FALL ARMYWORM: GLOBAL STATUS AND POTENTIAL THREATS FOR NEPAL

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ABSTRACT

Fall armyworm (FAW), Spodoptera frugiperda is a polyphagous insect with cosmopolitan in distribution. The rapid invasion of the pest in Africa and Asia has caused devastating damage in crops resulting a serious threat toglobal food security. The incidence of FAW in India has created a serious concern as it encircled Nepal within its potential radius. The paper attempts to review its biology and ecology assessing the likelihood of introduction and establishment of FAW in Nepal by rapid and intensive reviews of different publications. Moreover, the paper has also come up with potential monitoring and early warning system for FAW along with integrated management.

Keywords: Distribution, fall armyworm, food security, Nepal

INTRODUCTION

Fall Armyworm (*Spodoptera frugiperda*) (FAW) is a devastating insect species native to western hemisphere (Capinera, 2001) – especially tropical and subtropical regions of the Americas (FAO, 2017; CABI, 2017) under the Class - Insecta, Order - Lepidoptera and Family -Noctuidae. FAW is regarded as one of the world's most invasive pest species and causes large economic damage, especially on the major cereal crops - Maize, Rice, and Sorghum among others. Yield losses were recorded the highest in Argentina (72 percent) (Murua, *et al.*, 2006), which is signaling a serious threat to overall food security. FAW causes greater damage at larval stage (FAO, 2019a), which feeds on 186 plant species from 42 families (Early *et al.*, 2018); however, corn and rice are the major hosts (Hoy, 2013). It is polyphagous in nature (Hoy, 2013) and cosmopolitan in distribution. It can fly for a long distance during the summer (Capinera, 2001). The moth can fly up to 100 km per night (FAO, 2019a). The maize- strain and the rice-strain are two genetically and behaviorally distinct strains of FAW

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(Frerot *et al.,* 2017). PCR-RFLP analysis of FAW done by Hoy (2013) obtained from corn in Brazil and in Florida was reported genetically distinct.

In Nepal, rice is the staple food and is supplemented by wheat and maize. Since, FAW has two strains – rice and maize, it is of major concern for Nepal. FAW could pose a greater threat to subsistence and cash crops in large part of the world (Early *et al.,* 2018) and Nepal will not be an exception.

Characteristics of different stages of FAW are presented in Table 1. The adult moth feeds on flower nectar and is comparatively harmless whereas the larval stage, which generally, lasts for 13 to 14 days with six different instars are the most devastating; feeding more than 186 plant species. In addition to diverse feeding habit and strong flyer, they breed at the high rate and develop resistance towards pesticides. Therefore, it can easily adapt to diverse geographical and climactic conditions and hence is a threat to global food security, especially in agriculture-based developing countries in Africa and South Asia.

Table 1: Characteristics of different stages of FAW

Stage	Shape	Color	Duration (days)	Favorable temp	Special features
Egg	Spherical (0.75 mm diameter)	Green during oviposition Light brown prior to exclusion	2-3	20-30°C	Eggs in masses of 150-200 laid in 2-4 layers on leaf surface
Larvae	3-4 cm long	Light green to dark brown with longitudinal stripes	14-21	28°C	characterized by an inverted Y-shape in yellow on the head, black dorsal pinaculae with long primary and four black spots arranged in a square on the last abdominal segment
Pupa	1.3-1.7 cm	Shiny brown	9-13	13-15°C	A loose cocoon in an earthen cell
Adult	1.6 cm - 1.7 cm	Dark brown, grey, straw	12-14	Less than 30°C	Forewing is mottled (light brown, grey, straw) with a discal cell containing straw color on three quarters of the area and dark brown on one quarter of the area. The forewing is mottled. Hind wings are straw colored with a dark brown margin.

Source: (CABI, 2017)

DISTRIBUTION

FAW is native to tropical and subtropical parts of the Americas (CABI, 2017), which is rapidly spreading throughout Africa (Abrahams *et al.,* 2017). The modality of introduction, biological and ecological adaptation across Africa are still speculative (FAO, 2018), where its impact is severe. For the first time, FAW was detected in Central and Western Africa in early 2016 (FAO, 2018). It has been confirmed in more than 30 African countries. In 2018, it was also reported from the Indian sub-continent (CABI, 2017). The recent detection of FAW in India (IPPC, 2018), has created a serious concern for Nepal. Moreover, due to lack of clarity, whether the invasion originated from multiple sources or a single source (Early *et al.,* 2018) makes it more difficult in appropriate and effective preparedness. Warm and moist areas are favorable for FAW. However, it cannot survive in cold temperatures as it enters into diapause (Early *et al.,* 2018). The distribution of FAW is presented in Annex 1 and depicted in Figure 1.

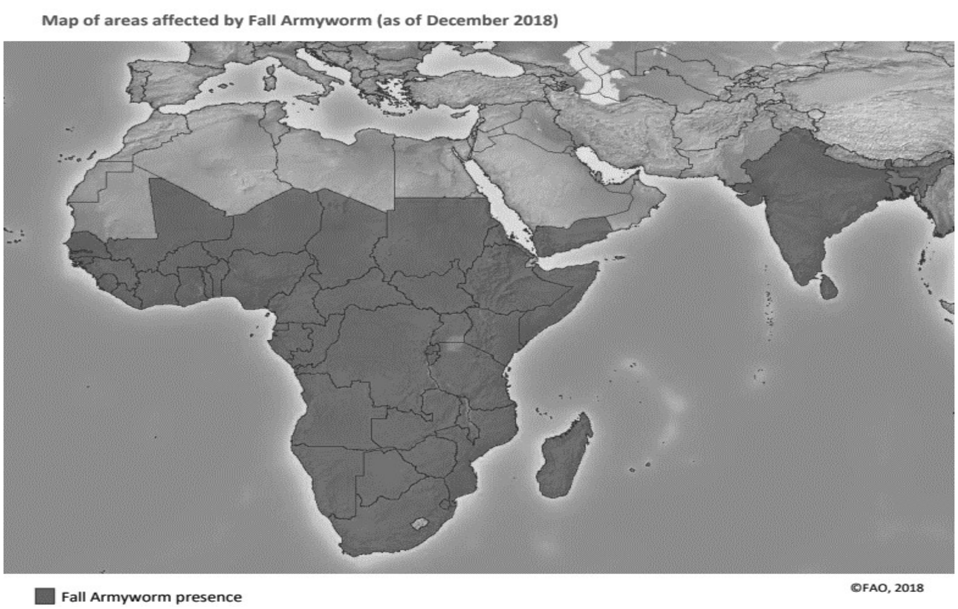

Figure 1. Distribution of FAW around the world

EARLY WARNING SYSTEM

Food security and food safety are of paramount importance. However, it is quite often threatened by incidence and insurgence of various disease-pests. Therefore, along with diagnosis and controlling disease-pests, forecasting them correctly is very critical, which is also known as early warning system (Li *et al.,* 2007). The convergence of the principles of biology, ecology and mathematics is the basis of an early warning system for crop diseases and insect-pests (Wang *et al.,* 2013).

The early warning methods are a logical thinking process, which includes the collection and sorting of data, and generation of early warning information (Wang *et al.,* 2013). There are more than 200 kinds of warning methods and are categorized into three groups – the expert experience method, modeled method and the index method (Wang *et al.,* 2013).

Figure 2 presents a generalized process flow of the early warning system. The foundation of the early warning system is the acquisition of data. Data can be accessed or collected from various sources including -artificial monitoring, sensor and survey. Data from plant diseases and pests information database, environment database, among others are also collected and the data were fed to an early warning model. The model will produce a forecast and can suggest the control measures. An appropriate early warming model is deemed urgent for FAW.

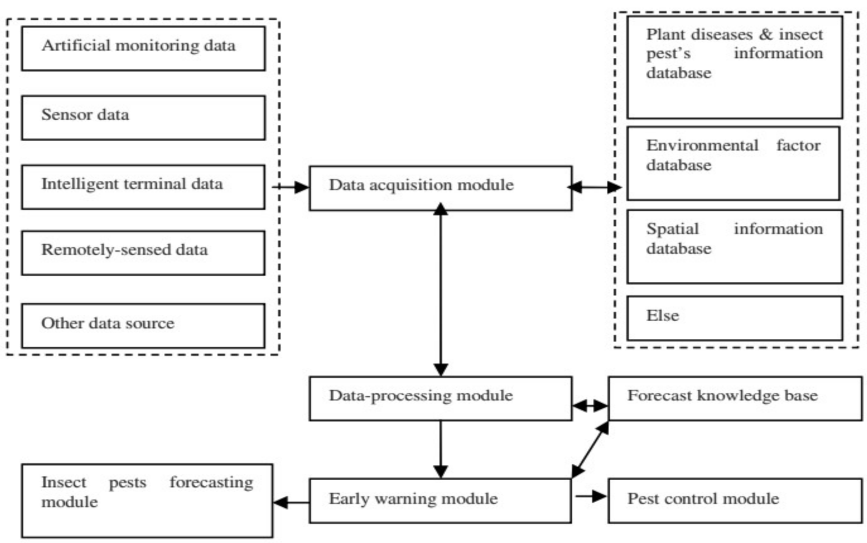

Figure 2. The overall framework of early warning

Source: Wang et al., 2013

MONITORING OF FAW

Monitoring of the crop health is of vital to make a decision to intervene (Abrahams *et al.,* 2017). For monitoring of FAW, three methods are in use - scouting, pheromone traps and light traps (Abrahams *et al.,* 2017).

The scouting helps farmer witha better understanding of the biology of the organisms in the field and their ecology, which enhances farmers' decision-making capacity for greater production, fewer wasted resources and sustainability (FAO, 2018a). FAO has suggested the guideline for scouting. For this purpose, the farmer has to walk on "W" path from a side of the field. At the start, at every turn and at the end, farmer inspects 10 plants in a row, which yield 50 plants in total. These ten plants are called a "station". The number of infected plants in each station is summed and multiplied by two in order to get the percentage infected.

The presence of FAW can be detected by using pheromone traps and funnel or bucket (FAO, 2018b). Pheromone traps were found more effective than backlight trap in order to detect and monitoring adult FAW (Starratt and McLeod, 1982). The traps should be checked and counted the moths twice a week.

FAO has also developed an Android-based mobile application -"Fall Armyworm Monitoring and Early Warning System (FAMEWS)". It was first implemented in Madagascar and Zambia (FAO, 2018c) and is successfully implemented in African countries through Farmer Field Schools (FSS) and community-based forum. In Nepal, the same or similar mobile application can be used or developed to monitor the FAW.

FAW AND NEPAL

Temperature Regime

Optimum temperature favorable for FAW is reported 25°C. Likewise, the minimum and the maximum temperature for FAW's survival is 8.7°C to 13.8°C and 32°C to 35°C, respectively. Figure 3 presents the average temperature of Nepal on a monthly basis and the optimum, minimum and maximum temperature are found suitable for FAW growth and development. The maximum, the minimum and the optimum temperature suggested that, in all months, by temperature parameter, the establishment of FAW was found likely.

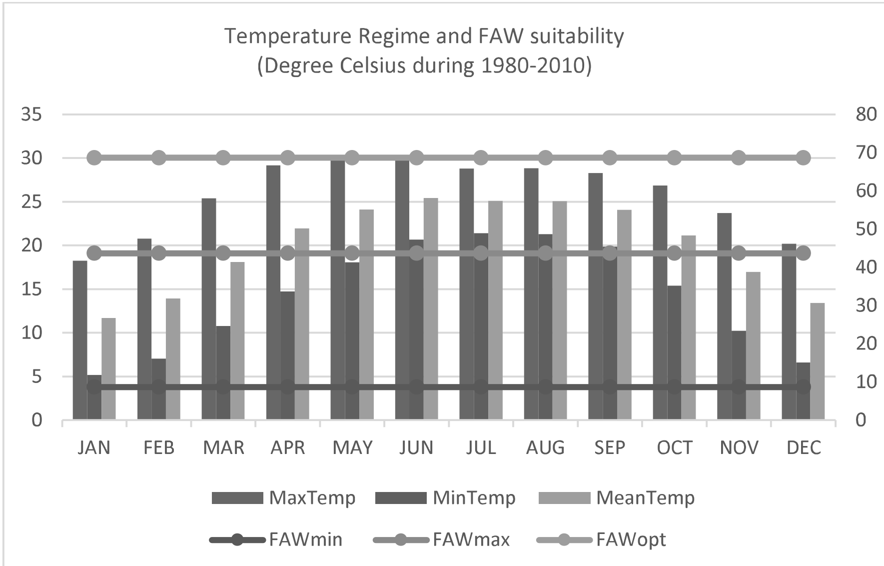

Figure 3. Temperature Regime and FAW suitability

Source: Department of Hydrology and Metrology, Nepal)

FAW has two strains - rice and maize and is the major pest. Therefore, understanding its host crop cycle is crucial. Although the average temperature permits FAW's development in all seasons, due to vast temperature and precipitation variability within Nepal, a location-specific study is needed to precisely understand the FAW's establishment and spread. Table 2 and 3 represent the crop calendar for maize and rice, respectively.

Table 2: Crop calendar of maize

Maize	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Terai and Inner Terai(Winter maize)												
Terai and Inner Terai(Rainy season maize)												
Terai and Inner Terai(Spring season maize)												
Mid Hill												
High Hill												

Source: Poudyal, et al., 2001

Table 3: Crop calendar of rice

Rice	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Rainy season rice												
Bhadaiyarice												
Boro rice												
Chaiterice												
Ghaiyarice												
Chaite rice												

Source: CDD and ASoN, 2017.

INTEGRATED MANAGEMENT OF FAW

FAO has developed a comprehensive guide on integrated management of the FAW. These options are categorized hereunder.

Crop Management

Right-planting date is crucial for successful crop production. FAW is a more difficult pest to control and the infestation is more likely on late planted and later maturing hybrids crops. Good soil health is an important criterion. Unbalanced inorganic fertilization can increase oviposition by FAW.

Crop Variety

Selection of variety is of paramount importance. In case of Nepal, evaluation has not yet to be done for FAW resistant varieties. Some GMOs including Bt-Maize was reported resistant in Africa, however, in the case of America, FAW has overcome Bt-Maize (FAO, 2018). Nevertheless, in Nepal, GMO is not allowed for the commercial purpose.

Biological Controls

Many natural enemies of FAW have been reported from around the globe. Earwigs, ladybird beetles, ground beetles, assassin, flower bugs and predatory wasps were reported to be a predator for FAW. Likewise, wasps were found as parasitoids of the FAW. Similarly, Nuclear polyhedrosis virus (NPVs) and *Spodoptera frugiperda* multi capsid nucleo polyhedrosis virus (SfMNPV) are reported lethal to the FAW. *Bacillus thuringenesis* (Bt), *Beauveriabassiana* and Baculovirus were found effective against controlling FAW (FAO, 2018a).

Biopesticides

In many cases, chemical pesticides have been found ineffective for control of FAW. Farmers are using different chemical pesticides at higher doses leading to the environment and human contamination. The use of neem based pesticides has been found effective to protect crops from FAW (Constanski *et al.,* 2016).

Synthetic Pesticides

Several synthetic pesticides were reported to be effective against FAW. They are methomyl, acephate, cyfluthrin, benfuracarb, methyl parathion, carbaryl, carbosulfan, lindane, chlorpyrifos, diazinon, and methyl parathion.

CONCLUSION

FAW is the most devastating insect. Its spread in Africa from the Americas is so rapid. More importantly, the incidence of FAW has been reported from India last year. It has rung the alarm to Nepal since the point of incidence in India encircled within its radius. Moreover, temperature and precipitation regime of Nepal was found very favorable for introduction, establishment, and spread of FAW. However, a location-specific study of temperature and precipitation along with elevation is deemed necessary. Therefore, an appropriate measure of FAW monitoring and early alarm system is crucial. Likewise, implementation of strong quarantine for FAW is deemed urgent. Similarly, farmer's awareness and preparedness of scientists and extension officers are of foremost importance to overcome the FAW. It is concluded that if serious action is not taken on time, FAW might pose a serious threat to food security.

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Annex 1: Distribution of FAW throughout the world

SN	Continent	Countries
1	Asia	India (Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu), Myanmar, Thailand, Yemen
2	Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Congo Democratic Republic, Cote d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mayotte, Mozambique, Namibia, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
3	North America	Bermuda, Canada (Manitoba, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Quebec) Mexico, USA (Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Lowe, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma , Pennsylvania, Rhode Island, South Dakota, Tennessee, Texas, Virginia, West Virginia, Wisconsin, Wyoming).
4	Central America and Caribbean	Anguilla, Antigua and Barbuda, Bahamas, Barbados, Belize, British Virgin Islands, Cayman Island, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Montserrat, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, United States Virgin Islands.
5	South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.
6	Europe	Germany, Netherlands, Slovenia.

Source: CABI: https://www.cabi.org/isc/datasheet/29810