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DESIGNING AN INTEGRATED PEST MANAGEMENT PROGRAM TO CONTROL WHITE-FLY *BEMISIA TABACI* (GENNADIUS, 1889) HEMIPTERA: ALEYRODIDAE ON EGGPLANT UNDER PROTECTED CULTURE

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Abstract

A multiple systems of whitefly integrated pest management (IPM) including the most successful agents (Biological, semi-chemical and chemical) has been designed to control *Bemisia tabaci* (Gen.) on eggplant in greenhouse. The agents used (Biofungicides, IGR`s and chemical pesticides) were tested as single elements and incorporated into multi-component programs. The application of nanotechnology, such as encapsulation of active ingredients, has showed an important value to avoid problems occurred due to the degradation of pesticide particles. Classical pesticides has shown good results to control the pest outbreaks in many IPM systems. However, the fast reproduction rate of that pest, adaptation to the host plant and fast development of resistance to chemicals enhanced the need to find alternative methods to keep the population of this pest under control (Kah *et al*., 2013). Thus, Evisect, a classical pesticide used against *B. tabaci* was transformed through encapsulation of active ingredients to improve its activity against this pest. Several treatments of single and multiple factors were also used to compare their ability to suppress *B. tabaci* on eggplant under protected culture during the winter seasons of 2018. The results for the first sample after application showed that T6 (Nano-Evisect) scored the best reduction in nymph densities with a percentage of (90.89%) that was significantly different from all the other treatments, followed by T5 (Classical Evisect) and T4 (Applaud) with a reduction percentage of (84.88%) and (82.83%) respectively with no significant difference between them. The control treatments recorded the lowest value (3.77 %). The 2^{nd} sample showed the continuation in reduction of nymph densities, T6 also scored the highest reduction percentage which was (98.94%) followed by T5 and T4 which scored (97.81%) and (96.86%) respectively with no significance difference among the treatments. The lowest was scored by the control treatment (16.98%). The 3^{rd} sample showed that reduction in population continued after the applications for all the treatments applied (except control). The highest reduction percentage was scored in four treatments (T6, T7, T8 and T9) which was (98.62%) with no significant difference among them. The lowest was scored by the control treatment (50.07%). The nanoformulation through encapsulation of the classical pesticide increased the activity of controlling *B. tabaci* under the greenhouse conditions.

Introduction

The whitefly (*Bemisia tabaci* Gennadius 1889) is one of the most important and economic pests in agriculture reported worldwide. Many cases of (outbreaks) were reported for this damaging pest on many crops. The clear damages caused by the pest may be occurred through plant sap feeding in the lower side of the leaves by its piercing-sucking mouthparts causing distortion of leaves which eventually get weak and fall. The damage of the pest can be indirect by the secretion of honey-dew which gather dust particles and cause the growth of saprophytic fungi such as (sooty mold) fungi. Moreover, the known way of feeding cause the transmission of the plant viruses especially to some sensitive crops (Secker *et al*., 1998). *B. tabaci* has high adaptation to its host plant as well as many geographical variations. Moreover, it was present and recorded in all continents where it was not established before due to the plant parts exchange and product exportation worldwide (Oliveira *et al*., 2001). Through history, *Bemisia tabaci* was difficult to control with conventional insecticides in different agricultural systems. In the last decade, new insecticide chemical have been introduced to provide a variation of novel modes of action and ways of activity to control this pest. The chemical compounds that have had the most immediate effect on *B. tabaci* include the nicotinoids and insect growth regulators (IGRs) (Palumbo *et al*., 2001). Neonicotinoids, a neurotoxins, targeting the recoptors` carrier (acetylcholine) in insects` nerve system while growth regulators are considered non-neurotoxic compounds. Buprofezin CSI (Chitin Synthesis Inhibitor) and Pyriproxyfen (Juvenile Hormone Analogue) were the most effective IGR`s used against *B. tabaci*. These compounds showed effective protection against the pest on cotton in the United States, however, repeated use of these products showed a decreased effect on *B. tabaci* which made it necessary to integrate these chemicals with other controlling methods such as cultural and biological approaches. Many insecticides were used to keep *B. tabaci* population under the economic thresholds. Abdullah (2006) showed that Evisect (Thiocyclam Hydrogen Oxalate) application scored the highest insect mortality and decreased the insect population densities, which is reflected on yield positively. On the other hand, in a study on potatos Evisect recorded relatively moderate influence reduction when used against the two stages of *B. tabaci* (Abd Allah *et al*., 2010). The term nanopesticide covers a wide range of compounds and cannot be included in a single category. Many nanoformulations combine several polymers and metal nanoparticles in the size range of nanometer. The aims of nanoformulations are generally to increase the solubility of poorly soluble active ingredients, to release the active ingredient in a slow/targeted manner and/or to protect particles from fast degradation (Kah *et al*., 2013). (Kamarudin, 2013) found that killing of oil nanoemulsion formulation in the early nymphal instars of *B.tabaci* was through giving wider coverage of active material on leaf surface and exposing larger areas of cuticle to the insecticides, this resulted in a better retention and enhanced the biological effect. Faria and Wraight (2001) found that the new methods of manufacturing and producing the pathogenic fungi developed a new bio-pesticides which can be used widely in pest control. The most used species were *Lecanicillium lecanii*, *Isaria fumosoroseus* and *Beauveria bassiana*. Many studies showed that these species can control *B. tabaci* both in greenhouse and field conditions. Touhidul and others (2009) showed that the integration of *Beauveria bassiana* and neem extract resulted in a good control of whitefly when scored (29.5%) and (97.2%) mortality for eggs and nymphs respectively. Ellsworth and Carillo (2001) found that the multi-component management system on whitefly could effectively reduce pest population. They found that the se of IGR`s such as Buprofezin and Pyriproxyfen with Imidacloprid on melon and vegetates was effective in the united stated that rely on sampling and depend on the economic threshold in timing of control and manage the pest resistance to pesticides.

Materials and Methods

The greenhouse preparation

The experiment was performed in a greenhouse (240 m^2). plants were planted in (5) parallel rows, each row contained two lines. Eggplant var. Barcelona seedlings eggplant aged (45) days were used. Plants were placed in the seed-beds in a zigzag to provide a space aeration and minimize humidity. Treatments were distributed in rows based on RCBD design.

The application of IGR`s

One gram per liter of Applaud (a.i. Buprofezin) diluted in distilled water (DW)(following the manufacture`s instruction), mixed thoughtfully and sprayed the vegetative part of the plant mainly on the lower side of the leaves where the most insect stages are located.

For the Admiral (a.i. Pyriproxyfen), 0.25 g/L was used (as recommended by the manufacturer) and sprayed as mentioned before.

Treatments

1. The application of *Isaria fumosorosea* and *Beauveria bassiana* five grams of *Isaria fumosorosea* commercial product was diluted in (1 liter) distilled water. Hand sprayer was calibrated manually to set the pressure of the sprayer and used Plants were sprayed as mentioned before and similar application was applied for treatment of commercial product of *B. bassiana*.
2. The application of classical Evisect and Nano Evisect

   Both WP and Nano Evisect was suspended in distilled water separately in the same manner and sprayed as mentioned before.
3. The application of multi component program

The multi component program (T7, T8, T9 and T10) included two or three steps (Tab. 1) with seventy two hour time interval among treatments.

Control treatment was sprayed only with DW.

Table 1 : The single and multiple program elements used to control *Bemisia tabaci* on eggplants for the winter season 2018 under protected system.

Tr.	Type of application	Elements	No. of sprays	Date
T1	Single	*Isaria fumosorosea*	1	15/3/2018
T2	Single	*Beauveria bassiana*	1	15/3/2018
T3	Single	Admiral (a.i. Pyriproxyfen)	1	15/3/2018
T4	Single	Applaud (a.i. Buprofezin)	1	15/3/2018
T5	Single	Evisect (Thiocyclam hydrogen oxalate)	1	15/3/2018
T6	Single	Nano-Evisect (encapsulated)	1	15/3/2018
T7	Program	*Isaria fumosorosea* +Admiral+Evisect	3 (one for each)	15/3/2018 18/3/2018 22/3/2018
T8	Program	*Isaria fumosorosea* +Nano-Evisect	2 (one for each)	15/3/2018 18/3/2018
T9	Program	*Beauveria bassiana* + Applaud + Evisect	3 (one for each)	15/3/2018 18/3/2018 22/3/2018
T10	Program	*Beauveria bassiana* +Nano-Evisect	2 (one for each)	15/3/2018 18/3/2018
T11	control	*Distilled water*	3	15/3/2018 18/3/2018 22/3/2018

The sampling for the estimation of *B. tabaci* population

Whitefly nymph densities were estimated by sampling 15 plants/treatment (5 plant/ replicate). Three leaves were collected from the top, middle and base of each plant. A (four cm^2) disc was taken from each leaf and then examined under a light microscope.

The statistical analysis

Experimental data for nymph densities and reduction percentage were analyzed using analysis of variance with SPSS.

Results and Discussion

The effectiveness of integrated pest management programs on the whitefly *Bemisia tabaci* on eggplant under protected culture for the winter season 2018

1. Reduction of nymph population after application of different treatments (1st sample)

The results shown in (Tab.2) refer to the reduction of nymph density (immobile stage) of the white fly *Bemisia tabaci* after application (1st sample). The number in the column of (number of insects after application) represents the number of living nymphs left after application while the column (the final reduction percentage represents the difference in the number of nymphs before and after application.

The results in (Tab. 2) showed that the best treatment recording the lowest nymph densities was T6 (Nano-Evisect) with a reduction percentage of (90.89%) which was significantly different from all the other treatments, followed by T5 (Classical Evisect) and T4 (Applaud) with a reduction percentage of (84.88%) and (82.83%) respectively with no significant difference. The rest of the treatments followed with a varied reduction percentages while the control treatments recorded the lowest value (3.77 %).

Table 2 : Average of nymph densities estimates for treatment of single and multiple program elements applied to control *Bemisia tabaci* on eggplants for the winter season 2018 under protected culture by using analysis of covariance

Treatments	Number of insects before application		Number of insects after application 1st sample		Reduction percentage before adjustment %	The death percentage in control	Final reduction percentage
T1	107	a	90	g	15.89	3.77	12.59
T2	102	a	67	f	34.31	3.77	31.74
T3	117	a	61	e	47.86	3.77	45.82
T4	115	a	19	b	83.48	3.77	82.83
T5	110	a	16	b	85.45	3.77	84.88
T6	114	a	10	a	91.23	3.77	90.89
T7	118	a	28	c	76.27	3.77	75.34
T8	104	a	42	d	59.62	3.77	58.04
T9	100	a	46	d	54.00	3.77	52.20
T10	105	a	85	g	19.05	3.77	15.88
T11 CONTROL	106	a	102	h	3.77	-	-
LSD	N.S		5.32				

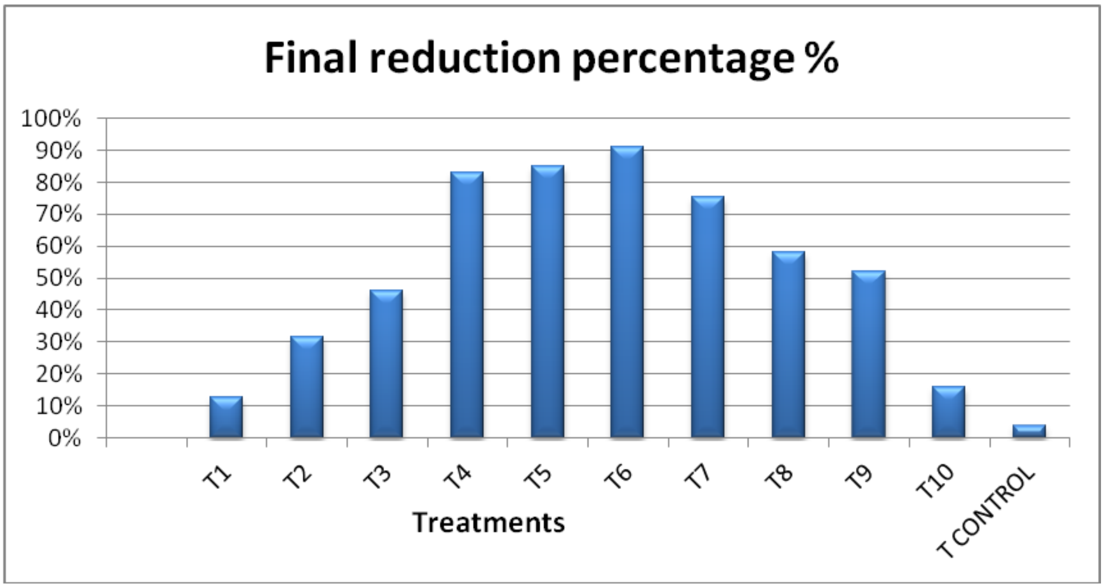

Fig. 1 : Final reduction percentage in nymphs densities after application of different treatments to control *Bemisia tabaci* on eggplants for the winter season 2018 under protected culture (1ST sample)

2. The continuation in reduction of nymph population after application of different treatments (2nd sample)

The results shown in (Tab. 3) refer to the continuation in reduction of nymph density of the white fly after application (2nd sample). The number in the column of (number of insects after application) represents the number of living nymphs left after application while the column (the final reduction percentage) represents the difference in the number of nymphs between the 1st and the 2nd sample after application.

The reduction in population continued after the applications for all the treatments applied (except control). The highest reduction percentage was scored in (T6) which was (98.94%) followed by (T5), (T4) and (T7) which scored (97.81%), (96.86%) and (95.92%) respectively with no significance difference among the treatments. The rest of the treatments scored different reduction percentages and the lowest was scored by the control treatment (16.98%).

Table 3 : The percentage of continuation in reduction of nymph population after application of different treatments (2nd sample) by using analysis of covariance

Treatments	Number of insects before application		Number of insects after application 2nd sample		Reduction percentage before adjustment %	The death percentage in control	Final reduction percentage
T1	107	a	18	D	83.18	16.98	79.74
T2	102	a	16	Cd	84.31	16.98	81.10
T3	117	a	10	B	91.45	16.98	89.70
T4	115	a	3	A	97.39	16.98	96.86
T5	110	a	2	A	98.18	16.98	97.81
T6	114	a	1	A	99.12	16.98	98.94
T7	118	a	4	A	96.61	16.98	95.92
T8	104	a	10	B	90.38	16.98	88.41
T9	100	a	12	Bc	88.00	16.98	85.55
T10	105	a	10	B	90.48	16.98	88.53
$T_{CONTROL}$	106	a	88	E	16.98	-	-
	N.S		4.36				

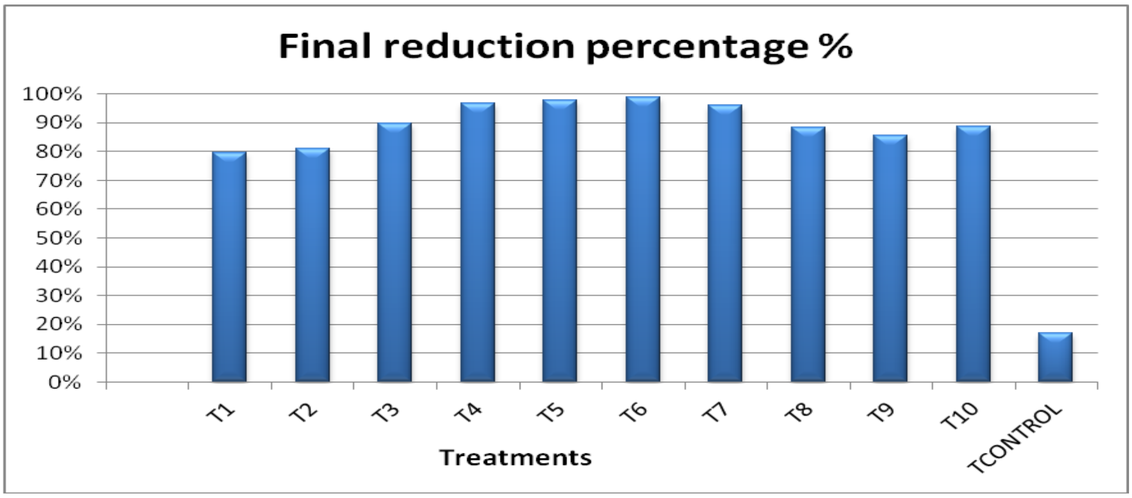

Fig. 2 : The percentage of continuation in reduction in nymphs densities after application of different treatments to control *Bemisia tabaci* on eggplants for the winter season 2018 under protected culture (2nd sample)

3. The continuation in reduction of nymph population after application of different treatments (3rd sample)

The results shown in (Tab.4) refer to the continuation in reduction of nymph density of the white fly after application (3rd sample). The column (the final reduction percentage) represents the difference in the number of nymphs between the 2nd and the 3rd sample after application.

The reduction in population continued after the applications for all the treatments applied (except control). The highest reduction percentage was scored in four treatments (T6, T7, T8 and T9) which was (98.62%) with no significant difference among the treatments. The rest of the treatments scored different reduction percentages and the lowest was scored by the control treatment (50.07%).

Table 4 : The percentage of continuation in reduction of nymph population after application of different treatments (3rd sample) by using analysis of covariance

Treatments	Number of insects before application		Number of insects after application 3rd sample		Reduction percentage before adjustment %	The death percentage in control	Final reduction percentage
T1	107	a	7.96	D	92.56	50.07	85.10
T2	102	a	2.84	Ab	97.22	50.07	94.43
T3	117	a	3.18	Abc	97.28	50.07	94.55
T4	115	a	1.14	A	99.01	50.07	98.02
T5	110	a	1.03	A	99.06	50.07	98.12
T6	114	a	0.79	A	99.31	50.07	98.62
T7	118	a	2.21	Ab	99.31	50.07	98.62
T8	104	a	2.55	Ab	99.31	50.07	98.62
T9	100	a	4.79	Bc	99.31	50.07	98.62
T10	105	a	5.91	Cd	94.37	50.07	88.72
$T_{CONTROL}$	106	a	52.93	E	50.07		
	N.S		2.95				

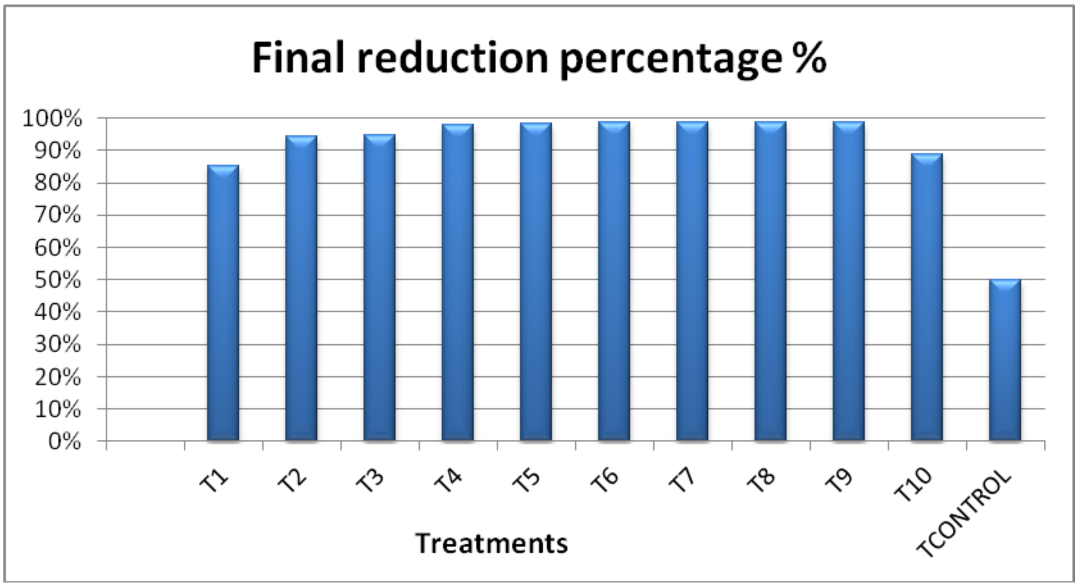

Fig. 3 : The percentage of continuation in reduction in nymphs densities after application of different treatments to control *Bemisia tabaci* on eggplants for the winter season 2018 under protected culture (3rd sample)

The encapsulated pesticide (Nano-Evisect) showed the highest reduction in pest population in the three samples taken after application; this might be caused by the slow release of the active ingredient in the pesticide which makes it more effective in pest control. Moreover, recent studies have shown that nano-pesticides have the capability to target specific control of crop pest (Hemraj, 2017). In addition, nanopesticide showed improved solubility and stabilities of (a.i.) for effective control of pest (Venugopal and Sainadh, 2016).

The nano-formulation can enhance the activity of some used materials and pesticides (Carvalho *et al*., 2015) found that different nano-formulations of neem oil are bioactives even about 30 days after application which means a better control for the different life stages of *B. tabaci*.

T5 (Classical Evisect) which followed the Nano-Evisect also scored good reduction percentage which agrees with (Abd Allah *et al*., 2010) who found that Evisect recorded relatively moderate influence reduction against the two stages of insect (nymphs and adults). This also agrees with (Jabbar, 2006) who found that the interaction between Evisect insecticide and sticky traps with used of two sprays gave a best protected from infection during the growth of crop and the use of third spray of pesticide and sticky traps gave a sure protected to the plants of tomato from the white fly infestation.

The IGR Applaud which also scored a good reduction percentage might be due to the specificity of this compound on white fly, the a.i. (buprofezin) is known to have a good control for this pest on different crops.

Buprofezin, a chitin synthesis inhibitor, was one of the most successful compounds that has allowed good management of *B. tabaci* for over 12 years (Ellsworth and Jones, 2001). Extensive field testing has demonstrated that it is not only highly effective against *B. tabaci* but also very selective, enhancing conservation of the pests` natural enemies and biological control (Naranjo *et al*., 2004).

Sohrabi *et al*. (2011) also found that Buprofezin significantly decreased stable population and other biological parameters of *B. tabaci*, however, it did not decrease the rate of population increase or the sex ratio of white fly following offspring.

Palumbo, (2009) found that buprofezin, regardless of which threshold was used, provided residual suppression of *B. tabaci* immature stages that was as good as or even better than foliar and soil-application of neonicotinoid application. He also demonstrated that this selective insecticides with unique modes of action can be used as an effective foliar alternative to the standard insecticides for controlling whiteflies on spring cantaloupes.

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