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Effect of some biocontrol agents and biopesticides against tomato leaf miner *Tuta absoluta* (Lepidoptera: Gelechiidae) on tomato crop at Alexandria, Egypt

Abu-Shall, Amany M. H.
Applied Entomology and Zoology Dept., Faculty of Agriculture, El-Shatby, Alexandria University..

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Abstract:

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetables around the world. In Egypt, tomato is widely grown vegetable crop annually in 2-3 plantations. Many pests attacking tomato crop causing very serious damage, one of the recent devastating exotic pests is the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *T. absoluta* insect is very difficult to control. Therefore, this study was conducted to find an effective and suitable management approach against tomato leaf miner. The experiment was carried out in the tomato plantation during two consecutive seasons for autumn (15^{th} of August 2018) and spring season (15^{th} of March 2019) at the Experimental Station Farm, Abies, Alexandria Governorate, Egypt. According to the infestation reduction rate of *T. absoluta*, the data detected that the treatment (Bio, *T.a*), release of the egg parasitoid, *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae) with rate 8 cards/¼ feddan showed successful results (42.71%) to management *T. absoluta*, followed by the foliar spray in both of (Bio, N.) treatment (application of Fytomax N based on Azadirachtin 1% extracted from the Neem tree seeds with rate 1ml./L. of water) and (Bio, *B.t*) treatment (application of *Bacillus thuringiensis* (Diple D.F.) with rate 100 gm./¼ feddan) 35.90% and 33.75%, respectively, lastly use of (Ch,Co.) treatment (application of chemical pesticide (Coragen) based on chlorantraniprole 20% SC with rate 15 cm./¼ feddan) (8.41%). The yield production and cost benefit were recorded. Results revealed that release of the egg parasitoid, *T. achaeae* as a biocontrol agent followed by application of Fytomax N (azadirachtin) as a biopesticide, bacteria of *B. thuringiensis* formulate (Dipel D.F.) and fungi of *Metarhizium anisopliae* formulate (Lycomax) as biocontrol agents performed best in reducing *T. absoluta* infestation, increase of yield production and cost benefit, comparing with apply of traditional agriculture practices (i.e. chemical pesticide, hand picking and destruction of infested leaves and fruits).

Introduction

The tomato leaf miner *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera) is native pest of neotropical region. In 2006, it was identified in Spain and after that it has spread to most of Europe, Africa, West, Central and South Asia (Sridhar *et al*., 2014 and Venkatramanan *et al*., 2017). It is originated come from South America, rapidly invaded different European countries and spread very fast along the Mediterranean Basin including Egypt (Desneux *et al*., 2010). In Egypt, *T. absoluta* was first detected in 2009 on tomatoes at Marsa Matrouh (northwestern Egypt), then the pest rapidly spread to the upper and lower regions of Egypt (Moussa *et al.*, 2013 and Salama *et al.*, 2015). It is oligophagous moth feeding on solanaceous crops and one of the key pests of tomato production (Garcia and Espul, 1982 and Germain *et al*., 2009). Tomato (*Solanum lycopersicum* L.) is considered one of the most economically important vegetables around the world. *T. absoluta* is one of the major devastating exotic pests attacking tomato crops in many regions of the tomato-producing worldwide. Severe infestation with *T. absoluta* can potentially result in significant damage by feeding on all aerial parts of tomato plant and affects both yield and fruit quality. If *T. absoluta* is not properly managed, it is causing 80–100% crop loss in the field and in protected cultivation (Desneux *et al*., 2010; Khanjani, 2013 and Ramzi Mansour *et al*., 2018).

In order to reduce the excessive use of insecticides in tomato fields, environmentally control strategies have been developed, including cultural control measures (e.g. crop rotation, selective removal and destruction of infested plant material) (Korycinska and Moran, 2009) and the use of entomopathogens (Urbaneja *et al*., 2012). Also, lepidoptera pheromones have been used for insect monitoring and mating disruption, which is a great biotechnological tool to successfully reduce *T. absoluta* infestations (Cherif and Kaouther, 2014). This involves only the follow-up of male flight activity during the growing season, which aims at deciding the most appropriate timing for applying either pestcticide treatments or biological control (Caparros Megido *et al*., 2013).

Biological control using natural enemies would be the concerted use as a major component of any integrated pest management (IPM) program for controlling *T. absoluta*. 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 and Ballal *et al*., 2016). They are easy to rear and release either in open fields or protected crops (Chailleux *et al.*, 2012). 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 parasitic wasp *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae) has been suggested as a possible biological control agent against *T. absoluta* (Pasquale *et al.*, 2015). On the other hand, botanicals have been the oldest tool used for the control of insect pests. Several plants exhibit antifeedent properties against an array of insects. Among them Neem is one of the important plants still find a place in modern pest management programmes (Kona *et al.*, 2014).

Tomato is known as the main host of *T. absoluta* and feeds, develops and reproduces also on other solanaceous plants such as potato, tobacco, eggplant, pepper, aubergines, black nightshade and several weeds such as jimson weed (Pereyra and Sanchez, 2006). 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).

Current management of *T. absoluta* in Egypt as a part of Mediterranean Basin, is mainly based on treatment with chemical insecticides (González-Cabrera *et al.*, 2011). At present, depending on the cropping system and infestation intensity, the main control tools used against tomato leaf minor, *T. absoluta* 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, 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 and Agamy, 2003).

This experiment aimed to identify a non-chemical pesticide approach to control *T. absoluta* at Alexandria Governorate, Egypt. So, the present study was conducted to manage of *T. absoluta* population using some biocontrol agents and biopesticides comparing with use of conventional practices (i.e. chemical pesticide, hand picking and destruction of infested leaves and fruits) in tomato field at Alexandria Governorate, Egypt, by estimating natural rate of infestation.

Materials and methods

1. Description of the study area:

The field experiment was carried out at the Experimental Station Farm, Abies, Faculty of Agriculture, Alexandria University, Alexandria Governorate, Egypt. An experimental area of one hectare (equal 2.5 feddan) (feddan = 4200 m^2) was planted with tomato (*Lycopersicon esculentum* Mill) variety Gold stone. Experimental area cultivated during two consecutive tomato plantations seasons for autumn (15th of August 2018) and spring season (15th of March 2019). Minimum, maximum temperature and relative humidity (RH) throughout the experimental period in the region was recorded from the metrological station: 623180 (HEAX), Ministry of Agriculture, Alexandria.

2. Experimental design:

The experimental was conducted a Randomized Complete Block design with 8 treatments and 3 replicates during two consecutive tomato plantations seasons. Each replicate per plot was contained 3 rows with 15 plants / row at 60 x 45cm spacing, for a total of 45 plants.

3. Experimental materials:

Delta traps supplied with *T. absoluta* pheromone were placed (4 traps/ feddan) at all the experimental plots and hung at a height of 1 m. The pheromone capsule was changed once a month and the sticky plate once a week. All the treatments started when more than 3 adults were caught in the traps. The number of 3 caught adults has been selected to prove the field pest presence without economic threshold correlations. After that, the pheromone traps were removed from all the field experiment. In Table (1) is given the treatments, trade name, scientific name, abbreviations of experimental treatments and application rate of each treatment. The experimental materials were diluted with tap water and applied at field rates based on the dose recommended by the companies. The treatments were (Bio, *T.a*) = release of the egg parasitoid, *T. achaeae* with rate 8 cards/¼ feddan as a biocontrol agent, were kindly hanged directly in the field on the tomato plants; (Bio, *M.a*) = application fungi of *Metarhizium anisopliae* (Lycomax) ½Kg./¼ feddan in soil as a biocontrol agent; (Bio, *B.t*) = application bacteria of *Bacillus thuringiensis* (Diple D.F. 9.4% WG) 100 gm./¼ feddan by foliar spray as a biocontrol agent; (Bio, N) = application of Fytomax N as a biopesticide, based on Azadirachtin 1% extracted from the Neem tree (*Azadirachta indica*) seeds with rate 1ml./L. of water by foliar spray; (Bio, Ph.T) = application of Pheromone lures through installation of delta sex pheromone trap with rate one trap/¼ feddan; (Ch, Co.) = application chemical pesticide of Coragen 20%SC, based on chlorantraniprole with rate 15 cm./¼ feddan; (H) = Hand picking and destruction of infested leaves and fruits; (C) = control (untreated), which left without any practices carried out by the farmers. Foliar sprays were applied by using a knapsack sprayer **(Molla *et al*., 2011)**.

4. Estimation the percent infestation by *Tuta absoluta:*

The plants in all treatments were weekly visually checked. Ten plants of medium row were used for data collection from each replicate/ plot before treatment as well as 3rd, 7th and 14th days after applied the experimental treatments. Data on number of healthy and infested plants; leaves and fruits infestation by leaf miner of *T. absoluta* were counted and recorded from all the experimental treatments per plot. Infested leaves per each treatment were placed in a plastic bag and taken to the laboratory. Leaves were examined under binocular microscope (no. of mines in the leaves/plant) and larvae of *T. absoluta* live or dead as well as mines were counted before treatment and in intervals 3rd, 7th and 14th days after applied the experimental treatments.

On the other hand, per ten plants percent infestation, leaves infestation per plant and fruits damage (visual estimation) by leaf miner per plant were calculated. To assess the effect of treatments on reduction in fruits damage, numbers of infested and uninfested tomato fruits from 10 plants were counted from each replicate in different control methods. After that, percent reduction in fruits infestation over control after two consecutive tomato plantations seasons was measured. Subsequently in the end of tomato plantations spring season 2019, fruits were weekly visually checked and harvested, then weighted. The data on yield production of tomato was recorded.

5. Cost-benefit of yield:

At the end of harvesting, cost-benefit of using all treatments and control were estimated according to the following formula: -

Cost benefit = cost of yield production – control costs.

The control costs included the costs of purchasing the experimental materials and labor crops cost at each treatment.

6. Data analysis:

The data recorded on different parameters were analyzed statistically by using Co-Stat computer software program (2004) for analysis of variance. ANOVA was made by F-variance test and the differences between treatment means were compared by Fisher's LSD test (Al-Rawi and Khalf-Allah, 1980).

Table (1): The different treatments applied on tomato crop infestation by *Tuta absoluta* during two consecutive tomato plantations seasons 2018-2019 at Abies, Alexandria Governorate, Egypt

Treatments	Trade name	Scientific name	Application rate
a) Bio-agents			
1. Egg parasitoid	1.1.*Trichogramma achaeae* **(Bio, *T.a*)**	*Trichogramma achaeae*	8 cards/¼ feddan
2. Entomopathogens	2.1. Lycomax **(Bio, *M.a*)**	*Metarhizium anisopliae*	½ Kg./¼ feddan
	2.2. Diple D.F. 9.4% WG **(Bio, *B.t*)**	*Bacillus thuringiensis*	100 gm./¼ feddan
b) Recommended pesticides			
3. Biopesticide	3.1. Fytomax N **(Bio, N.)**	*Azadirachta indica*	1ml./L.
	3.2. (Pheromone lures) **(Bio, Ph.T)**	----------------------	one trap/¼ feddan
4. Chemical pesticide	4.1. Coragen 20% SC **(Ch.Co.)**	Chlorantraniliprole	15 cm./¼ feddan
5. Hand picking and destruction of infested leaves and fruits (H)			
6. Control (untreated) (C)			

- Parasitoid cards of *Trichogramma achaeae* were provided by Agriculture Research Centre, Giza, Egypt.
- Lycomax, Diple D.F and Fytomax N were obtained from Russell IPM Company, UK.
- Pheromone lures were obtained from pheromone production unit, Plant Protection Research Institute, Agriculture research center, Alexandria, Egypt.
- Coragen 20% SC was obtained from Shoura Chemicals Company.

Results and discussion

1. Effect of different treatments on tomato plant, leaf and fruit infestation:

Effect of different treatments on percent plant, leaf and fruit infestation by *T. absoluta* during two consecutive tomato plantations seasons in experimental area, Abies, Alexandria Governorate, Egypt is presented in Table (2). In autumn season (15th of August, 2018), the lowest plant (46.63%) and leaf (15.07%) infestation was recorded in treatment (Bio, *T.a*), release of the egg parasitoid, *T. achaeae* with rate 8 cards/¼ feddan as a biocontrol agent followed by foliar spray in both of (Bio, N.) treatment (application of Fytomax N based on Azadirachtin 1% extracted from the Neem tree seeds with rate 1ml./L. of water) as a biopesticide and (Bio, *B.t*) treatment (application bacteria of *Bacillus thuringiensis* (Diple D.F. 9.4% WG) with rate 100 gm./¼ feddan) as a biocontrol agent, respectively. On the contrary maximum infestation was recorded in untreated treatment (control). The similar trend was also found in spring season (15th of March 2019).

While, other results revealed that spring season was highest population density of *T. absoluta* followed by summer season (Tabikha and Abdel Nasser, 2015). In several Egyptian tomato producing areas, the degree of damage by this insect even reached 100% (Moussa *et al*., 2013). Under plastic greenhouse conditions in Nasr city (Cairo area, northern Egypt), infestation began in the third week of March and both the highest numbers of *T. absoluta* larvae and percentage of tomato infestation occurred in July (Ata and Megahed, 2014).

Effect of different treatments on fruit infestation by *T. absoluta* per plant during two consecutive tomato plantations seasons 2018-2019 at Abies, Alexandria Governorate, Egypt is showed in Table (2). In autumn season, the treatment (Bio, *T.a*) had the lowest fruit infestation (11.44%) followed by (Bio, N.) treatment (12.80%) and (Bio, *B.t*) treatment (13.23%). Maximum fruit infestation (19.97%) was recorded in control (untreated treatment). The same trend was also found in spring season. Accordingly, maximum reduction of fruit infestation over control after two consecutive tomato plantations seasons was also found in treatment (Bio, *T.a*) (42.71%) followed by (Bio, N.) treatment (35.90%) and (Bio, *B.t*) treatment (33.75%) comparing with use of conventional agriculture practices, chemical pesticide (Ch, Co.); hand picking and destruction of infested leaves and fruits (H) in tomato field at Alexandria Governorate, Egypt. While, no significant differences were observed between treatments (Bio, N.), (Bio,*B.t*), (Bio, *M.a*) and (Bio, *T.a*).

All treatments reduced population density of tomato leaf miner significantly. This study also revealed that after 7 -10 days of treatment application *B. thuringiensis* and *M. anisopliae* indicated effect on the larvae of *T. absoluta*, can be supposed that, the establishment of bacteria and fungi on the larvae of insect pests take some days. While, the application of Neem seed extract against larvae of *T. absoluta* resulted after 3 - 4 days. The results of the present experiment are quite like that of (Trindade *et al*., 2000; Hamdy and Walaa, 2013; Shalaby *et al*., 2013 and Shiberu and Getu, 2018).

2. Effect of different treatments on tomato yield:

The results indicated in the end of tomato plantations spring season, 2019 that the treatment (Bio, *T.a*), release of the egg parasitoid, *T. achaeae* with rate 8 cards/¼ feddan as a biocontrol agent provided the highest yield (4.08 ton / ¼ feddan) followed by (Bio, N.) treatment, foliar spray of Fytomax N based on Azadirachtin 1% extracted from the Neem tree seeds with rate 1ml./L. of water as a biopesticid and (Bio, *B.t*) treatment, application bacteria of *B. thuringiensis* (Diple D.F. 9.4% WG) as a biocontrol agent with rate 100 gm./¼ feddan (3.95 and 3.88 ton/¼ feddan, respectively) (Table, 3). Accordingly, Minimum tomato yield (2.66 ton/¼ feddan) was recorded in control (untreated treatment).

3. Cost benefit of yield:

Cost benefit of different treatments for managing *T. absoluta* after two consecutive tomato plantations seasons 2018-2019 at Abies, Alexandria Governorate, Egypt is presented in Table (3). The cost benefit was the highest (5841.85 L.E) in treatment (Bio, *T.a*) followed by both of treatment (Bio, N), and treatment (Bio, *B.t*) (5699.04 and 5607.45 L.E, respectively). Data shown that the treatment (Bio, *T.a*), release of the egg parasitoid, *T. achaeae* with rate 8 cards/¼ feddan as a biocontrol agent proved to be effective considering reduction of *T. absoluta* infestation, increase of yield production and cost benefit. On other hand, using chemical pesticide (Ch, Co), application of Coragen 20%SC with rate 0.5ml./L. of water gave the low yield production and cost benefit. So, considering that the result after two consecutive tomato plantations seasons 2018-2019, the treatment (Bio, *T.a*) may be recommended for managing tomato leaf miner, *T. absoluta* at Abies, Alexandria Governorate, Egypt. Besides, the other advantages of using the safe biocontrol agents directly on the yield production and indirectly on the environment and living agents.

Generally, seasonal rate of infestation in biocontrol agents and biopesticides treatments was less than the chemical pesticide treatment, especially treatment with release of the egg parasitoid, *T. achaeae* showed least percentages of fruits infestation (11.44% and 3.38% in autumn and spring seasons, respectively) compared with (16.42% and 4.05% in autumn and spring seasons, respectively) in the chemical pesticide treatment Coragen 20%SC (chlorantraniprole). In the same trend, Laham *et al.* (2009) reported that chlorantraniliprole is a relatively new insecticide for the control of lepidoptera and selected other species, Because of the new mode of action on both larvicidal and ovicidal activity. Also, Chlorantraniliprole has negligible impact on key parasitoids, predators, and pollinators by use field rates. However, the efficiency of chemical control of tomato leaf miner infestations has been poor because of the endophytic habit of its larvae, which are protected in the leaf mesophyll or inside fruits (Cocco *et al.*, 2013).

In the present study, obtained results agree with Agamy (2003) and Mills (2010) who stated that 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. They are easy to rear and release either in open fields or protected crops (Chailleux *et al.*, 2012). Also, 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 pesticides’ treatments and relatively than the bio-rational solutions. Goda *et al.* (2015) revealed that oophagous parasitoid would play crucial role to the success of biological control program for management of tomato leaf miner, *T. absoluta*. Obtained results revealed that possible to reduce the tomato leaf miner impact by applying Fytomax N (Azadirachtin), which showed promising results in controlling *T. absoluta*. Researchers have focused on the use of botanical extracts, oils and plant powders, which are cheap, of short persistence and of low mammalian toxicity were indicated that many of these plant materials show a broad spectrum of activity against insect pests, such as lethal, antifeedant, repellent and growth regulatory effects (Shiberu and Getu, 2018). Fytomax N had great efficacy towards *T. absoluta* and rates of infestation were always less, because 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. Nevertheless, few biopesticides are effective against *T. absoluta* and selective to beneficial insects at the same time (Goda *et al*., 2015). Also, found that Azadirachtin caused high mortality in *T. absoluta* larvae allowing only 2.5–3.5% survival (Tomé *et al.*, 2013). While, Serviciode Sanidad (2008) recommended that use of Azadirachtin as a preventive spray cause light infestations (< 30 adult catches per week) of *T. absoluta*.

The studies that focused on the effect of *B. thuringiensis* on *T. absoluta* have been performed that the commercial formulates based on *B. thuringiensis* may be a good control alternative for *T. absoluta* as other insect pests. It is a Lepidoptera-specific microbial, which ingested and disrupts the mid gut membranes (Giustolin *et al*., 2001; Niedmann and Meza-Basso, 2006 and Mallia, 2009). The *B. thuringiensis* is highly efficient in controlling *T. absoluta*, because the first instar larvae were the most susceptible than the second and third instar larvae. This result has shown that the impact of *T. absoluta* can be greatly reduced by spraying only *B. thuringiensis* with no need for chemical insecticides (González-Cabrera *et al.*, 2011).

Hence, it is important to regularly survey solanaceous plants for the occurrence of *T. absoluta* and document natural enemies attacking different stages of the pest. It is crucial to educate farmers on pest stages and symptoms of damage caused by *T. absoluta*. So that, farmers can determine initiate action on time and prevent spread of the pest. It would also be useful to help the farmers in identifying potential biocontrol agents of the pest, *T. absoluta*. In conclusion, applying biocontrol agents or biopesticids like in this study achieved best rates of reduction of *T. absoluta* infestation at Abies, Alexandria Governorate, Egypt in two consecutive tomato plantations seasons 2018-2019. Further studies are needed for other tomato plantations as different rates of the *Tuta absoluta* population are expected. It is concluded that the identification of biocontrol agents against *T. absoluta* with high efficacy and fruits quality, may serve as an important in management programmes of *T. absoluta* as ecofriendly manner.

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Table (2): Effect of different treatments on percent plant, leaf and fruit infestation by *Tuta absoluta* during two consecutive tomato plantations seasons 2018-2019 at Abies, Alexandria Governorate, Egypt.

Treatments	% Plant infestation		% Leaf infestation		% Fruits infestation		% reduction over control after two consecutive tomato plantations seasons
	Autumn season (15th of August, 2018)	**Spring season** (15th of March, 2019)	**Autumn season** (15th of August, 2018)	**Spring season** (15th of March, 2019)	**Autumn season** (15th of August, 2018)	**Spring season** (15th of March, 2019)	
(Bio, *T.a*)	46.63**c**	43.04**c**	15.07**f**	5.93**c**	11.44**c**	3.38**c**	42.71
(Bio, *M.a*)	60.20**b**	50.17**b**	19.22**c**	7.58**c**	13.37**bc**	3.66**bc**	33.05
(Bio, *B.t*)	58.64**b**	49.96**b**	16.97**de**	7.26**c**	13.23**bc**	3.64**bc**	33.75
(Bio, N.)	49.14**c**	44.49**c**	16.06**ef**	7.26**c**	12.80**bc**	3.58**bc**	35.90
(Bio, Ph.T.)	80.43**a**	63.74**a**	23.35**b**	10.09**b**	18.29**ab**	4.28**ab**	17.78
(Ch, Co.)	58.99**b**	50.90**b**	17.69**d**	7.53**c**	16.42**abc**	4.05**abc**	8.41
(H)	81.28**a**	64.40**a**	23.43**b**	14.52**b**	16.98**abc**	4.05**abc**	14.97
(C)	84.64**a**	66.94**a**	25.40**a**	15.54**a**	19.97**a**	4.47**a**	-------
Level of significance	**	**	**	**	**	**	
CV%	5.33	8.51	3.00	5.17	7.00	9.06	

Abbreviations of Experimental Treatments

(Bio, *T.a*) = release of the egg parasitoid, *Trichogramma achaeae* with rate 8 cards / ¼ feddan.
(Bio, *M.a*) = application fungi of *Metarhizium anisopliae* (Lycomax) ½ Kg. / ¼ feddan in soil.
(Bio, *B.t*) = application bacteria of *Bacillus thuringiensis* (Diple D.F. 9.4% WG) 100 gm. / ¼ feddan by foliar spray.
(Bio, N.) = application of Fytomax N (based on Azadirachtin 1% extracted from the Neem tree seeds) 1ml / L of water by foliar spray.
(Bio, Ph.T)= application of Pheromone lures through installation of delta sex pheromone trap with rate one trap / ¼ feddan.
(Ch, Co) = application chemical pesticide of Coragen 20%SC (chlorantraniprole) 15 cm. / ¼ feddan.
(H) = Hand picking and destruction of infested leaves and fruits.
(C) = control (untreated).

Table (3): Estimated yield production of tomato, control costs and cost benefit in the experimental area of different control methods against *Tuta absoluta* in the end of tomato plantations spring season, 2019 at Abies, Alexandria Governorate, Egypt.

Treatments	Yield production Ton / ¼feddan	Cost of yield production L.E. / ¼feddan	Control costs L.E. / ¼feddan	Cost benefit (L.E.)
(Bio, *T.a*)	4.08	6120	278.15	5841.85
(Bio, *M.a*)	3.84	5760	210.64	5549.36
(Bio, *B.t*)	3.88	5820	212.55	5607.45
(Bio, N.)	3.95	5925	225.96	5699.04
(Bio, Ph.T.)	3.12	4680	134.40	4545.60
(Ch, Co)	3.00	4500	294.59	4205.41
(H)	3.03	4575	198.77	4376.23
(C)	2.66	3990	---------	3990

[Treatments: Same as indicated under Table 2]

- Cost of yield production (L.E. / ¼feddan) = Yield production (Ton / ¼feddan) X Price of Ton yield production (~ 1500 L.E. / Ton)
- Control costs (L.E. / ¼feddan) = Costs of purchasing the experimental materials and labor crops cost at each treatment.
- Cost benefit (L.E.) = Cost of yield production – control costs.