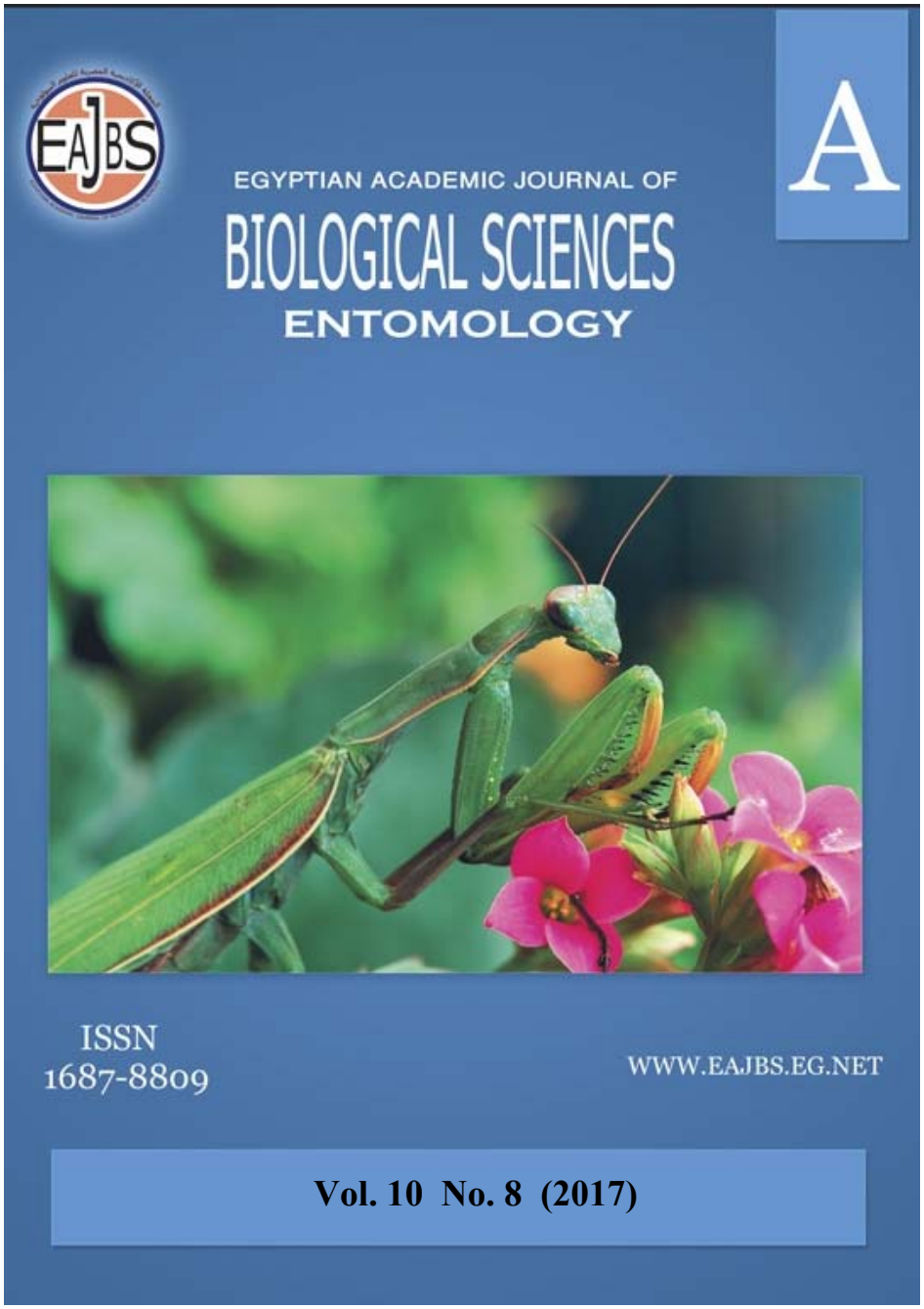

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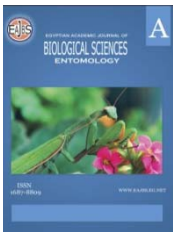

Management Control Strategy of Devastated Tomato Borer, *Tuta absoluta* on Tomato Crop at El-Behira Governorate, Egypt.

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ABSTRACT

Field experiments were conducted during two successive summer seasons, 2016 and 2017 to compare some methods of integrated pest management (IPM) program against *T. absoluta* with a control field (untreated field) from 3rd May to 3rd July at El- Berka village, Abu-Hommus district, El-Behira Governorate.

Results showed that larval activity of *T. absoluta* during both two seasons, 2016 and 2017 was higher in control field (23.11±1.82 mean no. of larvae/leaf) than in IPM field program (2.71±0.40 mean no. of larvae/leaf). The numbers of male captures per trap per 3 days were increased during the experiment in an IPM field with overall mean no. of 201.29±4.81 males per trap per 3 days. However, the mean no. of male catches was 186.9±7.23 males/trap/3 days in control field with significant difference between them during two successive seasons.

A thorough research program towards developing some sequence tactics in IPM program for *T. absoluta* including a foliar spray of Thiamethoxam 20%WG + Chlorantraniliprole 20%WG mixture, Flubendiamid 20%WG, Abamectin 8.4%SC, Spinetoram 12%SC and water mass trapping male moths using red plastic basin water trap (about 10 lure traps/ feddan) on tomato variety, K186. Such an approach would not only allow for reducing the pest, but also result in a better understanding management strategy of devastated tomato borer, *T. absoluta* in a given region.

INTRODUCTION

The tomato is an economically crop in many countries. The tomato borer, *Tuta absoluta* is an important pest of tomato crop which causing serious problems in tomato plantations. (Lietti *et al*., 2005). Its management is not simple, so it is necessary to integrate different practices. IRAC (2007) conducted that Abamectin, Cartap, Chlorfenapyr, Phenthoate, Methamidophos, Spinosad and Indoxacarb were effective against *T. absoluta* on the tomato-growing. Flubendiamide insecticide was an excellent performance pesticide against Lepidopteran like *T. absoluta* in tomato plants (Ebbinghaus *et al.*, 2007). On the other hand, tomato borer, *T. absoluta* on tomatoes was controlled by using the insecticides (Ortega *et al.*, 2008). Chlorantraniliprole was effective against *T. absoluta* for up to 18 days in tomato

crops (Laham *et al.*, 2009). The pesticide, Flubendiamide similarly performed as Chlorantraniliprole on tomatoes for controlling of tomato fruit worms (Roditakis *et al.*, 2013). Other insecticides as Chlorfenapyr and Spinosad proved to be highly effective against tomato borer (CDMS, 2010; Nannini *et al.*, 2011; Braham *et al.*, 2012 and Roditakis *et al.*, 2013).

The reliability of *T. absoluta* control undertook by employing the evaluation of several insecticides on tomato crops (Monfort and Gomez, 2011 and Hanafy and El-Sayed, 2013). The conventional and integrated on the tomato cultivar to verify the *T. absoluta* moths caught in sexual pheromone traps (Santos *et al.*, 2008). The integrated control method for *T. absoluta* conducted by Robredo and Cardenoso (2008) can be sued by massive trapping before planting, clearing crop residues and the application of Imidacloprid, Spinosad and Indoxacarb. A combine of available control methods including several registered used pesticides and sexual pheromone lures basin water mass trapping was applied by Hassan (2015) and Abou El-Fadel (2016). Many control methods were applied against the tomato borer, *T. absoluta* in integrated pest management programs by Viggiani *et al.* (2009), Galdino *et al.* (2011) and Taha *et al.* (2013).

The relationship of entire larvae in leaves and the catches by a pheromone trap of *T. absoluta* in commercial tomato field were conducted by Gomide *et al*. (2001), Bavaresco *et al.* (2005) and Benvenga *et al*. (2007). The *T. absoluta* male occurrences of in conventional and integrated tomato production systems caught in sex pheromone traps during two cropping seasons verified by Santos *et al.* (2008). On the other hand, The Ferolite-TUA, a combination of pheromone lures and a specific light frequency, was highly caught of *T. absoluta* moths. The pheromone trap had improved effectiveness (Russell IPM, 2009).

Accordingly, this work was conducted by using of plant protection chemicals helps in reducing *T. absoluta* infestation, thus it was essential in our study to explore the efficiency of a combination of some pesticides and using of sexual pheromone traps altogether to detected the most suitable an investigated management program.

MATERIALS AND METHODS

Field experiments were conducted during two successive summer seasons, 2016 and 2017 to compare an integrated pest management (IPM) program against *T. absoluta* with a control field (without any treatments) from 3rd May to 3rd July at El-Berka village, Abu-Hommus district, El-Behira Governorate. The tomato seedlings, K186 variety were transplanted on 10th April in one feddan with a randomized complete block design and replicated three times. The tomato variety was received standard commercial practices.

IPM program consisted of foliar sprays of some insecticides and water mass trapping male moths using red plastic basin water traps (about 10 traps/ feddan) (Table, 1), these traps were set up at transplanting till harvest. Traps were placed 50 cm above the crop canopy and 30 m apart. Traps were weekly visited to remove moths and replenish water and detergent. Lures of Phirodees 100% capsule (E3, z8 - Tetradecadienyl acetate + E3, z8, z11-Tetradecacatrienyl acetate) were renewed every six weeks. The distance between IPM field and control field was about 3 feddans apart. Control field consisted of non-treatment of tomato variety, K186 and four mass trapping male moths using water-basin traps.

Table (1): Insecticides used in IPM program of *Tuta absoluta*.

Treatment date	Trade name	Conc. & Formula	Active ingredient	MOA Group	Rate of application /Feddan
3rd May	Voliam-Flexi	40%WG	20%Thiamethoxam+ 20%Chlorantraniliprole	Neonicotinoid + Diamide	80 grams
10th	Takkomy	20%WG	Flubendiamide	Diamide (28)	100 grams
17th	Voliam-Flexi				
24th	Takkomy				
31st	Agremic gold	8.4%SC	Abamectin	Ivermectin (6)	60 cm
10th June	Radiant	12 % SC	Spinetoram	Spinosyn (5)	100 cm
17th	Agremic gold				

Tuta absoluta infestation in IPM and control field programs was weekly recorded by counting of larvae numbers in a random sample of 90 leaves from each treatment (30 leaves/ replicate). The numbers of *T. absoluta* males were weekly detected in water mass trapping male moths using red plastic basin water traps in each treatment. The tomato production in each treatment were assessed registration during two successive seasons, 2016 and 2017, then the economic evaluations of each treatments were assessed by calculated gross returns. Gross returns were based on yields of each treatment based on the pound average price per kg (LE).

Gross return was calculated by the equation:

Income return = Net return of treatments – Net return of control

Net return (LE)/ feddan = fruits return (LE) / feddan - Cost of treatments (LE)/ feddan

Fruits return/ feddan = fruits weight (kg)/fed.× Price of fruits kg.

Cost of treatments (LE) = Number of sprays × Cost of each application.

Cost of agriculture practices = Cost of Agriculture + Seedling + Irrigation + Fertilization

Cost of net applications= Cost of insecticidal and trap treatments + Cost of agriculture practices

The statistical analyses of data were carried out by using SAS program computer including t-test (SAS Institute, 2003).

RESULTS AND DISCUSSION

Tuta absoluta larvae infested all parts of tomato plant (leaves, stems, buds and fruits) at any developmental stage. Weekly mean numbers of *Tuta absoluta* larval and male capture moth densities per leaf on tomato variety, K186 were carried out between May and July during 2016 and 2017 seasons. At the beginning inspection, the population level of the pest was low as can be seen from number of larvae found per leaf. In IPM program, the resulted a decreasing of tomato borer, *T. absoluta* infestation as by reduced mean numbers of larvae/ leaf through summer season, 2016 season (Table, 2). The weekly mean no. of larvae was ranged between 0.00 to 11.00 larvae/ leaf (at 10th June and 24th May, respectively) in tomato variety, K186 during summer season, 2016 (Table, 2). Larval density was recorded highly mean no. of 43.33 larvae/ leaf at 29th May 2016 in control field (Untreated field). The second peak was 38.33 larvae/ leaf (14th June) during 2016 season. The last peak was noticed at 28th June during first season (33.33 larvae/ leaf) on tomato variety, K186 (Table, 2).

Also, results showed the same trend as in summer season, 2016 in both two programs, IPM and control fields during 2017 season. Abundance of *T. absoluta* larvae still remained low infestation in IPM program than control field throughout summer season, 2017. Three peaks were 43.67, 14.67 and 39.67 larvae/ leaf (at 3rd, 14th and 28th June 2017, respectively) in control field, but one peak was recorded in IPM program through the same season (7.67 larvae/ leaf at 20th May) (Table, 2). With t- test analyses, larvae infested tomato variety, K186 was showed a high

significant difference between IPM field and control field (Probability > |t| equal 0.0001 during investigated seasons, 2016 and 2017).

According to sexual pheromone based control strategies in two programs, weekly data for male of *Tuta absoluta* captured through using sex pheromone trap (Phirodees 100% capsule) recorded the lowest moth captures of 72.56 and 164.87 males/trap/3 days (at 1st inspection) during 1st season in control and IPM fields, respectively (Table, 2). The maximum male catches were 274.10 and 304.74 males/ trap/ 3 days in the control and IPM fields (at 24th June 2016), respectively. The lure pheromone based water trap noticed highly significant catches in IPM program than control field (untreated field) with overall mean no. of 235.74 ± 6.71 and 198.01 ± 8.07 males/trap/3 days (Table, 2). In contrast, the numbers of male captures in pheromone based water trap was also high, but its recorded high male catches in control field than IPM field (175.79 ± 7.70 and 166.83 ± 4.04 males/ trap/3 days) during the second summer season (Probability > |t| equal 0.0001). Results recorded that *T. absoluta* male population was ranged from 48.74 – 260.00 and 120.00 - 227.71 males/trap/3 days in control and IPM fields, respectively (Table, 2). The overall mean numbers of *T. absoluta* larvae was regarded a high significant population in control field than IPM field during investigated seasons, 2016 and 2017 (28.15 ± 2.00 – 18.07 ± 2.05 and 3.15 ± 0.51 – 2.26 ± 0.33, respectively) (Table, 2).

Table (2): The management of *Tuta absoluta* in the control and IPM field applications during summer seasons, 2016 and 2017.

Inspection date	Mean numbers of population density							
	Mean no. of larvae/ leaf				Mean no. of moths/ trap/ 3 day			
	1st season		2nd season		1st season		2nd season	
	Control field	IPM field	Control field	IPM field	Control field	IPM field	Control field	IPM field
May, 3rd	4.00	2.67	2.00	2.00	72.56	164.87	48.74	120.00
06th	8.00	3.67	3.00	2.00	100.38	198.97	113.88	138.61
10th	8.67	4.00	4.33	4.00	169.36	201.28	169.18	155.67
13th	14.67	4.67	3.67	3.00	172.95	199.74	135.30	138.01
17th	21.00	10.67	8.33	5.00	193.97	229.36	181.64	153.16
20th	28.67	8.67	12.00	7.67	221.15	243.85	188.63	171.34
24th	39.33	11.00	16.33	7.33	219.23	238.33	187.32	169.09
27th	43.33	1.00	30.67	0.33	216.79	252.56	192.68	174.37
31rd	41.67	0.00	38.00	1.67	183.46	217.31	197.60	178.27
June, 03rd	41.00	0.33	43.67	0.00	202.44	235.64	171.91	175.24
06th	40.33	0.67	37.67	1.00	209.23	241.92	220.11	164.68
10th	33.33	0.00	23.00	0.67	195.38	227.69	170.38	196.10
14th	38.33	2.00	6.33	0.33	182.82	214.49	173.44	156.71
17th	27.33	1.00	14.67	2.00	185.77	216.41	178.69	159.13
21rd	29.00	0.33	3.33	0.67	234.23	263.33	174.21	163.29
24th	24.00	1.67	12.33	2.00	274.10	304.74	260.00	159.74
28th	33.33	2.33	39.67	0.00	263.33	293.46	180.44	227.71
July, 03st	30.67	2.00	26.33	1.00	267.05	299.36	220.11	201.73
Overall mean ± SE	**28.15 ± 2.00**	**3.15 ± 0.51**	**18.07 ± 2.05**	**2.26 ± 0.33**	**198.01 ± 8.07**	**235.74 ± 6.71**	**175.79 ± 7.70**	**166.83 ± 4.04**
Probability	0.0001 **		0.0001 **		0.0005 **		0.0001 **	

** = High significance

Generally, the overall larval activity of *T. absoluta* during 2016 and 2017 seasons was higher in control field program (23.11±1.82 mean no. of larvae/leaf) than in IPM field program (2.71 ± 0.40 mean no. of larvae/leaf) (Probability > |t| equal 0.0001) (Table, 3). On the other hand, the overall numbers of male captures per trap per 3 days was increased during the experiment in IPM field with overall mean no. of 201.29 ± 4.81 males/ trap/ 3 days. However, the mean no. of male catches was 186.9 ± 7.23 males/ trap/ 3 days in control field with significant difference between them during two seasons (Probability > |t| equal 0.0036) (Table, 3). These previously results may be due to the non- effective foliar applications of the used insecticides against *T. absoluta* moths (Table, 3).

The tomato borer, *T. absoluta* is challenging lepidopteran pest to control due to rapidly expending on different host plant and high reproduction capacity, which it may be lead to gene mutation. *Tuta absoluta* are well controlled by a combination tactics of IPM program which consisted of a foliar spray of sequence pesticides being Thiamethoxam 20%WG + Chlorantraniliprole 20%WG, Flubendiamid 20%WG, Abamectin 8.4%SC, Spinetoram 12%SC and water mass trapping male moths using red plastic basin water trap (about 10 lure traps/ feddan). Lure and kill formulations (pesticides) are targeted to *T. absoluta* as in the present work was similarly conducted by Hassan (2015) and Al-Zaidi (2010), they controlled the tomato borer by some mixed applications between pheromone lures and numerous pesticides during the beginning plantation till harvest tomatoes. Also, the combine of available control methods including physical methods and correct use of registered pesticides as well as were reported by Retta and Berhe (2015), Megido *et al*. (2013) and Santos *et al*. (2008).

Table (3): Mean numbers of the *Tuta absoluta* population density in the control and IPM field applications during summer seasons, 2016 and 2017.

Season	**Mean numbers of population density**			
	Larvae/ leaf		**Male moths/ trap/ 3 days**	
	Control field	**IPM field**	**Control field**	**IPM field**
Summer season, 2016	28.15	3.15	198.01	235.74
Summer season,	18.07	2.26	175.79	166.83
Overall mean ± SE	**23.11±1.82**	**2.71±0.40**	**186.9±7.23**	**201.29±4.81**
Probability >|t|	0.0001 **		0.0036 **	

** = High significance

Otherwise, Hassan (2015) found that the mean number of eggs, larvae, mines and male adults of *T. absoluta* was significantly lower (0.11 egg, 0.06 larva and 0.08 mine/ leaflet and 216.33 adults/ trap) in field treated with pheromone-baited traps together with insecticide applications (IPM program) than in the field treated with insecticides (farmer field) (1.04 eggs, 1.20 larvae and 1.91 mines/ leaflet and 224.40 adults/ trap. Hanafy and El-Sayed (2013) and Abou El-Fadel (2016) evaluated several insecticides on tomato crops. Taha *et al.* (2013) concluded that IPM program which consisted of mass trapping *T. absoluta* males in red plastic basin water traps at a density of 8 traps/ feddan, biweekly application of Volium flexi 40% WG (20% Thiamethoxam +20% Chlorantraniliprole) and Dantop 50%WG (Clothianidin) in sequence during vegetative stage and weekly application of Dipel DF 6.4 % WG (Bt) during tomato fruit stage was compared with mass trapping only and farmers practice included several sprayed insecticides at their own discretion. They found that mass trapping of male moths together with selected insecticides (IPM) was effective in

reducing infestations. Therefore, further studies should be conducted to integrated strategy methods in order to use of chemicals at the tomato seedling period for improving food safety and environment quality.

Data in Fig. (1) illustrated that IPM field program gave significantly high tomato production than untreated check field (control field) in the two tested seasons, 2016 and 2017. The highest tomato fruit production was 33.00 and 42.00 tons/ feddan during summer seasons, 2016 and 2017 in IPM field program, respectively. However, untreated check field (control field) was received the lowest tomato fruit production being 4.5 and 7.8 tons/feddan during 2016 and 2017 seasons, respectively. The overall fruit production was also significantly higher in IPM field (37.5 tons/feddan) than untreated check field (6.15 tons/feddan) (Probability > |t| equal 0.02) (Fig. 1). Accordingly, the observed results clearly showed that IPM field program may be the best program for controlling devastated tomato borer, *Tuta absoluta* on tomato variety, K186 at El-Behira Governorate.

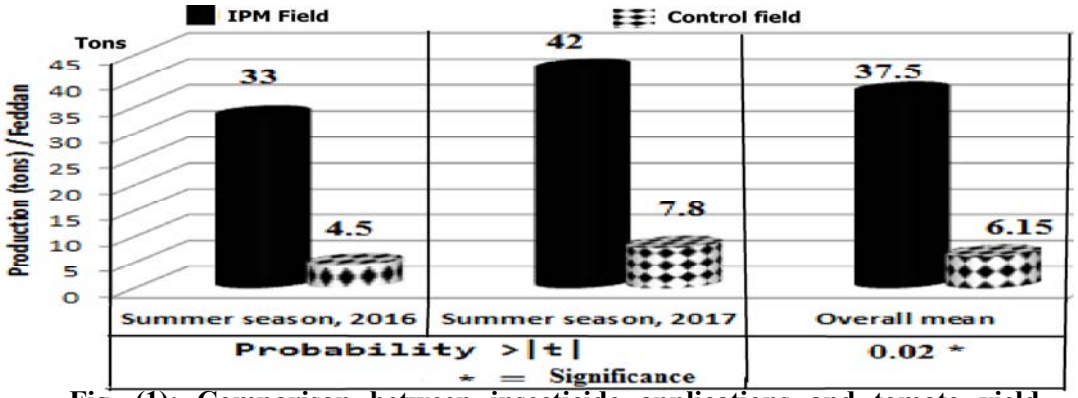

Fig. (1): Comparison between insecticide applications and tomato yield during summer seasons, 2016 and 2017.

A through the present study, clear that the net return of tomato fruit production increased in IPM approach when compared with untreated check field (control field). The net return of fruit productions was 53910 and 71910 LE in IPM field program, and 20 and 6620 LE in non-treated check field (control field) during 2016 and 2017 seasons, respectively (Table, 4). Subsequently, IPM program consisted of a foliar sprayed mixture of Thiamethoxam 20%WG + Chlorantraniliprole 20%WG, Flubendiamide 20%WG, Abamectin 8.4%SC, Spinetoram 12% SC and water mass trapping male moths using red plastic basin water trap (about 10 lure traps/ feddan) was received the highest income return during the both seasons, 2016 and 2017 being 53890 and 65290 LE, respectively (Table, 4). Similarly, Hassan (2015) noticed that fruit production was higher in IPM program (35.95 fruits/ plant) than in another farmer field (check field) (10.00 fruits/ plant) when IPM tactics included foliar sprayed mixture of Thiamethoxam 20% WG + Chlorantraniliprole 20% WG, Chlorfenapyr 36% SC, Chlorantraniliprole 20% SC and Spinosad 24% SC and using sex pheromone basin water traps (Tuta 100 N lure) on tomato plant, which were set up at transplanting till harvest.

Table (4): Economic evaluations of IPM and control fields on tomato yield during summer seasons, 2016 and 2017.

Treatment	Season	Economic evaluations						
		Yield weight (Kg)/ Feddan	Yield return (LE)/ Feddan	Cost of insecticidal treatments LE/ Feddan	Cost of agriculture practices LE/ Feddan	Cost of net applications/ Feddan	Net return LE/ Feddan	Income return/ Feddan
IPM	2016	33000	66000	3110	8980	12090	53910	53890
	2017	42000	84000				71910	65290
Control	2016	4500	9000	———		8980	20	———
	2017	7800	15600				6620	

Kg price = 2 LE

Moreover, Taha *et al.* (2013) recorded that tomato fruit damages were higher (39.16% fruit damages) in the farmer field (check field) than field treated with pheromone baited water traps (37.44% fruit damages). Furthermore, Santos *et al.* (2008) conducted the comparison between two approaches viz. conventional and integrated on tomato plant to detect the occurrence of *T. absoluta* male moths. To delay the using of insecticides, Monserrat *et al*. (2011) used the mating disruption technique to reduce *T. absoluta* infestation on tomato plant.

A thorough research program towards developing some sequence tactics in IPM program for *T. absoluta* including a foliar mixture spray of Thiamethoxam 20%WG + Chlorantraniliprole 20%WG, Flubendiamide 20%WG, Abamectin 8.4%SC, Spinetoram 12%SC and water mass trapping male moths using red plastic basin water trap (about 10 lure traps/ feddan) on tomato variety, K186. Such an approach would not only allow for reducing the pest, but also result in a better understanding management strategy of devastated tomato borer, *T. absoluta* in a given region.

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ARABIC SUMMARY

إستراتيجية مكافحة حافرة الطماطم المدمرة *Tuta absoluta* على محصول الطماطم بمحافظة البحيرة – مصر.

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أجريت تجارب حقلية خلال الموسمين الصيفيين 2016 و 2017 لتطبيق بعض طرق المكافحة المتكاملة لحافرة الطماطم *Tuta absoluta* ومقارنته بحقل غير معامل على محصول الطماطم فى الفترة من 3 مايو الى 3 يوليو بقرية البركة – أبو حمص- محافظة البحيرة.

أظهرت النتائج أن نشاط يرقات حافرة الطماطم *T. absoluta* خلال موسمى الدراسة كان أعلى فى الحقل غير المعامل (بمتوسط 23.11 ± 1.82 يرقة/ ورقة) عن الحقل الذى طبقت فيه بعض طرق المكافحة ((IPM) (بمتوسط 2.71 ± 0.40 يرقة/ ورقة). كما لوحظ زيادة عالية ومعنوية لمعدل إنجذاب ذكور حافرة الطماطم *T. absoluta* للفرمونات الجنسية فى حقل المكافحة (IPM) بمتوسط 201.29 ± 4.81 ذكر/ مصيدة/ 3 أيام عن حقل المقارنة (غير المعامل) بمتوسط 186.90 ±7.23 ذكر/ مصيدة/ 3 أيام خلال موسمى التجريب.

ومن خلال هذة الدراسة تبين أن إستخدام طريقة رش المبيدات وهى مخلوط Thiamethoxam 20%WG + Chlorantraniliprole 20%WG و Flubendiamide 20%WG و Abamectin 8.4%SC و Spinetoram 12%SC مع إستخدام المصائد الفرمونية الجنسية من خلال المصائد البلاستيكية الحمراء (بمعدل 10 مصيدة/ فدان) هى طريقة مثالية وأكثر فاعلية لمكافحة حافرة الطماطم *T. absoluta* فى المنطقة محل التجربة.