

First report of natural infestation of *Ovomermis sinensis* (Nematoda: Mermithidae) parasitizing fall armyworm *Spodoptera* sp. (Lepidoptera: Noctuidae) in Himachal Pradesh, India

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Abstract

Spodoptera frugiperda invaded in India at the end of 2018 and has caused severe damage to maize including other crops. Several *S. frugiperda* naturally parasitized by nematodes were observed in Nauri, Himachal Pradesh, India. The morphological features based on the results of scanning electron microscopy indicated that the nematode belongs to the family Mermithidae. Furthermore, characters discovered that the nematode belongs to *Ovomermis sinensis*, a known entomoparasitic nematode. Our finding was the first record that *S. frugiperda*, was naturally parasitized by *O. sinensis*. The results of this study are of great importance for potential biological control of *S. frugiperda* by indigenous natural beneficial organisms, i.e., *O. sinensis* within an integrated pest management system.

Background

Spodoptera frugiperda (J. E. Smith), fall armyworm (FAW) is a pest native of tropical to subtropical regions of America and widely distributed throughout the American continents (Todd and Poole, 1998). The indigenous pest is highly polyphagous, causing economic damage to various crops *viz.*, cotton, maize, beans and sorghum (Day *et al.*, 2017). It has already invaded many countries in Africa and Asia and is causing substantial yield losses due to its voracity, high dispersal ability, wide host range, and high fecundity. (Baudron *et al.*, 2019). FAW causes up to \$16 billion in crop losses across Africa annually (Harrison *et al.*, 2019). FAW invaded Yunnan province, China in late 2018. FAW then, dramatically spread in China (Zhang *et al.*, 2019; Li *et al.*, 2019) and was reported in 1 million hectares from 26 provinces in China by December 2019. In 2019 pest have been reached different new frontiers such as Sri Lanka, Bangladesh, Myanmar, Thailand, China, Lao, Nepal, Viet Nam, and more, recently, in the Republic of Korea in Asia (FAO 2019a). The global distribution, is available on CABI's FAW portal (<https://www.cabi.org/isc/datasheet/29810>) and FAO's FAMEWS global platform (http://www.fao.org/fallarmyworm/monitoring_tools/famews-global-platform/en/).

Fall Armyworm (FAW) continues to spread into a new region, moving further east and north in India. Harsh incidences of fall armyworm were reported from across different Indian states. In India, it was first noticed in mid-May 2018 in Shivamogga, Karnataka by (Sharanabasappa *et al.*, 2018). So far, FAW is reported from Karnataka, Telangana, Andhra Pradesh, Maharashtra, Gujarat, and Tamil Nadu.

FAW has developed resistance to a variety of chemical pesticides in several countries due to intensive pesticide application, (Yu *et al.*, 2003; Zhao *et al.*, 2019), i.e., substantially high levels of resistance to omethoate was reported in FAW captured in China (Zhao *et al.*, 2019). Based on the adverse effects of some chemicals on human health, the environment, and living organisms, researchers are focusing on potential biological control agents (Harrison *et al.*, 2019). FAW is attacked by various natural biocontrol agents *viz.*, parasitoids (Lopez *et al.*, 2018), bacteria (del Valle Loto *et al.*, 2019), fungi (Shylesha *et al.*, 2018), nematodes (Ruiz-Nájera *et al.*, 2013; Viteri *et al.*, 2018) and virus (Souza *et al.*, 2019). There is a dearth of information on natural enemies of FAW, in China, particularly because the insect only invaded the region within the past year. It is high time to develop biological control methods for FAW in China. Although assessing the virulence of commercial biological control agents is a crucial way to control FAW from the perspective of environmental protection, there is also a great need to understand, promote and maximize the effectiveness of indigenous populations of natural enemies. Nematodes are the most abundant metazoan on earth. Nematodes in numerous families can kill insects, known to be entomoparasitic nematodes. Mermithidae, Steinernematidae, and Heterorhabditidae have been studied a lot and some are considered as biological control agents for FAW (Huot *et al.*, 2019; Ruiz-Najera *et al.*, 2013; Tarla *et al.*, 2015; Viteri *et al.*, 2018).

In general, mermithids nematode parasites can infect various hosts like; mosquitoes, spiders, cockroaches, or grasshoppers (Kosulic and Masova, 2019; Kobylinski *et al.*, 2012; Tarla *et al.*, 2015). Also, mermithids are also deadly to the insect host (Nikdel *et al.*, 2011). Mermithid parasites have a great extent of species-specificity, so they are more promising to control target pests (Saringer-Kenyeres *et al.*, 2017). For example, in China the mermithid *Ovomermis Sinensis* is the key mortality factor for *Mythimna separata* (Walker) (Sharma *et al.*, 2002).

Recently, we found FAW naturally parasitized by a mermithid nematode in a field located in Nauni, Himachal Pradesh, India and that is the first report of *O. sinensis* (Nematoda: Mermithidae) parasitizing FAW *S. frugiperda* (Lepidoptera: Noctuidae) in India. Our discovery can provide vital and useful information on policymaking for the control of FAW in India and Asia.

Materials And Methods

Field survey

From March 27, 2019, to September 20, 2020, the collection of FAW was carried out in the tomato and cornfields of Nauni, Solan, Himachal Pradesh. Large numbers of larvae were collected by a chessboard sampling method in maize fields in the above areas. The instar and number of FAW larvae obtained were recorded and all insects were brought back to the laboratory for feeding and observation. Digital images were obtained using Olympus BX63 and the nematodes were removed from the parasitized FAW.

Results

The prevalence of parasitic nematodes in parts of Nauni, Himachal Pradesh is shown in Table 1. According to the data of the survey, the parasitic rate of the nematodes in FAW is about 2%. FAW was found during the cultivation process and the survey distribution of nematode infection rate is shown in Table 1.

Diagnostic characters

Based on morphological characteristics, these nematodes obtained from Nauni Himachal Pradesh belong to the family Mermithidae. This nematode has a stylet on the anterior portion of the post-parasitic juvenile (Fig. 1A) and a post-parasitic tail appendage (0.62mm) on the posterior end of the post-parasitic juvenile (Fig. 1B). The mermithids are white and 225.3mm in length (Fig. 3). *S. frugiperda* parasitized by the nematodes is illustrated in (Figure 4).

Discussion

For our knowledge, this is the first report that *S. frugiperda* was parasitized by *O. sinensis* in a natural context, an indigenous mermithid nematode in Himachal Pradesh, India. In a survey conducted in Mexico, mermithid nematode species from another genus, *Hexameris* sp., was observed to be parasitic on FAW, causing a mortality rate of 8.42 % (Ruiz-Najera *et al.*, 2013). *S. frugiperda* naturally parasitized by nematodes were recorded in Hainan Province, China (Sun *et al.*, 2020). The present study confirms new associations of mermithid nematodes *O. sinensis* as natural enemies of *S. frugiperda*.

O. sinensis had been efficiently used to control pest insects from family Noctuidae, i.e. *Spodoptera litura* and *Helicoverpa armigera* (Li *et al.*, 2003) as well as *M. separata* (Walker) (Chen *et al.*, 1991; Zhang *et al.*, 1992). *S. frugiperda*, also from Noctuidae, was found naturally parasitized by *O. sinensis* in the preset study. All these findings confirmed the great potential of *O. sinensis* for control against the invasive pest insect *S. frugiperda* and other pest insects from Noctuidae. An intriguing finding in this study is that we can exploit the great potential to use *O. sinensis* to control FAW. Information on the occurrence and rates of parasitism of indigenous natural enemies is of paramount importance in designing a biological control program for *S. frugiperda*, either through the conservation of native natural enemies or the introduction of new species for augmentative release. Major field releases of mermithids have been conducted for Anopheles population control (Kobylnski *et al.*, 2012). Therefore, further study is needed to understand the biological and ecological relationship between *O. sinensis* nematodes and their hosts and to explore the approach to artificially rear this nematode for potential field application in the future.

Table 1

Location, date, coordinates, and number of larvae, parasitic nematodes of fall armyworm (FAW) *Spodoptera frugiperda* [(J.E.Smith) (Lepidoptera: Noctuidae)] and conditions of plants at three surveyed sites in Vegetable Science farm, Dr YSP UHF, Nauni, India.

Date	Location	Coordinates	Total FAW (No.)	Parasitized FAW (No.)	Cornfield size (m ²)	Plant height (cm)	Plant status	Planting gap (cm)	Spray insecticide situation
August 28, 2020	Vegetable farm, UHF, Nauni, India	30° 51'33 N 77° 10' 30 E	48	2	700	40	The late seedling	75×25	No spray insecticide
September 4, 2020	Maize field Darja, Nauni	30° 51' 41 N 77° 12' 05 E	24	1	600	35	The late seedling	75×25	No spray insecticide
September 8, 2020	Vegetable farm, UHF, Nauni, India	30° 51'33 N 77° 10' 30 E	82	2	960	145	Mature stage	75×25	No spray insecticide

Abbreviations

FAW: Fall armyworm; FAO: Food and agriculture organization; UHF: University of horticulture and forestry

Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

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Figures

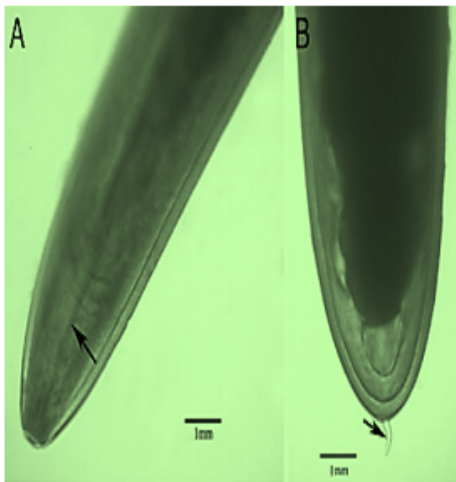


Figure 1

Microscopic photo of *Ovomermis sinensis*. A: Stylet on the anterior portion of post-parasitic juvenile (arrow); B: Tail appendage on post-parasitic juvenile (arrow).



Figure 2

Post-parasitic juvenile with FAW

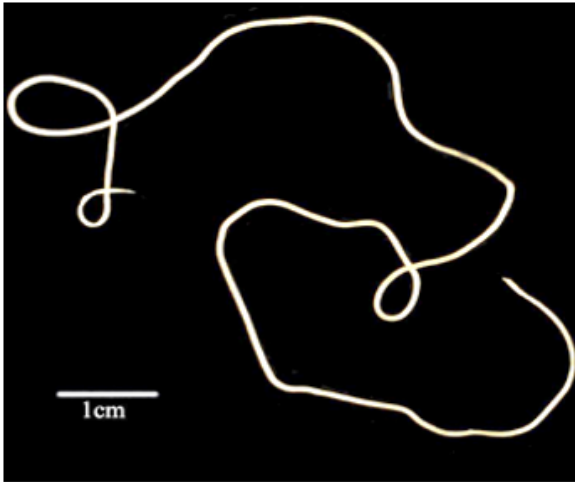


Figure 3

Post-parasitic juvenile *Ovomermis sinensis* nematode (scale bar: 1 cm).

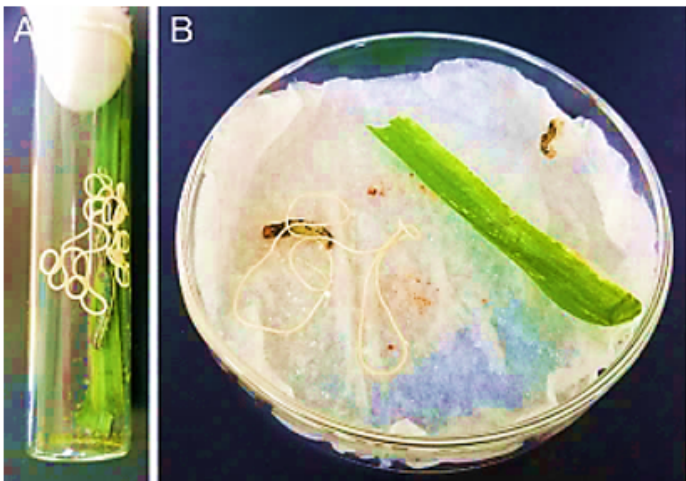


Figure 4

Post-parasitic juvenile *Ovomermis sinensis* nematode emerging from *Spodoptera frugiperda*.