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REVIEW ON STATUS OF INVASION AND INTEGRATED MANAGEMENT OF FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*)

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Abstract– Fall armyworm is a polyphagous, transboundary invasive pest that invaded India in May 2018. They have a wide host range, the potentiality to establish rapidly and are highly migratory. Spread and establishment of this pest are enhanced during the monsoon season of the country with favourable climate and temperature. However, climatic conditions of India favour the outbreaks of pests such as FAW in many maize grown areas. It causes considerable injuries to maize by feeding on leaf whorls, ears and tassel which often leads to total yield loss. This pest demands meticulous and stepwise plan for its management. This review emphasizes an introductory pathway of the invasive pest, biology, lifecycle, status, and management of fall armyworm in India. It includes adoption of IPM methods of pests' control, which is the integration of biological, cultural, physical, chemical, and technological approaches. Control of this invasive pest requires early monitoring, scientific research, and management strategy with awareness, knowledge, and technical support to Indian farmers.

INTRODUCTION

It is polyphagous in nature (Hoy, 2013) with host preference recorded more than 353 plants of 76 different families, majorly Poaceae (106), Asteraceae (31) and Fabaceae (31) (Montezano *et al*., 2018). Due to its migratory performances, it has been categorized as the sporadic pest (Hardke *et al*., 2015). It typically favors tropical region with annual temperature ranging from 18 to 26ºC and 500 to 700 mm annual precipitation (Early *et al*., 2018). The incursion of fall armyworm as an invasivepest into Asia was reported for the first time in India by Sharanabasappa *et al.* (2018), Ganiger *et al.* (2018), and Shylesha *et al.* (2018).

Considering the fact of its diversified uses such as animal feeds, poultry feeds, human consumption, and biofuel, the demand for maize, as compared to other cereal crops, is continually increasing. Greater part of the people, particularly in hill and mountainous regions are very much relied on maize for staple food (MoAD, 2020). FAW is a migratory polyphagouspest with a wide range of hosts. It feeds on leaves and stems of more than 350 plant species belonging to 76 plant families including maize, rice, millet, and vegetable crops causing severe damage (Pogue, 2002; CABI, 2020). It can quickly multiply, spread, and establish itself in new regions. FAW moth can fly 100 km per night and has several generations per year (Rice, 2017).

METHODOLOGY

Origin and distribution of *Spodoptera frugiperda*

Besides, this pest has numerous eggs laying capacity that increases species population in a very short time (Montezano *et al*., 2018). In Asia, the occurrence and prevalence of this pest was detected in Indian state of Karnataka at college of Agriculture, Shivamogga in May 2018 for the first time (Sharanabasappa *et al.*, 2018a). Then, it spreads to different tropical states of India like Bihar, Chhattisgarh, Gujarat, Maharashtra, Odisha, West Bengal etc. causing devastating damage within short duration (CABI, 2020).

Insect biology and identification

Spherical shaped of about 0.75 mm diameter eggs in mass of 150-200 are laid by female in two to four layers on leaf surface (CABI, 2019). Egg develops in

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2-3 days if favourable temperature of 20-30 °C is provided. The larval stage of fall armyworm completes in six larval instar stages. First instar larva are greenish with black head while second instar are greenish brown in colour that changes to brownish with three dorsal and lateral white lines in third instar larva. Fourth to sixth instar larvae are brownish black and have three white dorsal lines (Sharanabasappa *et al*., 2018b). Larva stops feeding and turns greenish and the bright brown color after completion of sixth instar larval stage (Sharanabasappa *et al*., 2018b). Chapman *et al.* (2000) reported that two or fourth instar larvae exhibited cannibalistic behaviour, accounting 40% mortality when maize plants were infested in field condition. Larvae forms protective covering called "cocoon" by webbing together leaf debris if the soil is too hard and pupal duration is 8-9 days in summer and 20-30 days in cooler season (Silva *et al*., 2017). Adult male has shaded forewing with gray and brown with triangular white patch at apical region whereas female has uniform grayish brown to a fine mottling of grey brown (Sharanabasappa *et al*., 2018b). Adult female is capable of laying around 1500 eggs which may increase up to 2000 during favourable environmental condition (Igyuve *et al*., 2018).

Nature of damage and yield loss

FAW larva is voracious feeder that consumes maize from seed-ling emergence to its maturity and defoliates the whole plant causing yield loss. This pest attacks leaves, stem and other reproductive part of host plant (Tefera *et al*., 2019). Earlier symptoms of fall armyworm resembles with other stem borer damage like window pan feeding and small holes (Deole and Paul, 2018). Window like structure appears on the developing leaf near the funnel and moist saw dust like fecal matter near feeding area is the symptom of fall armyworm larval feeding (Bateman *et al*., 2018). Adult larvae feed on growing point of shoot and tassel thus results in 'dead heart' which ease back fruit formation (Bateman *et al*., 2018).

Integrated pest management

Integrated pest management comprises of modification of cultural practices, emphasis on biological control (use of predators, parasitoids, and entomopathogens), botanical extracts, pest monitoring, crop management practices, judicious use of chemicals etc. Management of fall armyworm through only one approach is unimaginable so, different methods should be used in an integrated way in order to control fall armyworm infestation. These practices should be used in sustainable and economic manner such that the risk caused by them to the environment and human being are minimal (Bateman *et al*., 2018).

Pest monitoring

Scouting, pheromones traps, and light traps are the effective pest monitoring technique and mass trapping of FAW (Abrahams *et al*., 2017). Scouting helps in understanding biology of organisms in the field and their ecology which is the basis for understanding and knowledge, better decision making for FAW management (FAO, 2018b). Pheromone trap is the insect trap that is usually used to attract male by the use of pheromone and it has been found as effective tool to control male population (Basista-Pereira *et al*., 2006). Pheromone is chemical usually produced by female that attracts male for mating. *Spodoptera frugiperda* sex pheromone contains (z)-9-Tetradecenyl Acetate (Z-9-14: OAca) which is common to cab-bagelooper (*Trichoplusia Ni),* beet armyworm *(Spodopteraexigua)* and black cutworm *(Agrotisipsilonexigua)* (Klun *et al*., 1996). Being nocturnal insect black light trap can be used to monitor both male and female insects (Haftay and Fissiha, 2020).

Cultural practices

Cultural practices include intercropping, trap cropping, crop rotation and other measures that alter environmental condition. This enables FAW to attack less economic important crops. Intercropping of leguminous crop i.e. Soybean, Groundnut, bean etc. with maize protects crop from FAW as compared to that when it is mono cropped (Hailu *et al*., 2018). Deep ploughing before showing will expose FAW pupa to predators. Push-pull technology is the habitat management strategy that involves intercropping maize with repellent plants, i.e. Desmodium (push plant) which repels FAW and planting trap crop like Napier grass (pull plant) are shown in the maize field 3-4 rows and spraying with 5% NSKE or Azadirachtin 1500 ppm when trap crops show symptom of FAW damage (Firake *et al*., 2019; Khan *et al*., 2011). Climate adapted push-pull technology reported significant reduction in larval population and plant damage along with 2.7 times higher yield compared to maize grown as sole crop (Midega *et al*., 2018). *Bt*-maize was reported resistant in Africa but in some case of America, it has

overcome *Bt*-maize (FAO, 2018a). Infestation on plant can be reduced by planting early maturing variety as they are less exposed to FAW (Harrison *et al.*, 2019).

Mechanical control

Egg masses and neonate larva are hand-picked and destroyed by crushing or immersing in kerosene water (Firake *et al.*, 2019). As the adult female moth of fall armyworm lays eggs in cluster underneath of leaves, this allows easy destroying of eggs manually or by natural enemies (Wightman, 2018).

Biological control

Use of natural enemy of the pest is the main theme of biological management of pest. IPM concept mainly focuses in biological control as this method is environment friendly and sustainable. Biological management of FAW involves the use of predatory insect and mites which feed their prey, parasitoids which are free living in adult stage and parasitic in larval stage and entomopathogens like fungi, bacteria, viruses and nematodes that cause lethal infection (FAO, 2018b).

Parasitoid

They lay eggs on egg masses, larva and adult of fall armyworm and cease their growth by growing on them. Egg parasitoids are considered as most important among other biological control as they prevent any damage to crop and they can be easily grown in huge amount (Prasanna*et al.*, 2018). *Cotesiaicipie* is very important larval parasitoids which has potential to kill over 60% of fall armyworm (ICIPE, 2018).

Predators

Predators are the natural enemies that destroy eggs, caterpillars, pupa or adult of the fall armyworm during their lifecycle either as larva or adults (FAO, 2018b). Ants, wasps and spiders are also most important predators of FAW eggs, larvae or pupa. Similarly, vertebrate predator like birds, skunks and rodents around the maize field is also beneficial as they feed larva as well as pupae of fall armyworm (Capinera, 2000). Mostly fall armyworm reside inside whorl of maize where predatory earwig, *Dorulutepie s*occurs throughout the life span of maize whose nymphs feed 8-12 larva daily and adult one consumes 10-21 larva daily (Reis *et al*., 1988).

Entomopathogens

Generally, plant pathogen (viruses, fungi, protozoa, bacteria and nematodes) are harmful to the crops and play vital role in reducing crop yield but some of them regulate FAW population in the field (Assefa and Ayalew, 2019). Nuclear Polyhedrosis Viruses (NPVs) can be the useful and effective method against fall armyworm (de Romero *et al*., 2009). FAW is naturally affected by Nuclear Polyhedrosis Viruses (NPVs) such as the *Spodoptera frugiperda* Multicapsid Nucleopolyhedrovirus (*Sf*MNPV), fungi like *Metarhizium anisopliae, Metarhiziumrileyi, Beauveria bassiana, Protozoa* and bacteria like *Bt bacteria* (FAO, 2018b).

Botanical pesticides

Botanical pesticides are derived from different plant species of different plant family for pest control. Botanical pesticides are environment friendly, less harmful to farmer and consumer and safe to natural enemies of pest. The seeds or leaves of the plants of the Meliaceae family (*Azadirachta*) and Asteraceae family (*Pyrethrum*) can be used in order to manage fall armyworm (FAO, 2018b). Botanical extracts from *Azadirachta indica, Schinnus molle, Phytolacca dodecandra* caused maximum larval mortality (>95%) after 72 hours of application (Sisay *et al*., 2019). Likewise, plant oil extract from clove and palmarosa have potential to control first instar larvae whereas, plant oil extract from turmeric, clove and palmarosa have pronounced effects to control second instar of fall armyworm larvae (Barbosa *et al*., 2018).

Chemical pesticides

Chemical pesticides are the synthetic chemical compound that is used to kill or repel insect and pest which are which are invasive and causes damage to crop. Different insecticides and pesticides are reported to be effective against FAW. However, use of pesticide is not central idea of IPM but in severe condition chemical pesticide is used. Its judicious use is recommended so that risk caused by them is minimal to environment and human beings. Pesticides provide higher level of crop protection which other approaches cannot provide but they should be under the economic threshold. Pesticides should be used in judicious level due to their toxicity, persistence and tendency of accumulation and bio-magnification.

Emamectin benzoate 5 SG showed highest acute toxicity, followed by Chlorantraniliprole 18.5 SC and

Spinetoram 11.7 SC by leaf-dip bioassay method whereas, Chlorantraniliprole 18.5 SC, followed by Emamectin benzoate 5 SG, Spinetoram 11.7 SC, Flubendiamide 480 SC, indoxacarb 14.5 SC, Lamdacyhalothrin 5 EC and novaluron 10 EC are effective by field efficacy for 2 planting dates (Jun and Sept shown crop) for control of second instar larvae of fall armyworm (Deshmukh *et al*., 2020).

CONCLUSION

Fall armyworm is a voracious pest of maize. For many years, it has become a pest of major economic importance causing up to 100% yield reduction as warned by FAO. For this reason, this pest demands immediate action. Intercropping with leguminous crops, removal of alternate host, volunteer hosts, push-pull crop like Napier grass and Desmodium, use of plant-based pesticides, biological control measures like use of predators, parasitoids are some measures that can be adopted for effective pest management. Regular monitoring and scouting should be done for mass trapping and control of pest. Different synthetic chemicals like Emamectin benzoate, Chlorantraniliprole, Spinetoram, Flubendiamide, indoxacarb, novaluron etc. are recorded effective against FAW but they should be used below the threshold level. Future research work should be based on ecological methods of pesticides application, non-toxicological approach of insect pest management and environmental plus crop-friendly based of pest control. IPM approach combining various control measures available locally should be adopted by the farmers to sustainably manage FAW.

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