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Assessment of parasitic potential of *Telenomus remus* Nixon against different lepidopteran pests

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Abstract
Telenomus remus Nixon is the promising biocontrol agent as an egg parasitoid of *Spodoptera* spp., however, lack of information on the host spectrum of this parasitoid precludes its applied use in agriculture. It had been successively reared on the eggs of *Corcyra cephalonica* in some countries while, reports from China argued that it is infeasible. Therefore, we studied the parasitic potential of *T. remus* on eggs of different lepidopteran pests viz., *Spodoptera litura*, *Helicoverpa armigera* and *Scirpophaga incertulas*. The results demonstrated that *S. litura* was the most suitable alternate host with highest rate of parastization (93.50%) compared to others. However, it is important to emphasize the need for additional field studies in order to implement the biological control program based on this egg parasitoid.

Keywords: *Spodoptera frugiperda* FAW, *T. remus*, *Helicoverpa arm*igera, *Scirpophaga incertulas*

Introduction
The invasive alien species poses a serious threat to agriculture and cost billions of dollars in terms of reduced production and productivity mainly due to increased trans – boundary movement of agricultural commodities, anthropogenic activities, climate change etc. The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is one among the alien pests reported for the first time in India by Sharanabasappa *et al*. (2018) [19].
Among the natural enemies of *Spodoptera* spp., *Telenomus remus* Nixon (Hymenoptera, Scelionidae) stands out as a highly specialized egg parasitoid (Cave 2000) [4]. *Telenomus remus* Nixon (Hymenoptera, Scelionidae) has been observed parasitizing eggs of five different species of Spodoptera, even on overlapping layer egg masses (Bueno *et al*., 2008) [3]. Its efficiency in controlling the fall armyworm, *S. frugiperda* has been proved in countries such as Venezuela and Mexico.
Despite the great potential in using egg parasitoids as biological control agents, the success or failure of field releases of these insects depends, basically, on the knowledge of the bioecological characteristics of the parasitoids and of their interactions with the host spectrum (Bourchier & Smith 1996) [4]. For a successful biological control programme, it is important to consider that parasitoid should have wider host choice than in the laboratory. This host diversity may influence the capacity of the parasitoid in finding the target host. Another important point to be considered is the quality of the parasitoid reared under laboratory conditions. In general, an easy reared alternative host is normally used for mass production. However, the successive rearing on alternative hosts may affect the host preference of the natural enemy, by altering the control efficiency against the target (Cobert, 1985) [5]. To fortify the above facts, present investigation was carried out to identify the host spectrum as well as an efficient alternate host for the mass production of *T. remus.*

Materials and Methods
Host culture of Fall armyworm, *S. frugiperda*
Disease free healthy colonies of FAW was maintained at the Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University. For culturing the FAW, field collected larvae were placed individually in plastic containers (30 x 40 x 40 mm) and provided with artificial diet until pupation (Bueno *et al*., 2009) [2]. The lids of the containers were provided with holes of 12 mm diameter covered with a fine mesh synthetic fabric for ventilation purpose. After pupation, pupa was kept in adult emergence cages (30 x 30 x 30 cm). The adults emerging from the pupa were sexed and released in pairs into oviposition cages for mating.

The adults were fed with sugar: honey solution in the ratio of 1: 1 supplemented with two to three drops of Vitamin E and Zincovit. Fifteen days old maize seedlings produced through hydroponics were provided as oviposition substrate. The eggs from the seedlings were collected and transferred to maize seedlings grown in the screen house by hydroponics and left inside clear transparent plastic boxes (17 x 11 x 5 cm) containing the diet pieces. The second or early third instar larvae were transferred to individual rearing container with diet pieces until pupation to avoid cannibalism. Thus, the culture was maintained continuously and used for various experiments (Bueno *et al*., 2010) [1].

Culturing of egg parasitoid, *T. remus*

Telenomus remus nucleus culture was procured from NBAIR (National Bureau of Agricultural Insect Resources), Bengaluru as parasitized egg cards and kept in a plastic container (18 X 7 X 7 cm exposure container) for emergence. The adult parasitoids were provided with honey through cotton swabs and allowed to mate for 24 hours. Freshly laid egg masses of FAW were glued to paper strips with a thin layer of gum arabic / non – toxic glue (3 to 4 egg masses / paper strips of 3 x 5 cm) and shade dried for 5 to 10 minutes at room temperature. The egg cards were introduced into a plastic container (18 X 7 X 7 cm) for parastization by mated females of *T. remus* at the parasitoid host ratio of 1:40 (Pomari *et al*., 2013) [9]. Fresh egg cards were provided once in 24 hours until all adults died. The parasitized cards were maintained separately for parasitoid emergence. Thus, the parasitoid culture was maintained continuously for experimental purpose.

Host culture of *S. litura*

A disease-free continuous colony of *S. litura* was maintained on a chickpea based semi-synthetic diet (Shorey and Hale, 1965) [20] at the Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University.

Parasitic potential of *T. remus* on eggs of different lepidopteran pests under laboratory conditions

Freshly laid egg masses of *H. armigera S. litura* and yellow stem borer were glued to paper strips (3X 5 cm) (Bueno *et al*., 2010) [1], shade dried, kept in a plastic container (18 X 7 cm) and were subjected to parastization by *T. remus* at parasitoid host ratio of 1:40. The experiment was conducted in CRD with 3 treatments and 13 replications. After 24h of parasitization the egg cards were removed, kept separately and observed for percent parasitization and parasitoid adult emergence (Chen *et al*., 2021) [8].

Statistical Analysis

Percent parasitization was computed by calculating the ratio of the total number of eggs parasitized to the total number of eggs subjected for parasitisation. Similarly, the percent parasitoid adult emergence percentage was calculated by computing the ratio of total number of parasitoid adults emerged to the total number of eggs exposed for parasitization. The data were subjected to arcsine transformation with AGRES software. The means were separated by LSD (Least Significant Difference) (Laminou *et al*., 2020) [14].

Results and Discussion

The percent parasitization and parasitoid emergence was maximum in *Spodoptera litura* (93.50%) followed by yellow stem borer (62.45%) and *Helicoverpa armigera* (30.94%) (Table 1) and (Fig. 1). The parasitoid usually showed better development and adaptation on the more suitable eggs. Consistent with the previous studies of Chen *et al.* (2021) [8], parasitism capacity of *T. remus* was greater on *S. litura* eggs which may be due to more nutrients obtained from the comparatively big sized eggs that is evidenced from the highest parasitism (93.50%), adult emergence (92.12%), female parasitoid (90.54%) and lowest male parasitoid (9.4%). The results suggest that the *S. litura* can be utilized as an alternative host to *S. frugiperda* for mass culturing *T. remus* under laboratory.

Moreover, *S. litura* larvae can be reared in groups at a lower cost than *S. frugiperda*, since there is little or no cannibalism suggesting that *S. litura* eggs might be more suitable as alternative host for mass rearing *T. remus*. This information on the biological characteristics and of *T. remus* provides important reference for large scale production and release of parasitoid in biological control programs. Host preference is a key factor influencing the mass rearing and release of parasitoids. Although parasitoid rearing on the facitious host is one of the essential steps in a biological control program, continuous rearing on the same host may affect its efficiency against the target pest against which it was released into the field. Based on the findings of Chen *et al.* (2021) [8], the ability of the parasitoids to distinguish hosts may be reduced or even lost after successive rearing on an alternative host. Although our results indicated that the *S. litura* eggs could be an alternative host of *T. remus*, in order to ensure the control efficiency of *T. remus* against *S. frugiperda* in the field, it is necessary to further evaluate the host preference and parasitism when *T. remus* was successively reared on the *S. litura* eggs for several generations.

The Yellow stem borer *Scirpophaga incertulas* Walker is one among the major insect pests of rice in tropical and temperate areas. Over 100 species of parasitoids were recorded from stem borers worldwide (Nickel 1964) [16]. Delfinado (1959) [9] reared 17 species of parasites of stemborers collected from Rizal, Laguna and Pangasinan in the Philippines. Most studies of natural enemies of YSB have been directed at determining the species and seasonal abundance. Rao. (1972) [18] concluded that egg parasitism was the most important single mortality factor of the immature stages of Rice stem borer. *Telenomus remus* is found to parasitize egg masses with different layers effectively and hence, its efficiency was also evaluated on the egg masses of Yellow stem borer in rice. The present investigation revealed 62.45 percent parasitization, 57.72 percent parasitoid emergence with highest female parasitoid emergence than males. This is in corroboration with the findings of Merde *et al.*, (1986) [23] who concluded that *Telenomus remus* parasitized about 64 percent of the eggs in a mass.

Among the three hosts tested, *H. armigera* recorded lowest parasitization percentage. Since, the *H. armigera* eggs are laid singly, the parasitoid might have exhausted in searching the eggs for oviposition which is reflected in the reduced parasitization.

Table 1: Assessment of parasitic potential of *T. remus* against different lepidopteran pests

Treatment[#]	Parasitization (%) *	Parasitoid emergence (%)*	Female parasitoid emergence (%)*	Male parasitoid emergence (%)*
Spodoptera litura	93.50 (75.23) [a]	92.12 (73.89) [a]	61.23 (51.97) [a]	30.23 (33.85) [a]
Scirpophaga incertulas	62.45 (51.03) [b]	57.72 (49.44) [b]	40.05 (56.09) [b]	22.34 (32.89) [b]
Helicoverpa armigera	30.94 (33.80) [c]	29.84 (33.11) [c]	17.45 (24.69) [c]	12.39 (20.60) [c]
SE(d)	3.89	3.68	2.75	2.74
Cd (0.05)	7.35	7.47	5.58	5.56

#The values are mean of thirteen replications
*Figures in parentheses are arcsine transformed values
Means followed by different letters differ significantly at (p=0.05)
Means were differentiated by LSD

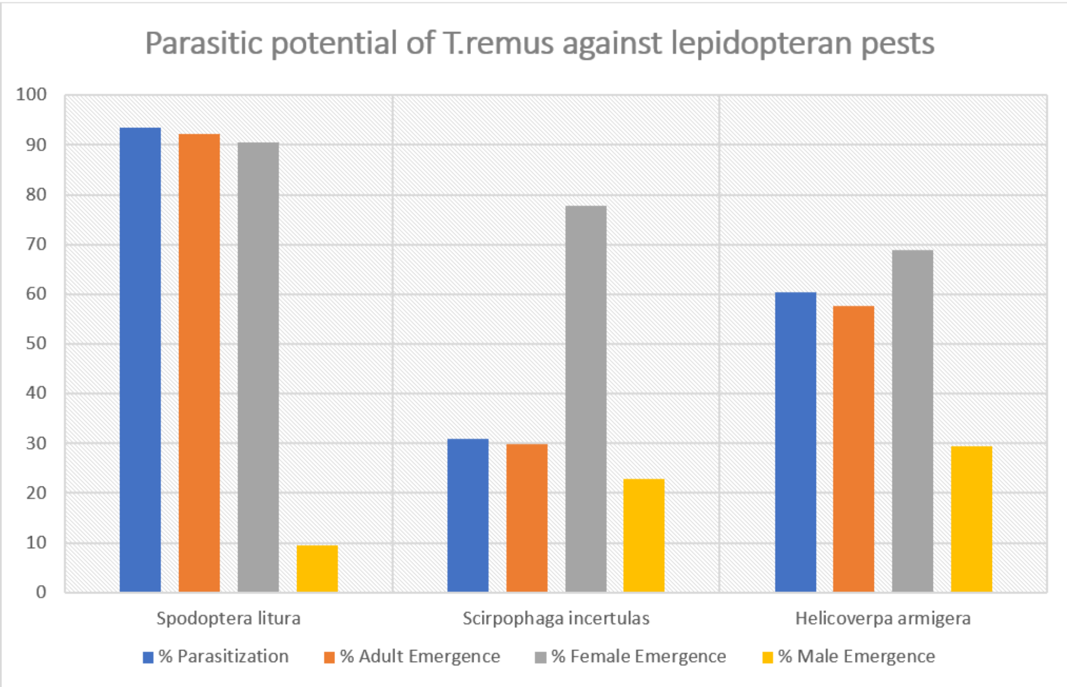

Fig 1: Assessment of Parasitic potential of *T. remus* against different lepidopteran pests

Conclusions

Among the hosts studied, the *T. remus* efficacy is found to be maximum on *S. litura* followed by *S. incertulas* and *H. armigera*. The results suggest that *S. litura* could be an effective target for field as well as laboratory culturing. However, in case of *H. armigera* and Yellow stem borer further research has to be conducted to study the field performance of *T. remus* against them before being deployed for their management.

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