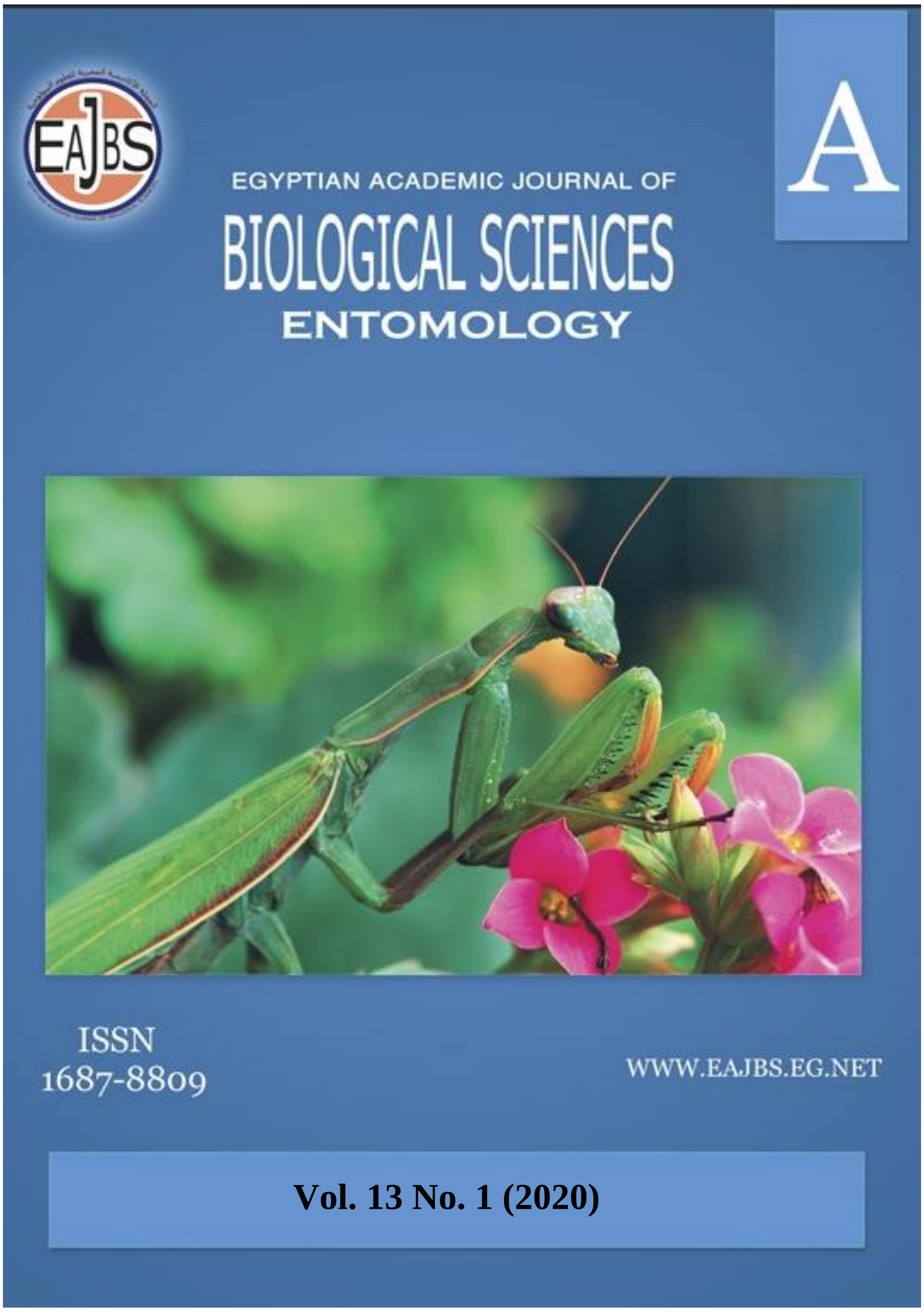

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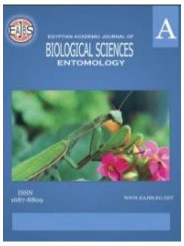

Field Application of Bio-Insecticides On Spiny Bollworm, *Earias insulana* (Bosid.) On Cotton by Using Recent Low Volume Ground Spraying Equipment

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ABSTRACT

Field experiments were carried out of about 11 kirats planted with (Giza 86) cotton variety during seasons 2018 and 2019 on 15th July and 1st, 15th August in a field located at Qaha Research Station, Plant Protection Research Institute, Qalyoupia governorate. The selected area was split into 10 plots and the control plot. Entomopathogenic fungi and a commercial formulation of *Bacillus thuringiensis* (Berliner) were sprayed by using Hand-held Hydraulic sprayer (Matabi) (56 L./fed.) and Economy Micron ULVA (15 L./Fed.) on cotton field highly infested with cotton Spiny bollworm *Earias insulana* larvae. All tested Bio-Insecticides revealed a significant negative influence on *Earias insulana* larvae. The most effective on reduction percentage of bolls infestation is *Metarhizium anisopliae*, *Beauveria bassiana* either isolates or (W. P.) with Economy Micron ULVA (15 L./Fed.) followed by *Bacillus thuringiensis* (W.P.) with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.). It could be recommended to use these Bio-Insecticides with ULV spraying equipment with not less than (15L/Fed.). A satisfactory coverage was obtained on cotton plants. The spectrum of droplets ranging between 130-166 μm (VMD). With a sufficient number ranging from 24-170 N/cm². The rate of performance of Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) was 3.5 Fed./day. It was the best equipment, but the lowest rate of performance was Economy Micron ULVA (15 L./Fed.) since it could spray only 3 Fed./day. The results indicated that there was no significant difference between the isolate form of fungi and wettable powder in reduction percentages of bolls infestation. Data showed that bio-insecticides may be recommended in integrated pest management because of their safety on animals, man and environment Also, Low Volume spraying reducing the time lost in the process filling the machines with the spray solution and saving the lost spray on the ground.

INTRODUCTION

Cotton *Gossypium barbadense* is one of the most important economic crops. Cotton crop is attacked by a large number of polyphagous pest (Dhawan, 1993). *Earias insulana* (Boisduval) (Noctuidae: Lepidoptera) is known as a cotton pest (Reed, 1994), (Kumar, *et al*. 2014) and also is obliterating and multivoltine Lepidopteron crawly insect pest of cotton. The genus Earias is widely distributed in the old world and Australasia, and some are pests of considerable importance in many of the cotton-growing countries of Africa and Asia. Spiny bollworm larvae infesting bolls, damaging cotton squares, buds, flowers, seeds, and fiber, especially at the late growth stage of cotton plants that cause decreasing in the quality and quantity in the lint and oil of the obtained yield. The societies worldwide are facing the problem of increasing the use of pesticides against agricultural pests in the absence of their natural enemies or bio-agents also using conventional chemical pesticides has direct and indirect risks to humans (Butt *et al*., 2001). On the other hand, many insects have developed resistance for many chemical pesticides during the last few years, biologists have turned their attention to the possibility of using other organisms as biological control agents and the microbiologists contributing in the development of the efficacy of microbial substances bacteria, fungi, and virus) for the control of many insect pests (Spadden and Gardher, 2004). Entomopathogenic fungi (EPF) have become a significant force in insect pest management schemes) (Lord, 2005) (Roy *et al*., 2006) (Khachatourians, 2008) (Maina, *et al*, 2018) The entomopathogenic mitosporic ascomycete, *Beauveria bassiana* (Bals.) Vuill. is an important natural pathogen of insects and it has been developed as a microbial insecticide for use against many major arthropod pests in agricultural, urban, forest, livestock and aquatic environments (Charnley and Collins, 2007, and Bayu and Prayogo, 2018, María ,*et al*. 2019). It has been developed as a microbial insecticide for use against many major pests, including lepidopterans and orthopterans. About 33.9% of the mycoinsecticides is based on *B. bassiana*, followed by *Metarhizium anisoplia*(33.9%), *Isaria fumosorosea* (5.8%) and *Beauveria brongniartii* (4.1%) (Faria and Wraight, 2007). *B. thuringiensis* is a spore-forming gram-positive bacterium considered to be an effective insecticide harmless to natural enemies, quite safe to mammals and environmentally acceptable (Entwistle *et al*., 1993).

A comparative study on the efficiency of different ground sprayers was carried out by (Hindy, 1992 and 1997), who detected a significant variation in the spray deposit due to the arrangement of the nozzles, spray volume, spraying type and rate of application. The world global attention was directed to the minimization of spraying volumes and the control costs which may be happened by using cheap and effective insecticides or using developmental ground spraying techniques with low application costs per feddan (Magdoline *et al*. ,1992) and(Mathews,1992). Maintaining sprayers for pesticide application in a good state of repairing and proper working in order to reduce their harmful effects on human health and environment Dokic *et al.* (2018) This work aimed to determine the best bioinsecticide and the best equipment controlling *E. insulana* larvae on cotton with the least hazard the natural enemies of those pests with conservation of agricultural environment.

MATERIALS AND METHODS

1-Source of Fungi and Bacteria Culture:

There were two sources of tested fungi: First source, (S1) isolates of *Beauveria bassiana* (Balsamo) and *Metarhizium anisopliae* (Metschnikoff) Sorokin were obtained from Assiutt University, Mycological Center Faculty of Science. The isolates were cultured on Sabouraud dextrose yeast agar (SDYA) medium g/l containing 40 g glucose, 20 g peptone, 20 g agar, 2 gm Yeast extract and 1000 ml of distilled water in flasks. These flasks were autoclaved at 21 C^0 for 15-20 min.

The second source (S2) was obtained as wettable powder produced by the Plant Protection Research Institute, Bio-pesticide Production Unit, Dokki- Giza, Egypt. The names of commercial bioagents were Bioranza® WP 10% (*Metarhizium anisopliae* Sorok.) Active ingredients 10%, Inert Ingredient 90%. It was formulated as a Wettable Powder with a count of 1 x 10^8 spore/ml. and Biovar® WP 10% (*Beauveria bassiana Balsamo*) active ingredients 10%, Inert Ingredient 90%. It was formulated as a Wettable Powder with count of 1x 10^8 spore/ml .and Protecto® WP 5% + 2% (Btk + SpliNPV).This product was a mixture of 5% of

Bacillus thuringiensis var. kurstaki and 2% of SpliNPV.

Preparation Tested Bioagent: The two sources were prepared as solution as follows:

Source 1 (S1): Fungal cultures were grown on Sabouraud dextrose yeast agar (SDYA) medium g/l and incubated at 25±2 ºC in darkness for 14 days. Conidial suspensions were prepared by scraping cultures with a sterile objective glass and transferred to 10 ml of sterile water containing 0.05% Tween 80 in a laminar flow chamber. The conidia were harvested by scraping the surface of the culture with the inoculation needle. The mixture was stirred for 10 minutes the hyphal debris was removed by filtering the mixture through a fine-mesh sieve. The conidial concentration of final suspension was determined by direct count using Haemocytometer.

Source 2 (S2): To prepare stock solution ($1x10^8$) spore/ml from commercial bioagent was weighted 5gram of powder and dissolved at 900 ml sterile water.

2-Spraying Equipment Tested on The Cotton Field:

Two ground application machines were selected to perform the scope of this work, as recommended used equipment in applying pesticides on cotton pests.

1. Economy Micron ULVA sprayer, spraying volume (15L./fed.), U.K. made.
2. Hand-held Hydraulic sprayer (Matabi) Spraying volume (56 L./fed.), Espine made.

categorization mentioned in table (1).

Calculations of productivity and rate of performance according to Hindy (1992).

3-Calibration and Performance Adjustment of The Tested Equipment:

. Collection and measurement of Spray deposit:

. Collection of the spray deposit.

Before spraying each cotton field treatment, a sampling line was constructed of a five-wire holder fixed in diagonal line inside each treatment to collect lost spray between plants; each wire holder top has fixed water-sensitive paper (Novartis Cards) on it. Also, each five cotton plants, the water-sensitive paper cards were put at three levels of the cotton plant; upper, middle and lower to collect the spray deposits on cotton leaves, were designed after Hindy (1989). All cards were collected and transferred carefully to the laboratory for measuring and calculating the number of droplets/cm² and its volumes (VMD) in all treatments.

. Determination of Spray Deposit:

Both of number and size of blue spots (deposited droplets) on water-sensitive papers (Novartis cards) were measured with a special scaled monocular lens (Strüben)® X15. The volume mean diameter (VMD) and the mean of droplets number in one square centimeter (N/cm²) was estimated according to Hindy (1992).

4-Execution of Field Experiments:

. Arrangements of the Experiments:

Field experiments were carried out during 2018 and 2019 cotton seasons at Qaha district, Qalyoubia Governorate. Cultivated with Giza 86 cotton variety on April 15th in cotton seasons 2018 and 2019. The experimental design was a randomized complete block with 3 replicates, the whole cultivated area (11 Kirats) was divided into equally 11plots, each plot was treated with one of the tested Bio-Insecticides, and one of the tested equipment while the remaining plot was left untreated as a control. Cotton seeds were sown at 20 cm distance between hills. Spraying of the tested pesticides took place on cotton plants three times on July, 15th, 1st, and 15th August, respectively, with two sprayers (Hand-held Hydraulic sprayer (Matabi) and Economy Micron ULVA sprayer). Each Bio-Insecticide was applied individually. The experiments were done at 4 pm. under local meteorological conditions of 37°C average temperature, 60 % average RH and 2 m/sec. average wind velocity during the experiment. To evaluate the effect of the three treatments against spiny bollworms, samples of 25 bolls/plots were randomly picked before and a week after application. Sampling continued weekly until harvest. The collected bolls were transported to the laboratory, where they were carefully dissected and the numbers of larvae, holes, infested squares, infestation percentage and percent of reduction (or increase) of infestation than control were recorded.

Phytotoxic Effect:

Determined by recording any colour change, leaf curling or flaming up to 8 days after spraying, according to Badr *et al*. (1995).

Calculation and data analysis:

a. The reduction percentages in the field experiment were calculated according to Henderson and Tilton (1955).

b. The statistical analysis of results was achieved according to SAS (1996) program for Biological studies: Duncan's for the biological evaluation of insecticides in the field.

Table (1): Techno-Operational data of certain ground sprayers applied to the Cotton field during seasons (2018,2019).

Items	Hand-held Hydraulic sprayer (Matabi	Hand-held Spining disc ULVA+ sprayer
Type of atomization	Hydraulic	Centrifugal(Rotary Spinning disc)
Nozzle type	Hollow cone nozzle 80°	One restirector
Pump type	Hydraulic air pump	-
Number of nozzles	1	1
Pressure (bar)	5	-
Spray tank (L.)	20	1+10
Rate of application (L/fed.)	56	15
Working speed (Km/h.)	2.4	2.4
Swath width (m.)	1.5	1
Flow rate (L/min.)	0. 8	0.150
Spray height (m.)	0.5	0.5
Type of Spraying	Targe spray in all treatments	
Productivity * (fed./h.)	0.860	0.571
Rate of performance* (fed./day)	3.4	3

* Number of spraying hours = 8 hours daily. *

Calculations of productivity and rate of performance according to Hindy (1992).

*Number of workers =2.

RESULTS

Data presented in Tables (2&3) showed that the application of the tested Bio-insecticides with Micron ULVA and Hand-held Hydraulic sprayer (Matabi) caused a significant reduction in percentages of infested cotton bolls by spiny bollworm *Earias insulana* at the two seasons 2018 and 2019. The average results of two seasons *Metarhizium anisopliae* either isolates or (W. P.) treatment showed 3.4 % boll infestation with *E. insulana* with Economy Micron ULVA (15 L./Fed.) followed by 4.35 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.), 4.5 % boll infestation with *Beauveria bassiana* either isolates or (W. P.) with Economy Micron ULVA (15 L./Fed.) followed by 5 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) , and 5.6 % boll infestation with *Bacillus thuringiensis* (W. P.) with Economy Micron ULVA (15 L./Fed.) followed by 5.38 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) compared with 50.6 % in the control. The *Metarhizium anisopliae* either isolates or (W. P.) treatment showed 92.8 % reduction in boll infestation with *E. insulana* with Economy Micron ULVA (15 L./Fed.) followed by 91 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.), 90.4 % boll infestation with *Beauveria bassiana* either isolates or (W. P.) with Economy Micron ULVA (15 L./Fed.) followed by 89. 8 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) and 88.5 % boll infestation with *Bacillus thuringiensis* (W. P.) with Economy Micron ULVA (15 L./Fed.) followed by 89 % with Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.). It could be recommended to use these Bio- Insecticides with ULV sprayers and spray volume not less than (15 L./Fed.). The results indicated that there was no significant difference between the isolate form of fungi and wettable powder in reduction percentages of bolls infestation.

I)The spectrum of droplets ranging between 130-166 μm (VMD). With a sufficient number ranging from 24-170 N/cm².

II)Lost spray-on ground, between plants, was the only measured loss, whereas other sources of loss such as by wind (drift), evaporation,... etc, were detected throughout this work.

III)The rate of performance of Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) was 3.5 Fed./day. It was the best equipment, but the lowest rate of performance was Economy Micron ULVA (15 L./Fed.) since it could spray only 3 Fed./day.

IV)The obtained results in Table (4) confirmed the positive relationship between spray volume and droplet sizes, which affects negatively the number of formed droplets.

Relationship Between Lost Spray-On Ground and The General Reduction of Two Seasons of Bio-Insecticides on Cotton:

Data in Table (4) showed that there was a negative correlation between lost spray-on ground equipment and the bioresidual activity of Bio-insecticides used.

Economy Micron ULVA Spryer (15 L/fed) :

Data in Table (4) showed that the lost spray percentages were 5, 5, 5.6, 5.5 & 6% from the total spray volume in the case of *M. anisopliae* isolate, *M. anisopliae* (W.P.) *B. bassiana* isolate, *B. bassiana* (W.P.) and *B. thuringiensis* (W.P.), respectively. The general reduction % of infestation of *E. insulana* in two seasons (2018-2019) were 92.8, 92.8, 90.4, 90.4 & 88.5 % larvae, respectively, in the case of the same Bio-insecticides.

Hand-held Hydraulic Sprayer (Matabi):

Data in Table (4) showed that the lost spray percentages were 15.2, 16.6, 16.2, 16& 14.9 % from the total spray volume in the case of *M. anisopliae* isolate, *M. anisopliae* (W.P.) *B. bassiana* isolate, *B. bassiana* (W.P.) and *B. thuringiensis* (W.P.), respectively. The general reduction % of infestation of *E. insulana* in two seasons (2018-2019) were 91, 91, 89.8, 89.8& 89% larvae, respectively, in the case of the same Bio-insecticides.

Table 2: Effect of spraying five tested Bio-insecticides on % infestation by spiny bollworm *E. insulana* during 2018 season using Micron ULVA and Hydraulic Matabi sprayers.

Treatments / Inspection date	Control	Hydraulic Matabi (56L.\Fed.)					Economy MicronULVA (15L.\Fed.)				
		Metarhizium anisopliae		*Beauveria bassiana*		*Bacillus thuringiensis*	*Metarhizium anisopliae*		*Beauveria bassiana*		*Bacillus thuringiensis*
		Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)	Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)
8/7	5	5	5	5	5	5	5	5	5	5	5
15/7 1st spray	10	10	10	10	10	10	10	10	10	10	10
22/7	50	6	6	6.8	6.8	7	4.6	4.6	6.6	6.6	7.4
Julay Mean	50	6	6	6.8	6.8	7	4.6	4.6	6.6	6.6	7.4
Reduction%	-	88	88	86.4	86.4	86	90.8	90.8	86.8	86.8	85
1/8 2rd spray	60	5.5	5.5	6.5	6.5	6.8	4.2	4.2	6.2	6.2	7
8\8	68	5	5	6	6	6.2	3.6	3.6	5.8	5.8	6.4
15/8 3rd spray	71	4.5	4.5	5.5	5.5	6	3.2	3.2	5.4	5.4	6.1
22\8	75	4	4	5.8	5.8	6	2.6	2.6	4.8	4.8	5.6
29\8	77	4	4	5.8	5.8	6	2.6	2.6	4.8	4.8	5.6
August Mean	70.2	4.6	4.6	5.9	5.9	6.2	3.24	3.24	5.4	5.4	6.14
Reduction%	-	93.4	93.4	91.6	91.6	91.2	95.4	95.4	92.3	92.3	91.3
General Mean	60.1	5.3^{c}	5.3^{c}	6.3^{ab}	6. 3^{ab}	6.6^{a}	3.92^{c}	3.92^{c}	6^{bc}	6^{bc}	6.77^{a}
General Reduction%	-	90.7	90.7	89	89	88.6	93.1	93.1	89.6	89.6	88.2
LSD between treatments		0.45					1.41				
LSD between equipments		0.45									

L.S.D. at (0.5 %) between treatments . Numbers followed by the same letter at the same column are not significantly different

Table 3: Effect of spraying five tested Bio-insecticides on % infestation by spiny bollworm *E. insulana* during 2019 using season Micron ULVA and Hydraulic Matabi sprayers.

Treatments / Inspection date	Control	Hydraulic Matabi (56L.\Fed.)					Economy MicronULVA (15L.\Fed.)				
		Metarhizium anisopliae		*Beauveria bassiana*		*Bacillus thuringiensis*	*Metarhizium anisopliae*		*Beauveria bassiana*		*Bacillus thuringiensis*
		Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)	Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)
8/7	3	3	3	3	3	3	3	3	3	3	3
15/7 1st spray	6	6	6	6	6	6	6	6	6	6	6
22/7	35	4	4	4.4	4.4	4.7	3.6	3.6	4	4	5
Julay Mean	35	4	4	4.4	4.4	4.7	3.6	3.6	4	4	5
Reduction%	-	88.6	88.6	87.4	87.4	86.6	89.7	89.7	88.6	88.6	85.7
1/8 2rd spray	37	3.8	3.8	4	4	4.2	3.4	3.4	3.9	3.9	4.5
8\8	43	3.2	3.2	3.5	3.5	3.8	2.8	2.8	3.6	3.6	4
15/8 3rd spray	49	2.8	2.8	3	3	3.6	2.5	2.5	3.3	3.3	3.9
22\8	52	1.6	1.6	2.4	2.4	3.2	1.2	1.2	2	2	3.6
29\8	55	1.6	1.6	2.4	2.4	3.2	1.2	1.2	2	2	3.6
August Mean	47.2	2.8	2.8	3	3	3.6	2.22	2.22	2.96	2.96	3.92
Reduction%	-	94	94	93.6	93.6	92.4	95.3	95.3	93.7	93.7	91.7
General Mean	41.1	3.4^{a}	3.4^{a}	3.7^{a}	3.7^{a}	4. 15 ^{a}	2.91^{a}	2.91^{a}	3^{a}	3^{a}	4.46^{a}
General Reduction%	-	91.3	91.3	90.5	90.5	89.5	92.5	92.5	91.2	91.2	88.7
LSD between treatments	3.34						2.45				
LSD between equipments	1.33										

L.S.D. at (0.5 %) between treatments. Numbers followed by the same letter at the same column are not significantly different.

Table 4: Spraying coverage on cotton plants and ground holders produced by Economy MicronULVA (15L.\Fed.) and Hydraulic Matabi sprayer (18L.\Fed.) at 2018 and 2019 seasons against *E. insulana* at Qalubiya Governorate

Equipment	Economy Micron ULVA (56L.\Fed.)										Hydraulic Matabi sprayer (15L.\Fed.)									
Treatments	*Metarhizium anisopliae*				*Beauveria bassiana*				*Bacillus thuringiensis*		*Metarhizium anisopliae*				*Beauvearia bassiana*				*Bacillus thuringiensis*	
	Isolate		(W.P.)		Isolate		(W.P.)		(W.P.)		Isolate		(W.P.)		Isolate		(W.P.)		(W.P.)	
Level	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD	N/cm^{2}	VMD
Upper Level	168^{a}	133^{b}	167^{a}	139^{b}	165^{a}	137^{b}	164^{a}	132^{c}	155^{a}	133^{b}	145^{a}	135^{a}	140^{a}	145^{c}	160^{a}	145^{b}	158^{a}	149^{b}	155^{a}	152^{b}
Middle Level	160^{b}	134^{b}	160^{b}	130^{b}	159^{b}	135^{bc}	155^{b}	136^{b}	149^{b}	137^{b}	160^{b}	140^{b}	150^{b}	151^{a}	170^{b}	150^{b}	168^{b}	150^{a}	165^{b}	157^{c}
Lower Level	136^{c}	130^{b}	136^{c}	132^{b}	129^{c}	133^{c}	129^{c}	135^{b}	120^{c}	134^{b}	130^{c}	145^{b}	130^{c}	154^{b}	150^{c}	155^{c}	148^{c}	154^{b}	175^{c}	162^{c}
Mean	154	132	154	134	151	135	149	134	141	135	145	140	140	150	160	150	158	151	165	157
Ground	24^{d}	149^{a}	24^{d}	149^{a}	27^{d}	146^{a}	26^{d}	149^{a}	27^{d}	146^{a}	26^{d}	151^{a}	28^{d}	160^{a}	31^{d}	156^{a}	30^{d}	160^{b}	29^{d}	166^{a}
% N/Cm^{2} on ground (spray lost	5	_	5	_	5.6	_	5.5	_	6	_	15.2	_	16.6	_	16.2	_	16	_	14.9	_
LSD between levels	3.77	3.84	3.56	4.03	3.76	3.77	3.84	3.80	3.76	4.03	4.04	4.03	3.76	3.77	3.26	2.11	3.77	3.26	2.72	3.26

L.S.D. at (0.5 %) between treatments. Numbers followed by the same letter at the same column are not significantly different.

Table 5: Relationship between field spray quality of Bio-insecticides by Economy MicronULVA (15L.\Fed.) and Hydraulic Matabi sprayer (18L.\Fed.) at 2018 and 2019 seasons against *E. insulana* at Qalubiya Governorate.

Equipment	Economy Micron ULVA (56L.\Fed.)					Hydraulic Matabi sprayer (15L.\Fed.)				
Treatments	*Metarhizium anisopliae*		*Beauveria bassiana*		*Bacillus thuringiensis*	*Metarhizium anisopliae*		*Beauveria bassiana*		*Bacillus thuringiensis*
	Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)	Isolate	(W.P.)	Isolate	(W.P.)	(W.P.)
Level	S.Q	S.Q	S.Q	S.Q	S.Q	S.Q	S.Q	S.Q	S.Q	S.Q
Upper Level	0.79	0.83	0.83	0.80	0.86	0.93	1.04	0.90	0.94	0.98
Middle Level	0.84	0.81	0.85	0.88	0.92	0.88	1.00	0.88	0.89	0.95
Lower Level	0.96	0.97	1.03	1.05	1.10	1.10	1.20	1.03	1.04	0.93

S.Q = spray quality**.** = VMD/N/cm^2= Spray quality (degree of homogeneity).
The spray height is constant ~ 0.5 meter in all treatments
VMD= Volume mean diameter ,N/cm^2= Number of droplets/cm
Numbers followed by the same letter at the same column are not significantly different at P= 0.05.

Relations Between Spray Quality and The General Reduction % Of Two Seasons of Certain Insecticides Applied in Cotton Season:

Data in Table (5) showed that *M. anisopliae* isolate, *M. anisopliae* (W.P.) *B. bassiana* isolate, *B. bassiana* (W.P.) followed by *B. thuringiensis* (W.P.), respectively. Using two ground spraying equipment and varied spraying volumes depending on the sprayer used. Data indicated that in general all the tested spraying equipment gave satisfactory coverage on cotton crop i.e. more than 50 droplets/ cm^2, and droplet sizes ranged from 130 to 166 μm (VMD). The difference in the mortality percentage was due to the different modes of action of the Bio- insecticides and the different spraying equipment.

DISCUSSION

According to our results which showed that *M. anisopliae* in both forms even isolate or commercial formulation (W.P.) is the more effective bio-insecticide against *E. insulana* followed by *B. bassiana* then *B. thurigiensis*, some authors were in agreement with our findings, (Reda, *et al*. 2019) found that *E.insulana* larval population reduction had slightly increased in 2019 than 2018 cotton seasons when treated with *B.thuringiensis* and *B. bassiana***.** In addition, (Hegab and Zak, 2012) reported that hatchability percentage of spiny bollworm decreased after treatment with biopesticides. And, Naguib *et al.* (1994) found that *E.insulana* larvae were more susceptible to bio-compounds. On the other hand, (Sahayaraj and Namachivayam, 2011) reported that the field treatment of *B. bassiana* caused greatly reduced in *Spodoptera litura* infestation. Also, (Al-shannaf, *et al*.2012) reported that residual reduction percentages were 13.3, 20.0 and 9.1% with Bioranza, Protecto, and Dipel DF, respectively against *Helicoverpa armigera* larvae in Egyptian cotton fields. (Sobita Simon, 2014 and Venugopal, *et al* 2017) recorded that the highest infestation reduction of *H. armigera* after treated cotton crop with Cypermethrin 0.01 % followed by *B. bassiana* 0.35 % over control.

Abdel Megeed (2008) found that foliar treatment of Eastena Aminofert with spinosad and chloropirifos reduced levels of *E. insulana* infestation.

A satisfactory coverage was obtained in field experiment on cotton plant, the optimum droplet sizes were agreed with the droplets spectrum which for controlling insects of field crop should be sized between 140 and 200 μm (VMD) with number not less than 30 and 50 droplets/cm^2 distributed homogeneously on the treated target Himel (1969). The best obtained result was 15 L./Fed. As spray volume, 145 μm and 121 droplets/cm^2, these results agreed with (Himel *et al*., 1969) in the optimum droplet size to control cotton leaf worm in the cotton fields by ground equipment. Isolated and (W.P) of *M. anisopliae* and *B. bassiana* revealed the best bio-efficiency results followed by *B. thuringiensis* (W.P.) with the two tested sprayers Economy Micron ULVA sprayer (15 L./fed.) and Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) that decreased infestation of spiny bollworm *E. insulana* on cotton crop, these results agreed with Hindy *et al*. (2004) and Genidy *et al*. (2005) which recommended KZ oil and Pyriproxyfen followed by Agerin using low volume spraying because of reducing the time lost in process filling the machines, improve the homogeneity of the spray solution on the plant leaves and saving the lost spray of the ground and Bakr *et al*.(2014). The data showed that Economy Micron ULVA sprayer (15 L./fed.) is the best equipment to control Spiny bollworm *E. insulana* on cotton crops. Also, the lowest spray volume and the lowest percentage of lost spraying between plants, these may be due to the Revolution Per Minute (R.P.M.) when we measured with Vebratack, Economy Micron ULVA sprayer =8000 cycle per minute, these results were agreed with Hindy *et al.* (1997), (2011) , Dar *et al*.(2015) and Dar (2016) who mentioned that there was a positive relationship between rate of application and spray lost on ground. Our Dar (2019) and Dar *et al*. (2019) who achieved best control results, spray volume per fedan, productivity and rate of performance with Motorized Knapsack sprayers. Dar *et al.* (2019) showed that Motorized Knapsack sprayer (Agromondo) (20 L.Fed.) was the best equipment to control seedling pests in the early season of cotton. The rate of performance of Hand-held Hydraulic sprayer (Matabi) (56 L./Fed.) was 3.5 Fed./day. It was the best equipment, but the lowest rate of performance was Economy Micron ULVA (15 L./Fed.) since it could spray only 3 Fed./day.

CONCLUSION

It could be concluded that, using *Metarhizium anisopliae* isolate, and (W.P.), *Beauveria bassiana* isolate and (W.P.) followed by *Bacillus thuringiensis* (W.P.) with Low Volume (ULV) ground spraying equipment with not less than (15L./fed.) revealed successful management against spiny bollworm *E. insulana* on cotton under our local conditions. There was a negative complete correlation between (VMD) and the general reduction % of infestation of *E. insulana* in two seasons (2018-2019) while there was a positive complete correlate between N/cm² and the general reduction % of infestation of *E. insulana* in two seasons (2018-2019) in all treatments. The results indicated that there was no significant difference between the isolate form of fungi and wettable powder in reduction percentages of bolls infestation. Fungal pathogens have certain advantages in pest control programs over other insect pathogens like bacteria and viruses. Mass production techniques of fungi and bacteria are much simpler, easier and cheaper. myco-insecticides able to pest management particularly in vegetable production because it was considered the safest for living organisms and the environment .Ultra-Low Volume sprayers promising for the application of Bio-insecticides for their minimum spray loss on the ground which reduces environmental pollution and keep the natural enemies and Beneficial soil organism is at their natural populations.

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ARABIC SUMMARY

التطبيق الحقلى لمبيدات حيوية على دودة اللوز الشوكية على القطن باستخدام الات رش حديثة ذات الحجم القليل

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تم رش ثلاثة من المبيدات الحيوية وهى ميتاريزيم وبيوفاريا عزلات او بودرة و باسيلس ثورينيجينسيس بودرة باستخدام وسيلتين رش أرضية ذات الحجم المتناهى فى الصغر و هما الرشاشة الاقتصادية ذات القرص الدوار (ميكرون اولفا) بحجم رش قدره (١٥ لتر\فدان) و الرشاشة ميتابى الهيدروليكية بحجم رش قدره (٥٦ لتر\فدان) على حقل قطن مصاب اصابة شديدة بيرقات دودة اللوز الشوكية.

تم الحصول على تغطية مرضية على نباتات القطن المعاملة و تراوح مدى طيف قطيرات الرش ما بين ١٣٠-١٦٦ ميكرون مع أعداد كافية من القطيرات\سم^2 تراوحت ما بين٢٤-١٧٠ قطيرة\سم^2 في المعاملات المختلفة. و كانت معدل كفاءة الرشاشة ميتابى الهيدروليكية ٣,٤ فدان\يوم باثنان من العمال بينما أقل كفاءة كانت الرشاشة الاقتصادية ميكرون اولفا ٣ فدان\يوم باثنين من العمال.

كما أوضحت النتائج أن ميتاريزيم وبيوفاريا سواء عزلات او بودرة أكثر فاعلية في مكافحة يرقات دودة اللوز الشوكية يليهم باسيلس ثورينيجينسيس بودرة و أن حجم الرش ١٥ لتر\فدان الناتج من استخدام ا لرشاشة ميكرون اولفا حقق أعلى النتائج يليه الرشاشة ميتابى الهيدروليكية بمعدل ٥٦ لتر\فدان.

يمكن التوصية بأن استخدام حجوم الرش القليلة أكثر اقتصادية في مكافحة دودة اللوز الشوكية و تقليل الوقت في اعادة التعبئة و تحقيق تجانس محلول الرش على نباتات القطن المعاملة توقير الفاقد من الرش على نباتات القطن .