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Biological Control Approaches Against the Invasive Pest, Fall Armyworm, Spodoptera frugiperda in Maize

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ABSTRACT

Fall Armyworm, *Spodoptera frugiperda* (J. E Smith) (Noctuidae, Lepidoptera) is a native pest to North and South America. It was reported out of its native region from Africa in 2016. Since then, FAW has invaded most of Africa and parts of the Middle East, Asia, and Australia. Their biological parameters, *viz.,* strong flying capacity, climate adaptability, and wide host range, make them a better colonizing agent than other species of armyworms. In India, it was reported in 2018 and has emerged as a key pest, dominating the existing pests within the span of 2–3 years. It has also become a threat to food security as it could also attack the other key food crops, *viz.,* rice, sorghum, soyabean, cotton and vegetables. Lack of larval diapause and the rapid development of resistance to insecticides and Bt toxins are also alarming factors. Hence, it is not an easy job to tackle the FAW with a single intervention. Many countries have realized that the integrated use of numerous viable management options is of greater importance than the intensive use of a single tactic. Integrated pest management (IPM) programmes targeting the FAW were formulated, emphasizing the utilization of biocontrol agents and bio-pesticides.

BACKGROUND

However, biocontrol agents and biopesticides have become the most sustainable and cost-effective options under the current IPM framework. Repeated application of chemicals may develop resistance, in addition to the growing number of health concerns for human, animal, and environmental life. Further, most of the small-holding farmers cannot afford to bear the cost of expensive insecticides. Hence, there is a strong urge to promote biocontrol against the major pests of crops, including fall armyworm. Since the introduction of FAW into India, there has been an extensive search and rigorous study for documenting and using the indigenous predators, parasitoids, and entomothogens of FAW through various ICAR institutes and state agricultural universities. In this article, an attempt was made to consolidate available information on natural enemies and conservation and utilisation programmes of important biocontrol agents of the FAW in maize.

NATURAL ENEMIES OF FALL ARMYWORM

Following its first report of FAW in India, many researchers documented the different natural enemies of FAW in the different regions of India. In this article we have provided the comprehensive list of natural enemies of FAW in Table. 1. Further, several new additions may be included in the near future as the natural enemy complex of FAW expands. The occurrence of these natural enemies may vary with geographical location, the season of the crop, the year of the study, and the agronomic practices of the farmers.

Table 1. Enlist of Different Natural Enemies Against Fall Armyworm

Sl.No.	Natural Enemy Name	Family	Order	Host stage affected
		Predators		
i.	*Forficula* sp.	Forficulidae	Dermaptera	Egg, larva
ii.	*Harmonia octomaculata*	Coccinellidae	Coleoptera	Egg, larva
iii.	*Coccinella transversalis* (Fabricius)	Coccinellidae	Coleoptera	Egg, larva
iv.	*Eocanthecona furcellata Wolff*	Pentatomidae	Hemiptera	Larva
v.	*Andrallus spinidens* (Fabricius)	Pentatomidae	Hemiptera	Larva
vi.	*Podisus maculiventris* (Say)	Pentatomidae	Hemiptera	Larva
vii.	*Cosmolestes* sp.	Reduviidae	Hemiptera	Larva
viii.	*Ropalidia brevita* Das & Gupta	Vespidae	Hymenoptera	Larva
ix.	*Polistes cf. olivaceous* (De Geer)	Vespidae	Hymenoptera	Larva
x.	*Rhene flavicomans* Simon	Alticidae	Arenae	Larva
xi.	*Marpissa* sp.	Salticidae	Arenae	Larva
xii.	*Oxyopes birmanicus* Thorell	Oxyopidae	Arenae	Larva
xiii.	*Lycosa* sp.	Lycosidae	Arenae	Larva
		Parasitoids		
i.	*Telenomus remus* Nixon	Platygastridae	Hymenoptera	Egg
ii.	*Trichogramma chelonis* Ishii	Trichogrammatidae	Hymenoptera	Egg

iii.	*Chelonus* spp.	Braconidae	Hymenoptera	Egg-Larva
iv.	*Chelonus formosanus* Sonan	Braconidae	Hymenoptera	Egg-Larva
v.	*Chelonus blackburni* (Cameron)	Braconidae	Hymenoptera	Egg-Larva
vi.	*Glyptapanteles creatonoti* (Viereck)	Braconidae	Hymenoptera	Larva
vii.	*Cotesia ruficrus* (Haliday)	Braconidae	Hymenoptera	Larva
viii.	*Aleiodes* sp.	Braconidae	Hymenoptera	
ix.	*Microplitis manilae* (Ashmead)	Braconidae	Hymenoptera	Larva
x.	*Coccygidium transcaspicum* (Kokujev)	Braconidae	Hymenoptera	Larva
xi.	*Phanerotoma* sp.	Braconidae	Hymenoptera	Larva
xii.	*Campoletis chlorideae* Uchida	Ichneumonidae	Hymenoptera	
xiii.	*Eriborus* sp.	Ichneumonidae	Hymenoptera	Larva
xiv.	*Metopius rufus* Ashmead	Ichneumonidae	Hymenoptera	Larva-Pupa
xv.	*Netelia* sp.	Ichneumonidae	Hymenoptera	Larva
xvi.	*Ichneumon promissorius* (Erichson)	Ichneumonidae	Hymenoptera	Larva
xvii.	*Exorista sorbillans* (Wiedemann)	Tachnidae	Diptera	Larva
xviii.	*Exorista xanthaspis*	Tachnidae	Diptera	Larva
xix.	*Odontepyris* sp.	Bethylidae	Hymenoptera	Larva
Entomopathogens				
i.	*Metarhizium*(=Nomuraea) *rileyi* (Farlow) Samson	Hypocreales	Claviceptaceae	Larva
ii.	*Metarhizium anisopliae* (Metschn.) Sorokin	Hypocreales	Claviceptaceae	
iii.	*Beauveria bassiana* (Balsamo) Vuillemin	Hypocreales	Cordycipitaceae	Larva, Pupa
iv.	*Spodoptera frugiperda* Nuclear Polyhydrosis Virus (SpfrNPV)	Lefavirales	Baculoviridae	Larva, Pupa
v.	*Bacillus* sp.	Bacillales	Bacillaceae	Larva
vi.	*Hexamermis* cf. *albicans* (Siebold)	Mermithida	Mermithidae	

CONSERVATION OF NATURAL ENEMIES OF FAW

FAW has many naturally occurring natural enemies. However, certain non-selective pest management practices are interfering with the ecological services being provided by these natural enemies. Further, due to the significant effort and financial support required in the establishment of mass rearing facilities, mass production and release of effective natural enemies are limited to some degree of field usage. As a result, conservation practices specific to natural enemies that may be adopted at the farmer's field level are highly desired. Habitat manipulation and selective use of insecticides are two broad aspects of conservation biocontrol.

With the increase in crop diversity on the same piece of land through intercropping, mixed cropping, strip cropping, etc., the microclimate of the crop can be modified to enhance the survival and growth of natural enemies and reduce pest incidence.

Vegetable, legume, and flower crop-based intercropping was tested against the FAW at many locations. Studies revealed that french bean, lablab, okra, spinach, cowpea, and coriander were the best options to use at 1:1 or 1:2 ratios in maize. Legume crops are also viable options to intercrop with maize. Apart from their role in pest management and providing additional income, they restore soil fertility through nitrogen fixation. Desmodium, broad bean, groundnut, and soyabean are found to attract more natural enemies of FAW than other crops. Now a days, the scientific community is widely popularizing the concept of the "push-pul" strategy. It is a habitat management system in which a repellent crop or attractive trap crop is grown to repel pests and attract natural enemies. In Africa, this strategy was popularized to manage the stemborers of maize, utilizing the Napier grass and Sudan grass as trap plants, whereas molasses grass and desmodium were used as repelling plants. In India, Napier grass and Sorghum are found useful as trap crop, whereas desmodium or any other legume crop is used as an intercrop. The growing of marigold (intercrop) and napier grass (Boarder crop) is gaining popularity due to the poor establishment of desmodium crops in field conditions.

UTILIZATION OF NATURAL ENEMIES OF FAW

Among the documented species, two major egg parasitoids (*T. chilonis* and *T. remus*) and two egg-larval parasitioids (*C. formosanus* and *C. blackburni*), two larval parasitoids (C. *chlorideae and Coccygidium spp.), three entomopathogens* (*M. rileyi*, *M. anisopliae, Beauveria bassiana, Bacillus thuringiensis* and SpfrNPV), are reported as effective biocontrol agents of FAW in India. Field Efficacy levels of the prominenet biocontrol agents may vary based on potency of strains or isolates, location, crop season and environmental factors. In addition to these biocontrol agents and biopesticides, Entomopathogenic nematodes are also reported to reduce the FAW damage. The Potential of EPN, of *Heterorhabditis indica* NBAII Hi101, was proven and verified by ICAR-NBAIR researchers, and its efficacy was equivalent with Emamectin benzoate and chlorpyrifos, with a 60-72% reduction in FAW incidence. In India, different FAW specific package of packages were formulated with minor changes in the IPM components. However, most of them were emphasized the use of the combination of tactics, viz., installation of pheromone traps, four releases of T. *pretiosum/chilonis* (to kill the eggs) at weekly interval, spraying of neem oil at the egg laying time and one or two sprays of any biopesticides i. e *B. thuringiensis*, *M. anisopliae*, *B. bassiana* or *H. indica* targeting the early to mid-aged larva.

CONCLUSION

Knowing the potential of the FAW, the scientific community, in collaboration with other stakeholders, announced the fight against the FAW from 2018 to 2022. It has resulted in the successful tackling of FAW in all the maize growing areas of India. Since FAW is an invasive species with a broad host range, we must monitor the dynamics of the pest and its reaction to the management strategies already in place. To fight against the FAW, there is a long way to go, and biocontrol will undoubtedly play a major role in tackling this noxious pest.

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