Bio Efficacy of Selected Plant Essential Oils against Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith)

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The fall armyworm, *Spodoptera frugiperda* (J.E. Smith), is a significant Lepidopteran pest of maize that causes economic damage to maize crops worldwide. Synthetic pesticides are widely used to control pests, but overuse leads to environmental contamination and several drawbacks. Therefore, natural alternatives such as plant essential oils (EOs) are needed to replace synthetic chemicals. This study aimed to evaluate the insecticidal potential of Lemon grass (*Cymbopogon citratus*), Peppermint (*Mentha piperita* L.) and Neem (*Azadirachta indica*) EOs and their effective doses on *S. frugiperda*. EOs were diluted into 1%, 3%, 5%, 8% and 10% dose levels, and antifeedant effects on 3rd instar larvae were assessed under *in vitro* conditions compared to the untreated control. The results revealed a significant effect of EOs on larval biology. The larval weight gain of the untreated control was 99.00 ± 0.62 mg and significantly ($p<0.05$) higher than all the tested essential oil doses. The 10% neem showed the least weight gain (3.00 ± 2.08 mg), and doses higher than 3% for mint and citronellol oil not showed a single unit of weight increment of 3rd instar larvae three days after treatment. The larval duration of 3% mint was restricted to 3.00 ± 0.57 days, and for 5% to 10% doses, it was only 2.00 ± 0.00 days. Additionally, the 10% neem and doses higher than 3% of mint and citronellol completely ceased pupal development. These results provide valuable insights for the use of plant-based EOs to manage the voracious pest, fall armyworm in a sustainable manner. Further research can be done by formulating neem, mint and citronellol with different combinations and ratios to assess their combine effects in managing fall armyworms in an environmentally friendly manner.

Keywords: Antifeedant, fall armyworm, essential oil

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INTRODUCTION

Maize (*Zea mays*: Poaceae) is the second most important cereal crop in Sri Lanka (Malaviarachchi, 2007) and the third most important in the world followed by rice and wheat (Bawa, 2021). The fall armyworm *Spodoptera frugiperda* (J.E. Smith) is a crucial lepidopteran pest of maize that can cause a high rate of economic damage and interference with global food production. The larval stages of the pest feed on maize plants in its all-growing period including seedling to cob formation. This leads to reduce photosynthetic active area and quality and quantity of yield (Goergen et al., 2016) and finally extensive defoliation and death of whorl plant (Arthur et al., 2016). Synthetic pesticides, such as organophosphates and neonicotinoids (Botha et al., 2019) are highly used by farmers to control pests due to its ease to use, readily available and quick feedback. Overuse of synthetic insecticides caused several drawbacks including development of resistant populations, reduction of natural enemy populations, environmental pollution and human health problems. In view of the serious concern of this pest, several natural alternative methods have been studied to replace the use of synthetic chemicals using phytochemicals and plant essential oils. Plant essential oils (EOs) are a mixture of complex secondary metabolite compounds generated by plants, which possessed insecticidal, antifeedant and /or repellent properties against insects and phytophagous mites (Isman, 2015). In addition, they can be used as antiviral, bactericidal, bacteriostatic, fungicidal, fungi static actions. Specially, those are considered as very low toxic to animals and humans (Barbosa et al., 2015). Thus, the present work aimed to evaluate the insecticidal potential of essential oils of castor, neem, mint, citronella and their effective doses and combine effects on *S. frugiperda* under invitro conditions.

METHODOLOGY

Plant and insect colony

The maize variety *Pacific-999* seeds were sown in pots containing topsoil: compost: sand in automated insect proof net cages located in faculty farm premises Agro tech park, Malwatte,

Ampara. Plants were fertilized as per the Department of Agriculture recommendations in Sri Lanka. The maize leaves needed for insect feeding and antifeedant evaluation test were taken from these plants.

A fall armyworm (FAW) insect culture was maintained at the Department of Biosystem Technology, Faculty of Technology, South Eastern University of Sri Lanka under the temperature 27±1 ºC, relative humidity, 70% and 12:12 light and dark hours. Initially, FAW were collected from infested maize fields at the faculty farm and reared in plastic containers that were covered with muslin cloth and individual larvae was kept in each container. The larvae were fed using fresh maize leaves daily. After pupation, they were transferred to the oviposition cages and allowed to reach adult emergence. The obtained eggs were transferred to the plastic container and reared until third instar larvae on immature maize leaves and those larvae were used for the experiment.

Essential oils

The tested plant essential oils were purchased by a commercial supplier (Glorchem enterprise, Chemicals in Sri Lanka) from the following botanical sources, Lemon grass *Cymbopogon citratus* (Poaceae), Peppermint, *Mentha piperita* L. (Lamiaceae), Neem *Azadirachta indica* (Meliaceae). EOs were diluted in distilled water using Tween 20 as an emulsifier into 1%, 3%, 5%, 8% and 10% dose levels. Then the immature leaf cuts taken from the above plants were sprayed with each EOs and dose level separately and fed to 3rd instar larvae as follows.

Larval antifeedant activity

The 3rd instar larvae were individually placed in plastic bottles (250 ml) and maize leaf cuts collected from caged plants were treated with essential oil treatments or control placed as feeding material. The leaves were replaced daily until pupation. Meantime, larval weight (after 3 days), pupal weight, larval duration and final fecal weight were recorded. All the treatments were replicated 5 times for each different dose level of essential oil to ensure results.

Statistical analysis

The data were subjected to ANOVA to determine the effect among the dose levels of each essential oil and significant means were separated by the Tukey post hoc test. All the statics were done at 5% significant level.

RESULTS AND DISCUSSION

A series of essential oils were tested including neem, mint and citronellal against 3rd instar

larvae and according to the results revealed through antifeedant bioassay, essential oils of neem ($F_{5, 19}$=11.11), mint ($F_{5, 19}$=61.78) and citronellol ($F_{5, 19}$= 67.22) showed significant differences ($p<0.05$) for the larval duration of FAWs among the dose levels and untreated control 13.00±0.44 days. The 1% dose of neem, mint and citronellol showed durations as more or less similar to the control. However, at 8% and 10% doses of neem oil showed significantly low survival of larvae notably at 10% dose level it was 7.33±0.88 days. The doses higher than 3% of citronellol oil, limited larval duration to 2.00±0.00 to 8.00±1.00 days. The 3% dose of mint could restrict larval age to 3.00±0.57 days and at 5%, 8% and 10% doses it was only 2.00±0.00 days (Figure 1). The weight gain of 3rd instar larvae of FAW showed a significant difference ($p<0.05$) among the dose levels of neem ($F_{5, 17}$= 41.91), mint ($F_{2, 8}$=122.03) and citronellol ($F_{4, 14}$=61.26). The larval weight gain of control was 99.00±.62 mg and significantly high compared to all the dose levels of tested essential oils. Neem showed a gradual decreasing trend of weight gain and at 10% dose level showed the least value 3.00±2.08 mg. Similarly, the doses higher than 3% for mint and citronellol oil showed negative values (Figure 2). The mean pupal weight of untreated control was 131.0±3.31 mg and which was significantly ($F_{3, 12}$= 8.68) ($p<0.05$) higher the values of 5% and 8% doses of neem oil. Moreover at 10% dose level of neem, there were no surviving pupae. Similarly, doses higher than 3% of mint and citronellol significantly suppressed the development of pupal stages (Figure 3). The fecal weight of untreated control was 273.00±17.49 mg and which was significantly ($p<0.05$) higher compared to the fecal weights of 5% -10% dosages of neem ($F_{5, 18}$= 16.94) and citronellol ($F_{3, 12}$= 72.39). In addition, mean fecal weight of 1% (189.00±4.93 mg) and 3% (7.66±0.88 mg) mint-treated samples showed significantly ($F_{2, 9}$=112.14) fewer weights than in control (Figure 4).

Hence, the tested EOs were affected on biological parameters of FAW such as weight gain, larval duration, digestibility and pupal weights. Similarly, Salinas *et al.,* (2012) tested the effect of *Tagetes erecta* L. (Asteraceae) diluted in acetone (500 ppm) on the biology of *S. frugiperda* and reported that 50% reduction of larval weight at 7 days after and substantial 60% mortality at 14 days. Moreover, aqueous extracts of (1% w/v) of *Talisia esculenta* and *Sapindus saponaria* showed 26.71% and 63.3% larval mortality respectively and *S. saponaria* showed 70% larval weight reduction comparing to control (Laizo et al., 2008). Another study conducted by Celis et al., (2014) using aqueous extracts of *Piper. elbancoanum* (200 mg/L) and *P. arboreum* (50 and 100 mg/L), the mortality rates were identified as similar to positive controls, *B. thuringiensis* and Chlorpyrifos which caused remarkable antifeedant effects. A laboratory study conducted by Maredia et al., (1992) with neem seed powder showed 70% mortality and Pérez-Gutiérrez et al., (2011) reported seed extracts of *Carica papaya* caused

100% mortality of FAW larvae. In addition to that turmeric, clove, palmarosa plant oils reported positive effects protecting maize from 1st and 2nd instars of FAW (Barbosa et al., 2018; Hruska, 2019).

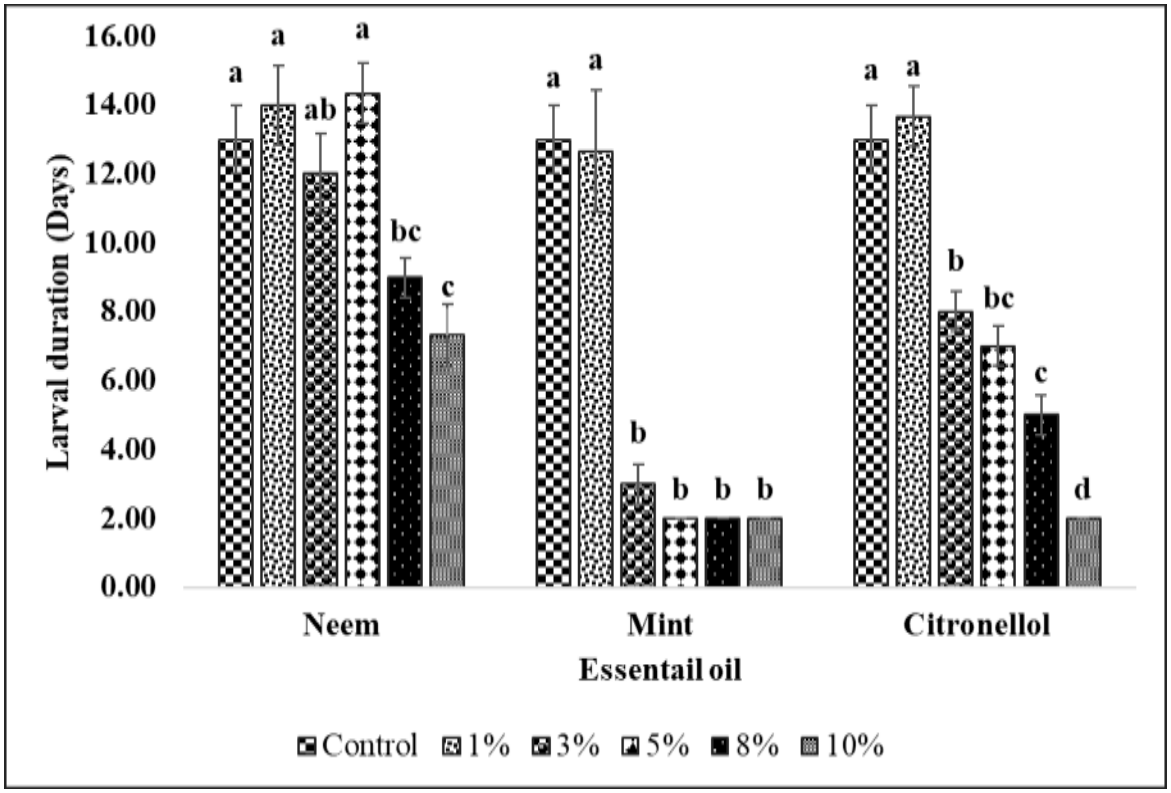

Figure 1. Larval duration of *S. frugiperda* (days) under different doses of essential oils of neem, mint and citronellol.

Note: Different letters on bars indicate significant differences between each dose of essential oils according to Tukey post hoc test at 5% significant level and error bars indicate standard error of mean (SEM).

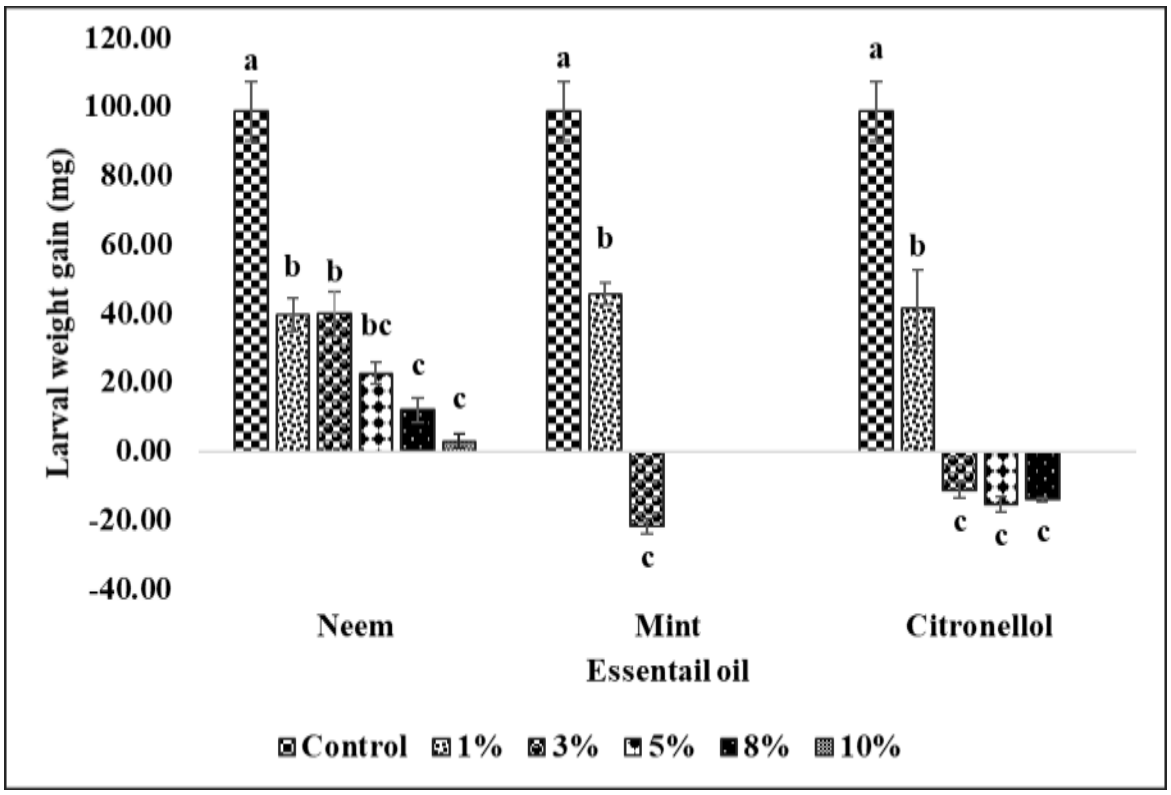

Figure 2. Larval weight gain (mg) of *S. frugiperda* under different doses of essential oils of neem, mint and citronellol.

Note: Different letters on bars indicate significant differences between each dose of essential oils according to Tukey post hoc test at 5% significant level and error bars indicate standard error of mean (SEM).

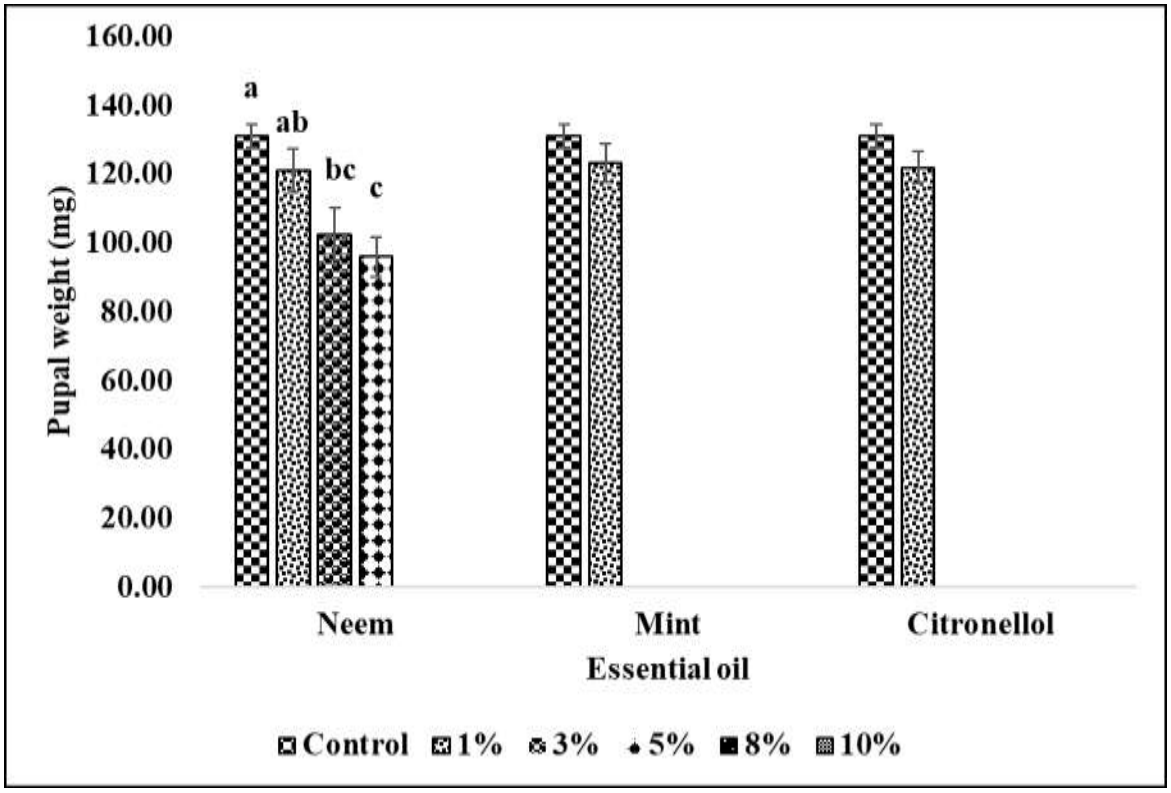

Figure 3. Pupal weight of *S. frugiperda* (mg) under different doses of essential oils of neem, mint and citronellol.

Note: Different letters on bars indicate significant differences between each dose of essential oils according to Tukey post hoc test at 5% significant level and error bars indicate standard error of mean (SEM).

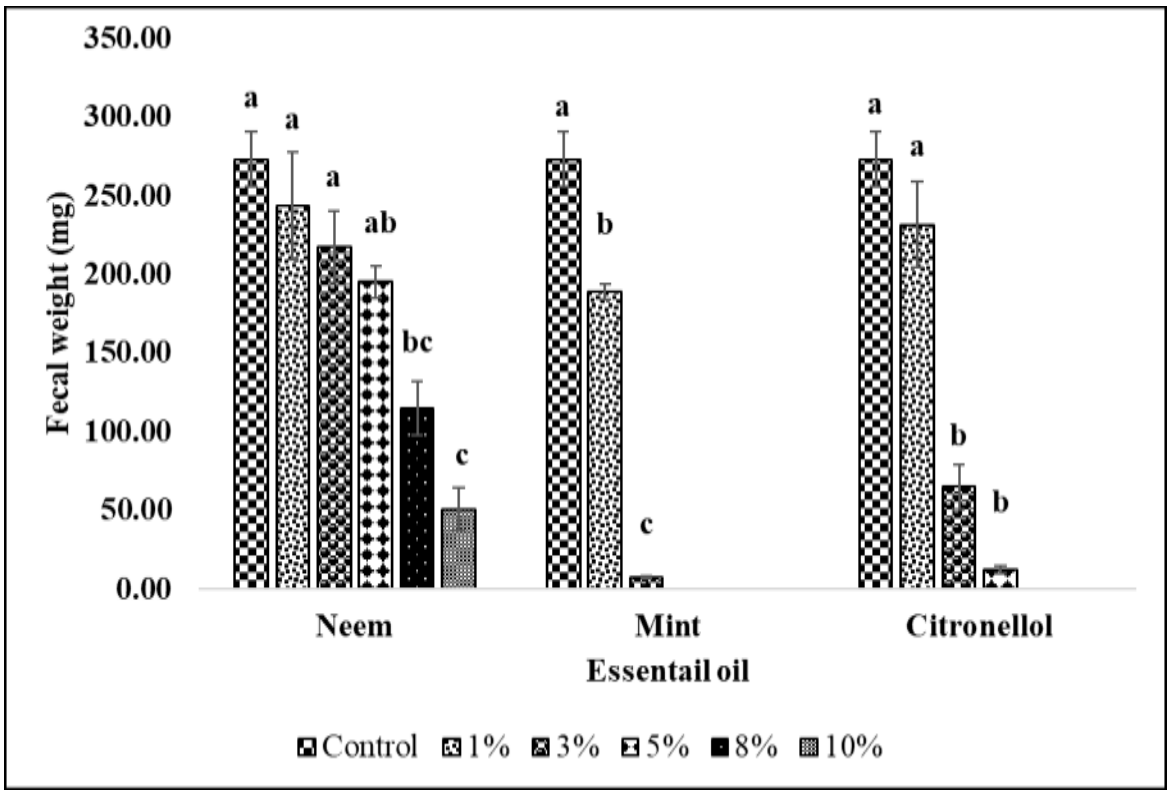

Figure 4. Fecal weight of *S. frugiperda* (mg) under different doses of essential oils of neem, mint and citronellol.

Note: Different letters on bars indicate significant differences between each dose of essential oils according to Tukey post hoc test at 5% significant level and error bars indicate standard error of mean (SEM).

CONCLUSIONS

The EOs of neem, mint and citronellol drastically retard larval performance by means of reducing larval weight gain and durations. The higher doses than 3% for mint and citronellol completely stop larval weight gain limiting larval duration less than 4 days without formation pupal stages. Thus, these plant based EOs could be used to formulate bio- pesticide to control fall armyworm through environmental friendly manner.

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REFERENCES

Arthur, V., Arthur, P. B., & Machi, A. R. (2016). Pupation, adult emergence, and F1 egg hatch after irradiation of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) last instars. Florida Entomologist, 59-61.

Barbosa, M. S., Dias, B. B., Guerra, M. S., & da Costa Vieira, G. H. (2018). Applying plant oils to control fall armyworm (*Spodoptera frugiperda*) in corn. Australian Journal of Crop Science, 12(4), 557-562.

Barbosa, M. S., Vieira, G. H. C., & Teixeira, A. V. (2015). Atividade biológica in vitro de própolis e óleos essenciais sobre o fungo Colletotrichum musae isolado de bananeira (*Musa* spp.). Revista Brasileira de Plantas Medicinais, 17(2), 254–261.

Bawa, A. (2021). Yield and Growth Response of Maize (*Zea mays* L.) to Varietal and Nitrogen Application in the Guinea Savanna Agro-Ecology of Ghana. Advances in Agriculture, 1–8.

Botha, A. S., Erasmus, A., Du Plessis, H., & Van Den Berg, J. (2019). Efficacy of Bt Maize for Control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in South Africa. Journal of Economic Entomology, 112(3), 1260–1266.

Celis F., A., Mendoza F., C., Roa-B., A., & Delgado-A., W. (2014). Effect of piper extracts in fall armyworm (*Spodoptera frugiperda* Smith), under semi-controlled conditions. *Acta Horticulturae*, *1030*, 49–54.

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., & Tamò, M. (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), e0165632.

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

Isman, M. B. (2015). A renaissance for botanical insecticides? Pest Management Science, 71(12), 1587–1590.

Laizo, W., Freire, G. M., Bogorni, P. C., Djair, J., & Macedo, M. L. R. (2008). Effect of the Aqueous Extracts of the Seeds of *Talisia esculenta* and *Sapindus saponaria* on Fall Armyworm. Brazilian Archives of Biology and Technology, 51(April), 373–383.

Malaviarachchi, M.A.P.W.K (2007). Influence of plant density on yield of hybrid maize (Journal of Agricultural Sciences, 3(02), 58–66.

Maredia, K. M., Segura, O. L., & Mihm, J. A. (1992). Effects of neem, *Azadirachta indica* on six species of maize insect pests. Tropical Pest Management, 38(2), 190–195.

Pérez-Gutiérrez, S., Zavala-Sánchez, M. A., González-Chávez, M. M., Cárdenas-Ortega, N. C., & Ramos-López, M. A. (2011). Bioactivity of Carica papaya (Caricaceae) against *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Molecules, 16(9), 7502–7509.

Salinas-Sánchez, D. O., Aldana-Llanos, L., Valdés-Estrada, M. E., Gutiérrez-Ochoa, M., Valladares-Cisneros, G., & Rodríguez-Flores, E. (2012). Insecticidal Activity of *Tagetes erecta* Extracts on *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Florida Entomologist, 95(2), 428–432.