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A review on fall armyworm (*Spodoptera frugiperda*) and its possible management options in Nepal

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Abstract
Fall armyworm, Spodoptera frugiperda (J. E. Smith) (Lepidoptera: Noctuidae), is an insect showing polyphagous nature, with more than 80 host species that causes severe damage to cereals and vegetable crops. On late 2016, occurrence of FAW was reported in West Africa for the first time and in was firstly collected and reported in Nepal at Nawal parasi district on 9th May 2019. Both migratory habit and a more localized dispersal habit are performed by the moths. They can migrate over 500 km (300 miles) before oviposition which can leads to greater spread and damage in short period. The insect cause heavy damage on corn and yield losses of 39% to over 70% has been recorded. Lack of access to market and chemicals helps farmers to adopt climate adopted push pull technology which could be considered as major option to control the FAW. Use of mechanical methods like hand picking, pheromone traps, light traps etc. could be the measures to monitor and control the pest for small scale farmers. Use of chemicals like Cholarantraniliprole, Sipnosad etc. can be used as a last resort option to control the FAW in case of Nepal.

Keywords: Damage, mechanical, push pull, recorded, resort, *Spodoptera frugiperda*

Introduction

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is an economic pest that attacks maize and other crops of Gramineae family (Andrews, 1980) [2]. Fall armyworm is an insect showing polyphagous nature, with more than 80 host species, causing severe damage to cereals and vegetable crops (Goergen *et al*., 2016; Roger *et al*., 2017; Prassana *et al*., 2018) [12, 33, 31]. Cereals and forage grasses are majorly damaged by the FAW caterpillars and are recorded of feeding 186 plant species from 42 different families (Casmuz Augusto *et al*., 2010). Young leaf whorls, ears and tassels are considered as major feed causing significant damage to maize, resulting occasional total yield loss (De Almeida Sarmento *et al*., 2002) [10]. Both migratory habit and a more localized dispersal habit are performed by the moths. They can migrate over 500 km (300 miles) before oviposition (Prasanna *et al*., 2018) [31].

On late 2016, occurrence of FAW was reported in West Africa for the first time (Goergen *et al*., 2016) [12] and has invaded the 44 African nations already (Rwomushana *et al*., 2018) [34]. The occurrence of this new invasive pest FAW was reported for the first time from India by Sharanabasappa and Kalleshwaraswamy (2018) [35] at Karnatak. The insect had been recorded for the first time in Nepal from Nawalparasi district (N 27o42'16.67" E 084o22'50.61") on 9th May 2019 (Bajracharya and Bhat, 2019) [3].

Among the cereal crops grown worldwide maize stand first, and in Nepal it's second in terms of area of production comprising 900,288 ha which is nearly about 29% of total cultivated area of 3.09 million ha (MoAD 2016/17) [28]. Among the total production area 752464 ha (83.58%) of the area is under mountain and mid-hills where maize is considered as a major staple food (MoAD 2016/17) [28]. Hence, it could be a great threat to the farmers engaged and dependent on maize farming for their livelihood if any management tactics are not applied.

Classification

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

Identification

Eggs of the FAW can be identified based on the clustered laying nature of the eggs ranging from few to hundreds in numbers (Sparks 1979; Sharanabasappa *et al*., 2018) [36, 35]. The eggs are dorso-ventrally flattened which looks greenish gray during early days later turns brown and almost black before hatching. The female covered a layer of scales (downy materials) on the egg mass and this gave moldy appearance (Sharanabasappa *et al*., 2018; Hardke *et al*., 2015) [35, 14].

First instar larvae are greenish with a black head capsule, and turned greenish brown in the second instars. Larvae darken in color as they feed and appear greenish (Luginbill 1928) [23]. The third instar are brownish with three dorsal and lateral white lines. Fourth to the sixth instars were brownish black and had three white dorsal lines and alight lateral line (Sharanabasappa *et al*., 2018) [35]. Notable inverted "Y" on the head capsule is observed in the larvae (Oliver and Chapin 1981) [29]. On the eighth abdominal segment in square like structure a distinct pattern of four "dots" is also visible in the larvae. Appearance of the pupal case is about orange-brown in color, similar to most Noctuids, and darker in color as it ages (Luginbill 1928) [23].

The upper portion of the forewings of the adult moths are a mottled dark gray, with a distinctive white spot near the dorsal tip, or apex, of the wing, while the lower portion of the forewings is a light gray to brown color. The antennae are common to Noctuids i.e. filiform (threadlike) antennae. These moths are also mostly active at night like other Noctuids (Oliver and Chapin 1981) [29].

Lifecycle

With the life cycle consisting of egg, six to seven larval instars, pupa, and adult FAW perform assorted generations per year (Luginbill 1928) [23]. Female lays eggs on the upper or lower portion of the leaves. Incubation period ranged from 2-3 days with a mean of 2.50 days (Sharanabasappa *et al*., 2018) [35]. Based on temperature and environmental conditions, the extent of time for larval development (hatching to pupation) varies and mostly ranges between 11 to 50 days (Luginbill 1928, Hogg *et al*. 1982) [23, 17]. Larval development on cotton takes 22 days when the temperature was maintained at 25°C (Pitre and Hogg 1983) [30]. After the hatching, Shranabasappa *et al* (2018) [35] has reported that each larva passed through six distinct instars over a period of 14 -19 days. Similar larval period of about 14–30 days has been reported by Pitre and Hogg (1983) [30]. Larvae drop from the plant and tunnels into soil to a depth of one to three inches below the and for 2–4 days remains as prepupal stage. Later approximately after 7 to 10 days they pupate (Luginbill 1928, Pitre and Hogg 1983) [23, 30]. Duration of the pupal period of about 9 to 12 days has been reported by Shranabasappa *et al* (2018) [35] while Débora *et al*. (2017) [9] during the study of the pupal period of *S. frugiperda* on maize found it to be 8.54 days.

The female adult within a range of 9-12 days survived for 10.80 days compared to male (8.20 days) with a range of 7 – 9 days (Shranabasappa *et al*., 2018) [35]. Estimation of an average of 10 days, with a range of about 7-21 days is made for adult life period (Prasanna *et al*., 2018) [31].

Damage

Constant fecundity of the pest at favorable environment condition is anticipated to result a severe damage to crops (Goergen *et al*., 2016) [12]. Both vegetative and reproductive structures of the plants are consumed by the larvae. Epidermal leaf tissues are mostly preferred by the young larvae and make holes in leaves, which is the peculiar damage symptom of FAW. Deadheart is a symptom caused by feeding of young plants through the whorl. The matured larvae present in the whorls of older plants can feed on maize cob or kernels, reducing yield and quality (Abrahams *et al*., 2017; Capinera 2017) [1, 5]. Considerable damage to maize is caused by FAW larvae by feeding on young leaf whorls, ears and tassel which occasionally leads to total yield loss (De Almeida Sarmento *et al*., 2002) [10].

The insect cause heavy damage on corn and yield losses of over 70% have been recorded (Hruska and Gould, 1997) [16]. Yield reduction in maize due to damage of FAW larva of about 39% was reported in America (Cruz *et al*., 2012) [8]. A forecast on yield losses due to FAW was made upto 40% in Honduras (Wyckhuys and O'Neil 2006) and 72% in Argentina (Murúa *et al*. 2006) [6]. Maize yield loss of 20–50% in recent estimates at Africa suggests severe impact on livelihoods of the farmers depended on Maize farming (Early *et al*., 2018) [11]. Successive investigations have showed that the pest has been identified in over 30 sub Saharan African countries where it has caused extensive damage to crops especially maize fields (Prasanna *et al*., 2018) [31].

Management

- Adaptation of climate-adapted push-pull system could be a best method to control the pest in Nepal. Intercropping of maize with drought-tolerant Greenleaf desmodium, *Desmodium intortum* (Mill.) Urb. and planting Brachiaria cv Mulato II as a border crop around this intercrop is promoted in this technology. Green leaf volatiles emitted by the companion crops is the mechanism mediated for control of the stem borer (Khan *et al*., 2010) [20]. Semiochemicals emitted by the trap plants are attractive to the gravid female moths while that emitted from intercrops deter oviposition on the maize (Chamberlain *et al*., 2006) [7] and helps to attract the natural enemies of the pest (Khan *et al*., 1997; Midega *et al*., 2009) [19, 26]. The trap plants act as non suitable crop for survival and developement of the larval stages of the pests, resulting in high mortality rates (Khan *et al*., 2006; Midega *et al*., 2011) [7, 25]. Increased abundance, diversity and activity of predatory insects in this system, further contributes to reduce pest populations and control it (Midega *et al*., 2006) [27].
- Maize intercropped with edible legumes crops helps to reduce the abundance of FAW. The intercropped leguminous crops i.e. French bean, Soybean and Groundnut provides better protection to the crop compared to that when it's mono cropped (Hailu *et al*., 2018) [13].

- Use of FAW pheromone trap in monitoring and mass trapping of the moths. Pheromone has been used for pest monitoring, mass-trapping, and interruption in mating. Pheromones have been a useful tool for monitoring male populations in different parts of the world (Malo *et al*. 2004; Batista-Pereira *et al*. 2006) [24, 4]
- Light traps can be used to control the adult FAW which helps to trap both male and female insects. Black light (BLB Sylvania®) traps were used to capture the adult moths (Hunt *et al*. 2001; Qureshi *et al*. 2006) [18, 32].
- Under small scale 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 reveled that these measures were 'somewhat successful' (Rwomushana *et al*., 2018) [34]. In Ethiopia, 15% of the farmers practiced only handpicking for FAW management (Kumela *et al*., 2019) [22].
- Plant-derived pesticides like neem based bio-pesticides can be used to control the larva of the FAW. Application of bio-pesticide with 0.25% neem oil under laboratory condition showed 80% mortality of the larva (Tavares *et al* 2010) [37].
- Use of biological control measures by use of tricho card of egg parasitoids i.e. *Trichogramma pretiosum* helps to control the FAW. These techniques help to control the pest and also benefit the environment and human health (Parra 2010).
- Use of insecticides like spinosad, chlorantraniliprole helps to reduce the pest population as last resort. The best performance of the insecticide spinosad, causing >90% larval mortality was reported by Cruz *et al*., (2012) [8]. In laboratory studies, mortality of FAW was reported better with new insecticides (*Cholarantraniliprole*, *flubendiamide*, and spinetoram) compared to traditional one (lambda-cyhalothrin and novaluron) when applied (Hardke *et al*. 2014) [15].

Faw management options in Nepal

The major problems affecting FAW management efforts in Nepal could be due to lack of adequate knowledge of the pest and its management options in the Nepalese context; lack of sound contingency and long-term plans; lack of coordinated research and development interventions; scarcity of financial and material resources. Being a developing country with most of the farmers lacking access to market and chemicals pesticides so; use of the climate adopted push pull technology could be one of the best option control the FAW. Use of intercropping of the legumes with maize which was earlier practiced by the farmers should be reintroduced among the farmers with awareness of controlling the FAW which may appear as havoc in days to come. Use of mechanical methods like hand picking, light traps and pheromone lures could be an option for monitoring and controlling the pest for small scale farmers. Use of neem oil based bio-pesticides could be an option to control the larva as it is been easily available in the local markets these days. Use of biological control measures like parasitoids could be irrelevant in case of Nepal due to the lack of sophisticated labs for rearing and production of the parasitoids. The use of the chemical pesticides like Cholarantraniliprole, Sipnosad etc can be used as a last resort option if all above mentioned measures cannot maintain the pest below economic threshold level.

Conclusion

The fall armyworm (*Spodoptera frugiperda*) has recently been introduced in Nepal and favorable environment for the insect helps them to quickly multiply and spread to more areas. There is an urgent need to increase awareness among the farming communities about the life stages of the pest and its best possible management options. At the same time, it is important to introduce, validate, and deploy low-cost, environmentally safer, and effective technological interventions to control the pest.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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