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Effectiveness of Three Bio-Rational Products and a Traditional Insecticide against *Thrips* spp. and *Bemisia tabaci* Attacking Tomato Fields in Kafr El-Sheik Governorate, Egypt

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Abstract

Destructive effects of conventional insecticides on environment have created a necessity to introduce bio-rational products in pest control programs. Effectiveness of bio-pesticide (*Beauvaria bassiana*), natural oil (anti-insect), a botanical extract (nimbecidine) and malathion insecticide was evaluated against *Thrips* spp. and *Bemisia tabaci* attacking tomato in Kafr El Sheik, Egypt. The trial was conducted during two successive seasons; 2017-18 in a total area of 4912 m^2 cultivated with tomato cultivar zero 42. The experiment was set up in a randomized complete block design with five replications for each treatment. Yellow sticky traps were used to monitor population of both pests before and after spraying, in addition, their numbers on plants were counted. Results revealed that highest control rates of both pests were recorded after the fourth day of each spraying. Long inter-applications periods decreased effectiveness and the greatest control resulted when three consecutive sprayings were applied. Malathion achieved the highest suppression of both pests. Within the bio-rational pesticides, nimbecidine gave the greatest thrips control whereas products showed no significant difference for whiteflies. The study recommends those bio-rational compounds to join Integrated Pest Management programs of both pests in Egypt, taking into consideration spraying for 3 consecutive times with at least 5 days intervals.

Keywords

Solanum lycopercicum, Bio-Pesticide, Natural Oil, Nimbecidine, Malathion

1. Introduction

Tomato (*Solanum lycopersicum*) is a major world food crop; it is commercially grown in 159 countries. The top five tomato producers are China, India, USA, Turkey and Egypt, representing about 60% of the world production [1]. Based on a comparison between 152 countries in 2013, Egypt was ranked the highest in tomato consumption per capita per year with 97.8 Kg. Therefore, the cultivated tomato area in Egypt considerably increased during the last two decades where it spread from the extreme North to the extreme South and approximately 223 thousand ha are cultivated with tomatoes. The majority of this area is concentrated in the Delta region [2] and total tomato production reached 7.94 million t in 2016 [3].

Tomato is subject to attack with scores of insect pests and diseases that affect its production [4]. Thrips and whiteflies, belonging to the piercing sucking insects, cause severe damage to tomato crop by transmitting virus disease rather than direct feeding. The cultivation of tomato and availability of alternate hosts encourage the development of pest pressure round the year. The whitefly *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) is considered a major insect pest for tomato crop infesting all stages throughout cropping season [5]. It is created by the over-use of pesticides that have killed off its natural enemies; for this reason the current study is investigating new and safe alternatives to control this pest. Whiteflies go round in hordes; suck plant sap resulting in a yellow mottling on the leaf surface, cause leaf loss, wilting and stunting. Not only do they feed on plants, but they also produce honey dews which spoil the plants' appearance, attract ants, which interfere with natural enemies activities that might control whiteflies [6]. Yield losses due to direct and indirect damage caused by whiteflies were reported to the extent of 20% to 100% [7].

On the other hand, thrips is another annoying pest that attacks tomato and reduces their marketability [8] [9]. While some species act as major vectors of viral plant diseases other damage tomatoes through their different feeding methods. Thrips feeding can stunt plant growth and causes damaged leaves to become papery and distorted, develop tiny pale spots and drop prematurely. Infested terminals may discolor and become rolled. They are difficult to control, therefore, it is recommended to follow an integrated program that combines the use of good cultural practices, natural enemies, and most selective least-toxic insecticides [10].

During the past three decades, efforts have been made to reduce the risk of human exposure to pesticides, especially insecticides. However, as a result of heavy selection pressures, caused by the extended, frequent and over-use of conventional insecticides, population of the piercing sucking insects has developed resistance worldwide [11]. Although malathion (an organophosphorus insecticide used against those pests) has a significant importance in Egypt due to its wide distribution, persistence and extensive use, yet, it had caused several environmental problems in addition to severe tomato damage [12]. Using an insecticide-only strategy faces major challenges, thus, there is a need to develop and introduce bio-rational insecticides that are highly selective, eco-toxicologically safe and have novel modes of action to be integrated in pest management programs [13]. Bio-rational pesticides include several compounds such as soap, horticultural oil and neem. The neem-based pesticides are reported to control young nymphs of thrips; however, more information is needed to formulate an effective, low-cost and eco-friendly pest-management strategy that can be adopted sustainably in the existing agricultural framework [9]. In addition, *Beauvaria bassiana* (Balsamo Crivelli) is a promising bio-control agent that can be integrated in the control strategy of piercing sucking pests [14]. This fungus is safe to plants, humans and animals, as well as non-targeted insects and can kill thrips at all life-cycle stages [15] [16].

Consequently, a comparison between three bio-rational pesticides (a bio-pesticide, natural oil and a botanical extract) and malathion (as a conventional insecticide) was conducted against two important pests attacking tomato plantation in Egypt, *i.e.* whitefly and thrips, during 2017-18 seasons. The aim was to identify the most effective bio-rational pesticide for each target pest, the effective number of spraying times and post-treatment highest control days. The identified effective bio-products are recommended to join tomato Integrated Pest Management (IPM) programs under the Egyptian conditions hoping to reduce the severe effect of pesticides.

2. Materials and Methods

2.1. Experimental Site, Time and Area

A field study was performed in a private farm in Qulien district, Kafr El Sheikh Governorate, Egypt, during Nili tomato plantation in two seasons, *i.e.* 2017-18 under a mean temperature and relative humidity of 28.11˚C ± 3.6˚C and 66.38% ± 0.82%, respectively, to compare between 3 bio-rational pesticides and one conventional insecticide on both thrips and whiteflies. A total area of 4912 m^2 was cultivated with tomato cultivar zero 42 seedlings in mid-May of each season.

2.2. Bio and Conventional Pesticides

A bio-pesticide, natural oil, a botanical extract, in addition to a conventional chemical insecticide was used. Table 1 presents the four products, their trade

Table 1. Pesticides used in the experiments and their information.

Type of Product	Trade Name	Source	Active Ingredient	Rate of Application
Chemical Insecticide	Malathion Cheminova 57% EC	El-Helb Company	Malathion 57% EC	1000 ml/feddan
Botanical Extract	Nimbecidine	Gaara-Establishment	Azardirachtin 0.03%	
Bio-Pesticide	Bio-powder		*Beauvaria bassiana* Adjusted to 1×10^8 C.F.U/1cm^3	
Natural Oil	Anti-insect	CLOA/ARC/ Egypt*	Mixture of cotton and sunflower oils	1000 ml/100 L water

*CLOA/ARC: The Central Laboratory for Organic Agriculture, the Agriculture Research Center.

name, source, active ingredient and rate of application as recommended.

2.3. Experiment Design

The experimental area was divided into 5 plots each of 608 m^2/treatment (16 × 38 m), laid in a randomized complete block design. Each plot was divided into 5 replicates. A distance of about half meter was left between plots and a distance of 30 cm was left between plants. Each plot was planted by about 715 tomato seedlings (=5000 plant/feddan where 1 feddan = 0.42 ha). All agronomic practices were maintained constantly when required. Each treatment was adjusted according to the plot size, calibrated and sprayed. A twenty liters volume sprayer was used and spraying was carried out three times during the season, *i.e.* June, 8^{th} and 24^{th} and July, 10^{th}.

2.4. Results' Recording

Numbers of both pests were recorded before and after spraying. Two methods were followed in results' recording:

1) Yellow sticky traps

Yellow sticky traps measuring 16 × 17 cm were used for monitoring pests' population before and after treatments during the whole period of the study. Five traps were used in each plot including the untreated control plot (1 trap/replicate). Traps were hanged horizontally 30 cm above the top of the plants reversing wind direction and adjusted vertically whenever the crop attained additional growth. Numbers of insects caught on the sticky traps were counted one day before the first application and 4, 8, 12 and 16 days after each application. Upon the collection of the sticky traps, they were wrapped for protection, transferred to the laboratory for sorting, identifying, counting and meanwhile replaced with new ones after each inspection date.

2) Sampling

For sampling, 10 plants were randomly selected and 10 leaves from each plant were investigated to detect the number of thrips and whiteflies. The sampling was done in five steps including one day before treatment, 4, 8, 12 and 16 days post treatment.

2.5. Statistical Analysis

Results were statistically analyzed using SPSS statistical package according to the analysis of variance (ANOVA). LSD was chosen to determine significant differences among various treatments at $p < 0.05$.

3. Results

3.1. *Thrips* Spp.

3.1.1. Thrips Population Pre-Application

Results showed an acceptable degree of uniformity in the thirps's population before application. Overall mean numbers of thrips on the yellow sticky traps for the two seasons (2017-18) before spraying of nimbecidine, anti-insect, bio-power, malathion and in control plot were 90, 92, 94, 95.7 and 93.3, respectively.

3.1.2. Best Results Obtained and the Effect of Repeating Spraying

1) First season (2017)

To determine the effectiveness of the products used in controlling thrips; sticky cards were monitored every 4 days and results were recorded for 4 inspection dates. This technique was also followed by Gill *et al.* [17]. Results showed that there was a significant difference among the four inspection days in each of the 3 applications (Table 2). The least number of thrips (best control level) was recorded immediately after spraying, *i.e.* 4 days post treatment. First spraying mean numbers of thrips were 0.8 ± 0.8, 0, 3.6 ± 1.6 and 0 in nimbecidine, anti-insect, bio-power, and malathion treatments, respectively. Moreover, when spraying for the 2nd time, results recorded on the 1st inspection date were almost the same as those recorded in the first application, *i.e.* 0.8 ± 0.37, 0, 3.4 ± 1.3, and 0.4 ± 0.4, respectively. All mean numbers recorded after 4 days of the third

Table 2. Mean numbers of *Thrips* spp. caught on the yellow sticky traps in the different treatments during season 1 (2017).

Apps.	Inspection Date \ Treatment	A	B	C	D	E
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
1st Application	June 12th	0.80 ± 0.80	0.00	3.60 ± 1.60	0.00	22.80 ± 4.28
	June 16th	21.60 ± 6.67	39.00 ± 5.56	28.00 ± 5.83	52.00 ± 8.60	72.00 ± 4.28
	June 20th	11.00 ± 1.37	25.00 ± 5.70	23.40 ± 2.42	16.80 ± 3.59	7.60 ± 2.04
	June 24th	3.40 ± 2.13	3.00 ± 2.00	3.60 ± 2.29	10.20 ± 3.55	8.60 ± 2.22
	Mean ± SE	9.20 ± 2.48	16.75 ± 4.14	14.65 ± 3.01	19.75 ± 5.03	27.75 ± 6.52
	LSD	6.02	6.89	5.79	8.36	9.14
2nd Application	June 28th	0.80 ± 0.37	0.00	3.40 ± 1.43	0.40 ± 0.40	13.00 ± 5.77
	July 02nd	11.60 ± 2.73	0.00	3.60 ± 1.69	3.00 ± 1.48	8.80 ± 1.85
	July 06th	3.80 ± 2.45	9.60 ± 2.58	10.00 ± 4.18	18.00 ± 4.78	26.00 ± 4.30
	July 10th	12.00 ± 1.14	3.20 ± 2.05	14.60 ± 4.37	4.40 ± 1.96	14.40 ± 3.04
	Mean ± SE	7.05 ± 6.37	3.20 ± 1.17	7.90 ± 1.82	6.45 ± 1.99	15.55 ± 2.35
	LSD	3.24	2.77	5.40	4.52	6.74
3rd Application	July 14th	0.00	0.00	0.80 ± 0.37	0.00	14.40 ± 1.72
	July 18th	0.00	0.00	1.40 ± 0.98	0.00	11.20 ± 0.80
	July 22nd	0.00	0.00	1.20 ± 0.80	0.00	10.80 ± 0.58
	July 26th	0.80 ± 0.49	0.60 ± 0.60	1.80 ± 1.35	3.20 ± 2.05	11.60 ± 1.16
	Mean ± SE	0.20 ± 0.14	0.15 ± 0.15	1.30 ± 0.44	0.80 ± 0.56	12.00 ± 0.62
	LSD	0.41	0.50	1.59	1.73	1.93
General mean		5.48	6.70	7.95	9.00	18.43

A: Nimbecidine; B: Anti-insect; C: Bio-power; D: Malathion; E: Control spraying dropped to zero, except for the bio-power that recorded a mean number of 0.8 ± 0.37. ANOVA one analysis showed significant differences between the inspection dates for the different sprayed product in most cases (LSD for each product is calculated and listed in Table 2). All treatments were significantly superior over the untreated control as presented in the same table.

Repeating spraying resulted in raising products effect where each time the bio-rational pesticides and the malathion were applied, numbers of thrips stuck to the traps decreased till it reached the least records after the third application indicating more effectiveness, as shown in Figure 1(a). Mean numbers of 0.20 ± 0.14, 0.15 ± 0.15, 1.30 ± 0.44, and 0.80 ± 0.56 were recorded on the last inspection date of the 3rd application for each of nimbecidine, anti-insect, bio-power and malathion, respectively whereas control treatment recorded a mean number of 12 ± 0.62. Moreover, in the third application, and mainly during the first inspection date of nimbecidine, anti-insect and malathion; mean numbers of thrips dropped to zero. Results pointed out that it is essential to spray these products for 3 consecutive times to obtain the best results.

2) Second season (2018)

It was noticed that numbers of thrips recorded in the second season (2018) were, in general, much higher than those caught on the first season, but still, results of the second season confirmed the data obtained in the first season. Thrips recorded their lowest mean numbers on the yellow sticky traps on the fourth day post treatment in the 3 spraying times, as shown in Table 3.

Mean numbers of thrips decreased form one application to the next in all the experimental plots till it reached the lowest numbers on the third application as was found during the first season. The average mean numbers recorded within the bio-rational products after the 3rd spraying were as follows: nimbecidine (4.95 ± 1.2), anti-insect (1.68 ± 0.6), bio-power (7.50 ± 1.64). Whereas, malathion mean number was 1.75 ± 0.49. Control treatment recorded a mean number of 12.90 ± 1.89. These results assured again that numbers of thrips decreased the most when products were sprayed for three consecutive times as illustrated in Figure 1(b).

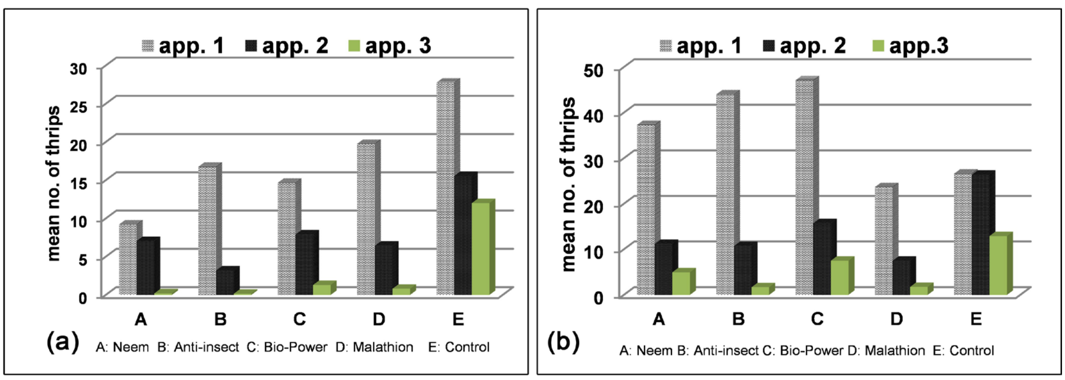

Figure 1. Mean numbers of *Thrips* spp. caught on yellow sticky traps for the four treatments and the control during each of the three applications in season 1 (a) and season 2 (b).

Table 3. Mean number of *Thrips* spp. caught on the yellow sticky traps in the different treatments during season 2: (2018).

Apps.	Inspection Date / Treatment	A	B	C	D	E
		Mea ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
1st Application	June 12th	22.00 ± 2.55	13.80 ± 1.53	19.20 ± 2.22	9.40 ± 2.78	21.61 ± 1.07
	June 16th	73.40 ± 6.16	104.00 ± 1.87	99.00 ± 0.54	52.00 ± 6.04	19.80 ± 3.80
	June 20th	23.00 ± 4.11	26.00 ± 3.14	31.80 ± 5.21	10.60 ± 2.54	30.80 ± 4.14
	June 24th	30.80 ± 3.36	32.20 ± 2.90	38.00 ± 8.36	22.60 ± 3.73	34.20 ± 4.15
	Mean ± SE	37.30 ± 5.22	44.00 ± 8.16	47.10 ± 7.18	23.65 ± 4.34	26.60 ± 2.13
	LSD	7.15	4.10	5.04	6.74	9.92
2nd Application	June 28th	3.60 ± 1.20	5.80 ± 1.15	10.80 ± 1.56	2.80 ± 1.49	38.20 ± 4.81
	July 02nd	8.40 ± 2.00	9.00 ± 1.58	12.60 ± 1.50	6.40 ± 2.00	29.40 ± 4.86
	July 06th	23.20 ± 3.76	20.00 ± 2.60	21.60 ± 2.83	5.60 ± 3.10	19.00 ± 3.71
	July 10th	9.60 ± 2.90	8.20 ± 2.15	18.00 ± 3.24	15.20 ± 3.08	19.00 ± 7.46
	Mean ± SE	11.20 ± 2.06	10.75 ± 1.54	15.75 ± 1.48	7.50 ± 1.57	26.40 ± 3.08
	LSD	4.49	3.27	4.04	4.22	9.04
3rd Application	July 14th	2.20 ± 1.74	0.60 ± 0.60	4.00 ± 1.41	0.0	23.20 ± 3.80
	July 18th	4.20 ± 1.82	1.20 ± 0.80	8.00 ± 2.00	1.60 ± 0.81	15.20 ± 1.11
	July 22nd	9.80 ± 3.54	4.75 ± 2.01	5.20 ± 2.31	1.20 ± 0.8	4.20 ± 1.15
	July 26th	3.60 ± 1.60	0.80 ± 0.58	12.80 ± 5.34	4.20 ± 1.15	9.00 ± 0.63
	Mean ± SE	4.95 ± 1.25	1.68 ± 0.60	7.50 ± 1.64	1.75 ± 0.49	12.90 ± 1.89
	LSD	3.88	1.68	5.29	1.28	3.50
General mean		17.81	18.81	23.41	10.90	21.90

A: Nimbecidine; B: Anti-insect; C: Bio-power; D: Malathion; E: Control

3.1.3. Combined Analysis of Thrips Results for Both Seasons before and after Spraying

1) On yellow sticky traps

As shown in Figure 2(a), a complete reduction occurred in the pest population after application, either for the three used bio-rational products or for malathion. Comparing the mean numbers of thrips stuck to traps before and after application, it was found that nimbecidine treatment decreased thrips mean numbers from 90 to 11.64 (7.7 times less), while the mean numbers caught in case of malathion dropped from 95.7 to 9.95 (about 9.6 times less). Each of the anti-insect and bio-power compounds caused 7.2 and 6 times reduction in pests' numbers, respectively. These results prove within the bio-rational products nimbecidine achieved the highest control level.

2) On tomato plants

Investigation of thrips numbers on plants after the use of the tested products was also carried out during the two seasons to cover all pest stages that are not capable of reaching the traps and to confirm the results obtained from traps

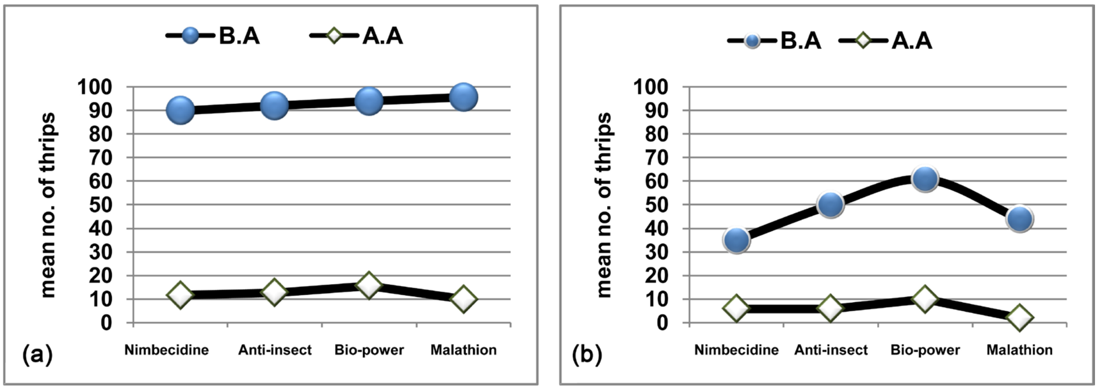

Figure 2. General mean number of *Thrips* spp. caught before application (B.A) and after application (A.A) of the tested products on both the yellow sticky traps (a) and tomato plants (b) during the two seasons.

experiment. Figure 2(b) shows that all 4 treatments decreased thrips numbers on plant's leaves. Mean number of thrips before application were 35, 50, 61 and 44 for nimbecidine, anti-insect, bio-power and malathion, respectively. After spraying malathion gave the best thrips control followed by both nimbecidine and anti-insects as was found previously in traps test and mean numbers were; 2 ± 0.6, 6 ± 2.1 and 6 ± 2, respectively. There was a significant difference between malathion, on one hand, and both nimbecidine and anti-insect on the other hand (LSD 0.05 = 2.75). Moreover, no significant difference appeared between the bio-power and the control confirming again that bio-power is a weak product for thrips control.

3.2. *Bemisia tabaci*

3.2.1. Whiteflies' Population Pre-Application

The general mean numbers of *B. tabaci* on the yellow sticky traps before application, for the two seasons (2017-18), in the 5 treatments, *i.e.* nimbecidine, anti-insect, bio-power malathion and control treatments, were 17.1, 18.8, 16.8, 17.3 and 17.13, respectively. These numbers reflect adequate degree of uniformity in the whiteflies' population before applying any of the products.

3.2.2. Best Results Obtained and Effect of Repeating Spraying

1) First season (2017)

Results recorded in Table 4 indicate that the first day of inspection (4 days post spraying) after each of the three applications in all the used products showed the highest reduction numbers in pest population. Mean numbers in the first application were 1.20 ± 0.49, 4 ± 1.79, 3.4 ± 0.4, 4.8 ± 2.34 and 23.6 ± 9.79 for each of the nimbecidine (A), anti-insect (B), bio-power (C), malathion (D) and control plot (E), respectively. Repeating spraying for the second time resulted in decreasing the pest mean numbers after 4 days of spraying to 0.40 ± 0.24, 0.20 ± 0.2, 0.60 ± 0.6, and 0.40 ± 0.24 for the 4 products (A, B, C and D) respectively. It was also noticed that in the second application no significant differences appeared between the 4^{th} and 8^{th} days of spraying of all products, LSD at

Table 4. Mean numbers of *Bemisia tabaci* caught on the yellow traps in different treatments during season 1: (2017).

Apps.	Inspection Date / Treatment	A	B	C	D	E
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
1st Application	June 12th	1.20 ± 0.49	4.00 ± 1.79	3.40 ± 0.40	4.80 ± 2.34	23.60 ± 9.79
	June 16th	6.40 ± 2.90	14.00 ± 4.30	8.00 ± 3.39	6.00 ± 26.19	28.00 ± 3.74
	June 20th	3.20 ± 1.58	4.40 ± 1.20	4.80 ± 3.08	16.00 ± 5.33	17.60 ± 2.04
	June 24th	6.20 ± 2.15	10.80 ± 2.15	6.60 ± 2.13	5.80 ± 1.49	17.20 ± 2.08
	Mean ± SE	4.25 ± 1.01	8.30 ± 1.56	5.70 ± 1.23	8.15 ± 7.25	21.60 ± 3.28
	LSD	3.21	4.47	4.25	5.35	9.12
2nd Application	June 28th	0.40 ± 0.24	0.20 ± 0.20	0.60 ± 0.60	0.40 ± 0.24	13.20 ± 0.86
	July 02nd	8.60 ± 2.97	5.80 ± 1.88	3.80 ± 1.77	4.60 ± 1.72	13.60 ± 2.73
	July 06th	2.40 ± 0.87	3.20 ± 1.46	3.80 ± 1.24	1.60 ± 0.74	13.20 ± 1.35
	July 10th	6.20 ± 1.85	7.40 ± 5.95	4.40 ± 1.63	4.40 ± 1.96	16.80 ± 2.088
	Mean ± SE	4.40 ± 1.63	4.15 ± 1.01	3.15 ± 0.71	2.75 ± 0.75	14.20 ± 1.30
	LSD	3.04	2.90	2.30	2.29	3.18
3rd Application	July 14th	4.000 1.30 ±	0.80 ± 0.58	2.00 ± 0.94	0.40 ± 0.24	13.80 ± 1.15
	July 18th	2.40 ± 1.03	1.20 ± 0.58	5.20 ± 0.58	0.80 ± 0.37	15.40 ± 1.43
	July 22nd	6.0 ± 0.86	3.00 ± 0.89	8.40 ± 1.03	2.00 ± 0.83	18.00 ± 1.92
	July 26th	5.00 ± 1.78	0.60 ± 0.40	8.20 ± 0.97	8.40 ± 1.91	15.20 ± 1.77
	Mean ± SE	4.40 ± 0.67	1.40 ± 0.36	5.95 ± 0.72	2.90 ± 0.88	15.60 ± 0.81
	LSD	2.17	1.07	1.51	1.79	2.68
General mean		4.12	4.61	4.90	4.60	17.13

A: Nimbecidine; B: Anti-insect; C: Bio-power; D: Malathion; E: Control

0.05% for all treatments during the whole experiment periods are presented (Table 4). Whitefly's mean numbers increased slightly when the 3rd spraying was carried out, except for the anti-insect product. These results indicate that the best control levels appear after 4 days of spraying followed by a fluctuation in pest numbers that differed from one treatment to another. *B. tabaci* numbers in control plot were always higher than all other treatments.

Repetition of spraying did not always cause reduction in *B. tabaci* population as shown in Figure 3(a). The three consecutive applications of nimbecidine gave almost the same results with no significant difference among the applications, *i.e.* 4.25 ± 1, 4.40 ± 1.63, 4.40 ± 0.67, respectively. However, anti-insect and malathion treatments showed continuous reduction in *B. tabaci* numbers from one application to the other as presented in the same figure.

2) Second season (2018)

Results of the second season (2018) confirmed the data obtained during the first season (2017), where the mean number of whitefly caught on the yellow sticky traps was the least on the fourth day post treatment and this was found in all plots (Table 5). Moreover, mean number of *B. tabaci* decreased from one application to the next in all the experimental plots till it reached its minimum number in the third application. In case of nimbecidine; mean number of the pest decreased from 13.45 ± 4.15 to 2.75 ± 0.92 and then to 2.25 ± 2.48 in the 3

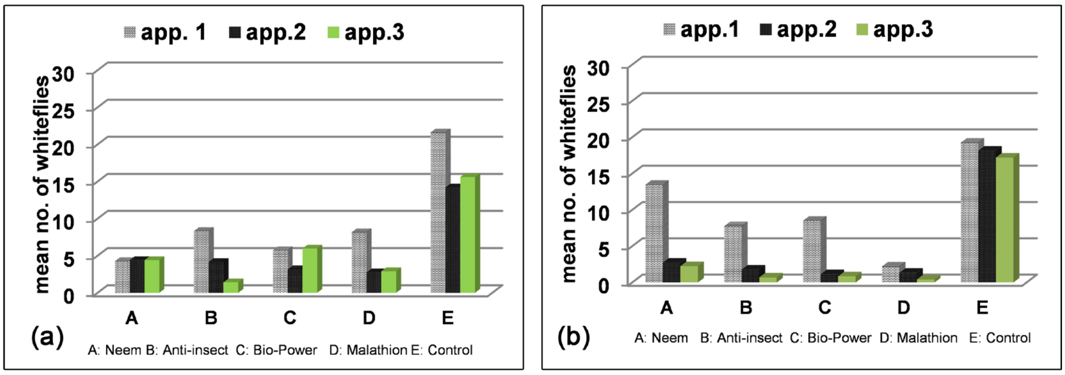

Figure 3. Mean numbers of *B. tabaci* caught on yellow sticky traps for the four treatments and the control during each of the three applications in season 1 (a) and season 2 (b).

Table 5. Mean numbers of *Bemisia tabaci* caught on the yellow sticky traps in different treatments during season 2: (2018).

Apps.	Treatment / Inspection Date	A	B	C	D	E
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
1st Application	June 12th	1.60 ± 1.03	2.80 ± 0.58	7.80 ± 2.22	0.60 ± 0.40	0.0
	June 16th	41.00 ± 7.81	17.00 ± 2.21	8.60 ± 1.80	3.20 ± 1.59	30.00 ± 1.64
	June 20th	2.20 ± 1.20	3.80 ± 1.24	10.20 ± 1.93	3.00 ± 3.00	9.60 ± 0.81
	June 24th	9.00 ± 1.64	7.40 ± 1.20	7.40 ± 1.56	2.00 ± 1.09	17.80 ± 3.12
	Mean ± SE	13.45 ± 4.15	7.75 ± 1.44	8.50 ± 0.90	2.20 ± 0.85	19.25 ± 2.01
	LSD	3.41	2.41	3.18	3.01	4.17
2nd Application	June 28th	0.0	0.40 ± 0.40	0.20 ± 0.20	0.0	15.60 ± 2.13
	July 02nd	5.20 ± 0.86	3.40 ± 1.69	0.80 ± 0.58	0.0	13.40 ± 3.07
	July 06th	0.0	2.20 ± 1.49	0.20 ± 0.20	0.20 ± 0.20	6.20 ± 0.86
	July 10th	5.80 ± 2.78	1.20 ± 0.49	3.40 ± 1.63	5.20 ± 1.46	13.40 ± 1.80
	Mean ± SE	2.75 ± 0.92	1.80 ± 0.60	1.15 ± 0.50	1.35 ± 0.61	18.15 ± 1.27
	LSD	2.44	1.97	1.47	1.24	3.56
3rd Application	July 14th	1.00 ± 1.00	0.0	0.0	0.0	11.40 ± 0.51
	July 18th	2.20 ± 1.02	1.20 ± 0.58	0.60 ± 0.60	0.0	4.80 ± 1.06
	July 22nd	2.60 ± 1.24	0.40 ± 0.24	0.40 ± 0.40	0.60 ± 0.60	8.20 ± 2.15
	July 26th	3.20 ± 1.28	1.20 ± 0.80	2.40 ± 1.28	1.25 ± 1.25	4.40 ± 0.40
	Mean ± SE	2.25 ± 2.48	0.70 ± 0.26	0.85 ± 0.39	0.42 ± 0.29	17.20 ± 0.86
	LSD	1.92	0.86	1.24	0.99	2.09
General mean		6.15	3.41	3.48	1.32	18.20

A: Nimbecidine; B: Anti-insect; C: Bio-power; D: Malathion; E: Control applications, respectively, which differs from the first seasons where the mean numbers did not show significant differences among the 3 applications as discussed above. The three other products, *i.e.* anti-insect, bio-power and malathion caused high reduction in insect mean numbers recorded on the traps as by the third spraying they reached 0.7 ± 0.26, 0.85 ± 0.39 and 0.42 ± 0.29, respectively, as presented in Figure 3(b).

3.2.3. Combined Analysis of Whiteflies' Results for the Two Seasons before and after Spraying

1) On the yellow sticky traps:

As shown in Figure 4(a), there was a reduction in the general mean numbers of whitefly recorded before and after applications for all the used bio-rational products and the malathion pesticide. The mean numbers of *B. tabaci* caught in case of the malathion decreased from 17.3 to 2.96 (about 5.8 times less), while mean insects' numbers stuck to the traps in case of anti-insect and bio-power decreased from 18.8 to 4.01 (4.7 times less) and 16.8 to 4.19 (4 times less), respectively. Finally, nimbecidine caused the least reduction in whitefly's numbers, *i.e.* 17.1 to 5.13 (3.3 times less). These results highlighted that among the tested products malathion proved to be the best compound against *B. tabaci* where it caused the highest suppression in pest population, while, no significant differences appeared among the three bio-rational products in controlling this pest (LSD at 0.05 was 1.5).

2) On tomato plants

As shown in Figure 4(b), a complete reduction occurred after spraying where whitefly's numbers before application recorded 8, 13, 15 and 21, for nimbecidine, anti-insects, bio-power and malathion, respectively. Results after application of the products showed that malathion gave the best control level; whereas, no significant differences were recorded among the bio-rational products (LSD at 0.05 = 1.30). Malathion pesticide recorded the lowest mean number (1.08 ± 0.43 insects), whereas bio-power recorded a mean number of 1.83 ± 0.87 and each of the anti-insect and nimbecidine recorded a general mean number of 2.17 ± 1.47 and 2.67 ± 1.1, respectively. On the other hand, significant differences

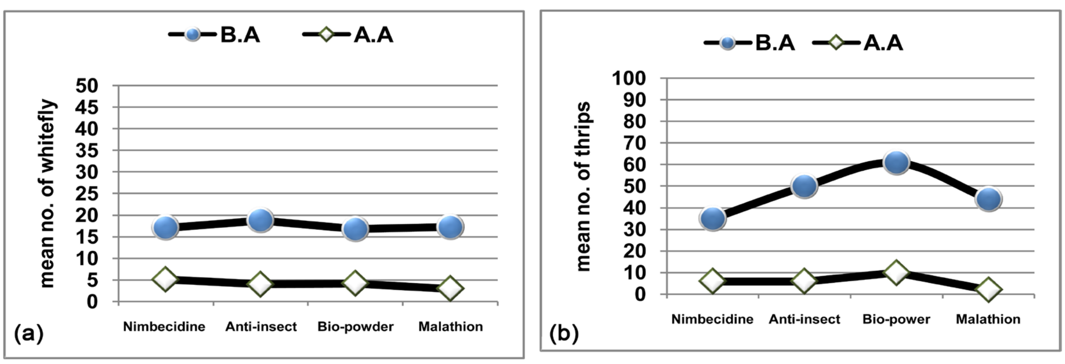

Figure 4. General mean numbers of *B. tabaci* caught before application (B.A) and after application (A.A) of the tested products on both the yellow sticky traps (a) and tomato plants (b) during the two seasons.

were recorded between the control treatments and all the tested products where control recorded a general mean number of 3.67 ± 1.

4. Discussion

Tomato crop is subjected to severe damage caused by the piercing sucking insects, which is considered of the most serious pest groups all over the world. Yield losses due to direct and indirect damage caused by whiteflies, for example, can reach 100% [8]. The current study aimed to find some alternatives to be used in controlling such pests.

Fluctuations in thrips numbers obtained during the different inspection dates, in some experimental plots within the two seasons, could be explained according to Gill *et al.* [17] who stated that thrips adults fly readily and can be carried on wind currents and move from sprayed to unsprayed areas as well. Concerning inter-application periods, our results did not correspond to what was found by Wagh *et al.* [18] who stated that spinosad, as one of the bio-rational natural compound, was very effective against whitefly and thrips on tomatoes during ten days after spray interval. However, our work coincided with a research carried out at Cornell University, stating that 5-day application intervals are more effective than 7-day intervals [17]. In the current study the highest control of both thrips and whitefly was always obtained after the 4th day of each application, and therefore, the idea of increasing the inter-application periods up to 16 days was not effective, as it was too long. Accordingly, we recommend that time between applications should not exceed 5 days to achieve better control levels.

In pest control, it is also important to decide how often a product should be used. The current results recommend that three consecutive spraying are necessary to achieve the best control. These findings highly corroborates the investigation of Emami [19] where he used four organically-farming insecticides, among which was the nimbecidine extract, and assured that applying the products for 3 times gave excellent control. Therefore, repeating applications may be necessary for better pest control [20]. Moreover, Magsi *et al.* [21] supported our recommendation where they stated that applying different synthetic insecticides for 3 consecutive times against *B. tabaci* decreased pest population in all the tested insecticides.

According to our study malathion pesticide proved to be the best product among the tested chemicals where it achieved the highest control rates in both thrips and whitefly. However, although systemic insecticides may be highly effective, still they can have negative impacts on beneficial insects and pollinators [20]. Not only that the pesticides kill natural enemies, but both thrips and whiteflies quickly build up resistance to them [12]. On the other hand, Horowitz and Ishaaya [14] stated that bio-rational insecticides are good alternatives or supplemental forms of pest control and they are to be used in the IPM programs. In addition, according to the US Environmental Protection Agency (EPA), bio-rational pesticides display minimal risk to the environment, break down quickly, have minimal residues, safe to applier and relatively small amounts are needed for successful control [22] [23]. In the current investigation, within the bio-rational pesticides, nimbecidine gave the highest control percentage in case of thrips, while in case of whitefly both bio-power (*B. bassiana*) and the anti-insect caused the highest control levels followed by nimbecidine. Difference in the effectiveness of used bio-rational products against the study pests could be attributed to their age specific toxicity, variant modes of action, the developmental stage of the pest and its location [24].

5. Conclusion

In conclusion, nimbecidine oil, bio-power and anti-insect are available promising products as alternatives or supplements to chemical insecticides in controlling thrips and whiteflies; one might choose two of them to alternate between. Therefore, it is recommended to integrate those three bio-rational compounds in the IPM programs of both piercing sucking insects in Egypt, provided that applications' numbers, period between sprayings and the suitable type of product, are taken into consideration. In addition, application's methodologies and concepts should be transformed to farmers to encourage their use and adoption.

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Conflicts of Interest

The authors have declared no conflict of interest.

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