*Biological Forum – An International Journal* **14(4): 833-837(2022)**

**ISSN No. (Print): 0975-1130**
**ISSN No. (Online): 2249-3239**

# Evaluation of Commercial Sex Pheromone Lures for Management of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith)

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*(Received 17 September 2022, Accepted 29 October, 2022)*
*(Published by Research Trend, Website: www.researchtrend.net)*

**ABSTRACT: The utilization of female sex pheromones for management of insect pests through mass trapping of males can be an important tool for ecofriendly pest management. Hence, the present investigation was undertaken to evaluate the commercial sex pheromone lures for management of fall armyworm, *Spodoptera frugiperda* through mass trapping under field condition in maize ecosystem. The lures evaluation was done using Randomized Block Design (RBD) with seven treatments including control and were replicated four times. The results showed a significant difference in male moth trap catches among different sex pheromone lures across different weeks of the crop growth. Further, the interaction between the sex pheromone lures and weeks also exhibited a significant difference in the attraction of male moths of *S. frugiperda*. The highest trap catches were recorded during the July third week which capturing 16.32 moths/trap/week and the lowest number of moths were captured during third week of September (0.18 moths/trap/week).**

**Keywords:** Fall armyworm, sex pheromone, lure evaluation, management, moths, trap catches.

## INTRODUCTION

Among the recent invasive insect pests that have become a threatening nightmare, the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) stands vital for frightening the livelihood of millions of maize farmers across the globe (FAO, 2020). FAW has already been reported in several other countries such as Brazil, Argentina and the USA (Prowell *et al*., 2004; Clark *et al*., 2007) causing 34 per cent reduction in grain yield (Lima *et al*., 2010) and annual crop losses up to US$ 400 million in Brazil (Figueiredo *et al*., 2005).

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a notorious trans boundary insect pest of America and has recently become an invasive pest in Africa (Goergen *et al*., 2016; Prasanna *et al*., 2018), Asia (Sharanabasappa *et al*., 2018) and Australia (Qi *et al*., 2021). The invasion of fall armyworm into Asia was reported for the first time from India on maize in May 2018 by Sharanabasappa *et al*. (2018) and subsequently in all the maize growing states in the country (Suby *et al*., 2020). FAW was also reported from Yemen, Bangladesh, Myanmar (Yee *et al*., 2019); China (Jing *et al*., 2020; Sun *et al*., 2021).

In northern Karnataka, the fall armyworm infestation in different districts ranged between 13.50 to 66.50 per cent (Mallapur *et al*., 2018) and more incidence was noticed in *Kharif* season than *Rabi* season (Pradeep *et al*., 2022). The frequency of pesticide application by maize farmers of Karnataka increased significantly from 0.10pesticide sprays per season in 2017 to 2.10 applications in 2020 during *Kharif* season (Deshmukh *et al*., 2021). Non-availability of potential biocontrol agents (as FAW is an exotic pest) and other management strategies are pushing farmers to solely depend on chemical insecticides to manage this devastating pest, which can potentially damage the crop biodiversity across large swathes of land and also increase farmers' production costs and ultimately farmers had to face huge losses when they are deprived of adequate yield.

Pheromones produced by insects are crucial for the sexual communication system of males and females in a natural environment (Raina, 1997). Hence, exploiting this behaviour for monitoring and mass trapping of male individuals using the female sex pheromone is of greater importance in successful management of FAW and serves as one of the important tool in IPM for eco-friendly management of fall armyworm by reducing the insecticide load.

## MATERIAL AND METHODS

**Study site.** The field investigation on evaluation of commercial sex pheromone lures for *S. frugiperda* was carried out in farmer field of maize near Matthodu village (13.97′10.7″ N, 75.59′76.4″E), Shivamogga during *Kharif*, 2021. The crop in the grower's field was sown on 16th of June, 2021.

**Experimental details.** The study on evaluation of commercial pheromone lures was designed in a Randomized complete Block design (RCBD) in an area of six acres, which was divided into four blocks of 1.5 acre area for each replication. The study was undertaken with seven treatments which includes six different commercial lures + control (trap without lure) and they were replicated four times. The moth traps with different commercial lures with different trade names purchased from different sources were installed at a distance of 30 m between each trap. The detailed field layout of the experimental design is shown in. The treatments deployed in the field are as follows, $T_1$= *Spodoptera frugiperda* pheromone lure purchased from Harmony Ecotech Pvt. Ltd., Hyderabad, $T_2$ = Fall armyworm lure from Gaiagen Technologies Pvt. Ltd., Bangalore, $T_3$ = Armyworm detector from Pheromone Chemicals, Hyderabad, $T_4$ = FAW lure from Indian Institute of Chemical Technology, Hyderabad, $T_5$ = Pheromate lure-FAW from Innovac Biosciences Pvt. Ltd., Gujarat, $T_6$ = FAW lure (Premium) from ATGC Biotech Pvt. Ltd., Hyderabad and $T_7$ = Control (pheromone trap without lure).

### Recording Observations

**Observations on trap catches.** The observations on moth trap catches were recorded at weekly interval, for a period of 12 weeks (for pheromone lure evaluation study) and for 14 weeks (in case of monitoring study). The height of the traps was adjusted 15 cm above crop canopy level throughout the crop period. At every week, traps were cleaned and the numbers of FAW males trapped were recorded. The traps were installed 7 DAS for monitoring study and 10 DAS for lure evaluation study. The pheromone lures were replaced at an interval of 25 days.

**Statistical analysis.** The data pertaining to evaluation of sex pheromone lures was analysed by fitting the general linear model analysis (univariate) with IBM®-SPSS (Version 20). The moth trap catches under different treatments were considered as dependent variable and the treatments (different commercial lures) were considered as fixed factors. The interaction effect of treatments across the weeks was analysed by considering weekly mean (of all treatments) as one variable and overall treatment means (of total weeks) as another variable. The means were again compared to checked for significance with multiple comparison of means using Tukey's test ($p = 0.05$).

## RESULTS AND DISCUSSION

The evaluation of different commercial sex pheromone lures to attract males of *S. frugiperda* showed a significant difference both among the treatments ($F_{(6, 18)} = 150.64$, $p < 0.001$) as well as across the weeks ($F_{(11, 18)} = 150.64$, $p < 0.001$). Further, the interaction between the treatments and weeks also exhibited a significant difference ($F_{(66, 18)} = 150.64$, $p < 0.001$) in the attraction pattern of male moths of *S. frugiperda* (Table 2).

During June fourth week, the treatments showed a significant difference between them ($F_{(6, 18)} = 14.96$, $p < 0.001$). The treatments 1 and 2 significantly differed from 5 and 7, whereas, all other treatments were on par with each other (Table 1 and Fig. 1).

During July first week, there was a significant difference among the treatments ($F_{(6, 18)} = 24.93$, $p < 0.001$). The treatments 2, 5 and 7 differed significantly from each other, whereas, rest of the treatments were on par with each other. During July second week, the treatments showed a significant difference between them ($F_{(6, 18)} = 34.48$, $p < 0.001$). The treatments 1 and 2 significantly differed from treatments 4, 5 and 7, whereas, rest of the treatments were on par with each other (Table 1 and Fig. 1).

During July third week, the treatments 1 and 2 significantly differed from 3, 4, 5, 6 and 7 ($F_{(6, 18)} = 76.31$, $p < 0.001$). The treatments 1 and 2 were on par with each other. Similarly, treatments 3, 4, 5 and 6 were on par with each other. The treatment 7 significantly differed from all other treatments. During July fourth week, the treatments 1 and 2 significantly differed from 4, 5 and 7 ($F_{(6, 18)} = 49.80$, $p < 0.001$). The treatments 1 and 2 were on par with each other and also with treatments 3 and 6. Similarly, treatments 3, 4, 5 and 6 were on par with each other. Similarly, treatments 4 and 5 were on par with each other and treatment 7 significantly differed from all other treatments (Table 1 and Fig. 1).

During August first week, the treatment 2 significantly differed from treatments 5, 6 and 7 ($F_{(6, 18)} = 55.96$, $p < 0.001$). The treatments 1 and 2 were on par with each other, similarly, treatment 3, 4 and 6 were on par with each other. The treatment 4 and 5 were on par with each other and the treatment 7 significantly differed from all other treatments. During August second week, the treatment 2 differed significantly from 4, 5 and 7. The treatments 1, 2, 3 and 6 were on par with each other ($F_{(6, 18)} = 28.78$, $p < 0.001$). The treatment 4 was on par with 3, 5 and 6. The treatment 7 significantly differed from all other treatments (Table 1 and Fig. 1).

During third week of August, The treatment 1 significantly differed from 5 and 7 ($F_{(6, 18)} = 7.59$, $p < 0.001$). During August fourth week, the treatments 1 and 2 significantly differed from 4 and 7 ($F_{(6, 18)} = 6.36$, $p < 0.001$). The treatments 1 and 2 were on par between each other and also with treatments 3, 5 and 6. The treatment 7 was on par with treatments 3, 4 and 5 (Table 1 and Fig. 1).

During September first week, there was no significant difference found among the treatments ($F_{(6, 18)} = 1.00$, $p = 0.451$). Similarly, even during the second ($F_{(6, 18)} = 1.21$, $p = 0.338$) and third ($F_{(6, 18)} = 0.92$, $p = 0.498$) week of September, no significant difference in the trap catches were observed among the treatments during both the weeks (Table 1and Fig. 1).

**Table 1: Attraction of *Spodoptera frugiperda* male moths to different commercial sex pheromone lures evaluated on maize during *Kharif*- 2021.**

| Weeks | Mean (± SEM) no. of moths/trap/week | | | | | | | F-value (df = 6, 18) | p-value (α = 0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | | |
| June-IV | 4.25 ± 0.41 (2.17)*$^{a}$ | 4.00 ± 0.35 (2.11)$^{a}$ | 2.50 ± 0.56 (1.70)$^{ab}$ | 2.25 ± 0.22 (1.65)$^{ab}$ | 1.50 ± 0.25 (1.40)$^{b}$ | 2.50 ± 0.56 (1.70)$^{ab}$ | 0.00 ± 0.00 (0.71)$^{c}$ | 14.96 | $p < 0.001$ |
| July-I | 6.25 ± 1.14 (2.56)$^{ab}$ | 6.75 ± 0.65 (2.68)$^{a}$ | 4.50 ± 0.56 (2.22)$^{abc}$ | 3.75 ± 0.54 (2.04)$^{abc}$ | 2.75 ± 0.41 (1.78)$^{c}$ | 3.50 ± 0.25 (1.99)$^{bc}$ | 0.00 ± 0.00 (0 .70)$^{d}$ | 24.93 | $p < 0.001$ |
| July-II | 9.25 ± 0.82 (3.11)$^{a}$ | 9.25 ± 0.74 (3.11)$^{a}$ | 6.75 ± 0.54 (2.68)$^{ab}$ | 5.00 ± 0.35 (2.34)$^{b}$ | 4.25 ± 0.54 (2.16)$^{b}$ | 6.75 ± 0.74 (2.67)$^{ab}$ | 0.25 ± 0.22 (0.83)$^{c}$ | 34.48 | $p < 0.001$ |
| July-III | 26.25 ±1.75 (5.16)$^{a}$ | 26.75 ± 1.63 (5.21)$^{a}$ | 16.75 ± 1.14 (4.14)$^{b}$ | 13.25 ± 0.96 (3.69)$^{b}$ | 14.25 ± 0.74 (3.83)$^{b}$ | 16.50 ± 1.25 (4.11)$^{b}$ | 0.50 ± 0.25 (0.96)$^{c}$ | 76.31 | $p < 0.001$ |
| July-IV | 15.50 ± 1.15 (3.99)$^{a}$ | 16.00 ± 0.79 (4.05)$^{a}$ | 11.50 ± 1.03 (3.45)$^{ab}$ | 9.50 ± 1.03 (3.14)$^{b}$ | 9.25 ± 0.54 (3.11)$^{b}$ | 13.75 ± 1.34 (3.75)$^{ab}$ | 0.25 ± 0.22 (0.83)$^{c}$ | 49.80 | $p < 0.001$ |
| Aug-I | 11.50 ± 1.03 (3.45)$^{ab}$ | 12.00 ± 0.79 (3.52)$^{a}$ | 8.00 ± 0.61 (2.90)$^{bc}$ | 5.75 ± 0.41 (2.49)$^{cd}$ | 3.75 ± 0.41 (2.05)$^{d}$ | 7.00 ± 0.35 (2.73)$^{c}$ | 0.25 ± 0.22 (0.83)$^{e}$ | 55.96 | $p < 0.001$ |
| Aug-II | 6.00 ± 0.94 (2.52)$^{ab}$ | 6.25 ± 0.82 (2.58)$^{a}$ | 4.50 ± 0.25 (2.23)$^{abc}$ | 2.50 ± 0.25 (1.72)$^{c}$ | 3.50 ± 0.25 (1.99)$^{bc}$ | 4.00 ± 0.35 (2.11)$^{abc}$ | 0.00 ± 0.00 (0.70)$^{d}$ | 28.78 | $p < 0.001$ |
| Aug-III | 3.25 ± 0.41 (1.92)$^{a}$ | 3.00 ± 0.71 (1.82)$^{ab}$ | 1.75 ± 0.41 (1.47)$^{ab}$ | 1.50 ± 0.25 (1.40)$^{ab}$ | 1.00 ± 0.35 (1.18)$^{bc}$ | 2.00 ± 0.35 (1.56)$^{ab}$ | 0.00 ± 0.00 (0. 70)$^{c}$ | 7.59 | $p < 0.001$ |
| Aug-IV | 1.25 ± 0.54 (1.25)$^{a}$ | 1.50 ± 0.25 (1.40)$^{a}$ | 0.75 ± 0.22 (1.09)$^{abc}$ | 0.25 ± 0.22 (0 .83)$^{bc}$ | 0.75 ± 0.41 (1.05)$^{abc}$ | 1.00 ± 0.35 (1.18)$^{ab}$ | 0.00 ± 0.00 (0 .70)$^{c}$ | 6.36 | $p < 0.001$ |
| Sep-I | 0.50 ± 0.25 (0.96)$^{a}$ | 0.75 ± 0.22 (1.09)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.50 ± 0.25 (0.96)$^{a}$ | 0.00 ± 0.00 (0 .71)$^{a}$ | 1.00 | $p = 0.451$ |
| Sep-II | 0.50 ± 0.25 (0.96)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 0.50 ± 0.25 (0.96)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 1.21 | $p = 0.338$ |
| Sep-III | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.50 ± 0.25 (0.96)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.25 ± 0.22 (0 .83)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 0.00 ± 0.00 (0 .70)$^{a}$ | 0.92 | $p = 0.498$ |

*The figures in the parentheses are square root transformed values. T1 = *Spodoptera frugiperda* Pheromone Lure, T2 = Fall Armyworm Lure, T3 = Armyworm detector, T4 = FAW lure, T5 = Pheromate Lure-FAW, T6 = FAW lure (Premium), T7 = Pheromone trap without lure (Control). Values with different lowercase superscript letters indicate significant difference between the treatments

**Interaction of trap catches by different commercial sex pheromone lures with different weeks of the crop growth during *Kharif*-2021.** The interaction of overall treatment means across different weeks with the weekly trap catches of all the treatments showed a significant difference between them ($F_{(66, 18)} = 15.072$, $p < 0.001$). While the weekly mean of all treatments were considered, the highest trap catches were recorded during the July third week which capturing 16.32 moths/trap/week, followed by fourth week of July which recorded 10.82 moths/trap/week, first week of August (6.89 moths/trap/week), second week of July (5.93 moths/trap/week), first week of July (3.93 moths/trap/week), second week of August (3.82 moths/trap/week) and so on. The lowest number of moths were captured during third week of September (0.18 moths/trap/week). The trap catches during fourth week of June were on par with those captures during August third week. Likewise, the trap catches during July first and second week were on par with those from August second and first week, respectively. The trap catches during all the three weeks September did not vary significantly among them (Table 2).

When the treatment means of overall weeks were considered, the treatment 2 had the highest mean number of trap catches (7.25 moths/trap/week), followed by treatment 1 which captured 7.06 moths/trap/week, treatment 6 capturing 4.81 moths/trap/week, treatment 3 which captured 4.77 moths/trap/week, treatment 4 which captured 3.73 moths/trap/week and treatment 5 capturing 3.46 moths/trap/week. The lowest number of moths were captured in treatment 7 which captured 0.10 moths/trap/week. The comparison of above seven treatments showed that the treatment 1 and 2 were on par with each other with respect to number of trap catches. Similarly, the treatment 3, 5 and 6 were on par in capture of male moths in traps. The treatments 4 and 7 significantly differed from all other treatments (Table 2).

The current investigation showed significant difference among the different commercial lures used for mass trapping of FAW males. Similar difference among the lures were recorded by Adams *et al*. (1989) who tested four commercial lures in field for capturing FAW males, wherein traps baited with the Terochem lure (Raylo Chemicals) captured significantly more fall armyworm moths than other lures. A total of 2,809 FAW moths were captured with a mean of 3.22 FAW moths per trap per observation date from 16$^{th}$ July to 25th September 1985. In the current study, a total of 1497 moths were recorded with a mean of 4.46 moth/trap/observation week during the observation period from fourth week of June to September third week during the *Kharif*-2021.

Based on our one season study, fall armyworm lure (by Gaiagen Technologies Private Ltd., Bangalore) and *Spodoptera frugiperda* Pheromone Lure (by Harmony Ecotech Pvt. Ltd., Hyderabad) performed better and were on par with each other. These two lures were on par with each other with respect to male trap catches, however, these two lures hold a significant difference from other lures tested. In the current investigation, over the entire observational period the largest number of FAW males were collected during July third week and the lowest trap catches were recorded during third week of September *Kharif*-2021.

Similar investigations was carried out by Hall *et al*. (2005) who evaluated five commercial available synthetic lures against FAW in Florida. The study showed a significant difference among the lures tested, wherein, the centurion lure attracted significantly more FAW than rest of the other lures. The Trece and Scentry 2 lures ranked second in capturing the highest number of moths. Another investigation by Malo *et al*. (2004) also yielded similar results, wherein out of the four commercial lures evaluated in field, Pherotech and Scentry lures performed significantly different from Chemtica and Trece lures. Chemtica and Trece lures out performed all other lures tested in capturing highest number of male moths but they were on par with each other.

Similar scenario was observed with investigations of Bhan *et al*. (2013) who also evaluated similar lures and found that Trece lures performed best as compared to all other lures tested which is in-line with the findings of the previous study and also which is similar to the present investigation results, wherein, the lure from Gaiagen and Harmony Ecotech company though outperformed all other lures, they were on par with each other. Hence, use of the pheromone traps in field for the management of fall armyworm can serve as an important component of the IPM module (Kavyashree *et al*., 2022).

The performance of a pheromone lure mainly depends on the appropriate composition of the pheromone blend, pheromone loading rate, the type of material in which the pheromones are impregnated and its dispensing rate etc. In addition, extraneous factors such as temperature, relative humidity, wind-speed and light may also influence lure efficiency under field condition. Due to non-availability of the information related to pheromone blend composition and its loading rate, which is abide by the non-disclosure proprietary regulations by the companies. It becomes difficult to draw an exact conclusion as to why there is differences in lure performance. Further, as the experiment was carried out for only *Kharif* season, it becomes difficult to provide substantial evidence on the efficacy of lures with single season data.

**Table 2: Interaction of trap catches by commercial sex pheromone lures with different weeks of the crop growth period during *Kharif*-2021.**

| **Weeks** | **June-IV** | **July-I** | **July-II** | **July-III** | **July-IV** | **Aug-I** | **Aug-II** | **Aug-III** | **Aug-IV** | **Sep-I** | **Sep-II** | **Sep-III** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weekly mean of overall treatment ($T_1 – T_7$) | $2.43^{e}$ | $3.93^{d}$ | $5.93^{c}$ | $16.32^{a}$ | $10.82^{b}$ | $6.89^{c}$ | $3.82^{d}$ | $1.79^{ef}$ | $0.79^{fg}$ | $0.36^{h}$ | $0.21^{h}$ | $0.18^{h}$ |

| **Treatments** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** |
|---|---|---|---|---|---|---|---|
| Overall treatment mean (June-IV week to September-III week) | $7.06^{a}$ | $7.25^{a}$ | $4.77^{b}$ | $3.73^{c}$ | $3.46^{b}$ | $4.81^{b}$ | $0.10^{d}$ |

| | **F-value** | **df** | **p-value** |
|---|---|---|---|
| **Treatment** | 150.64 | 6 | p < 0.001 |
| **Week** | 363.88 | 11 | p < 0.001 |
| **Treatment*week** | 15.072 | 66 | p < 0.001 |

Mean values with different lowercase superscript letters indicate significant difference between them. The means were compared using multiple comparison of means with Tukey's test (p< 0.05)

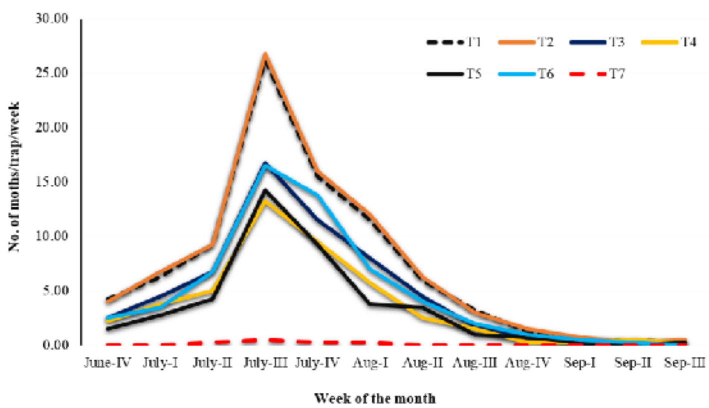


**Fig. 1.** Trap catches of *Spodoptera frugiperda* male moths to different commercial sex pheromone lures evaluated on maize during *Kharif*- 2021.

## CONCLUSION

The current investigation exhibited a remarkable variation in performance of commercial sex pheromone lures of fall armyworm with respect to attraction of male moths under field conditions. The attraction of male moths by different lures varied significantly among the treatments and during different weeks of the crop growth. These variations among treatments could be due to differences in blend ratio of different lures orimpact of extraneous factors such as temperature, humidity and rainfall on the lure and also due to evaporation rate of the compound. The variation across the weeks could be due to differences in the infestation in the field and also adult moth population. Hence the current study serves as an important tool for monitoring fall armyworm and also helps in deciding the frequency of insecticide application for further studies.

## FUTURE SCOPE

Use of sex pheromone lures for management of insect pests through monitoring and mating disruption could serve as an important tool in IPM for successful eco-friendly management of the insect pest. It also helps in reducing the frequency of insecticide application for insect pest management, which in turn solves the problem of insecticide resistance in insects.

**Acknowledgement.** The authors acknowledge all the members of the FAW laboratory, Department of Entomology, College of Agriculture, Shivamogga for extending their kind support for carrying out the evaluation work and College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India for providing all the facilities to carry out this research work.
**Conflict of Interest.** None.

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**How to cite this article:** K.N. Sharath, Sharanabasappa S. Deshmukh, Bathini Nagendra Babu, C.M. Kalleshwaraswamy, B.K. Shivanna and G.N. Thippeshappa (2022). Evaluation of Commercial Sex Pheromone Lures for Management of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith). *Biological Forum – An International Journal*, *14*(4): 833-837.