Biology of *Spodoptera litura* on Cabbage and Efficacy of Botanical Extracts and Insecticides

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Abstract

This study assesses the biology of *Spodoptera litura* about cabbage plants and investigates the efficacy of environmentally friendly botanical extracts and conventional insecticides against second-instar larvae of the pest. The mean incubation period of *S. litura* was 3.21±0.01 days. The developmental period of the first, second, third, fourth, and fifth larval instar was 2.32±0.64, 2.34±0.65, 3.54±0.71, 3.54±0.71, and 2.43±1.81 days, respectively. Pupae were pale yellowish and then changed into dark reddish brown. Male pupae and female adults were shorter-lived than female pupae and male adults. The average mean longevity of males and females was 6.50±0.54, and 7.53±1.87 days, respectively. The total life cycle of pests was 32.63-37.43 days on cabbage. *Azadirachta indica* was recorded as the most toxic extract followed by *Jatropha curcas*, *Nicotina tabacum*, *Eucalyptus globulus*, and *Allium sativum. A. indica*, and *J. curcas* caused 56.07, and 50.11% mortality to the larvae ($F = 41.07$; df = 5; $p < 0.001$) after 24 h and 93.33 and 81.44% mortality ($F = 51.71$; df = 5; $p < 0.001$) after 72 h of application. Significant variations were found in all insecticides on larval mortality at 24 hours ($F = 46.44$; df = 5; $p < 0.001$), 48 hours ($F = 49.89$; df = 5; $p < 0.001$), and 72 hours ($F = 59.94$; df = 5; $p < 0.001$) following treatment application. Specifically, 55.14, 50.33, 46.11, 33.21, and 18.01% of mortality was caused by radiant, coragen, tracer, imidacloprid, and malathion, respectively. Radiant demonstrated the highest level of toxicity, while Malathion was the least effective and least toxic. Notably, at the 72-hour, Radiant and Coragen induced larval mortalities of 96.17% and 83.56%, respectively.

Keywords: Cabbage; *Spodoptera litura; Azadirachta indica*; Spinetoram; Bio-rational; Eco-friendly; Integrated Pest Management

Introduction

The armyworm (*Spodoptera litura*), stands as a significant threat to various agricultural and horticultural crops around the world, including cotton, eggplants, tomatoes, and some ornamental plants. This pest species inflicts damage on over 100 different host plants, resulting in substantial yield losses of up to 50%, primarily attributable to its voracious larval foliage consumption activity (Garrido-Jurado et al., 2020). It poses a considerable economic challenge due to its rapid reproductive rate, destructive potential, and ability to feed on a wide range of plant species (Ponsankar et al., 2016; Ramzan et al., 2021). Effectively managing insect pests like the armyworm is a foremost concern for agricultural researchers (Srivastava et al., 2018; Rani et al., 2021; Samsidar et al., 2018). In pursuit of cultivating high-quality crops that are free from pests while also safeguarding the environment, researchers have directed their efforts toward discovering alternative, efficient, and eco-friendly methods of control. It allows for the use of control measures that are not only efficient in reducing pest populations but also environmentally responsible and sustainable in the long term. Botanical substances, derived from plants, have emerged as significant components in integrated pest management (IPM) strategies aimed at curbing insect pests and reducing the reliance on synthetic insecticides (van den Berg et al., 2020; Khan et al., 2017). Consequently, plant extracts have emerged as viable alternatives because they can influence the biological and behavioral aspects of pest insects, thereby regulating their populations (Jepson et al., 2020; Lengai et al., 2020). While numerous plant species exhibit pesticidal properties, only a select few are suitable for practical application. Plants are abundant sources of various secondary metabolites (Zhang et al., 2022), all of which possess insecticidal properties against a wide range of agriculturally significant pests (Babu and Singh, 2023). These plant-derived compounds impact pest insects through multiple mechanisms, including acting as antifeedants, larvicides, ovicides, oviposition deterrents, and growth inhibitors, among others (Hoesain et al., 2023). These remarkable properties of plants can be harnessed for the management of agriculturally important pests and diseases. In this context, Neem (*Azadirachta indica*), Garlic (*Allium sativum*), and *Jatropha curcas* stand out as the most promising botanical options from an entomological perspective, making them the focus of the present study. These phytochemicals are renowned for their ability to shield plants from attacks by insect pests. Understanding the biology of a pest is fundamental to developing targeted and effective pest management strategies. For this purpose, the biology of pests on cabbage was also determined to provide proper knowledge before adopting control measures.

Methodology

Insect collection and rearing

The larvae of *S. litura* were obtained from a cabbage field located near the research site. These larvae were then nurtured under controlled laboratory conditions. The rearing of Fall Armyworm (FAW) followed the procedures outlined by previous researchers (Ramzan et al., 2020; Safder et al., 2022). These laboratory-reared larvae were subsequently employed in bioassays, and the cultures were consistently maintained throughout the study.

Collection of plant extracts and source of insecticides

In July 2018, a total of five botanical specimens, namely Neem (*Azadirachta indica*), Jatropha (*Jatropha curcas*), *Eucalyptus globulus*, tobacco (*Nicotina tabacum*), and Garlic (*Allium sativum*), were collected from various regions in Pakistan. The leaves of these plants were meticulously cleaned with fresh water and subsequently air-dried in the shade under laboratory conditions at a stable temperature of 27.0 ± 2°C. After drying, the plant leaves were ground into a fine powder with a pestle and mortar. Each botanical powder was then soaked in distilled water at concentrations that had been previously determined as effective by different researchers for lepidopteran larvae. These specific concentrations were as follows: 5 g of *A. indica*, 11.5 g of *J. curcas* seeds, and 25 g of *N. tabacum* leaves and *E. globulus* seed extracts (Moustafa et al., 2023; Idrees et al., 2023). Each botanical powder was mixed with 100 mL of water and left to soak for 24 hours. Subsequently, the mixtures were filtered through cheesecloth, and the resulting solutions were allowed to settle overnight. Five insecticides *i.e.* spinetoram (Radiant 120 SC), chlorantraniliprole (Coragen 200 SC), spinosad (Tracer 480 SC), Malathion 50% EC, and Imidacloprid were obtained from different sources to conduct the bioassay study.

Application of botanical extracts and insecticides

The five aforementioned botanicals were tested against third-instar larvae. To provide a favorable environment for the larvae, roughly 60 grams of cabbage leaf cuttings, prepared as previously described, were placed in rectangular plastic containers measuring 4 cm in height, 15 cm in width, and 21 cm in length. To allow for ventilation, these containers had perforated wire mesh covers. Each container containing leaves was sprayed with 20 cc of one of the botanical extracts using a handheld sprayer. It's worth noting that we tested several water volumes for the botanicals and found that 20 mL offered consistent and adequate coverage. Then, 10 third-instar larvae were placed into each container containing the treated leaves. The experiment included a control group of leaves treated with sterile water. The experimental setup utilized a fully randomized design (CRD) with four replications. Insects were reared as described above until a sufficient population was achieved to run the experiment, and 2nd instar larvae were used to test the efficacy of insecticides using the method of early researchers (Sisay et al., 2019; Asad et al., 2023; Ramzan et al., 2020a). Insect mortality was measured at 24-hour, 48-hour, and 72-hour intervals following treatment administration. A larva was judged dead if it couldn't correct itself when placed on its dorsal surface.

Statistical analysis

The mean percentage of larval mortality was analyzed using a one-way ANOVA and a generalized linear model. To stabilize the variances, the % larval death data from botanical bioassays in the laboratory were transformed using the arcsine function. The significance level was chosen at 0.05, and means were separated using Tukey's honest significant difference test.

Results and discussion

Various strategies have been explored by both researchers and farmers worldwide to combat insect pests, whether they are those that chew on crops or those that extract nutrients from them. One effective means of bolstering crop production involves reducing pest populations through the application of various chemical pesticides, which play a pivotal role in shielding crops from numerous destructive pests. Among the strategies tested, chemicals in the form of insecticides have gained widespread adoption on a global scale for pest control, as noted by Ramzan et al. (2019). However, the excessive use of such chemical agents has led to detrimental consequences, which can be harmful to both humans and animals. Additionally, these chemical interventions can negatively impact biological organisms such as predators and pollinators, as highlighted by research conducted by Murugasridevi et al. (2017), Ramzan et al. (2020b), and Gorawade et al. (2022). Eggs were laid by females at night time in masses and several eggs per female was 747-921. The mean incubation period of *S. litura* was 3.21±0.01 days. The spherical-shaped eggs were laid on the wall of the container as well as leaves of the cabbage and covered with yellowish brown hairs. The color of the eggs was yellowish creamy with a hatching percentage of 86.64-90.72. the incubation period and hatching percentage can vary according to hosts and environmental conditions (Narvekar *et al.,* 2018). The incubation period of pests on black gram, tomato, cabbage, and cauliflower was 5, 4, 3, and 3 days, respectively (Maharjan et al., 2023). The highest fecundity was reported on cabbage and 25-30^{o}C suitable temperatures for the growth and reproduction of *S. litura* (Ahmad et al., 2023). 2.32±0.64, 2.34±0.65, 3.54±0.71, 3.54±0.71, and 2.43±1.81 days were the developmental period of the first, second, third, fourth, and fifth *S. litura* larval instars, respectively. Pupae were pale yellowish and then changed into dark reddish brown. Male pupae were short-lived than female pupae. Our current study findings are in line with the previous study findings as done by researchers (Sunitha et al., 2023). The pre-pupal and pupal period of pests on cabbage was 0.99-1.23 and 6- 7 days, respectively. Kumar and Bhattacharya (2019) reported similar findings about the pupal period. The pupal period of the pest varies not only with hosts but also cultivars of the host such as 2.89 days on pride of India, 2.78 days on KGMR-1, 2.32 days on golden acre 2.26 days on pusa mukta cultivars of cabbage. Females lived more than males. The average

mean longevity of males and females was 6.50±0.54, and 7.53±1.87 days, respectively. The total life cycle from egg to adult was 32.63-37.43 days on cabbage while Safder et al. (2022) and Murtaza et al. (2019) reported 30.83-38.79 days. Table 1 shows the biological traits of *S. litura* on cabbage.

Table 1. Biological traits of *Spodoptera litura* on cabbage.

Stage	Mean ± SE	Range
Incubation period	3.21±0.01	3-4
First instar	2.32±0.64	2-3
Second instar	2.34±0.65	2-3
Third instar	3.54±0.71	3-4
Fourth instar	2.81±0.82	2-3
Fifth instar	2.43±1.81	2-3
Total larval period	15.09±4.55	12-18
Pre-pupa	0.99±0.45	0.99-1.23
Pupa	6.87±0.91	6-7
Male longevity	6.50±0.54	6-7
Female longevity	7.53±1.87	7-9
Pre-oviposition	2.51±0.71	2.04-3.58
Oviposition	3.57±0.91	2.89-5.71
Fecundity	794.93±22.63	747-921
Hatching % age	88.99±6.84	86.64-90.72
Total life cycle	35.88±3.89	32.63-37.43

Table 2. Toxicity of plant extracts against 2nd instar *S. litura* larvae at 24, 48, and 72 h.

Botanicals	Larval mortality percentage		
	24 h	**48 h**	**72 h**
A. indica	56.07 ± 0.09 a	74.19 ± 4.67 a	93.33 ± 1.70 a
J. curcas	50.11 ± 3.56 a	67.45 ± 1.98 ab	81.44 ± 1.73 ab
N. tabacum	24.44 ± 1.94 de	34.55 ± 2.84 de	42.58 ± 1.94 cd
E. globulus	12.15 ± 0.10 e	21.76 ± 1.83 f	35.09 ± 2.51 ef
A. sativum	9.58 ± 4.91 a	19.21 ± 3.23 ab	30.13 ± 1.75 a
Untreated	0.1 ± 0.00 e	0.3 ± 0.01 f	1.50 ± 1.60 f
ANOVA			
F=	41.07	43.66	51.72
DF =	5	5	5
p <	0.001	0.001	0.001

Means within a column with different letter are significantly different at $p < 0.05$ using Tukey's test.

The presence of plant extract had a noticeable impact on the overall development period, resulting in a reduction. Furthermore, significant inhibitory effects were observed in the case of ethyl acetate and hexane extracts of *Moringa oleifera*, particularly at higher concentrations, which led to more pronounced effects on adult emergence. A majority of the larvae that consumed a diet enriched with *M. oleifera* extracts exhibited incomplete molting and progressed into intermediate stages between larvae and pupae (Kaur et al., 2021). The significant differences between plant extracts were recorded in causing larval mortality. *A. indica* was recorded as the most toxic extract followed by *J. curcas, N. tabacum, E. globulus,* and *A. sativum.* After 24 hours of treatment, *A. indica, J. curcas, N. tabacum, E. globulus,* and *A. sativum* caused 56.07, 50.11, 24.44 and 12.15% larval mortality, respectively. *A. indica*, and *J. curcas* caused 56.07, and 50.11% mortality to the larvae ($F = 41.07$; df = 5; $p < 0.001$) after 24 h and 93.33 and 81.44% mortality ($F = 51.71$; df = 5; $p < 0.001$) after 72 h of application (Table 2). *A. sativum* was least toxic extract that caused 9.58, 19.21, and 30.13% larval mortality after 24, 48 and 72 h of treatment application, respectively. Murugasridevi et al. (2017) reported that *A. indica* was the most toxic botanical with 79.39 to 82% *S. litura* larval mortality. *A. sativum* had caused 26.60% larval mortality. In another study, *A. indica* showed 66.63% larval mortality in contact bioassay, while 46% mortality and *N. tabacum* showed 66% through feeding bioassay (Asad et al., 2023). It has been observed that the toxicity of insecticides, as well as botanicals, increased with the increase in time duration and dose rates. The mortality % of *S. litura* due to botanicals is shown in Figure 1.

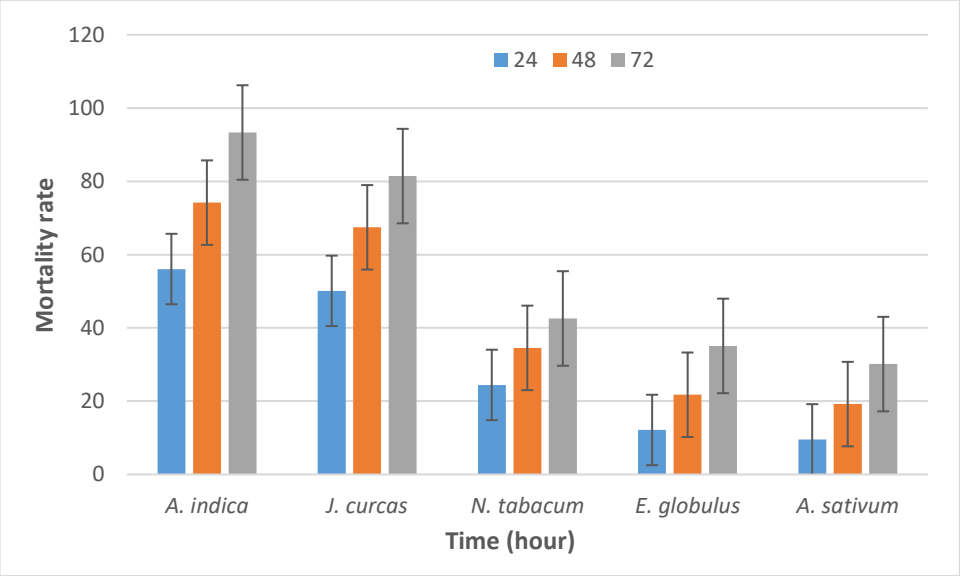

Figure 1. Mortality percentage of *S. litura* larva at different time interval.

Table 3. Toxicity of insecticides against 2nd instar *S. litura* larvae at 24, 48, and 72 h.

Botanicals	Larval mortality percentage		
	24 h	48 h	72 h
Radiant 120 SC	55.14 ± 1.54 ab	71.12 ± 2.18 a	96.17 ± 0.01 a
Coragen 200 SC	50.33 ± 3.71 ab	65.51 ± 3.40 abc	83.56 ± 4.10 abc
Tracer 480 SC	46.11 ± 4.67 bc	59.18 ± 4.34 ab	76.78 ±3.30 a
Imidacloprid	33.21 ± 4.92 bc	48.34 ± 3.56 c	67.91 ± 4.10 cd
Malathion 50% EC	18.01 ± 3.33 d	29.11 ± 4.71 d	55.39 ± 4.55 d
Control	0.0 ± 0.00 e	0.2 ± 0.01 f	1.44 ± 1.58 f
ANOVA			
F=	46.44	49.89	59.94
DF =	5	5	5
p <	0.001	0.001	0.001

This means that a column with different letters are significantly different at $p < 0.05$ using Tukey's test.

Significant variations were observed among the synthetic insecticides in terms of their impact on larval mortality at 24 hours ($F = 46.44$; $df = 5$; $p < 0.001$), 48 hours ($F = 49.89$; $df = 5$; $p < 0.001$), and 72 hours ($F = 59.94$; $df = 5$; $p < 0.001$) following treatment application, as detailed in Table 3. Radiant exhibited the highest level of toxicity among the insecticides, followed by Coragen, Tracer, Imidacloprid, and Malathion at each time point. Specifically, 55.14, 50.33, 46.11, 33.21, and 18.01% of mortality was caused by radiant, coragen, tracer, imidacloprid, and malathion, respectively. Among all the insecticides tested, Radiant demonstrated the highest level of toxicity, while Malathion was the least effective and least toxic in the current study. Notably, at the 72-hour mark following application, Radiant, and Coragen induced larval mortalities of 96.17% and 83.56%, respectively (Table 3). Lufenuron was reported as the least toxic insecticide causing 18.40% mortality and (methoxyfenozide (Runner 240 SC) most toxic with 25% larval mortality of *S. litura* after 48 h of treatment (Sabri et al., 2016). de Castro et al (2018) reported spinosad and chlorantraniliprole the most toxic insecticides. Their toxicity increased when mixed with botanicals against *S. exigua*. Early instars of the pest were reported to be more susceptible than older instars and insecticide toxicity enhanced with

the dose and time durations of treatment. The mortality % of *S. litura* due to insecticides is shown in Figure 2.

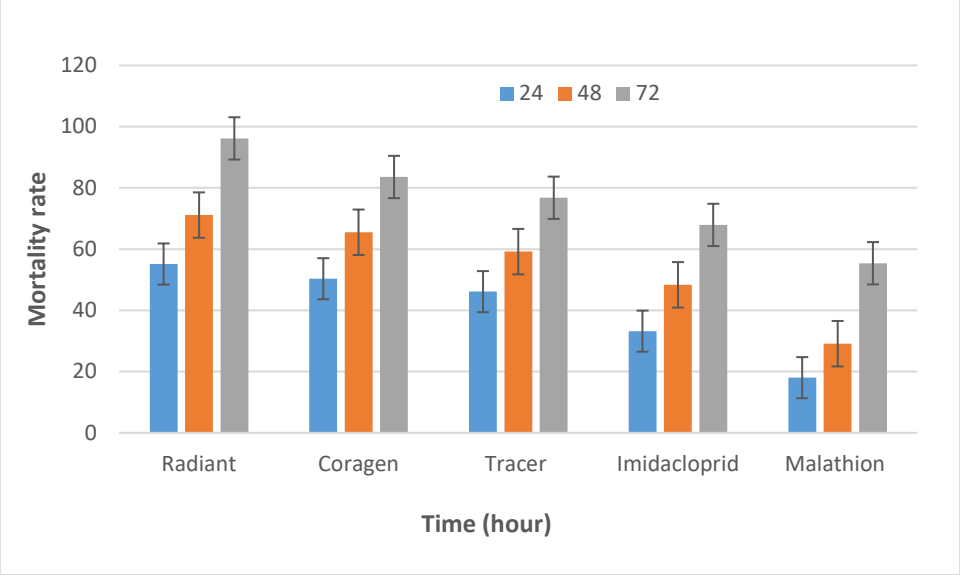

Figure 2. Mortality percentage of *S. litura* larva at different time intervals.

Conclusion

Results concluded that *A. indica* and radiant are the most toxic chemicals for controlling the *S. litura* population. The killing time of these chemicals is very rapid as compared to other tested chemicals. It's worth noting that these findings were obtained under controlled laboratory conditions. To gain a comprehensive understanding of the insecticide's impact on both pests and natural predators, it is recommended that further testing be conducted in greenhouse and field environments.

References

1. Ahmad, M. S., Afzal, M., Feng, L. Y., Majeed, M. Z., Safdar, H., Mehmood, A., ... & Adnan, M. (2023). Laboratory Evaluation of Selected Biorational Insecticidal Formulations against Potato Leafworm Spodoptera litura Fabricius (Lepidoptera: Noctuidae).

2. Asad, M., Khan, R. R., Aljuboory, A. B., Rashid, M. H. U., Kumar, U., Haq, I. U., ... & Alharbi, K. (2023). Toxic and Antifeedant Effects of Different Pesticidal Plant Extracts against Beet Armyworm (*Spodoptera exigua*). *Phyton (0031-9457)*, *92*(4).
3. Babu, S. R., & Singh, B. (2023). Resistance in Spodoptera litura (F.) to insecticides and detoxification enzymes. *Indian Journal of Entomology*, 90-94.
4. de Castro AA, Legaspi JC, Tavares WdS, Meagher RL, Jr., Miller N, Kanga L, et al. (2018) Lethal and behavioral effects of synthetic and organic insecticides on *Spodoptera exigua* and its predator *Podisus maculiventris*. PLoS ONE 13(11): e0206789. https://doi.org/10.1371/journal. pone.0206789
5. Garrido-Jurado, I., Montes-Moreno, D., Sanz-Barrionuevo, P. & Quesada-Moraga, E. Delving into the causes and effects of entomopathogenic endophytic *Metarhizium brunneum* foliar application-related mortality in *Spodoptera littoralis* Larvae. Insects 11, 429. https://doi.org/10.3390/insects11070429 (2020).
6. Hoesain, M., Suharto, Prastowo, S., Pradana, A. P., Alfarisy, F. K., & Adiwena, M. (2023). Investigating the plant metabolite potential as botanical insecticides against Spodoptera litura with different application methods. *Cogent Food & Agriculture*, *9*(1), 2229580.
7. Idrees, A., Afzal, A., Chohan, T. A., Hayat, S., Qadir, Z. A., Gaafar, A. R. Z., ... & Li, J. (2023). Laboratory evaluation of selected botanicals and insecticides against invasive Spodoptera frugiperda (Lepidoptera: Noctuidae). *Journal of King Saud University-Science*, *35*(7), 102811.
8. Jepson, P. C., Murray, K., Bach, O., Bonilla, M. A. & Neumeister, L. Selection of pesticides to reduce human and environmental health risks: A global guideline and minimum pesticides list. The Lancet Planetary Health 4, e56–e63. https://doi.org/10.1016/ S2542-5196(19)30266-9 (2020).
9. Kaur, M., Choudhary, A., Saraf, I., Singh, I. P., & Kaur, S. (2021). Efficacy of *Moringa oleifera* (Lam.) extract against *Spodoptera litura* (Fabricius),(Lepidoptera: Noctuidae). *International Journal of Tropical Insect Science*, 1-6.
10. Khan, S., Taning, C. N. T., Bonneure, E., Mangelinckx, S., Smagghe, G., & Shah, M. M. (2017). Insecticidal activity of plant-derived extracts against different economically important pest insects. *Phytoparasitica*, *45*, 113-124.
11. Kumar, H. D., & Bhattacharya, S. (2019). Biology of *Spodoptera litura* (Fabricius) on different crop plants. *Journal of Entomological Research*, *43*(2), 165-168.
12. Lengai, G. M. W., Muthomi, J. W. & Mbega, E. R. Phytochemical activity and role of botanical pesticides in pest management for sustainable agricultural crop production. Sci. Afr. 7, e00239. https://doi.org/10.1016/j.sciaf.2019.e00239 (2020).
13. Maharjan, R., Hong, S., Ahn, J., Yoon, Y., Jang, Y., Kim, J., ... & Yi, H. (2023). Temperature and Host Plant Impacts on the Development of Spodoptera litura (Fabricius)(Lepidoptera: Noctuidae): Linear and Nonlinear Modeling. *Insects*, *14*(5), 412.
14. Moustafa, M. A., Moteleb, R. I., Ghoneim, Y. F., Hafez, S. S., Ali, R. E., Eweis, E. E., & Hassan, N. N. (2023). Monitoring resistance and biochemical studies of three Egyptian field strains of Spodoptera littoralis (Lepidoptera: Noctuidae) to six insecticides. *Toxics*, *11*(3), 211.

15. Murugasridevi, K., Saranya, M., & Muthaiah, C. (2017). Bio-Efficacy of Different Botanicals Against Tobacco Caterpillar, Spodoptera litura Fab. Environment and Ecology, 35(3C), 2227-2231.
16. Ramzan, M., Ilahi, H., Umar, A. B., Nasir, M., Zahid, M. K., Rukh, S., & Rehman, M. U. (2021). Biological parameters of Armyworm, Spodoptera litura and toxicity of three insecticides against 3rd instars larvae under laboratory conditions. Indian Journal of Pure & Applied Biosciences, 9(1), 12-17. https://doi.org/10.18782/2582- 2845.8518
17. Ramzan, M., Murtaza, G., Javaid, M., Iqbal, N., Raza, T., Arshad, A., & Awais, M. (2019). Comparative efficacy of newer insecticides against *Plutella xylostella* and *Spodoptera litura* on cauliflower under laboratory conditions. Indian Journal of Pure & Applied Biosciences, 7(5), 1-7. https://doi.org/10.18782/2320-7051.7796
18. Ramzan, M., Sajid, Z., Sattar, Z., Abbas, D., Yaseen, T., Mehmood, S., & Yaseen, I. (2020b). Biological and Morphological Parameters of Armyworm, *Spodoptera litura* in Cabbage and Maize Plants under Laboratory Conditions in Southern Punjab, Pakistan. *Journal of Environmental Issues and Agriculture in Developing Countries*, *12*(2&3).
19. Ramzan, M., Sultan, Y., Sabir, M. W., Haseeb, U. R., Shafiq, M., Murtaza, G., Shahid, M., Umair, M., & Asif, H. M. (2020a). Effect of host plant on the biology of *Spodoptera litura*. Indian Journal of Entomology, 82(3), 123-126. https://doi.org/10.5958/0974-8172.2020.00090 5.
20. Ramzan, M., Usman, M., Sajid, Z., Ghani, U., Basit, M. A., Razzaq, M., Shafee, W., & Shahid, M. R. (2020). Bio-ecology and management of *Spodoptera frugiperda* (Lepidoptera: Noctuidae): A review. Journal of Pure and Applied Agriculture, 5(4), 1-9
21. Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., Grewal, A. S., ... & Kaushal, J. (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *Journal of cleaner production*, *283*, 124657.
22. Safder, A., Afzal, Z., Munawar, F., Hashmi, A. M., Ali, R. B., & Amanat, N. (2022). Efficacy of botanicals extracts against *Spodoptera litura* (Lepidoptera: Noctuidae) under laboratory condition. *Journal of Scientific Agriculture*, *6*, 32–35. https://doi.org/10.25081/jsa.2022.v6.8103.
23. Samsidar, A., Siddiquee, S. & Shaarani, S. M. A review of extraction, analytical and advanced methods for determination of pesticides in environment and foodstuffs. Trends Food Sci. Technol. 71, 188–201. https://doi.org/10.1016/j.tifs.2017.11.011 (2018).
24. Sisay, B., Tefera, T., Wakgari, M., Ayalew, G., & Mendesil, E. (2019). The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in maize. *Insects*, *10*(2), 45.
25. Srivastava, K., Sharma, D., Anal, A. K. D., & Sharma, S. (2018). Integrated Management of Spodoptera litura: a review. *International Journal of Life-Sciences Scientific Research*, *4*(1), 1536-1538.
26. Sunitha, S. V. L., Swathi, M., Madhumathi, T., & Kumar, P. A. (2023). Efficacy of Botanicals against Armyworm, Spodoptera frugiperda (JE SMITH) in Sorghum. *Journal of Experimental Zoology India*, *26*(1).

27. Zhang, Z., Gao, B., Qu, C., Gong, J., Li, W., Luo, C., & Wang, R. (2022). Resistance monitoring for six insecticides in vegetable field-collected populations of Spodoptera litura from China. *Horticulturae*, *8*(3), 255.