per feddan and the corresponding values were 83.73, 88.22, 86.05, 92.31, 89.84, 96.45, 93.67 and 85.86% % effective as mean efficacy of gamma irradiated nematodes at rate of 80 IJ's + 2 Gy / ml; respectively after the 1<sup>st</sup> application and were 83.87, 88.25, 86.87, 92.41, 91.04, 95.95, 94.06 and 88.20 % effective as the efficiency of nematodes at rate of 80 IJ's + 2 Gy / ml; respectively in case of the 2<sup>nd</sup> treatment, with mean average of 83.80, 88.24, 86.46, 92.36, 90.44, 96.20, 93.87 and 87.03 %; respectively for the two treatments.

$$\text{Khidr's control index} = \frac{\text{Mean reduction percentages of the treated control agent}}{\text{Mean reduction percentage of the most effective control agent}} \times 100$$

$$\text{Potency levels} = \frac{\text{Mean of reduction percentages of the tested control agent}}{\text{Mean reduction percentage of the least effective control agent}}$$

Furthermore, the relative potency levels could be used as a convenient method in comparing the degree of the efficiency of different control methods to any pest. The potency levels of the tested agents expressed as number of folds, at the required reduction value are compared with the least efficient control method included in the evaluation against the pest (Khidr *et al.*, 2004). In this respect, treatment with nematodes at a rate of 10 IJ's / ml the lowest effective agent according to the mean reduction in infestation with the larval pest was considered the standard agent under this study (Table 2). Therefore, the mean effectiveness of the normal and gamma irradiated nematodes applied at rates of 10 IJ's+ 2 Gy, 20 IJ's / ml, 20 IJ's + 2 Gy / ml, 40 IJ's / ml, 40 IJ's + 2 Gy / ml, 80 IJ's / ml and 80 IJ's +2 Gy /m as well as the egg parasitoid released at rate of 150000 individuals/ feddan after both 1<sup>st</sup> and 2<sup>nd</sup> application were 1.05 & 1.05, 1.03 & 1.04, 1.10 & 1.10, 1.07 & 1.09, 1.15 & 1.16,

1.12 & 1.12, 1.19 & 1.19 and 1.02 & 1.05, with corresponding mean average of 1.05, 1.035, 1.10, 1.08, 1.155, 1.12, 1.19 and 1.035 folds as effective for reducing the larval infestation as the efficacy of nematodes at a rate of 10 IJ's / ml; respectively.

### **Insecticidal applications:**

#### **Comparisons on basis of reduction percentages in larval infestation:**

Results represented in Table (3), revealed that the highest reduction percentages in larval infestation with *T. absoluta* were recorded at ten days post 1<sup>st</sup> and 2<sup>nd</sup> applications with each of match, chlorfan and proclaim. The corresponding reduction percentages in the larval infestation on tomato plants were 84.91, 79.15 and 87.25 %, respectively for the 1<sup>st</sup> insecticidal application and 87.36, 82.47 and 88.32%; respectively in case of 2<sup>nd</sup> treatment; respectively. The lowest reduction percentages in *T. absolutalarvae* were noticed at 3 days after the insecticidal treatments that mentioned previously. The corresponding reduction values in the larval infestations were 72.33, 66.81 and 75.67 %; respectively for the 1<sup>st</sup> insecticidal applications, compared with reduction values of 68.45, 67.29 and 77.89% in the larvae infesting tomato fruits associated to the 2<sup>nd</sup> insecticidal applications. Based on the mean reduction percentages in the larval infestations, it was noticed that proclaim insecticide was the most toxic insecticide for controlling the pest, where the mean reduction rate recorded 81.99 & 84.35% and for the 1<sup>st</sup> and 2<sup>nd</sup> applications; respectively, on the hand, chlorfan was the lowest toxic insecticide on the pest, where the corresponding mean reduction values were 73.62&75.85 % for the 1<sup>st</sup> and 2<sup>nd</sup> the insecticidal treatments; respectively. On the other hand, chitin synthesis inhibitor, match occupied the middle situation among the two abovementioned compounds against the pest, where the mean reduction percentages were 79.30&80.02 % for the 1<sup>st</sup> and 2<sup>nd</sup> insecticidal applications; respectively.

Table 3: Potency of three insecticidal applications against tomato leaf miner, *T. Absoluta* larvae on tomato vegetable plants.

% Reduction in infestation at indicated insecticides treatment			
1 <sup>st</sup> Application			
Periods (days)	Match	Chlorfan	Proclaim
3	72.33	66.81	75.67
5	82.88	76.24	84.33
10	84.91	79.15	87.25
15	77.13	72.26	80.69
<b>Mean</b>	<b>79.30</b>	<b>73.62</b>	<b>81.99</b>
2 <sup>nd</sup> Application			
3	68.45	67.29	77.89
5	84.16	80.05	87.14
10	87.36	82.47	88.32
15	80.09	73.59	84.05
<b>Mean</b>	<b>80.02</b>	<b>75.85</b>	<b>84.35</b>
<b>Grand mean</b>	<b>79.66<sup>b</sup></b>	<b>74.74<sup>c</sup></b>	<b>83.17<sup>a</sup></b>
<b>L.S.D</b>	<b>1.9185</b>		

Values having the same letters vertically are non-significant for different treatments

#### **Comparisons on basis of controlling index and relative potency levels:**

According to comparisons on basis of the controlling index as well as the relative potency levels, the obtained results are shown in Table (4). Concerning the control index, proclaim was taken the standard control method and given arbitrary index value as 100 units. The efficacy of the two insecticides match and chlorfan exhibited 96.72 and 89.79 % as effective as the effectiveness of proclaim for controlling the pest after 1<sup>st</sup> application and 94.87&89.92% as effective as the

efficacy of proclain against the pest after the 2<sup>nd</sup> application; respectively. The corresponding mean control index values of the two insecticidal applications that mentioned previously were 95.80 and 89.86 % as efficient as the efficacy of proclain; respectively.

Concerning the relative potency levels compared with chlorfan, the least effective insecticide for controlling the pest under this study represented in Table (4) revealed that the effectiveness of match and proclain recorded 1.08 and 1.11 folds for the 1<sup>st</sup> application as well as 1.05 and 1.11 times for the 2<sup>nd</sup> application with mean averages 1.07 and 1.11 folds of the two insecticidal treatments as effective as efficiency of chlorfan; respectively against the larval infestations in tomato fields.

**Comparisons of the different control agents against. *absoluta* larvae on tomato plants on basis of general mean reduction percentages in infestation rates, control index and relative potency levels:**

The required values; general mean reduction percentages in the larval infestation rates, control index and relative potency levels represented in Table (5) showed the effectiveness of normal and gamma irradiated nematodes, *S. carpocapsae* in addition to the egg parasitoid, *T. evanescens* as well as three insecticides against. *T. absoluta* larvae on tomato fields. Based on the general mean reduction in infestation rates caused by the larvae of the pest as mean average of two successive applications, the efficiency of these agents could be divided into three categories, the first category included gamma irradiated nematodes at rate of 80 IJ's +2 Gy / ml recorded the most promising nematode for controlling the pest where the mean reduction percentage was 89.20%. The second category included normal nematodes at rate of 10,20 and 40 IJ's / ml and gamma irradiated nematodes at rates of 10 IJ's +2 Gy / ml and the egg parasitoid, *T. evanescens* as well as the insecticides treatments i.e. match and chlorfan recorded the least effective agents for controlling the pest. The corresponding mean reduction values in the larval infestation were 74.77, 77.12, 80.67, 78.70, 77.64, 79.66 and 74.74%; respectively. The third one included irradiated nematodes at rate of 20 IJ's+2 gy /ml and 40 IJ's +2gy/ml, well as normal nematode at rate of 80 IJ's/ml and the insecticidal application proclain occupied the middle situation among the three categories for controlling the pest, the corresponding mean reduction in infestation attained 82.38, 85.81, 83.73 and 83.17%; respectively.

On the ground of controlling index as shown in Table (5), gamma irradiated nematodes at rate of 80 IJ's + 2 Gy /ml the most effective agent was taken the standard control method and given arbitrary index value as 100 units. In this respect, The efficacy of the different control agents, normal and gamma irradiated nematodes at rates of 10 IJ's/ ml, 10 IJ's +2Gy /ml, 20 IJ's / ml, 20 IJ's + 2 Gy / ml, 40 IJ's / ml, 40 IJ's + 2 Gy /ml, 80 IJ's / ml, the egg parasitoid as well as the chemical insecticides; match, chlorfan and proclain were 83.82, 88.23, 86.46, 92.35, 90.44, 96.20, , 93.87, 87.04, 89.30, 83.79 and 93.24 % as effective for controlling the larvae of the pest under the study as the efficacy of the nematodes at rate of 80 IJ+ 2 Gy / ml; respectively. Concerning the relative potency levels, the chemical insecticide, chlorfan the lowest effective agent against the pest was chosen as a standard material, therefore the effectiveness of the different control agents, normal and Gamma irradiated nematodes at rates of 10 IJ's/ml, 10 IJ's +2Gy /ml, 20 IJ's / ml, 20 IJ's + 2 Gy / ml, 40 IJ's / ml, 40 IJ's + 2 Gy



/ml, 80 IJ's/ml and 80 +2Gy IJ's / ml as well as the egg parasitoid, *T. evanescens*, in addition the chemical insecticides; match, chlorfan and proclain recorded recorded 1.00, 1.05, 1.03, 1.10, 1.08, 1.15, 1.12, 1.19, 1.04, 1.07 and 1.11 folds as effective as efficiency of chlorfan; respectively for controlling the pest in tomato fields.

Table 4: Relative comparison between three insecticides for controlling *T. Absoluta* larvae on basis of controlling index and relative potency levels on tomato plants.

Insecticides used	Mean		Control index based on			Potency levels based on		
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	Mean	1 <sup>st</sup>	2 <sup>nd</sup>	Mean
Match	79.30	80.02	96.72	94.87	95.80	1.08	1.05	1.07
Chlorfan	73.62	75.85	89.79	89.92	89.86	1.00	1.00	1.00
Proclaim	81.99	84.35	100.00	100.00	100.00	1.11	1.11	1.11

Table 5: Comparisons between the different control agents against *T. absoluta* larvae on basis of general mean reduction percentages in the larval infestation rates, control index and relative potency levels.

Treatments	% General mean reduction	Control index	Relative Potency levels
Nematodes conc. IJ's			
10	74.77	83.82	1.00
10 + 2 G Y	78.70	88.23	1.05
20	77.12	86.46	1.03
20 + 2 G Y	82.38	92.35	1.10
40	80.67	90.44	1.08
40 + 2 G Y	85.81	96.20	1.15
80	83.73	93.87	1.12
80 + 2 G Y	89.20	100.00	1.19
<i>T. evanescens</i>	77.64	87.04	1.04
Insecticides			
Match	79.66	89.30	1.07
Chlorfan	74.74	83.79	1.00
Proclaim	83.17	93.24	1.11

Data illustrated in Table (6), demonstrated that the highest tomato yield production, price of production recorded in case of treatment with gamma irradiated nematode sat a rate of 80 IJ' + 2 Gy / ml. The corresponding healthy yield production and price of production were 13.40 tons / feddan and 20100 L.E. / feddan; respectively. On the other hand, using normal nematodes at rate of 10 IJ's / ml, the chemical insecticide, chlorfan gave the lowest healthy yield production and price of production. The corresponding values of healthy yield production were 10.25 and 9.75 tons / feddan and the price of the healthy yield production attained 15375 and 14625 L.E. / feddan; respectively.

It is interest to note that the entomopathogenic nematode used in the present study is nontoxic to vertebrates. They are widely produced in vivo; they kill insects in 24-48 h. once the infective juveniles have located the insect body. The present data denoted an increase in gamma irradiated *S. carpocapsae* that reduce the levels of infestation caused by the larvae of the pest under the study than normal *S. carpocapsae*. This result agreed with the findings of Yussef (2006) who stated that *S. carpocapsae* irradiated with lower dose (2.5, 5 and 10 Gy) was more effective against *Callosobruchus*

*maculatus*. In addition, Salem *et al.* (2014) concluded that gamma irradiated (2Gy) *S. carpocapsae* may attribute as a major control method of *Galleria mellonella*. Also, Sayed *et al.* (2015) who stated that 2 Gy irradiated *S. carpocapsae* disrupted the antioxidant contents of *S. littoralis* larvae with lead to larval death faster than normal *S. carpocapsae*. The present results are accordance with those finding with Sayed (2011). The author concluded that *S. carpocapsae* BA2 used against the pests; *Galleria mellonella*, *Ephestia kuehniella* and *Corcyra cephalonica* and biological activity represented in causing 100 % mortality within three days, under laboratory conditions. Moreover, the gamma irradiation of *S. carpocapsae* increased the rates of pest's mortality to reach 100 % within two days. In this field of results, Gaugler and Boush (1979) reported that gamma radiation doses caused harmful effect to the *S. carpocapsaea* exposure to 10 rad. The reason of increased.

Table 6: Estimation of yield production, price of yield production and relative price benefit percentage in the experimental trials of different control agents applied against *T. absoluta* infestation on tomato fields.

Control Methods	No. of treatments	Yield production Ton/feddan	Price of production L.E/feddan	Relative price benefit %
Nematodes conc. IJ's				
10	2	10.25 <sup>fg</sup>	15375 <sup>a</sup>	153.09
10 + 2 G Y	2	11.10 <sup>def</sup>	16650 <sup>a</sup>	174.07
20	2	11.20 <sup>def</sup>	16800 <sup>a</sup>	176.54
20 + 2 G Y	2	11.80 <sup>bcd</sup>	17700 <sup>a</sup>	191.36
40	2	12.05 <sup>bcd</sup>	18075 <sup>a</sup>	197.53
40 + 2 G Y	2	12.25 <sup>b</sup>	18375 <sup>a</sup>	202.47
80	2	12.20 <sup>bc</sup>	18300 <sup>a</sup>	201.23
80 + 2 G Y	2	13.40 <sup>a</sup>	20100 <sup>a</sup>	230.86
<i>T. evanescens</i>	2	10.90 <sup>ef</sup>	16350 <sup>a</sup>	169.14
Insecticides				
Match	2	11.05 <sup>def</sup>	16575 <sup>a</sup>	172.84
Chlorfan	2	9.75 <sup>g</sup>	14625 <sup>a</sup>	140.74
Proclaim	2	11.95 <sup>bcd</sup>	17925 <sup>a</sup>	195.06
Control	2	4.05 <sup>h</sup>	60.75 <sup>b</sup>	-
L.S.D.		1.0302	5056.30	-

Values having the same letters vertically are non-significant for different treatments.

The pathogenicity may be attributed to the effect of low doses of gamma radiation to increase toxins production of its symbiotic bacteria; *Xenorhabdus nematophila*. This is consistent with Bashandy and El-Sinary (2002), who stated that gamma irradiation of *Bacillus thuringiensis* produced six mutants which gave larval mortality of the range of 20-66 % while the wild type and the control gave 20% mortality; respectively. Rahman and MacNee (2000) stated that bacteria and parasitic infections elevated production of reactive oxygen species and free radical oxygen that are responsible as oxidative stress. The reduced Catalase, Peroxidase and Glutathion are antioxidant enzymes involved in impeding the scavenger in demonstrate the effect of *S. carpocapsae* on these enzymes. Khidr *et al.* (2004) stated that match was more effective for controlling the American bollworm, *H. armigera* in lettuce fields than dursban and selecron under field conditions. The results are accordance with that of Khidr *et al.* (2017), they revealed that 2 Gy irradiated *S. carpocapsae* BA2 was substantially more effective in controlling the insect larvae of

the American boll worm, *Helicoverpa armigera* compared with normal nematodes on tomato fields. The results are going in line with those published by Khidr *et al.* (2013). They recorded that the egg parasitoid, *T. evanescens* caused over 80% reduction in *T. absoluta* larvae infesting tomato plants.

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#### ARABIC SUMMARY

#### فعالية النيماتودا المشعة بأشعة جاما مقارنة بطفيل الترياكوجراما وبعض المبيدات الحشرية لمكافحة حافرة أوراق الطماطم على نباتات الطماطم في مصر

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أجرى البحث لدراسة فعالية طرق مكافحة مختلفة ضد آفة حافرة الاوراق *Tota absoluta* التي تصيب نباتات الطماطم في مركز بطليم بمحافظة كفر الشيخ خلال موسم 2016. تم تطبيق طرق المكافحة مرتان بين كل منها 15 يوما. خلال شهرى أكتوبر، نوفمبر موسم 2016. أخذت النتائج علي فترات 3 و5 و10 و15 يوما بعد كل معاملة قدرت فعالية طرة المكافحة المختلفة علي اساس النسب المئوية للخفض في اصابة ثمار الطماطم بحشرة حافرة الاوراق *Tota absoluta*. ويهدف البحث الى دراسة تأثير أشعة جاما علي فعالية المسبب المرضي النيماتودي *Steinernema carpocapsae* BA2 مقارنة بفعالية كل من طفيل البيض الترياكوجراما ، وثلاث مبيدات حشرية هي ماتش ،كلور فان ،بروكليم لمكافحة آفة حافرة الاوراق التي تصيب محصول الطماطم تحت الظروف الحقلية. أظهرت النتائج أن تعريض النيماتودا لأشعة جاما بجرعة 2 جراى كانت أكثر فعالية في مكافحة الآفة مقارنة باستخدام نيماتودا طبيعية. بناء على المتوسط العام للخفض في اصابة ثمار الطماطم بالآفة أمكن ترتيب فعالية طرق المكافحة المختلفة تنازليا كما يلي : نيماتودا مشعة بمعدل 80 طور معدي + 2 جراي/ مل، نيماتودا مشعة بمعدل 40 طور معدي + 2 جراي/ مل، نيماتودا طبيعية بمعدل 80 طور معدي/ مل، المبيد الحشرى بروكليم، نيماتودا مشعة بمعدل 20 طور معدي + 2 جراي / مل، نيماتودا طبيعية بمعدل 40 طور معدي / مل، المبيد الحشري ماتش ، نيماتودا مشعة بمعدل 10 طور معدي + 2 جراي/ مل، طفيل البيض تريكوجراما ، نيماتودا طبيعية بمعدل 20 طور معدي/ مل، 10 طور معدي/ مل، المبيد الحشري كلور فان. بلغ المتوسط العام للنسب المئوية المطابقة للخفض في اصابة ثمار الطماطم بيرقات الآفة كما يلي: 89.20، 85.81، 83.73، 83.17، 82.38، 80.67، 79.66، 78.70، 77.64، 77.12، 74.77، 74.74% على الترتيب. سجلت اعلي انتاجيه لمحصول الطماطم للثمار السليمة 13.40 طن / فدان في حالة المكافحة باستخدام نيماتودا مشعة بأشعة جاما بجرعة 80 طور معدي + 2 جراي / مل، وكانت اقلها 9.75 طن / فدان عند المكافحة باستخدام المبيد الحشرى كلور فان. وكانت نسب السعر المقابل 230.86، 140.74% علي التوالي مقارنة بالحقل غير المعامل.