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Use of Abamectin as An Eco-Friendly Pesticide Against Diamondback Moth on Cabbage Crop

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ABSTRACT: The diamondback moth, *Plutella xylostella*, is the greatest damaging insect of cabbage plants. Two field experiments were conducted at private farm in El-Kattawia area, Abu-Hammad City, Sharkia Governorate, Egypt to assess the effectiveness of abamectin 1.8 EC against cabbage diamondback moth. Two field experiments were performed at the same farm in different seasons (2019 and 2020).The experiments were conducted in a randomized block design with a plot size of 4 x 5 m with three replications. The concerned treatments were enjoined four times at 14 days intervals beginning from the 30th day after cultivation. The pneumatic Knapsack sprayer was used to spray fluid (600 liters per hectare). Observations on larval population were made before spraying and on 3, 7, 10, and 14 days after spraying from 10 randomly tagged plants in each plot. Four doses of abamectin @ 9, 11,13, and 15 g a.i.ha^{-1} were assessed against the *Plutella xylostella* under study. Besides, Cypermethrin 10 EC @ 70 g a.i./ha , endosulfan 35 EC @ 420 g a.i./ha, spinosad 45 SC @ 75 g a.i./ha, and an untreated blank were also included in the field experiment.The findings concluded that treating with abamectin at 15 g a.i./ ha was the highest mean reduction which meaningfully blocked the population of diamondback moth larvae and recorded a mean reduction of 72.5, 70.7, 75.2, and 78.0 percent from untreated check after first, second, third and fourth sprays, respectively. While the results obtained from abamectin at 11 g a.i./ ha were on par with standard check spinosad at 75 g a.i./ha and excelled over cypermethrin and endosulfan. A similar trend was also observed in the second experiment. The yield of cabbage heads also increased significantly at all the doses tested in the two experiments under field conditions as compared to the control plot. The study demonstrates the potentiality of abamectin 1.8 EC as an eco-friendly bioinsecticide against the diamondback moth (*Plutella xylostella)*. The doses of the studied abamectin @ 15, 13, and 11 g a.i.ha^{-1} were found to be highly effective to control the infestation of diamondback moth in the cabbage plants under the conditions of a semi-arid zone in Egypt.

Keywords: Eco-friendy, Abamectin, Diamondback moth, Cabbage, Egypt.

INTRODUCTION

The cabbage plant is an important vegetable crop from the cruciferous group and is widely grown all over Egypt. It is mainly used either as a cooked vegetable or as a raw salad in households and hotels. Among the various insect pests attacking cabbage, diamondback moth (DBM), *Plutella xylostella* L., is the most dreaded pest throughout the world and the annual cost incurred for managing this pest is estimated to be 1 billion USD (Talekar, 1990). A female moth deposits an average of 150 eggs over about 10 days (Capinera, 2018) DBM *Plutella xylostella* (Linn.), a butterfly of the family Plutellidae, is injurious to cruciferous plants. Where cabbages are a major food crop and insecticides are inefficient for control (Diab, 2011). The DBM incidence and damage of DBM are now found to be the most devastating one in Cole crops causing a 52 percent loss in marketable produce and thus assuming the status of national importance (Krishnakumar *et al*., 1986).

Extreme use of insecticides leads to resistance difficulties to these pesticides either individual or multiple (Dara 2020). In the 1990s, the use of synthetic insecticides has eliminated the application of natural insecticides. Nowadays, this insect pest resisted major insecticides viz, BHC and DDT (Dara 2020). Numerous recent pesticides were suggested to manage *Plutella xylostella* L. but the observation showed that 60% of the farmers cannot control this pest effectively (Harika *et al.*, 2019). In the 1980s, there have several new pesticides were produced to reduce *P. xylostella* viz, triazophos, permethrin, fenvalerate, cartop, and methomyl. These insecticides were found to be less active after three to five years of foliar application by the agriculturalists (Fauziah *et al.*, 2012).

Vegetable crops hold residues of a mixture of chemicals since these are sprayed at growth stages of the crop, causing health problems to the customers. As the elimination of chemical pesticides is unviable in the farmers, it has required the use of substitute eco-friendly insecticides for maintainable controlling of diamondback moth which can reduce it to minor pest status by the natural enemies and eco-friendly materials. The change of resistance against these outdated insecticides may be simply degraded by the new group of sustainable compounds to protect the environment (Harika *et al.*, 2019). Keeping because of the seriousness of this pest and the economic importance of the cabbage crop, the current research was conducted to evaluate the effectiveness of the best-known insecticides viz., abamectin, spinosad, cypermethrin, and endosulfan under field conditions of a semi-arid zone at El-Kattawia, Abu-Hammad City, Sharkia Governorate, Egypt against *Plutella xylostella* on cabbage.

MATERIALS AND METHODS

Study site and experiments layout

The research work was done in a semiarid zone of Egypt to assess the effectiveness of abamectin 1.8 EC on the cabbage diamondback moth (*Plutella xylostella* L). The two experiments were carried out on two seasons under field conditions. The field experiments were conducted in a private farm at El-Kattawia area, Abu-Hammad City, Sharkia Governorate, Egypt during the 2019 and 2020 seasons (Fig. 1). The field experiment area is situated between latitudes 30˚ 33' 47" and 30˚ 33' 52" N; and longitude 31˚ 39' 41" and 31˚ 39' 46" E (Fig. 1). In this region, the mean annual rainfall was 55 mm and the mean maximum and minimum temperatures were 31 and 22° C, respectively (Egyptian Meteorological Authority, 2020). The soil texture, pH, and soil salinity (dS/m) were determined using a 1:1 soil/water extract (Jackson, 1973). Soil organic carbon content was carried out using the Walkley-Black method (FAO, 1970) and available macronutrients (N, P, and K) were measured based on the standard methods outlined in Soil Survey Staff (2014). Soils of the farm fields have clay loam texture (moderately fine-textured soils), with pH at 7.9, EC at 0.95 dS/m, 0.95% of organic carbon, 5.59 g kg^{-1} of total nitrogen, 7.27 mg kg^{-1} of available phosphorus, and 105.13 mg kg^{-1} of available potassium. The River Nile water was the source of the irrigation water. The farm ecosystem provides the cabbage plants with the optimum growth requirements (soil, water, and climate) to grow healthily. The experiments were performed in a randomized block design (RBD) with a plot size of 4 x 5 m with three replications.

The treatments in each experiment were as follows:

Treatments	**Pesticides**	**Doses (g a.i./ha)**
T_1	Abamectin1.8 EC	**9**
T_2	Abamectin1.8 EC	**11**
T_3	Abamectin1.8 EC	**13**
T_4	Abamectin 1.8 EC	**15**
T_5	Spinosad 45 SC	**75**
T_6	Cypermethrin 10 EC	**70**
T_7	Endosulfan 35 EC	**420**
T_8	Untreated check	**--**

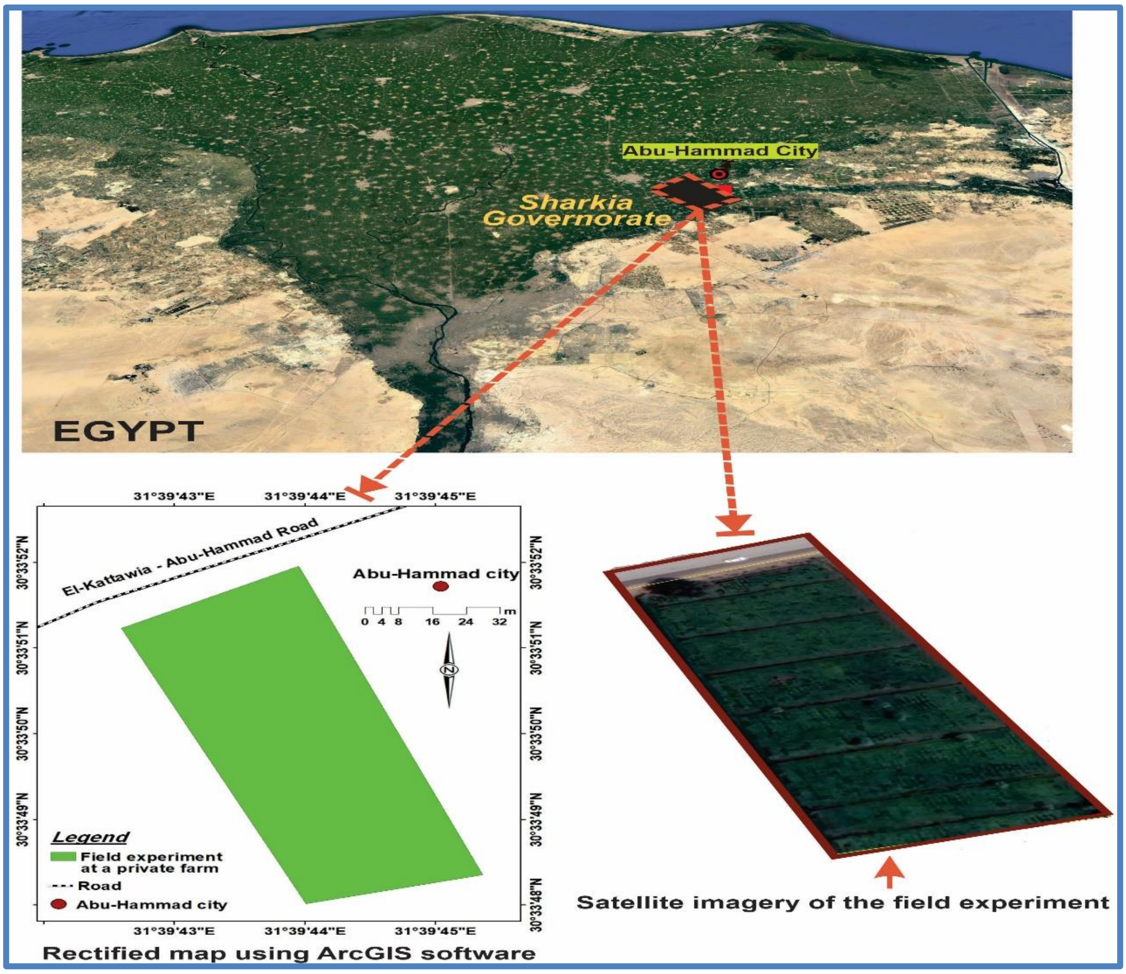

Fig. 1. Location of the field experiments at El-Kattawia area, Abu-Hammad City, Sharkia Governorate, Egypt

The treatments were imposed four times at 14 days intervals commencing from the 30th day after planting with a pneumatic Knapsack sprayer using 600 liters of spray fluid per hectare. The third application was given 21 days after the second spray since the larval population did not cross the Economic Threshold Level ETL 14 days after the second spray in the experiment. Applications were done during morning hours in such a way to give uniform coverage on foliage and to avoid drift and photo-oxidation of the insecticides. Observations on larval population were made before spraying and on 3, 7, 10, and 14 days after spraying from 10 randomly tagged plants in each plot. The cabbage yield was moreover documented throughout the harvest stage.

The analysis of variance was carried out by randomized block design using IRRISTAT ver 3.1. ANOVA was carried out for the field experiment. The percentages data were altered to arcsine percentage. The mean values of treatments were separated using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1976).

RESULTS AND DISCUSSION

Bioefficacy of the studied abamectin against *Plutella xylostella* L.

a) First experiment (Season of 2019)

The findings of the first field experiment of the 2019 season are outlined in Tables 1 and 2. The pretreatment population of DBM varied from 34.5 to 36.6 larvae per 10 cabbage plants. In the studied treatments, the highest value of larval reduction (66.5%) was registered in treated plots at 15 g a.i.ha^{-1} of abamectin followed by 60.0 % at 13 g a.i. ha^{-1} of abamectin and which was in line with cypermethrin 10 EC (58.7 %) on 3 days after treatments (DAT). While on 7 DAT, the doses of abamectin 15 g a.i.ha^{-1} and 13 g a.i.ha^{-1} recorded 84.2% and 79.6% reduction in population, respectively, besides on 14 DAT was 64.1% and 59.2%, respectively as shown in Table.1.

The buildup of the DBM population at 14 DAT necessitated the second spray. The population before treatment ranged between 23.8 and 65.5 per 10 plants. Abamectin 15 g a.i.ha^{-1} registered an 82.4 percent reduction on 7 DAT and the lowest percent reduction was observed in endosulfan 35 EC (42.9 %). Though endosulfan and cypermethrin affected more reduction of DBM population till 3 DAT, all doses of abamectin observed more reduction compared to endosulfan and cypermethrin in the successive days. A similar trend was similarly observed in treated plots on 14 DAT. After the third spray, a significant reduction in the DBM population was observed in all the insecticide treatments. Among them, abamectin at 15 and 11g a.i.ha^{-1} registered 89.2 and 73.5 percent reduction in population on 7 DAT whereas, the same results were obtained by spinosad 45 SC 75 g a.i.ha^{-1} (73.5 %) (Table 2). The same trend of efficacy was observed throughout the study period.

Seven days after the fourth round of spray, abamectin at 15 g a.i./ha documented a 91% reduction in larval population followed by a 13 g a.i.ha^{-1} of abamectin (84.1%). On 10 DAT, abamectin at 9, 11, 13 and 15 g a.i.ha^{-1} caused 61.9, 67.5, 71, and 78.5% reduction, respectively, while endosulfan at 420 g a.i./ha and cypermethrin at 70 g a.i./ha listed 36.5% and 43.4% reduction, respectively. On 14 DAT, abamectin at 15 g a.i./ha itemized 67.9 percent reduction followed by abamectin at13 g a.i./ha(63.4 %) whereas, the standard checks, cypermethrin, and endosulfan recorded 34.9 and 24.0 percent reduction, respectively. A significant reduction in the DBM population was noticed in all the doses of abamectin, which were superior to the standard chemicals *viz.,* cypermethrin 10 EC, endosulfan 35 EC, and spinosad 45 SC as presented in Table 2.

b) The second experiment (Season of 2020)

The pretreatment population ranged from 52.5 to 57.1 larvae per ten plants. There was a significant reduction of DBM larval population after spraying insecticides. The population reductions were higher (63.1 % and 66.9%) in both of abamectin at 13 g a.i.ha^{-1} and 15 g a.i.ha^{-1} on 3 DAT, respectively. These findings agreed with cypermethrin 10 EC (61.5 %). While the foliar spraying of abamectin after 7 days (7 DAT) at 15 and 13 g a.i.ha^{-1} recognized reductions of 83.9% and 82.1%, respectively. Whereas, abamectin at 15 g a.i. ha^{-1} verified a reduction of 62.1% against 57.6% using the dose of 13 g a.i.ha^{-1} on 14 DAT (Table 3).

After the second round of spray, abamectin at 15 g a.i.ha^{-1} registered a maximum of 84.5 percent reduction on 7 DAT and the lowest percent reduction was observed in endosulfan 35 EC (44.8%). Though endosulfan and cypermethrin recorded more percent reduction of DBM population up to 3 DAT, all tested doses of the abamectin increased more reduction compared to the tested doses from cypermethrin and endosulfan in the subsequent days. On 10 DAT, abamectin at 15 g a.i.ha^{-1} reduced to 71.3 % and abamectin at 13 g a.i.ha^{-1} (67.6%). After the third round of spraying, abamectin at 15 and 11g a.i.ha-1 registered 92.2 and 81.2 percent reduction in population on 7 DAT, respectively which was on par with spinosad at 75 g a.i.ha-1 (80.9%). The same trend of effectiveness was recognized up to 14 days after treatments (Table 4). After the fourth round of spray, abamectin at 9, 11, 13 and 15 g a.i.ha-1 caused 62.1%, 70.2%, 77.1% and 86.0% decrease, respectively on 10 DAT. The doses of endosulfan at 420 g a.i.ha^{-1} and cypermethrin at 70 g a.i.ha^{-1} noted reductions of 43.0% and 49.0%, respectively. On 14 DAT, the doses of abamectin at 13 g a.i/ha and 15 g a.i ha^{-1} increased the reductions to 66.5 % and 71.0%, respectively. Whereas, endosulfan and cypermethrin reduced the population to 34.9% and 38.7%, respectively. A major reduction of DBM population was detected in all the treatments of abamectin which was superior to the standard chemicals *viz.*, spinosad 45 SC, cypermethrin 10 EC, and endosulfan 35 EC (Table 4).

The results of the present study conducted on bioefficacy of abamectin against cabbage diamondback moth, in the two experiments are depicted in Figs. 2 and 3. The results of the first experiment revealed that abamectin 15 g a.i./ ha registered the highest mean reduction (72.5, 70.7, 75.2, and 78 percent) of the DBM population from control after first, second, third, and fourth foliar sprayings, respectively. Likewise, abamectin at 11 g a.i./ ha recorded 61.5, 61.8, 63.4 and 66.7 percent, respectively. Abamectin showed a 50 percent reduction in larval population up to 14 DAT even at lower concentrations. Though the mortality was not higher immediately after treatment in abamectin, the damage was significantly reduced as compared to check. This may be due to the feeding of the larvae at different time intervals on treated plants which might have resulted in varying degrees of larval deformities due to reduced food consumption and loss of weight. In the second experiment, abamectin at 15 g a.i./ ha recorded 71.75, 71.33, 79.96 and 80.63% mean reduction of the DBM population from control after first, second, third, and fourth foliar sprayings, respectively, respectively. The bioefficacy trend of abamectin against *P. xylostella* was similar in the two field experiments for all the doses. Abamectin at all concentrations and doses excelled when compared to cypermethrin and endosulfan. The treated plants with abamectin at 15 g a.i./ha have got a reduction in DBM population over control in the range of 84.5 to 92.5 percent in the second field experiment on 7 DAT. This finding showed that abamectin has a remarkable knockdown effect on the DBM larvae, which could be due to the innate nature of abamectin to interfere with chloride ion permeability and GABA receptors and which were well demonstrated by Scott and Dwe (1985). The present findings obtain strength from the report of Murugan and Ramachandran (2000) who reported that Vertimec® 1.8 EC @ 15 g a.i. ha^{-1} recorded 0.25, 0.43, and 0.40 larva per plant on 5 days after first, second and third sprayings, respectively compared to untreated check which recorded 3.55, 3.33, and 2.65 larvae per plant, respectively. Sengonca and Liu (2001) also pinpointed that GCSC- BtA was highly toxic to the third instar of *P. xylostella* with 91.18% mortality followed by abamectin with 78.0%. Agrimec® 1.8 EC on cabbage and cauliflower was the most effective insecticide in controlling DBM and was superior to spinosad, profenofos, lufenuron, and cyhalothrin (Syed *et al*., 2004). Though the mortality was not higher immediately after treatment in abamectin 1.8 EC, the destruction of the studied crop was significantly decreased as compared to the control. This may be due to the feeding of the larvae at various time intervals on treated plants which might have resulted in varying degrees of larval deformities due to reduced food consumption and loss of weight.

Table 1. The larval populations after the first and second rounds of application in the first field experiment (Season of 2019).

Treatments	PTC	Number of larvae per ten cabbage plants								Mean of %R
		Days after treatment (DAT)								
		3		7		10		14		
		No	%R	No	%R	No	%R	No	%R	
a): After the first round of application										
T1	36.0	22.1	47.3^{d} (43.34)	14.3	68.5^{d} (55.86)	21.0	59.2^{d} (50.30)	31.7	51.0^{d} (45.57)	56.5
T2	34.5	18.1	54.2^{c} (47.18)	11.3	73.5^{c} (59.03)	17.0	65.0^{c} (53.73)	28.3	53.5^{c} (47.00)	61.5
T3	35.5	16.5	60.0^{b} (50.36)	9.1	79.6^{b} (62.95)	14.7	71.2^{b} (57.55)	25.9	59.2^{b} (50.13)	67.5
T4	36.6	14.5	66.5^{a} (53.97)	7.4	84.2^{a} (65.97)	13.0	75.2^{a} (60.14)	23.8	64.1^{a} (52.89)	72.5
T5	36.2	18.7	54.0^{c} (47.24)	12.7	72.1^{c} (58.12)	18.0	65.0^{c} (53.73)	30.0	53.6^{c} (47.06)	61.2
T6	36.5	16.5	58.7^{b} (49.84)	20.0	56.4^{e} (48.68)	27.7	46.8^{e} (43.16)	43.3	33.6^{e} (35.42)	48.9
T7	35.1	18.2	53.2^{c} (46.89)	24.0	45.6^{f} (42.48)	32.3	35.4^{f} (36.51)	47.0	25.1^{f} (30.06)	39.8
T8	35.5	39.3		45.0		51.0		65.5		
(b): After the second round of application										
T1	36.0	18.0	49.5^{d} (44.71)	13.0	64.5^{d} (53.43)	13.7	60.4^{d} (51.00)	17.3	51.4^{d} (45.80)	56.5
T2	34.5	14.3	55.0^{c} (47.87)	9.3	71.5^{c} (57.74)	11.0	64.5^{c} (53.43)	14.0	56.1^{c} (48.51)	61.8
T3	35.5	12.3	58.4^{b} (49.84)	6.7	78.1^{b} (62.11)	9.0	68.7^{b} (55.99)	12.0	59.5^{b} (50.48)	66.2
T4	36.6	9.7	64.2^{a} (53.25)	4.0	82.4^{a} (64.91)	7.0	73.3^{a} (58.89)	10.0	63.0^{a} (52.54)	70.7
T5	36.2	15.3	54.6^{c} (47.64)	10.0	71.2^{c} (57.55)	12.0	63.4^{c} (52.77)	15.3	54.7^{c} (47.70)	61.0
T6	36.5	18.0	63.1^{a} (52.60)	25.0	50.1^{e} (45.06)	26.3	44.4^{e} (41.78)	30.0	38.5^{e} (38.35)	49.0
T7	35.1	22.7	57.1^{b} (49.08)	30.8	42.9^{f} (40.98)	31.3	39.1^{f} (38.70)	37.0	30.0^{f} (33.21)	42.3
T8	35.5	72.0		74.0		70.0		72.0		

Explanations: PTC (Pre-treatment count); % R (Percent reduction from control); Parentheses are arcsine of the square root of percent transformed values; the values followed by a lowercase character(s) aren't significantly different by DMRT(at 0.05 level)

Table 2. The larval population of *P. xylostella* after the third and fourth rounds of application in the first field experiment of the 2019 season.

Treatments	PTC (21 DAIIT)	Number of larvae per ten cabbage plants								
		Days after treatment (DAT)								
		3		7		10		14		Mean of %R
		No	%R	No	%R	No	%R	No	%R	
(a): After the third round of application										
T1	37.0	14.7	55.4^{e} (48.10)	11.0	68.5^{d} (55.86)	15.7	59.9^{d} (50.71)	25.7	44.4^{d} (41.78)	57.2
T2	35.0	11.0	64.6^{c} (53.49)	8.5	73.5^{c} (59.22)	12.7	65.7^{c} (54.16)	22.0	49.7^{c} (44.83)	63.4
T3	33.7	9.0	69.9^{b} (56.73)	6.0	81.1^{b} (64.25)	11.0	69.0^{b} (56.17)	19.7	53.2^{b} (46.84)	68.3
T4	36.3	7.3	77.4^{a} (61.62)	3.0	89.2^{a} (70.03)	10.0	73.9^{a} (59.28)	18.0	60.3^{a} (50.95)	75.2
T5	35.3	11.3	64.0^{c} (53.13)	8.5	73.5^{c} (58.70)	13.0	65.1^{c} (53.79)	22.7	48.6^{c} (44.20)	62.8
T6	36.0	13.0	59.4^{d} (50.42)	16.3	52.0^{e} (46.15)	21.0	44.7^{e} (41.96)	29.0	35.6^{e} (36.63)	48.0
T7	34.7	14.0	54.6^{e} (47.64)	18.3	44.1^{f} (41.61)	23.3	36.3^{f} (37.05)	31.0	28.5^{f} (32.26)	41.0
T8	36.0	32.0		34.0		38.0		45.0		
(b): After the fourth round of application										
T1	37.0	13.0	53.3^{d} (46.89)	9.0	71.3^{d} (57.61)	12.6	61.9^{d} (52.18)	16.0	54.1^{d} (47.35)	61.2
T2	35.0	9.7	59.3^{c} (50.36)	5.3	80.3^{c} (63.67)	8.9	67.5^{c} (55.50)	12.0	59.8^{c} (50.66)	66.7
T3	33.7	8.3	61.1b^{c} (51.42)	3.5	84.1^{b} (65.98)	7.1	71.0^{b} (57.36)	9.5	63.4^{b} (52.95)	70.0
T4	36.3	5.0	74.3^{a} (59.55)	1.5	91.0^{a} (72.48)	4.9	78.5^{a} (62.18)	7.5	67.9^{a} (55.06)	78.0
T5	35.3	10.0	59.3^{c} (50.36)	5.3	80.9^{c} (64.10)	9.9	66.5^{c} (54.58)	12.3	60.0^{c} (50.77)	66.7
T6	36.0	12.0	61.8^{b} (51.83)	16.7	52.9^{e} (46.66)	20.8	43.4^{e} (41.03)	26.0	34.9^{e} (36.63)	55.8
T7	34.7	15.0	55.3^{d} (48.04)	18.7	50.6^{e} (45.34)	24.0	36.5^{f} (37.28)	33.1	24.0^{f} (29.19)	49.9
T8	36.0	48.7		55.0		57.3		61.0		

Explanations: PTC (Pre-treatment count); DAIIT (Days after second treatment); % R- Percent reduction from control; Lowercase letters aren't significantly at P=0.05.

Table 3. The number of diamondback moth's larvae after the first and second rounds of application in the second field experiment (Season of 2020).

Treatments	Number of larvae per ten cabbage plants									
	PTC	Days after treatment (DAT)								Mean of %R
		3		7		10		14		
		No	%R	No	%R	No	%R	No	%R	
(a): After the first round of application										
T1	57.1	31.0	52.9^{d} (46.66)	22.3	71.4^{d} (57.68)	34.7	60.4^{d} (51.00)	50.0	49.9^{d} (44.94)	58.65
T2	54.0	27.3	56.7^{c} (48.85)	18.7	75.0^{c} (60.01)	28.7	65.8^{c} (54.22)	45.7	52.3^{c} (46.32)	62.45
T3	52.5	24.0	63.1^{b} (52.54)	13.7	82.1^{b} (64.47)	24.0	70.9^{b} (57.36)	40.0	57.6^{b} (49.26)	68.42
T4	54.7	21.0	66.9^{a} (55.06)	12.0	83.9^{a} (66.59)	22.0	74.1^{a} (59.41)	37.0	62.1^{a} (51.83)	71.75
T5	55.7	28.3	56.5^{c} (48.74)	20.0	74.1^{c} (59.41)	30.0	65.3^{c} (53.91)	48.3	51.0^{cd} (45.57)	61.73
T6	54.7	23.7	61.5^{b} (51.53)	31.0	59.1^{e} (50.25)	43.3	49.0^{e} (44.43)	64.3	33.6^{e} (35.42)	50.80
T7	53.7	26.7	57.5^{c} (49.31)	38.0	48.9^{f} (44.37)	55.0	34.1^{f} (35.73)	72.0	24.3^{f} (29.53)	41.2
T8	55.3	64.7		76.7		86.0		98.0		
(b): After the second round of application										
T1	57.1	22.0	58.5^{e} (49.90)	18.0	68.5^{d} (55.86)	22.0	58.0^{d} (49.61)	24.0	45.5^{d} (42.42)	57.63
T2	54.0	18.0	62.9^{c} (52.48)	14.0	73.2^{c} (58.83)	17.3	63.8^{c} (53.02)	19.0	52.8^{c} (46.61)	63.18
T3	52.5	14.7	65.4^{b} (53.97)	9.0	80.3^{b} (63.66)	13.7	67.6^{b} (55.13)	15.3	56.5^{b} (48.74)	67.45
T4	54.7	12.0	69.4^{a} (56.42)	6.7	84.5^{a} (66.59)	11.3	71.3^{a} (57.30)	13.0	60.1^{a} (50.83)	71.33
T5	55.7	19.7	61.6^{cd} (51.71)	15.3	72.3^{c} (58.25)	18.7	63.0^{c} (52.54)	20.7	51.3^{c} (45.75)	62.05
T6	54.7	27.0	60.5^{d} (51.06)	32.0	56.5^{e} (48.74)	35.3	47.6^{e} (43.62)	38.0.	32.9^{e} (35.00)	49.38
T7	53.7	33.0	56.8^{e} (48.91)	44.7	44.8^{f} (42.53)	46.7	38.1^{f} (38.11)	49.3	22.3^{f} (28.17)	40.50
T8	55.3	104.0		112.0		102.7		86.3		

<u>Explanations:</u> PTC (Pre-treatment count); DAIIT (Days after second treatment); % R- Percent reduction from control; Lowercase letters aren't significantly at P=0.05.

Table 4. Number of *P. xylostella's* larvae after the third and fourth round of application in the second field experiment of 2020 season.

Treatments	Number of larvae per ten cabbage plants									
	PTC (21DAIIT)	Days after treatment (DAT)								Mean of %R
		3	7		10		14			
		No	%R	No	%R	No	%R	No	%R	
(a): After the third round of application										
T1	55.3	23.0	59.9^{e} (50.71)	14.0	76.4^{d} (60.94)	21.0	65.7^{d} (54.15)	28.0	55.2^{d} (47.99)	64.3
T2	53.7	18.	67.6^{c} (55.31)	11.0	81.2^{c} (64.11)	17.3	70.9^{c} (57.36)	23.7	60.9^{c} (51.30)	70.08
T3	52.7	13.	74.9^{b} (59.94)	7.0	87.6^{b} (69.41)	15.0	74.3^{b} (59.55)	21.0	64.7^{b} (53.55)	75.38
T4	54.0	11.	80.3^{a} (63.66)	5.0	92.5^{a} (72.99)	12.0	79.9^{a} (63.37)	20.0	67.2^{a} (55.06)	79.96
T5	59.0	19.	67.8^{c} (55.43)	12.3	80.9^{c} (63.80)	20.0	69.4^{c} (56.42)	26.0	61.0^{c} (51.36)	69.78
T6	54.0	21.0	62.5^{d} (52.24)	26.0	55.1^{e} (47.93)	34.0	43.1^{e} (41.03)	38.0	37.7^{e} (37.88)	49.6
T7	55.3	24.	58.1^{e} (49.66)	30.0	49.4^{f} (44.66)	38.7	36.8^{f} (37.34)	42.0	32.8^{f} (34.94)	44.28
T8	56.0	58.0		60.0		62.7		63.3		
(b): After the fourth round of application										
T1	55.3	10.3	63.6^{d} (52.89)	8.7	69.6^{d} (56.54)	11.0	62.1^{d} (51.77)	12.3	57.2^{d} (49.14)	63.13
T2	53.7	8.0	66.6^{c} (54.70)	5.3	78.1^{c} (62.11)	7.3	70.2^{c} (56.80)	9.0	63.0^{c} (52.54)	69.48
T3	52.7	6.3	70.3^{b} (56.98)	3.3	84.6^{b} (66.92)	5.0	77.1^{b} (61.22)	7.3	66.5^{b} (54.40)	74.63
T4	54.0	5.0	75.3^{a} (60.21)	2.0	90.2^{a} (71.79)	3.0	86.0^{a} (67.56)	6.0	71.0^{a} (57.30)	80.63
T5	59.0	9.0	65.8^{c} (54.21)	5.7	78.6^{c} (62.45)	7.7	71.2^{c} (57.55)	10.0	62.5^{c} (52.24)	69.53
T6	54.0	14.3	62.8^{d} (52.42)	19.0	51.1^{e} (45.63)	20.0	49.0^{e} (44.25)	24.0	38.7^{e} (38.35)	50.40
T7	55.3	19.	54.6^{e} (47.64)	23.0	46.4^{f} (42.94)	24.7	43.0^{f} (40.80)	28.0	34.9^{f} (36.33)	45.18
T8	56.0	64.0		64.7		65.0		65.0		

Explanations: PTC (Pre-treatment count); DAIIT (Days after second treatment); % R- Percent reduction from control; Lowercase letters aren't significantly at P=0.05.

The present findings are by following the reports of Rui (2001) who found that the effect of abamectin was lesser one day after application, but rapidly increased three days after application. However, on 7 DAT, abamectin (1.5 %) + Bt WP at a dilution rate of 1:750 and 1500 and abamectin (0.9 % EC) at a dilution rate of 1:3000 showed 90.9 percent control of DBM. These results were also found by Yan *et al.* (2001), Elzen and James (2002), Pramanik and Chatterjee (2003), and Sawant and Patil (2017) who have reported the effectiveness of abamectin against the diamondback moth.

The treated cabbage plants with spinosad were in line with abamectin at 11 g a.i./ ha throughout the study period in the experiments. Spinosad registered 72.1, 71.2, 73.0, and 80.9% reduction in the population of DBM across the first, second, third, and fourth spray application in the first experiment on 7 DAT, respectively. The same trend of efficacy was seen in the second experiment also (Figs. 2 and 3). The obtained data approves the findings of Walunj *et al*. (2001) who found that spinosad 2.5 % SC at the doses of 12.5, 15, and 17.5 g a.i./ ha on cabbage resulted in the lowest larval population of 0.47 to 2.27 larvae plant^{-1} as against 5.3 to 6.73 larvae plant^{-1} in the control. The efficacy of spinosad against DBM has been stated by Yan *et al*. (2001), and Syed *et al*. (2004). Vaseem*et al.*, 2014, Stanikzi and Thakur, 2016, Reddy *et al.*, 2017, and Sharma *et al.*, 2017.

The treated plant with Cypermethrin registered a maximum reduction in larval population (58.4, 63.1, 59.4, and 61.8%) while the plants treated with endosulfan recorded 3.3, 57.1, 54.6, and 55.3 percent from untreated check after the first, second, third, and fourth spray, respectively in the first experiment on 3 DAT. Thereafter, the efficacy was drastically reduced in these treatments. The same trend of efficacy was observed in the second experiment too. The present findings agree with the reports of Walunj *et al*. (2001), Umashankar and Raju (2002), Sakthi *et al*. (2003), Bhavani and Punnaiah (2004), Chandrasekhar and Marutiram (2004), and Ojha *et al*. (2004) who reported moderate control of DBM was obtained with cypermethrin and endosulfan. Legwaila *et al. (*2014) showed that cypermethrin can still be used to achieve effective control of DBM eggs and larvae.

Effects on Yield

a) First experiment (Season of 2019).

The highest yield (37.6 tonnes/ha) of marketable cabbage heads with an increase of 60 % was obtained with abamectin at 15 g a.i./ha over the untreated check. Abamectin at 11 g a.i./ ha recorded 34.3 tonnes/ha, which was on par with spinosad at 75 g a.i./ ha (34.0 tonnes/ha), whereas the control treatment registered the lowest yield of 23.5 tonnes/ ha (Table 5; Fig. 4).

b) Second experiment (Season of 2020).

The highest yield of 37.7 tonnes/ ha of marketable cabbage was realized in abamectin 15 g a.i/.ha followed by abamectin at 13 g a.i./ha (36.6 tonnes/ ha). abamectin at 11 g a.i./ha registered 35.4 tonnes/ha, which was agreed with the obtained yield (35 tonnes/ ha) by 75 g a.i./ha of spinosad, while cypermethrin 10 EC at 70 g a.i./ha and endosulfan 35 EC at 420 g a.i./ha registered 31.6 and 30.8 tonnes /ha, respectively (Fig.4). The control check verified the lowest yield of 25.0 tonnes/ ha (Table 5).

An increase in the yields of marketable cabbage heads was recorded in all the abamectin treatments which ranged from 33.2 to 37.6 tonnes/ ha and 33.6 to 37.7 tonnes /ha in the first and second experiments, respectively while the untreated check recorded 23.5 and 25.0 tonnes /ha, respectively (Fig. 4). It is therefore concluded that abamectin at 11, 13, and 15, g a.i./ha was more operative and effective against *P. xylostellla* and these results conform with the earlier results of Murugan and Ramachandran (2000) who found that Vertimec®1.8 EC @ 15 and 20 g a.i./ha recorded 51 and 52 tonnes /ha of marketable cabbage heads, respectively while the control treatment registered 33 tonnes per ha of yield. Spinosad 45 SC at 75 g a.i./ ha recorded 34 and 35 tonnes/ ha in the first and second field experiments, respectively (Fig.4). This was in agreement with the findings of Walunj *et al.* (2001) that spinosad 2.5 SC at 15 g a.i.ha-1 recorded 58.12 tonnes/ ha.

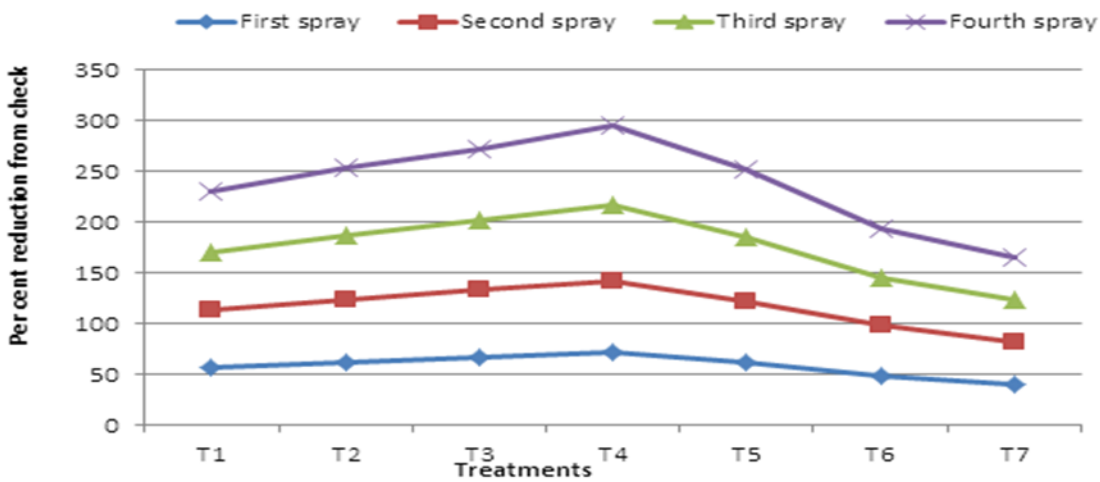

Fig. 2. Effect of abamectin 1.8 EC on the larval population of Plutella xylostella L. on cabbage in the first experiment (Season of 2019).

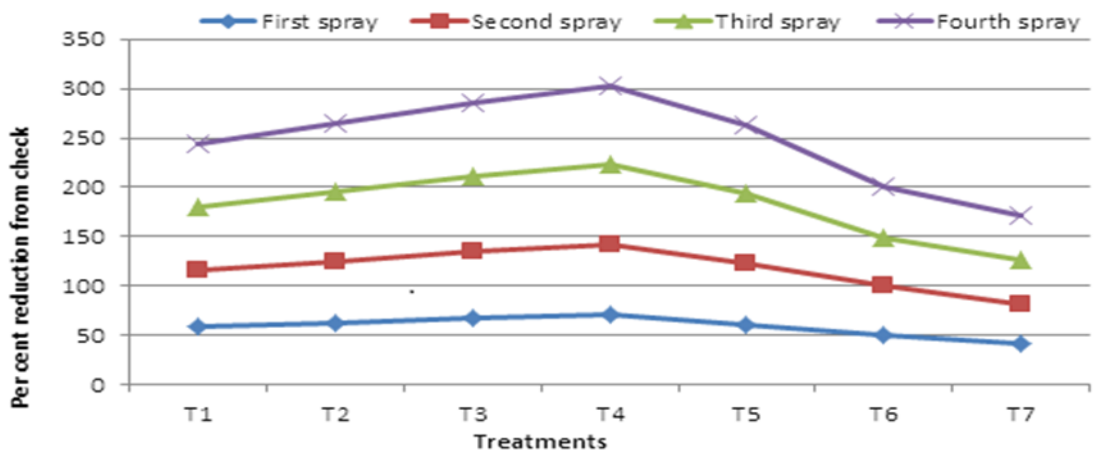

Fig. 3. Effect of abamectin 1.8 EC on the larval population of P. xylostellaon cabbage based on the second experiment (Season of 2020).

Table 5. Effect of abamectin 1.8 EC on cabbage yield in the two field experiments.

Treatments	Yield in the first experiment			Yield in the second experiment		
	Kg $plot^{-1}$	Tonnes ha^{-1}	Percent increase over control	Kg $plot^{-1}$	Tonnes ha^{-1}	Percent increase over control
T1	66.4^{cd}	33.2	35.1	67.2^{cd}	33.6	34.4
T2	68.6^{bc}	34.3	45.9	70.8^{abc}	35.4	41.6
T3	71.0^{ab}	35.5	51.1	73.2^{ab}	36.6	46.4
T4	75.2^{a}	37.6	60.0	75.4^{a}	37.7	50.8
T5	68.0^{bc}	34.0	44.7	70.0^{bc}	35.0	40.0
T6	63.6^{cd}	31.8	35.3	63.2^{de}	31.6	26.4
T7	62.0^{d}	31.0	31.9	61.6^{ef}	30.8	23.2
T8	47.0^{e}	23.5	-	50.0^{f}	25.0	-

Explanation: Lowercase letter(s) followed the mean values aren't significantly different by DMRT at P=0.05 level.

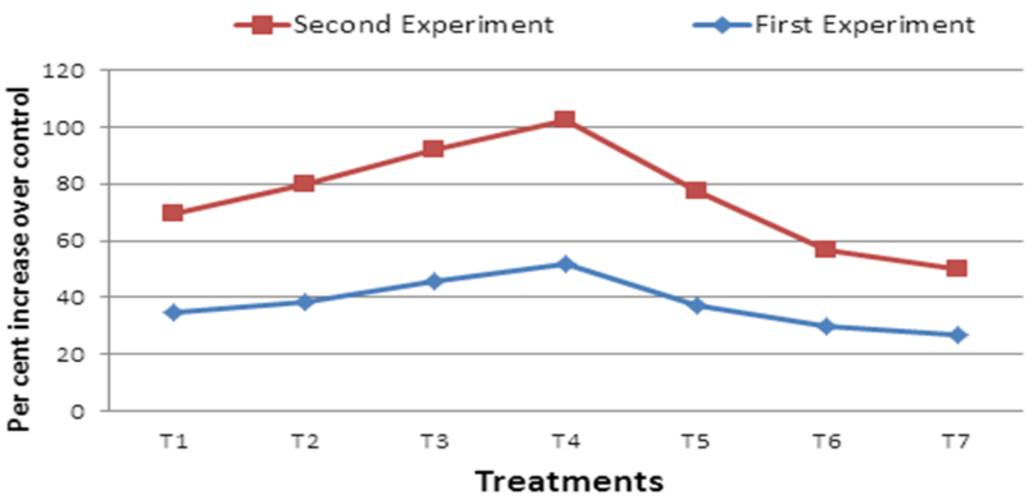

Fig. 4. The increase over control of abamectin 1.8 EC treatments in cabbage yield in the two experiments (Seasons of 2019 and 2020).

CONCLUSION

Two field experiments in different seasons were conducted at El-Kattawia area, Sharkia Governorate, Egypt to evaluate the bioefficacy of abamectin 1.8 EC against cabbage diamondback moth (*Plutella xylostella* L). The results of the experiment revealed that abamectin at 15 g a.i./ ha registered the highest mean reduction of 772.5, 70.7, 75.2, and 78.0 percent of diamondback moth population from untreated check after first, second, third, and fourth sprays, respectively. But, abamectin at 11 g a.i./ ha also significantly suppressed the population of diamondback moth larvae and recorded a mean reduction of 61.5, 61.8, 63.4, and 66.7 percent from untreated check after first, second, third, and four rounds of sprays, respectively and was on par with standard check spinosad 75 g a.i./ha and excelled over cypermethrin and endosulfan. A similar trend was also observed in the second experiment. Abamectin resulted in increased cabbage yield at all the doses tested in the experiments. The effective order of relative efficacy was 15 >13 > 11 g a.i./ha of abamectin1.8 EC ≥ 75 g a.i./ha of spinosad 45 SC > 9 g a.i./ha of abamectin >70 g a.i./ha of cypermethrin 10 EC > 420 g a.i./ha of endosulfan 35 EC. The field experiments presented a highly positive eco-friendly method of abamectin 1.8 EC at suggested doses to manage the diamondback moth under a semi-arid zone in Egypt.

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الملخص العربي

استخدام الأبامكتين كأحد المُبيدات الصديقة للبيئة لمُكافحة الفراشة ذات الظهر الماسي على محصول الكرنب

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تعتبر الفراشة ذات الظهر الماسي Diamondback Moth من أكثر الآفات تدميراً لمحصول الكرنب Cabbage crop في جمهورية مصر العربية. إستهدف البحث تقييم الفاعلية الحيوية Bioefficiency لمكون الأبامكتين Abamectin 1.8 EC كمبيد صديق للبيئة Eco-friendly pesticide ضد الفراشة ذات الظهر الماسي على محصول الكرنب. تم إجراء بعض التحليلات المعملية الخاصة بالتربة التي أستخدمت في التجارب الحقلية للتعرف على بعض صفاتها الطبيعية والكيميائية وذلك بالتكامل مع الإحتياجات المناخية والمائية لمحصول الكرنب تحت الدراسة؛ من أجل التأكيد على توفير البيئة المناسبة والإحتياجات الأساسية لتغذية ونمو نباتات الكرنب بشكل مثالي؛ وذلك للحصول على نتائج عالية الدقة عند تنفيذ التجارب الحقلية. لذا فقد تم إجراء الدراسات الحقلية على مدار موسمين متتاليين لعامي 2019 و 2020 بإحدى المزارع الخاصة بمنطقة القطاوية، مدينة أبو حماد، محافظة الشرقية تماشيا مع الظروف الحقلية الطبيعة كنموذج ممثل لبعض المناطق شبه الجافة بشرق الدلتا. تم إستخدام عدد من المُبيدات المختلفة للوقوف على مدى كفاءة مبيد الأبامكتين من خلال إجراء المعاملات التالية لكلا من التجربتين، على الصورة التالية: مبيد الأبامكتين (Abamectin 1.8 EC) بواقع اربع تركيزات (9 ، 11، 13و 15 جم مادة فعالة/هكتار)، مبيد الأسبينوساد (Spinosad 45 SC) بتركيز 75 جم مادة فعالة/هكتار، مبيد السيبرمثرين (Cypermethrin 10) بمعدل 70 جم مادة فعالة/ هكتار، وأخيرا مبيد الاندوسولفان (Endosulfan 35 EC) بتركيز 420 جم مادة فعالة/ هكتار، بالاضافة إلى معاملة الكنترول (القطعة غير المعاملة) وذلك للمقارنة بين نتائج كافة المعاملات في كلتا التجربتين. اظهرت النتائج المتحصل عليها أن إستخدام مبيد الأبامكتين عند تركيز 15 جم مادة فعالة/ هكتار سجل أعلى معدل انخفاض ليرقات الفراشة ذات الظهر الماسي بمحصول الكرنب بشكل ملحوظ في كلا الموسمين حيث كان متوسط معدل الانخفاض كالتالي: 72.5 ، 70.7 ، 75.2 و 78.0 % بعد المعاملات الأولى، الثانية، الثالثة، والرابعة، على التوالي. في حين أظهرت النتائج المتحصل عليها من المعاملة بمبيد الأبامكتين بتركيز 11 جم مادة فعالة/ هكتار كانت تقريباً متشابهة مع نتائج المعاملة بمبيد الأسبينوساد بتركيز 75 جم مادة فعالة/ هكتار وذلك مقارنةً مع نتائج المعاملتين لكل من مبيد السيبرمثرين ومبيد الإندوسلفان. كما زاد محصول رؤوس الكرنب Yield بشكل ملحوظ في جميع الجرعات المُختبرة في كلا التجربتين تحت الظروف الحقلية للمناطق شبه الجافة. وبمقارنة نتائج التجربة الأولى لموسم عام 2019 مع نتائج التجربة لموسم 2020؛ فقد تم الحصول على نتائج مماثلة للتجربة الأولى بالتي أجريت عام 2020 مما أكد صحة ودقة النتائج المتحصل عليها. ولُخصت نتائج فعالية Effectiveness المُبيدات المُستخدمة في التجارب الحقلية تحت الدراسة، وفقاً للترتيب التالي (حيث الأكثر كفاءة وفعالية More effectiveness إلى الأقل فعاليةLess effectiveness): الجرعات 11، 13، و15 جم مادة فعالة/هكتار من الابامكتين > 75 جم مادة فعالة/ هكتار من مبيد الاسبينوساد > 9 جم مادة فعالة/هكتار من مبيد الابامكتين > 70 جم مادة فعالة/ هكتار من مبيد السيبرمثرين > 420 جم مادة فعالة/ هكتار من مبيد الاندوسولفان. ووفقا لما تم الحصول عليه من نتائج لهذه الدراسة؛ فقد نوصي باستخدام مبيد الأباميكتين بتركيزاته الأكثر فاعلية وهي 11، 13 و 15 جم مادة فعالة/هكتار لمكافحة الفراشة ذات الظهر الماسي على محصول الكرنب بطريقة فعالة وآمنة، واعتباره أحد المُبيدات صديقة للبيئة والتي يمكن استخدامها ضمن برامج المكافحة المتكاملة والمُستدامة لمحاصيل الخضر وخاصة الكرنب.