International Journal of Advanced Research and Review

www.ijarr.in

A REVIEW ON ALIEN INVASIVE PEST FALL ARMYWORM (*Spodoptera frugiperda*) INFESTATION AND ITS CONTROL IN SRI LANKA

R. Vassanthini*[1] and A.M.K.D.M.Attanayaka[2]

Faculty of Agriculture, Eastern University, Sri Lanka.
vassanthini93ratnarajah@gmail.com, kanchanidarshika@gmail.com

ABSTRACT

Fall armyworm (FAW) *Spodoptera frugiperda* is an alien invasive pest which has been highly adapted to the climatic conditions of Sri Lanka in recent times. The fall armyworm caused a severe loss of maize production since its introduction in late 2018. The pest infected approximately 50% of the maize cultivation and caused 20% of total damage by its fast migration as well as breeding abilities. It is hard to control the fall armyworm because of these special characteristics. However, there are several methods used in other countries to keep the population and infestation under control. Hence, integrated pest management strategies are believed to be an effective strategy to control the FAW. Therefore, this review discusses the infestation and control of FAW, which could be important to improve the control in Sri Lanka.

Key words: Fall Armyworm, Maize, Sri Lanka, Control, Integrated Pest Management

INTRODUCTION

Next to the staple diet rice, maize is considered to be the second most valuable food crop grown in Sri Lanka. There are two cropping seasons related to maize cultivation as Maha and Yala. The estimated maize growing extent is about 82,539 ha in Maha and about 9,000 – 10,000 ha during the yala season. It is widely used in both food and feed industries. Maize has received high demand in recent years due to increased local demand with the expansion of the feed industry as fodder, silage and grains for manufacturing livestock feed. In 2018/2019, 54,416 ha of maize cultivation has been infested in Maha season by the pest (DOA, 2019). In recent years, there is a common discussion about Fall Armyworm (*Spodoptera frugiperda*) which has attacked maize cultivation. Number of countries in the South Asian region have already been invaded by the Fall ArmyWarm (*Spodoptera frugiperda*). At the very first in Sri Lanka, the pest Fall ArmyWarm (FAW) was reported in August 2018, in Ampara district (Perera *et al*., 2019). The first report of FAW attack in some sugarcane fields was reported in Habaraluwewa zone at Sevanagala (6° 23'N, 80° 55'E).

FAW is a polyphagous lepidopteran that belongs to the family Noctuidae and is native to South and North America (Otim *et al*., 2018). It feeds on more than eighty plant species including major cereals. In 2016, there was global attention about the severe economic losses in corn fields in West and Central Africa. It was reported the possibility that this destructive pest could spread rapidly to other continents to cause extensive crop losses up to 80% depending on

existing conditions (Perera *et al*., 2019). In 2018, the pest reached the Indian subcontinent, arriving in Asia (Sharanabasappa *et al*., 2018). It is possible that the FWA arrived in Sri Lanka over the Indian Ocean through wind currents (Mudugamuwa, 2019). Advanced larval stage of the FAW is the critical stage of this pest and it is hard to control by using single pesticide. With the absence of natural control and good cultural control methods, the FAW causes severe damage to the maize cultivation. Understanding the armyworms breed, travel and feed is important to managing devastation they can cause.

BIOLOGY AND DISTRIBUTION

Taxonomy

Domain: Eukaryota
Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta
Subclass: Pterygota
Order: Lepidoptera
Family: Noctuidae
Subfamily: Noctuinae
Genus: *Spodoptera*
Species: *Spodoptera frugiperda*

Biology and life cycle of the pest

Biology and the behavior of the FAW are greatly affected by the existing environmental factors especially the tropical climate. FAW represents complete metamorphosis and all four stages in the life cycle namely eggs, larva, pupa and adult (Figure 1). Female moth lays eggs on the upper and lower sides of the leaves. Spherical shaped eggs are approximately 0.75 mm diameter and after oviposition they are yellowish green in colour and with maturity, the colour turns darker and in the verge of hatching appear in light brown. Egg masses are covered with grey coloured setae by the moth during oviposition for their protection. Rarely eggs without the protected covering are also reported (Pantoja-Lopez, 1985 and Perera *et al*., 2019). Consecutive six larval stages are there when completing life cycle. Based on the temperature and environmental conditions, the extent of time for larval development varies from 11 to 50 days (Perera *et al*., 2019). There is green colour with black lines in hatching and spots and when they grow commonly, they become brownish. Fully grown larvae range from 3-4 cm in length (Pantoja-Lopez, 1985). From L1-L6 larvae are feeding on the host plant while causing considerable damage in the crop. It is a possibility to spread the young FAW by the air currents on hanging silken threads. There is a problem to protect the FAW from predators due to hiding of larva inside leaf whorls of maize (Hailu *et al*., 2018).

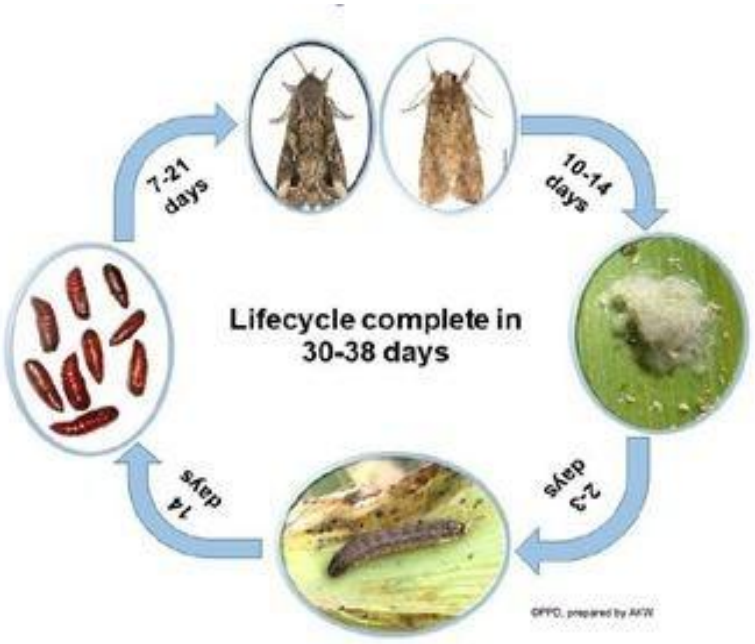

Figure-1: Complete life cycle of FAW (Source: FAO,2020)

Larval stages are the prominent feeding period of FAW. Duration of the pupal stage is from 9 to 12 days (Sharanabasappa *et al*., 2018). Mostly the pupal stage takes place inside the soil with loose cocoon and in some cases in the leaves of the maize plant. Pupa is shorter than the mature larva and is shiny brown in colour. The male pupa is slightly shorter than the male. Both males and females of adult moths have mottled brown-grey coloured forewings and dirty white-straw coloured hind wings. Fore wings of males are having more prominent markings with white colour patches in distal ends of the wing (Passoa, 1991).

Distribution of the pest in Sri Lanka

Fall armyworm caterpillars were first detected in Nigeria in 2016 and in India 2018 followed by other South Asian countries. India started to suffer with an infestation in March 2018 (Mudugamuwa, 2019).The worm is suspected to have invaded the corn fields of Sri Lanka through India with the wind speed of 100km per night, during the months of September to October in the year of 2018. TheFAO said that all the major growing areas of maize had been affected by the pest in Sri Lanka. Fall armyworm caterpillar initially detected in Ampara and Anuradhapura districts and now spread to other districts as well. It spreads rapidly on the corn fields and infected nearly 50% (82,000 ha) of maize cultivation. The total estimated damage by the Department of Agriculture was about 20% (Dissanayake, 2019).

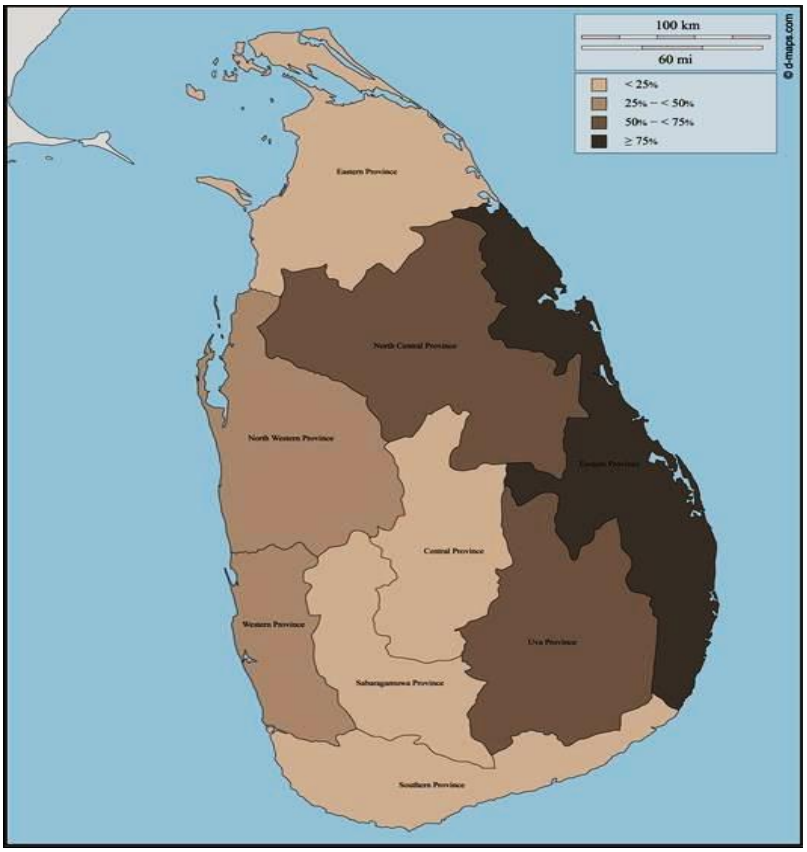

Figure-2: Distribution of FAW attack in maize in Sri Lanka during Maha season (2018-2019). Highest yield loss reported in Eastern province indicated by the dark brown colour and lighter colours indicate lower distribution of FAW in different provinces (Source: DOA, 2019).
In March 2019, damage from Fall Armyworms was reported in the provinces East, Uva and North-Central in particular. The hardest hit areas are Anuradhapura, Ampara, Badulla, and Monaragala. In mid-February 2019, 41,880 hectares of maize were affected (Governmen tofSriLanka and World Food Programme, 2019).

Figure-3: Spread of Fall Armyworm in Sri Lanka during 2018-2019 © Department of Agriculture/KNC Gunewardena (Source: FAO, 2019)

Current status of the pest in Sri Lanka

All major maize-growing areas in Sri Lanka have reported Fall Armyworms (FAW) or *Spodoptera frugiperda*, which have also affected sugarcane cultivation. Farmers are increasingly concerned that other crops, including rice and vegetable crops like tomato, cabbage and knol-khol will be affected. (FAO, 2019a). The maize harvest in the seasons of 2019 in Anuradhapura, Ampara, Badulla, and Monaragala areas was affected by the armyworm infestation. According to official reports, around 50% of the maize plantation was affected in April 2019 and the crop loss is estimated at 10% of the expected production (FAO ,2019b). FAO has proposed a three year global action between 2020-2022 to control the spread of FAW. Global resources and expertise are expected to be mobilized to strengthen the national capacities to control FAW and step up efforts to end the widespread use of highly hazardous pesticides and allocate resources to scientific research and innovation for effective development to find solutions to control the pest, such as the fall armyworm monitoring mobile application and the FAO early warning system (FAO, 2019a).

Over 60% of the countries' maize crop was completely destroyed, in addition to that rice cultivation in Polonnaruwa and Anuradhapura also were affected by the FAW. The damage caused by the FAW resulted in losses of several million rupees. This devastation is getting serious day by day, which ultimately had a huge impact on the farming community and in the country. The epidemic has destroyed several hectares of corn land at an alarming rate. As this threat invades the country exponentially and destroys agriculture, it threatens the pulse of the nation, as well as economic, social and political aspects of the country (Skandha, 2019).

NATURE OF DAMAGE AND SYMPTOMS

Damage can be seen in all the growth stages of the host plant including early vegetative up to reproductive stages. First sign of the infestation is the appearance of different egg masses on the upper and lower side of the leaves (Alam *et al*., 2020). But, it is very difficult to detect early infestations because the larvae of the FAW burrow into the leaf whorl of the crop.

Figure-4,5: Damages caused by FAW (Source: FAO, 2020).

Larvae of the FAW are initially fed on one side and remain in the other sides' epidermis layer intact. Later, second and third instar larvae begin to make leaf holes (Figure 5) and cuttings (Figure 4) in the stem in young plants. Later instar larvae cause extensive defoliation by feeding voraciously on the leaves, leaving only the stalks and ribs of the maize plant. Feeding the growing point of young plants leads to no cob formation in maize. Larval feeding can be observed by large accumulations of wet fecal matter (Passoa, 1991). The dry droppings look like that of saw dust. Plants with 2-3 leaf whorls to tasseling are the most preferable stages for the pest in the maize fields in Rathnapura District (Perera *et al*., 2019) caused by Larvae feeding of young plants through the whorl. The matured larvae can feed on cob or kernels, reducing yield and quality (Abrahams *et al*., 2017).

CONTROL MEASURES

The common management strategy of FAW in the United States is to use pesticide sprays and genetically modified plants (Bt corn) (Abrahams*et al*., 2017). Soon after the FAW epidemic began, African governments implemented a plan to spray chemical pesticides on a large scale (Prasanna*et al*., 2018). However, most small farmers in Africa cannot afford to repeatedly spray pesticides, and there is no Bt corn in Africa. In addition, excessive use of chemical pesticides will eliminate potential natural enemies, have a negative impact on human and animal health, lead to resistance to target pests and increase plant production costs (Yu, 1991).

The overuse of pesticides and the risks it brings have caused people to worry about food safety and sustainability. Integrated pest management (IPM) strategy is an important method to control FAW to meet the needs of smallholder farmers in Africa. Since FAW is an invader on the continent, information on natural enemies related to this pest related to Africa is not yet complete(Sisay *et al*., 2019). So far, there is no single solution for sustainable management of FAW in Africa or Asia. An effective IPM strategy is important for the control of FAW. To protect the crops from economic injury while declining the negative impacts on human beings, animals, and the environment, the biological and cultural control, and environmentally safer synthetic and bio-pesticides are most proper against the FAW (Padhee and Prasanna, 2019). Natural enemies, including parasitoids, predators and entomopathogens, attack FAW in America, its centre of origin. Molina-Ochoa *etal*. (2003) have documented around 150 species of FAW parasitoids in America and the Caribbean. In East and West Africa, the scientists have reported the certain types of parasitoids against the eggs and larvae of FAW (Rwomushana *et al*., 2018).

Cultural control methods

Use some early maturity maize varieties which can escape the pest damage to some level and early planting also can help protect the crop from attack of FAW to considerable level. Early harvesting allows many maize ears to escape the higher armyworm densities that develop later in the season (Roberts and All, 1993). Intercropping is a best cultural practice that can reduce the pest attack and against the FAW can use soybean, black gram and cowpea with maize as intercropping crops.The intercropped leguminous provides better protection to the crop compared to that when it's mono cropped (Hailu *et al*., 2018). Planting Brachiaria cv Mulato ll as a border crop around the intercrop is promoting in Nepal as a solution for FAW. Some semiochemicals emitted by the trap plants are attractive to the female moths while that emitted semiochemicals from intercrops counteract the oviposition on the maize (Chamberlain *et al*.,

2006) and contribute to attract the natural enemies of the pest (Khan *et al*., 1997; Midega *et al*., 2009). Trap plants which are used in traditional cultivation act as non-suitable crops for survival and development of the larvae of the pests, resulting in high mortality rates (Khan *etal* ., 2006; Midega *et al*., 2011). Use of pheromone traps is a better cultural measure against the FAW. Pheromone is prominent for pest monitoring, mass-trapping, and interruption in mating. Pheromone is a useful tool for monitoring male populations in different parts of the world (Malo *et al*., 2004 and Batista-Pereira *et al*. 2006). Light traps can be used to control the adult FAW which helps to trap both male and female moths. Under small scale crop production hand picking of the egg masses during regular monitoring of the field helps to control the pest. The majority of farmers using these techniques revealed that these measures were a 'somewhat successful story' (Rwomushana *et al*., 2018).

Chemical control methods

The larvae feed on leaves and the whorl of the maize plant and also on the ears where they feed on silk hairs, kernels and soft inner leaves. Therefore, an ample amount of insecticide is applied to control the population of fall armyworm. Insecticide may be applied as foliar spray and granular form which is applied inside the whorl for feasible control of FAW. Emamectin benzoate 5SG 0.4g/l and Chlorantraniliprol 18.5SC 0.4ml/l much more provable to control the infestation of fall armyworm (Foster, 1989). Use of insecticides like spinosad, chlorantraniliprole also helps to reduce the pest population at last resort. Spinosad, causing >90% larval mortality. (Cruz *et al*., 2012). Mortality rate of FAW was reported better with new insecticides (*Cholarantraniliprole* , *flubendiamide* and spinetoram) compared to lambda-cyhalothrin and novaluron (Hardke *et al*. 2014). A pesticide called "NGV' has been introduced by the Department of Agriculture in 2020 December to control the Fall Armyworm in Sri Lanka.

Biological control methods

Biological control is considered as an important component in the IPM strategy. Biological control method is defined as the reduction of pest populations by natural enemies and typically involves an active human role. Bio pesticides are considered to be non-toxic and an effective method to FAW management. Biopesticides are based on pathogens of the pest, plant extracts, biochemicals and also some predators and parasites. These bio control based IPM strategies can help to keep the FAW under control and also they reduce the use of synthetic chemicals (Padhee and Prasanna, 2019). Some biopesticides are available in Sri Lanka, however the efficiency against FAW has not been identified yet. *Bacillus thuringiensis* is feasible to control the abundance of FAW (Alam *et al*., 2020). Natural strains of *B.Thuringiensis* are not most feasible but genetically improved strains are more effective (All *et al*., 1996). Use of the tricho card of egg parasitoids such as *Trichogramma pretiosum* also helps to control the FAW (Consoli*et al*., 2010).

CONCLUSION

Fall Armyworm (FAW) is a major cross-border agricultural insect pest that has become one of the greatest threats to food security and agricultural sustainability worldwide. The fall armyworm (*Spodoptera frugiperda*) has been introduced in Sri Lanka since 2018, and Sri Lanka provides a suitable environment for the pest to breed and spread quickly than other temperate countries. Thus resulted in a high yield loss. In order to control the pest IPM is

believed to be an important strategy to reduce the use of pesticides and avoid the pesticide resistance and detrimental effects on environment and human health.

REFERENCES

Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Day, R., Early, R., Godwin, J.L., 2017. Fall armyworm: Impacts and Implications for Africa; Evidence Note (2); CABI: Oxfordshire, UK.

Alam, T., Saroj, S., Dubey, V.K., Yadav, M.K., 2020. New invasive alien species in maize, fall armyworm *Spodoptera frugiperda* (J.E.Smith) lepidoptera: Noctuidae. Modern Technology of Agriculture, Forestry, Biotechnology and Food Science. 133-138.

All, J.N., Stancil, J.D., Johndon, T.B., Gouger, R., 1996. Controlling fall armyworm infestation in whorl stage corn with genetically modified *Bacillus thuringiensis* formulations. Florida Entomologist. 79: 311-317.

Batista-Pereira, L.G., Stein, K., de Paula, A.F., Moreira, J.A., Cruz, I., Figueiredo Mde, L., Perri, J.Jr., Corrêa, A.G., 2006. Isolation, identification, synthesis, and field evaluation of the sex pheromone of the Brazilian population of Spodoptera frugiperda. J Chem Ecol. 32(5):1085-99.

Capinera, J.L., 2017. Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Insecta: Lepidoptera: Noctuidae). Department of Entomology and Nematology, UF/IFAS Extension Series. University of Florida.

Chamberlain, K., Khan, Z.R., Pickett, J.A., Toshova, T., Wadhams, L.J., 2006. Diel periodicity in the production of green leaf volatiles by wild and cultivated host plants of stem borer moths, *Chilo partellus* and *Busseola fusca.* J. Chem. Ecol. 32:565-577.

Consoli, F.L., Parra, J.R.P., Zucchi, R.A. (Eds.), 2010. Egg parasitoids commercialization in the world, pp. 373-388. In:Egg parasitoids in agroecosystems with emphasis on Trichogramma..1st edition, Springer, New York .

Cruz, I., Figueiredo, M.L.Corrêa., da Silva, R.B., da Silva, I.F., Paula, C.S., Foster, J.E.,2012. Using Sex Pheromone Traps in the Decision-Making Process for Pesticide Application against Fall Armyworm (*Spodoptera frugiperda* [Smith] [Lepidoptera: Noctuidae]) Larvae in Maize. International Journal of Pest Management 58(1): 83–90.

Department of Agriculture (DOA), Government of Sri Lanka. (2019). Available on: https://www.doa.gov.lk/index.php/en/

Dissanayake, C., 2019. War against fall armyworm [online]. Daily FT. Available on: http://www.ft.lk/top-story/War-against-Fall-Armyworm/26-671465

Food and Agricultural Organization of the United Nations (FAO). 2019a. FAOscales up fight against Fall Armyworm.

Food and Agricultural Organization of the United Nations (FAO). 2019b.GIEWSCountry Brief Sri Lanka.

Foster, R.E., 1989. Strategies for protecting sweet corn ears from damage by fall armyworms (Lepidoptera:Noctuidae) in southern Florida. Florida Entomologist. 72: 146-151.

Goergen, G., Kumar, P.L., Sankung, S.B., Togola, A., Tamo, 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.

Government of Sri Lanka and World Food Programme. 2019. Climate & Food Security Monitoring Bulletin: 2019.

Hailu, G., Niassy, S., Zeyaur, K. R., Ochatum, N., Subramanian, S., 2018. Maize–legume intercropping and push–pull for management of fall Armyworm, Stem borers, and Striga in Uganda. Agronomy Journal, 110: 2513-22.

Hardke, JT., Jackson, R.E., Leonard, B.R., 2014. Opportunities to manage fall armyworm (Lepidoptera: Noctuidae) on Bollgard IIVR cotton with reduced rates of insecticides. J. Cotton Sci.18:59–67.

Khan, Z.R., Midega, C.A.O., Bruce, T.J.A., Hooper, A.M., Pickett, J.A., 2010. Exploiting phytochemicals for developing a push–pull crop protection strategy for cereal farmers in Africa. J Exp. Bot. 61:4185–4196.

Khan, Z.R., Midega, C.A.O., Hutter, N.J., Wilkins, R.M., Wadhams, L.J., 1997. Assessment of the potential of Napier grass (Pennisetum purpureum) varieties as trap plants for management of *Chilo partellus*. Entomol. Exp. Appl. 119:15–22.

Malo, E.A., Bahena, F., Miranda, M.A., Valle-Mora, J., 2004, Factors affecting the trapping of males of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) with pheromones in Mexico. Florida Entomol. 87(3):288-293.

Midega, C.A.O., Khan, Z.R., Pickett, J.A., Nylin, S., 2011. Host plant selection in *Chilo partellu*s and its implication for effectiveness of a trap crop. Entomol. Exp. Appl. 2011; 138:40–47.

Midega, C.A.O., Khan, Z.R., van den Berg, J., Ogol, C.K.P.O., Bruce, T.J., Pickett, J.A., 2009. Non-target effects of the 'push–pull' habitat management strategy: parasitoid activity and soil fauna abundance. Crop Prot. 28:1045-1051.

Molina-Ochoa, J., Carpenter, J.E., Heinrichs, E.A., Foster, J.E., 2003. Parasitoids and parasites of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas and Caribbean basin: An inventory. Fla. Entomol. 86 , 254–289.

Mudugamuwa, I., 2019. Rallying against Sena! Daily News. The Associated Newspapers of Ceylon Ltd.,Colombo, Sri Lanka. Available on: http://www.dailynews.lk/2019/01/22/features/175007/rallying-against-sena

Otim, M.H., Tay, W.T., Walsh, T.K., Kanyesigye, D., Adumo, S., Abongosi, J., Ochen, S.,Sserumaga, J., Alibu, S., Abalo, G., Asea, G., Agona, A., 2018. Detection of sister-speciesin invasive populations of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) from Uganda. PLOS One, 13.

Padhee, A.K., Prasanna, B.M., 2019. The emerging threat of fall armyworm in India:time for proactive and collective action. Indian Farming 69(01): 51-54.

Pantoja-Lopez, A., 1985. Biology, Economic Injury, and Plant Resistance Studies with the FallArmyworm, Spodoptera Frugiperda (JE Smith), on Rice, *Oryza Sativa L.*(Screening, Puerto Rico, Louisiana), Department of Entomology, Louisiana State University. Baton Rouge, LA 70803, United States.

Passoa, S., 1991. Color identification of economically important *Spodoptera* larvae in Honduras (Lepidoptera: Noctuidae). Insecta Mundi, 5: 185-93.

Perera, N., Magamage, M., Kumara, A., Galahitigama, H., Dissanayake, K., Wekumbura, C., Iddamalgoda, P., Iddamalgoda, P., Siriwardhana, C., Yapa, P., 2019. Fall Armyworm (FAW) Epidemic in Sri Lanka: Ratnapura District Perspectives. InternationalJournal of EntomologicalResearch, 7(1), 09-18.

Prasanna, B.M., Huesing, J.E., Eddy, R., Peschke, V.M., 2018. Fall Armyworm in Africa: A Guide for Integrated Pest Management, 1st ed.; CIMMYT: Edo Mex, Mexico.

Roberts, P.M., All, J.N., 1993. Hazard for fall armyworm (Lepidoptera: Noctuidae) infestation of maize in double-cropping systems using sustainable agricultural practices. Florida Entomologist 76: 276-283.

Rwomushana, I., Bateman, M., Beale, T., Beseh, P., Cameron, K., Chiluba, M., Clottey, V., Davis, T., Day, R., Early, R., Godwin, J., Gonzalez-Moreno, P., Kansiime, M., Kenis, M., Makale, F., Mugambi, I., Murphy, S., Nunda. W., Phiri, N., Pratt, C., Tambo, J., 2018. Fall Armyworm: Impacts and Implications for Africa; Evidence Note Update; CABI: Oxfordshire, UK.

Sharanabasappa, C.M., Kalleshwaraswamy, C.M., Asokan, R., Mahadeva Swamy, H.M., Marutid, M.S., Pavithra, H.B., Hegde, K., Navi, S., Prabhu, S.T., Goergen, G., 2018. First report of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Management in Horticultural. Ecosystems, 24:23–29.

Sisay, B., Simiyu, J., Mendesil, E., Likhayo, P., Ayalew, G., Mohamed, S., Subramanian, S., Tefera, T., 2019. Fall Armyworm, *Spodoptera frugiperda* Infestations in East Africa: Assessment of Damage and Parasitism. Insects. 3;10(7):195

Skandha, G., 2019.Invasion of the fall armyworm.The Sunday Morning. Available on: http://www.themorning.lk/invasion-of-the-fall-army-worm/

Yu, S.J., 1991. Insecticide resistance in the fall armyworm, *Spodoptera frugiperda* (J.E. Smith). Pestic. Biochem. Physiol.39 :84–91.