REVIEW ARTICLE

FALL ARMYWORM: AN EMERGING THREAT TO AGRICULTURE-A REVIEW

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ABSTRACT

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American Fall armyworm (*Spodoptera frugiperda*) is a polyphagous agricultural pest that migrates from one to another place quite rapidly & destroys agricultural crops especially maize from eclosion to last instars of its life cycle causing an average of 45% of economic loss by foliar & reproductive part feeding. The pest has become so destructive that the food & nutritional security of small-scale farmer are in great threat. The ability of pest to lay several hundred eggs & rapid migration in a quite short time duration of 30 days makes the pest extremely hard for control. Scouting regularly the field & following Integrated pest management (IPM) technique have been found to be the best against the control FAW but lack of technical knowledge, lack of extension of research output have been a great problem for successful control of Fall armyworm all around the globe.

KEYWORDS

Fall armyworm, Maize, IPM, FAW

1. INTRODUCTION

Fall armyworm (*Spodoptera frugiperda*) is a major polyphagous pest of maize that affects preliminarily maize & other more than 80 crop species such as rice, millet, sorghum, cotton etc. by feeding in large number of leaf & stem especially during June to August when the minimum average temperature exceeds 10 C (Pogue, 2002; Sparks, 1979). This invasive pest with extreme migratory nature (1600 km in 3 hours; was firstly seen in central & western Africa in 2016 whereas in Nepal on 9th May, 2019 on Nawalparasi district in Maize crop & is currently present in more than 100 countries (Goergen et al., 2016; Rose et al., 1975; Bahadur Chhetri and Acharya, 2019; Kandel and Poudel, 2020). The food & nutritional security of small scale farmers are in great threat as the invasive species is likely to migrate further from India to China (Highest producer of Maize in world) (Food, 2020). From 2015, except America, FAW has already been reported in southern karnataka of India & Thailand in 2018, Bangladesh, China, Myanmar & Sri Lanka in 2019 (Kandel and Poudel, 2020). Open border of Nepal & lack of management of Quarantine of seed of Delay maturing Hybrids & late planting maize type are found to be the cause & effect of this pest in Nepal (Kandel and Poudel, 2020). The feeding stage (larva) of FAW damages the crop by foliar tissue feeding making hole on leaf which is the typical symptoms of this pest, larval feeding through leaf whorl may also lead to dead heart & defoliation of leaf leaving only ribs & stalks leads to torn or ragged appearance of the plant causing an average of 45% economic loss (Barros et al., 2010; Kumela et al., 2019; Capinera, 1999; Day et al., 2017). The rapid invasiveness of FAW could be explained by its egg batches that often contains several hundreds of eggs with its massive ability to migrate for long distances (Rose et al., 1975). Because of yield & nutritional composition of Maize, it plays very important role in human consumption in both developed & developing countries, the use of maize is very much varied from animal feed in seed or fodder forms to industrial raw materials its also called "Queen of Cereals" & "oldest & powerful crop"

so, even a minor effect of FAW on maize would be a highly economic loss (Sparks, 1979; Bariw et al., 2020; Macauley and Ramadajita, 2015; Rouf Shah et al., 2016; Huma et al., 2019).

2. HISTORY OF FALL ARMYWORM

The actual history of FAW is unknown, but according to United States of America had been hit with FAW at very irregular intervals; first being in 1797 on Georgia, West Florida on 1856 had reported several damage of FAW outbreaks in US from 1856 to 1928, Missouri & Illinois in 1870 (Sparks, 1979; Glover, 1856; Luginbill, 1928). A period of heavy FAW infestation took place in 1975-1976-1977 throughout southeast along Atlantic coast causing an economical damage of \$61.2, \$31.9, \$137.5 million dollars in 1975, 1976, 1977 respectively (Sparks, 1979; Wiltshire, 1977). Wiltshire, had suggested FAW had established in Israel. Talking about current century, in early 2016, reported the presence of FAW in central & western Africa & later on sub-Saharan Africa (Goergen et al., 2016; Day et al., 2017).

3. ENTOMOLOGY OF FAW

Fall armyworm is an noctuid family pest, hence called moth indigenous to western Hemisphere especially on (North & South America) (Nagoshi et al., 2012). Fall armyworm has several generations per year with the life cycle consisting egg, 6 caterpillar growth & development stages (Instars), Pupa & adult (Moth) which is completed in 30 days during summer & 60 days during winter & might also take 4 wks in southern part & up to 12 wks during the period low temperature of spring & fall (Vickery, n.d.) (Hardke et al., 2015; CABI, 2019; Luginbill, 1928). The life cycle starts with adult female moth laying eggs on (abaxial) underside surface of leaves, typically at the base of the plant, close to the junction of leaf & stem, however on the period of high oviposition, female oviposit egg all over

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plant structures (Hardke et al., 2015; Luginbill, 1928; Sparks, 1979). The mother protects egg masses by covering with protective scales that is rubbed off from moth's abdomen after laying.

After 3-6 days, eggs starts to hatch out (After 4 days under normal condition & young caterpillars start feeding superficially, usually on the undersides of leaves (Dew, 1913). The superficial feeding results on semi-transparent patches on the leaves called "papery Window". The caterpillars prefer leaf whorls in young plants & to the leaves around cob silks in older plants. The caterpillar themselves spin thread, catch the wind & transport themselves to new plants. The feeding of caterpillar is more prominent during the Night. The early instars prefer vegetative tissue whereas later ones prefer reproductive structures like cob & silk (Hardke et al., 2015). In between day 6-14, it reaches leaf whorl, doing the most effective damage, resulting in ragged holes in leaves. The whorl damage on young plants might lead to killing of growing point, resulting in no new leaves or cob development.

Most of the time there are only 1 or 2 caterpillars in each whorl as they become cannibalistic where larger one will eat each other to reduce competition for food. The caterpillar excrement (Frass) can also be seen in leaf whorl upon drying it resembles as sawdust. If the plant has already developed cobs the caterpillar will eat its way through the protective leaf bracts into the side of the cob & starts feeding on developing young kernels (seeds). There might be 6-7 instars depending upon environment & food availability. Later instars increase food consumption rate & the final instars consume food even in greater quantity than all other previous instars combined (Luginbill, 1928). The larval development duration also varies accordingly, at 25 C larval development takes about 22 days.

Source: (FAO, 2017)

After approximately feeding for 14 days the fully-grown caterpillars will drop to the ground. The caterpillar then bore 2-8 cm deep into soil for pupation if the soil is too dry & hard for caterpillar to bore then the caterpillar will cover itself with leaf debris before pupation (Prasanna et al., 2018). The depth of pupation of larva depends upon several edaphic factors like soil texture, soil moisture & soil temperature (Sparks, 1979). The pupa is a loose, silk, oval-shaped cocoon of 20-30mm in length inside which an adult moth develops within 8-9 days, emerges from soil. The mating of FAW might take place locally or migrate up to 300 miles before mating & ovipositing the life cycle repeats again (Ashley et al., 1989). After approximately feeding for 14 days the fully-grown caterpillars will drop to the ground. The caterpillar then bore 2-8 cm deep into soil for pupation if the soil is too dry & hard for caterpillar to bore then the caterpillar will cover itself with leaf debris before pupation (Prasanna et al., 2018). The depth of pupation of larva depends upon several edaphic factors like soil texture, soil moisture & soil temperature (Sparks, 1979). The pupa is a loose, silk, oval-shaped cocoon of 20-30mm in length inside which an adult moth develops within 8-9 days, emerges from soil. The mating of FAW might take place locally or migrate up to 300 miles before mating & ovipositing the life cycle repeats again (Ashley et al., 1989).

4. IDENTIFICATION OF FAW

FAW is very destructive pest so, we have to identify its every life stages so as to effectively scout & prevent yield loss.

4.1 Eggs

The freshly oviposited eggs are initially greenish gray in color with "Oblate-Spheroidal" shape with the dimension of 0.39mm in height & 0.47 mm in diameter (Luginbill, 1928). 12 hours later eggs turn brown & become black at the time just prior to larval eclosion (Luginbill, 1928).

Figure 1: *S. frugiperda* egg mass with little or no covering of scales (A); egg mass covered with scales (B); and egg mass nearing larval eclosion (C) (Hardke et al., 2015).

4.2 Larva

Figure 2: *S. frugiperda* newly hatched larvae (A) and neonates (B).

Figure 3: *S. frugiperda* early-instar larva (Hardke et al., 2015).

Figure 4: *S. frugiperda* late-instar larva (Hardke et al., 2015).

Figure 5: *S. frugiperda* late-instar larva prior to pupation (Hardke et al., 2015).

Figure 6: *S. frugiperda* late instars showing inverted "Y" on head capsule (Hardke et al., 2015).

Figure 7: *S. frugiperda* late instar showing four black dots in a square pattern on eighth abdominal segment (Hardke et al., 2015).

The early larval instars especially first(L1) are greenish in color with second change to orange in color. Larvae are of 1mm in 1st instars stage & length increases up to 45mm in six instar whereas head capsule width ranges from 0.314mm for first instars to 2.78mm for sixth instars (Prasanna et al., 2018; Luginbill, 1928). The fourth & six instar larva have head that is reddish brown mottled in color with white with lateral lines (Igyuve et al., 2018). The three final stage (L3-L6) larva instars have a distinct inverted "Y" shape on the head capsule. The head capsule is generally dark in color, fourth & fifth instars lack primary setae & are generally smooth in texture (Hardke et al., 2015). Larvae also possess distinct four "dots" on the eighth abdominal segment. The fall armyworm larva possesses tooth-like projections on their mandibles.

4.2 Pupa

Orange-Brown pupal case is typical to Noctuids means same is for FAW pupa which turns darker with age (Hardke et al., 2015). Loose oval silk cocoon of 20-30 mm length is secreted during the process of pupation inside which a reddish brown colored pupa of approximately 14-18mm length & 4.5mm width differentiates to adult (Kandel and Poudel, 2020).

Figure 8: *S. frugiperda* pupa (Hardke et al., 2015).

4.4 Adult

The wing span of adult Fall armyworm (Moth) is of about 1.5 inches (3.81cm) with upper portion of forewing mottled dark grey in color with a distinctive triangular white spot near the dorsal tip, or apex of the wing, while the lower portion of the forewing is light grey to brown color (Oliver and Chapin, 1981). The hind wing on the other hand appears light grey to white in color. The adult phase of FAW lasts for about 7-21 days.

Figure 9: *S. frugiperda* adult (Hardke et al., 2015).

The adult female has a high fecundity rate of 900-1000 eggs per female on a relatively short life cycle of 7-21 days (Johnson, 1987).

5. CONTROL MEASURES

Maize, because of its multiple uses from cereal to animal feed is most important cereal crop in terms of its calorie intake in the world hence, it's given the second most cultivation area (Assefa et al., 2019; Tsedeke Abate et al., 2015). So, the detection of FAW armyworm before they cause economic damage is very important for successful management. There are many management practices which are categorized on following headings:

5.1 Cultural Method

The most common cultural control method is deep plowing before planting to kill larva & pupa (Kandel and Poudel, 2020). Push-Pull trap with Desmodium as push crop & Napier grass as pull crop also reduce the infestation (Hailu et al., 2018). Pheromone trap for trapping male is also a very good tactic to successful IPM management (Batista-Pereira et al., 2006). Other cultural control of avoiding late planting as maize ears would be greatly attacked on late planted maize (Assefa et al., 2019). Crop rotation with sunflower & beans also helps to minimize the infestation (FAO, 2018). Handpicking, killing the caterpillar, application of wood ashes to soil & leaf whorls also reduces infestation (Abate et al., 2000).

5.2 Biological Method

In biological method various biological agents are used such as parasites, pathogen are used but only a good understanding the adaptation & establishment of applied biological agents in given agro ecosystem determines the successfulness of biological control measure (Makanza et al., 2018). (R., n.d.) had listed 53 species of parasitoids that are just reared from FAW egg & larvae. Parasitoid wasps like *Trichogramma* or *Telenomus remus* wasp, *Cotesia icipe*, *palexarista zonata*, *Charops ater* these parasitoid insects lay eggs inside of the FAW eggs & eggs of parasitoid upon hatching give offspring that feeds the eggs of FAW (Assefa et al., 2019; Kandel and Poudel, 2020). *Cotesia icipe* have been found to parasitize on an average of 40% FAW on larva stage, tachinid fly, *Archytas marmoratus* with 12.5% parasitism (Sisay et al., 2018).

The braconid wasp *Chelonus insularis* also parasitizes eggs of FAW & controls FAW (Kumela et al., 2019; Meagher et al., 2016). Many predatory insects like ground beetle (Coleoptera: Carabidae); the striped earwig, *Labidura riparia* (Dermaptera: Forficulidae, Labiduridae), insidious flower bug, *Orius insidiosus* (Hemiptera: Anthocoridae); spined soldier bug, *Podisus maculiventris* are also found to be predatory against FAW (Jones et al., 1988; Sánchez-Rodríguez et al., 2010; Silva et al., 2018; Capinera, 1999). Many entomopathogenic pathogens like *Bacillus thuringiensis*, *Metarhizium anisopliae* & *Beauveria bassiana* were also found to be very effective against FAW (Clark et al., 2007).

5.3 Botanical Method

The plant extracts of Neem (*Azadiracta indica*), long pepper (*Pepper hispidinervum*), castor (*Ricinus communis*), *Croton macrostachyus*, *Phytolacca docendra*, *Jatropha curcas*, *Nicotina tabacum*, *chrysanthemum cinerariifolium* have been found to be effective against FAW (Kandel and Poudel, 2020; Schmutterer, 1985; Silva et al., 2015).

6. CONCLUSION

Fall armyworm is very destructive invasive agricultural pest which can damage a significant large area of agricultural crop on a relatively short duration of time. The control of FAW doesn't look as easy as for other crops. Cultural control, use of botanical extracts, good crop husbandry, regular scouting for pest as well as its natural enemies & applying Integrated pest management approach are found to be the best control measure for FAW. Excessive use of chemical insecticide for short duration effective management practice might lead to creation of super bug strain of FAW on future. Hence, Farmer, researchers & technical knowledge extensions should be done with thinking of future in present.

REFERENCES

- Abate, T., Van Huis, A., Ampofo, J.K.O., 2000. Pest management strategies in traditional agriculture: An African perspective. *Annual Review of Entomology*, 45, Pp. 631–659. <https://doi.org/10.1146/annurev.ento.45.1.631>
- Abate, Tsedeke, Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., Kassie, M., Bogale, G., Tadesse, B., Keno, T., 2015. Factors that transformed maize productivity in Ethiopia. *Food Security*, 7 (5), Pp. 965–981. <https://doi.org/10.1007/s12571-015-0488-z>
- Ashley, T.R., 1979. Classification and distribution of fall armyworm parasites. *Literature Review Articles*, 62, Pp. 114–122.
- Ashley, T.R., Wiseman, B.R., Davis, F.M., Andrews, K.L., 1989. The Fall Armyworm: A Bibliography. *The Florida Entomologist*, 72 (1), Pp. 152. <https://doi.org/10.2307/3494982>
- Assefa, F., Ayalew, D., Tejada Moral, M., 2019. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. *Cogent Food & Agriculture*, 5 (1), Pp. 1641902. <https://doi.org/10.1080/23311932.2019.1641902>
- Bahadur, C.L., and Acharya, B., 2019. Fall armyworm (*Spodoptera frugiperda*): A threat to food security for south Asian country: Control and management options: A review, 4 (1), Pp. 38–44. <https://doi.org/10.31830/2456-8724.2019.004>
- Bariw, S.A., Kudadze, S., Adzawla, W., 2020. Prevalence, effects and management of fall army worm in the Nkoranza South Municipality, Bono East region of Ghana. *Cogent Food & Agriculture*, 6 (1), Pp. 1800239. <https://doi.org/10.1080/23311932.2020.1800239>
- Barros, E.M., Torres, J.B., Ruberson, J.R., Oliveira, M.D., 2010. Development of *Spodoptera frugiperda* on different hosts and damage to reproductive structures in cotton. *Entomologia Experimentalis et Applicata*, 137 (3), Pp. 237–245. <https://doi.org/10.1111/j.1570-7458.2010.01058.x>
- Batista-Pereira, L.G., Castral, T.C., Da Silva, M.T.M., Amaral, B.R., Fernandes, J.B., Vieira, P.C., Da Silva, M.F.G.F., Corrêa, A.G., 2006. Insecticidal activity of synthetic amides on *Spodoptera frugiperda*. *Zeitschrift Fur Naturforschung - Section C Journal of Biosciences*, 61 (3–4), Pp. 196–202. <https://doi.org/10.1515/znc-2006-3-408>
- Capinera, J.L., 1999. Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Insecta: Lepidoptera: Noctuidae) 1 Introduction and Distribution. In *journals.flvc.org*. <http://creatures.ifas.ufl.edu>
- Clark, P.L., Molina-Ochoa, J., Martinelli, S., Skoda, S.R., Isenhour, D.J., Lee, D.J., Krumm, J.T., Foster, J.E., 2007. Population variation of the fall armyworm, *Spodoptera frugiperda*, in the Western Hemisphere. *Journal of Insect Science*, Pp. 7. <https://doi.org/10.1673/031.007.0501>
- Day, R., Abrahams, P., Bateman, M., Beale, T., Clotney, V., Cock, M., Colmenarez, Y., Corniani, N., Early, R., Godwin, J., Gomez, J., Moreno, P.G., Murphy, S.T., Oppong-Mensah, B., Phiri, N., Pratt, C., Silvestri, S., Witt, A., 2017. Fall armyworm: Impacts and implications for Africa. *Outlooks on Pest Management*, 28 (5), Pp. 196–201. https://doi.org/10.1564/v28_oct_02
- Dew, J.A., 1913. Fall Army Worm. *Journal of Economic Entomology*, 6 (4), Pp. 361–366. <https://doi.org/10.1093/jee/6.4.361>
- Food, W., 2020. World Food and Agriculture - Statistical Yearbook 2020. In *World Food and Agriculture - Statistical Yearbook 2020*. <https://doi.org/10.4060/cb1329en>
- 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). <https://doi.org/10.1371/journal.pone.0165632>
- Hailu, G., Niassy, S., Zeyaur, K., 2018. Maize–legume intercropping and push–pull for management of fall armyworm, stemborers, and striga in Uganda. *Wiley Online Library*, 110 (6), Pp. 2513–2522. <https://doi.org/10.2134/agronj2018.02.0110>
- Hardke, J.T., Lorenz Iii, G.M., Leonard, B.R., 2015. Fall Armyworm (Lepidoptera: Noctuidae) Ecology in Southeastern Cotton. *J. Integ. Pest Mngmt.*, 6 (1), Pp. 10. <https://doi.org/10.1093/jipm/pmv009>
- Huma, B., Hussain, M., Ning, C., Yuesuo, Y., 2019. Human Benefits from Maize Article Information. In *Scholar Journal of Applied Sciences and Research*, 2, (2). www.innovationinfo.org
- Johnson, S.J., 1987. Migration and the life history strategy of the fall armyworm, *Spodoptera frugiperda* in the western hemisphere. *International Journal of Tropical Insect Science*, 8 (4–5–6), Pp. 543–549. <https://doi.org/10.1017/s1742758400022591>
- Jones, R.W., Gilstrap, F.E., Andrews, K.L., 1988. Biology and life tables for the predaceous earwig, *Doru taeniatum* [Derm.: Forficulidae]. *Entomophaga*, 33 (1), Pp. 43–54. <https://doi.org/10.1007/BF02372312>
- Kandel, S., Poudel, R., 2020. Fall Armyworm (*Spodoptera Frugiperda*) in Maize: An Emerging Threat in Nepal and its Management. *International Journal of Applied Sciences and Biotechnology*, 8 (3), Pp. 305–309. <https://doi.org/10.3126/ijasbt.v8i3.31610>
- Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L., Tefera, T., 2019. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *International Journal of Pest Management*, 65 (1), Pp. 1–9. <https://doi.org/10.1080/09670874.2017.1423129>
- Macauley, H., Ramadita, T., 2015. Cereal crops: Rice, maize, millet, sorghum, wheat. <https://erl.ucc.edu.gh/jspui/handle/123456789/4510>
- Makanza, R., Zaman-Allah, M., Cairns, J.E., Eyre, J., Burgueño, J., Pacheco, Á., Diepenbrock, C., Magorokosho, C., Tarekegne, A., Olsen, M., Prasanna, B.M., 2018. High-throughput method for ear phenotyping and kernel weight estimation in maize using ear digital imaging. *Plant Methods*, 14 (1). <https://doi.org/10.1186/s13007-018-0317-4>
- Meagher, R.L., Nuessly, G.S., Nagoshi, R.N., Hay-Roe, M.M., 2016. Parasitoids attacking fall armyworm (Lepidoptera: Noctuidae) in sweet corn habitats. *Biological Control*, 95, Pp. 66–72. <https://doi.org/10.1016/j.biocontrol.2016.01.006>
- Nagoshi, R.N., Meagher, R.L., Hay-Roe, M., 2012. Inferring the annual migration patterns of fall armyworm (Lepidoptera: Noctuidae) in the United States from mitochondrial haplotypes. *Ecology and Evolution*, 2 (7), Pp. 1458–1467. <https://doi.org/10.1002/ece3.268>
- Pitre, H.N., Hogg, D.B., 1983. Development of the fall armyworm on cotton, soybean and corn. *Journal of the Georgia Entomological Society*, 18, Pp. 187–194.
- Pogue, M., 2002. A world revision of the genus *Spodoptera* Guenée (Lepidoptera: Noctuidae). *Mem Am Ent Soc*, 43.
- Rose, A.H., Silversides, R.H., Lindquist, O.H., 1975. Migration flight by an aphid, *rhopalosiphum maidis* (hemiptera: Aphididae), and a noctuid, *spodoptera frugiperda* (lepidoptera: Noctuidae). *The Canadian Entomologist*, 107 (6), Pp. 567–576. <https://doi.org/10.4039/Ent107567-6>

- Rouf, S.T., Prasad, K., Kumar, P., 2016. Maize A potential source of human nutrition and health: A review. *Cogent Food & Agriculture*, 2 (1). <https://doi.org/10.1080/23311932.2016.1166995>
- Sánchez-Rodríguez, E., Rubio-Wilhelmi, M., Cervilla, L.M., Blasco, B., Rios, J.J., Rosales, M.A., Romero, L., Ruiz, J.M., 2010. Genotypic differences in some physiological parameters symptomatic for oxidative stress under moderate drought in tomato plants. *Plant Science*, 178 (1), Pp. 30–40. <https://doi.org/10.1016/j.plantsci.2009.10.001>
- Schmutterer, H., 1985. Which insect pests can be controlled by application of neem seed kernel extracts under field conditions? *Zeitschrift Für Angewandte Entomologie*, 100 (1–5), Pp. 468–475. <https://doi.org/10.1111/j.1439-0418.1985.tb02808.x>
- Silva, G.A., Picanço, M.C., Ferreira, L.R., Ferreira, D.O., Farias, E.S., Souza, T.C., Rodrigues-Silva, N., and Pereira, E.J.G., 2018. Yield losses in transgenic Cry1Ab and non-bt corn as assessed using a crop-life-table approach. *Journal of Economic Entomology*, 111 (1), Pp. 218–226. <https://doi.org/10.1093/jee/tox346>
- Silva, M.S., Broglio, S.M.F., Trindade, R.C.P., Ferreira, E.S., Gomes, I.B., Micheletti, L.B., 2015. Toxicity and application of neem in fall armyworm. *Communicata Scientiae*, 6 (3), Pp. 359–364. <https://doi.org/10.14295/CS.v6i3.808>
- Sisay, B., Simiyu, J., Malusi, P., Likhayo, P., Mendesil, E., Elibariki, N., Wakgari, M., Ayalew, G., Tefera, T., 2018. First report of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), natural enemies from Africa. *Journal of Applied Entomology*, 142 (8), Pp. 800–804. <https://doi.org/10.1111/jen.12534>
- Sparks, A.N., 1979. A Review of the Biology of the Fall Armyworm. *The Florida Entomologist*, 62 (2), Pp. 82. <https://doi.org/10.2307/3494083>
- Vickery, R. A., 1929. Studies on The Fall Army Worm in The Gulf Coast District of Texas L J 3 I l A R ^ Studies on The Fall Army Worm' In the Gulf Coast District Of Texas, Pp. 1-29.