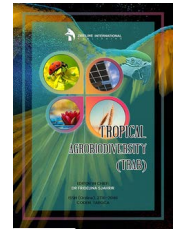


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REVIEW ARTICLE

DAMAGING NATURE OF FALL ARMYWORM AND ITS MANAGEMENT PRACTICES IN MAIZE: A REVIEW

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ABSTRACT

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a polyphagous pest which is arising as one of the major threats to agricultural crop production. It has around 80 host species that cause severe damage to cereals and vegetable crops. This pest was first discovered in Africa (2016) and first collected and reported in Nepal at Nawalparasi district on 9th May 2019. The larvae of FAW are found on young leaves, leaf whorls, tassels or cobs according to their growth stages. First instar larvae scrape leaves and shows pin-hole symptoms and window-pane feeding symptoms whereas in the later vegetative stages, damage results in skeletonised leaves and heavily windowed whorls. If climatic condition for pest establishment is suitable this pest could cause approximately 100% crop loss in maize if not managed in time. Regular scouting, push and pull method, black light traps, commonly available botanicals like neem locally available materials like ash and some recommended insecticides with recommended dose can be used for the control of fall armyworm. There is an urgent need for developing ecologically sustainable, economically profitable, and socially acceptable integrated pest management strategies to mitigate the impacts of the fall armyworm and not just rely on single management practice.

KEYWORDS

Corn, Damage, Management, Nepal, *Spodoptera frugiperda*

1. INTRODUCTION

The noctuid moth, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), commonly called fall armyworm (FAW), is a polyphagous pest (Todd and Poole 1980; Cock et al., 2017). FAW is native to tropical and subtropical regions of America (CABI, 2018). It appeared suddenly in Africa in early 2016, when it was first reported in central and western Africa (Goergen et al., 2016). Within a year FAW was reported in most of sub-Saharan Africa (Day et al., 2017). This economic pest is capable of threatening food security of the world (Devi, 2018). Fall armyworm can spread to wide range of geographical distribution (Goergen et al., 2015, Early et al., 2018, Sharanabasappa et al., 2018). A single generation aggregation of moths can spread more than 500km (300 miles) with the help of wind current before they are ready for oviposition (FAO 2017; Pogue, 2002; Prasanna et al., 2018). It highly attacks crop of graminiae family like maize (Andrews, 1980).

More than 80 different plant species are also found to be damaged by this pest (CABI, 2018). Fall armyworm mainly attacks growing points of maize plant and borrows into the cobs of older plants which degrades yield, quantity and quality of the maize plant (FAO, 2018). Fall Armyworm are known to be recorded in various states of India like Karnataka, Bihar, Chhattisgarh, Gujarat, Andhra, Odisha, Tamil Nadu, West Bengal (CABI,

2019). Pest has entered Nepal as well. Plant Quarantine and Pesticide Management Centre had proved the presence of this pest in Nepal after verification in Lab test report with its morphological and molecular diagnosis in 12th August, 2019 (NPPO, 2019).

The Lab report were collected from Jhapa in the East to Dang in the West twice but both the cases confirmed the presence of *Spodoptera litura* and finally in the 3rd time the presence of *Spodoptera frugiperda* was confirmed in Nepal (Guragain, 2019). According to Nepal Agricultural Research Council (NARC), first case of Fall Armyworm was reported from Nawalparasi district on 9th May, 2019 and then it was seen in neighbouring district Chitwan. Maize (*Zea mays* L.) is an important annual cereal crop grown in the world and the second most important cereal crop in Nepal belonging to family Poaceae.

Maize is a principal crop of farmers of hilly regions, 86% maize production has been used for human consumption and is also an important source of animal feed for feed industries of terai as 80% maize production in the terai is used for poultry and animal feed (Gurung et al., 2011; KC et al., 2015).

Maize covers about 29% of total cultivated area of Nepal i.e. 900,288 hectares area out of 3.09 million ha. The total production of maize is about

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2.3 million tonnes with average productivity of 2.5t/ha. Demand for maize has been constantly increasing by about 5% annually in the last decades (Sapkota and Pokhrel, 2010). Productivity of maize (2.45t/ha) is not satisfactory as it has the potential to attain the yield of 5.7 t/ha in Nepal (MOAD, 2014; KC et al., 2015). FAW is mainly seen in tropical and subtropical regions and maize is the staple food for hills people of Nepal, production in mid hills which contributes highest in terms of area possess a great threat hence everyone should be concerned of management and control of fall armyworm before it does great damage to the crop fields.

1.1 Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Hexapoda
Class:	Insecta
Subclass:	Pterygota
Order:	Lepidoptera
Family:	Noctuidae
Sub Family:	Noctuinae
Genus:	<i>Spodoptera</i>
Species:	<i>frugiperda</i>

Source: Journal of Entomology and Zoology Studies

1.2 Identification

The female worm lays 100-200 eggs (on lower surface of leaf) and they are covered by scales from female stomach (Sharanbasappa et al., 2018). Larvae are green at first and turn brown and then black with time. It has 4 black dots forming a square on eighth segment of larvae (CABI, 2019). Mature larvae have an inverted "Y" shaped structure white in colour and when examined closely the epidermis of larva is rough and granular in texture (Prasanna et al., 2018, CABI, 2017b). The caterpillar has a dark head with three light yellow stripes down the back (CABI, 2020). Male moths have whitish patches at the lower outer edges (arrowed) while white with dark trimmings are seen on inner wings. Larvae have four pairs of fleshy abdominal pro legs in addition to the pair at the end of the body (CABI, 2020). Female moth is slightly larger than male moth (FAO, 2018). A full-sized caterpillar can be as long as a matchstick (4-5 cm) (CABI, 2019).

1.3 Damage

Constant fecundity of the pest at favourable condition is anticipated to result an adverse damage to the crops (Goergen et al., 2016). Depending on the growth stage of maize, fall armyworm larvae are found on young leaves, leaf whorls, tassels or cobs (Goergen et al., 2016). Larvae of fall armyworm being voracious in nature cause huge damage by defoliating host plant. First instar larvae scrape leaves and shows pin-hole symptoms like steam borer attack and windowpane feeding symptoms like European corn borer attack (Sisay et al., 2019). But in the later vegetative stages, damage results in skeletonized leaves and heavily windowed whorls (Goergen et al., 2016).

Both vegetative and reproductive structures of the plants are consumed by the larvae. 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). The damage caused by young larvae by feeding on young leaf whorls, ear and tassel sometimes leads to total yield loss (De Almeida Sarmiento et al., 2002). Although young leaf tissue is suitable for growth and survival of pest while in matured plants leaves tissue are unsuitable, so they feed on ear zone, on silk tissues etc (Pannuti et al., 2015). Nepal pose best climatic condition for pest establishment so, this pest could cause approximately 100% crop loss in maize if not managed with due consideration (CABI, 2019). Hruska and Gould reported that Fall Armyworm cause heavy damage on corn and yield losses of above 70% (Hruska and Gould, 1997).

2. MANAGEMENT PRACTICES

2.1 Cultural control

It is a key component of the FAW's pest management strategy. Winter kill by exposing larvae and pupae within the upper soil surface lowers the chance of incidence of the pest. Cultural regulation involves preventing late planting as the maize ears will be heavily infested by FAW than those from the early plantings (Bilbo, 2019). Intercropping and rotating maize with non-host crops such as sunflower and bean may also be helpful in minimizing the FAW invasion (FAO, 2018). For the control of FAW, International Maize and Wheat Improvement Centre (CIMMYT) is looking for the efficient effect of Push and Pull cropping system which is considered an important climate smart technology (Pradhan et al., 2019). CIMMYT has been using 2 plants namely Napier-grass (*Pennisetum purpureum*) and Silver leaf desmodium legumes (*Desmodium uncinatum*). From the research in control of Fall Army Worm in Kenya, Uganda and Tanzania studies have confirmed superiority of push-pull technology in control of FAW relative to other mixed cropping strategies (Hailu et al. in Press).

2.2 Physical control

Without effective monitoring activity successful implementation of integrated pest management is not possible. Pheromones and light traps are found effective in monitoring fall armyworm. Commonly used pheromones are sex pheromone and aggregation pheromones (Prasanna et al., 2018). Black light traps can also be used to capture adult moths (Hunt et al., 2001; Qureshi et al., 2006).

2.3 Mechanical control

Scouting for damage is especially important for this pest because it feeds rapidly and is very destructive. Hand picking of the egg masses during regular monitoring of the field helps to control the pest in small scale and has been proved somewhat successful (Rwomushana et al., 2018). In Ethiopia, 15% of the farmers practiced only handpicking for FAW management (Kumela et al., 2019).

2.4 Biological control

Metarhizium anisopliae and *Beauveria bassiana* have been proven effective against eggs and second – instar larvae of fall armyworm (Komivi et al., 2019). *B. bassiana* caused moderate mortality of 30% to second instar larvae and the egg mortalities caused by *M.anisopliae* was 79.5-87.0% under laboratory conditions. *Spodoptera frugiperda* Multiple Nucleo Polyhedro Virus (SfMNPV), use of predatory insects and parasitic wasps (parasitoids), use of genetically modified crops containing Bt genes that produce proteins that are toxic to the larvae of FAW, mass trapping of male moths using pheromones, preventing them from mating (Day et al., 2017) are some of the important biological controls. The important predatory insects are earwigs, ladybird beetles, flower bugs, and ants (FAO, 2018).

2.5 Botanical and local control

The use of botanical pesticides is very important mostly in developing countries as it is a lot safer, cheap and environmentally friendly than the chemical pesticides which may result in disturbances in the environment, increasing user cost, pest resurgence and pest resistance to insecticides (Arya and Tiwari, 2013). There are many botanicals and among them, extracts of plants such as, *Milletia ferruginea*, *Azadirachta indica*, *Jatropha curcas*, *Nicotiana tabacum*, *Chrysanthemum cinerariifolium* and *Croton macrostachyus* have been proved to be successful to control insect pests (Jirnmci, 2013). A study reported that the larva of FAW had high mortality when seed cake extract of *A. indica* was used (Silva et al., 2015). A group researchers concluded that the *Argemone ochroleuca* (Papaveraceae) ethanolic extracts caused FAW larval mortality due to a reduction in feeding and slowed down larval growth (Martinez et al., 2017).

Nicotiana tabacum was reported to have highest larval mortality rate i.e. 66% and *Lippia javanica* (66%) by contact toxicity tests and highest larval mortality by feeding bioassay test was obtained when *L. javanica* (62%) and *N. tabacum* (60%) were used (Phambala et al., 2020). Many extracts from plants were used as a botanical insecticide but only few are commercialized and used widely and found to be effective. Azadirachtin (from neem) and pyrethrin (from pyrethrum) are the most widely used

products some other products are rotenone, garlic, nicotine, rianodine, quassia and so on (Isman, 1997). Some small holder farmers in America reported that use of ash, sand, sawdust, or dirt into whorls proved effective to control FAW larvae (FAO, 2018). Ash, sand, and sawdust kills larvae desiccating them. Use of lime, salt, oil, and soaps as control measures is practiced by maize growers in central America and Africa.

2.6 Chemical control

Fall armyworm can be controlled by applying synthetic insecticides (Blanco et al., 2014, 2010). Dry sand mixtures with trichlorfon (granules or powder), applied to whorls containing a plastic bottle are considered effective and widely used by smallholder farmers in Ethiopia and Kenya (Kumela et al., 2019). Chemical control is not at all economical in case of Fall Armyworm as frass of this insect may become so heavy that it can create a "plug" which reduces the effectiveness of insecticide and may not reach into the whorl where the larvae may be feeding (Day et al., 2017). However, it may be necessary if infestation is extremely severe and/or the plants are under stress. When 75% of the plant's whorl shows sign of feeding damage and larvae are less than 31 mm long, and the plants are under stress, insecticides may be advisable (CABI, 2019). Insecticides should not be applied at day time as the pest is nocturnal (Day et al., 2017). Emamectin benzoate 0.4gm/L, choranthraniprol 0.4ml/L, spinosad 0.3ml/L has been proved effective against FAW in Nepal (unpublished note). Threshold level are not still considered before jumping off to chemical control and this may lead to plant damage, resistance development and also risk to human and environment (Togola et al., 2018).

3. CONCLUSION

Fall army worm has the ability to breed rapidly, migrate, and feed on the wide range of host plants, all of which makes it very difficult to control. However, there are several ways of managing the pest as reported in other parts of the world that can potentially be adapted and/or validated and used in Nepal. 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. However, single control method is not sufficient to control this pest, integrated pest management strategies should be considered while fighting against this pest.

CONFLICT OF INTEREST

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

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