

Review Article

FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*) IN MAIZE: CURRENT STATUS AND COLLABORATIVE EFFORTS FOR ITS MANAGEMENT IN NEPAL

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ABSTRACT

Fall Armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith), is a voracious pest of agricultural crops with native origins in the Americas. The pest accidentally landed in Africa in 2016, successfully wreaking havoc in over 40 countries. It has now reached Asia and was reported in India in May 2018, ravaging especially maize. FAW is likely to create a high risk of food insecurity especially in the hills of Nepal where maize has been established as the principal food crop. A joint effort has been made by many stakeholders and organizations in Nepal to design an action plan for combating the pest, involving even small-scale farmers to generate safer, accessible, effective, and sustainable solutions against FAW. A national level task force has been formed with chairmanship of the Secretary of Ministry of Agriculture and Livestock Development and involving representatives from Government of Nepal (GoN), International Organizations, Developmental Projects, Research Centers, and freelance experts under which a technical committee has been formed for FAW IPM and surveillance protocol development and quarantine alerts. Detection surveys and regular monitoring of FAW, orientations on FAW identification tips, distribution of FAW identification kits, IEC materials development, and awareness are considered joint efforts of all the stakeholders involved. In addition, a national level stakeholders' workshop on the preparedness and rapid response of the threats of FAW in Nepal and an international workshop on Fall Armyworm Preparedness and Management involving different national and international experts and stakeholders has been conducted to produce synergy in effectively fighting against the pest. The paper carries the major objective of reviewing the status of fall armyworm, in the country and control measures on maize crop in Nepal.

Key words: *Fall armyworm, stakeholders, surveillance, task force, monitoring, IPM*

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INTRODUCTION

Global agriculture is increasingly affected by the spread of invasive pests and diseases, which are often considered one of the largest constrain in the production of agricultural crops. Some of these pests prove to be remarkable by creating havoc and causing ultimate harm to the national economy and food security. Maize is an important cereal crop and staple food for many people around the world. The Fall Armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:Noctuidae), a polyphagous and an economically important pest of maize crop is capable of causing huge losses, especially in its yield and in some cases is responsible for the total crop loss. It can affect all stages of development in maize and is difficult to control (USAID, 2017). According to Montezano (2018) FAW larvae can reportedly feed 353 different plant species but in Nepal this pest is a major threat especially for maize crop as the temperature regime, vegetation, staggered and scattered planting of maize in Nepal is highly favorable for the pest to be established. Maize (the most preferable host of FAW) is the second largest crop cultivated in the country in terms of area and quantity of production with the total area of cultivation of 954,158 hectare and total crop production of 2555847 metric tons (AICC, 2019/20). The loss due to this pest in Africa was estimated to be USD13.38 billion (CABI, 2017). The pest was then suspected to have migrated to Asia and till date has been reported from 17 Asian countries (Bangladesh, China, China - Taiwan Province, India, Yemen, Indonesia, Japan, Laos, Myanmar, Malaysia, Nepal, Philippines, Egypt, Republic of Korea, Sri Lanka, Thailand and Viet Nam) (FAO, 2020).

Maize crop in Nepal is mainly cultivated as summer crop but with the increased irrigation facilities in river basins and plain areas, the year round cultivation of maize crop is also increasing (Poudyal *et al.*, 2001). For FAW to be established, the temperature during pre-monsoon, monsoon and post monsoon is highly favorable. According to CABI (2019), the climatic conditions in Nepal are suitable for the establishment of FAW populations, which could potentially cause upto 100 percent crop loss in maize if not managed properly. Besides the capacity to migrate over long distances during its life span, the fecundity of this pest is high (more than 1000 eggs/moth); thus, there can be multiple pest generations per cropping season or year. Adults typically use their natural pre-oviposition period of 3-4 days to migrate over 500 km before oviposition (CABI, 2019). Thus, the infestation of this pest possesses very high risk of food and seed insecurity especially in the mid hill region of Nepal. FAW has been reported in maize and sorghum field so far in Nepal. The yield losses from FAW in Africa have been reported ranging from 21 to 53% in maize (Prasanna *et al.*, 2018).

MATERIALS AND METHODS

The paper is based primarily on the review of the available information and literatures. It is mostly linked with the initiatives taken by the Governmental and non-governmental organizations on identifying the threats of FAW and its management in Nepal.

RESULTS AND DISCUSSION

Threats of FAW incidence in Nepal

FAW is a major threat for Nepal especially in maize. Its larvae can reportedly feed 353 different plant species (Montezano, 2018). The temperature regime, vegetation, staggered and scattered planting of maize in Nepal is highly favorable for the pest to spread which could potentially cause up to 100 percent crop loss in maize if not managed properly (CABI, 2019). Maize (the most preferable host of FAW) is the second largest crop in terms of area of cultivation (954,158 ha) and quantity of production (2,555,847 MT). Maize is mainly the summer crop in Nepal though year round cultivation of maize with irrigation facilities in the river basins and plain areas is increasing. The temperature regime during pre-monsoon, monsoon and post monsoon is highly favorable for FAW. Its infestation possesses very high risk of food and seed insecurity especially in the mid hill region of Nepal.

Declaration of FAW invasion in Nepal

National Plant Protection Organization (NPPO) Nepal had alert on invasion of FAW since the entry of this pest in Karnataka of India in 2018. Continued surveillance and field visits were carried out to detect the potential invasion of this pest especially in the maize growing areas of Nepal. The insect had been recorded for the first time in Nepal from Nawalpur district (N 27°42'16.67" E 084°22'50.61") on 9th May 2019 (Bajracharya *et al.*, 2019) and after multiple surveillance field visits and the investigation of many suspected samples, NPPO of Government of Nepal authentically declared the introduction of fall armyworm in Nepal on 12 August 2019 (PQPMC, 2019).

Collaborative efforts after FAW Invasion

After the declaration of FAW invasion in Nepal, following collaborative efforts have been made by stakeholders to minimize the high risk of food and seed insecurity due to heavy loss in production of maize crop.

Collaborative activities on planning, campaigns and trainings

- Protocol for FAW Surveillance, Integrated Pest Management (IPM) and Action plan prepared and endorsed in Technical Team and NPPO Meeting.
- Developing FAW fact sheets and information materials: A common communication material (fact sheet) on FAW has been developed for mass awareness campaigns. The material is being used in training and workshops at provincial and local levels. This has also been distributed to the farmers and technicians.
- Technical Task force led by Joint Secretary, MoALD on August 21, 2020.
- Pest Management Decision Guide (PMDG) and Photo Guide (identification, life cycle, damage system) of FAW prepared with support of Centre for Agriculture and Bioscience International (CABI) and distributed to the technicians and farmers

- Training of Trainers (TOT) on FAW identification and management to the provincial level technicians at central level organized by High level Task force in collaboration with PQPMC, Entomology Division, Plant Protection Society (PPS) Nepal, International Maize and Wheat Improvement Center (CIMMYT), International Development Enterprises (iDE) Nepal, the United States Agency for International Development (USAID).
- Private sector engagement training on FAW identification and management (Pesticide importers and distributors) at central level organized by High level Task force in collaboration with PQPMC, Entomology Division, PPS, CIMMYT, iDE Nepal, USAID and Pesticide Entrepreneurs Association of Nepal (PEAN).
- Provincial level FAW management task force formed.
- District level FAW management taskforce also formed in different district
- Province Level Trainings for technicians on identification and management of FAW (Table 2)
- FAW campaign in Banke in coordination with Prime Minister Agriculture Modernization Project (PMAMP) and CIMMYT (Nepal Seed and Fertilizer Project/Cereal Systems Initiative for South Asia) during Jan 30-31, 2020 and distributed FAW Fact Sheet prepared by FAW Technical team and published by PQPMC. In total, more than 1000 participants were participated in the program.

Collaboration for various research activities on FAW

Rearing of FAW egg parasitoids by the Nepal Agricultural Research Council (NARC) and National Maize Research Program (NMRP) with the financial support from the USAID's Feed the Future Nepal Integrated Pest Management (FTFNIPM) project.

- NARC Entomology Division in Khumaltar is maintaining the culture of *Trichogramma* and *Telenomus*.
- Entomology Division, NARC, Khumaltar also conducted the following five different experiments regarding FAW management in field condition at NMRP, Rampur as below topics: (1) Monitoring of FAW through pheromone lures and black light trap, (2) Study of seasonal infestation of FAW, (3) Evaluation of safe chemical insecticides available in market against FAW, (4) Screening of maize genotypes against FAW, (5) Habitat management of FAW through Push-Pull approach.
- National Maize Research Program (NMRP)/NARC and NSAF/CIMMYT have been testing the trials to evaluate the efficacy of push-pull cropping system which is considered one among the best climate-smart technologies. Napier grass (*Pennisetum purpureum*) as pull and silver leaf desmodium legume (*Desmodium uncinatum*) as push crop have been included in the study.

- Efforts are being made to collect and identify the local races of bio-control agents effective against FAW. *Trichogramma* and *Telenomus* have been identified and cultures have been maintained in the Entomology lab of NARC and National Maize Research Program.
- Study on biology of FAW in the laboratory conditions and efficacy of different pesticides and indigenous methods for the management of FAW are also going on.

Occurrence and distribution of FAW

Soon after declaration of its invasion in Nepal, FAW has been reported by different from different regions of the country during the last winter of maize cultivation seasons (PQPMC, 2019). Twenty districts of Nepal (Chitwan, Lalitpur, Sindhupalchowk, Kavrepalanchowk, Dolakha, Sindhuli, Ramechhap, Okhaldhunga, Khotang, Bhojpur, Banke, Kanchanpur, Rolpa, Pyuthan, Salyan, Parsa, Bara, Rautahat, Sarlahi and Udayapur) had been reported with fall armyworm infestation (GC and Bhatta, 2019) ranging from mid hills to terai districts of Nepal.

Loss assessment of the pest in Nepal has not been done due to the recent introduction in the few areas of the country. Nepal, the FAW has the potential to cause maize yield losses of 20-25% equivalent, if the pest is left unrestrained, its impact will be huge for farmers and the economy (CIMMYT, 2020). During the early months of 2020, its spread is extremely fast to become a major threat to maize production in Nepal (CIMMYT, 2020)

The PQPMC through the Technical task force has been monitoring FAW occurrence in different districts of the country in coordination with provincial FAW response team along with the development projects including USAID’s Feed the Future FTF projects along with other projects implemented in Nepal. Fifty-two districts of Nepal reported the infestation of FAW till April 2020. Based on the information collected from different sources, the following are the districts in each province infested by FAW until May 7, 2020 (Fig. 1).

Table 1. Province wise FAW infested districts till May 7, 2020.

Provinces	No. of districts infested	FAW Infestation reported districts	Sources
No. 1	14	Udayapur, Okhaldhunga, Khotang, Dhankuta, Morang, Sunsari, Jhapa, Bhojpur, Illam, Panchathar, Ramechhap, Tehrathum, Taplejung, Sankhuwasabha	PQPMC, FAW task force experts, Agriculture Development Directorate (ADD) of Province
No. 2	6	Bara, Parsa, Rautahat, Mahotari, Sarlahi, Siraha	PQPMC, ADD of Province

Provinces	No. of districts infested	FAW Infestation reported districts	Sources
Bagmati	10	Chitwan, Makawanpur, Sindhuli, Sindhupalchowk, Nuwakot, Kavrepalanchowk, Dolakha, Lalitpur, Bhaktapur, Dhading	NMRP/NARC, Knowledge-based Integrated Sustainable Agriculture in Nepal (KISAN) II, NSAF and FTFNIPM, ADD of Province
Gandaki	4	Nawalpur (Gaidakot), Syanja, Tanahun, Gorkha	PQPMC, KISAN II, NSAF and FTFNIPM, ADD of Province
No. 5	11	Banke, Bardiya, Dang, Rolpa, Pyuthan, Arghakhanchi, Kapilbastu, Rupandehi, Gulmi, Nawalparasi, Palpa	PQPMC, KISAN II, NSAF and FTFNIPM, ADD of Province
Karnali	3	Surkhet, Dailekh, Salyan	PQPMC, KISAN II, NSAF and FTFNIPM, ADD of Province
Sudurpaschim	4	Kailali, Kanchanpur, Bajhang, Bajura	PQPMC, KISAN II, NSAF and ADD of Province
Total	52		

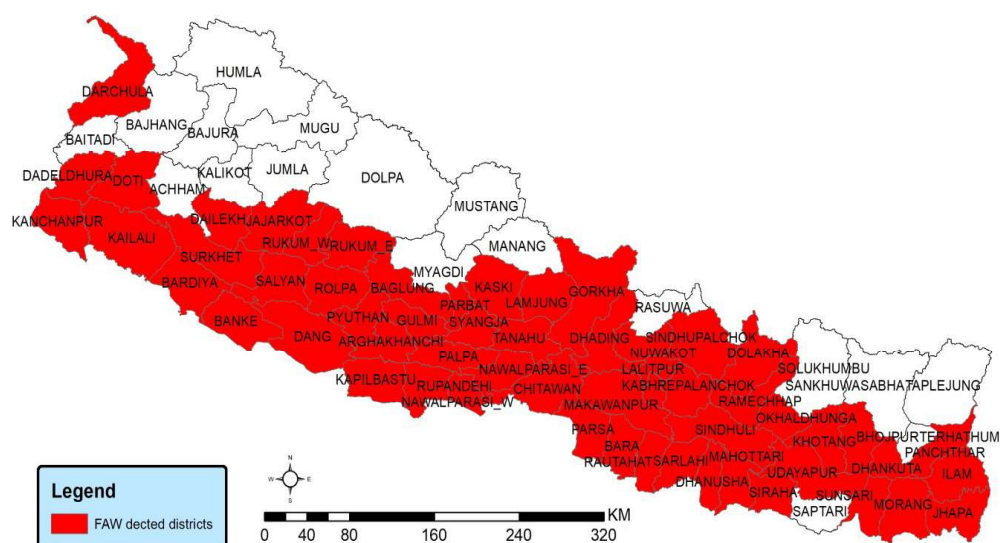


Fig. 1: Nepal Map showing the districts where FAW has been detected as of July, 2020.

Table 2. Development partners involvement for FAW management at Province Level

SN	Development partners	Province	Remarks
1	Swiss Agency for Development and Cooperation (SDC) through Nepal Agricultural Services Development Program (NASDP)	1	Collaboration with PQPMC
2	FAO	Province No. 2 and Gandaki	Collaboration with PQPMC
3	USAID Projects: NSAF-CIMMYT, FTFNIPM-IDE/ KISAN II	Bagmati, Lumbini, Karnali and Sudur Paschim	Collaboration with PQPMC

Integrated options for FAW management

There must be a meticulous and step-wise plan to prevent outbreaks and further spread of FAW in Nepal. As the Integrated Pest Management (IPM) strategies are developed for an entire cropping system/crop there is the need to apply integrate management practices developed for FAW into the IPM package developed for maize crop. For immediate response to FAW management the management options were prepared and suggested to the technicians and farmers (PQPMC, 2019) as follows:

- Seed treatment by Imidacloprid 48% FS @ 4 ml per kg of seed.
- Selection of variety of maize in which husk fully covers the cob.
- Adjustment in plantation dates of to escape the peak migration of FAW adults.
- Optimum fertilizer application or manure to boost the crop growth vigor.
- Deep ploughing of the maize field before planting to expose and kill pupal life stage of FAW.
- Maintaining plant diversity on farms.
- Use of push-pull technology (Desmodium grass for push and Napier grass for pull but need to be validated).
- Destroy the eggs, larvae and pupae in the crop residues after harvest by deep burying the plant residues in soil.
- Practice of crop rotation and intercropping.
- Mechanical crushing of egg masses and young larvae.
- Use of ash, sand, sawdust or dirt into whorls which may desiccate young larvae.
- Use of local botanicals (Neem, hot pepper, local plants).
- Conservation of naturally occurring biological control agents of parasitoids, predators and entomopathogens.
- Use of introduced bio-control agents like *Trichogramma chilonis* @100000 per ha.
- Chemical pesticides:

SN	Common name of Pesticide	Recommended dose	Application method
1.	Imidacloprid 48% FS	4 ml per kg of seed	Seed treatment
2.	Azadiractin 1500 ppm	5 ml per lit. of water	Foliar spray against Early stage larvae
3.	Spinetoram 11.7% SC	1 ml per 2 lit. of water	Foliar spray
4.	Emamectin benzoate 5% SG	1 gm per 2.5 lit. of water	Foliar spray
5.	Chlorantraniliprole 18.5% SC	1 ml per 2.5 lit. of water	Foliar spray
6.	Spinosad 45% SC	1 ml per 3 lit of water	Foliar spray

Some of the collaborative activities conducted during COVID -19 lockdown period (24 March 2020 to end of May, 2020):

i. Virtual meetings conducted during the lockdown situations:

Virtual meetings organized by Technical Working Group with Province level FAW response team (Two events, on April 11 and May 2, 2020): This virtual meeting was conducted to update on the FAW situation in the field and agriculture input supply situation during current country lockdown situation due to COVID-19 pandemic. In the meeting, 28 participants including from all Provincial Government (except Sudhur Paschim #7), FAO, USAID and FtF projects- NSAF/ CIMMYT and FTFNIPM projects and FAW experts participated. The technical committee members have decided to continue this meeting fortnightly on regular basis so as to update the field status and two way communication between provincial and federal Government team. Similarly, another Virtual meeting on FAW status and management options was organized on May 2. In that meeting 24 participants from Nepal and abroad were involved and discussed about the status of FAW research in Nepal, the status paper was presented by Dr Ghanshyam Bhandari, Entomologist, NMRP.

- ii. Due to the COVID 19 epidemic the whole country has been locked down by the Government, Government and others development partners developed and disseminated messages through virtual media on Fall armyworm (FAW).The SMS text message is being disseminated on a regular basis on every Friday.
- iii. Consultations on FAW management through the Virtual communications (phone call. Skype, Zoom, Viber, Whatsapp, Facebook messenger etc)
- iv. Working on capacity building and two-way communication/ interaction meeting with project and Government staff at Provincial and district level (FAW task force) using online platforms like Zoom, Skype and others.
- v. Air interview on impacts of FAW on Maize and its management on Mountain Business Plus TV (April 23,2020) @ 6:20PM onwards; (https://youtu.be/lk_9LeT11Vk) on

the FAW impacts and its management in Nepal through the Mountain Business TV which covers throughout the country.

- vi. Air interview on the “Agriculture Program” of Radio Nepal covering the Identification and Management aspects of FAW
- vii. Routine delivery of audio visual message on Krishi TV on identification and management of FAW (PQPMC)
- viii. Radio Jingles broadcasting from different FM radios on identification and management of FAW (PQPMC, CIMMYT)
- ix. FAMEWS Training facilitated from Rome (Virtual Training)
On 28 April FAO HQ (Jean) and RAP, Bangkok conducted the FAWMEWS application session to the colleagues of Nepal. FAO, Nepal coordinated the program in Nepal, where the participants were from NPPO, quarantine, pesticide management, Ministry, Department, NARC, FAO, iDE (USAID supported institute), CIMMYT, other technical people participated in the program.
- x. Virtual training on management of FAW (F2F)

The Virtual meetings with Dan McGrath were hosted by F2F/ CRS to organize online capacity building training for Government and the Feed the Future project staff.

CHALLENGES AND WAY FORWARD

There are various challenges faced in the management of FAW in Nepal. There is the high need of the effective management of FAW through one door system with the collaborative and optimum effort of all the stakeholders from government, non-government, research organizations and private sectors at present. Some of the major challenges and way forwards for the management of FAW in Nepal have been mentioned below:

Challenges

- Current lockdown of the country due to COVID-19 pandemic has disrupted the implementation of the different planned activities (training, workshop, set up of the recommended packages trials, and collaborating activities on time.
- Low level of research and technology known (zero local knowledge as it is new pest, botanicals will be cheaper but not tested and recommended yet, biologicals not yet developed but initiated for the mass rearing of the *Trichogramma chilonis* and *Telenomus* by NARC, the other non-chemical approach not tested in country, poor access to recommended pesticides and costly pesticides, under capacity of frontline workers etc, less manpower and resources in research. Unavailability of true type of FAW lure to monitor (many lures are found less efficacy which catches the mixed types of moths into the trap) effectively, late reporting by farmers, less number and less

capacitated front line technicians, low capacity on system development need to be addressed.

The way forwards

- Capacity enhancement through trainings and orientation to farmers, technicians and input suppliers.
- Increasing resources on research and extension.
- More co-ordination and networking with international level stakeholders.
- Monitoring and early warning system development.
- Botanicals and biological pest management solutions.
- Reporting system functionalizing and co-ordination mechanism strengthened to three tiers of government.
- Co-ordination mechanism further strengthened among national and international level organizations.
- Use of digital technology in current lock down through Virtual meetings and the utilization of social media platforms can be effective in the current lockdown to communicate important information regarding FAW management and IPM practices and technologies. Bulk SMS messages to the extensions practioners Community Business Facilitators (CBFs), Plant doctors, and MPC/CCs members, not only provide timely alerts but also provide valuable IPM recommendations for FAW management.

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