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Integrated Pest Management of the Tomato Leaf Miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Tomato Fields in Egypt

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ABSTRACT

Tomato (*Solanum lycopersicum* L) is universally one of the most important vegetable crops worldwide. In Egypt, the crop is cultivated annually in 2-3 plantations. The tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the recent devastating pests attacking tomato crop in several countries. It is a new exotic pest in Egypt. A study to evaluate the efficacy of integrated control methods against the pest was carried out at Fayoum Governorate, Egypt in the tomato Nili plantation (September – December) of 2014. Based on the infestation reduction rate, release of the egg parasitoid, *Trichogrammatoidea bactrae* + mass trapping (plot B) showed best results, followed by the application with Biotrine and Fytomax + mass trapping (plot A) and lastly use of insecticides (control) (plot C). Respective seasonal rate of infestation was 9.2, 11.1 and 29.3%. Highest yield production and cost benefits were recorded in plot (B).

Key words: Tomato, *Tuta absoluta*, *Trichogrammatoidea bactrae*, IPM, Cost benefit, Egypt.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is universally considered one of the most important vegetable crops worldwide. This crop is subject to attack with scores of insect pests and diseases that affect its production. The tomato leaf minor (TLM), *Tuta* (*Scrobipalpuloides*) *absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the major devastating insect pests attacking tomato in many of the tomato-producing regions worldwide. It is originated from south America, rapidly invaded various European countries and spread very fast along the Mediterranean Basin including Egypt (Desneux *et al.*, 2010). It is considered a key agriculture threat to European and North Africa tomato production (Germain *et al.*, 2009). Tomato is known as the main host of *T. absoluta*, but it also feeds, develops and reproduces on other solanaceous plants such as potato, tobacco, eggplant, pepper, aubergines, black nightshade and several related weeds such as jimson weed (Pereyra and Sanchez, 2006). Severe infestation with *T. absoluta* can potentially result in significant damage by feeding on all aerial parts of tomato plant, causing economic losses of up to 80-100%, if the pest is not properly managed (Desneux *et al.*, 2010). However, the main damage is usually observed on the leaves and fruits, but inflorescences and stems can also be affected. Eggs of *T. absoluta* are deposited chiefly on the leaves, singly or in small groups, and the larvae attack leaves, stems and fruits. Larvae of *T. absoluta* feed on the mesophyll of the leaf leaving only the epidermis intact with its feces, which subsequently widens and then the damaged tissue dries. Under intense attack, the damaged leaves turn yellow, wither, and senescence; the fruits are destroyed; and the plant is ultimately die (Maluf *et al.*, 1997).

At present, depending on the cropping system and infestation intensity, the main control tools used against TLM rely too heavily on conventional insecticides that have led to the development of insecticide resistance (Haddi, 2012). In addition, the problems of using chemical control are further exacerbated by awareness of environmental pollution, toxicity to natural enemies and increasing risks to human and mammals (Tillman *et al.*, 2000). Therefore, the use of insecticides has become subordinated to other control methods, such as biological control singly and/or in integrated with other methods as use of aggregation pheromones and biopesticides that have gained more credibility in the last decades (Senior *et al.*, 2001; Agamy, 2003 and Mandour *et al.*, 2012). Biological control using natural enemies would be the concerted use as a major component of any integrated pest management (IPM) program for controlling TLM. Egg parasitoid species of family Trichogrammatidae are considered efficient biological control agents and are widely used commercially for the suppression and control of lepidopterous pests on many crops (Agamy, 2003). More than 32 million hectares are treated worldwide using different species of *Trichogramma* (Mills, 2010). They are easy to rear and release either in open fields or protected crops (Chailleux *et al.*, 2012)mostly through innudative releases (Mills, 2010). Selection of the appropriate *Trichogramma* species for controlling a given insect pest is a crucial factor to the success of biological control program (Desneux *et al.*, 2010; Mills, 2010 and Chailleux *et al.*, 2012).

The present study aimed to monitoring of *T. absoluta* population in tomato fields using pheromone traps, estimate natural rate of infestation of the pest in tomato fields at Fayoum Governorate, Egypt, testing an IPM package based on use of sex pheromone aggregation traps + use of biorational solutions or a biocontrol agent comparing with use of conventional pesticides. Cost-benefit of the package was also estimated.

MATERIALS AND METHODS

Biorational solutions

The tested biorational solutions used in this study were Fytomax N and Biotrine produced by Russell IPM Company, UK. These two products are highly recommended for controlling *T. absoluta* in vegetables crops.

1- Fytomax N: is a bio-rational solution based on Azadirachtin 1% (10000 ppm) extracted from the neem tree seeds *Azadirachta indica* in ULV formulation. Fytomax N prevents or interferes with an insect's development. It has an ovicidal effect and controls target pests by contact as well as by ingestion. It acts as repellent, antifeedant, and interference with the molting process of insect pest. Treated insects stop feeding and growing.

2- Biotrine: is a bio-rational solution based on a natural fermentation of the soil bacterium *Streptomyces avermitilis*. It is a broad spectrum in its action, killing insects through contact and as they feed on treated plants. Biotrine works by paralyzing the insect, contact, ingestion and by suffocation. It acts as an antifeedant product with residual protection for the crop.

Soapy water traps

Pheromone lures used in this study were obtained from Russell IPM Company, UK. Rubber septa dispenser of 120 days was used. Water traps were used for monitoring and mass- trapping program. Trap designs vary and can be as simple as deep plastic trays filled with soapy water and with the pheromone lure suspended over the center of the tray just above the water line attracted moths become trapped when they touch the soapy water.

Trichogrammatoidea bactrae Nagaraja and Nagarkatti

The egg parasitoid species *T. bactrae* was recommended to be used against the pest. Parasitoid cards, included parasitized *Sitotroga cerallela* eggs, provided by Dr. El–Heneidy (Dept. of Biological Control, Agriculture Research Centre, Giza, Egypt), were kindly hanged directly in the field on the tomato plants.

Methodology and experimental design

An experimental area of one hectare (equal 2.5 feddan) (feddan = 4200 m^2) located at Fayoum governorate Egypt, cultivated with tomato plants, variety Gold stone (planted in the nursery on 20th of June and transplanted to the permanent field by early August), was subdivided into three experimental plots. The experiment was carried out at the tomato plantation (September- January), which is so-called Nili plantation. Plot A (one feddan) was subdivided into 4 subplots (A1 – A4) as replicates and treated with Bio-rational solutions. Plot B (one feddan) was subdivided into 4 subplots (B1 – B4) as replicates and was treated by releasing *T. bactrae* (at two release rates; 60000 and 100000 parasitoids per feddan). Plot C (control) (½ feddan) was subdivided into 2 subplots (C1 and C2) as replicates and left for regular practices carried out by the grower himself, depends mainly on use of pesticides. The pheromone-soapy water basin traps were placed at all the experimental plots. Metrological data (minimum, maximum temperature and relative humidity (RH) in the region of the experiment throughout the experimental period was obtained from the metrological station of Fayoum, located in the Agricultural Research Station, Fayoum, Egypt.

Monitoring of pest population

A total of 10 pheromone traps per hectare (4 per feddan), obtained and recommended by Russell IPM, UK were placed as 4, 4 and 2 traps in plots A, B and C, respectively as mass-trapping. Trap catches were examined and counted twice a week throughout the tomato growing season that extended from early September 2014 to early January 2015.

Estimation of the rate of infestation with *T. absoluta*

A total of 100 plants (25 plants/ replicate)/ plot was examined weekly and rate of infestation (no. of mines in the leaves, stems and fruits/plant) was counted and recorded at the three experimental plots A, B and C, starting early September until harvesting.

Experimental plot A (Biorational solutions' trial)

Four pheromone–soapy water traps were placed, one trap/ replicate, at each of the subplots A1, A2, A3 and A4. By catching the first *T. absoluta* moth in any of the plot traps, the plot was treated weekly by one of the two tested compounds; Biotrine and Fytomax N, alternatively until harvesting.

Experimental plot B (Parasitoid's trial)

Four pheromone–soapy water traps were placed, one trap/ replicate, at each of the subplots B1, B2, B3 and B4. By catching the first *T. absoluta* moth in the plot traps, the plot was treated bi-weekly by releasing the egg parasitoid *T. bactrae* at two release rates; 60000 and 100000 parasitoids per feddan. The first rate (15000 parasitoids per subplot) was applied in subplots B1 and B2, while the second rate (25000 parasitoids per subplot) was applied in subplots B3 and B4. Each was considered as a replicate. Releases were applied until harvesting.

Experimental plot C (Control)

Half feddan (2100 m^2) was subdivided into 2 subplots (2 replicates) (C1 and C2), each replicate (about 1000 m^2). Two pheromone– soapy water traps were placed, one trap/ replicate at the subplots C1 and C2. The plot was sprayed by the grower himself using recommended pesticides in the region, without any interference. Pesticides names, rates and dates of application were recorded.

Cost-benefits of IPM packages

At the end of harvesting, cost-benefits of using each of the IPM packages; bio-rational solutions, biological control and pesticides application (control) were estimated. The costs included the costs of purchasing the traps, materials and labor cost at each plot.

Statistical analysis

Obtained date was subject to statistical analysis using the computer program one way ANOVA and T test. Means were compared by Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Trap catches

Data of the trap catches of *T. absoluta* moths in the pheromone traps placed in the experimental field at Fayoum Governorate, Egypt in tomato Nili plantation of 2014 was summarized in table (1). By early September 2014, the beginning of the study in the permanent field, 2 pheromone traps were placed in plot C (control plot) for monitoring the pest population. The first catches (7 moths/ trap) were found on September 9th. Accordingly, other traps were placed in plots A and B (treatments) (4 traps/ plot = a rate of 10/ hectare) to serve for monitoring as well as mass-trapping control method. The first records 3.75 and 7.75 moths/ trap in plots A and B, respectively were recorded on September 12th. Occurrence of the moths continued throughout the whole study period September 2014 – January 2015. The month of October represented the highest mean numbers of moth catches/ traps (46.8 moths), followed by November (27.6 moths), while the months of September and December were the lowest (16 moths) (Table, 1 and Fig. 1).

The technique of mass trapping with pheromone has been widely used for the control of different insect species (Rodriguez-Saona and Stelinski, 2009).These findings agree with those reported earlier by Ltd (2009b) who mentioned that mass trapping can be used to reduce *T. absoluta* populations and it is particularly useful in production of greenhouse tomatoes. Also, Salas (2004) reported that water traps were the most common pheromone traps used for mass trapping of *T. absoluta*, as they are easier to maintain and less sensitive to dust than Delta or light traps and also have a larger trapping capacity than Delta traps. Cocco *et al.* (2012) stated that use of mass trapping alone for controlling male *T. absoluta* populations was not effective in reducing leaf and fruit damage.

Seasonal general mean of trap catches in plot C (control) was 23 and 27% higher than that in plots A and B, respectively. Total catch difference between plots A and B was 8% in favor of plot A. Number of moth catches in plot C was lower than that in plots A and B in September, while it was higher in the other three months, especially in December. Peak numbers of the moth catches (60, 82 and 84 moths/ trap) was recorded on October 27th, 19th and 19th in plots A, B and C, respectively. As well, the month of October represented the highest mean numbers of moth catches/ trap (43.6, 42.5 and 54.5 moths/ trap) in plots A, B and C, respectively (Table.1 and Fig. 2).

Percentages of infestation

Percentages of infestation with *T. absoluta* at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014 were summarized in tables 2, 3 and 4.

<u>Plot A</u>: treated weekly by each of Biotrine and Fytomax N alternatively, started September 21st and ended November 23rd. Each compound was treated 5 times**;** Biotrine on 21/9, 5/10, 19/10, 2/11 and 16/11/2014 and

Table (1): Monthly mean numbers of *T. absoluta* moth catches/ trap in pheromone traps placed in different experimental plots at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014

Date of Inspection	Trap Catches (No. of moths/trap)													Mean /trap
	Plot A (Plant extracts)					Plot B (Release of *T. bactrae*)					Plot C (Control)			
	A1	A2	A3	A4	Mean	B1	B2	B3	B4	Mean	C1	C2	Mean	
September	16.5	14.5	18.5	17.16	16.66	14.66	13.66	21.16	36	21.37	9.7	10.4	10.05	16.03
October	49.5	68	40.6	46.3	51.1	40.12	40.3	42.5	47.1	42.5	50.5	58.5	54.5	49.37
November	32.2	26.1	21.8	21.7	25.5	23.7	26.4	19.3	38.2	26.9	34.4	32.2	33.33	28.57
December	6.5	7.6	8.5	9	7.9	4.8	5.3	10.8	6.5	6.9	34.7	38	36.35	17.05
Grand mean	23.48	22.63	22.61	23.94	25.3	21.35	22.13	23.48	32.53	24.4	33.14	35.46	32.1	

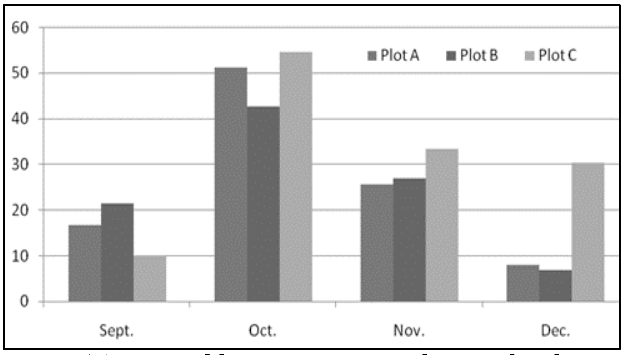

Fig. (1): Monthly mean no. of *T. absoluta* moths/trap/plot at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014.

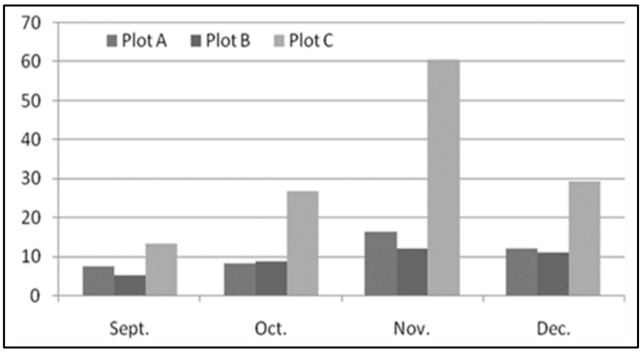

Fig. (2): Monthly mean percentages of infestation with *T. absoluta* in different treated plots at Fayoum Governorate, Egypt in the tomato plantation of 2014.

Table (2): Monthly mean rates of infestation with *T. absoluta* (no. of mines/ plant) at Plot (A) (sprayed with biorational solution) at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014

Date of inspection	Mean				
	A1	A2	A3	A4	Mean
September	9.3	9.3	5.3	5.3	7.3
October	9.6	10.4	8	7.2	8.2
November	19	23	13	10	16.3
December	10	18	13	7	12
Grand mean	12	15.2	9.8	7.4	11.1

Table (3): Monthly mean rates of infestation with *T. absoluta* at Plot (B) (release of *T. bactrae*) at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014

Date of inspection	Mean				
	B1	B2	B3	B4	Mean
September	8	1.3	5.3	5.3	5
October	7.2	7.2	13.6	6.4	8.6
November	11	17	13	7	12
December	10	10	17	7	11
Grand mean	9.1	8.9	12.2	6.4	9.2

Table (4): Monthly mean rates of infestation with *T. absoluta* at Plot (C) (control -sprayed with pesticides) at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014

Date of inspection	Mean				
	C1		C2		Mean
	I	II	I	II	
September	18.7	0	8	0	13.3
October	24	0	29.6	0	26.8
November	60	0	61	0	60.5
December	46	10	47	14	20
Grand mean	37.2	10	36.4	14	29.3

I = < 3 mines/plant II = 4 -10 mines/plant
III = > 11 mines/plan

Table (5): Estimated yield production of tomato, control costs and cost benefits in the experimental plots of different control methods at Fayoum Governorate, Egypt during the tomato Nili plantation, 2014

Plot	Yield production Ton/feddan	Price of production L.E./feddan	Control costs L.E./feddan	Cost benefit (L.E.)
A	14.36	21540	873.8	20666
B	15.2	22800	505.2	22295
C	13.4	20100	1180	18920

Feddan = 0.4 hectare
One US $ = 7.5 L.E.

Fytomax N on 28/9,12/10, 26/10, 9/11 and 23/11/2014. Monthly rate of infestation started with (7.3%) in September, increased in the following months to reach (8.2%) in October, (16.3%) in November and then reduced to (12%) in December (Table 2 and Fig. 2). Rates of infestation were always less, following the application with Biotrine than that following Fytomax, except the application practiced by early November (Table 2). Seasonal rate of infestation at plot A was 70% less than the control (pesticides' treatments). Statistical analysis showed highly significant difference between the use of Bio-rational solutions (t= 0.00111**) and the control.

Current management of TLM in Egypt as a part of Mediterranean Basin is mainly based on treatment with chemical insecticides (González-Cabrera *et al.*, 2011). Nevertheless, few bio-rational solutions are effective against TLM and selective to beneficial insects at the same time. Obtained results revealed that it is possible to reduce the tomato leaf miner impact by applying Biotrine and Fytomax N alternatively + mass trapping combination which showed promising results in controlling the pest. The Azadirachtin based-bio-rational solution Fytomax N had great efficacy towards *T. absoluta*. These findings agree with those reported earlier by Tomé *et al.* (2013) who found that Azadirachtin caused high mortality in insect larvae allowing only 2.5–3.5% survival. Also, Servicio de Sanidad (2008) who recommended use of Azadirachtin as a preventive spray and for light infestations (< 30 adult catches per week) of *T. absoluta* in Spain. Abamectin based bio-rational solution Biotrine efficiency was also confirmed under field conditions. These findings are in agreement with those reported earlier by Zalom *et al.* (208)who recommended abamectin for controlling the tomato pinworm in IPM programs. Salvo and Valladares (2007) stated that abamectin is primarily a stomach poison and has some contact activity, therefore it is used against mites and leaf miners Also, it had a good translaminar action, penetrating the leaf surfaces of the host plant. Moussa *et al.* (2013) mentioned that abamectin provided excellent control against *T. absoluta* in Egypt. Mass trapping and using of Biotrine alternatively with Ftyomax N induced showed a better control of the pest. Rates of infestation were always less, following the application with Biotrine than that following Fytomax N and this is maybe an evidence of the efficacy of the Biotrine. Generally, seasonal rate of infestation was much less than the control (pesticides' treatments).

Plot B: treated biweekly by 2 rates of the egg parasitoid, *T. bactrae;* 60000 (in subplots B1 and B2) and 100000 (in subplots B3 and B4) parasitoids/ feddan. Dates of releases were on25/9, 9/10, 23/10, 6/11 and 20/11/2014. Releases started on September 25th and ended November 20th. Both release rates were applied 5 times. Monthly rate of infestation started with (5%) in September, increased in the following months to reach (8.6%) in October, (12%) in November and continued around the same level (11%) in December (Table 3 and Fig. 2). Rates of infestation were almost similar at the 2 different rates of releases in September, increased slightly in October at the high rate of release and then a vice versa was recorded in November (Table 3 and Fig. 2). Total seasonal mean rate of infestation with *T. absoluta* at Fayoum in the Nili tomato plantation of 2014 was nearly equivalent in plots A and B (11.1 and 9.2%, respectively). Seasonal rate of infestation at plot B was 75% less than the control (pesticides' treatments) and 17% less than applying Biotrine or Fytomax. Statistical analysis showed highly significant difference between the use of *T. bactrae*(t=0.003587**) and the control. Also, insignificant difference was found between the two rates of releasing *T. bactrae* (t= 0.086433) in plot B.

T. bactrae is one of the most effective parasitoid against TLM as indicated by the higher percentages of parasitism (Abd El-Hady, 2014). In the present study, obtained results revealed that these oophagous parasitoid would play crucial role for management of TLM. Abd El-Hady (2014) stated that increasing the number of released parasitoids caused significant increase of parasitization and the seasonal rate of infestation was obviously less than the control (pesticides' treatments) and relatively than the bio-rational solutions. Such result is evidence of the efficacy of the combining of mass trapping technique and release of *T. bactrae* in management of TLM. Abbes *et al.* (2012)recorded 20% infestation of leaves in the IPM cropping system (mass trapping + release of *Nesidiocoris tenuis*) versus 98% in the conventional cropping system and the infestation rate of fruits was 18.2% in the IPM cropping system versus 46.8% in the conventional one.

Plot C: (control plot), treated 7 times by the grower, using three different pesticides; Nomolt 15% SC (2 times), Pleo 50% EC (2 times) and Oshin 20% SG (3 times). Dates of application were as follow: Nomolt 15% SC on 18/10 and 22/11/2014 & Pleo 50% EC on 7 and 13/11/2014 & Oshin 20% SG on 22/10, 28/11 and 2/12/2014. Monthly mean rate of infestation with the pest increased from 13.3% in September to 26.8% in October, to 60.5% in November and then decreased to 29.3% in December (Table 4 and Fig. 2). Seasonal mean rate of infestation was obviously higher in plot C (29.3%) than in the other 2 plots, 11.1 and 9.2% at plots A and B, respectively. This indicates that application of either Biotrine or Fytomax or release of parasitoid achieved about 70-75% less rates of infestation than using pesticides.

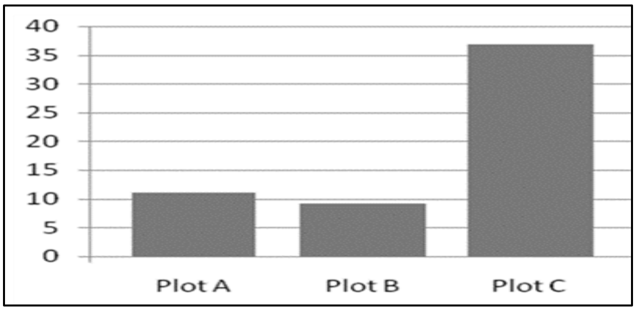

Fig. (3): General mean percentages of infestaion with *T. absoluta* in different treated plots at Fayoum Governorate, Egypt in the tomato Nili plantation of 2014.

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Although plot C was treated 7 times by the pesticides (Nomolt 15% SC, Pleo 50% EC and Oshin 20% SG), highest total rate of infestation (36.8%) was recorded in it (Fig. 2). Percentages of infestation did not exceed level one (< 3 mines/ plant) in plots A and B throughout the experimental period. Level 2 (4-10 mines/ plant) was recorded twice in the pesticide plot (C) by late December (Table 4). Highest monthly mean percentage of infestation (60.5%) was recorded in plot C (control) in November, while it was 16.3 and 12% in plots A and B, respectively in the same month (Fig. 3). Generally, the peak number of moths/ trap, recorded in the pheromone traps in October (46.8 moths), led to an increase in the pest's rates of infestation in the all experimental plots in November (Fig. 2).

Treatment with the parasitoid releases in plot B (5 times) showed least mean percentages of infestation (9.2%) compared with (11.1%) in the bio-rational solutions treatment (plot A) (treated 10 times) (Fig. 3).

In conclusion, applying an IPM packages depended upon mass trapping plus either release of the parasitoid, *T. bactrae* or applying Biotrine or Fytomax achieved best rates of reduction of T. *absoluta* infestation at Fayoum in the Nili tomato plantation of 2014. Further studies are needed for other tomato plantations as different rates of the pest population are expected.

Cost Benefits

Cost benefit = costs of yield production – control costs. Data shown in table (5) demonstrated that the highest yield production, production costs and cost benefit in the experimental plots of the tomato Nili plantation, 2014 was recorded in plot B, where the egg parasitoid *T. bactrae* was released five times combined with mass-trapping, followed by plot A (using bio-rational solution integrated with mass trapping). On other hand, using insecticides in plot C (control) gave the lowest yield production and highest costs. Plot B showed 11.8 and 5.3% higher in yield production (ton/feddan) than plot C and A, respectively and correspondent less control costs 57.19 and 42.18%. Seasonal cost benefit achieved in the experimental plots was 15.14 and 7.31% higher in plot B than that in plot C and A, respectively. Besides, the other advantages of using the safe biocontrol method directly on the crop and indirectly on the environment.

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