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Nature of Damage and its Management of Fall Armyworm (*Spodoptera frugiprda*) on Maize Crop: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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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 Madhya Pradesh at Research Farm RVSKVV, Gwalior of the August Month in2019-20. The *S. frugiperda* larval are found in newly leaves, leaves whorls, tasseling or cobs according to their growth stages. Scrape leaves, pin hole symptoms due to early larval stage and pane window symptoms whereas in the later vegetative stages due to larval of fall armyworm, damage results in skeletonized leaves and seriously windows whorls. Whereas weather condition for insects firm is good for pest could cause about 100% losses in maize crop but not control in the time.

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Normal investigation, push and pull method, light traps are used, common botanical pesticides are available of neem locally available materials of ash and several suggested chemical pesticides with dose can be used for the management of *S. frugiperda*. In present a vital requirement for development of eco-friendly environment, cost-effectively and collectively adopted IPM strategies to easily the impacts of the *S. frugiperda*.

Keywords: Maize; fall armyworm; nature of damage; management; Madhya Pradesh.

1. INTRODUCTION

"The fall armyworm, *S. frugiperda* (J. E. Smith) are found in order Lepidoptera and family Noctuidae also know as armyworm, *Spodoptera frugiperda*, it is polyphagous pests" [1,2]. "*Spodoptera frugiperda* is an insect native in tropical and subtropical areas of the America. The larval of fall armyworm feed on the leaves, stem and vegetative parts large than 100 crop species" [3]. Its emerged is sudden in Africa in early on 2016, whereas, first reported in central and western Africa [4] within a year fall armyworm was reported in most of Sub-Saharan Africa [5]. "It is economically pests are able of aggressive food security in the world" [6]. "*Spodoptera frugiperda* can be migrating to wide range in geographically areas" [6 and 7]. "It is one generation aggregation of adult moths can migrate more than 500kilometres (300 miles) with help of air current before they are ready for oviposition" [8-10]. "It is very extremely attacks on crop of graminae family *i.e.* Maize [11]. Larger than eight various host plant species are also initiate to be attacked by the pests" [12]. "This pest attack mainly whorl part of Maize crop and bore in the cobs of later stage of the crops which reduced the yield, quantity and quality of the maize crop" [13].

"Fall armyworm in India was first reported in the month of May 2018 on the maize field at CoA, UAHS, Shivamogga, Karnataka after than various state of India *i.e*. TN, AP, MH and Telengana in the crop of Sugarcane and Bihar, CG, Karnataka, Odisha, Gujarat and WB in the maize crop fields" [12]. "The maize a main crop of farmers of hilly areas production of 86 per cent has been used for consumption of human and animal feed for feed industries of tarai areas production of 80 per cent in the terai is used for poultry and animal feed" (Gurung *et al*., 2011) [14].

In India, Maize is the 3rd important food crops after than Rice and Wheat. In India production of 22.23 MT mainly during Kharif which covers 80% areas. In India contributes almost nine percent NFB. It is cultivated many ted throughout in the year in various state of the various country for various purposes of grain, green cobs, sweet, baby, pop corn and fodder in the Urban areas [15-23].

"The main growing states of contributes more than 80 per cent of the total production of maize crop are AP, Karnataka, Rajasthan, MH, Bihar, UP, MP and HP apart from these states maize is also grown in J&K and North-Eastern states. Therefore, the maize crop has appeared as main crop in the non-traditional areas i.e. peninsular in India as the state i.e. AP which ranks 5th in area and highest production (4.14 MT) and productivity (5.26 t ha-1) in the country although the productivity in some of the districts of AP is more or equal to the USA" [24]. Which supply most in terms of area possesses a great hazard hence everyone should be disturbed of control and management of *S. frugiperda.*

Systemic Position of FAW:

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: *Spodoptera*
Species: *frugiperda*

Identification of FAW: The adult female laid 100-200 eggs on the undesirable and upper side of the leaves and covered by silky scales from female stomach [7] and fecundity of more the 2000 eggs every one female. "Hatching period of 2 to 5 days in optimum whether condition. Fall armyworm larval are first green in colour after than black with four black dots forming a square on the last 8th segment on the larval" [12]. "The full mature larval seen an inverted "Y" shaped structure with white in colour on the head and when exanimate closely the epidermis of larval is rough and granular in texture" [10,3]. "The larval head dark in colour with three light yellowish bands down the back" [12]. "Caterpillar has four pair's false abdominal legs" [12]. "Adult female moth is Slightly larger than male" [25]. "A full

developed larval size 4 to 5 cm" [12]. "Pupation on Soil, cobs and plant debris with reddish brown in colour. Adult male moths are whitish patches at the lower outer edges while whitish with dark decoration are show on inner surface of wings" [26]. "The female forewings are less marking uniform range with grayish brown inn colour. In Larval of *S. frugiperda* was found of cannibalism and average mortility of 40 per cent when maize crops are infested with 2 to 4 stage of larval over a day period" (Chouhan *et al*., 2000). This insect pest larval highly active and fast feeding habitat and more damage of very few times.

Nature of damage: Regular fecundity of the pest at suitable for weather conditions are estimated to result adifficult damage to the maize crops [4], depended on the growth phase of the maize crop, larval are initiate on young on leaves, whorls portion of leaves, tasseling or cobs of maize crop [4]. Larvae are voracious in habitat causes vast injure by defoliating plant. The larvae of fall armyworm scrape green matter of leaves and showed pin head holes stem borer attack and pane windows feeding damaging symptoms of European corn borer attack [27,28-30]. But later stage of crop damage results in skeletonization on leaves and shows high windows symptoms of whorls portion of plant [4].

All plant portions are devoted by the larva of *S. frugiperda*. The full mature stage of larval found in the whorls of later host plants can feed cob or kernels on maize crop, reduced yield, quality and quantity of host plant [5,31]. While young leaves tissue is appropriate for survival and development of insect pest of maize whereas unsuitable of mature crop stage of host plant [32].

In Nepal pose favorable weather conditions for pest development so, it is pest might cause average 100 per cent loss in maize crop it is not managed [12]. Hruska and Gould recorded *S. frugiperda* highly damage cause on maize crop and heavy yield losses up to 70 per cent [33].

2. CONTROL METHODS OF FALL ARMYWORM

Scouting and method employed to scout effectively: The first showed that the seedling phase of maize. At nursery to start early whorl phage of the host plant (3-4 weeks after appearance). Act can be taken if 5 per cent hosts are damaged. At middle whorl portion to late whorl portion phase (5-7 weeks after appearance) - Act can be taken condition 10 per cent whorls are newly damaged in middle whorl phase and 20 per cent whorl damaged in later whorl phase, on tassels and post tassels (silking phase or milky stage of the crop) - Do not used chemical insecticides. However 10 per cent cobs damaged require several eco-friendly action (collection and destruction of egg or larvae) [34].

Cultural: It is a major component key of the fall armyworm management strategy. In winter killed by exposing larval or pupal with the upper soil surface and lowers the chance of incidence of the fall armyworm [35-39]. A mechanical and cultural practice engage preventing later planting of host plant cobs are highly infested due to fall armyworm than the early stage of planting [40]. Intercropping of maize and crop rotation recommended minimizing infestation of fall armyworm [25]. "The managed fall armyworm CIMMYT is looks for the efficient effect method of Push and Pull cropping system which it is measured a vital climate smart technology" (Pradhan *et al*., 2019). "CIMMYT are use two non host plant *i.e.* Napier-grass (*Pennisetum purpureum*) and Silver leaf Desmodium legumes (*Desmodium uncinatum*) from research control of fall armyworm in Kenya, Uganda and Tanzania cause study confirm superiority of push pull technology for managed of *S. frugiperda*. 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 relation to other any non host plant mixing cropping system strategies" ([41] in Press). "It is provided good soil health and adequate moisture is critical. They are necessary to sown healthy host plant material, which can improved withstand pests infestation and damage" [34,42-44].

Physical: Continuous of monitoring of the pest activity successful achievement of IPM is not possible. Setting light and pheromones traps are found most effective in pest monitoring, Mass traping and mating disruption techniques of *S. frugiperda* [10]. "When the last instars were irradiated with 200 Gy, the population rate was reduced to 30% and adult emergence was reduced to 10% and all of the adults that emerged were deformed, unable to fly and died after about 2 h. Therefore, irradiation with 200 Gy is recommended as the appropriate dose for phytosanitary irradiation of FAW eggs and larvae, this research was conducted with last instars larvae with the understanding that a dose that controls last instars will control the preceding

instars and the eggs. Use of black light traps can also be used to capture adult moths of fall armyworm" (Hunt *et al*., 2001; Qureshi *et al*., [45]).

Mechanical: "Investigation for damage is special important for this pest because it feed rapid and highly destructive. Hand picking of the egg masses during regular monitoring of the field helpful to manage the pest population in small scale and has been proved somewhat successful" [46]. "In Ethiopia, 15 per cent of the farmers practiced only handpicking for fall armyworm control" [47]. Setting of 5 pheromone traps/ acre and installation of one light trap/ ha during night hours to monitoring the adult moth activity in and around maize fields. Used15 pheromone traps per acre for mass trapping of the pest [34] and effective management of fall armyworm of maize crop field, the farmers are advised to installation fifty pheromone traps per hectare and lure will be changed after forty days according to [48,49,50].

Botanical: Use of botanical insecticides are mostly in developing countries it is very safer, cheap and eco-friendly than the insecticides but may result in effect of weather conditions, costly, resurgence and pest resistance against pesticides [51]. Many botanical insecticides are used for pest control like *Milletia ferruginea*, Neem products, Jatropha, Tobacco, Sawanti, Custared apple seed and *Croton* proved to be successful to insect pests management [52]. Similarly the larval of fall armyworm had high mortality when NSKE was used (Silva *et al*., 2015). A group researchers completed that the *A. ochroleuca* (Papaveraceae) ethanolic extracts caused fall armyworm mortality due to a reduction in feeding and slowed down larval growth (Martinez *et al*., 2017).

"Tobacco extract 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 Tobacco (60%) were used" [53]. "Many plant extracts were used as a botanical insecticide but only few are commercialized and widely used and found to be effective. Neem products and pyrethrum are the very most important widely used products some other products are rotenone, garlic, nicotine, rianodine, quassia and so on" [54]. "Small holder farmers in America use of ash, sand, sawdust or dirt into plant whorls part proved effective management of larval of fall armyworm" [25].

Biological: "Use of entomopathogenic fungus of *Metarhizium anisopliae* and *Beauvaria bassiana* effective against eggs and second – instar larval of *S. frugiperda"* (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. Use of SfMNPV and use of predatory insects and parasitic wasps (parasitoids), use of genetically modified crops containing bacteria of *Basillus thuringensis* genes that produce proteins that are toxic to the larval of fall armyworm [5] are some of the important biological controls. "Used of important predatory insects are *Chrysoperla*, lady bird beetles, flower bugs and ants" [8]. In situ protection of natural enemies by habitat management: increase the plant diversity by intercropping with pulses and ornamental flowering plants which help in buildup of natural enemies. Eggs, larval and pupa of fall armyworm are attacked by several species of parasitoids. Release of egg parasitoids *Telenomus sp* and *Trichogramma sp* are recommended for many countries. Augmentative release of *Telenomus rumus* and *Trichogramma pretisomon* @ 50,000 per acre at weekly intervals [34].

Use of effective control of fall armyworm on maize crop, the farmers are advised to Spray of three sprays of *B. bassiana* 15 WP (2×10^6 cfu/g) @4 kg or *Nomuraea rileyi* 1.15 WP (2×10^6 cfu/g) @ 3 kg + *Sf*NPV 450 LE 1 litfirst at initiation of pest population and subsequent two sprays at 10 day interval [48]. Entomopathogenic fungal formulations suitable at 5 per cent damage in seedling to early whorl stage and 10 per centcob or tassel infesting with entomopathogenic fungal and Bacteria. Spray of *Metarhizium anisopiae@* 2.5-3 kg/ha or *Nomuraea rileyi* rice grain (1×10^8 cfu/g) @ 1-1.5 kg/in whorl application at 15-25 days after sowing and 1-2 sprays at 10 days interval of depending on pest infestation and bacteria *Bacillus thuringiensis* kurstaki @ 1.0 kg/ha or 400 g/ acre application [34].

Chemical: If seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 4 ml/kg seed for 2-3 weeks after germination [34]. To manage fall armyworm spray emamectin benzoate 5%SG @ 5 gm/10 litre of water or thiodicarb 75% WP @10 gm/ 10 litre of water or Spinectoram 11.7% EC @10 ml/ 10 litre of water first at initiation of pest infestation and second at 10 days interval m [48].

"Spodoptera frugiperda can be controlled by applying synthetic insecticides" (Blanco *et al*., 2014, 2010). "Chemical insecticides management is not at all economical in case of *S. frugiperda* as frass of this insect may become so highly 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" [5]. "But, it is essential extremely severe and/or the plants are under stress infestation. When 75 per cent of the whorl portion of host plants shows infestation sign due to feeding of fall armyworm and larval are smaller and the host plants are under stress, pesticides may be advisable" [12]. "Chemical insecticides not use at day time as the pest are nocturnal" [5]. "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). Spray of 5 per cent NSKE or *Azadirechin* 1500 ppm @ 5 ml per litre of water at first whorls of host plant in seeding to early whorls phase reduce the hatching per cent of freshly lay eggs of fall armyworm. Spray of emamectin benzoate @ 0.4 gm or thiamethoxam 12.6% + lamda cyhalothrin 9.5% EC @ 0.5 ml or chlorantraniliprole 5% SC @0.3 ml per litre of water to manage second and third instars larval stage at 2ndwindow of middle whorl to later whorl stage. Used of recommended poison baiting to manage later instars larval of fall armyworm at second whorl windows and prepared baiting mixture of 10 kg rice bran + 2 kg jiggery with 2-3 litre of water for 24 hrs to ferment and add 100 gm thiocarb just half an hour before applied in the maize field crop. Pesticides control measured not cost effective at third window stage of eight weeks after appearance to tasseling and post tasseling stage of the host plant crop. Advised for farmers' use of hand picking of the larvae of fall armyworm in maize field. All the insecticide spraying should be directed towards whorls and either in the early hours of the day or in the evening time [34].

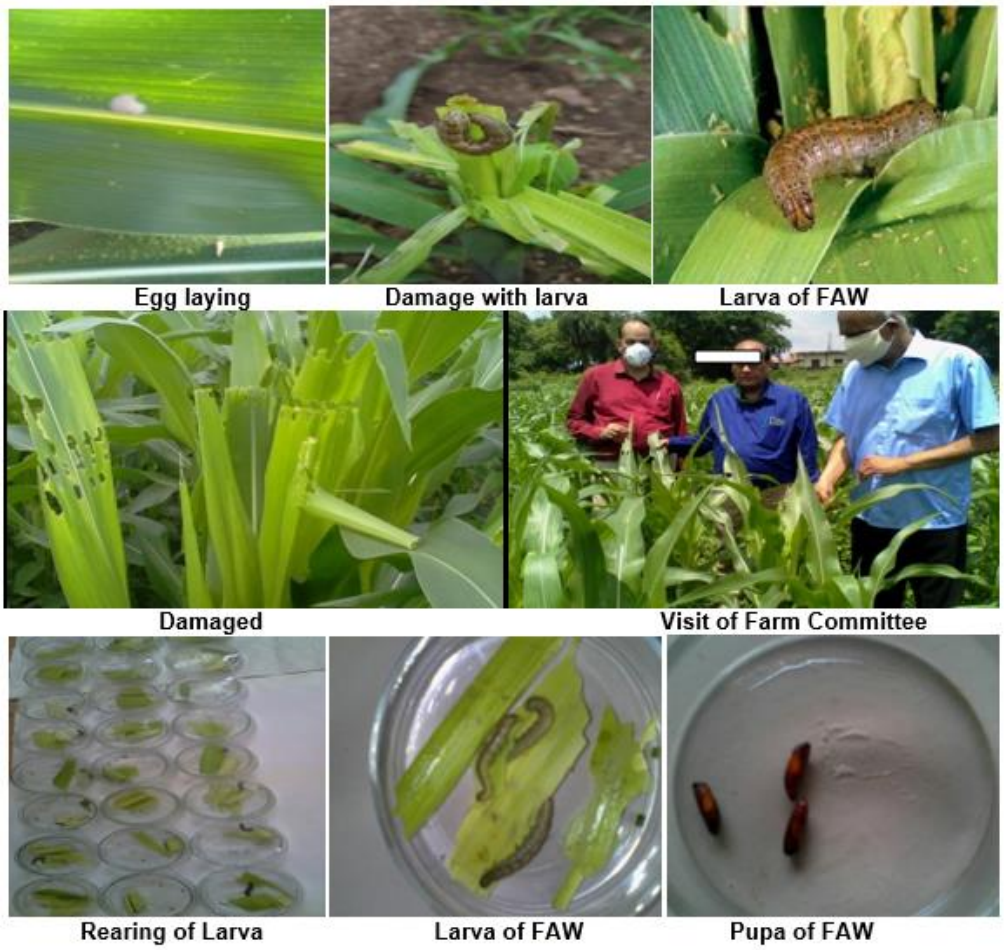

Plate 1. Culture of *Spodoptera frugiperda and observation of damage in maize crop*

3. CONCLUSION

Spodoptera frugiperda has the capability to breed very fast, migration and feeding on the wider host plants, it is very difficult to control measures. But, there are many traditions of managing the pest population as reported in other parts of the world that can potentially be adapted or validated and used in Madhya Pradesh. While the loss estimation of the pest infestation in Madhya Pradesh is not calculated yet (CIMMYT) has been working to managing the pest population in Madhya Pradesh through evaluation of intercropping strategy in which soybean is cultivated with maize crop. However, single control method is not sufficient to control this pest population; IMP strategies should be considered while fighting against this pest population infestation it is not published research work.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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