

## Evidence of exploitative competition among egg parasitoids of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize

Evidencia de competencia por explotación entre parasitoides de huevos de *Spodoptera frugiperda* (Lepidoptera: Noctuidae) en el maíz

CHERRE SADE BEZERRA DASILVA<sup>1,2</sup>, JACI MENDES VIEIRA<sup>3</sup>, MARTA LOIÁCONO<sup>4</sup>,  
CECILIA MARGARÍA<sup>4</sup> and JOSÉ ROBERTO POSTALI PARRA<sup>2</sup>

**Abstract:** *Telenomus remus* and *Trichogramma* spp. (Hymenoptera: Platygasteridae, Trichogrammatidae) are known egg parasitoids of the fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Brazil. Parasitism of trichogrammatid on eggs of *S. frugiperda* has been relatively common, whereas the occurrence of *T. remus* in Brazilian crops has rarely been reported. Consequently, literature that gives insights about the interspecific competition among individuals of *T. remus* and *Trichogramma* spp. in the field is very scarce. Here we report the simultaneous occurrence of *T. remus*, *Trichogramma pretiosum*, and *Tr. atopovirilia* on eggs of the FAW in maize (Piracicaba, São Paulo, Brazil). Our findings imply that these three egg parasitoid species were engaged in exploitative competition (indirect interactions in which the depletion of resources by one species prevents the other access to them) toward eggs of *S. frugiperda*. Moreover, given the emergence of combinations of two and three of these parasitoid species from a single egg mass, our data strongly suggest that *T. remus*, *Tr. pretiosum* and *Tr. atopovirilia* were also engaged in interference competition (direct interactions among adults and/or immature individuals resulting in behavioral changes or even death of individuals). Both exploitative and interference competition may affect the population dynamics of parasitoids, with consequences for the biological control of pests. Hence, the present findings highlight the importance of determining the outcome of competition among *T. remus*, *Tr. pretiosum* and *Tr. atopovirilia* toward eggs of *S. frugiperda* in laboratory and field studies.

**Key words:** Egg parasitoid. Extrinsic competition. Fall armyworm. Field occurrence. Interference competition.

**Resumen:** *Telenomus remus* y *Trichogramma* spp. (Hymenoptera: Platygasteridae, Trichogrammatidae) son parasitoides de huevos del gusano cogollero del maíz (GCM), *Spodoptera frugiperda* (Lepidoptera: Noctuidae) en Brasil. Mientras que los informes sobre el parasitismo de *Trichogramma* en huevos de *S. frugiperda* son relativamente comunes, los registros de *T. remus* en los cultivos brasileños son escasos. En consecuencia, la literatura sobre la competencia entre *T. remus* y *Trichogramma* spp. en campo es poca. En este trabajo, se presenta la presencia simultánea de *T. remus*, *Trichogramma pretiosum* y *Tr. atopovirilia* en huevos del GCM en el cultivo de maíz (Piracicaba, São Paulo, Brasil). Los resultados muestran que estas tres especies de parasitoides estuvieron involucradas en competencia exploratoria (interacción indirecta, donde el agotamiento de los recursos por parte de una especie impide que la otra tenga acceso a ellos) por los huevos de *S. frugiperda*. Sin embargo, teniendo en cuenta que se observó el surgimiento de dos y tres especies de parasitoides de una sola masa de huevos, los resultados sugieren que *T. remus*, *Tr. pretiosum* y *Tr. atopovirilia* también participaron en competencia por interferencia (interacciones directas entre los adultos y/o inmaduros que resultan en cambios en el comportamiento o muerte de los individuos). Ambos tipos de competencia pueden afectar la dinámica poblacional de parasitoides con consecuencias para el control biológico de plagas. Por consiguiente, nuestro trabajo destaca la importancia de investigar la competencia entre *T. remus*, *Tr. pretiosum* y *Tr. atopovirilia* por huevos de *S. frugiperda* en estudios de laboratorio y campo.

**Palabras clave:** Parasitoides de huevos. Competencia extrínseca. Cogollero del maíz. Presencia en campo. Competencia por interferencia.

### Introduction

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is a key pest of maize in Brazil, as well as the greater Americas. Although its control is based mostly on pesticide sprayings, its biological control by means of augmentative releases of egg parasitoids is promising (Cave 2000; Beserra *et al.* 2002; Parra and Zucchi 2004; Beserra and Parra 2005). The goal of this work was to collect and identify egg parasitoids of *S. frugiperda* in maize in order to start laboratory cultures and perform studies to assess their competitiveness and potential as biological controllers of the FAW.

### Material and methods

We conducted a field survey on May 29th (late autumn) 2010, in a maize plot (1 ha; plants with *ca.* 90 days after emergence) located at Piracicaba, São Paulo, Brazil (22°42'18.57"S 47°38'6.37"W). Fifty-two egg masses (< 18h, *ca.* 300 eggs) of *S. frugiperda* were randomly scattered in the plot, with a minimal distance of 10 m from each other. Egg masses were produced in laboratory according to Da Silva and Parra (2013). In an attempt to protect the eggs from predators and direct sunlight, we taped the egg masses inside a collection device, which consisted of a white disposable cup (50 mL) with a punctured bottom and a cotton string (50 cm) passed

<sup>1</sup> Corresponding author. <sup>2</sup> D. Sc. Laboratório de Biologia de Insetos, Departamento de Entomologia e Acarologia, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo (ESALQ/USP). Av. Pádua Dias, 11, Piracicaba-SP, Brazil, 13.418-900. [entomologista@gmail.com](mailto:entomologista@gmail.com), [jrpparra@usp.br](mailto:jrpparra@usp.br). <sup>3</sup> M. Sc. Laboratório de Biologia de Insetos. Departamento de Entomologia e Acarologia. ESALQ/USP, [jacimvieira@yahoo.com.br](mailto:jacimvieira@yahoo.com.br). <sup>4</sup> D. Sc. División Entomología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata. Address: Paseo del Bosque s/n, B1900FWA, La Plata, Argentina. [loiacono@fcnym.unlp.edu.ar](mailto:loiacono@fcnym.unlp.edu.ar), [cmargaria@fcnym.unlp.edu.ar](mailto:cmargaria@fcnym.unlp.edu.ar).



**Figure 1.** Method used for collecting parasitized eggs of *Spodoptera frugiperda* in field. **A.** Collector device hanging from a maize leaf. **B.** Inner view of the device highlighting the egg mass of *S. frugiperda* (arrow).

through it. A knot was made at one extremity of the string in order to prevent the detachment of the cup, while the other extremity was tied to a maize leaf (Fig. 1). The collection devices were recovered two days later and the egg masses were introduced individually into glass tubes (2 x 8 cm) and maintained in incubators ( $24 \pm 1$  °C, 70% RH, 14L:10D photoperiod) until parasitoid emergence. In the meantime, caterpillars from non-parasitized eggs were eliminated on a daily basis to prevent injury to the parasitized eggs. Adult females were then individualized, multiplied on eggs of *S. frugiperda*, and had some adult individuals of their offspring killed in 70% alcohol. The male individuals were set on glass slides with Hoyer's medium and identified based on the keys developed by Querino and Zucchi (2005), Johnson (1984), Nixon (1937), Nixon (1940) and Chou (1987).

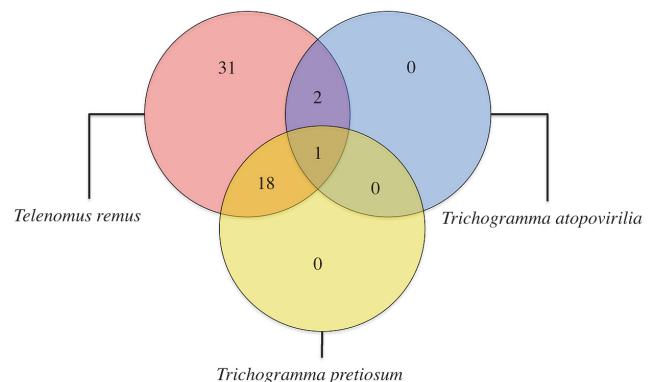
### Results and discussion

None of the fifty-two *S. frugiperda* egg masses exposed to parasitism in field showed any signal of predation (missing eggs or residues of predated eggs). Three species of egg parasitoids were identified: (1) *Trichogramma atopovirilia* Oatman & Platner, (2) *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae), and (3) *Telenomus remus* Nixon (Hymenoptera: Platygasteridae). The latter species emerged from all 52 egg masses exposed in field, implying that both trichogrammatids always had to compete with the platygastid for the same egg masses. *Trichogramma pretiosum* and *Tr. atopovirilia* emerged from 19 and 3 egg masses, respectively. Surprisingly, a combination of the three egg parasitoid species was found in one out of the 52 exposed egg masses (Fig. 2). The fact that *T. remus* emerged from every egg mass exposed in field suggests a competitive dominance in relation to both trichogrammatids. Facing such a high dominance, *Tr. atopovirilia* and *Tr. pretiosum* simply may have not been able to emerge from *T. remus*-free egg masses. Alternatively, the fact that the emergences of *Tr. atopovirilia* and *Tr. pretiosum* were invariably associated with the emergence of *T. remus* might be an indication that both trichogrammatids practice hyperparasitism on *T. remus*. It has been demonstrated that *Tr. pretiosum* can develop as

facultative hyperparasitoid of *T. sphingi* (Strand and Vinson, 1984), although Carneiro and Fernandes (2012) found no evidence of emergence of *Tr. pretiosum* from *S. frugiperda* eggs previously parasitized by *T. remus*.

*Telenomus remus*, *Tr. atopovirilia* and *Tr. pretiosum* have been the most cited egg parasitoids of the FAW in Latin America (Cave 2000; Beserra *et al.* 2002; Parra and Zucchi 2004; Beserra and Parra 2005). Although *Telenomus remus* was introduced in Brazil 29 years ago, reports on its natural occurrence in field have been very rare, while wild populations of *Tr. pretiosum* and/or *Tr. atopovirilia* are often reported (Beserra *et al.* 2002; Bueno *et al.* 2009; Bueno *et al.* 2010). Out of these three species, *T. remus* has been considered the best candidate for augmentative biological control programs due to their large size, robustness, and ability to reach the inner layers of the FAW egg masses (Cave 2000). Indeed, laboratory studies have demonstrated that *T. remus* parasitizes eggs of *S. frugiperda* faster than *Tr. pretiosum* and, when both species are put together in an arena containing FAW eggs, the majority of the adults emerged are of *T. remus* (Carneiro and Fernandes 2012). Nevertheless, there are no actual studies exploring the interference and the exploitative competitions among *T. remus*, *Tr. atopovirilia* and *Tr. pretiosum* in field conditions.

According to Park (1954), a serious study of interspecific competition should start with proof that competition exists. Our report shows the coexistence of these three egg parasitoid species in the same environment and using the same host species, which implies that they are engaged in a competitive interaction with each other. Other species of *Telenomus* and *Trichogramma* have been found sharing host species at the same time/space in Japan and Spain (Cabello 1989; Hirose *et al.* 1968a; Hirose *et al.* 1968b). However, we are unaware of previous reports of the coexistence of *T. remus*, *Tr. atopovirilia* and *Tr. pretiosum* in the same environment and especially on the same egg mass. These results are not only evidence that *T. remus*, *Tr. atopovirilia* and *Tr. pretiosum* are engaged in exploitative competition (indirect interaction, where the depletion of resources by one species prevents the other access to it) towards *S. frugiperda* eggs, but our findings also strongly suggest that the three parasitoids are also displaying interference competition (direct interactions among adults and/or immature individuals resulting in behavioral changes or even death of individuals). Both



**Figure 2.** Number of *Spodoptera frugiperda* egg masses parasitized by *Telenomus remus*, *Trichogramma atopovirilia* and *Tr. pretiosum*, in a maize field located in Piracicaba, São Paulo, Brazil.

kinds of competition, combined or not, may have profound implications in the population dynamics (Ricklefs and Miller 2000) of these egg parasitoids and, must be matter of further investigations. Additionally, recent studies (Penaflor *et al.* 2011a; b) showed that oviposition by *S. frugiperda* on maize leaves changes the volatile emissions of maize plants, and the authors hypothesize that such changes might constitute chemical signals that attract egg parasitoids of FAW. Our study showed that such signals are not critical for *T. remus*, *Tr. atopovirilia* and *Tr. pretiosum* to successfully find eggs of *S. frugiperda* in the field, since we attached the egg masses to the collection devices instead of inducing female moths to lay eggs directly on the maize leaves, and even so the parasitoids were able to find the hosts despite the lack of chemical cues released from the maize plants.

Here we reported the spontaneous occurrence of *T. remus*, *Tr. pretiosum* and *Tr. atopovirilia*, three egg parasitoids of *S. frugiperda*, in maize, implying that these wasp species were engaged in exploitative competition and likely involved in interference competition towards eggs of *S. frugiperda* in field. Since both kinds of competition may affect the population dynamics of parasitoids with consequences to the biological control of pests, our study highlights the importance of determining the outcome of competition among *T. remus*, *Tr. pretiosum* and *Tr. atopovirilia* towards eggs of *S. frugiperda* in laboratory and field studies.

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