ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 48(3): 371-383, September 2023

OVICIDAL AND LARVICIDAL EFFICACY OF FOUR BOTANICAL OILS AGAINST *SPODOPTERA FRUGIPERDA* (FAW) INFESTING MAIZE

I. AKTER[1], M. A. HOSSAIN[2], M. A. ALIM[3] AND H. F. EL TAJ[4]

Abstract

The study was conducted to evaluate the efficacy of four botanical oils viz., neem, castor, black cumin and sesame against *Spodoptera frugiperda* in the laboratory during the period from November 2021 to March 2022. Tween-20 as an emulsifier was used with the tested oils at 5, 7.5 and 10% concentration along with an untreated control were evaluated for their toxic effect against *S. frugiperda.* The botanical oils gave profound toxic effect against eggs, first, second and third instar larvae of *S. frugiperda*. Each dose of different oils showed 100% inhibition of egg hatching and caused mortality of first instar larvae. Castor oil at 10% concentration gave the highest mortality (32.22 and 30.00%) while sesame oil at 5% showed the lowest (11.11 and 10.00%) against second and third instars larvae, respectively. Castor oil performed the highest toxicity of LD_{50} values against second (2015.8 mg kg^{-1}) and third (3525.5 mg kg^{-1}) instars larvae. Conversely, sesame oil performed the lowest toxicity of LD_{50} values against second (8391.3 mg kg^{-1}) and third (15222.3 mg kg^{-1}) instars larvae after 72 hours of exposure. Castor oil might be used as ovicidal and larvicidal ingredients against *S. frugiperda*.

Keywords: *Spodoptera frugiperda*, essential oils, mortality, maize.

Introduction

Maize (*Zea mays* L.) is the world's top-ranking cereals followed by wheat and rice due its higher importance as a staple food as well as animal feed and fuel (Abebe *et al.,* 2017). Globally it is called as a queen of cereals (Jeyaraman, 2017). Nutritionally grain contains 10% protein, 4% oil, 70% carbohydrate, 2-3% crude fibers, besides Vitamin A, E, nicotinic acid and riboflavin (Joshi, 2015). The farmers of Bangladesh are interested for maize cultivation for so many advantages such as suitable for cultivation, high demand, higher profit, cost effective, higher yield, feed for fish and livestock as well as soil fertility (Mottaleb *et al.,* 2018; Islam and Knan, 2021). But the production of maize is severely affected by a number of insect pests (Adhikari *et al.*, 2020; Azad *et al.*, 2020). Among them, *Spodoptera frujiperda* (Lepidoptera: Noctuidae) is commonly known as fall armyworm recognized as a highly invasive serious polyphagous pest of crops but regarded as major pest of maize (Hoy, 2013; Kandel and Poudel, 2020). *S. frugiperda* is native to tropical and subtropical regions of the America (Capinera,

---

[1]MS, Department of Entomology, Faculty of Agriculture, [2,3&4]PhD, Professor, Department of Entomology, Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

2017). It attacks more than 353 crops including maize, sorghum, soybean, cotton, potato, rice, millet, oat, barley, wheat, sugarcane, para grass and different types of vegetable crops (Bueno *et al.*, 2011). The caterpillars attack and feed on maize plants from seedling to cob formation, reducing photosynthetic activity, structural damages, plant lodging and slower reproduction causing enormous yield losses (Georgen *et al.*, 2016; Chimweta *et al.*, 2019).

At present farmers are solely relying on the use of synthetic pesticides against this pest for quick knockdown (Tumma and Chandrika, 2018). But the indiscriminate, overdoses and repeated use of chemicals against fall armyworm causes ecological imbalance, pest resurgence, residues, pests' outbreak, creates phytotoxicity, environmental risks, human health hazard and killing of beneficial organisms (Negrini *et al.*, 2019; Mweke *et al.*, 2020; Wan *et al.*, 2021). Therefore, researchers are globally now trying to adopt alternatives of chemicals to protect crop from insect infestation (Isman, 2006). It has been reported that essential plant oils viz., *Corymbia citriodora*, *Myrciaria dubi*a (Myrtaceae), *Lippia microphylla* (Verbenaceae), and *Piper umbelattum* as well as 1% oils of clove, lemon grass, basil, and rosemary demonstrated insecticidal activity against fall armyworm (Negrini *et al.*, 2019; Siddhartha *et al.*, 2019). Botanicals are safe, ecofriendly, economical, target-specific, varied modes of action, low toxicity, easily biodegradable, compatible with other low risk pesticides and no possibility of development of resistance with minimal adverse effects on agro ecosystems and human health as well (Abdelghany, 2015). So, an attempt was made to find out the ovicidal and larvicidal efficacy of four botanical oils such as black cumin, castor, neem and sesame against fall armyworm.

Materials and Methods

The experiment was carried out in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh from November 2021 to March 2022 following Completely Randomized Design (CRD).

Rearing of *S. frugiperda*

Mass culture of *S. frugiperda* was maintained in laboratory to obtain a large number of larvae for experimental use. Approximately 100 numbers of different instars healthy *S. frugiperda* larvae were collected from an infested maize field in Kornai and Sadipur village near the HSTU campus, Dinajpur. They were kept in plastic zipper bags (200 L × 175 W) (mm) and brought to the laboratory for rearing. The larvae were identified as the frons has white inverted "Y" line on the head, and four dark warts in a square form on the dorsal surface of the eighth abdominal segment (Prasanna *et al.*, 2018). The larvae were placed individually into ventilated plastic boxes (6 L × 6 W × 4 H) (cm) with 15-30 days old maize leaves (Hybrid Variety-Dalia 4455, Tista Seeds Company Private Ltd., Bangladesh). The rearing boxes were cleaned every day and supplied with new fresh maize leaves. The pre-pupal stage was transferred to a plastic box (6 L × 6 W × 4 H) (cm) one third filled with soil for pupation. The pupae were collected and kept into the oviposition cage (40 L × 40 W × 40 H) (cm). Sterile cotton soaked in sugar solution and honey (mixed with water) was placed on a Petri dish inside the cage as a food source for newly emerged adults. Male and female also verified as described by Ganiger *et al*., (2018) and allowed for mating. Forewing of male having gray brown with white triangular patch at the apical region and circular spot at the center of the wing while female has uniformly grayish brown forewings mottled with dark brown spots. The hind wings of both male and female with silvery white and a dark border.

Maize plants (8-10 days old) and piece of wax paper were introduced into rearing cage for oviposition. The eggs were collected every day after deposition. After 2-3 days, black-head-stage egg batches were collected and placed in sterile plastic box for hatching. Eggs were monitored daily up to hatching; as soon as the first instars emerged, they were introduced into several Petri dishes provided with tender and fresh maize leaves. Rearing was performed at ambient conditions (22 ± 5^0 C, 70 ± 10 RH) and repeated until a desired population was achieved for the experiment.

Treatments

The botanical oils of black cumin (*Nigella sativa*), castor (*Ricinus communis*), neem (*Azadirachta indica*) and sesame (*Sesamum indicum*) were collected from the local market. Three doses such as 10.0, 7.5, and 5.0% of each of the tested oils were prepared separately by diluting in water as solvent which emulsified by using one drop of tween-20 with the help of micro pipette (Dragon lap China, model: C40038142).

Ovicidal test

The eggs (1 to 2-days-old) of *S. frugiperda* were collected from the culture. A cohort of 26-33 eggs was separated under the Stereo Microscope by removing excess eggs with a camel hairbrush before applying treatments. The cohort of eggs was sprayed with each concentration of each oil separately by hand sprayer and air dried for 30 minutes then placed into ventilated plastic boxes (6 L × 6 W × 4 H) (cm). The distilled water was applied for untreated control. Three replications were maintained with 30 eggs for each concentration. The numbers of hatched and non-hatched eggs were recorded daily until 7 days after treatment with the help of magnifying glass.

Toxicity test against larva

First to third instars larvae were selected to determine the toxicity of the botanical oils against *S. frugiperda* by leaf dipping method. Freshly collected young (15-30-

days-old) maize leaves were treated separately with each concentration of each oil and air dried for 30 minutes. The treated leaves were placed into ventilated plastic boxes (6 L × 6 W × 4 H) (cm) and a larva of each of 1st, 2nd and 3rd instars was placed separately with a fine camel hair brush. Three replications were maintained providing 10 larvae per replication for each concentration. Leaves treated with water only maintained for control treatments with equal number of larvae. Larval mortality was observed and recorded up to the 72 hours at 24 hours intervals after treatment. A larva was considered dead if it could not respond after being gently touched or itself after being placed on its dorsal surface with a camel hair brush. The percent mortality was corrected by the Abbott's (1987) formula.

$$P = \frac{P' - C}{100 - C} \times 100$$

Where, P = Corrected mortality (%), P′=Observed mortality (%), C=Mortality (%) at control

Statistical analysis

The data were analyzed statistically based on Completely Randomized Design (CRD) with the help of MSTAT-C, IBM SPSS Statistics version 25.0 and mean values were separated by Duncan's New Multiple Range Test (DMRT).

Results

Toxic effect of botanical oils on egg hatchability

Toxicity effects of botanical oils on egg hatchability of *S. frugiperda* were found similar among the treatments at different times after intervals. No neonate larva was hatched from treated eggs of *S. frugiperda* at different doses of botanical oils.

Toxic effect of botanical oils against the first instar larvae

Toxic effects of botanical oils on the mortality of first instar larvae of *S. frugiperda* were found similar among the treatments. Treated larvae of first instar were died at different doses of botanical oils.

Toxic effect of botanical oils against the second instar larvae

Mortality of second instar larvae of *S. frugiperda* in four botanical oils at three doses and their efficacy differed significantly at different time intervals (Tables 1-3). The highest mean mortality (29.26%) was recorded in castor oil ($p < 0.00$, $F = 214.42$, $df = 4$) as against the lowest (14.44%) in sesame oil having significant difference between them (Table 1). In case of dose effects, significantly ($p < 0.00$, $F = 29.35$, $df = 2$) the highest mean mortality (21.33%) was found at 10% concentration as against the lowest (14.67%) at 5% concentration (Table 2). In the interaction effects of oils and doses, significantly ($p < 0.01$, $F = 2.72$, $df = 12$) the highest mortality (32.22%) was observed at 10% concentration of castor oil while the lowest (11.11%) at 5% of sesame oil having significant difference between them (Table 3). But no mortality was recorded in the untreated control at 24, 48 and 72 hours after treatments (HATs).

Table 1. Toxic effect of botanical oils against the second instar larvae of *S. frugiperda* at different hours after treatment

Treatments (oils)	Mortality (%) at different HATs			Average mortality (%)
	24	48	72	
Neem	13.33 ab	21.11 a	45.56 a	26.67 b
Castor	16.67 a	23.33 a	47.78 a	29.26 a
Black cumin	11.11 b	16.67 b	31.11 b	19.63 c
Sesame	11.11 b	11.11 c	21.11 c	14.44 d
Untreated control	0.00 c	0.00 d	0.00 d	0.00 e
CV (%)	34.96	29.19	19.83	13.24

CV = Coefficient of variation, HATs = Hours after treatments, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Table 2. Toxic effect of different doses of botanical oils against second instar larvae of *S. frugiperda* at different hours after treatment (Interaction of doses and times)

Doses (%)	Mortality (%) at different HATs			Average mortality (%)
	24	48	72	
5	8.66 b	10.67 c	24.67 b	14.67 c
7.5	10.00 ab	14.67 b	29.33 a	18.00 b
10	12.67 a	18.00 a	33.33 a	21.33 a
CV (%)	34.96	29.19	19.83	13.24

CV = Coefficient of variation, HATs = Hours after treatment, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Toxic effect of botanical oils against the third instar larvae

Toxic effects of botanical oils, doses and their efficacy differed significantly among the treatments against the third instar larvae (Tables 4-6). Of tested oils, significantly ($p < 0.00$, $F = 209.64$, $df = 4$) the highest mean mortality (27.04%) was recorded in castor oil while the lowest (11.85%) in sesame oil (Table 4). Irrespective of oils among the doses, significantly ($p < 0.00$, $F = 33.33$, $df = 2$) the highest mean mortality (18.45%) was found at 10% concentration while the lowest (12.00%) at 5% concentration (Table 5). Due to the interaction effects of botanical oils, doses and times of intervals significantly ($p < 0.00$, $F = 3.58$, $df = 12$) the highest mean mortality (30.00%) was observed at 10% concentration of castor oil as against the lowest (10.00%) at 5% concentration of sesame oil (Table 6). Conversely, no mortality was recorded in the untreated control treatment at 24, 48 and 72 hours after water spraying.

Table 3. Interaction effect of botanical oils and doses on mortality of second instar larvae of *S. frugiperda* at different hours after treatment

Treatments (oils)	Doses (%)	Mortality (%) at different HATs			Average mortality (%)
		24	48	72	
Neem	5	10.00 b	13.33 de	43.33 ab	22.22 de
	7.5	13.33 b	23.33 abc	46.67 a	27.78 bc
	10	16.67 ab	26.67 ab	46.67 a	30.00 ab
Castor	5	13.33 b	16.67 cde	46.67 a	25.56 cd
	7.5	16.67 ab	23.33 abc	50.00 a	30.00 ab
	10	20.00 a	30.00 a	46.67 a	32.22 a
Black cumin	5	10.00 b	13.33 de	20.00 c	14.44 f
	7.5	10.00 b	16.67 cde	33.33 b	20.00 e
	10	13.33 b	20.00 bcd	40.00 ab	24.44 cd
Sesame	5	10.00 b	10.00 e	13.33 c	11.11 f
	7.5	10.00 b	10.00 e	16.67 c	12.22 f
	10	13.33 b	13.33 de	33.33 b	20.00 e
Untreated control	-	0.00 c	0.00 f	0.00 d	0.00 g
CV (%)	-	34.96	29.19	19.83	13.24

CV = Coefficient of variation, HATs = Hours after treatments, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Probit analysis for toxic effect of botanical oils

The results of the probit analysis for the estimation of LD_{50} values, χ^2 values and their 95% fiducial limits at 24, 48 and 72 HATs of FAW larvae are presented in Tables 7-8. The highest LD_{50} values were calculated as 1234092.3, 73896.8 and 8391.3 mg kg^{-1} for sesame oil but the lowest as 83841.1, 10180.0 and 2015.8 mg kg^{-1} at 24, 48 and 72 HATs, respectively for castor oil for 2nd instar larvae (Table 7). Similarly, the highest LD_{50} values were calculated as 1234092.3 mg kg^{-1} at 24 HATs for neem, black cumin and sesame oil while 1265469.5 and 15222.3 mg kg^{-1} at 48 and 72 HATs, respectively for sesame oil for 3rd instar larvae (Table 8). Conversely, the lowest LD_{50} values were calculated as 90495.0, 11829.4 and 3525.5 mg kg^{-1} at 24, 48 and 72 HATs, respectively for castor oil. The order of toxicity of oils was found as castor > neem > black cumin > sesame at 24, 48 and 72 HATs.

Table 4. Toxic effect of botanical oils against third instar larvae of *S. frugiperda* at different hours after treatment

Treatments (oils)	Mortality (%) at different HATs			Average mortality (%)
	24	48	72	
Neem	11.11 a	14.44 b	42.22 a	22.59 b
Castor	13.33 a	22.22 a	45.56 a	27.04 a
Black cumin	11.11 a	12.22 bc	22.22 b	15.19 c
Sesame	11.11 a	10.00 c	14.44 c	11.85 d
Untreated control	0.00 b	0.00 d	0.00 d	0.00 e
CV (%)	35.71	25.31	20.75	14.12

CV = Coefficient of variation, HATs = Hours after treatments, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Table 5. Toxic effect of doses of botanical oils against third instar larvae of *S. frugiperda* at different hours after treatment (Interaction of doses and times)

Doses (%)	Mortality (%) at different HATs			Average mortality (%)
	24	48	72	
5	8.00 b	9.33 b	18.67 b	12.00 c
7.5	8.66 b	11.33 b	26.67 a	15.55 b
10	11.33 a	14.67 a	29.33 a	18.45 a
CV (%)	35.71	25.31	20.75	14.12

CV = Coefficient of variation, HATs = Hours after treatments, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Table 6. Interaction effect of botanical oils and doses on mortality of third instar larvae of *S. frugiperda* at different hours after treatment

Treatments (oils)	Doses (%)	Mortality (%) at different HATs			Average mortality (%)
		24	48	72	
	5	10.00 b	10.00 d	30.00 e	16.67 cd
Neem	7.5	10.00 b	13.33 cd	46.67 abc	23.33 b
	10	13.33 ab	20.00 b	50.00 ab	27.78 a
	5	10.00 b	16.67 bc	40.00 cd	22.22 b
Castor	7.5	13.33 ab	20.00 b	53.33 a	28.89 a
	10	16.67 a	30.00 a	43.33 bc	30.00 a
	5	10.00 b	10.00 d	13.33 fg	11.11 ef
Black cumin	7.5	10.00 b	13.33 cd	20.00 f	14.44 de
	10	13.33 ab	13.33 cd	33.33 de	20.00 bc
	5	10.00 b	10.00 d	10.00 g	10.00 f
Sesame	7.5	10.00 b	10.00 d	13.33 fg	11.11 ef
	10	13.33 ab	10.00 d	20.00 f	14.44 de
Untreated control	-	0.00 c	0.00 e	0.00 h	0.00 g
CV (%)	-	35.71	25.31	20.75	14.12

CV = Coefficient of variation, HATs = Hours after treatments, within column mean values followed by different letter(s) are significantly different by DMRT at 5% level of probability

Table 7. Probit analysis of treated botanical oils against the second instar larvae of *S. frugiperda*

Treatments (oils)	No. of insects used	LD_{50} (mg/kg)	95% confidence limits lower	95% confidence limits upper	χ^2 values with 1 *df*
24 HATs					
Neem	30	90495.0	-		0.009
Castor	30	83841.1	-		0.003
Black cumin	30	105788.7	-		0.250
Sesame	30	1234092.3	-		0.069
48HATs					
Neem	30	11966.5	-		0.043
Castor	30	10180.0	-		0.016
Black cumin	30	20163.7	-		0.163
Sesame	30	73896.8	-		0.002
72HATs					
Neem	30	3535.1	79.9-5014.9		0.017
Castor	30	2015.8	-		0.890
Black cumin	30	5830.7	2849.8-7210.5		0.125
Sesame	30	8391.3	6027.6-5302395.1		0.607

Values were based on three concentrations, three replications of 10 insects of each, HATs = Hours after treatments, χ^2 = Goodness of fit, the tabulated value of χ^2 is 3.84 (*df* =1 at 5% level)

Table 8. Probit analysis of treated botanical oils against the third instar larvae of *S. frugiperda*

Treatments (oils)	No. of insects used	LD_{50} ($mgkg^{-1}$)	95% confidence limits lower	95% confidence limits upper	χ^2 values with 1 *df*
24 HATs					
Neem	30	1234092.3	-		0.069
Castor	30	90495.021	-		0.009
Black cumin	30	1234092.3	-		0.069
Sesame	30	1234092.3	-		0.069
48 HATs					
Neem	30	22415.4	-		0.169
Castor	30	11829.4	-		0.179
Black cumin	30	73896.8	-		0.002
Sesame	30	1265469.5	-		0.043
72HATs					
Neem	30	5035.0	2099.5-6241.9		0.190
Castor	30	3525.5	179.6-4952.5		0.280
Black cumin	30	7059.5	5248.4-9121.8		0.200
Sesame	30	15222.3	-		0.156

Values were based on three concentrations, three replications of 10 insects of each, HATs = Hours after treatments, χ^2 = Goodness of fit, the tabulated value of χ^2 is 3.84 (*df* =1 at 5% level).

Discussion

Present results revealed that the tested oils had profound toxic effects against the first, second and third instars larvae of *S. frugiperda*. Each doses of different oils showed 100% inhibition of eggs hatchability and caused mortality in case of first instar larvae. Parallel results were cited by Guedes *et al.*, (2020) who found that *azadirachtin* suppressed embryonic development of eggs, altered egg morphology, changed chorion structure and caused embryonic damage. Shu *et al.*, (2021) observed that azadirachtin also acted as growth inhibition and mortality against the larvae of *S. frugiperda*.

The second and third instars larval mortality by the tested oils were observed and found doses and time exposure dependent. The larval mortality percentages were increased proportionally with the increase of time intervals. Present results are in line with those of Silvestre *et al.*, (2021), Babendreier *et al.*, (2020), Lin *et al.*, (2020), Zhou *et al.*, (2020), Hruska (2019), Sisay *et al.*, (2019), Barbosa *et al.*, (2018), Lima *et al.*, (2010) and Farias-Rivera *et al.*, (2002). They experienced that neem oil, seed, and leaf powder caused 70% larval mortality of *S. frugiperda*. Parallel results were also obtained by Varella *et al.*, (2015). Present findings are also comparable with those of Farias- Rivera *et al.*, (2002). They mentioned that castor oil and vicinine extracts from the seeds and leaves of *Ricius communis* (L.) were effective, while methanol extract from residual fiber of *Zea diploperennis* caused high mortality and adversely affected the pupal size of *S. frugiperda*. Hruska (2019) observed another plant-based material as *Eucalyptus urograndis* oil and *Carica papaya* (L.) seeds and were found highly effective in inducing *S. frugiperda* mortality compared to the synthetic insecticide malathion. Again, Barbosa *et al.*, (2018) concluded that the oils extracted from *Corymbia citriodora, E. urograndis* had significant effects in protecting maize from *S. frugiperda* larvae, while oils extracted from turmeric, clove palmarosa, and neem were highly efficacious against first and second instars larvae of *S. frugiperda.*

The biological activities of tested oils can be attributed to several alkaloid contents as an insecticidal potency (Ghosal *et al*., 2005; Alice *et al*., 2007). The alkaloids like ricinin is present in castor oil (Prakash and Rao, 1996). The other phytochemicals as alkaloids, terpinoids, steroids, glycosides as morgason-O, nimbin, nimbidine, meliacins present in neem oil (Rejesus *et al.*, 1990) while sesamin in sesame oil (Prakash and Rao, 1996). Again, black cumin seeds characterized both qualitatively and quantitatively for phytochemicals, proved the secondary metabolites as bio-pesticide potentials against *D. maculatus* (Bob-Manuel and Ukoroije, 2020). It contains several phytoconstituents as phenols, alkaloid, flavonoid, terpenoid, saponin, tannin, cardiac glycoside, anthraquinone, steroid and oxalate in different proportion. All these chemical compounds might associate with insecticidal potency. The biological activity of oils interferes with normal respiration of insects resulting accelerate suffocation leading to death (Schoonhoven, 1978).

Novel innovative research illustrated that diverse plant products have been tried by several researchers with a good degree of success against *S. frugiperda* (Lin *et al.*, 2020; Zhou *et al.*, 2020). These findings are in line with that of Lima *et al.*, (2010). They found that leaves of *Ageratum conyzoides* potential against fall armyworm. Some scholars opined that botanical oils have also broad-spectrum insecticidal activity affecting insect nervous and defense systems (Hold *et al*., 2000; Isman, 2000; Ketoh, 2004). These chemical compounds might associate with deterrent, repellent and anti-feeding actions consequently leads to mortality against the tested caterpillars of *S. frugiperda*. The present findings are comparable with various researchers (Silvestre *et al.*, 2021; Babendreier *et al.*, 2020; Sisay*et al.*, 2019). They experienced those essential oils of neem, zinger, based products causing toxicity to larvae of *S. frugiperda* has induced larval growth inhibition under laboratory conditions might accelerate fatality.The present results are in parallel with those of Silvestre *et al.*, (2021). They cited that essential botanical oil of *Crocus speciosus* induced low larval mortality (33.2%) at 0.8% v/v while 86.6% at 1.0% v/v but caused 100% at 1.5% v/v at 72 hours of exposure in *S. frugiperda*.

The LD_{50} values of the tested botanicals oils have also been calculated to compare the efficacy. Probit results indicated that all the tested oils would more or less effective against the second and third instar larvae of *S. frugiperda*. But castor oil had the most effective followed by the neem oil. The present results are in line with the findings of Lima *et al.*, (2020). They opined those essential botanical oils from *Lippia sidoides*, and thymol showed LD50 values of 3.21 and 4.91 mg g^{-1}, respectively on *S. frugiperda*. Dutra *et al.*, (2020) also observed the insecticidal potency of three essential oils of *Piper corcovadensis*, *P. marginatu*, and *P. arboretum* on *S. frupigerda* and found LD_{50} values as 3.58, 4.18, and 10.91 mg g^{-1}, respectively. Outcome of the present findings are comparable with those of Tithi *et al.* (2021). They experienced that botanical oil of castor *R. communis* at 10% performed the highest toxicity of LD_{50} value as 6.4 mg kg^{-1} against the 3rd instar grub of *Epilachna dodecastigma* after 72 hours of exposure.

Based on efficacy of the tested botanicals, castor oil was found the most effective against the eggs and 1st to 3rd instar larvae of *S. frugiperda*. However, further studies need to be conducted to isolate and evaluate the active compound of trialed oils with its mode of action.

Acknowledgement

The authors acknowledge the Institute of Research and Training (IRT), HSTU, for financial support as research grants.

References

Abbott, W. S. 1987. A method of computing the effectiveness of an insecticide. *J. Am. Mosq. Control Assoc*. **3**: 302 - 303.

Abdelghany, T. M. 2015. Entomopathogenic Fungi and Their Role in Biological Control. OMICS Group e Books. pp. 1 - 41.

Abebe, Z., C. Dabala and T. Birhanu. 2017. System Productivity as Influenced by Varieties and Temporal Arrangement of Bean in Maize-climbing Bean Intercropping. *J. Agron*. **16**: 1 - 11.

Adhikari, K., S. Bhandari, L. Dhakal and J. Shrestha 2020. Fall armyworm (*Spodoptera frugiperda*): A threat in crop production in Africa and Asia. *Peruv. J. Agron*. **4(3):** 121 - 133.

Alice J., R. P. Sujeetha, N. Mathurani and L. Nadarajan. 2007. Effect of indigenous plant products and oils against the pulse beetle, *Callosobruchus chinensis* (L.) on stored blackgram. *Asian J. Biol. Sci*. **2(1&2):** 203 - 204.

Azad, A.B., M. Miaruddin, M. A. Ohab, M. H. R. Shak, B. L. Nagh and M. H. H. Rahman. 2020. KRISHI PROJUKTI HATBOI (Handbook on Agro-Technology). 9th edition Bangladesh Agricultural Research Institute. Gazipur-1701. Bangladesh.

Babendreier, D. L. K., P. Agboyi, M. Beseh, J. Osae, S. E. K. Nboyine, J. O. Ofori, V. A. Frimpong, M. Clottey and M. Kenis. 2020. The efficacy of alterna- tive, environmentally friendly plant protection measures for control of fall armyworm, *Spodoptera frugiperda,* in maize. *Insects*. **11**: 240.

Barbosa, M. S., B. B. Dias, M. S. Guerra and G. H. Costa Vieira. 2018. Applying plant oils to control fall armyworm (*Spodoptera frugiperda*) in corn. *Aust. J. Crop Sci*. **12**(4): 557 - 62.

Bob-Manuel, R. B. and R. Ukoroije. 2020. Insecticidal property of black seed (*Nigella sativa*) powder as an eco-friendly management of skin beetle *Dermestes maculatus* (Coleoptera: Dermestidae) in Atlantic codfish *Cadus morhua* (Gadiformes: Gadidae). *Asian J. Adv. Agric. Res.* **13(3):** 47 - 56. DOI:10.9734/ajaar/2020/v13i330108

Bueno, R. C. O. F., A. F. Bueno, F. Moscardi, J. R. Parra and C. B. Hoffmann-Campo. 2011. Lepidopteran larvae consumption of soybean foliage: basis for developing multiple-species economic thresholds for pest management decisions. *Pest Manag. Sci*. **67**: 170 -174.

Capinera, J. L. 2017. *Featured Creatures: Fall Armyworm*. Entomology and Nematology Circular, University of Florida IFAS. http://entnemdept.ufl.edu/creatures/field/ fall_army-worm.htm.

Chimweta, M., I. W. Nyakudya, L. Jimu and A. B. Mashingaidze. 2019. Fall armyworm [*Spodoptera frugiperda* (JE Smith)] damage in maize: management options for flood-recession cropping smallholder farmers. *Int. J. Pest Manag*. **66(2):** 1 - 13.

Dutra, K., V. Wanderley-Teixeira, C. Guedes, G. Cruz, D. Navarro, A. Monteiro, A. Agra, C. L. Neto, and A. Teixeira. 2020. Toxicity of essential oils of leaves of plants from the genus piper with influence on the nutritional parameters of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae). *J. Essent. Oil-Bear*. **23**: 213 - 229.

Farias-Rivera, L. A., J. L. Hernandez-Mendoza, J. Molina-Ochoa and A. Pescador-Rubio. 2002. Effect of leaf extracts of teosinte, *Zea diploperrennis* L. and a Mexican maize variety, Criollo "uruapeno" on the growth and survival of the Fall armyworm (Lepidoptera: Noctuidae). *Fl. Entomol*. **86**: 239 - 343.

Goergen, G., P. L. Kumar, B. Sagnia, Sankung, T. Abou and T. Manuele. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLOS ONE*. **11(10):**1 - 9.

Ghosal, T. K., S. K. Senapati and D. C. Dev. 2005. Pesticidal effect of edible and non-edible oils on pulse beetle, *Callosobruchus chinensis* (Coleoptera: Bruchidae). *J. Ecobiol*. **17(4):** 321 - 327.Global

Guedes, C. A, V. W Teixeira, K. A. Dutra, D. M. A. Navarro, G. S. Cruz, C. J. C. L. Neto, A. A. Correia, J. M. Sandes, F. A. Brayner and L. C. Alves. 2020. Evaluation of *Piper marginatum* (Piperales: Piperaceae) oil on the embryonic development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in comparison to formulated products. *J. Econ. Entomol*. **13**: 239 - 248.

Hold, K. M., N. S. Sirisoma, T. Ikeda, T. Narahashi and J. E. Casida. 2000. Thujone (the bioactive component of absinthe): Aminobutyric acid type a receptor modulation and metabolic detoxification. *Proc. Nat. Academy Sci*. **97**: 3826 - 3831.

Hoy, M. 2013. Insect Population ecology and Molecular Geetics. In M. Hoy, Insect Molecular Genetics. 3rd Edn. pp. 591 - 659.

Hruska, A. J. 2019. Fall armyworm (*Spodoptera frugiperda*) management by smallholders. CABI Reviews. **14(43):** 1 - 11.

Islam, S. and M. R. I. Khan 2021. The Potentiality of major crops by products as livestock feed in Bangladesh, A Review. *Adv. Anim. Vet. Sci*. **9(12):** 2103 - 2115.

Isman, M. B. 2006. Botanical insecticides, Deterrents, and Repellents in Modern Agriculture and an Increasingly Regulated World. *Annu Rev. Entomol*. **51**: 45 - 66.

Isman, M. B. 2000. Plant essential oils for pest and disease management. *Crop Prot*. **19**: 603 -608. Jeyaraman, S. 2017. Field Crops Production and Management Vol I. New Delhi: Oxford and IBH Publishing Company Private Limited.

Oso, A. A. and A. O. Ashafa. 2021. Nutritional Composition of Grain and Seed Proteins. DOI:10.5772/intechopen.97878

Kandel, S. and R. Poudel. 2020. Fall Armyworm (*Spodoptera frugiperda*) in Maize: An emerging threat in Nepal and its management. *Int. J. Appl. Sci. Biotechnol*. **8(3):** 305 - 309.

Lima, A. P.S., E. D. R. Santana, A. C.C. Santos, J. E. Silva, G. T. Ribeiro, A. M. Pinheiro, I. T.B.F. Santos, A. F. Blank, A. P. A. Araújo and L. Bacci. 2020. Insecticide activity of botanical compounds against *Spodoptera frugiperda* and selectivity to the predatory bug *Podisus nigrispinus*. Crop Prot. **136**: 105230, https://doi.org/10.1016/j.cropro.2020.105230

Lima, R. K., M. D. Cardoso, J. C. Moraes, M. A. Andrade, B. A. Melo and V. G. Rodrigues. 2010. Chemical characterization and insecticidal activity of the essential oil leaves of *Ageratum conyzoides* L. on fall armyworm (*Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae). *J. Biosci*. **26**: 1 - 5.

Lin, S., K. Liu, R. Wang, B. Liu, Y. Zhang, J. Wu and Z. Zhang. 2020. Indoor toxicity of azadirachtin to *Spodoptera frugiperda* and its control effect in field. *J. South China Agric*. **41**: 22 - 27.

Mottaleb, M. A., G. Kruseman and O. Erenstein. 2018. Determinants of maize cultivation in a land-scarce rice-based economy: The case of Bangladesh. *J. Crop Improv*. **32**: 453 - 476.

Mweke, A., K. S. Akutse, C. Ulrichs, K. K. M. Fiaboe, N. K. Maniania and S. S. Ekesi. 2020. Integrated management of *Aphis craccivora* in cowpea using intercropping and entomopathogenic fungi under field conditions. *J. Fungi*. **60(6):** 1 - 20.

Negrini, M., E. Gomes, E. G. Fidelis, D. A. Schurt, F. Silva, R. S. Pereira,H. Ribeiro and H. R. Bizzo. 2019. Insecticidal activity of essential oils in controlling fall armyworm, *Spodoptera frugiperda*. *Arq. Inst. Biol.* **86**: 1 - 9.

Prakash, A. and J. Rao 1996. Botanical Pesticides in Agriculture, CRC Press, New Delhi, India, 480p.

Prasanna, B. M., J. E. Huesing, R. Eddy and V. M. Peschke. 2018. Fall armyworm in Africa: a guide for integrated pest management. USAID CIMMYT. **7**: 109.

Resjusus, B. M., H. A. Mani, K. Ohsawa and Yamamoto I. 1990. Insecticidal actions of several plants to *Callosobruchus chinensis* (L.) in Fujii. Bruchids and Legumes: Ecology and Co-evolution, Kluwer Publishers, Dordrecht, The Netherlands. pp. 53 - 62.

Schoonhoven, A.V. 1978. Use of vegetable oils to protect stored beans from bruchid attack. *J. Econ. Entmol.* **71**: 254 - 256.

Shu, B., H. Yu, Y. Li, H. Zhong, X. Li, L. Cao and J. Lin 2021. Identification of azadirachtin responsive genes in *Spodoptera frugiperda* larvae based on RNA-seq. *Pestic. Biochem. Phys*. **172**: 104 - 745.

Siddhartha, K., C. Chinniah and M. Shanthi. 2019. *In vitro* bioassay of certain botanical oils for their efficacy against maize fall army worm (J.E. Smith) *Spodoptera frugiperda* (Noctuidae: Lepidoptera). *J. Entomol. Zool. Stud*. **7**(5): 606 - 609.

Silvestre, W. P., C. B. Vicenço, R. A. Thomazoni and G. F. Pauletti. 2021. Insecticidal activity of *Callistemon speciosus* essential oil on *Anticarsia gemmatalis* and *Spodoptera frugiperda. Int. J. Trop. Insect Sci*. **42**: 1307 - 1314.

Sisay, B., T. Tefera, M. Wakgari, G. Ayalew and E. Mendesil. 2019. The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda* in maize. *Insects*. **10**: 45 - 58.

Tithi, D.A., M.A.Alim, H.F. El Taj, M.A. Hossain, and A.T.M.S. Islam, 2021. Potency of natural oils against the grub of epilachna beetle on bitter gourd. *Bangladesh J. Ecol*. **3(1):** 81 - 85.

Tumma, M., and K. Chandrika. 2018. Fall Armyworm [Web log post]. Retrieved from http://vikaspedia.in/agriculture/crop-production/integrated-pest-managment/fall-armyworm-faw

Varella, A. C., A. C. Menezes-Netto, J. D. S. Alonso, D. F. Caixeta, R. K. D. Peterson and O. A. Fernandes. 2015. Mortality dynamics of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) immature in maize. *PLOS ONE*. **10**. 1 - 12.

Wan, J. C. Huang , C. Y. Li , H. Zhou, Y. L. Ren, Z. Y. Li , L. S. Xing, , B. Zhang, X. Ao , C. H. Liu, Y. I. Xi, W. I. Liu, W. Wang, W. I. Qian, S. S. Mckirdy and F. Wan. 2021. Biology, invasion and management of the agricultural invader: Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *J. Integ. Agric*. **20(3):** 646 - 663.

Zhou, Y., D. Q. Qin, P. W. Zhang, B. J. Liu, X. T. Chen and Z. X. Zhang. 2020. The comparative metabolic response of *Bactrocera dorsalis* larvae to azadirachtin, pyriproxyfen and tebufenozide. *Ecotoxicol. Environ. Saf.* **189**. 110020. https://doi.org/10.1016/j.ecoenv.2019.110020.