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Efficacy of neem bio-pesticide and synthetic insecticides against control of fall armyworm (*Spodoptera frugiperda*) in Maize

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Abstract
Fall Armyworm (FAW), *Spodoptera frugiperda*, is prevalent in Zimbabwe, causing significant damage to maize and yield losses. Three synthetic insecticides (Nemesis, Ecoterex and Lamda-cyhalothrin) belonging to different chemical groups and neem bio-pesticide (Neem Leaf Extract) were tested for their efficacy against FAW under laboratory and field conditions. The aim of the study was to assess the effect of neem bio-pesticide and synthetic insecticides on the population of FAW larvae, level of leaf damage and maize grain yield in comparison with untreated control plants. In laboratory experiment, neem bio-pesticide and the three synthetic insecticides resulted in significantly higher FAW larval mortality ($p < 0.05$) at 24, 48 and 72 hours after application of treatments as compared with the untreated plants. Neem bio-pesticide and the synthetic insecticides caused highest percentage of larval mortality (> 90%) at 72 hours after treatment application. In the field, both bio-pesticide and synthetic insecticides resulted in significantly higher efficacy ($p < 0.05$) against fall armyworm larvae, reduced the level of leaf damage and increased maize grain yield as compared to the untreated control plants. The untreated maize plants were found to be extensively damaged by FAW as compared to those treated with insecticides and neem bio-pesticide. The highest efficacy was recorded on plants treated with Nemesis, followed by Neem Leaf Extract, Ecoterex and lastly Lamda-cyhalothrin, respectively. The neem bio-pesticide and synthetic insecticides which were used in this study showed high efficacy against FAW larvae and can be recommended to be used as components for integrated pest management (IPM) plans for FAW under smallholder farmer conditions in Zimbabwe and the rest of Africa.

Keywords: Fall armyworm, neem bio-pesticide, synthetic insecticides, integrated pest management (IPM)

Introduction
Fall Armyworm (FAW) *(Spodoptera frugiperda)*, an insect pest native to the tropical and subtropical regions of America, is a polyphagous (feeds on several hosts) and long-distance migratory pest that survives and feeds on different plant species, including maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), sorghum [*Sorghum bicolor* (L.) *Moench*] and rice (*Oryza sativa* L.) [1, 2]. As a highly polyphagous pest, *S. frugiperda* larvae feed on a total of 353 different host plants belonging to 76 plant families, including *Poaceae*, *Asteraceae* and *Fabaceae* [1]. Fall Armyworm was first reported in Africa in 2016 [2]. In Zimbabwe, infestation with Fall Armyworm has led to substantial maize yield losses of up to 12% to 58% based on rigorous field scouting and farmers perception resulting in food insecurity [3]. Maize is the most important staple food crop in Africa and is predominantly grown by smallholder farmers for human consumption and livestock feed [3, 4]. However, maize production has been affected for the majority of households due to attack by the Fall Armyworm. The Fall Armyworm invasion in Sub-Saharan Africa has caused a huge concern on food and nutrition security which have been worsened by lack of resistant or tolerant cultivars, poor capacity to control and manage the insect pest [1, 5] and the suitability of climatic conditions for the rapid multiplication and perpetuation of the pest [6].
The occurrence of Fall Armyworm in African countries, has resulted in the wide use of synthetic insecticides as an emergency response to reduce the spread of the pest and damage to maize [7].

In order to mitigate and reduce crop loss due to FAW infestation, many farmers apply synthetic chemical insecticides. However, the use of synthetic insecticides has caused unintentional harmful consequences to the environment, including food and water pollution and pose risk to human health [8]. In addition, most smallholder farmers in Africa have little or no access and some cannot afford to purchase insecticides for controlling the FAW [6]. Furthermore, dependence on insecticides results in development of insect resistance, increased risk to human health due to lack of appropriate safety precautions, harmful effects on non-target organisms and risks to the environment [8]. Given the concerns on adverse effects and confirmed reports of the development of insecticide resistance in FAW populations, the development of low-risk management approaches using bio-pesticides is imperative for sustainable integrated pest management strategy for FAW [2]. Research has shown that neem extract is effective against nearly 200 species of insects some of which are resistant to pesticides or are inherently difficult to control with chemical insecticides [9]. Previous research studies have shown that in India neem bio-pesticides have been effective for controlling pests in stored grains such as rice, wheat, corn, legumes, potato and tomato [10]. On the other hand, neem leaf extract is still used in various parts of the world against pests in different crops and has desirable properties that include: less toxicity, bio-degradable, target specific and maintenance of ecological balance [11]. This research study was conducted in order to evaluate the efficacy of locally available neem bio-pesticide and synthetic insecticides against the control of fall armyworm.

Materials and Methods

Study area

The field trials were conducted in three different agro-ecological regions namely; Harare (SIRDC - Natural Region IIb: high rainfall of 750-1 000 mm, temperature range of 25-28 ^{o}C); Wedza - Natural Region III: (600-1 000 mm, temperature range 25-30^{o}C), Zaka and Chiredzi- Natural Regions IV and V: low rainfall of 400 -600 mm, temperature range of 28-35^{o}C) during the 2020/2021 maize growing season. The laboratory experiment was carried out in the Entomology laboratory at SIRDC under controlled temperature environment (temperature (24-28 ^{0}C) and humidity (60-80%).

Preparation of neem leaf extract

Fresh leaves of Neem tree (*Azadirachta indica)* were washed and soaked in water at a 1:2 ratio (500 grams in I Litre of Water) for 24 hours at room temperature to remove impurities. After soaking the leaves were then ground into small pieces and stored in a clean 1 Litre glass container. The glass container was filled with water and then placed in a shaker and the leaves were further broken down. The solution was filtered through a mutton cloth to obtain pure neem leaf extract which was then transferred to a glass bottle in preparation for use in the laboratory and field experiments.

Laboratory Bio-assay of bio-pesticide and selected synthetic insecticides against FAW

The laboratory experiment was carried out in a Complete Randomized Design (CRD) with three replications. Fall Armyworm larvae (3-Instar larval stage) were collected from a 0.1ha unsprayed maize field at SIRDC. They were placed in plastic containers with perforated lids to allow for ventilation under the lab conditions and subjected to the following treatments: Neem leaf extract, Ecoterex, Nemesis, Lamda-cyhalothrin and control (untreated). Maize leaf cuttings (20 grams) were prepared and sprayed with the respective pesticide treatment and placed in each plastic container. Ten larvae were released into each container with treated leaves. The pesticide measurements were as follows: Water (2 ml/ litre), Nemesis (2 ml/L), Lamda-cyhalothrin (25 ml/L), Neem (7.5ml/L) and Ecoterex (5 g/L). Insect mortality was assessed at 24 hr, 48 hr, and 72 hr after treatment application. A larva was considered dead if it could not right itself after being placed on its dorsal surface.

Field Evaluation of neem bio-pesticide and selected synthetic insecticides against FAW

The trials were laid out in a Randomised Complete Block Design (RCBD) with five treatments and three replicates. Maize hybrid Sirdamaize 113 was planted in marked rows using a spacing of 75 cm by 25 cm in plot size of 10 m by 5 m for each treatment. Basal fertiliser (Compound D) was applied at planting at 300 kg/ha and top-dressed with Ammonium Nitrate at 200 kg/ha at four weeks after planting. Good Agronomic Practices (GAP), i.e. fertiliser application and weeding were carried out for crop maintenance during the entire maize growing season.

The treatments used were Neem leaf Extract and synthetic insecticides (Nemesis, Ecoterex, and Lambda) and control (untreated) (Table 1). Synthetic insecticides and neem bio-pesticide treatments were applied using a knapsack sprayer at 15, 35 and 42 days after planting using the recommended application rates: (Neem (100 ml/10 litres of water), Nemesis (20 ml/10 litres of water), Lambda-cyhalothrin (20 ml/10 litres of water) and Ecoterex (3 kg/ha). After spraying each treatment, the sprayer was rinsed with liquid soap once and then washed with water. The control plots were not sprayed with any synthetic insecticides.

Table 1: Insecticides and bio-pesticides used in Maize- FAW Laboratory and Field Trials

Trade Name	Active Ingredients	Chemical Class
Nemesis	Emamectin benzoate, Acetampirid	Avermectin
Ecoterex	Deltamethrin, Pirimiphos methyl	Organophosphate
Lamda-cyhalothrin	Lamda-cyhalothrin	Diamides / Pyrethroid
Neem Leaf Extract	Azadirachtin, Salannin, Nimbidin	Biopesticide

Data was collected for the following parameters: number of plants with infested leaves, number of live larvae on infested plants, leaf damage and grain yield. Before each spraying, both destructive (number of live larvae per plant) and non-destructive samples (leaf damage score) were taken. FAW leaf damage severity was recorded at seven-day intervals based on the rating scale described by Davis *et al*. Maize cobs from undamaged and damaged plots were harvested at 12% moisture content and weighed for comparison of yield and yield losses due to FAW damage. Data was analysed using

Genstat Version 14 and the separation of means difference was done using Fishers protected test at $p < 0.05$.

Results and Discussion

Laboratory evaluation of neem bio-pesticide and synthetic insecticides against FAW

There were significant differences in percentage of FAW larval mortality at 24, 48 and 72 hours after application of the neem bio-pesticide and synthetic insecticides (Nemesis, Ecoterex and Lambda) at $p < 0.05$ (Table 2). The application of synthetic insecticides and neem bio-pesticide resulted in high mortality of FAW larvae as compared to the control treatment. FAW larval mortality percentage ranged from (60% to 68%, 78% to 90% and 90 to 100%) at 24, 48 and 24 hours respectively. Nemesis recorded the highest number of dead larvae at 72 hours followed by bio-pesticide (Neem leaf extract), Ecoterex and Lamda-cyhalothrin (Table 2). Some of the synthetic insecticides reported by other authors corroborate the findings of the present study. For example, nemesis had more than 95% FAW mortality after 24 hours of application in another study according to the US Environmental Protection Agency Office of Pesticide Programs, (2010). Sisay *et al.* [12] reported that neem bio-pesticide and other synthetic insecticides (Radiant, Karate, Ambligo, Tracer) caused more than 90% FAW larval mortality at 72 hours after application.

Table 2: Mean percentage of FAW larval mortality at 24, 48 and 72 hours after treatment application under laboratory

Treatments	Mean numbers of percentage FAW larval mortality		
	24 hr	**48 hr**	**72 hr**
Nemesis	67.5 a	90 a	100 a
Ecoterex	59 a	84 b	94 b
Neem Leaf Extract	65.4 a	80 b	92 b
Lambda-cyhalothrin	60 a	78 a	90 b
Untreated (Control)	0 b	0 b	0 c
LSD	5.01	6.4	6.01
CV%	1.7	4.3	1.6
P-value	0.001	0.001	0.001

*Means with different letters in the same column are significantly different @ p<0.05 using Fishers Test

The number of maize plants with FAW damage symptoms were high (92 to 96) before treatment application compared with number of infested plants after application treatment. The number of maize plants with FAW damage symptoms were significantly decreased ($p < 0.001$) after application of neem bio-pesticide and synthetic insecticides (Nemesis, Ecoterex, Lambda- cyhalothrin) compared to untreat maize plants. The lowest number of infested plants were recorded in maize plants treated with Nemesis (9.27) followed by Ecoterex (13.13), Neem leaf extract (13.12) and lastly Lambda-cyhalothrin (32.13) at 42 DAT (Table 3). There was an increase in the number of infested plants in untreated maize plots as the pest continued to multiply under favourable environmental conditions. The results indicated that neem bio-pesticide is comparatively effective in reducing the effect of FAW on maize in comparison with other synthetic insecticides (Nemesis, Ecoterex, and Lambda-cyhalothrin).

Table 3: Mean number of infested maize plants by FAW after treatment application in the field

Treatments	Mean numbers of plants with FAW damage symptoms		
	14 DBT	**28 DAT**	**42 DAT**
Nemesis	94.53a	23.13a	9.27a
Ecoterex	95a	31.27a	13.13a
Neem Leaf Extract	96.2a	32.13a	13.15a
Lambda-cyhalothrin	95a	61.27b	32.13b
Untreated (Control)	92.13a	95.47c	99.07c
LSD	5.01	13.6	6.83
CV%	1.7	4.3	1.6
P value	0.585	0.001	0.001

*Means with different letters in the same column are significantly different at $p < 0.05$ using Fishers Test
*DBT- Days before treatment
*DAT- Days after treatment

The number of FAW live larvae were significantly lower in all treated maize plants in the first, second and third round sprays ($p < 0.001$) compared with the control (untreated plants). There was a significant decrease in FAW larval density after application of chemical insecticides (Nemesis, Ecoterex, Lambda-cyhalothrin) and Neem bio-pesticide compared to untreated plots. The reduction in the number of larvae in maize plots after the first round of spray of synthetic insecticides and neem bio-pesticide ranged from (65 - 89). Both bio-pesticide and synthetic insecticides were effective in controlling the fall armyworm larva as indicated by the reduction in larval density after treatment applications. However, Nemesis recorded the lowest FAW larvae (0.23), followed by Ecoterex (1.13), Neem Leaf Extract (1.33) and lambda-cyhalothrin at third round spray (Table 4). These results agree with findings by Sangle *et al.* [12] which concluded that emamectin benzoate was most effective for management of fall armyworm compared with other insecticides (chlorantraniliprole flubendiamide indoxacarb and thimethoxam + lambda cyhalothrin). The effect of neem on insects was described by Mordue & Nisbet [14] as a deterrent to feeding, interfering mainly in the physiology of the ecdysis and in cellular processes, possibly resulting in the death of the insect. Additionally neem-based products are capable of inducing a variety of disruptive developmental phenomena in lepidopteran larvae.

Table 4: Mean number of FAW live larvae after treatments application in maize field

Treatments	Mean numbers of FAW larvae (Average of 100 plants)			
	No spay	**1st Spray**	**2nd Spray**	**3rd Spray**
Nemesis	112a	22.67a	3.07a	0.23a
Ecoterex	99a	24.8a	4.73a	1.13b
Neem Leaf Extract	105a	32.8a	6.6a	1.14b
Lambda-cyhalothrin	100a	34.33a	11.33b	2.13c
Untreated (Control	108a	112.93b	116.8 bc	119.73b
LSD	69.7	37.51	29.59	25.94
CV%	8.3	6.2	5.8	14.4
P-value	0.974	0.001	0.001	0.001

*Means with different letters in the same column are significantly different $p < 0.05$ using Fishers Test

The results showed a decrease in leaf damage after application of neem bio-pesticide and synthetic insecticides compared to untreated plots. The lowest leaf damage score was found to be in maize plants treated Nemesis (1.93) followed by Ecoterex (2.0), Neem (2.27) and Lambda-cyhalothrin (3.67) at third round spray (Figures 1 and 2). The difference in leaf damage under synthetic insecticides and bio-pesticide treatments was highly significant ($p < 0.001$) compared to untreated plants. The untreated maize plants were extensively damaged by FAW compared to maize plots treated with insecticides and bio-pesticide. In another study, Dhobi *et al.* [15] observed a reduction in leaf damage and number of larvae per plant after application of neem bio-pesticide in comparison with other plant-based bio-pesticides (Tobacco decoction and Lantana camara leaf extract).

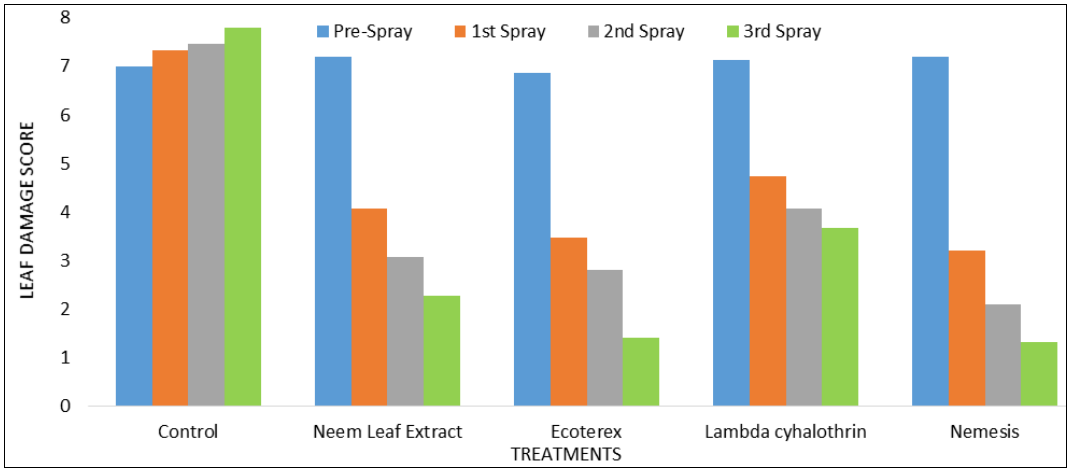

Fig 1: Mean leaf damage caused by FAW under different treatments in maize plots

Control (No Treatment) **Bio-pesticide (Neem Leaf Extract)**

Nemesis **Ecoterex**

Fig 2: Leaf damage caused by Fall Armyworm under different treatments in maize plots

There was a significant difference in maize grain yield from treated and untreated plots ($p < 0.001$). The results indicated that Neem Leaf Extract and synthetic insecticides were effective in controlling the effects of FAW on maize which ultimately results in increase of maize grain yield. The highest yield was recorded under Nemesis (8.22), followed by Neem Leaf Extract (7.18), Ecoterex (7.17) and Lambda cyhalothrin (6.09) (Table 5). The lowest grain yield was recorded in untreated maize plots (2.57).

This shows that FAW has the potential to cause significant yield losses if it remains uncontrolled in the field. These results agree with the discoveries by Anyim *et al.* [5] which showed that insecticidal application significantly increased yields of different crops. Abla & Seth [16] found that yield of *Solanum macrocarpon* plants sprayed with medium and high doses of the neem leaf extract were higher than those plants sprayed with the synthetic insecticide (Cydim Super).

Table 5: Mean grain yield of maize under different treatments

Treatments	Yield (tons / ha)
Nemesis	8.22 a
Ecoterex	7.17 b
Neem Leaf Extract	7.18 b
Lambda cyhalothrin	6.09 c
Untreated (Control)	2.57 d
LSD	0.61
CV%	1.1
P-value	< 0.001

*Means with different letters in the same column are significantly different $p < 0.05$ using Fishers Test

In this study, both neem bio-pesticide and synthetic insecticides were found to be effective in controlling the FAW. It was observed that in both the laboratory and field trials, the percent larval mortality increased over time after application of neem bio-pesticide and synthetic insecticides, which may indicate residual toxicity of the neem bio-pesticide and synthetic insecticides to FAW. The results obtained in the field study indicated a significant reduction in number of plants infested by FAW and leaf damage to maize as compared to the control, which is attributed to the reduced number of larvae in treated maize plants. The results revealed that the use of Neem bio-pesticide has a great potential in controlling the Fall Armyworm as compared to other synthetic pesticides (Lamba-cyhalothrin, Nemesis and Ecoterex). This was evidenced by a significant reduction in number of infested plants, number of FAW larvae and leaf damage and yield losses in maize plants treated with neem bio-pesticide and synthetic insecticides as compared to untreated maize plants. Other previous laboratory studies has also discovered that oral application of neem-based products adversely affected development and survival of Lepidoptera larvae [17]. Bio-pesticides are usually considered to be more target-specific and inherently less toxic than synthetic insecticides hence limiting their impact on non-target species, such as other insects, birds and mammals. They usually are biodegradable in the natural environment, thus reducing exposure to environmental pollution and chances of developing insect resistance [16]. Among the botanical bio-pesticides currently under study for commercialization, neem-based bio-pesticides are one of the least toxic to humans, shows very low toxicity to beneficial organisms and promising for the control of many insect pests [18]. These plants are locally grown in many parts of Africa and can be used by small-scale farmers wherever available as an alternative approach to FAW management. In addition, the availability, affordability and effectiveness of neem-products in controlling the FAW will ultimately contribute to the increase in maize yield especially, in small-holder farmers hence ensuring food security.

Conclusions

In this study, it was observed that application of the neem bio-pesticide and synthetic insecticides (Nemesis, Ecoterex, Lambda- cyhalothrin) was effective and significantly increased FAW larval mortality, reduced leaf damage, and increased maize grain yield compared to the untreated control. Nemesis had the highest efficacy in terms of causing the highest mortality to FAW larvae. However, neem bio-pesticide was highly effective in controlling the FAW larvae and reducing its damage on maize leaves in comparison with other synthetic insecticides. Neem bio-pesticide is therefore recommended for the management of FAW in maize especially for the poor-resourced small-holder farmers. Nevertheless, neem bio-pesticides are comparatively non-toxic to mammals, environmentally friendly and highly effective for controlling FAW, hence they can be used as a suitable substitute for synthetic insecticides. However, an Integrated Pest Management approach is needed for effective and sustainable control of FAW and reliance on chemical pesticides may increase the likelihood of FAW resistance to insecticides. This study, therefore, contributes to the sustainable management of the FAW by assessing effectiveness of neem-based bio-pesticide as an alternative to the use of synthetic insecticides.

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References

1. Montezano DG, *et al.*, Host Plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas, African Entomol. 2018;26(2):286-300. Doi: 10.4001/003.026.0286.
2. Bateman ML, Day RK, Luke B, Edgington S, Kuhlmann U, Cock MJW. 'Assessment of potential biopesticide options for managing fall armyworm (*Spodoptera frugiperda*) in Africa', Journal of Applied Entomology. 2018;142(9):805-819. Doi: 10.1111/jen.12565.
3. Baudron F, Zaman-Allah MA, Chaipa I, Chari N, Chinwada P. Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* J.E. Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe', Crop Prot. 2019;120:141-150. Doi: 10.1016/j.cropro.2019.01.028.
4. Tambo JA, *et al.*, 'Impact of fall armyworm invasion on household income and food security in Zimbabwe', Food Energy Secur. 2021;10(2):299-312. Doi: 10.1002/fes3.281.
5. Day R, *et al.* 'Fall armyworm: Impacts and implications for Africa', Outlooks Pest Manag. 2017;28(5):196-201. Doi: 10.1564/v28_oct_02.
6. Padhee A, Prasanna B. 'The emerging threat of Fall Armyworm in India', Indian Farming. 2019;69(1):51-54.
7. Prasanna PBBM, Huesing JE, Eddy R, Peschke VM. 'Fall Armyworm in Africa : Fall Armyworm in Africa, Food Energy Secur., 2018.
8. Yigezu G, Wakgari M. 'Local and indigenous knowledge of farmers management practice against fall armyworm (*Spodoptera frugiperda*) (J. E. Smith) (Lepidoptera: Noctuidae): A review, ~ 765 ~ J. Entomol. Zool. Stud. 2020;8(1):765-770. [Online]. Available: http://www.entomoljournal.com.
9. Ajenifujah-Solebo SOA, *et al.* 'Advances and Trends in Agricultural Sciences Vol 1', Adv. Trends Agric. Sci. 2019;1:17–26. Doi: 10.9734/bpi/atias/v1.
10. Tulashie SK, Adjei F, Abraham J, Addo E. 'Potential of neem extracts as natural insecticide against fall armyworm (*Spodoptera frugiperda* (J. E. Smith)

(Lepidoptera: Noctuidae)', Case Stud. Chem. Environ. Eng, 2021 Dec, 4. Doi: 10.1016/j.cscee.2021.100130.
11. Anyim UU. Page, 'Evaluation of Neem Leaf Extract As A Substitute For Chemical Insecticides In The Control of Fall Armyworm (*Spodoptera frugiperda*) And Yield of Maize In Umudike Abia State, Nigeria Accessible at: https://jccr', J. Community Commun. Res. 2020;25(1):25-30, [Online]. Available: https://jccr.sccdr.org.ng.
12. Sisay B, Tefera T, Wakgari M, Ayalew G, Mendesil E. 'The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in maize', Insects.. 2019 Feb, 0(2). Doi: 10.3390/insects10020045.
13. Sangle S, Krushi Vidyapeeth M, Jayewar IN IN. Corresponding Author, N. Jayewar, and D. Kadam, 'Efficacy of insecticides on larval population of fall armyworm, *Spodoptera frugiperda* on maize', ~ 1831 ~ J. Entomol. Zool. Stud. 2020;8(6):1831-1834. [Online]. Available: http://www.entomoljournal.com.
14. Mordue (Luntz) AJ, Nisbet AJ. Azadirachtin from the neem tree Azadirachta indica: its action against insects, An. da Soc. Entomológica do Bras. 2000;29(4):615-632. Doi: 10.1590/s0301-80592000000400001.
15. Dhobi CB, *et al.* 'Evaluation of Bio-pesticides against Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) in Maize', Int. J. Curr. Microbiol. Appl. Sci. Aug. 2020;9(8):1150-1160. Doi: 10.20546/ijcmas.2020.908.127.
16. Abla DM, Seth WN, Effects of neem leaf extracts on Lepidopteran pest species attacking *Solanum macrocarpon* L. (Solanaceae) in southern Togo, J. Entomol. Nematol. 2019;11(4):50-57. Doi: 10.5897/jen2019.0230.
17. Shannag HK, Capinera JL, Freihat NM, Use of neem-based insecticides against southern armyworm, Spodoptera eridania (Stoll) (Lepidoptera : Noctuidae), Trends Entomol, 2013, 9.
18. Usharani K, Dhananjay N, Manjunatha R. Neem as an organic plant protectant in agriculture, J. Pharmacogn. Phytochem. 2019;8(3):4176-4184.