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Research Article

Record of natural enemies of invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in fodder maize ecosystem in Goa

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ABSTRACT: Fall Armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), a recent invasive pest, poses a serious threat to maize production and productivity in India. Very little information is available on FAW indigenous natural enemies in authors are ecosystems. Hence, the present study assessed and documented the native natural enemies of FAW in the fodder maize ecosystem of Goa. Under field conditions, various life stages of FAW were attacked by 22 species of native natural enemies comprising two egg parasitoids, five larval parasitoids, eleven predators, and four entomopathogens. The field egg parasitism of *Trichogramma chilonis* Ishii and *Telenomus remus* Nixon was 13.90% and 29.37%, respectively. Among the egg parasitoids, *T. remus* was the dominant one. With a parasitism rate of 6.58%, *Campoletis chlorideae* Uchida was the most prevalent larval parasitoid. Eleven different species of predators were found predating on FAW. Among the predators, the rove beetle, *Paederus fuscipes* Curtis was the most abundant, with 1-2 adults per plant. Four entomopathogens *viz*., *Metarhizium rileyi* (Farlow), *Bacillus* sp., *Spodoptera frugiperda* nuclear polyhedrosis virus, and entomopathogenic nematode, *Hexamermis* sp. were found infecting the FAW larvae. The present study reports the indigenous natural enemies associated with FAW in fodder maize. These native natural enemies must be conserved and exploited for the biological control of FAW.

KEYWORDS: Fall Armyworm, fodder maize, natural enemies, entomopathogens, Goa

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INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) has emerged as a significant threat to maize cultivation in India. The endemic pest in the Americas was first reported in India in 2018 (Sharanabasappa *et al*., 2018). It has quickly spread across the maize-growing states of India and caused a 21 to 53% yield loss. FAW damage incidence varied from 16 to 52% on fodder maize (Maruthadurai & Ramesh, 2020). To safeguard the maize against FAW attack, farmers mostly rely on insecticide applications. The rampant and excessive use of insecticides has serious adverse effects on the environment, human and animal health, and insecticide residue. There have been several reports of cattle deaths in western Maharashtra due to pesticide residue in green fodder maize (Times of India, 2019). Fodder maize is used as fresh feed for livestock and silage-making. So, it is necessary to keep the fields untreated from harmful pesticides to control FAW and follow other non-chemical measures. Biological control agents are environment-friendly and safe to use and provide sustainable management solutions for insect pests. Native natural enemies of lepidopteran pests may adopt and regulate the spread of FAW. Several parasitoids, predators and entomopathogens were reported from India that cause significant mortality of FAW (Sharanabasappa *et al*., 2019; Firake & Behere, 2020). Since, FAW is a recent invasive pest in India, very little information is available on local natural enemies in different ecosystems. Information on local natural enemies is crucial to develop biological control-based management strategies for FAW. Hence, the present study was formulated to record the native natural enemies of FAW and their abundance and parasitism rates in the fodder maize ecosystem under Goa conditions.

MATERIALS AND METHODS

Field experiments were conducted during the *Kharif* and *Rabi* seasons 2020-2021 at ICAR – Central Coastal Agricultural Research Institute, Old Goa (15° 29' N, 73° 55' E). The experiment was conducted in an area of 0.75 acres with an individual plot size of 6 m × 5 m.

Fodder maize variety African tall was sown with a spacing of 50 cm between the row and 30 cm between the plants. All the necessary agronomic practices like weeding, and fertilizer applications were carried out for the better

growth of the plant, but to record the natural enemy complex of FAW, the field was kept untreated with any pesticides throughout the cropping period.

A weekly collection of FAW egg masses, larvae, and pupae was carried out from the experimental field from July 2020 to September 2020 and from February 2021 to April 2021.

To estimate the egg number per mass, hairs on the egg mass were gently removed by an entomological brush. Individual numbers of eggs were visually counted layer by layer under the Stereozoom microscope (Model, Leica S8APO). Further, the counted egg masses were observed until the number of parasitoids that emerged per egg mass was recorded and identified. The per cent parasitization of eggs was calculated with the following formula.

$$\text{Parasitization percentage} = \frac{\text{Number of parasitized eggs}}{\text{Total number of eggs}} \times 100\%$$

Field-collected larvae and pupae were individually kept in a circular polystyrene insect breeding dish (Dimension: 90 × 40 mm, Ventilation mesh hole: 40 mm) with fodder maize leaf bits as feed. Fresh feed and the dishes were changed daily, and this rearing process continued until pupation. Larvae and pupae were continuously observed for the emergence of parasitoids and entomopathogenic nematodes. Emerged larval, pupal parasitoids and parasitic nematodes were preserved in 70% ethanol and taxonomically identified. Manual collection and photographic observation were carried out every week to record the predators, entomopathogens, and their abundance in the field.

RESULTS AND DISCUSSIONS

A total of 22 species of native natural enemies comprising two egg parasitoids, five larval parasitoids, eleven predators and four entomopathogens were found attacking various life stages of FAW during both *Kharif* and *Rabi* seasons of 2020-2021 (Table 1). Two egg parasitoids emerged from the egg mass and were taxonomically identified as *Trichogramma chilonis* Ishii and *Telenomus remus* Nixon (Figure 1). The field egg parasitism of *T. chilonis* and *T. remus* was 13.90 % and 29.37%, respectively. Our results indicate that *T. remus* was a major egg parasitoid of FAW under the fodder maize ecosystem. The present results are in agreement with recent studies conducted by Keerthi *et al*., (2023). They revealed that *T. remus* was the dominant egg parasitoid which naturally parasitized the FAW eggs, and the parasitism rate varies from 0-23.48%. The egg parasitoid *Telenomus* sp. was found to

Table 1. List of recorded natural enemies of *Spodoptera frugiperda* in fodder maize ecosystem

S. No.	Name of the natural enemies	Order and family	Host stage	Percentage Parasitism/ Number per plant
Parasitoids				
1	*Trichogramma chilonis* Ishii	Hymenoptera: Trichogrammatidae	Egg	13.40
2	*Telenomus remus* Nixon	Hymenoptera: Platygastridae	Egg	29.37
3	*Campoletis chlorideae* Uchida	Hymenoptera: Ichneumonidae	Larval	6.58
4	*Exorista sorbillans* (Wiedemann)	Diptera: Tachinidae	Larval	0.2
5	*Megaselia scalaris* (Loew)	Diptera: Phoridae	Larval	0.1
6	*Chelonus formosanus* Sonan	Hymenoptera: Braconidae	Egg-larval	1.24
7	Larval parasitoid (unidentified)	Hymenoptrea	Larval	0.001
Predators				
1	*Paederus fuscipes* Curtis	Coleoptera: Staphylinidae	Eggs and larvae	1-2
2	*Forficula* sp.	Dermaptera: Forficulidae	Eggs and larvae	0.5-1
3	*Rhynocoris fuscipes* Fabricius	Hemiptera: Reduvidae	Larvae	0-1
4	*Eucanthecona fursellata* Wolff	Hemiptera: Pentatomidae	Larvae	0.2-1
5	*Chelomenes sexmaculata* [F]	Coleoptera: Coccinellidae	Eggs and larvae	1-2
6	*Coccinella transversalis* Fabricius	Coleoptera: Coccinellidae	Eggs and larvae	0.5-1
7	*Micraspis discolor* [F]	Coleoptera: Coccinellidae	Eggs and larvae	1-2
8	*Anegleis cardoni* [F]	Coleoptera: Coccinellidae	Eggs and larvae	0.5-1
9	Carabid beetle	Coleoptera: Carabidae	Larvae	0.2-0.5
10	Predatory wasp	Hymenoptera: Vespidae	Larvae	0.5-1
11	*Oxyopes* sp.	Arenae: Oxyopidae	Larvae	1-2
Entomopathogens				
1	*Metarhizium rileyi* Farlow	Entomopathogenic fungus	Larvae	1-2
2	Nuclear Polyhydrosis Virus (NPV)	Entomopathogenic virus	Larvae and pupae	0.01
3	*Bacillus* sp.	Entomopathogenic bacteria	Larvae	2-3
4	*Hexamermis* sp.	Parasitic nematode	Larvae	0.01

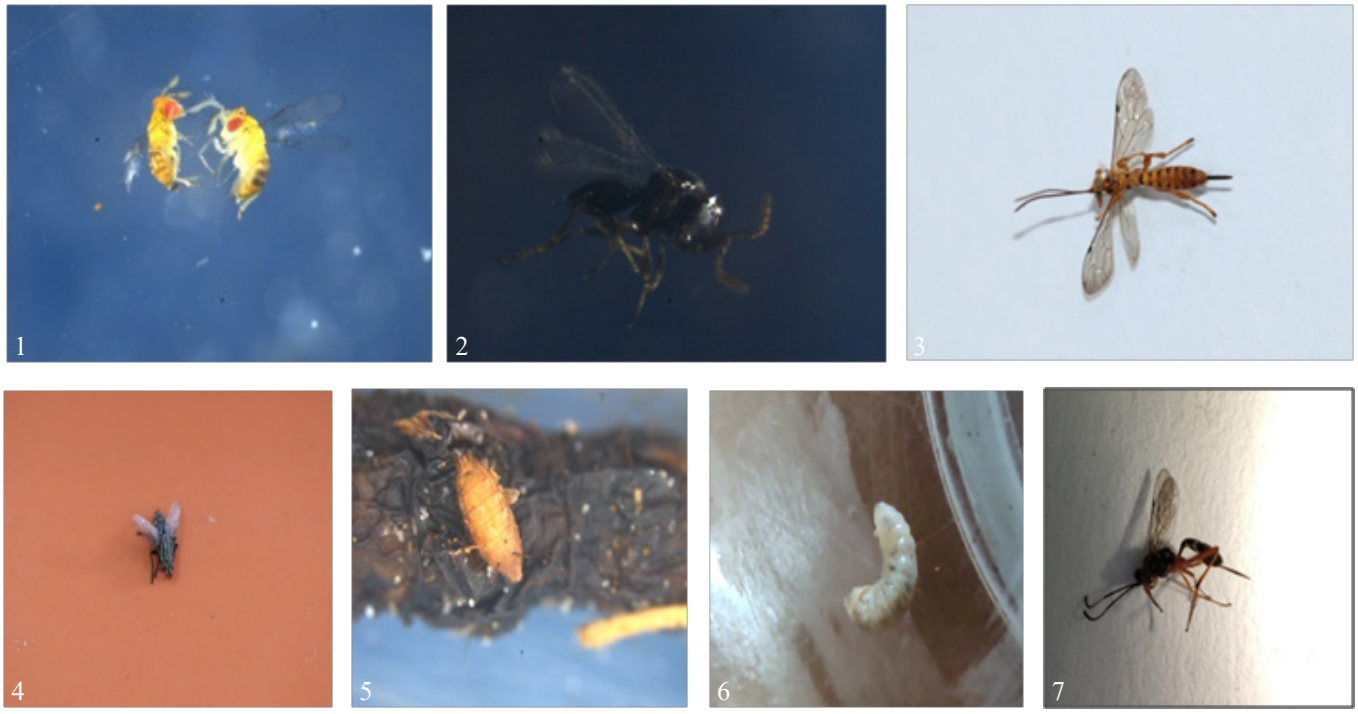

Figure 1. Parasitoids of FAW. **(1).** *Trichogramma chilonis* Ishii; **(2).** *Telenomus remus* Nixon; **(3).** *Campoletis chlorideae* Uchida; **(4).** *Exorista sorbillans* (Wiedemann); **(5).** Pupa of *Megaselia scalaris* (Loew); **(6).** Larva of *Chelonus formosanus* Sonan; **(7).** Larval parasitoid (unidentified).

be more dominant than *Trichogramma* sp. in parasitizing the FAW eggs, further recorded the highest and lowest parasitization of FAW eggs by *Telenomus* sp. was 63 % and 3 %, respectively (Wowor *et al*., 2021). The findings of the major egg parasitoid in the present study also differ from the results of Navik *et al*., (2021) who reported *T. chilonis* as a major egg parasitoid of FAW under rainfed maize in Karnataka. Among the larval parasitoids, *Campoletis chlorideae* Uchida was the most dominant parasitoid and recorded throughout the cropping period with 6.58% parasitism. Early instars FAW larvae were prone to parasitism by *C. chlorideae* (Navik *et al*., 2021). The egg larval parasitoid *Chelonus formosanus* Sonan was recorded with a parasitism rate of 1.24%. However, the egg larval parasitoid, *C. formosanus* was reported as the most abundant parasitoid of FAW (Firake & Behere, 2020; Jindal *et al*., 2021). The dipteran parasitoids, *Exorista sorbillans* and *Megaselia scalaris* were found with 0.2% and 0.1% parasitism, respectively. A negligible rate of parasitism by *E. sorbillans* against FAW larvae was reported by Sharanabasappa *et al*. (2019).

Eleven different species of predators were found predating on various stages of FAW (Figure 2). The most prevalent predator was the rove beetle *Paederus fuscipes* Curtis, which was found preying on FAW eggs and early instar larvae with 1-2 adults per plant. Adult rove beetles were mostly recorded at the whorls of fodder maize and their maximum abundance was found at the flowering phase of the crop. The results of the current study are in agreement with Rasheed *et al*. (2020). They have reported rove beetle was a potential natural enemy of FAW and their population varied from 5-7 number in maize in Chittoor district, Andhra Pradesh.

The other recorded generalist predators were earwig, *Forficula* sp., reduvid bug, *Rhynocoris fuscipes*, pentatomid bug, *Eucanthicona fursellata*, carabid beetle, predatory wasp, and spider, *Oxyopes* sp. A significant population of coccinellid predators, *Cheilomenes sexmaculata* [F.], *Micraspis discolor* [F.], *Anegeles cardoni* Weise and *Coccinella transversalis* [F.] were recorded and found predating on neonate larvae of FAW. Generalist predators like pentatomid, reduviid, rove beetle, earwigs and coccinellids were occasionally found feeding on FAW (Shylesha *et al*., 2018; Maruthadurai *et al*., 2022). Four entomopathogens were found infecting the FAW larvae (Figure 2). Around 1-3% larval mortality of FAW was recorded due to natural infection of *Metarhizium rileyi* (Farlow) and *Bacillus* sp. Entomopathogenic nematode, *Hexamermis* sp. and *Spodoptera frugiperda* nuclear polyhedrosis virus (SpfrNPV) were also found parasitizing the FAW larvae in fodder maize. More than 50% of FAW larvae were naturally infected by *M. rileyi*, baculovirus, and SpfrNPV (Firake & Behere, 2020). Entomopathogenic nematode, *Hexamermis* sp. caused significant mortality to the FAW. Under field conditions, the parasitism rates vary from 25.4% to 57.2% (Balde *et al*., 2022).

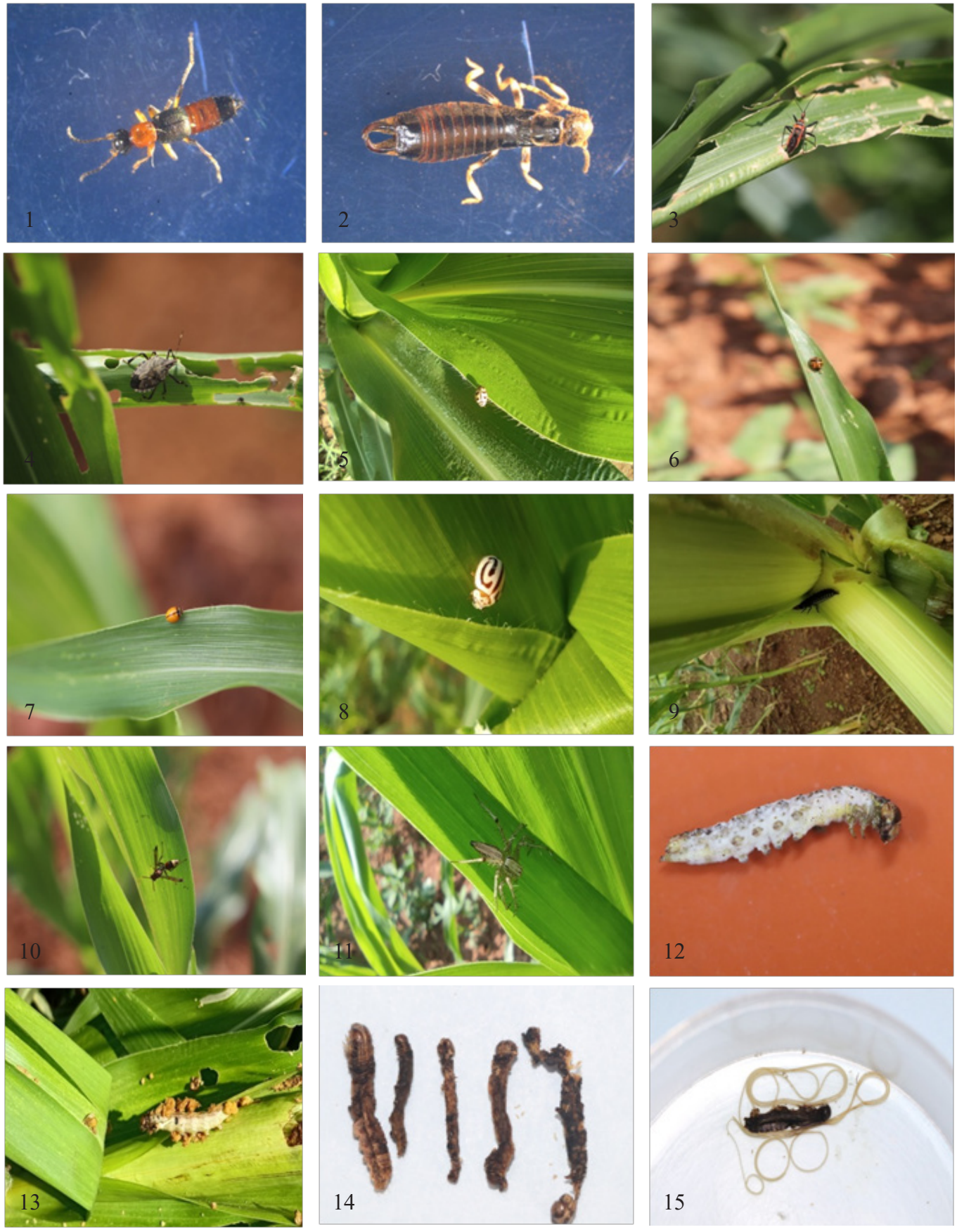

Figure 2. Predators and Entomopathogens of FAW. **(1).** *Paederus fuscipes* Curtis; **(2).** *Forficula* sp.; **(3).** *Rhynocoris fuscipes* Fabricius; **(4).** *Eucanthecona fursellata* Wolff; **(5).** *Chelomenes sexmaculata* [F]; **(6).** *Coccinella transversalis* Fabricius; **(7).** *Micraspis discolor* [F]; **(8).** *Anegleis cardoni* [F]; **(9).** Carabid beetle; **(10).** Predatory wasp; **(11).** *Oxyopes* sp.; **(12).** *Metarhizium rileyi* Farlow; **(13).** Nuclear Polyhydrosis Virus (NPV); **(14).** *Bacillus* sp.; **(15).** *Hexamermis* sp.

The identification and documentation of native bio-control agents will serve as a strong base to formulate a biological control-based integrated pest management programme for FAW. The present study reports the natural occurrence, parasitism rates, and abundance of 22 species of native natural enemies associated with FAW in the fodder maize ecosystem of Goa. These bio-control agents are safe to use, compatible with other management methods and very well fit into the organic cultivation of fodder maize. It is imperative to use, promote, augment, and conserve these local natural enemies for the biological control of FAW. Further, studies should be focused on mass production, field release, and evaluation of potential local bio-control agents against FAW.

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