STUDY THE POSSIBILITY OF INTEGRATING A BACTERIAL BASED INSECTICIDE, EMAMECTIN BENZOATE (PROCLAIM 1.9 EC) IN THE MANAGMENT STRATEGY OF LEPIDOPTERA PEST COMPLEX

Sanaa A. Ibrahim
Abdelrahman M. Younis
Minia University
Minia, Egypt

Abstract

Semi-field and field studies were undertaken during 2013 and 2014 cotton growing seasons to evaluate the initial performance and residual toxic effects of a commercial product from emamectin benzoate (Proclaim 1.9-EC)) against 4th instar larvae from a field collected cotton leafworm, *Spodoptera littoralis* (Boisduval). The possible inhibitory effect on predatory populations was also of great interest. Data revealed that this product gave 100% initial mortality within the first 48 hr after application even when half of the recommended rate was used. Residual performance of this insecticide slightly enhanced as the rate of application increased. However, emamectin benzoate completely lost its toxic residues after one week of field application even when 200% of the recommended field rate was used. Another advantage of using this product is its compatibility with predator populations. The only negative impact appeared one day after treatment; however predator populations backed to their normal abundance within 48hr post application particularly with half of the recommended rate as well as the field rate of application. Based on these data, the authors suggest using this chemical to control Lepidoptera pests on vegetable crops to minimize the pre-harvest interval, make these crops edible for human use shortly after treatment and also to preserve beneficial arthropods.

Introduction

Environmental concerns with using conventional pesticides must be taken in consideration. The success of any pesticide in pest control programs must be depended not only on its efficiency in pest control, but also on its environmentally safety. Continuous use of synthetic pesticides as a unique method for pest control has created many environmental problems such, for examples, as 1) negative impacts on beneficial arthropods (parasites; predators and honey bee colonies); 2) negative impact on soil fauna such as nitrogen fixed bacteria; 3) affect soil constructions; 4) leaching properties result in the contamination of surface and ground water; 5) volatile chemicals may contaminate air; 6) persistent soil treated herbicides may carry over to the next cultivated crop and injury it if susceptible; 7) persistent and systemic pesticides may contaminate plant tissue and sometimes raise food safety concerns; 8) develop of resistance phenomena toward insecticides and herbicides; and 9) negative impact on human health and wild life (Gupta & Dikshit, 2010 and Borgio *et al*., 2014).

It's considerable to depend on all possible methods of pest control (agricultural; biological; mechanical and also chemical means). Chemical control using synthetic pesticides must be the last choice. The control philosophy is not to eradicate the pest, but keeps it under the economic injury level to preserve natural enemies alive for environmental equilibrium. Egyptian farmers must be educated regarding the benefits of using integrated pest management strategy in the long run.

In addition to the nonchemical means of pest control, eco-friendly alternative products are commercially sold in the pesticide market and must be involved in pest management strategy. Avermectin insecticides such as abamectin and emamectin benzoate are produced by the fermentation of the soil actinomycete, *Streptomyces avermitilis* and have shown low toxicity to non-target beneficial arthropods which has accelerated their acceptance into Integrated Pest Management (IPM) programs for controlling field crop pests (Ishaaya *et al.,* 2002). The objective of this study is an attempt to confirm the role of emamectin benzoate under Egyptian weather conditions during summer in the management strategy of cotton pest complex including cotton leafworm, *Spodoptera littoralis* as well as its compatibility with predator populations.

Materials and Methods

In 2013 and 2014 cotton growing seasons, Emamectin benzoate (commercially named Proclaim®, EC-1.9%) was evaluated for its initial toxicity as well as the persistence of toxic residues on the target pest (cotton leafworm) and on the non-target beneficial arthropods (predator populations). Four rates are tested; the recommended field rate (250ml from formulated material per feddan (4200m^2) equivalent to 4.75gm active ingredient /feddan); also 50%, 150% and 200% of the recommended rate were also included in this study. Control treatment was handled the same way except receiving water only. For conducting this experiment, almost an area of about 0.25 feddan was divided to 25 plots of 42 square meters each. Five plots were used for each treatment as replications and the replicates of each treatment were distributed in completely randomized block design. Treatment was started on June 7 and July 3 in 2013 and 2014 seasons, respectively. Weather conditions during the period from June 7 to June 15, 2013 (mean ± SD) were as follows: Minimum temperature 22.56 ± 0.53; maximums temperature was 34.33 ± 0.50; minimum relative humidity was 31.33 ± 0.50 and maximum relative humidity was 70.0 ± 0.71. Weather conditions during the period from July 3 to July 11, 2014 were as follows: minimum temperature was 24.0 ± 0.0; maximum temperature was 35.0 ± 0.0; minimum relative humidity was 34.78 ± 0.67 and maximum relative humidity was 75.11 ± 0.60.

For evaluating this chemical at the four tested rates against cotton leafworm, leaf samples were collected from each plot and taken to the laboratory just after the dryness of spray solution (day 0) and at daily intervals up to 8 days. The evaluation was ended on day 8 because the chemical toxic residues even when is used at the duplicated rate were ineffective against the 4th instar larvae of cotton leafworm. To conduct the experiment, leaf samples were collected from the field, taken to the laboratory and placed in 1/2kilogram glass jars, each provided with ten fourth instar larvae (five jars for each treatment). Treated leaves were enough for feeding larvae for two successive days and then mortality percentages were recorded for the replicates of each treatment. For each rate of application, means were compared between the eight time intervals using analysis of variance followed Duncan Multiple Comparison test at 5% level of probability. For each time interval, control and emamectin benzoate different rates were statistically compared based on the least significant difference at 5% level of probability.

For monitoring the negative impact of emamectin benzoate at different rates on predator populations, predator population was counted on 25 plants, randomly chosen from each plot. These counts were conducted just before starting the field treatment and repeated at daily intervals up to eight days after emamectin benzoate field application. Percent reduction in predator population was calculated according to the formula of Henderson and Tilton (1955).

Results and Discussion

Effect on cotton leafworm

In 2013 cotton growing season, per cent mortality of cotton leafworm larvae in control treatment ranged between 0.0 to 6.0%, however the difference was insignificant during the whole period of experiment (Table 1). In general emamectin benzoate persists shorter under hot temperature during summer. Toxic residues slightly increased as concentration increased. It is obvious that the four rates of emamectin benzoate gave 100% initial mortality within the first 24hr after treatment. On day 2, mortality percentages at 150 and 200% of the recommended rate were the greatest averaging 88.0 and 100.0%, respectively. The chemical even when the recommended rate of application duplicate lost its toxic residues after one week. This finding was confirmed in 2014 season; while all rates gave 100% initial mortality within the first 24hr of treatment. Toxic residues is concentration dependent, since 150 and 200% of the recommended rate persisted longer, exhibiting 92.0 and 100% mortality in the second day and their toxic residues extended to the fourth day after treatment (54.0 and 72.0%, respectively) compared to 34.0% with the recommended rate. All concentrations completely lost their toxic residues one week after treatment (Table 2). Pooling the two season data (Table 3 and Fig 1) revealed that the initial performance of emamectin benzoate within the first 24hr after treatment was statistically similar between the four rates of application; moreover emamectin benzoate at half of the recommended rate gave 100% initial mortality. However residues of this chemical was concentration and time dependent. There was a dramatic decrease in the toxic residues as time elapsed and also as concentration decreased (Fig. 1). In general, there were no toxic residues one week after field application even when the field rate was duplicated.

Negative impact on predatory population

Data obtained in 2013 season revealed that mean number of predators, at each rate of emamectin benzoate, was insignificant different between the eight time intervals, and the population density did not significantly differ when compared between pre- and post-treatment. At each time intervals, the effect of emamectin benzoate different rates was compared. There was no significant difference at each of all tested intervals, except on day one. At this date increasing the rate of application to 150 and 200% of the recommended rate significantly affect predator population (Table 4). However for the time of inspection start from day 2 up to day 8, mean number of predators did not significantly differ among the four rates of application and the untreated check. This result confirms that emamectin benzoate had minimum harmful risk on the predatory population even when duplicating the rate of application.

Repeating the experiment in 2014 confirmed the reduced risk of emamectin benzoate different rates on predatory population. For each rate of emamectin benzoate application, as seen in Table 5, predator populations were insignificant different at all time intervals post applications. For each time interval, the comparisons between the four rates of application confirmed the previous data obtained in the first season since emamectin benzoate significantly affect predator population on the first day after spray and this negative impact was negligible starting from day 2. The only difference with the data of 2013 season is that this negative impact reported on day one extended to include all tested rates in 2014 season, however was reported with the two highest concentrations in 2013.

Based on the combined data of the two seasons, it is clear that population density of predators was greater in the untreated plots at all time intervals post- treatment (Table 6 and Fig. 2). In contrast the lowest number was in the plots treated with the highest rate of emamectin benzoate. However, the difference between treatments was significant only on day 1. On day 1, the greatest number was in control plots, followed by emamectin 0.5X, emamectin 1X and emamectin 1.5Xwith no significant differences between the three treatments. However, the highest tested rate exhibited significantly the lowest number. It seems that the recommended rate and also one half the recommended had no inhibitory effects on predator population.

When the comparisons either between different rates of emamectin benzoate at each time interval or between the residues of each rate at different time intervals, the trend of harmful effects was different from the comparisons based on the mean number of predators. It is more accurate to depend on per cent reduction on predator population because in this criterion the pre spray and post spray counts for each of control and chemical treatments will be taken in consideration. In 2013 season, at each tested rate, the greatest reduction in predator population was on day 1. In contrast, lowest reduction was recorded on day 8 (Table 7). Initial effect ranged between 31.29% in 0.5X treatment to 52.07% in 2X treatments. However the reduction in predator population dropped starting from day 2 (9.14% to 15.27%) and reach to the minimum (0.29 to 0.61%) on day 8. Data of 2014 (Table 8) confirmed that the greatest harmful effect appear on the first day after treatment (22.68 to 48.40%) and dramatically decreased with time to become negligible on day 8 (4.13% to 7.99%). Pooled the data of the two seasons (Table 9 and Fig. 3) reconfirmed that this chemical negatively affect predator population within the 24 hr after application and the negative effect completely disappeared after one week, suggesting to release natural enemies one week after the field application.

Recent advantages in pest control are to integrate different means of pest control with introducing selective novel pesticides with minimum risk on the environment including beneficial arthropods. Emamectin benzoate, a macro-cyclic lactone insecticide belongs to microbial based insecticides from an avermectin family. It is being developed for the control of Lepidoptera pests on a variety of crops in Egypt including vegetables. In the present study, semi-field trials were conducted in 2013 and 2014 cotton growing seasons to evaluate the initial performance and residual effect of this chemical against the fourth instar larvae from field collected cotton leafworm, *Spodoptera littoralis*. Initial activity of emamectin benzoate at four rates of application was evaluated on day 0.0, just after drying spray solution. Toxic residues at daily intervals up to 8 days after treatment were also considered. In recent study, emamectin benzoate at half of the recommended rate offered 100% initial mortality within the first 24hr after field application. However the toxic residues increased as rate of application increased. Generally this chemical short lived under the environmental conditions of middle Egypt during June and July. At the highest tested rate, which represents 200% of the field recommended rate, emamectin benzoate completely lost its toxic residues at one week after application. In previous field study, the effect of emamectin benzoate against Lepidoptera larvae was undertaken under laboratory and field conditions. In agreement with our finding with cotton leafworm, regarding the short life of emamectin benzoate; Ishaaya *et al.* 2002 stated that emamectin benzoate at 25mg AI litre^{-1} in a cotton field maintained its initial activity against Egyptian cotton leafworm *Spodoptera littoralis* Boisduval, for 3 days only, however contrary they confirmed that this chemical under the same rate and conditions resulted in over 90% suppression of *H. armigera* larvae up to day 28 after treatment. The long residual activity against *H. armigera* larvae could be explained that this species is more susceptible to similar residues could be tolerated by *S. littoralis* larvae. Two years later, Clarke-Harris *et al.* (2004) evaluated some novel insecticides against the Lepidoptera complex attack *Amaranthus spp.* Pest frequency values for tebufenozide and emamectin benzoate test plots were in the ranges of 0-5.2 larvae/plant and 0-4.25 larvae/plant respectively. Percent marketable yield for tebufenozide (58.38%) and emamectin benzoate (55.23%) showed improvements over lambda-cyhalothrin (49.51%). In more recent study, emamectin benzoate 5 SG (NF) at 11 g a.i./ha was effective in controlling the larval population of *Helicoverpa armigera* which ultimately increased the yield of cotton (Govindan *et al.,* 2011). In our study, toxic effect of emamectin benzoate appeared within 48hr after feeding larvae on treated leaves when the recommended rate or its half was within 48 hr after treatment. However previous study by Wankhede and Kale (2010) revealed that critical time required to affect 50 per cent *Leucinodes orbonalis* larval population mortality for emamectin benzoate was observed 4.46 days with upper and lower fiducially limits of 5.172 and 3.849 days, respectively. In this study the authors did not mention which concentration they used to make this chemical act very slowly. However the recommended rate in our study had its initial kill within 48 hr after feeding larvae on treated leaves. The great initial performance of emamectin benzoate under field condition was confirmed in another study with another pest species. Wankhede *et al.* (2009) found that emamectin benzoate (Proclaim 5SG; 200 g/ha) was effective in reducing the shoot damage by the brinjal shoot and fruit borer. Khan *et al.* (2011) reported that Emamectin benzoate proved great efficacy against the armyworm, *Spodoptera litura* (Fab.) in the laboratory, after 3 days of the insecticide treatment, 100% mortality was observed in emamectin benzoate at 100 and 110 ml/acre treatment. In more recent study by Xia *et al.* 2014 who tested different populations of the diamondback moth, *Plutella xylostella* (L) for baseline susceptibility tests and resistance monitoring to spinosad, indoxacarb, and emamectin benzoate and found that most populations were susceptible to all three insecticides. In our study emamectin benzoate completely lost its toxic residues against field collected 4th instar larvae of cotton leafworm at one week interval after field application on cotton during June-July. These finding was confirmed in the two successive seasons. Duplicated the rate of field application, did not significantly help in extend the chemical bio-residual effect more than one week. Our results are concurred with those obtained by Abdu-Allah (2010) with the same insect species and the same host plant, the mortality percentages were 98.00, 70.00, 36.67 and 0.0% after 0, 3, 6 and 10 days, respectively. Data obtained in our and previous study suggest the importance of integrating this chemical in controlling Lepidoptera pests particularly on vegetables such as tomatoes to reduce the preharvest interval and make treated plants edible after short time of treatment.

Another advantage of using emamectin benzoate in the integrated pest management strategy is its compatibility with the predatory populations. In the current study, emamectin benzoate was compatible with the predators associated with cotton during June and July. The only drop in predator populations was after one day of field application; however they back to their normal abundance within 48 hr of treatment. In previous study by Grundy (2007), a range of new generation insecticides registered for use in cotton were tested for compatibility with the assassin bug, *Pristhesancus plagipennis* (Walker), a potential biological control agent for *Helicoverpa spp*. He found that emamectin benzoate was moderate toxic; the author suggested using half of the recommended rate to reduce the risk on beneficial arthropods. In our study half of the recommended rate have the same initial effect on cotton leafworm as the recommended rate and was safer on predator population. The risk was only at one day after treatment and these data were confirmed during the two years of study. The only negative impact was achieved at 24hr after field application; however predator populations quickly backed to their normal abundance. Laboratory study conducted by Dilbar *et al.* (2010) revealed that emamectin benzoate 40 ppm, lufenuron 1000 ppm, triflumuron 400 ppm and imidachloprid 500 ppm had no adverse effect on the emergence of *Trichogramma chilonis* when exposed to all immature stages of development (egg, larvae, pre-pupae, early pupae and pupae) in the host eggs of *Sitotroga cerealella*. The direct exposure of Trichogramma adults to these insecticides revealed that none of the insecticides was safer for *Trichogramma chilonis* adult after 24 hour. The chemical have very short residual activity did not exceed 7 days even when the field rate of application was duplicated. Laboratory study was conducted by Kawazu *et al.* (2011) and data confirmed that emamectin benzoate showed no inhibitory effect on the foraging behavior of *Cotesia vestalis* (Hymenoptera: Braconidae) females, a larval parasitoid of the diamondback moth *Plutella xylostella* (Lepidoptera: Plutellidae). Furthermore, the mortality of wasps after foraging on the clothianidin-treated plants was significantly higher than after foraging on emamectin benzoate-treated plants. Our data was confirmed with the finding of Amor *et al. (*2012) who suggested releasing predators to the field three days after emamectin benzoate application because the chemical was toxic when directly applied on predator field population.

Table 1. Mortality percentages of cotton leafworm 4th instar larvae exposed to the residues of emamectin benzoate at daily intervals post field application (date of field application June, 7, 2013).

Rate of application	Mortality percentages (Mean ± SE) at daily intervals after spraying emamectin benzoate different rates during 2013 cotton growing season (date of spray June 7, 2013)									LSR 0.05
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	6.0 ± 4.0	4.0 ± 2.45	6.0 ± 4.0	6.0 ± 5.48	0.0	0.0	0.0	0.0	0.0	NS
0.5X	100.0 ± 0.0a	100.0 ± 0.0a	58.0 ± 3.74b	26.0 ± 6.0c	18.30 ± 3.74cd	12.0 ± 2.0de	4.0 ± 2.45ef	0.0f	0.0f	11.45
1.0X	100.0 ± 0.0a	100.0 ± 0.0a	66.0 ± 2.45b	40.0 ± 7.07c	26.0 ± 5.09de	16.0 ± 2.45e	10.0 ± 3.16ef	4.0 ± 2.45ef	0.0f	13.17
1.5X	100.0 ± 0.0a	100.0 ± 0.0a	88.0 ± 3.74ab	80.0 ± 7.07b	52.0 ± 3.74cd	46.0 ± 5.09d	32.0 ± 3.74de	16.0 ± 2.45ef	0.0f	16.61
2.0X	100.0 ± 0.0a	100.0 ± 0.0a	100.0 ± 0.0a	78.0 ± 8.60b	58.0 ± 3.74cd	54.0 ± 5.09de	40.0 ± 5.48ef	24.0 ± 4.0f	0.0g	16.24
LSD 0.05	8.50	5.21	14.80	13.88	14.88	15.62	16.94	10.31	NS	---

For each row, means share at least one letter are not significantly different based on Duncan Multiple Comparison test with least significant range at 5% level of probability. Comparison within each column between different rates of emamectin benzoate applications is based on LSD 0.05.

Table 2. Mortality percentages of cotton leafworm 4th instar larvae exposed to the residues of emamectin benzoate at daily intervals post field application (date of application July 3, 2014).

Rate of application	Mortality percentages (Mean ± SE) at daily intervals after spraying emamectin benzoate different rates during 2014 cotton growing season (date of spray July 3, 2014)									LSR 0.05
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	6.0 ± 4.0	2.0 ± 2.0	4.0 ± 2.45	6.0 ± 2.45	2.0 ± 2.0	4.0 ± 2.45	4.0 ± 2.45	2.0 ± 2.0	0.0	NS
0.5X	100.0 ± 0.0a	100.0 ± 0.0a	66.0 ± 4.0b	36.0 ± 4.0c	24.0 ± 4.0de	16.0 ± 2.45ef	8.0 ± 3.74fg	4.0 ± 2.45g	0.0g	8.58
1.0X	100.0 ± 0.0a	100.0 ± 0.0a	72.0 ± 3.74b	48.0 ± 4.89c	34.0 ± 5.09d	24.0 ± 4.0e	14.0 ± 4.0f	8.0 ± 2.0fg	0.0g	9.06
1.5X	100.0 ± 0.0a	100.0 ± 0.0a	92.0 ± 3.74a	74.0 ± 8.12b	54.0 ± 2.45c	42.0 ± 3.74c	24.0 ± 2.45de	10.0 ± 3.16ef	0.0f	14.03
2.0X	100.0 ± 0.0a	100.0 ± 0.0a	100.0 ± 0.0a	88.0 ± 5.83b	72.0 ± 3.74c	56.0 ± 4.0d	44.0 ± 5.09e	28.0 ± 13.04f	0.0g	11.65
LSD 0.05	8.50	4.91	15.91	16.91	17.59	15.77	16.37	13.25	NS	

For each row, means share at least one letter are not significantly different based on Duncan Multiple Comparison test with least significant range at 5% level of probability. Comparison within each column between different rates of emamectin benzoate applications is based on LSD 0.05.

Table 3. Mortality percentages of cotton leafworm 4th instar larvae exposed to the residues of emamectin benzoate at daily intervals post field application (pooled data of the two seasons).

Rate of application	Mortality percentages (Mean ± SE)									LSR 0.05
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	6.0 ± 4.47	3.0 ± 2.23	4.0 ± 2.74	6.0 ± 2.74	1.0 ± 1.12	2.0 ± 1.37	2.0 ± 1.37	1.0 ± 1.12	0.0	NS
0.5X	100.0 ± 0.0a	100.0 ± 0.0a	62.0 ± 2.85b	33.0 ± 4.47c	21.0 ± 3.71d	14.0 ± 2.09de	6.0 ± 2.74ef	2.0 ± 1.37f	0.0f	7.09
1.0X	100.0 ± 0.0a	100.0 ± 0.0a	69.0 ± 2.74b	44.0 ± 6.47c	30.0 ± 4.68d	20.0 ± 3.06e	12.0 ± 2.24ef	6.0 ± 1.12fg	0.0g	8.74
1.5X	100.0 ± 0.0a	100.0 ± 0.0a	90.0 ± 3.95ab	77.0 ± 8.02b	53.0 ± 2.24c	44.0 ± 4.11c	28.0 ± 2.85d	13.0 ± 2.85e	0.0e	13.41
2.0X	100.0 ± 0.0a	100.0 ± 0.0a	100.0 ± 0.0a	83.0 ± 6.02b	65.0 ± 3.54c	55.0 ± 3.95c	42.0 ± 5.48d	26.0 ± 2.09e	0.0f	11.41
LSD 0.05	8.50	4.25	12.80	21.83	17.59	13.55	16.37	6.59	NS	---

For each row, means share at least one letter are not significantly different based on Duncan Multiple Comparison test with least significant range at 5% level of probability. Comparison within each column between different rates of emamectin benzoate applications is based on LSD 0.05.

Table 4. Mean number of predators counted on 25 plants randomly chosen from each replicate in control and emamectin different rate treatments (first season, June 7, 2013).

Rate of application	Number of predators (Mean ± SE)									LSR 0.05
	Pre-spray	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	18.25 ± 1.18	16.50 ± 0.87a	14.0 ± 2.12	14.75 ± 2.36	15.25 ± 1.89	17.75 ± 1.03	18.50 ± 10.50	17.25 ± 1.49	17.75 ± 1.03	NS
0.5X	16.50 ± 1.56	10.25 ± 1.03ab	11.50 ± 1.56	12.25 ± 1.49	12.75 ± 2.29	15.25 ± 1.03	15.75 ± 2.18	14.75 ± 1.97	16.0 ± 1.23	NS
1.0X	16.0 ± 1.23	9.75 ± 1.97ab	10.75 ± 0.75	11.50 ± 1.56	12.25 ± 1.49	14.0 ± 1.68	14.75 ± 1.75	14.0 ± 1.68	15.0 ± 2.04	NS
1.5X	17.0 ± 1.78	7.75 ± 1.89b	11.0 ± 1.23	12.0 ± 2.86	12.75 ± 2.29	14.75 ± 1.97	15.25 ± 1.65	14.50 ± 1.66	16.50 ± 1.56	NS
2.0X	15.0 ± 2.04	6.50 ± 0.87b	9.75 ± 1.18	10.25 ± 1.89	10.75 ± 0.75	12.75 ± 2.78	13.38 ± 2.21	12.75 ± 2.78	14.50 ± 2.10	NS
LSD 0.05	NS	7.66	NS	NS	NS	NS	NS	NS	NS	---

For each row at each rate of application, there were no significant differences between mean numbers of predators at the eight time intervals based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For each column, the only significant difference was on day 1. At day 1, mean number of predators was significantly reduced when emamectin benzoate applied at 1.5 and 2.0X.

Table 5. Mean number of predators counted on 25 plants randomly chosen from each replicate in control and emamectin different rate treatments (Second season, July 7, 2014)

Rate of application	Number of predators (Mean + SE)									LSR 0.05
	Pre-spray	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	15.63 ± 1.19	19.38 ± 0.63a	17.50 ± 1.02	17.5 ± 1.77	18.13 ± 1.19	20.0 ± 1.02	16.88 ± 1.19	17.50 ± 1.44	15.63 ± 1.19	NS
0.5X	15.0 ± 1.02	14.38 ± 0.63b	15.0 ± 1.02	15.0 ± 1.77	15.63 ± 1.19	18.13 ± 1.19	15.63 ± 1.88	16.25 ± 1.61	14.38 ± 2.14	NS
1.0X	16.25 ± 0.72	11.88 ± 1.88b	15.0 ± 1.44	15.63 ± 0.63	16.25 ± 0.72	18.13 ± 1.19	16.25 ± 1.61	16.88 ± 1.19	15.63 ± 1.19	NS
1.5X	16.25 ± 0.72	11.25 ± 1.61b	13.75 ± 0.72	15.0 ± 1.02	15.63 ± 2.14	17.50 ± 1.02	15.63 ± 2.14	16.25 ± 0.72	15.63 ± 0.63	NS
2.0X	15.63 ± 1.19	10.0 ± 1.02b	13.13 ± 2.14	14.38 ± 1.19	15.0 ± 1.02	16.88 ± 1.19	15.0 ± 1.02	15.63 ± 1.19	14.38 ± 1.88	NS
LSD 0.05	NS	4.61	NS	NS	NS	NS	NS	NS	NS	---

For each row, there was no significant difference between mean population densities of predators based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For the third column (day one), all emamectin treatments exhibiting drop in predator population compared to the untreated control treatment ($LSD_{0.05}$ = 4.61).

Table 6 Mean number of predators counted on 25 plants randomly chosen from each replicate in control and emamectin different rate treatments (combined data of the two seasons)

Rate of application	Number of predators (Mean + SE)									LSR 0.05
	Pre-spray	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.0X	16.94 ± 1.05	17.94 ± 0.66a	15.75 ± 1.04	16.13 ± 2.06	16.69 ± 1.43	18.88 ± 0.07	17.69 ± 0.69	17.38 ± 1.18	16.69 ± 1.08	NS
0.5X	15.75 ± 0.59	12.31 ± 0.28a	13.25 ± 0.57	13.63 ± 1.54	14.19 ± 1.30	16.69 ± 1.06	15.69 ± 1.96	15.50 ± 1.08	15.19 ± 1.63	NS
1.0X	16.13 ± 0.63	10.81 ± 1.35a	12.88 ± 0.99	13.56 ± 1.03	14.25 ± 0.92	16.06 ± 1.30	15.50 ± 1.58	15.44 ± 1.42	15.31 ± 1.39	NS
1.5X	16.63 ± 0.90	9.50 ± 0.81a	12.38 ± 0.78	13.50 ± 1.12	14.19 ± 2.11	16.13 ± 1.11	15.44 ± 1.65	15.38 ± 0.84	16.06 ± 0.74	NS
2.0X	15.31 ± 0.59	8.25 ± 0.67b	11.44 ± 1.23	12.31 ± 1.34	12.88 ± 0.29	14.81 ± 1.24	14.19 ± 0.84	14.19 ± 1.42	14.44 ± 1.92	NS
LSD 0.05	NS	8.55	NS	NS	NS	NS	NS	NS	NS	

For each row at each tested rate, there was insignificant difference between all time intervals based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For the third column which represents data of day 1, the only significant difference was achieved with the duplicated rate of field application.

Table 7. Reduction percentages in predator populations counted on 25 plants randomly chosen from each replicate in control and emamectin benzoate different rate treatments (First season, June 7, 2013).

Rate of application	Percentages of reduction (Mean ± SE)								$LSR_{0.05}$
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.5X	31.29 ± 1.76a	9.14 ± 0.74b	8.14 ± 2.43b	7.53 ± 2.15b	4.97 ± 1.14b	5.84 ± 1.07b	5.42 ± 1.62b	0.29 ± 0.16b	9.15
1.0X	32.59 ± 1.92a	12.42 ± 2.34b	11.07 ± 1.86bc	8.38 ± 1.42bc	10.04 ± 1.79bc	9.06 ± 0.74bc	7.43 ± 0.82bc	3.61 ± 0.65c	8.28
1.5X	49.58 ± 2.02a	19.94 ± 1.76b	12.66 ± 2.77bc	10.25 ± 0.79bc	10.79 ± 0.95bc	11.51 ± 1.14bc	9.76 ± 1.07bc	0.21 ± 0.08c	11.71
2.0X	52.07 ± 2.35a	15.27 ± 1.31b	15.45 ± 0.91b	14.23 ± 1.17b	12.61 ± 0.71bc	12.01 ± 1.15bc	10.07 ± 1.09bc	0.61 ± 0.11c	13.54
$LSD_{0.05}$	5.17	4.39	2.16	3.89	5.11	4.45	3.15	NS	---

For each row, means share at least one letter are not significantly different based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For each column, the value under each column, represent the least significant difference for the means represented in each column.

Table 8. Reduction percentages in predator populations counted on 25 plants randomly chosen from each replicate in control and emamectin benzoate different rate treatments (Second season, July 3, 2014)

Rate of application	Percentages of reduction (Mean ± SE)								LSR 0.05
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	
0.5X	22.68 ± 2.15a	10.69 ± 1.66b	10.69 ± 1.12b	10.17 ± 0.87b	5.54 ± 1.86b	3.52 ± 2.14b	3.24 ± 1.65b	4.13 ± 2.23b	8.45
1.0X	42.06 ± 1.46a	20.96 ± 0.76b	14.09 ± 1.82bc	13.79 ± 2.29bc	12.81 ± 1.34bc	7.41 ± 0.81c	7.22 ± 2.05c	3.81 ± 1.19c	11.48
1.5X	44.17 ± 1.89a	24.43 ± 2.08b	17.55 ± 1.75b	17.08 ± 2.69b	15.84 ± 0.79b	10.94 ± 1.86bc	10.69 ± 1.63bc	3.81 ± 0.56c	10.08
2.0X	48.40 ± 2.23a	24.97 ± 1.34b	17.83 ± 2.57b	17.26 ± 1.81b	15.60 ± 1.47bc	11.14 ± 2.74c	10.69 ± 1.39c	7.99 ± 0.68c	10.88
$LSD_{0.05}$	7.42	3.42	3.76	5.83	4.63	3.83	5.42	NS	---

For each row, means share at least one letter are not significantly different b based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For each column, the value under each column, represent the least significant difference for the means represented in each column.

Table 9. Reduction percentages in predator populations counted on 25 plants randomly chosen from each replicate in control and emamectin benzoate different rate treatments (Combined data of the two seasons)

Rate of application	%Reduction (Mean ± SE) Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	LSR $_{0.05}$
0.5X	26.19 ± 1.88a	9.52 ± 1.08b	9.11 ± 1.71b	8.56 ± 1.43b	4.92 ± 1.53b	6.04 ± 2.67b	4.08 ± 1.29b	2.11 ± 0.47b	8.71
1.0X	36.72 ± 0.89a	14.12 ± 1.56b	11.71 ± 1.52bc	10.33 ± 2.07bc	10.66 ± 0.78bc	7.98 ± 1.43bc	6.70 ± 2.21bc	3.66 ± 0.54c	9.64
1.5X	46.06 ± 1.23a	19.93 ± 2.11b	14.74 ± 1.24b	13.39 ± 1.78b	12.97 ± 2.12b	11.09 ± 0.89bc	9.86 ± 2.45bc	1.98 ± 0.28c	10.76
2.0X	49.12 ± 1.08a	19.63 ± 2.32b	15.56 ± 1.13bc	14.61 ± 2.78bc	13.21 ± 0.72bc	11.25 ± 2.14bc	9.66 ± 1.03bc	4.27 ± 1.23c	11.45
LSD $_{0.05}$	6.11	3.35	2.13	4.62	5.21	3.08	4.87	NS	---

For each row, means share at least one letter are not significantly different based on Duncan Multiple Comparison test with least significant range at 5% level of probability. For each column, the value under each column, represent the least significant difference at each time interval.

.

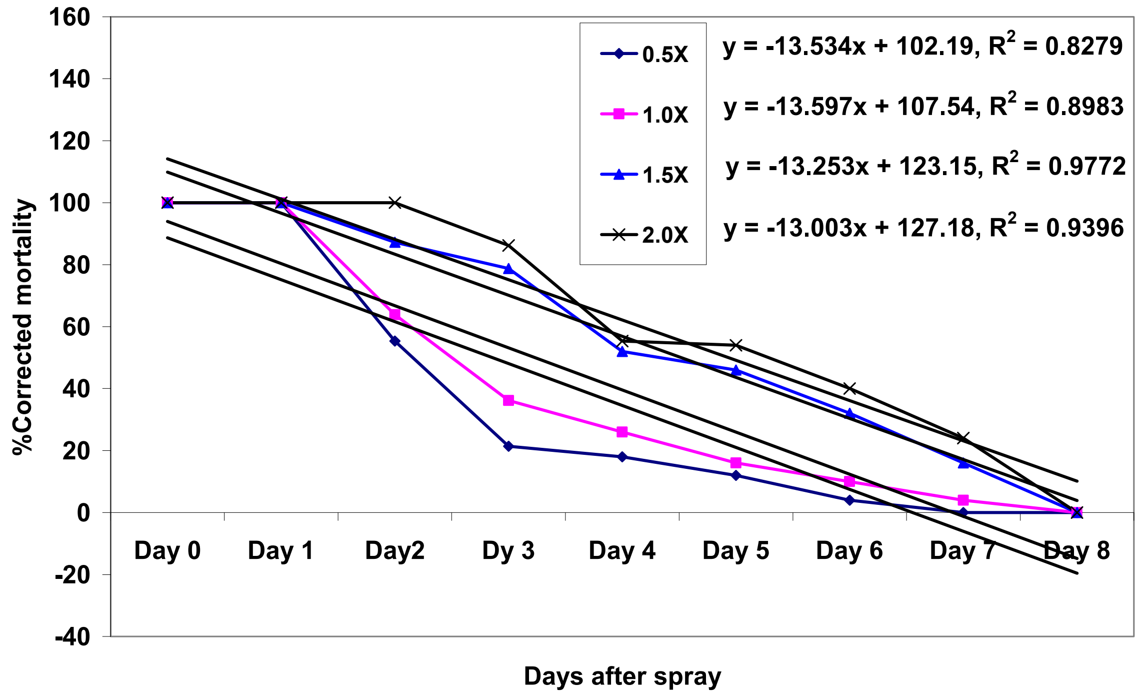

Figure 1. Residue profiles of emamectin benzoate (Proclaim EC-1.9%) applied at four rates (date of field application June, 7, 2013). Biological half lives estimated using fourth instar larvae as indicator for the residual activity (LT_{50}s are estimated to 3.86, 4.23, 5.52 and 5.94day at 50%, 100%, 150% and 200% of the recommended rate, respectively).

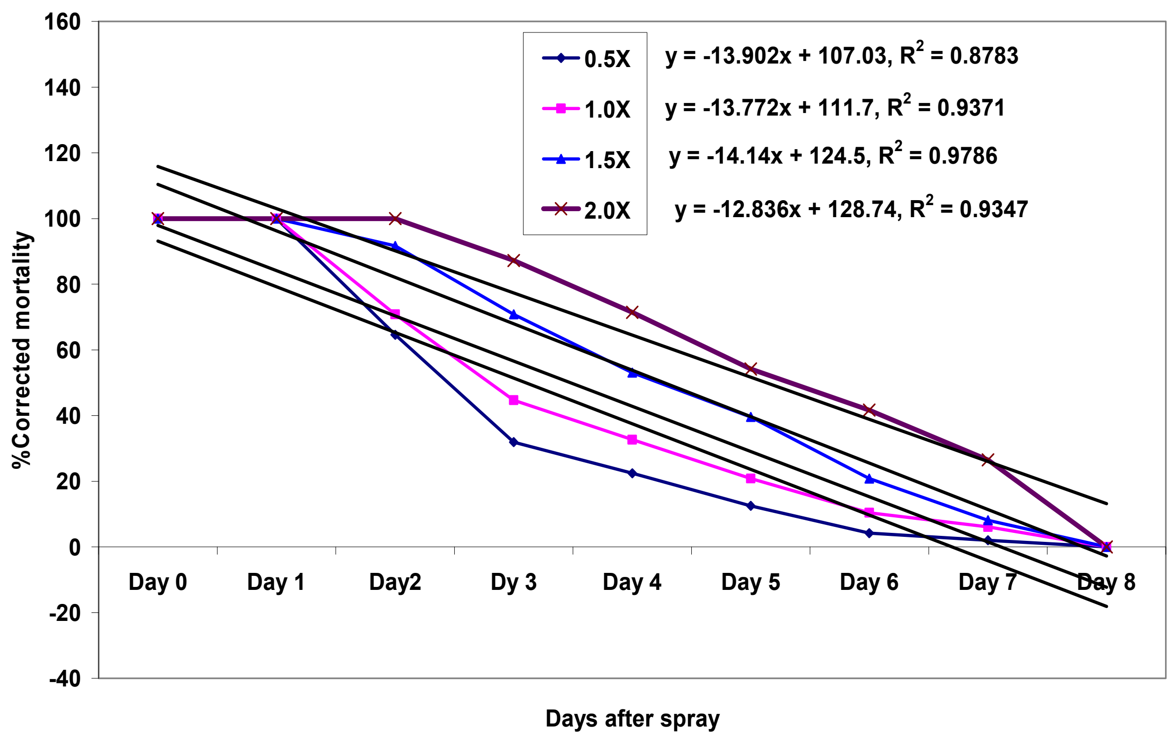

Figure 2. Residue profiles of emamectin benzoate (Proclaim EC-1.9%) applied at four rates (date of field application July 3, 2014). Biological half lives estimated using fourth instar larvae as indicator for the residual activity (LT_{50}s are estimated to be 4.10, 4.48, 5.27 and 6.13day at 50%, 100%, 150% and 200% of the recommended rate, respectively).

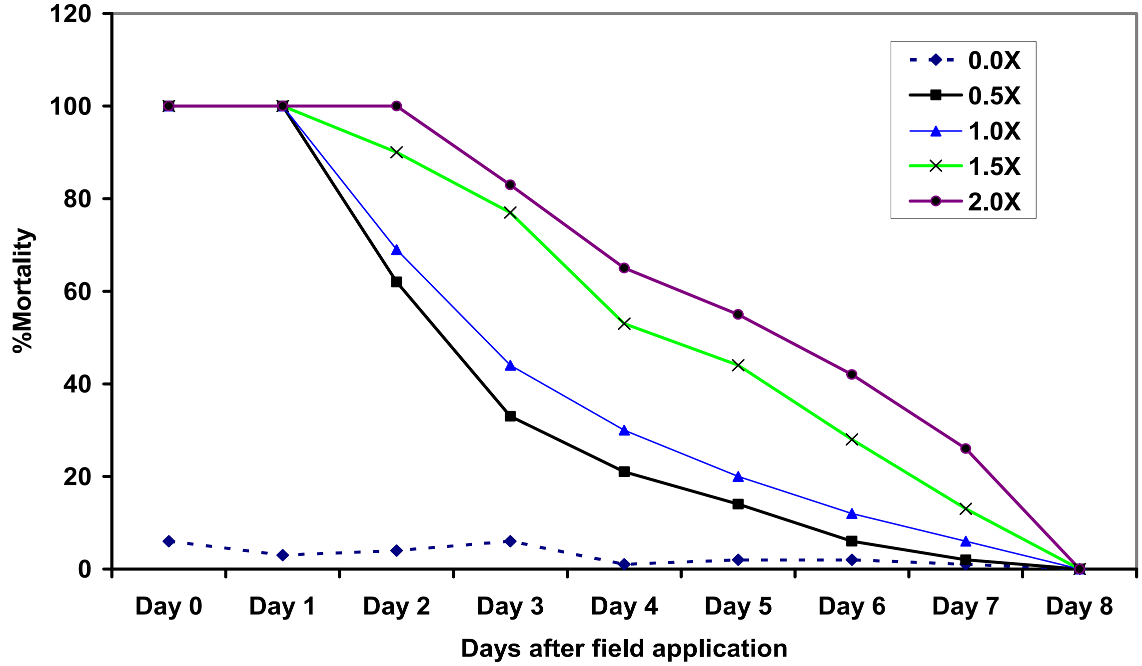

Figure 3A. Mortality percentages (Mean ± SE) at daily intervals after spraying emamectin benzoate different rates on cotton (combined data of the two seasons). X means the recommended rate of field application.

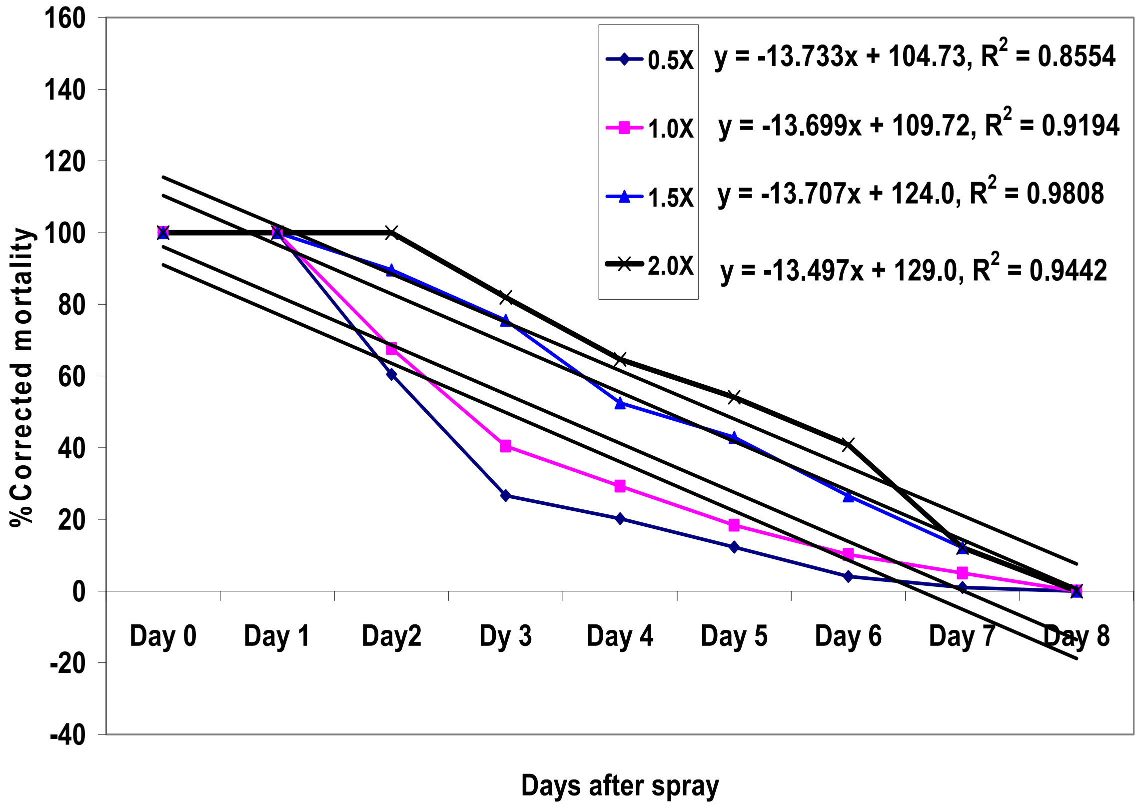

Figure 3B. Biological residue profiles of emamectin benzoate (Proclaim EC-1.9%) applied at four rates (combined data of the two seasons). Biological half lives estimated using fourth instar larvae as indicator for the residual activity (LT_{50}s are estimated to be 3.99, 4.36, 5.39 and 5.85day at 50%, 100%, 150% and 200% of the recommended rate, respectively

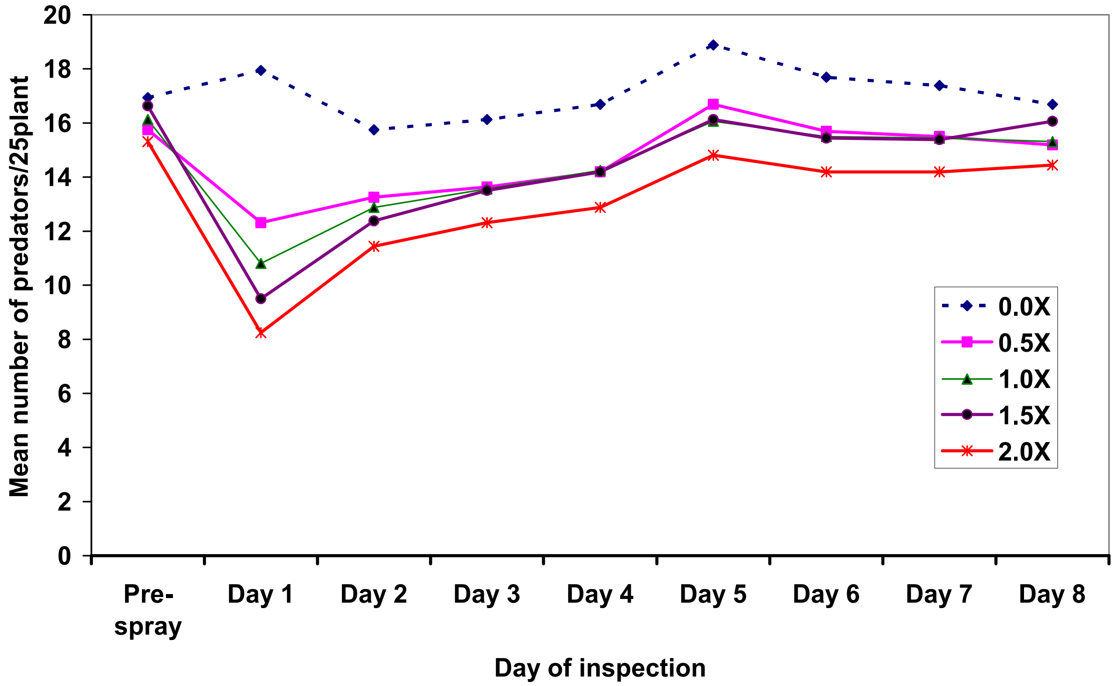

Figure 4. Population density of predators counted just before treatment and at daily intervals post applying emamectin benzoate four rate treatments.

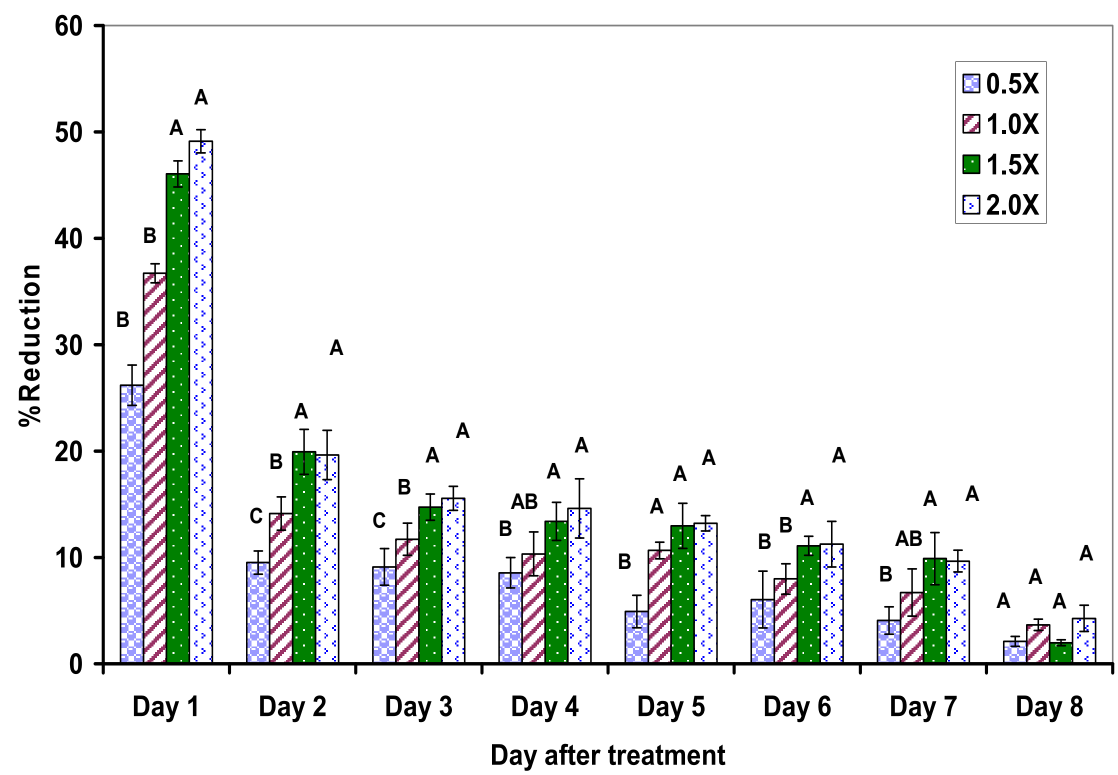

Figure 5. Reduction percentages in predator populations calculated from the counts on 25 plants randomly chosen from each replicate in control and emamectin benzoate different rate treatments (Combined data of the two seasons). For each time interval, bar graphs share at least one litter are not significantly different based on $LSD_{0.05}$ (See Table 9).

Summary

Emamectin benzoate exhibited very short residual activity under Egyptian weather conditions during summer. The advantage of using this chemical is to minimize the post-harvest interval to one week. The half lives of emamectin benzoate (LT_{50}s) were estimated to be 3.86, 4.23, 5.52 and 5.94day at 50%, 100%, 150% and 200% of the recommended rate, respectively). Data of 2014 season confirmed the short residual activities with biological half lives were 4.10, 4.48, 5.27 and 6.13day at 50%, 100%, 150% and 200% of the recommended rate, respectively). However the quick degradation may need repeat the application and increase the control cost. It's more suitable for controlling foliage feeding larvae on vegetable crops because plant tissues will be edible after a short time of application. Its safety on beneficial's increase the possibility of its integration in the pest management strategy.

Acknowledgments

Fund for participating in this conference was completely offered by Minia University, Egypt. A facility for getting the non-immigrant visa was offered by the American Embassy in Cairo.

References

Abdu-Allah, G. A. L. M. 2010. Laboratory and field evaluation of emamectin benzoate and spinetoram on cotton leafworm larvae. Resistant Pest Management Newsletter; 20 (1): 12-16.

Amor, F.; P. Medina; P. Bengochea; M. Canovas; P. Vega; R. Correia; F. Garcia; M. Gomez; F. Budia; E. Vinuela and J. A. Lopez 2012. Effect of emamectin benzoate under semi-field and field conditions on key predatory biological control agents used in vegetable greenhouses. Biocontrol Science and Technology; 22 (2): 219-232.

Borgio, F. J; K. Sahayaraj and I. Alper Susurluk (eds) 2014. Microbial Insecticides: Principles and Applications, Nova Publishers, USA. 492pp. ISBN 978-1-61209-223-2.

Clarke-Harris, D.; S. J. Fleischer; C. Fuller and J. Bolton 2004. Evaluation of the efficacy of new chemistries for controlling major Lepidoptera pests on vegetable amaranth in Jamaica. CARDI Review; 4: 12-19.

Dilbar, H.; M. Akram; Z. Iqbal; A. Ali and M. Saleem 2010. Effect of some insecticides on *Trichogramma chilonis* Ishii. (Trichogrammatidae: Hymenoptera) immature and adult survival. Journal of Agricultural Research (Lahore); 48 (4): 531-537.

Govindan, K.; K. Gunasekaran; S. Kuttalam and K. K. Aiswariya 2011. Bio-efficacy of emamectin benzoate 5 SG against *Helicoverpa armigera* (Hubner) in cotton. Annals of Plant Protection Sciences; 19 (2): 364-368.

Grundy, P. R. 2007. Utilizing the assassin bug, *Pristhesancus plagipennis* (Hemiptera: Reduviidae), as a biological control agent within an integrated pest management programme for *Helicoverpa* spp. (Lepidoptera: Noctuidae) and *Creontiades* spp. (Hemiptera: Miridae) in cotton. Bulletin of Entomological Research; 97 (3): 281-290.

Gupta, Suman and A. K. Dikshit 2010. Biopesticides: An ecofriendly approach for pest control. Journal of Biopesticides 3 (1 Special Issue): 186 – 188.

Henderson, C. F. and E. W. Tilton 1955. Tests with acaricides against the brown wheat mite. J. Econ. Entomol.; 48: 157-161.

Ishaaya, I.; S. Kontsedalov and A. R. Horowitz 2002. Emamectin, a novel insecticide for controlling field crop pests. Pest. Manag. Sci.; 58: 1091–1095.

Kawazu, K.; T. Shimoda and Y. Suzuki 2011. Effects of insecticides on the foraging behaviour and survival of *Cotesia vestalis*, a larval parasitoid of the diamondback moth, *Plutella xylostella*. Journal of Applied Entomology; 135 (9): 647-657.

Khan, R. R.; S. Ahmed and S. Nisar 2011. Mortality responses of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) against some conventional and new chemistry insecticides under laboratory conditions. Pak. Entomol.; 33 (2): 147-150.

Wankhede, S. M. and V. D. Kale 2010. Determination of LT_{50} values of novel insectides against *Leucinodes orbonalis* Guenee. International Journal of Plant Protection; 3 (2): 394-395.

Wankhede, S. M.; V. D. Kale and S. M. Gangurde 2009. Evaluation of bio-efficacy and persistence toxicity of some novel insecticides against larvae of the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. Pest Management and Economic Zoology; 17 (1): 77-83.

Xia, Yaomin; Yanhui Lu; Jun Shen; Xiwu Gao; Hao Qiu and Jianhong Li. 2014. Resistance monitoring for eight insecticides in *Plutella xylostella* in central China. Crop Protection; 63: 131-137.