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Evaluating the Efficacy of Insecticides in Managing the Egyptian Cotton Leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) Infestation and Their Impact on Associated Predator Populations in Sugar Beet Fields"

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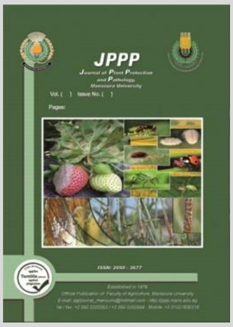

ABSTRACT

The cotton leafworm, *Spodoptera littoralis*, poses a serious threat by infesting sugar beet crops and causing significant economic losses. This study aimed to assess the effectiveness of three insecticides, the Chlorfenapyr compound, Lambda-cyhalothrin, and Methoxyfenozide - in managing early *S. littoralis* infestations in sugar beet fields across two growing seasons (2021-2022). The research evaluated the impact of the tested compounds on both the target pest and associated arthropod predator populations. The tested insecticides led to substantial reductions in *S. littoralis* larval population density. Notably, Lambda-cyhalothrin achieved a rapid 77.25% reduction within one day. Reductions of 92.33% to 97.61% occurred after seven and ten days, respectively. Cumulatively, larval population reductions recorded varied from 88% to 90% over both seasons. Assessing the impact on associated predator populations, *C. Carnae* (larvae), *Scymnus spp*, and formicides (adults) revealed unexpected declines in predator populations immediately after the Chlorfenapyr compound and Methoxyfenozide application. However, predator resilience was evident, with over 50% recovery within three days. Lambda-cyhalothrin showed a balance between pest reduction and predator preservation, though some predators were inadvertently eradicated.This study underscores the potential of tested insecticides for controlling *S. littoralis* in sugar beet fields. The varying effects on predator populations call for a balanced approach that considers pest management and predator preservation. Further research is needed to gauge the long-term ecological consequences and develop strategies ensuring effective pest control without disrupting predator populations. Ultimately, this study contributes valuable insights into sustainable pest management and ecosystem balance in agriculture.

Keywords: field, *S. littoralis*, Sugar beet, predators.

INTRODUCTION

The lepidopterous sugar beet insects is the most significant hazard to the sugar industry in Egypt. The control programs for *S. littoralis* primarily depend on the extensive use of traditional insecticides, which can lead to adverse consequences for the environment, non-target organisms, and beneficial insects, as well as the development of resistance and multiple resistances so it is essential to enhance the efficiency of pest control strategies. (USDA, 2022, Fergani *et al*., 2022). Efforts to manage this pest are primarily concentrated on exploring novel approaches that incorporate biological and ecological characteristics. One of these approaches involves utilizing recently developed insecticides like chlorfenapyr and Methoxyfenozide. Chlorfenapyr (arylpyrrole derivative) is a compound commonly used as an insecticide due to its broad-spectrum activity against a wide range of insects including *S. littoralis*. It belongs to the class of pyrroles and exhibits a unique mode of action by disrupting the energy production process leading to the eventual death of target pests (EPA, 2001). Another advantage of Chlorfenapyr is its residual activity with low mammalian toxicity, which means it remains effective for an extended period even after application. This property can provide long-lasting control of pests, reducing the need for frequent reapplications additionally; it is classified by the WHO as a slightly hazardous insecticide due to its unique mode of action (Tomlin, 2000).

Methoxyfenozide is effective against a wide range of insect pests, including *S. littoralis*, which can cause significant damage to crops. It disrupts the insect's hormonal balance, ultimately preventing them from reaching their next developmental stage. Insect Growth regulators (IGRs) such as Methoxyfenozide with novel mode of action is a valuable tool in pest management due to its effectiveness, and relatively low environmental impact (Pineda *et al.,* 2009). In addition to its selective action, that primarily affects the targeted pests while having minimal impact on beneficial insects, such as pollinators and predators. This makes it a favourable choice for integrated pest management strategies. Additionally, Methoxyfenozide has low toxicity to mammals and poses a reduced risk to the environment compared to some other insecticides (Schneider *et al.,* 2008). Lambda-cyhalothrin is a widely used insecticide that belongs to the class of synthetic pyrethroids. It is known for its effectiveness in controlling a broad range of insects, rapid knockdown effect and long residual activity. It acts by targeting the nervous system of insects, disrupting their normal functioning and ultimately leading to their demise. While pyrethroids such as cyhalothrin, Lambda-cyhalothrin is an effective tool in managing *S. littoralis* due to their cost-effectiveness and extended duration of action, compared to natural pyrethrins it is important to note that it can also impact non-target organisms (Maia *et al*., 2016).

The extensive utilization of conventional insecticides requires employing diverse insecticide options for pest control.

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Dependent on the ongoing rotation of multiple insecticides to prolong and uphold their efficiency has resulted in a range of issues. These encompass contamination of the environment, reduction in populations of natural predators and advantageous insects, and the emergence of insects that are resistant to particular insecticides. (Mosallanejad and Smagghe, 2009).

The red-flanked ladybird *Scymnus interruptus* Goeze, Coleoptera (Coccinellidae, Staphylinidae), the green lacewings (*Chrysoperla carnea* Stephens) (Neuroptera: Chrysopidae), and certain predatory ant species (Hymenoptera: Formicidae) are significant predators associated with sugar beet pests. They exhibit polyphagous feeding behaviour, effectively controlling various insect pests, including *S. littoralis* (Hegazy, 2018). In integrated pest management, a crucial aspect is evaluating the vulnerability of these predators to both conventional and organic pest control approaches.

Therefore, this study aimed mainly to examine the effects of the synthetic Pyrethroids Lambda-cyhalothrin, Methoxyfenozide and Chlorfenapyr compound before incorporating them into a control program to the cotton leafworm, *S. littoralis* using two parameters: toxicity and the safety of non-target insects through field application during two successive growing seasons (2021-2022).

MATERIALS AND METHODS

Tested Insecticides:

1- **Methoxyfenozide: (**Runner® 24% SC) a diacyl hydrazine, ecdysone agonist, applied at the rate of 37.5 cm / was supplied by Syngenta Agro Egypt Company (Basel, Switzerland).
2- **The Chlorfenapyr compound:** (arylpyrrole derivative), 4-bromo-2-(4-chlorophenyl)-1-(ethoxymethyl)-5-(trifluoromethyl)-1H-pyrrole-3-carbonitrile, fanty exstera ® application rate of 150 Cm /Feddan was supplied by EgyptChem International Agricultural Chemicals Company (Cairo, Egypt).
3- **Lambda-cyhalothrin renatol ®:** thiamethoxam (0.11/ 0.083) {(R)-cyano (3-phenoxyphenyl) methyl (1S,3S)-rel- 3-[(1Z)-2-chloro-3,3,3,-trifluoro-1-propenyl]-2,2-dimethylcycloproanecarboxylate} + *[(EZ)*-3- (2-chloro-1,3- thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadiazinan-4-ylidene (nitro)amine], application rate of 5% Ec 350 Cm / Feddan was supplied by Sama For Agricultural Development Company (Beijing, China).

Field Experiments

This evaluation took place in the Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt as the location for carrying out the field experiments over the course of two consecutive planting seasons, specifically in 2021 and 2022. The local sugar beet variety known as (HOSAM) was planted in August in an experimental area of approximately 168 m^2, following a complete randomized block design during the two seasons. The entire area was divided into equal plots, with each plot measuring 42 m2. In both the treated and untreated areas, four plots were designated for each treatment. In order to assess the impact of the evaluated insecticides on the predators present, two rows of plants were intentionally left unsprayed between the plots. The application of the tested compouds was conducted at sunset before August 15. Aqueous suspensions of the recommended dose of all insecticides were prepared. The treatments were administered using a motorized knapsack sprayer with a capacity of 20 litres. Conventional agricultural practices were followed, applying the recommended field rate for all tested insecticides as recommended by the Agricultural Pesticide Committee (http://www.apc.gov.eg/ar/APCReleases.aspx). A control group was established by using only water. The application dose was one for every replicate/ season. For insect sampling, 10 plants /plots/treatments were selected randomly a few hours prior to the first application as well as at 3, 7, and 10 days following the application of Methoxyfenozide and Similarly 1, 7, and 10 days following the application of The Chlorfenapyr compound and Lambda-cyhalothrin. The percentage of reduction in the larval population density of *S. littoralis* was computed. The population densities of the associated predators, *C. Carnae* (larvae), *Scymnus spp* and formicide (adults), were also assessed prior to the treatment and at intervals of 3, 7, and 10 days following the treatments.

Statistical analysis.

The calculation of infestation reduction percentages for each treatment in both seasons was conducted using the formula provided by Henderson and Tilton in 1955.

$$\textbf{Reduction \%}=\left\{1-\frac{n\ in\ Co\ before\ treatment\ x\ n\ in\ T\ after\ treatment}{n\ in\ Co\ after\ treatment_{x}\ n\ in\ T\ before\ treatment}\right\}\times 100.$$

n: Insect population, C: control, T: treated.

Insect population data were statistically compared using statistically significant differences determined by one-way analysis of variance (ANOVA) (SPSS, 2004).

RESULTS AND DISCUSSION

The efficacy of the tested insecticides, the Chlorfenapyr compound, Lambda-cyhalothrin, and Methoxyfenozide for suppressing early sugar beet infestation with *S. littoralis* in field trials in sugar beet fields was evaluated in the field over two successive seasons in December (2021–2022) (Tables 1, 2). Meanwhile, the susceptibility of the most associated arthropod predators, *C. Carnae* (larvae), *Scymnus spp* and formicide (adults) to endure the adverse effects of these treatments throughout the experiment was indirectly determined by monitoring the predators' population fluctuations in response to insecticide treatment. The population density fluctuation of *S. littoralis* larvae and predators was recorded before and after treatments, and the percentage of population reduction was calculated (Tables 3, 4).

Reduction of Pest Infestation

Following the application of the Chlorfenapyr compound, Lambda-cyhalothrin, and Methoxyfenozide through the 2021growing season, the daily reduction percentage in *S. littoralis* larval population density was calculated in sugar beet fields (Fig. 1). In a natural infestation pattern, the larval population rose prior to any treatment. One day after treatment, the recommended dose of Lambda-cyhalothrin was shown to be particularly efficient against *S. littoralis* larvae, resulting in a 77.25% reduction in pest infestation. Furthermore, three days following treatment, insect populations were reduced by more than 88%, indicating that the treatment was effective. After seven and ten days of Chlorfenapyr compound, Lambda-cyhalothrin, and Methoxyfenozide treatments, the pest reduction percentage increased significantly ($P\leq 0.05$) compared to the untreated area, ranging from 92.33% to 97.61%, respectively.

Throughout both the 2021 and 2022 seasons, the application of Chlorfenapyr compound, Lambda-cyhalothrin, and Methoxyfenozide had a significant effect on reducing the *S. littoralis* larval population, resulting in a cumulative reduction ranging from approximately 88% to 90%. In the integrated pest management strategy aimed at cultivating sugar beets, the utilization of chemical pesticides plays a vital role in protecting crops. However, when assessing the environmental effects of this method, attention is directed towards the negative consequences on humans, environmental pollution, and the influence on biodiversity. This encompasses the impact on pests as well as unintended damage to associated predators. Therefore, there is a growing requirement to transition from applying conventional insecticides to new control strategies in control programs in order to advance sustainable agricultural practices in pest management to enhance food security and enhance nutritional outcomes.

Table 1. Reduction percentage of *Spodoptera littoralis* larvae in sugar beet field after treatment with the tested insecticides during the 2021 season.

Treatment	Before treatment	Days after treatments								Total reduction
		1 DAY		3 DAYS		7 DAYS		10 days		
	Mean ±SE*	Mean ±SE	Reduction %	Mean ±SE	Reduction %	Mean ±SE	Reduction %	Mean ±SE	Reduction %	
Methoxyfenozide	20.50	-		5.75	78.47%[a]	2.75	92.33%[a]	1.50	95.74%[b]	88.67%
Chlorfenapyr	20.50	-		4.75	79.17%[a]	2.50	93.11%[a]	1.25	96.41%[ab]	89.30%
Lambada Cyhalothrin	20.75	5.25	77.25%	3.00	88.77%	2.75	92.33%[a]	1.00	97.61%[a]	89.81%
Untreated area	20.00	22.25		25.75		35.00		34.00		29.25

-In a column, means followed by the same letters are non-significantly different, P≥0.05

Table 2. Reduction percentage of *Spodoptera littoralis* larvae in sugar beet field after treatment with the tested insecticides during the 2022 season.

Treatment	Before treatment	Days after treatments								Total reduction
		1 DAY		3 DAYS		7 DAYS		10 days		
	Mean ±SE*	Mean ±SE	Reduction %	Mean ±SE	Reduction %	Mean ±SE	Reduction %	Mean ±SE	Reduction %	
Methoxyfenozide	19.50			6.50	73.00%	3.25	89.69%[a]	2.00	92.30% [b]	89.12
Chlorfenapyr	22.00			4.25	82.41%	2.00	91.56%	1.50	95.39%[a]	89.98
Lambada Cyhalothrin	19.75	5.00	76.95	2.50	89.74%	3.25	89.82%[a]	1.25	95.72%[a]	88.05
Untreated Area	20.25	22.25		25.00		32.75		30.00		27.50

-In a column, means followed by the same letters are non-significantly different, P≥0.05

Reduction in the Associated Predators Population

Investigating the effect of tested insecticides on the population of pest-associated predators in sugar beet fields serves as a crucial factor in determining the safety of these insecticides for non-target pests. Specifically, the effects of the treatment on the quantities of relevant arthropod predators *C. Carnae* (larvae), *Scymnus spp* and formicide (adults) were documented for both the 2021 and 2022 seasons (Table 3).

Unexpectedly, immediately after treatment with the recommended amount of Chlorfenapyr compound and Methoxyfenozide, a significant decrease in the population density of *C. Carnae* (larvae), *Scymnus spp* and formicide (adults) was observed in both seasons (2021-2022), indicating that this dose had a harmful impact on these predators. Nevertheless, after three days following the treatment, more than 50% of the associated predator populations were able to recover from the toxic effects of the tested insecticide.

On the other hand, while the use of Lambda-cyhalothrin treatment did decrease the number of predators, it did not completely eradicate them and maintained a population level of predators that ensured their ongoing contribution to controlling the pest populations. Interestingly, in the first and second seasons, a rapid eradication effect on most of the predators occurred after just three days of treatment, which can be seen as an unfavorable outcome.

Regarding the overall deduction in predator populations, the population of *Scymnus spp* was reduced by 75.36% and 79.69% when treated with Lambda-cyhalothrin in the first and second seasons, respectively (Fig.5). In contrast, the application of Lambda-cyhalothrin led to a much more significant reduction the population of *C. Carnae*, with population decreases of 88.06% and 76.18% during the first and second seasons, respectively.

Throughout the two growing seasons, the Chlorfenapyr compound exhibited a notable reduction in formicide (adult) populations, with reductions of 76.42% and 86.31% observed during the first and second seasons, respectively, in comparison to untreated plots.

The obtained data from Tables 1, 2 and 3 assessed the efficacy of three insecticides: Chlorfenapyr, Lambda-cyhalothrin, and Methoxyfenozide. The results indicated that the application of the tested insecticides led to a notable reduction in the population density of *S. littoralis* larvae. The treatment with Lambda-cyhalothrin was particularly effective, with a rapid reduction of 77.25% in pest infestation within one day of application. Moreover, the insecticides continued to exhibit significant efficacy, with reductions ranging from 92.33% to 97.61% after seven and ten days of treatment. Throughout the entire experiment, the cumulative reduction in S. littoralis larval population ranged from approximately 88% to 90%.

The Chlorfenapyr (arylpyrrole derivative) which is mainly stomach with some contact action was able to reduce S. littoralis population, with a percentage reduction of approximately 80%. Lambda-cyhalothrin and Methoxyfenozide achieved lower reductions, with percentages of approximately 70% and 60%, respectively. According to our findings, Chlorfenapyr became highly toxic against S. littoralis after 7 days of treatment causing more than a 90% reduction even though it also, displayed significant impacts on its connected predators, leading to a reduction of over 90%. Conversely, Lahm *et al.*, 2007 that Chlorfenapyr exhibits limited harm to mammals and beneficial organisms, as noted by Liu *et al.*, (2012) and Nawaz *et al.*, (2017). Simultaneously, it exhibits substantial toxicity towards intended insect targets, as emphasized by Lahm et al., (2009). Nonetheless, it remains important to follow the proper protocols for handling and application to avoid potential risks. Moreover, exercising caution is recommended when using Chlorfenapyr in regions inhabited by associated predators to prevent unintentional harm. The effectiveness of these applications could be influenced by various factors, such as dosage, application timing, and environmental conditions, which need to be considered when interpreting the results in future research.

Table 3. The total reduction percentage of *Scymnus sp* in the Sugar beet field after treatment with the tested insecticides during the 2021/ 2022 season.

Treatment	Pre-treatment	Mean Reduction % post-treatment				Overall mean of reduction
		One day	3 days	7 days	10 days	
Methoxyfenozide	4.00	-	50.00	64.13	71.15[c]	61.76
Chlorfenapyr	3.75	-	73.33	73.33	84.61[b]	77.09
Lambada Cyhalothrin	3.75	65.99	70.00	77.78	87.69[a]	75.36
Control	3.00	4.00	4.50	5.75	6.50	5.18
		2022				
Methoxyfenozide	3.00	-	57.01	55.68	61.31[c]	58.00
Chlorfenapyr	3.00	-	59.37	75.37	84.52[b]	73.08
Lambada Cyhalothrin	3.25	68.75	78.94	81.81	89.28[a]	79.69
Control	3.25	4.00	4.75	5.50	7.00	5.31

-In a column, means followed by the same letters are non-significantly different, P≥0.05

Table 4. The total reduction percentage of *C. Carnae* (larvae) in the Sugar beet field after treatment with the tested insecticides during the 2021/ 2022 season.

Treatment	Pre-treatment	Mean Reduction % post-treatment				Ov Overall mean of reduction
		One day	3 days	7 days	10 days	
Chromafenozide	7.50	-	30.19	43.75	37.05[a]	35.64
Chlorfenapyr	7.25	-	67.74	85.00	90.69[a]	81.14
Lambada Cyhalothrin	7.00	97.58	76.98	87.05	90.36[a]	88.06
Control	7.25	7.75	9.00	10.00	10.75	9.37
		2022				
Chromafenozide	6.25	-	29.60	35.06	42.40[c]	35.68
Chlorfenapyr	6.50	-	68.05	81.05	90.77[a]	79.95
Lambada Cyhalothrin	6.00	61.54	73.33	82.36	87.50[b]	76.18
Control	6.00	6.50	7.50	8.50	10.00	8.12

-In a column, means followed by the same letters are non-significantly different, P≥0.05

Reduction in the Associated Predators Population:

An important aspect of the study was assessing the impact of the insecticides on the population of predator arthropods, such as *C. Carnae* (larvae), *Scymnus spp*, and femicides (adults), which play a role in controlling the pest populations. Surprisingly, the immediate application of Chlorfenapyr compound and Methoxyfenozide led to a significant decrease in the population density of these predators. However, the predators demonstrated resilience, as more than 50% of their populations recovered within three days of treatment.

In the case of Lambada-cyhalothrin, while it did lead to a reduction in predator populations, it did eliminate them, maintaining a balance that ensured ongoing predator contributions to pest control. Notably, there was a rapid and unfavorable eradication effect on most of the predators after just three days of Lambda-cyhalothrin treatment.

The obtained results showed that Lambda-cyhalothrin is efficient in controlling *S. littoralis* after 7 days of treatment causing more than 90% reduction. Even though Lambda-cyhalothrin also showed dramatic effects against its associated predators causing more than 80% reduction, it is essential to be aware that it can also harm non-target organisms, including beneficial insects and pollinators. Thus, it is vital to employ correct application methods, follow label instructions, and incorporate integrated pest management practices to reduce potential ecological risks. Helaly, 2021 also mentioned that Lambda-cyhalothrin is a powerful insecticide with the ability to effectively manage a broad spectrum of insect pests. Similar results were noted by Amarasekare and Shearer (2013), affirming that lambda-cyhalothrin led to larval death in both green lacewing species, namely *C. carnea* and *Chrysoperla johnsoni* (Henry). However, Maia *et al.*, (2016) discovered that lambda-cyhalothrin only exhibited minor harm to *C. carnea* larvae.

Table 5. The total reduction percentage of formicide (adults) *sp* in the Sugar beet field after treatment with the tested insecticides during the 2021/ 2022 season.

Treatment	Pre-treatment	Mean Reduction % post-treatment				Overall mean of Reduction
		One day	3 days	7 days	10 days	
Chromafenozide	4.75	-	32.00	50.00	69.77 [c]	50.59
Chlorfenapyr	5.00	-	69.77	68.33	91.16 [a]	76.42
Lambada Cyhalothrin	4.75	59.10	60.00	53.33	88.37 [b]	65.2
Control	4.75	5.50	6.25	7.50	10.75	7.50
		2022				
Chromafenozide	4.25	-	28.33	50.59	68.24 [c]	49.05
Chlorfenapyr	4.50	-	71.43	90.00	97.50[a]	86.31
Lambada Cyhalothrin	4.50	61.90	84.61	86.67	95.00b	82.05
Control	4.50	2.25	6.50	7.50	10.00	6.56

-In a column, means followed by the same letters are non-significantly different, P≥0.05

The findings of the study provide valuable insights into the efficacy of the tested insecticides in controlling S. littoralis infestation in sugar beet fields. While these insecticides effectively reduced pest populations, their impact on associated predator populations varied. Lambda-cyhalothrin, although effective against the target pest, had a substantial negative effect on predator populations. This suggests that a more selective approach may be needed to minimize the impact on beneficial predator arthropods.

CONCLUSION

This field experiment displayed the potential of the tested insecticides for suppressing *S. littoralis* infestation in sugar beet fields. However, careful consideration is required to strike a balance between effective pest control and preserving the populations of beneficial arthropod predators. Further investigation into the long-term effects of these insecticides on predator populations and their potential impact on the overall ecosystem would be beneficial. It is also essential to weigh the benefits of pest reduction against potential unintended consequences on the predator populations, as they play a crucial role in maintaining a balanced ecosystem and sustainable pest control.

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تقييم فعالية بعض المبيدات الحشرية في مكافحة دودة ورق القطن، وتأثيرها على تعداد بعض المفترسات المرتبطة بها في حقول بنجر السكر.

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[2]مركز المكافحة الحيوية- معهد بحوث وقاية النباتات-مركز البحوث الزراعية

الملخص

تشكل دودة ورق القطن تهديدًا خطيرًا من خلال انتشارها في محاصيل بنجر السكر وتسبب خسائر اقتصادية كبيرة. هدفت هذه الدراسة إلى تقييم فعالية ثلاثة مبيدات حشرية - مركب كلورفينابير، ولامبدا-سايهالوثرين، وميثوكسيفينوزيد، في إدارة الانتشار المبكر لـ دودة ورق القطن في حقول البنجر السكري عبر موسمين زراعيين (2021-2022). قامت الدراسة بتقييم تأثير هذه المبيدات على الآفات المستهدفة وكذلك على سكان الحشرات المفترسة المرتبطة بها .أدت المبيدات الحشرية المختبرة إلى انخفاض كبير في تعداد يرقات دودة ورق القطن حيث لوحظ أن لامبدا-سايهالوثرين حقق تقليلًا سريعًا بنسبة 77.25% في يوم واحد فقط. حدثت انخفاضات في تعداد الحشرات من 92.33% إلى 97.61% بعد سبعة وعشرة أيام، على التوالي. بشكل تراكمي، بلغت الانخفاضات في تعداد اليرقات حوالي 88% إلى 90% خلال الموسمين المتتاليين. عند تقييم تأثير المبيدات الحشرية على تعداد المفترسات المرتبطة بها *C. Carnae*(اليرقات)، و*Scymnus spp*، والنمل (البالغين) حيث تبين انخفاضًا غير متوقع في تعداد المفترسات على الفور بعد تطبيق مركب كلورفينابير وميثوكسيفينوزيد. ومع ذلك، كانت قدرتهم على تجاوز المفترسين واضحة، حيث تجاوز أكثر من 50% من سكانهم استعادة قوتهم خلال ثلاثة أيام. أظهر لامبدا-سايهالوثرين توازنًا بين تقليل الآفات والحفاظ على سكان المفترسين، على الرغم من أن بعض المفترسين تم استئصالهم بشكل غير مقصود .تسلط هذه الدراسة الضوء على إمكانية المبيدات الحشرية المختبرة للتحكم في انتشار *S. littoralis* في حقول بنجر السكر. تتطلب التأثيرات المتباينة على تعداد المفترسات المرتبطة بها توازنًا حكيمًا يأخذ في الاعتبار إدارة الآفات والحفاظ على تعداد المفترسات المفيدة. يُنصح بإجراء مزيد من البحوث لتقييم العواقب البيئية على المدى الطويل لهذه المعاملات ووضع استراتيجيات تضمن التحكم الفعال في الآفات مع الحد من التأثيرات غير المقصودة للمفترسات. في النهاية، تُسهم هذه الدراسة في تقديم رؤى قيمة في مجال إدارة الآفات المستدامة وتوازن النظام البيئي في المناظر الزراعية.