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Natural enemies of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), a recent invasive pest on maize in South India

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The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), native to the Americas, is considered one of the important invasive polyphagous pests. It is prevalent in several countries such as Brazil, Argentina, and the USA (Prowell et al. 2004; Clark et al. 2007), instigating economic losses in a variety of crops such as maize, soybean, cotton, beans (Pogue 2002; Nagoshi et al. 2007; Bueno et al. 2010), rice, other grasses, and a number of weeds (Nabity et al. 2011). Because of its wide host range, *S. frugiperda* is one of the most harmful pests threatening annual crops in tropical regions (Andrews 1980; Cruz et al. 1999). Severe incidences of fall armyworm were reported from African countries such as Sao Tome, Nigeria, Benin, and Togo in 2016 (Goergen et al. 2016). The incursion of fall armyworm as an invasive pest into Asia was reported for the first time in India by Sharanabasappa et al. (2018), Ganiger et al. (2018), and Shylesha et al. (2018). Recently this pest has been widely reported in many parts of southern and northern India (Mahadeva Swamy et al. 2018). Other species of *Spodoptera*, such as *S. litura* (F.), *S. exigua* (Hübner), and *S. mauritia* (Boisduval), are major pests of several crops in India with a rich array of indigenous natural enemies. The native bioagents of *Spodoptera* spp. have an opportunity to expand their niche by parasitizing *S. frugiperda*, a closely related pest of foreign origin. It is highly probable that the local bioagents may widen their niche by adapting to *S. frugiperda*, and check its population buildup and further spread. Hence, there is a need to identify the existing natural enemies of fall armyworm in India, which could be used for its management in the future. This study was undertaken to document the natural enemies of fall armyworm, and to record their abundance from different locations in Karnataka and Tamil Nadu in southern India.

Surveys for the occurrence of *S. frugiperda* were conducted in different maize growing areas of Karnataka and Karur District of Tamil Nadu. An attempt was made at each site, e.g., Shivamogga, Davanagere, Chitradurga, Chikmagalur, Chamarajanagar, Bellary and Belagavi districts of Karnataka, to collect at least 100 larvae of different stages; however, greater numbers of larvae were collected in only a few loca-

tions. In the infested field, feeding injury in the leaf whorl and the presence of fresh frass were used to identify the infestation of *S. frugiperda* larvae. Larvae were pulled from the whorl and placed in a circular insect breeding dish (HiMedia TCP030, HiMedia Laboratories Pvt. Ltd., Mumbai, Maharashtra, India; 90 mm diam, 40 mm height) containing cut maize leaf bits, brought to the laboratory and maintained at 26 ± 2 °C, 75 to 80% relative humidity, and 12:12 h (L:D) photoperiod. These were observed for the emergence of parasitoids; parasitoids emerging from fall armyworm at different stages (larval and pupal) were preserved in 70% ethanol and later identified taxonomically. Larvae from 2 unsprayed maize fields were brought to the laboratory in 25 mL plexiglass vials, and reared individually in the laboratory until the emergence of the parasitoids. Observations were recorded on the number of adult parasitoids that emerged from larvae, and the percentage parasitization and sex ratio were calculated. For the entomofungal pathogens, numbers of field-infected larvae and total larvae were recorded and converted to percentage infection.

In total, we recorded 5 larval parasitoids, 3 predators, and 1 entomopathogenic fungus in our surveys (Table 1), of which 3 parasitoids, namely *Coccygidium melleum* (Roman) (Hymenoptera: Braconidae) (Fig. 1), *Odontepyrus* sp. (Hymenoptera: Bethyilidae) (Fig. 2), and *Eriborus* sp. (Hymenoptera: Ichneumonidae), are reported for the first time on *S. frugiperda* in the world. The single female specimen reared from *S. frugiperda* matched the description of *C. melleum* by Achterberg (2011). *Coccygidium melleum* is “common in the Afrotropical region (from South Africa up to Senegal and Somalia) and reaching Yemen and the United Arab Emirates” (Achterberg 2011), but it has not been recorded so far in the Indian subcontinent. *Coccygidium* spp. (Hymenoptera: Braconidae) are known to parasitize Noctuidae, including *Spodoptera* spp. (Achterberg 2011). Sisay et al. (2018) reported *Coccygidium luteum* (Brullé) (Hymenoptera: Braconidae) as a parasitoid of *S. frugiperda* in Ethiopia. Three species of *Coccygidium* (*C. luteum*, *C. melleum*, and *Coccygidium sissoo* [Wilkinson]) have been known to parasitize *S. exigua* (Hübner). This is the first report

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

Sl. No.	Scientific name	Family	Host stage	Place	Percentage parasitism number of predators per plant
1	<i>Coccygidium melleum</i> (Roman)**	Hymenoptera: Braconidae	Endo larval parasitoid	Karnataka: Davanagere: Honnali; 29.VI.2018	0.001
2	<i>Campoletis chlorideae</i> Uchida	Hymenoptera: Ichneumonidae	Endo larval parasitoid	Davanagere: Honnali; 29.VI.2018	2-4
3	<i>Eriborus</i> sp.**	Hymenoptera: Ichneumonidae	Endo larval parasitoid	Davanagere: Honnali; 29.VI.2018	0.001
4	<i>Odontepyrus</i> sp.**	Hymenoptera: Bethyloidae	Larval parasitoid	Tamil Nadu: Karur: Kulithalai; 20.VIII.2018	0.001
5	<i>Exorista sorbillans</i> (Wiedemann)	Diptera: Tachinidae	Endo larval parasitoid	Chitradurga: Basapur; 19.VII.2018	0.001
6	<i>Forficula</i> sp.	Dermaptera: Forficulidae	Predator	Karnataka: Shivamogga; 18.VI.2018	1-2
7	<i>Harmonia octomaculata</i> (Fabricius)	Coleoptera: Coccinellidae	Predator	Karnataka: Shivamogga: Muttodu; 25.VI.2018	0.5-1.00
8	<i>Coccinella transversalis</i> Fabricius	Coleoptera: Coccinellidae	Predator	Karnataka: Shivamogga: Muttodu; 25.VI.2018	0.5-1.00
9	<i>Nomuraea rileyi</i> (Farlow) Samson	Ascomycota: Clavicipitaceae	Entomo-pathogen	Shivamogga, Badravati: Kudarekonda, 18.VII.2018, Sogalu, Honnali; Davanagere 25.VIII.2018	10-15

**First report from India

of *C. melleum* as a parasitoid of *S. frugiperda* in the world. We recorded 2 more larval endoparasitoids, *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae) and *Eriborus* sp. on *S. frugiperda* in Karnataka. The extent of parasitism by *C. chlorideae* was 2 to 3% in 2 untreated maize fields monitored at Shivamogga and Davanagere districts of Karnataka. Shylesha et al. (2018) also recorded it on *S. frugiperda*. *Campoletis chlorideae* and *Eriborus argenteopilosus* (Cameron) (Hymenoptera: Ichneumonidae) are responsible for the regulation of 2 major noctuid pests in India, *S. litura* and *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae). Both parasitoids attack the host larvae in the first or second instar stage (Bajpai et al. 2006). About 6 species of *Campoletis* have been known to parasitize *S. frugiperda* in the Americas and the Caribbean (Molina-Ochoa et al. 2003). Species of *Odontepyrus* are known to be ectoparasitoids of lepidopteran larvae belonging to Noctuidae, Pyralidae, Oecophoridae, and Tortricidae (Lim & Lee 2013), and this is the first report of it as a parasitoid of *S. frugiperda*. We recorded negligible levels of parasitism of fall armyworm by a tachinid, *Exorista sorbillans* (Wiedemann) (Diptera: Tachinidae). Predators such as earwigs and coccinellids (*Harmonia octomaculata* [F.] and *Coccinella transversalis* [F.]) (both Coleoptera: Coccinellidae) also were found to be active in fall armyworm infested maize fields in the surveyed locations. *Harmonia octomaculata* and *C. transversalis*, which were found to be abundant in fall armyworm infested maize fields, may play a significant role in controlling the early stage larvae. Various larger species of Coccinellidae attack caterpillars and other beetle larvae (Hodek et al. 2012), and several genera feed on various insects or their eggs. For instance, in India, *Micraspis vincta* (reported as *Veraniavincta*) (Coleoptera: Coccinellidae) was found feeding on the egg masses of *S. litura* on a groundnut crop (Rajasekhara Rao 1997), and *S. exigua* on an onion crop (Subba Rao 1998; Sailaja Rani 2004). *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) is known to feed on eggs and larvae of *S. exigua* in China (Liu et al. 2016), and *Coccinella* sp. is a predator of *S. exigua* in Vietnam (Chau 1995). Shylesha et al. (2018) recorded earwigs (*Forficula* sp.) (Dermaptera: Forficulidae) as predators of fall armyworm on maize. The entomofungal pathogen *Nomuraea rileyi* (Clavicipitaceae), was found to be associated commonly with fall armyworm and caused 10 to 15% larval infection in August.

The present study reports new associations of natural enemies with fall armyworm in India. A wide range of parasitoids has been recorded on fall armyworm worldwide as shown by the inventory of parasitoids and parasites of fall armyworm in the Americas and the Caribbean basin that included approximately 150 species of parasitoids and parasites from 14 families (Molina-Ochoa et al. 2003). Our results clearly indicate that native parasitoids of other *Spodoptera* spp. in India, such as *C. chlorideae* and *E. argenteopilosus*, may also adapt to *S. frugiperda* in due time. It would be worthwhile to evaluate indigenous parasitoids of *Spodoptera* spp. that known to be effective in India against *S. frugiperda*. For instance, *Telenomus remus* Nixon (Hymenoptera: Platygasteridae), an effective egg parasitoid of *S. litura*, is known to parasitize *S. frugiperda* as well (Molina-Ochoa et al. 2003). *Nomuraea rileyi* was found to be very effective against *S. litura* (Padanad & Krishnaraj 2009) in Karnataka.

Further information on the occurrence and rates of parasitism of indigenous natural enemies is of paramount importance in designing a biological control program for fall armyworm, either through conservation of native natural enemies or the introduction of new species for augmentative release. The current blanket recommendation and indiscriminate use of pesticides against the fall armyworm may have a negative impact on natural enemies. Application of insecticides that are less toxic to natural enemies should be encouraged, rather than the continued use of conventional broad-spectrum insecticides, so as



Fig. 1. *Odontepyrus* sp.: Larval parasitoid on *Spodoptera frugiperda*.

to protect natural enemies from the adverse effects of insecticides. The design of more comprehensive IPM programs for fall armyworm management in the region would be a useful strategy.

Summary

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is a pest recently invading maize in India. Studies were conducted in southern India from Jun to Aug 2018 to identify and assess the abundance of natural enemies attacking *S. frugiperda*. In total, 5 species of larval parasitoids, 3 predators, and 1 entomopathogen were found attacking larvae of *S. frugiperda*. The larval parasitoids were *Coccygidium melleum*, *Campoletis chlorideae*, *Eriborus* sp., *Exorista sorbillans*, and *Odontepyrus* sp. Three predators, *Forficula* sp., *Harmonia octomaculata*, and *Coccinella transversalis*, and 1 entomofungal pathogen, *Nomuraea rileyi*, were recorded. The average parasitism caused by *C. chlorideae* was found to be 2 to 3%, whereas the remaining parasitoids showed negligible parasitism. *Nomuraea rileyi* recorded 10 to 15% larval infection in Aug. Three parasitoids, *Coccygidium melleum*, *Eriborus* sp., and *Odontepyrus* sp., were reported for the first time attacking *S. frugiperda*. Efforts should be undertaken to identify more natural enemies and to preserve the existing ones,

through ecofriendly practices and judicious use of pesticides, allowing them to function effectively.

Key Words: fall armyworm; parasitoids; predators; entomopathogen

Sumario

El cogollero, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) es una plaga invasora reciente sobre el maíz en la India. Se realizaron estudios en el sur de la India desde el junio hasta el agosto de 2018 para identificar y evaluar la abundancia de enemigos naturales que atacan a *S. frugiperda*. En total, se encontraron 5 especies de parasitoides larvales, 3 depredadores y 1 entomopatógeno que atacan las larvas de *S. frugiperda*. Los parasitoides larvales fueron *Coccygidium melleum*, *Campoletis chlorideae*, *Eriborus* sp., *Exorista sorbillans*, y *Odontepyrus* sp. Se registraron tres depredadores, *Forficula* sp., *Harmonia octomaculata*, y *Coccinella transversalis* y 1 patógeno entomofúngico, *Nomuraea rileyi*. Se encontró que el promedio de parasitismo causado por *C. chlorideae* fue de 2 a 3%, mientras que los parasitoides restantes mostraron un parasitismo insignificante. *Nomuraea rileyi* registró una infección en las larvas del 10 al 15% en agosto. Se reportan por primera vez tres parasitoides, *Coccygidium melleum*, *Eriborus* sp., y *Odontepyrus* sp. atacando a *S. frugiperda*. Se



Fig. 2. *Coccygidium melleum*: Larval parasitoid on *Spodoptera frugiperda*.

deben realizar esfuerzos para identificar más enemigos naturales y preservar los existentes, a través de prácticas respetuosas con el medio ambiente y el uso prudente de pesticidas, que les permite funcionar de manera efectiva.

Palabras Clave: cogollero; parasitoides; depredadores entomopatógeno

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