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Review Article

Threats of fall armyworm (*Spodoptera frugiperda*) incidence in Nepal and it's integrated management-A review

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ABSTRACT

Fall Armyworm *(Spodoptera frugiperda)* is in the state of major threat for Nepal especially in maize although it has more than 80 host to continue its life cycle. After its first incidence in Africa in 2016, it has already spread in more than 100 countries within a short period of time. It was seen in India for the first time in 2018. Due to the open border between Nepal and India, there is high threat of pest incidence in Nepal. The temperature regime of Nepal is highly suitable for the pest establishment. Now is the time to think about the pest which can cause severe damage to the second most produced cereal crop of Nepal i.e. maize. Management of the pest is possible through many biological, chemical and cultural means. Planting of legumes as a trap crop and ploughing field properly before planting the field can be a best possible cultural method of managing the pest. Natural enemies like *Telenomus, Trichogramma chilotraeae* for controlling the eggs, *Bacillus thuringiensis* for larvae and *Brachymeria ovata* for pupa of Fall Armyworm are found to be effective in Maize and Vegetables. Similarly, Neem extracts are found be larvicidal and the oil extracted from the seeds of long pepper are found to be checking spermatogenesis of the pest. Chemicals like Methomyl, Cyfluthrin, Methyl parathion are used to control the pest. Use of chemicals at the initiation of the pest spread is discouraged as it can hamper the natural enemy present in the surrounding ecology. However, the use of pesticides can be done below the economic threshold level so that the pest does not develop any resistance towards the chemicals.
Keywords: Fall Armyworm, Integrated Pest Management, maize

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INTRODUCTION

Maize is the third most important cereal grain after wheat and rice globally, which is also called the “Queen of Cereals” because of its highest genetic yield potential (Jeyaraman, 2017). Maize is a traditional crop that is generally cultivated in the rainfed uplands in the hills as a source of food, feed and fodder which is generally cultivated as a single crop during summer season or relayed with millet in the late season (Paudyal et al., 2001). The total Area (900,288 ha), Production (2,300,121 t) and Yield (2555 t/ha) of Maize in Nepal ranks second after the Area (1552469 ha), Production (5230327 t) and Yield (3369 t/ha) of Rice with the maximum production (665975 t) of maize in Eastern Development Region and minimum production (98947 t) in Far-Western Development Region (MoAD, 2018). Demand of maize crop is increasing in higher amount every year due to the higher nutritional benefits. Nutritionally, maize grains have 10% protein, 4% oil, 70% carbohydrate, 2-3% crude fibers, besides having Vitamin A and E, nicotinic acid and riboflavin but its protein Zein is deficient in tryptophan and lysine among essential acids and is deficient in calcium (Joshi, 2015). One of the major reasons for the decline in maize productivity is due to the insect pest infestation. The crop losses due to the presence of insects vary from country to country. Similarly, the crop losses also vary according to the pests. Maize stem borers cause significantly more damage to the crop in comparison to aphids and grasshoppers (Neupane & Subedi, 2019). The insect pests of maize field include cut worms, maize stem borer, white grub and chaffer beetle, armyworm, gram pod borer, wireworm, hairy caterpillar and so on. (Arifie et al., 2019). However, the losses are also seen during the storage of grains by various storage pests like weevils and moth.

Fall Armyworm (FAW) (*Spodoptera frugiperda*) (Lepidoptera; Noctuidae) is also a major pest of maize field. The pest is native to tropical and subtropical regions of the Americas and is the key insect pest of maize in tropical (Sisay et al., 2019). Researchers have shown that this pest can cause high damage to the crop. Results like loss of photosynthetic area, impaired reproduction, direct damage to grain, lodging and structural damage in the whorl are the damages seen in the maize plant. (Chimweta et al., 2019). The fall armyworm is polyphagous and its hosts exceed 80 plant species including maize, sorghum, cotton, rice, millet, peanut, alfalfa, and other cultivated and wild plant species (Belay, et al., 2012). There are two strains of the fall armyworm, namely, the rice strain and the maize strain (Adamczyk et al., 1997). Among those two strains, the maize strain is more prevalent and feeds on maize leaves and stem. In Nicaragua, Huis, 1981 found a 33% increase in maize yield when plants were protected with an insecticide. According to (Hruska & Gould, 1997), infestations during the mid-to-late corn stage resulted in yield losses of 15-73% when 55-100% of the plants were infested with *S. frugiperda*.

Integrated Pest Management (IPM) refers to the management of insects and pests through the proper use of locally available biological resources and minimal use of pesticides. It is a broad-based approach of pest control whose major objective is to suppress pests below the economic injury level. In other way, Integrated Pest Management is an approach which discourages pest population by use of justified level of pesticides. IPM emphasizes the growth of a healthy crop with the least possible disruption to Agri-ecosystems and encourages natural pest control mechanisms so that risks to human health and environment is reduced or minimized (FAO, 2019a).

Origin and Distribution of Fall Armyworm:

Although being native to tropical and subtropical regions of Americas, FAW was first detected in Central and Western Africa in early 2016 (Benin, Nigeria, Sao Tome and Principe, and Togo) and further reported and confirmed in the whole of mainland Southern Africa (except Lesotho), in Madagascar and Seychelles (Island State) (FAO, 2018). By 30 January 2018, FAW had been detected and reported in almost all Sub Saharan African countries, except Djibouti, Eritrea and Lesotho (FAO, 2018). Being distributed to 40 sub- Saharan African countries, the pest has already migrated to India where first incidence was seen in July, 2018 (Beshir et al., 2019).
FAW population distribution (table 1) can be summarized as,

Table 1: Global distribution of Fall Armyworm

S.N.	Areas	No. of Countries (Incidence of FAW)
1.	Africa	43
2.	North America	41
3.	Central America	38
4.	South America	28
5.	Asia	9*

Source: (Dively, 2018)

(*= Among the nine countries in Asia, the presence of FAW is unofficial in Thailand)

Threats of Fall Armyworm Incidence in Nepal:

Several researches and data have shown that Fall Armyworm is a rapid migrating pest of maize which have significantly high damage to the crop. (Rose et al., 1975) reported that Fall Armyworm can fly over 1600 Km in just 30 hours. This data redirects towards the possibility of Fall Armyworm spreading towards Nepal from India. In India, Fall Armyworm has already been present in different states like Karnataka, Bihar, Chhattisgarh, Gujarat, Andhra Pradesh, Odisha, Tamil Nadu and West Bengal (CABI, 2019). All these regions are tropical regions of India. Thus, there is a maximum possibility of Incidence of Fall Armyworm in Tropical Regions i.e. Terai region of Nepal. In addition to this, Nepal and India are sharing open border and there is no any restriction in the border during the import and export of goods. Due to the open border between Nepal and India, fruits and vegetables from India enter Nepal without any quarantines and proper checking. This might be a major reason for the pest to be introduced in Nepal. Similarly, Maize being a second ranked crop in terms of production in Nepal, there are many commercial growers and production area of maize in Nepal is very high. This also adds to the possibility of the Fall Armyworm spread in Nepal which is a voracious feeder of maize. In addition to this, other crop species like sorghum, cotton, rice, millet and other host species that are cultivated in Nepal could be an attraction to the pest.

FAO believed that there is a high probability of the pest to reach Nepal soon. (CABI, 2019) mentioned that the deadly pest has a voracious appetite for maize and other crops and its impact would be huge for the Nepalese farmers and economy. They believed that the climatic conditions in Nepal are suitable for the establishment of Fall Armyworm populations, which could potentially cause up to 100 percent crop loss in maize if not managed properly. Thus, Nepalese people must be prepared and be ready for the threats that can be caused by the FAW.

Status of American Fall armyworm in Nepal

Lab reports have already confirmed the presence of Fall armyworm in Nepal. Plant Quarantine and Pesticide Management Center (NPPO, 2019) has confirmed the presence of this pest in Nepal after the lab reports in 12th August, 2019 showed positivity towards the presence of the pest in Nepal. Lab test for the pest was continuously done in Nepal by the NPPO after the pest was introduced in the Karnataka state of India. The first two lab reports from the samples collected from all Nepal (Jhapa in the east to Dang in the west) confirmed the pest to be *Spodoptera litura* and the test for the third time confirmed the presence of *Spodoptera frugiperda* in Nepal (Guragain, 2019). Online Khabar, a national level online news channel of Nepal notified that Nepal Agricultural Research Council (NARC) reported the first sighting of FAW, locally known as Phaujikira, in Nepal. According to NARC, the first case was reported from Nawalparasi district of western Nepal. After this, the pest was also observed in Chitwan and (FAO, 2019b) confirms the geographical distribution of the pest in Mid inner terai and mid hills of Nepal.

Loss assessment of the pest in Nepal has not been done because of the recent introduction in the few regions of the country. However, to control the pest, CIMMYT has been putting efforts to evaluate the efficacy of push-pull cropping system which is considered one among the best climate-smart technologies (Pradhan et al., 2019). It has been reported that the CIMMYT is using two crops: Napier grass *(Pennisetum purpureum*) and silverleaf desmodium legume (*Desmodium uncinatum*). Among them, Desmodium is intercropped in rows with the maize crop and napier grass is cropped surrounding the maize. It has been believed that the desmodium plays a great role in repelling the fall armyworm moth by producing volatile compounds and Napier attracts the female moths by producing chemical compounds (Pradhan, et al., 2019). This push-pull strategy helps in the controlling the maize field from fall armyworm without any adverse effect to the environment.

Pest Identification

Major pests that can be observed in a maize field of Nepal are *Sesamia, Helicoverpa, Chilo partellus*, Armyworm (*Mythimna separata*), cutworm, grasshopper, field cricket, white grub, termites, tiger beetle, red ant and many other pest species. These insect data are based on the two years research on types of pests that are attracted to black light trap and maize crop in Kaski district. FAW is also a major pest of maize in African Countries that could totally damage a maize field.

Moving towards the FAW identification, In the male moth, the forewing generally is shaded grey and brown, with triangular white spots at the tip and near the center of the wing while the forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown (Prasanna et al., 2018).

Damage Symptoms

Larvae is the voracious feeder which causes a huge damage by defoliating the host. When the number of larvae increases in a field, they begin to defoliate every plant that comes on their way while spreading in the maize field. The typical damage symptom of FAW is presence of holes in the maize leaves due to the feeding of epidermal tissues by the young larvae. (Sisay

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et al., 2019)

Loss Assessment

Although primary damage to the foliage is done by the younger larvae, (Abrahams, et al., 2017) and (Capinera, 2017) reported that the major reason for the reduction in yield and quality of the maize grains is due to the feeding of the cob and kernels by the larger larvae that are present in the whorls of older plants. A research has shown that the estimated national mean loss of maize in Ghana was 45% (range 22-67%), and in Zambia 40% (range 25-50%) (CABI, 2017). (Abrahams, et al., 2017) estimated that without control measures, fall armyworm is expected to reduce maize yield by 8.3 to 20.6 million tons per year of the total expected production of 39 million tons per year. (Hruska & Gould, 1997) reported yield losses ranging from 15 to 73% when 55 to 100% of the maize plants were infested with the fall armyworm during mid through late whorl stage in Nicaragua. (Chimweta et al., 2019) have reported leaf, silk and tassel damage levels ranging between 25 and 50% and grain yield decrease of 58%. Similarly, (CABI, 2019) believed that FAW could potentially cause up to 100 percent maize crop loss in Nepal, if not managed properly because of the suitable climatic conditions for pest establishment.

Significance of the Pest

Being a highly migratory in nature, the pest can cause huge damage to the crop species. Causing severe loss in the African Countries, FAW has already been the matter of ache to the farmers in Asia too. The pest cannot survive in extreme hot areas and the optimum temperature for the pest spreading is about 28^{0}C. The pest is believed to survive in the clay soil mixed with sand i.e. sandy clay or clay-sand soil in which the pupation and adult emergence is favored (CABI, 2019). Similarly, the emergence of pest in such soil increases with increase in temperature i.e. directly proportional to temperature and decreases with increase in relative humidity i.e. inversely proportional to relative humidity. (CABI, 2019)

Biology of the Pest

Being a lepidopteran pest, life cycle of FAW completes in four phases viz. Egg, larva, Pupa and Adult. The pest requires 30 days in summer, 60 days in autumn and spring to complete its life cycle. However, the duration may be prolonged to 80 to 90 days during winter season (Luginbill, 1928). Every stage of the pest metamorphosis is described as,

Egg

Approximately, Egg masses containing 150-200 eggs are laid by the female in two to four layers that are deep on the surface to the lower part of the leaf (CABI, 2019). The egg is dome shaped that measures 0.4 mm in diameter and 0.3 mm in height, pale yellow or creamy in color at the time of oviposition which later changes into light brown before hatching (CABI, 2019), (Prasanna et al., 2018). A female can lay about 1500 eggs on an average which may rise over to 2000 (maximum) (Igyuve, et al., 2018). The eggs are laid in masses in the surface of the leaf, generally underside. Abdomen of the female moth bear a layer of scales that are grey to pink in color called setae which cover the egg masses and protect them. It is believed that providing a temperature of 20-30^{0}C helps the egg to be matured within 2-3 days.

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Larvae

The larval stage of Fall Armyworm completes in six instar stages. The larva at its young stage are greenish in color having black head that changes into orange in the second instar whereas formation of lateral white lines and conversion of the dorsal body surface into brownish color is the feature of third instar larva. The color of head changes to reddish brown that is mottled with white while white sub dorsal and lateral lines in the brownish body is observed during the stage of fourth to sixth instars (Igyuve et al., 2018). Black tubercles were found dorsally on the body which bears spines (Sharanabasappa et al., 2018). The larvae in the back contains 3 yellow stripes followed by a black and again yellow stripe on the side whereas on the second to last segment, four dark spots are seen that forms a square. (FAO, 2018). The young larvae feeds on the leaves near the surface of the ground for the first few days and then climbs up onto the corn plant to consume all leaf tissue leaving only the veins and midrib after about one week (Bohnenblust & Tooker, 2012). Larvae have four pairs of fleshy abdominal prolegs in addition to the pair at the end of the body (Bessin, 2019). Full-grown larvae have body length of about 1-1/2 inches (38 mm) long (CABI, 2019). (Pitre & Hogg, 1983) reported that the longevity of larval period is about 14-30 days depending upon the weather.

Pupa

The full-grown larva stops feeding, turns greenish and bright brown color during the prepupal period (Sharanabasappa, et al., 2018). Usually, pupation occurs in the soil 2-8 cm deep which also can occur in reproductive parts such as mature maize ears; However, if the soil surface is hard, the leaf debris and other material are webbed together on the soil surface by the larvae so as to form a cocoon (CABI, 2019). The larva binds the particles of soil together to form a loose, oval and 20-30 mm long cocoon inside which a reddish-brown pupa measuring 14 to 18 mm in length and 4.5 mm in width resides (Igyuve et al., 2018). The pupal stage duration depends upon the weather which completes in 8 to 9 days in summer and in 20 to 30 days in cooler season (CABI, 2019). For Pupal Sexing, the distance between the genital opening and anal slot is observed. Male pupa is the one having shorter distance and female is the one having more distance (Sharanabasappa et al., 2018).

Adult

Adult male is smaller than female having 1.6 cm of body length and wingspan of 3.7 cm with body length of 1.7 cm and wingspan of 3.8 cm in case of female. Male can be easily distinguished with its forewing that is mottled and contains a discal cell having straw color on three quarters and dark brown on one quarter of the area with triangular white spots at the tip and near the center of the wing (CABI, 2019). However, females cannot be distinguished with their forewings since they are less distinctly marked which ranges from uniform greyish brown to a fine mottling of grey and brown and in both the sexes, the hindwing is iridescent silver-white containing a narrow dark border. (Igyuve et al., 2018). According to (CABI, 2019), the nocturnal behavior of the adult makes them active generally during the warm and humid evenings. Female moths have a pre-oviposition period of 3 to 4 days after which laying of eggs occur during the first 4 to 5 days of life up to 3 weeks in some cases, and the duration of the adult life ranges about 7 to 21 days with an average of 10 days (Prasanna et al., 2018).

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Integrated Pest Management:

Integrated Pest Management (IPM) is the best and preferred method of FAW management (Day et al., 2017). Control methods need to be utilized in a way that are sustainable and cost-effective and the risks caused by them to the environment and humans are as minimum as possible (Bateman et al., 2018). Due to the devastating loss caused by the pest, many farmers do not want to take the risk of IPM and use chemicals to control the pest directly. However, in Nepal, the pest is in the phase of incidence, thus the IPM method of pest control will be the best method for management. IPM method of pest management includes various practices of pest control like cultural, physical and biological methods.

Cultural Methods:

The major cultural practices that are efficient for the management of these pests are plantation of trap crops like legumes. Plantation of beans at the edges of maize field 10 days prior to the plantation of maize will attract the FAW towards the bean and hence maize can be protected. Another major cultural practice can be planting early or with the other farmers that have field near to own field. This will cause the equal distribution of FAW in all fields. However, if the maize crop is planted late, the pest will have high probability of entering the field due to the lack of maize in nearby fields. Planting of maize earlier than the actual date will bypass the time of arrival of the pest and hence crop could be protected or less infected.

Another major management method to be considered is ploughing properly before planting the maize crop. This will expose the pupa of FAW in soil to the birds and predators. Hence the FAW population can be reduced. However, the larvae and pupa can also be killed by exposing them during the winter season. The larvae cannot resist the freezing temperature and hence die (CABI, 2019). In line with this, deep tillage and plant residue after harvest favor the pest to rest in the soil. If the pest population is low, handpicking of larvae and pupa can also be practiced but this practice is not generally proper in case of higher infestations. Sanitation of the field, clean cultivation and proper weeding are the other major cultural practices. Similarly, plantation of scented and flowering plants like coriander, fennel, rose, marigold etc. can attract natural pest of FAW and hence reduce the pest population. Push-pull strategy is also one of the strategies of cultural management of the pest in which maize is intercropped with pest-repellent “Push crop” (*Desmodium spp*), surrounded by pest-attractive “pull crop” (Napier Grass, *Pennisetum purpureum* or *Brachiaria* spp) (Dively, 2018).

Pest Monitoring:

For the successful implementation of an Integrated Pest Management program, effective monitoring activity is required. Pheromones and Light traps are effective monitoring tools for FAW management. According to (Klun et al., 1996). The sex pheromone for *S. frugiperda* contains (Z)-9-Tetradecenyl acetate (Z-9-14: OAca) which is common to *Trichoplusia ni, Spodoptera exigua* and *Agrotis ipsilon exigua.* In Tomato, Lucerne and cotton fields, mating disruption for *S. exigua* was possible by the release of (9Z, 12E)-9, 12-tetradecadienyl acetate at high concentration. Thus, (Shorey et al., 1994) believed that the mating disruption may be possible. Universal bucket type pheromones are used in which sex pheromones or chemicals produced by females to attract males are kept which can travel a very long distance through air and make the monitoring easy whereas most commonly used pheromones are sex pheromones and aggregation pheromones (Prasanna et al., 2018). Similarly, Light traps are also used in the monitoring of fall armyworm. The nocturnal behavior of the moth makes it

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monitorable through black light traps.

Biological Control

If the management of a pest in a crop field is done using another insect which is the natural enemy of the pest, then it is called the biological control of the pest. Biologically, a pest can be controlled using pathogen, parasites or predators. *Telenomus remus* is one of the important biological agents that is used to control FAW in the maize and vegetable fields. It is so small that it can enter inside the FAW eggs and lay offspring inside. These offspring grow and eat the egg of fall armyworm. When the offspring develop into adult, it comes out breaking the shell and hence the FAW can be controlled.

Parasites

Trichogrammatoidea armigera is used in the control of FAW and *helicoverpa* eggs which is the main reason of its mass production in the ICRISAT-Niger Laboratory (Prasanna et al., 2018).

Table 2: Parasitic Natural Enemies of Fall Armyworm

S.N.	Natural Enemy	Life Stage	Host
1	*Archytas incertus*	Larva	Maize
2	*Archytas marmoratus*	Larva/Pupae	Maize/Sorghum
3	*Campoletis flavicincta*	Larva	Maize
4	*Chelonus curvimaculatus*	Eggs/Larva	Maize
5	*Chelonus insularis*	Eggs/Larva	Maize/Sorghum
6	*Cotesia marginiventris*	Larva	Maize
7	*Cotesia ruficrus*	Larva	Maize
8	*Euplectrus platyhypenae*	Larva	Maize
9	*Glyptapanteles creatonoti*	Larva	Maize
10	*Lespesia archippivora*	Larva	Maize
11	*Microchelonus heliopae*	Eggs/Larva	Maize
12	*Brachymeria ovata*	Pupa	
13	*Telenomus remus*	Eggs	Maize/Vegetables
14	*Trichogramma achaeae*	Eggs	Maize
15	*Trichogramma chilotraeae*	Eggs	Maize
16	*Trichogramma pretiosum*	Eggs	Maize
17	*Trichogramma rojasi*	Eggs	Maize

Source: (CABI, 2019)

Among the several biological control agents of FAW, *Chelonus insularis* Cresson (Hymenoptera: Braconidae) is the most dispersed biological control agent geographically. The relationship of leaf consumption between healthy and parasitized (by *Chelonis insularis)* caterpillars is 15:1, meaning less damage to the plant (Prasanna et al., 2018). Among the several parasites and parasitoids of FAW, some are listed below in the table 2 with their host (mostly maize) and life stage of the pest in which they attack.

Pathogens

The larva which is affected by pathogens start to change the color into increased pale and its

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movement is decreased when touched. But, the major way to detect a FAW larvae diseased from pathogen is when it is dead. Particularly for FAW larvae infected with baculovirus, the dead larvae will generally be observed in the upper parts of the maize plant and will hang upside down (Prasanna et al., 2018). The major entomopathogens that are helpful in the management of FAW in maize are listed below in the table 3.

Table 3: Pathogenic Natural Enemy of Fall Armyworm

S.N.	Natural Enemy	Life Stage
1	*Bacillus cereus*	Larvae
2	*Bacillus thuringiensis*	Larvae
3	*Bacillus thuringiensis alesti*	Larvae
4	*Bacillus thuringiensis darmstadiensis*	Larvae
5	*Bacillus thuringiensis thuringiensis*	Larvae
6	*Bacillus thuringiensis kurstaki*	Larvae
7	*Beauveria bassiana*	Eggs/Larvae
8	*Granulosis virus*	Larvae
9	*Metarhizium anisopliae*	Eggs/Larvae
10	*Nucleopolyhedrosis virus*	Larvae

Source: (CABI, 2019)

Predators:
The most preferred site of FAW in maize is the maize whorl inside which a predatory earwig, *Doru luteipes* (Scudder) lays its eggs (Reis et al., 1988) and occurs throughout the maize crop cycle. Nymphs of *D. luteipes* consume 8–12 larvae daily, while in the adult stage they consume 10-21 larvae of *S. frugiperda* daily (Reis et al., 1988). According to (Pasini et al., 2007), the FAW eggs are equal to the insect pupa flour and pollen that are required for the preparation of artificial diets for rearing of *D. luteipes*. Some of the predators of FAW in maize are in the table 4 below.

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Table 4: Predators of FAW larva and pupa in maize

S.N.	Natural Enemy	Life Stage
1	*Calleida decora*	Larva
2	*Calosoma alternans*	Larva
3	*Calosoma sayi*	Larva
4	*Carabidae*	Larva/pupa
5	*Doru luteipes*	
6	*Doru taeniatum*	
7	*Ectatomma ruidum*	
8	*Geocoris punctipes*	
9	*Stelopolybia pallipes*	
10	*Podisus maculiventris*	

Source: (CABI, 2019)

Botanical Pesticides

The pesticides which are derived from plant or plant extracts are called as plant-based pesticides or botanical pesticides. The botanical pesticides are recommended because they neither harm the farmers nor the natural enemies of the pest. Similarly, Botanical pesticides are environment friendly, degradable and easy to use. Among the large group of plants that have insecticidal properties, some are used in the management of FAW (Table 5).

Table 5: Potential botanical pesticides against FAW, based on studies in America

S.N.	Species	Family	Extract	Mode of Action
1	Neem, *Azadirachta indica*	Meliaceae	0.25% Neem Oil	Larvicidal with up to 80% mortality in the lab
2	*Aglaia cordata Hiern*	Meliaceae	Hexane and ethanol extracts of seeds	Larvicidal with up to 100% mortality in the lab
3	*Annona mucosa Jacquin*	Annonaceae	Ethanolic extract from seeds	Larval growth inhibition
4	*Vernonia holosenicea, Lychnophora ramosissima, and Chromolaena chaseae*	Asteraceae	Ethanol extracts from leaves	Ovicidal
5	*Cedrela salvadorensis and Cedrela dugessi*	Meliaceae	Dichloromethane extracts of wood	Insect growth regulating (IGR) and larvicidal with up to 95% mortality
6	Long pepper, *Piper hispidinervum*	Piperaceae	Essential oil from seeds	affects spermatogenesis and hence egg laying
7	Chinaberry, *Melia azedarach*	Meliaceae	Ethanolic extracts of leaves	Antifeedant to larva; synergistic with pesticide
8	*Jatropha gossypifolia*	Euphorbiaceae	Ethanolic extracts of leaves	Antifeedant to larva; synergistic with pesticide
9	Castor, *Ricinus communis*	Euphorbiaceae	Castor oil and Ricinine (seed extracts)	Growth inhibition and larvicidal

Source: (Prasanna et al., 2018)

Chemical Control

Chemical pest control refers to the control of pests using the chemical pesticides. Pesticides are synthetically produced chemical compounds that are developed in such a way that they

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affect the certain life stage of pest and hence the effect of pest on the crop will be reduced or the pest will die.

Different insecticides and pesticides are used in different FAW-infected countries due to the higher risk of other management practices. Insect control using chemicals is the risk-free method of the pest control. In IPM, the use of pesticides is not considered good. However, the use of chemicals under the economic threshold does not harm the human health excessively. For the control of FAW pest, carbamate insecticide like Methomyl, Pyrethroid insecticide and common household pesticide, Cyfluthrin and organophosphate insecticide, methyl parathion can be used (Table 6). (Tumma & Chandrika, 2018)

Insect Resistance Management (IRM)

Use of same chemical pesticide on the same place to control same pest for a long period of time makes the pest resistance to the chemicals applied. The pest develop character that the Mode of Action (MOA) of the pesticide does not work properly on the pest. If the chemicals are used according to the dose and label directions, they can be considered as a great and safe tool in the pest control. However, the negligence and haphazard use of chemical can be a major issue to the human as well as plant health.

Laboratory experiments have demonstrated that evolution of insect resistance to pest-control measures can be delayed or prevented in the presence of natural enemies (Liu X et al., 2014). However, indiscriminate spraying of toxic pesticides often adversely affects these natural enemies, reducing benefits from biocontrol (Meagher et al., 2016) and the secondary pest population may increase eventually. The FAW in tropical climates completes its life cycle in 30-40 days so avoiding treating successive generations of FAW with the same active ingredient and rotating active ingredient with products that have ingredients with different modes of action every 30 days may reduce the resistance of the pest. The pesticides must be applied at the recommended rates, intervals, and seasonal totals, as specified by the label and the instructions because the pesticide label specifies how often and at what rate an insecticide should be applied per season which are based on research, and are designed to slow down the development of insecticide resistance in the FAW population. (Prasanna et al., 2018)

Table 6: Agrochemicals registered to control FAW in South Africa

S. N.	Brand Name	Active Ingredients	Type	Resistance Group and Subgroup	Registered for Use on the crops:
1.	Agropyrifos	Chlorpyrifos	Contact insecticide	1A	Maize, pastures and Potatoes
2.	Pyrinex 480 EC	Chlorpyrifos	Contact insecticide	1A	Maize
3.	Methomex 900 SP	Methomyl	Contact insecticide	1A	Maize
4.	Marshal 48 EC	Carbosulfan	Systemic insecticide	1A	Maize
5.	Vitex 50	Emamectin benzoate	Stomach translaminar insecticide	6	Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize, sweetcorn
6.	Ag-Tap 500 SP	Cartap hydrochloride	Contact and systemic action	14	Barley, cabbage, canola, maize, onions, potatoes,

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			insecticide		sorghum, soybeans, sugarcane, sunflower, sweetcorn and wheat cauliflower and brussels sprouts)
7.	Akito	Betacypermethrin	Stomach and contact insecticide	3A	maize, sorghum, sweetcorn, wheat, tomatoes, peas, lupins, Lucerne, groundnuts and Cruciferae (cabbage, broccoli,

***Insecticide Resistance MOA Groups and subgroups**:*
Group 1: Acetylcholine esterase (AChE) inhibitors
Sub-Group 1A: Carbamates
Group 3: Sodium channel modulators
Sub-Group 3A: Pyrethrins & Pyrethroids
Group 6: Chloride channel activators
Group 14: Nicotinic acetylcholine receptor (nAChR) blockers

Source: (IRAC South Africa, 2018)

Note: The trade name or brand name of the chemical that would be used in Nepal can be different because these are the chemicals available in South Africa.

CONCLUSION

Fall Armyworm is a highly damaging pest of maize. It has a very rapid spreading capacity. It's spread in Africa from America was also rapid. Some of the news channel already reported its presence in Nepal. Its entry in Nepal may cause up to 100% yield decline as warned by FAO. Although the loss assessment of the pest in Nepal is not calculated yet, CIMMYT has been working to control the pest in Nepal through evaluation of push-pull strategy in which Napier grass and Desmodium are cultivated with maize crop. Furthermore, the major step that can be taken is to strengthen the quarantine measures at the India-Nepal Border so that the further entry of pest through different medium can be controlled. Regular monitoring and scouting for the presence of the pest should be done. If in case, the spreading of FAW in Nepal occurred, it should be managed at the primary level using the integrated pest management methods like cultural control, biological control and use of chemicals below the economic injury level. However, the use of chemicals during the initial phase of pest spreading is not suggested as it can harm the natural enemies of the pest too.

Authors Contribution

Chapagain, E: Collected the information. Bhusal. S: wrote the paper.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding publication of this manuscript.

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