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ASSESSING THE EFFICACY OF ECO-FRIENDLY INSECTICIDES AGAINST THE *SPODOPTERA LITURA* (TOBACCO CUTWORM) POPULATION

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Abstract *In the investigation conducted, the assessment of environmentally friendly insecticides, including Abamectin, Spinosad, Insect Growth Regulators (IGRs), and Bacillus thuringiensis, was undertaken with a focus on evaluating their efficacy and toxicity in controlling the tobacco cutworm, Spodoptera litura. The study aimed to provide insights into the ecological compatibility of these insecticides within the context of controlling the target pest. Among the various treatment applications, Diflubenzuron + Deltamethrin exhibited the highest efficacy in causing mortality among the larvae of the cutworm and Abamectin demonstrated significant approachability, resulting in mortality rates of 91.35% and 91.23%, respectively. The untreated control group exhibited the highest growth rate, while treatment with Diflubenzuron + Deltamethrin yielded the lowest growth rate at 2.03. Bacillus thuringiensis treatment demonstrated significant impacts on both larval-pupal transition and survival rates, registering values of 1.34 and 0.43, respectively. This indicates a notable influence on the developmental stages and overall survival of Spodoptera litura larvae. The findings of this study underscore the potential of eco-compatible pesticides, with Diflubenzuron + Deltamethrin, Abamectin, and Bacillus thuringiensis presenting distinct outcomes in the control of Spodoptera litura. The observed effects on mortality, growth rates, and developmental transitions provide valuable insights into the practical applicability of these environmentally friendly insecticides in managing pest populations in an ecologically sustainable manner.*

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Keywords: *Spodoptera litura*; *tobacco-cutworm; armyworm; insecticide-toxicity; eco-friendly insecticides*

Introduction

Spodoptera litura (Lepidoptera: Noctuidae) is identified as a polyphagous insect pest and feeds on a variety of plants (Holloway, 1989). Originating as an indigenous pest in South Asia, it poses a significant threat to a diverse range of crops. Notably, its impact has been observed in groundnut crops, resulting in yield losses ranging from 26% to 100% (Dhir et al., 1992). It is commonly known as a tobacco caterpillar, cutworm, or Indian leafworm because of their disastrous nature of leaf eating and destroying crops. A noteworthy incident occurred in 2003 when *Spodoptera litura* experienced a widespread outbreak in Pakistan, particularly affecting the cotton belt, resulting in severe crop devastation. Under optimal environmental conditions, they produce a larger population and feed on enormous plants. That's why they're referred to as armyworms (Armes et al., 1997; Kranthi et al., 2002). This characteristic behavior contributes to its ability to inflict widespread damage across agricultural landscapes. The foliage feeder, *Spodoptera litura*, destructively attacks more than 90 species of plants, and about 19 families include Malvaceae, Fabaceae, Solanaceae, and Cruciferae (Mehrkhou et al., 2012a; Mehrkhou et al., 2012b). This pest causes severe damage to commercial crops and vegetables such as cauliflower, sugar beet, cabbage, sorghum, cotton, and maize. They can cause economic damage ranging from 25 to 100% yield loss (Dhir et al., 1992) in cases of severe infestation if control measures are not adopted in the early or initiation stages. Besides their harmful and destructive effects on the main commercial crops and vegetables, early and effective control measures are required (Zhou, 2009). To control this pest, the farmers use various chemicals and insecticides to control the population, which results in an excessive amount of chemical usage. The result not only deteriorates the environment, causes pollution, and kills beneficial insects but also causes resistance in pests against insecticides (Ahmad et al., 2007). For successive results, the use of broad-spectrum insecticides that only target the pest without causing resistance and are safe for the environment and non-targeted species under the integrated pest management model (Ahmad, 2023).

The current focus is to promote 'green consumerism' for a healthier and safer environment and use alternative things that cause damage to the environment and sustainability. Hence, to minimize the use of chemical pesticides, there is a need to use alternative IPM strategies to control pests and be effective against them (Chen et al., 2004). Environmentally friendly pesticides that are safer for health and non-target insects should be employed, like botanicals, entomopathogens (*Bacillus thuringiensis)*, and growth regulators that have a low impact on the environment when used in crops.

This pest feeds on high-quality crops and likes to oviposit in these crops to meet their nutritional requirements (Prudic et al., 2005). The food quality and quantity not only affect the oviposition and development but also the growth rate (GR) and their entire biology, including their behavior (Khedr et al., 2015; Reese, 1978). To control and sustain the management of *Spodoptera litura*, several pesticide treatments can be employed that alter the behavior, development, and growth rate. This investigation specifically focuses on growth, survival rate, larval and pupal indices, and the adult emergence of larvae after feeding on treated leaves.

Materials and Methods

In this study, cabbage (*Brassica oleracea* var. *capitata* L.) was cultivated in the field despite the application of commercial insecticides. *Spodoptera litura* larvae were collected from the field and reared in a laboratory with controlled conditions at the Faculty of Agricultural Sciences, University of the Punjab, Lahore, Pakistan. The aim was to investigate how significantly environmentally friendly insecticides affected the development and survival of *Spodoptera litura*. The experiments were performed in an environment with a temperature range of 26 to 37 °C and a relative humidity (RH) of 48–87%. Fresh cabbage leaves have been divided into evenly sized parts after being collected from the field. As shown in Table 1, treatments of Spinosad 45% SC, *Bacillus thuringiensis* 5% WP, Abamectin 400 FS, insect growth regulators Diflubenzuron + Deltamethrin 22% SC, botanical-Neem Seed Kernel Extract (NSKE) were made. After that, cabbage leaves were momentarily soaked in different solutions, and they were allowed to dry in the shade. Starved 2nd instar larvae of about equal sizes were subjected to the treated leaves for 24 hours after being starved for eight hours. After one day, new cabbage leaves of similar dimensions were provided, and any wasted leaves, in addition to faeces, were quickly removed. The experiment was repeated four times for each treatment, with 20 larvae included in each replication. The larvae were fed fresh cabbage leaves every day until they pupated (Waldbauer, 1968). At regular day intervals, observations were conducted to assess various parameters, including larval mortality, larval period duration, larval survival percentage, pupation percentage, pupal period duration, and adult emergence percentage (Deshmukh et al., 1982). Subsequently, growth indices will be computed based on the acquired data.

$$\text{Growth Index (G.I)} = \frac{\text{Percent pupation}}{\text{Larval period}}$$

$$\text{Larval-pupal Index} = \frac{\text{Av. larval period (days) on untreated check} + \text{Av. pupal period (days) on untreated check}}{\text{Av. larval period (days) on treatment} + \text{Av. pupal period (days) on treatment}}$$

$$\text{Survival Index (SI)} = \frac{\text{The no. of adult emerged from the larva reared on treatment}}{\text{The no. of adult emerged from the larvae reared on untreated check}}$$

Table 1: Treatment details and dose for *Spodoptera litura*

Treatments	Name and Concentration	Dose (% a.i)
Treatment 1	Spinosad 45% SC	0.006
Treatment 2	*Bacillus thuringiensis* 5% WP	0.2
Treatment 3	Abamectin 400 FS	0.03
Treatment 4	Diflubenzuron + Deltamethrin 22% SC	0.02
Treatment 5	NSKE (Neem seed kernel extract)	2.6
Untreated	No treatment (control)	-

The critical differences (CD) at a significance level of 0.05% were calculated based on the data about the percentage reduction in the population of replications before treatment and at various intervals post-treatment. The data, analyzed using a Completely Randomized Design (CRD) (Goos and Vandebroek, 2004), underwent the Duncan's Multiple Range Test (DMRT) at a 5% significance level after angular transformation as per the methodology (K.A. Gomez, 1984).

Results

This study aimed to systematically investigate the toxicity of various eco-friendly pesticides against second-instar larvae of *Spodoptera litura* in laboratory conditions. The research focused on evaluating the relative toxicity of these insecticides by analyzing the percentage of mortality observed in treated larvae. The results, encompassing comprehensive data on mortality percentages for each insecticide, are detailed in Table 2, providing valuable insights into the effectiveness of eco-friendly insecticides in controlling *Spodoptera litura* populations.

Table 2: Effect of eco-friendly insecticides against *Spodoptera litura*

Treatments	Dose (%a.i)	Mortality % at different days after treatment				Mean
		One-DAT	Three-DAT	Five-DAT	Seven- DAT	
Treatment 1	0.006	33.50	53.50	64.75	84.75	59.12
		(5.68)[b]	(47.51)[a]	(54.09)[abc]	(67.41)[ab]	
Treatment 2	0.2	8.85	47.60	60.10	72.60	47.28
		(17.77)[d]	(44.57)[ab]	(51.78)[bc]	(59.49)[bc]	
Treatment 3	0.03	24.75	58.85	75.10	91.23	62.48
		(29.19)[bc]	(50.21)[a]	(60.39)[a]	(74.61)[a]	
Treatment 4	0.02	45.10	55.10	71.35	91.35	65.72
		(42.22)[a]	(47.98)[a]	(58.69)[ab]	(74.23)[a]	
Treatment 5	2.6	18.50	39.75	54.75	69.75	45.68
		(24.55)[c]	(39.44)[b]	(48.18)[c]	(57.06)[c]	
Untreated	0	0.00	0.00	0.00	0.00	0
		(4.06)[e]	(4.06)[c]	(4.06)[d]	(4.06)[d]	
S.E		2.42	2.33	2.63	2.96	
CD at 0.05%		6.99	6.71	7.62	8.61	

* DAT=Days after treatment.
* Figures within parentheses are angular transformed values.
* In a column, means followed by same alphabet are not significantly different (p=0.05) by DMRT.

Larval phase and duration

Following the findings presented in Table 3 of this research endeavor, it is evident that the larval period varies significantly among distinct treatments. Notably, the application of Abamectin 400 FS yielded the highest larval period, standing at 11.25 days. Subsequently, Diflubenzuron + Deltamethrin 22% SC and Spinosad 45% SC demonstrated larval periods 10.75 days. Conversely, the application of NSKE at a concentration of 2.6% resulted in the lowest larval period recorded at 9.75 days. It is noteworthy that all treatments exhibited statistical parity with each other, except for the control group, which manifested a comparatively prolonged larval period of 13.00 days (Shahout et al., 2011), who reported a significant reduction in larval duration when larvae were subjected to a diet consisting of cabbage leaves, with a recorded duration of approximately 15.55 days. These findings collectively contribute to the growing body of knowledge on the efficacies of various treatments in modulating the larval period, thereby offering valuable insights for pest management strategies in the context of agricultural practices.

Table 3: Effect of eco-friendly insecticides on the growth and development of *Spodoptera litura*

Treatments	Dose (% a.i.)	Larval Period (Days)	Pupal Period (Days)	% Pupation	% Adult Emergence
Treatment 1	0.006	10.75[b]	5.00[a]	24.75	25.93
				(30.09)[b]	(31.46)[b]
Treatment 2	0.2	10.50[b]	5.25[a]	23.85	26.83
				(29.19)[b]	(30.56)[b]
Treatment 3	0.03	11.25[b]	4.75[a]	13.50	29.27
				(20.71)[b]	(33.63)[b]
Treatment 4	0.02	10.75[b]	5.25[a]	11.00	38.50
				(19.43)[b]	(38.50)[b]
Treatment 5	2.6	9.75[b]	4.50[a]	26.35	28.92
				(30.85)[b]	(31.87)[b]
Untreated	0	13.00[a]	4.25[a]	71.00	79.37
				(60.60)[a]	(63.00)[a]
S.E	-	0.6	0.47	4.32	2.48
CD at 0.05%	-	1.59	1.21	1254%	8.07

Pupation percentage (Pupal %)

The findings (presented in Table 3) underscore the notable variations in the percent pupation of

Spodoptera litura, ranging from 11.00% to 26.35%. These values are markedly lower than the corresponding rate observed in the untreated control group, which recorded a pupation percentage of 71%. Among the various treatments administered, the highest percentage of pupation, 26.35%, was documented in the application of NSKE at a concentration of 2.6%. Conversely, the lowest pupation percentage, 11%, was observed in the treatment involving Diflubenzuron + Deltamethrin - 22% SC at a concentration of 0.02%. Statistical analysis revealed significant differences between all treatments and the untreated group (Xue et al., 2010), who similarly reported accelerated pupal development in cowpea compared to Chinese cabbage. These outcomes contribute valuable insights into the efficacy of the treatments in managing *Spodoptera litura* pupation, substantiating the potential utility of NSKE and highlighting the diminished impact of Diflubenzuron + Deltamethrin at the specified concentrations.

Pupal period

The examination of pupal periods revealed notable findings (Table 3). Specifically, the highest pupal period, lasting 5.25 days, was observed in instances where *Bacillus thuringiensis* was applied at a concentration of 0.2%, as well as with the application of Diflubenzuron + Deltamethrin 22% SC at 0.02%. Following closely, a pupal period of 5.00 days was recorded in association with Spinosad 45%SC at 0.006%. In contrast, the untreated group (control) exhibited a comparatively shorter pupal period of 4.25 days (Shahout et al., 2011), who similarly reported an extended pupal duration of 7.54 days when larvae were subjected to a diet consisting of cabbage leaves. The outcomes presented in Table 3 provide valuable insights into the impact of different treatments on the pupal development period, contributing to the broader understanding of insecticidal effects on pupal life stages.

The indices of Larval and Pupal Development (LPD)

The investigation of larval pupal indexes, as presented in Table 4, reveals a range of values from 1.34 to 1.59. Notably, the highest index is observed in the treatment group utilizing Diflubenzuron + Deltamethrin 22% SC at a concentration of 0.02%. Subsequently, the index is recorded as 1.47 in the Abamectin 400 FS treatment. In contrast, the lowest index of 1.34 is documented in the *Bacillus thuringiensis* treatment group at a concentration of 0.2%. These findings contribute valuable insights into the differential effects of various formulations and concentrations on the larval pupal indices, thereby enhancing our understanding of potential insecticidal efficacy.

The Growth Rate (GR)

It was noteworthy that the untreated group exhibited a notably higher growth index of 6, signifying a substantial variance from all other experimental treatments. Among the treatments, the maximum growth index observed was 4.03, while the minimum was 2.03, corresponding to treatments involving NSKE at a concentration of 2.6% and Diflubenzuron + Deltamethrin 22% SC at 0.02%, respectively. The higher growth index of *Spodoptera litura* on untreated cabbage leaves demonstrates the latent nutritional content in the untreated plant material (Greenberg et al., 2001). This observation underscores the potential influence of the experimental treatments on the nutritional attributes of the cabbage leaves, thereby contributing to variations in the growth indices of the test organism.

Adult Emergence (AE)

Following the investigation, the outcomes presented in Table 3 demonstrate a noteworthy variance in adult emergence rates, ranging from 25.93% to 38.50%. Remarkably, all administered treatments exhibited a statistically significant reduction in adult emergence in comparison to the untreated group, which registered an emergence rate of 79.37%. Notably, the treatment involving *Bacillus thuringiensis* at a concentration of 0.2% 26.83% and Spinosad 45%SC at 0.006% demonstrated the lowest adult emergence at 25.93%. The findings underscore the pronounced efficacy of these treatments in mitigating the emergence of *Spodoptera litura* adults. Furthermore, our investigation revealed a significant reduction in both larval and pupal periods compared to the untreated control group. The treatments exerted an adverse impact on the pupation process, influencing the pupal period and subsequent adult emergence of *Spodoptera litura*. Of particular note is the prolonged pupal period observed in the *Bacillus thuringiensis* treatment (Singh et al., 2015) in the context of *Spodoptera obliqua*. This consistency in results suggests a potential universality of the observed effect across related species. The implications of these findings are crucial for the development of targeted pest management strategies and contribute valuable insights to the existing body of research on the subject.

Table 4: Impact of eco-friendly insecticides on growth indices of *Spodoptera litura*

Treatments	Dose (% a.i.)	Growth Index	Larval Pupal Index	Survival Index
Treatment **1**	0.006	$(3.48)^b$	1.39	0.43
Treatment **2**	0.2	$(3.53)^b$	1.34	0.43
Treatment **3**	0.03	$(2.24)^c$	1.47	0.47
Treatment **4**	0.02	$(2.03)^c$	1.59	0.57
Treatment **5**	2.6	$(4.03)^b$	1.39	0.45

Untreated	0.00	(6.00)[a]	-	-
SEm±	-	0.34	-	-
CD at 0.05%	-	0.80	-	-

Survival Index

The experimental findings, as presented in Table 4, show significant variations in the survival index of the tested formulations. Notably, the combination of Diflubenzuron + Deltamethrin at a concentration of 0.02% exhibited the highest survival index, quantified at 0.57. Subsequently, Abamectin at a concentration of 0.03% demonstrated a survival index of 0.47, while NSKE at 2.6% yielded a survival index of 0.45. Conversely, the formulations containing *Bacillus thuringiensis* at 0.2% and Spinosad 400 FS at 0.006% manifested the lowest survival indices at 0.43. These outcomes underscore the differential efficacy of the various formulations in influencing survival rates, providing valuable insights for further research and practical applications in pest management strategies.

Discussions

This research aimed to systematically assess the toxicity of different eco-friendly insecticides against second-instar larvae of *Spodoptera litura* under laboratory conditions. The study focused on quantifying the relative toxicity of these pesticides by analyzing the percentage of mortality observed in treated larvae, as detailed in Table 2. The comprehensive results offer valuable insights into the efficacy of eco-friendly pesticides in controlling *Spodoptera litura* populations. The investigation extended to the larval phase and duration, revealing significant variations among treatments (Table 3). Notably, Abamectin 400FS resulted in the longest larval period (11.25 days), while NSKE at 2.6% induced the shortest period (9.75 days) (Shannag et al., 2015). All treatments exhibited statistical parity, except for the control group, aligning with Shahout et al.'s findings (2011) (Shahout et al., 2011). This contributes to our understanding of treatments modulating the larval period, which is crucial for pest management strategies. Pupation percentage variations (Table 3) highlighted significant differences among treatments, with NSKE at 2.6% yielding the highest pupation (26.35%) and Diflubenzuron + Deltamethrin (22% SC at 0.02%) resulting in the lowest (11%) (Xue et al., 2010), emphasizing the treatments' impact on *Spodoptera litura* pupation. The examination of pupal periods (Table 3) revealed noteworthy differences. *Bacillus thuringiensis* at 0.2% and Diflubenzuron + Deltamethrin 22% SC at 0.02% led to the longest periods (5.25 days) (Shahout et al., 2011). This contributes to understanding insecticidal effects on pupal life stages. The larval and pupal development indexes (Table 4) varied from 1.34 to 1.59, with the highest index in Diflubenzuron + Deltamethrin. These findings provide insights into the differential effects of formulations and concentrations on larval-pupal indices. The growth index (Table 4) revealed a higher index in the untreated group (6.00), emphasizing the nutritional content of untreated cabbage leaves. This underscores the treatments' influence on cabbage leaves' nutritional attributes and subsequent variations in growth indices. Adult emergence rates (Table 3) ranged from 25.93% to 38.50%, significantly lower than the untreated group (79.37%). Amonkar and his colleagues (Amonkar et al., 1985) elucidated the efficacy of distinct strains of *Bacillus thuringiensis*, namely kurstaki, aizawi, and kenyae, in combating *Spodoptera litura*. Treatments, notably *Bacillus thuringiensis* and Spinosad, demonstrated the lowest emergence rates (Singh et al., 2015). The survival index (Table 4) varied significantly, with Diflubenzuron + Deltamethrin exhibiting the highest index (0.57) and formulations containing *Bacillus thuringiensis* at 0.2% and Spinosad 400 FS at 0.006% showing the lowest indices (0.43). These outcomes underscore the formulations' varying efficacy in influencing survival rates. The study revealed the differential impact of treatments on various developmental aspects of *Spodoptera litura*, offering valuable insights for pest management strategies and contributing to existing research on the subject.

Conclusion

In our research, we systematically evaluated eco-friendly insecticides against *Spodoptera litura* larvae. Results revealed significant variations in mortality, larval and pupal phases, pupation percentages, and pupal periods among treatments. Diflubenzuron + Deltamethrin demonstrated the highest growth index. Treatments influenced cabbage leaf nutritional attributes, impacting growth indices. Adult emergence rates were lower for *Bacillus thuringiensis* and Spinosad. Survival index variations emphasized diverse efficacy among formulations, with Diflubenzuron + Deltamethrin exhibiting the highest index. Overall, our findings contribute valuable insights for effective pest management strategies, elucidating the nuanced impacts of eco-friendly insecticides on *Spodoptera litura's* developmental aspects.

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AA wrote the initial draft of manuscript. AA and MS edit the manuscript for final submission. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

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Competing interests

The authors declare that they have no competing interests.