EVALUATION OF BOTANICAL AND CHEMICAL INSECTICIDES AGAINST JUTE HAIRY CATERPILLAR (*Spilosoma obliqua)* IN MUNG BEAN (*Vigna radiata)* IN RAMPUR, CHITWAN, NEPAL

Basu Dev Joshi, Bhola Gautam and Chiran Adhikari

Agriculture and Forestry University, Chitwan, Nepal
Correspondence: basudevjoshi700@gmail.com

ABSTRACT

The jute hairy caterpillar (JHC) is a destructive, sporadic, polyphagous pest that requires timely management. This study, conducted in Rampur, Chitwan, Nepal, during the spring season of April 2022 to evaluate the efficacy of various insecticides against JHC through both laboratory and field experiments. In the laboratory, 3rd instar larvae were treated with ten treatments: chlorantraniliprole 18.5% SC, abamectin 5% EC, spinetoram 11.7% SC (each at 0.40 ml/L), essential oils of Mugwort, Lantana, and Neem (2.5 ml/L), leaf extracts of these plants (100 ml/L), and a water control. Larval mortality was recorded over 80 hours. Abamectin achieved 100% mortality within 56 hours, while chlorantraniliprole, spinetoram, Neem essential oil, and Neem leaf extract reached the same by 72 hours. Mugwort and Lantana leaf extracts showed similar efficacy to their essential oil extracts. The subsequent field experiment tested eight treatments (excluding leaf extracts of Mugwort and Lantana), applied four times at weekly intervals, starting 45 days after sowing. All treatments significantly reduced egg masses compared to the control, with no statistical difference between chemical and botanical insecticides. These findings suggest that botanical alternatives are as effective as chemical insecticides in reducing egg masses and larval populations, while also posing fewer environmental risks, making them a viable option for early-stage JHC management in the field. The 100% larval mortality observed under laboratory conditions suggests that all tested insecticides are also equally effective against the larval stage; however, further field research is needed to confirm this efficacy. Botanical alternatives thus offer a promising, eco-friendly option for early-stage JHC management.

Key words : Botanical, chemical insecticides, jute hairy caterpillar, mung bean, plant extract

INTRODUCTION

Mung bean, or green gram (*Vigna radiata* (L.) R. Wilczek, 1954), is an important pulse crop (Itoh et al., 2006). In Nepal, it is cultivated over an area of 8,265 hectares, with an average productivity of 1.27 mt/ha, resulting in a total annual production of 10,468 mt (Prasai et al., 2018). The jute hairy caterpillar (JHC), *Spilosoma obliqua* Walker (1855), is a highly destructive polyphagous pest belonging to the order Lepidoptera. It feeds on a wide range of crops, including groundnut, sunflower, sesame, linseed, jute, sunn hemp, beans, cotton, rice, pea, black gram, green gram, red gram, pearl millet, soybean, maize, and banana (Lefroy, 1907). In mung bean, JHC can cause yield losses of up to 30% annually (Mohapatra & Gupta, 2018).

To manage such pests, both chemical and botanical methods are in use. Chemical pesticides are widely favored for their cost-effectiveness, reliability, ease of application, and immediate impact (Haider & Ahmed, 2014). However, they can also harm non-target organisms and wildlife (Budhathoki et al., 2020). To mitigate these impacts, botanical pesticides—derived from plant parts such as leaves, roots, and essential oils offer an eco-friendly alternative. These botanicals are natural compounds produced by plants as a defense against pests and diseases (Khan et al., 2016).

In Nepal, many farmers struggle to choose between synthetic and botanical options due to limited knowledge of their effectiveness against specific pests. Therefore, this study aims to evaluate and compare the efficacy of available chemical and botanical insecticides for the management of JHC in mung bean crops.

MATERIALS AND METHODS

This research was carried out from April to July 2022 at Rampur, Chitwan, Nepal. Experiments were carried out in laboratory and field conditions for the management of JHC, and the details on the experiments are presented below.

Bioassay of insecticides on larvae of JHC in the laboratory (leaf dip bioassay)

The study was conducted in the Entomology Laboratory of the Department of Entomology, Agriculture and Forestry University (AFU), Rampur, Chitwan, using a Completely Randomized Design (CRD) to evaluate the efficacy of chemical and botanical insecticides against 3rd instar larvae of jute hairy caterpillar (JHC) in mung bean. Ten treatments were tested: chlorantraniliprole 18.5% SC (0.40 ml/L), abamectin 5% EC (0.40 ml/L), spinetoram 11.7% SC (0.40 ml/L), Mugwort essential oil (2.5 ml/L), Lantana essential oil (2.5 ml/L), Neem essential oil (2.5 ml/L), Mugwort leaf extract (100 ml/L), Lantana leaf extract (100 ml/L), Neem leaf extract (100 ml/L), and a control (water only) (Table 1).

Mung bean was cultivated in pesticide-free plots at the AFU horticulture field. JHC egg masses were collected from these plots along with infested leaves, using scissors, and placed in aerated one-kilogram polythene bags for transport to the laboratory. Eggs were transferred to ventilated transparent plastic boxes (19 × 12.5 × 7.5 cm), incubated at 28 ± 2 °C. Larvae hatched within 2–3 days and were reared in Petri dishes (8.5 cm diameter and 1.2 cm height) lined with damp blotting paper. Fresh mung bean leaves were provided regularly, and petri dishes were cleaned daily using forceps and camel hair brushes.

To compare the efficacy of different available alternatives against JHC larvae, essential oils from mugwort, lantana, and neem were extracted through steam distillation using a Clevenger apparatus in the Biotechnology Laboratory of AFU, while commercial chemical insecticides were sourced from local agrovets. A leaf dip bioassay was performed to evaluate the larval mortality of JHC. Insecticidal treatment solutions were prepared by diluting each insecticide to its recommended concentration using distilled water (Table 1). Tender mung bean leaves were cut into uniform sizes, dipped in the insecticidal solutions for 10 seconds, and air-dried for 10 minutes at room temperature. Each treatment was replicated five times using separate Petri dishes.

Newly molted 3rd instar JHC larvae were starved for 24 hours prior to the experiment. Five larvae were released into each Petri dish, totaling 25 larvae per treatment. Larval mortality was recorded at

8, 16, 24, 32, 40, 48, 56, 64, 72, and 80 hours after treatment application. Larvae were considered dead if they showed no movement when gently prodded with a camel hair brush.

Table1. Treatment details for laboratory bioassay, Rampur, Chitwan, Nepal

S.N.	Treatments	Formulation	Dilution	Trade Name	Hazard Label
1.	Chlorantraniliprole (18.5%)	SC	0.40ml/L	Allcora	Green
2.	Abamectin (5%)	EC	0.40 ml/L	ABA-5	Blue
3.	Spinetoram (11.7%)	SC	0.50 ml/L	Deligate	Green
4.	Mugwort essential oil	-	2.5 ml/L	-	-
5.	Lantana essential oil	-	2.5 ml/L	-	-
6.	Neem essential oil (0.30%)	EC	2.5 ml/L	Gorakha Bio-Neem	Green
7.	Mugwort leaf extract	-	100 ml/L	-	-
8.	Lantana leaf extract	-	100 ml/L	-	-
9.	Neem leaf extract	-	100 ml/L	-	-
10.	Control	-	-	-	-

Field experiment

Following the laboratory experiment, a field experiment was conducted at the Horticultural Research Field of Agriculture and Forestry University (AFU), Bharatpur Metropolitan City-19, Rampur, Chitwan, from April to July 2022. A Randomized Complete Block Design (RCBD) was used to evaluate the efficacy of chemical and botanical insecticides against JHC egg masses in mung bean. Based on the laboratory findings, Mugwort and Lantana leaf extracts were excluded from the field study due to their similar performance to essential oils. Thus, eight treatments were tested: chlorantraniliprole 18.5% SC (0.4 ml/L), abamectin 5% EC (0.40 ml/L), spinetoram 11.7% SC (0.50 ml/L), Mugwort essential oil (2.5 ml/L), Lantana essential oil (2.5 ml/L), Neem essential oil 0.30% EC (2.5 ml/L), Neem leaf extract (100 ml/L), and a control (water only) (Table 2). Each treatment was replicated three times, with individual plot sizes of 2.1 × 2.0 m. A spacing of 1 m was maintained between replications and 0.5 m between plots within a replication.

Mung bean variety 'Pratigya' was used, and recommended doses of fertilizers were applied: NPK at 20:20:20 kg/ha and farmyard manure (FYM) at 5 tons/ha. Insecticide solutions were prepared according to recommended concentrations (Table 2), and each treatment was applied using a separate 2 L capacity portable hand sprayer. For essential oil treatments, an emulsifier was mixed with the oils in a 1:1 ratio before dilution.

Spraying began on the 45th day after sowing, coinciding with a noticeable increase in egg mass presence in the field. All treatments were applied uniformly across the entire plots at 7-day intervals, for a total of four applications. Data on the number of egg masses were recorded one day before each spray, and again on the 3rd and 6th days after spraying. The 6th-day data following each application was used as pre-treatment data for the subsequent spray.

Table 2. Treatment details of the field experiment in Rampur, Chitwan, Nepal

S.N.	Treatments	Formulation	Dilution	Trade Name	Hazard Label
1.	Abamectin (5%)	EC	0.40 ml/L	ABA-5	Blue
2.	Chlorantraniliprole (18.5%)	SC	0.40 ml/L	Allcora	Green
3.	Spinetoram (11.7%)	SC	0.50 ml/L	Deligate	Green
4.	Lantana essential oil	-	2.5 ml/L	-	-
5.	Neem leaf extract	-	100 ml/L	-	-
6.	Neem essential oil (0.30%)	EC	2.5 ml/L	Gorakha Bio-Neem	Green
7.	Mugwort essential oil	-	2.5 ml/L		-
8.	Control(water)	-	-	-	-

Statistical analysis

Data were organized using Microsoft Excel and analyzed in R Studio (version 2022.02.3) using a General Linear Model (GLM). The GVLMA test was used to assess the normality of data. Where data were not normally distributed, Arcsine transformation was applied, following the method described by Gomez and Gomez (1984). Analysis of variance (ANOVA) was used to determine treatment effects, and mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

RESULTS AND DISCUSSION

Effect of various insecticides on larval mortality of JHC under laboratory conditions

In the laboratory bioassay, the mortality of 3rd instar *Spilosoma obliqua* (JHC) larvae was assessed at eight-hour intervals following treatment with various insecticides. Among the treatments, abamectin 5% EC demonstrated the most rapid and complete efficacy, achieving 100% larval mortality within 56 hours of application (Table 3). In contrast, chlorantraniliprole 18.5% SC, spinetoram 11.7% SC, neem essential oil, and neem leaf extract reached 100% mortality only by 72 hours, indicating slightly slower but still effective control. Other botanical treatments, including mugwort essential oil, lantana essential oil, mugwort leaf extract, and lantana leaf extract, exhibited similar patterns of activity, achieving complete mortality of larvae by 80 hours post-application. The control group, treated with water only, showed no larval mortality, confirming that observed effects were due to the treatments applied and not environmental or handling factors.

These findings suggest that both chemical and botanical insecticides are effective against JHC larvae under laboratory conditions, though chemical treatments, particularly abamectin, act more rapidly. The superior performance of abamectin aligns with findings by Soares et al. (2019), who reported its high lethality (79.98%) against *Macrolophus basicornis* in tomato crops. Similarly, Poornima et al. (2023) found abamectin effective in managing yellow mites, reinforcing its broad-spectrum efficacy across multiple pest species. The ability of botanical extracts, especially Neem-based treatments and essential oils, to eventually achieve full mortality is particularly significant. While their action was slower than chemical alternatives, their comparable effectiveness by 80 hours supports their potential as eco-friendly, sustainable alternatives in integrated pest management (IPM) programs. This is crucial

in minimizing chemical residue, conserving beneficial insects, and reducing environmental impact, especially in regions like Nepal, where awareness and access to safe alternatives remain limited. However, further studies under field conditions are needed to validate these laboratory results, particularly to assess persistence, residual activity, and cost-effectiveness in real agricultural settings.

Table 3. Effect of different treatments against 3rd instar JHC under laboratory conditions

Treatment	Cumulative mortality percent recorded at different time intervals(hr)									
	8	**16**	**24**	**32**	**40**	**48**	**56**	**64**	**72**	**80**
Chlorantraniliprole	0	8	24	28	36	52	68	92	100	100
Abamectin	12	52	60	68	84	92	100	100	100	100
Spinetoram	0	16	36	36	44	68	80	96	100	100
Mugwort essential oil	8	20	32	36	44	52	72	84	96	100
Lantana essential oil	0	4	8	16	24	40	56	84	88	100
Neem essential oil	8	20	20	24	40	60	76	92	100	100
Mugwort leaf extract	4	12	16	24	60	68	84	92	96	100
Lantana leaf extract	4	8	16	24	36	48	68	88	92	100
Neem leaf extract	4	4	12	12	24	36	68	96	100	100
Control	0	0	0	0	0	0	0	0	0	0

Effect of treatments on egg mass of JHC under field conditions

The field evaluation of chemical and botanical insecticides demonstrated a clear and consistent suppression of JHC egg mass densities across all four spray applications. After the first spray, a significant reduction in the number of egg masses was observed on both the 3rd and 6th days post-application (Table 4). The most effective treatments included abamectin 5% EC, spinetoram 11.7% SC, chlorantraniliprole 18.5% SC, and Neem essential oil, all of which recorded the lowest egg mass counts. Although these treatments showed no statistically significant differences among themselves, their effects were consistently and significantly better than the untreated control, indicating their strong ovipositional deterrence. Similar trends were evident following the second and third sprays (Tables 5 and 6). In each case, all treatments significantly outperformed the control, and abamectin, spinetoram, chlorantraniliprole, and lantana essential oil repeatedly ranked among the most effective, though again being statistically similar. This consistency suggests broad-spectrum and sustained activity of these treatments, especially under field conditions where environmental factors often compromise efficacy.

Table 4. Effect of different treatments on the number of egg masses per plot after 1st spray

Treatments	Before 1st spray	After 1st spray	
		3 DAS	**6 DAS**
Abamectin	1.17 ± 0.25(1.07)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Chlorantraniliprole	1.34 ± 0.12(1.15)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Spinetoram	1.05 ± 0.17(1.02)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Lantana essential oil	1.00 ± 0.29(0.98)	0.88^{b} ± 0.17(0.93)	0.71^{b} ± 0(0.84)

Treatments	Before 1st spray	After 1st spray	
		3 DAS	6 DAS
Neem leaf extract	1.38 ± 0.34(1.15)	1.05^{ab} ± 0.17(1.02)	0.88^{b} ± 0.17(0.93)
Neem essential oil	1.05 ± 0.17(1.02)	0.71^{b} ± 0(0.84)	0.88^{b} ± 0.17(0.93)
Mugwort essential oil	1.17 ± 0.25(1.07)	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)
Control(water)	1.77 ± 0.1(1.33)	1.34^{a} ± 0.12(1.15)	1.56^{a} ± 0.19(1.24)
F value	1.11	3.59*	5.77**
LSD(α=0.05)	0.32	0.18	0.17
CV %	16.91	11.12	10.54
SEm(±)	0.18	0.10	0.09
Grand mean	1.24	0.87	0.88

DAS: Days after spraying of Treatments; CV: Coefficient of Variation; *: Significant at P<0.05; **: Significant at P<0.01; ***: Significant at P<0.001; LSD: Least Significant Difference; SEm: Standard error of mean; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); figure in parenthesis indicate Arcsine transformation of original values outside parenthesis and are followed by ± and their standard error

Also, after the fourth spray (Table 7), the effectiveness of these treatments remained evident. Egg mass counts in plots treated with abamectin, spinetoram, chlorantraniliprole, and Neem essential oil were again the lowest and statistically comparable, reinforcing their reliable suppressive potential even at later crop stages. The consistent efficacy across multiple spray intervals and replications highlights the robustness of these treatments in managing JHC populations under real-world conditions. The superior performance of abamectin can be attributed to its mechanism of action; it disrupts chloride channels in the insect nervous system, leading to loss of motor control, feeding inhibition, and death (Wolstenholme, 2012). Spinetoram, a spinosyn-class insecticide, targets nicotinic acetylcholine receptors and has been shown to retain strong residual toxicity against lepidopteran pests (Sial & Brunner, 2010). Chlorantraniliprole acts by activating ryanodine receptors, causing muscular paralysis in insects. The combined neurotoxic effects of these chemicals explain their rapid and consistent efficacy.

Table 5. Effect of different treatments on the number of egg masses per plot after 2nd spray

Treatments	Before 2nd spray	After 2nd spray	
		3 DAS	6 DAS
Abamectin	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Chlorantraniliprole	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Spinetoram	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)	0.71^{b} ± 0(0.84)
Lantana essential oil	0.71^{b} ± 0(0.84)	0.71^{b}±0(0.84)	0.71^{b} ± 0.17(0.93)
Neem leaf extract	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)
Neem essential oil	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.84)
Mugwort essential oil	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)	0.88^{b} ± 0.17(0.93)
Control (water)	1.56^{a} ± 0.19(1.24)	1.65^{a} ± 0.0.21(1.28)	1.22^{a} ± 0(1.10)

Treatments	Before 2nd spray	After 2nd spray	
		3 DAS	6 DAS
F value	5.77**	5.72**	2.5
LSD(α=0.05)	0.17	0.19	0.17
CV %	10.54	11.5	10.9
SEm(±)	0.09	0.11	0.09
Grand mean	0.88	0.89	0.84

DAS: Days after spraying of Treatments; CV: Coefficient of Variation; *: Significant at P<0.05; **: Significant at P<0.01; ***: Significant at P<0.001; LSD: Least Significant Difference; SEm: Standard error of mean; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); figure in parenthesis indicate Arcsine transformation of original values outside parenthesis and are followed by ± and their standard error.

Table 6. Effect of different treatments on number of egg mass per plot after 3rd spray

Treatment	Before 3rd spray	After 3rd spray	
		3DAS	6DAS
Abamectin	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Chlorantraniliprole	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Spinetoram	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Lantana essential oil	$0.71^{b} \pm 0.17(0.93)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Neem leaf extract	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$
Neem essential oil	$0.88^{b} \pm 0.17(0.84)$	$1.00^{b} \pm 0.29(0.98)$	$0.88^{b} \pm 0.17(0.93)$
Mugwort essential oil	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$
Control(water)	$1.22^{a} \pm 0(1.10)$	$1.56^{a} \pm 0.18(1.24)$	$1.65^{a} \pm 0.21(1.28)$
F value	2.5	4.24**	5.7**
LSD(α=0.05)	0.17	0.2	0.19
CV%	10.9	12.35	11.5
SEm (±)	0.09	0.11	0.11
Grand mean	0.84	0.89	0.89

DAS: Days after spraying of Treatments; CV: Coefficient of Variation;*: Significantat P<0.05;**:Significant at P<0.01; ***: Significant at P<0.001; LSD: Least Significant Difference; SEm: Standard error of mean; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); figure in parenthesis indicate Arcsine transformation of original values and are followed by ± and their standard error

Botanical treatments also played a significant role. Essential oils, especially from Neem and Lantana, exhibited substantial anti-ovipositional and larvicidal activity. The lipophilic nature of essential oils enhances their ability to penetrate insect cuticles and respiratory systems, disrupting vital physiological functions (Lee et al., 2004). Neem's azadirachtin and salanin act as powerful insect growth regulators, antifeedants, and repellents, making it particularly effective in reducing oviposition (Gisbert et al., 2006; Ware & Whitacre, 2004). Similarly, Mugwort (*Artemisia* spp.) essential oil has been shown to induce mortality by disrupting neural and respiratory functions

(Ivanescu et al., 2021; Kostyukovsky et al., 2002).These findings are in line with field trials conducted by Thumar et al. (2020), who reported that spinetoram outperformed chlorantraniliprole in controlling *Spodoptera frugiperda* and resulted in increased crop yield, further validating its broad-spectrum efficacy. Therefore, this field study demonstrates that both chemical and selected botanical insecticides are effective for the suppression of JHC egg mass in mung bean. While synthetic treatments generally act faster and more consistently, botanical alternatives—especially essential oils—offer a promising, eco-friendly option for integrated pest management, particularly for sustainable and organic farming systems in regions like Nepal.

Table 7. Effect of different treatments on the number of egg mass per plot after 4th spray

Treatment	Before 4th spray	After 4th spray	
		3DAS	6DAS
Abamectin	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Chlorantraniliprole	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Spinetoram	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Lantana essential oil	$0.71^{b} \pm 0(0.84)$	$1.05^{b} \pm 0.17(1.02)$	$0.88^{b} \pm 0.17(0.93)$
Neem leaf extract	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$	$1.05^{ab} \pm 0.17(1.02)$
Neem essential oil	$0.88^{b} \pm 0.17(0.93)$	$0.71^{b} \pm 0(0.84)$	$0.71^{b} \pm 0(0.84)$
Mugwort essential oil	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$	$0.88^{b} \pm 0.17(0.93)$
Control(water)	$1.65^{a} \pm 0.21(1.28)$	$1.46^{a} \pm 0.12(1.20)$	$1.34^{a} \pm 0.12(1.15)$
Fvalue	5.72**	4.84**	3.59*
LSD(α=0.05)	0.19	0.18	0.18
CV%	11.5	10.8	11.12
SEm(±)	0.11	0.1	0.10
Grand mean	0.89	0.89	0.87

DAS: Days after spraying of Treatments; CV: Coefficient of Variation; *: Significant at P<0.05; **: Significant at P<0.01; ***: Significant at P<0.001; LSD: Least Significant Difference; SEm: Standard error of mean; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); figure in parenthesis indicate Arcsine transformation of original values and are followed by ± and their standard error

CONCLUSIONS

The study evidently demonstrated the effectiveness of both chemical and botanical insecticides in managing the jute hairy caterpillar (JHC), *Spilosoma obliqua* in mung bean. Under laboratory conditions, all treatments, including chemical and botanicals, achieved 100% mortality of 3rd instar larvae within 80 hours, although botanicals acted more slowly than chemical insecticides. In field conditions, although chemical insecticides recorded the lowest egg mass counts, Neem and Lantana essential oils also showed comparable efficacy, offering eco-friendly alternatives, particularly during early infestation stages. These results indicate that botanical insecticides can be effectively integrated into integrated pest management (IPM) strategies, providing a sustainable solution for smallholder farmers in Nepal and similar agro ecosystems.

REFERENCES

Budhathoki, P., Gnawali, P., Baral, D., & Gyawal, A. (2020). Pesticidal potential of ethno botanically important plants in Nepal – a review. *Acta Scientifica Malaysia,* 4(2), 69–74.http://doi.org/10.26480/asm.02.2020.45.50

Gisbert, C., Prohens, J., & Nuez, F. (2006). Efficient regeneration in two potential new crops for subtropical climates, the scarlet (*Solanum aethiopicum*) and gboma (*S. macrocarpon*) eggplants. *New Zealand Journal of Crop and Horticultural Science*, 34(1), 55-62. https://doi.org/10.1080/01140671.2006.9514388

Haider, A., Ahmed, S. (2014). Study on seed quality and performance of some Mung bean varieties in Pakistan. *Advances in Life Science and Technology*. 26, 43-47.

Itoh, T., Garica, R. N., Adachi, M., Maruyama, Y., Tecson-Mendoza, E. M. & Mikami, B., (2006). Structure of 8Sα globulin, the major seed storage protein of mung bean. *Acta Crystallographica Section D: Biological Crystallography,* 62(8), 824- 832. https://doi.org/ 10.1107/S090744490601804X

Ivănescu, B., Burlec, A. F., Crivoi, F., Roşu, C., & Corciovă, A. (2021). Secondary metabolites from *Artemisia* genus as biopesticides and innovative nano-based application strategies. *Molecules,* 26(10), 3061

Khan, I., Qureshi, N., Khan, S. A., Ali, A., Ahmad, M., & Junaid, K. (2016). Efficacy of several plant extracts as growth inhibitors against red flour beetle, *Tribolium castaneum*(Herbst) (Coleoptera: Tenebrionidae). *Acta Zoologica Bulgarica*, 68(3), 443-450.

Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N., & Shaaya, E. (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Management Science: formerly Pesticide Science,* 58(11), 1101-1106. https://doi.org/10.1002/ ps.548

Lee, B.H., Annis, P.C., Tumaalii, F., & Choic, W.S. (2004). Fumigant toxicity of essential oils from the Myrtaceae family and1,8-cineole against 3 major stored-grain insects. *Journal of Stored Products Research,* 40(5), 553-564.https://doi.org/10.1016/j.jspr. 2003.09.001

Lefroy, H. M. (1907). The more important insects injurious to Indian agriculture. *Memoirs of the Department of Agriculture India,* 1(2), 113-252.

Mohapatra, M. M., & Gupta, P. K. (2018). Evaluation of insecticides against Bihar Hairy Caterpillar, *Spilosoma obliqua* Walk. on black gram, *Vigna mungo* (Linn.). *International Journal of Current Microbiology and Applied Sciences*, 7(6), 605-608.https://doi.org/10.20546/ijcmas. 2018.7 06.069

Paré, P. W., & Tumlinson, J. H. (1999). Plant volatiles as a defense against insect herbivores. *Plant physiology,* 121(2), 325-332.https://doi.org/10.1104/pp.121.2.325

Prasai, H. K., Sah, S. K., Gautam, A. K., & Regmi, A. P. (2018). Conservation agriculture for productivity and profitability of wheat and lentil in maize based cropping system in far western Nepal. *Journal of the Bangladesh Agricultural University,*16(3), 403–410.

Thumar, R. K., Zala, M. B., Varma, H. S., Dhobi, C. B., Patel, B. N., Patel, M. B., & Borad, P. K. (2020). Evaluation of insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) infesting maize. *International Journal of Chemical Studies*, 8(4), 100-104.

Ware, G.W., & Whitacre, D.M.(2004). An introduction to insecticides. *The pesticide book*, 6

Wolstenholme, A. J. (2012). Glutamate-gated chloride channels. *Journal of Biological Chemistry*, 287(48), 40232-40238. https://doi.org/10.1074/jbc.R112.406280