New records of predation on eggs of Bemisia tabaci (Hemiptera: Aleyrodidae) by Chrysopodes (Chrysopodes) lineafrons (Neuroptera: Chrysopidae) in Northwestern Argentina

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Bemisia tabaci has become a major economic importance pest, affecting several crops worldwide. Among their natural enemies, species of Chrysopidae family, with larvae predators of different pests, are a very effective biological control agent. The developmental time and survival of the immature stages of Chrysopodes (Chrysopodes) lineafrons, and the longevity and oviposition of adults fed with eggs of B. tabaci was determined. C. (C.) lineafrons adults were collected in tomato crops in Lules department, Tucumán province. To determine the developmental duration of each instar, and larvae survival, 90 eggs of C. (C.) lineafrons were randomly selected, of which only 71 eggs hatched; of these, 34 larvae were fed with B. tabaci eggs and 37 with Sitotroga cerealella eggs, used as control. Oviposition and longevity of adults fed with the two preys were recorded. C. (C.) lineafrons larvae consumed an average of 127.04 B. tabaci eggs and 44 S. cerealella eggs per day. Mean developmental time of C. (C.) lineafrons fed with B. tabaci eggs was 45 days; while for those fed with S. cerealella eggs it was 35 days. Immature stages survival, number of eggs per adults and longevity were higher when C. (C.) lineafrons were fed with S. cerealella eggs than with B. tabaci eggs. C. (C.) lineafrons proved to be an efficient predator, thus representing an excellent tool for the biological control of B. tabaci in tomato crops .

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New records of predation on eggs of *Bemisia tabaci* (Hemiptera: Aleyrodidae) by *Chrysopodes* (*Chrysopodes*) *lineafrons* (Neuroptera: Chrysopidae) in Northwestern Argentina

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ABSTRACT

Bemisia tabaci has become a major economic importance pest, affecting several crops worldwide. Among their natural enemies, species of Chrysopidae family, with larvae predators of different pests, are a very effective biological control agent. The developmental time and survival of the immature stages of *Chrysopodes (Chrysopodes) lineafrons,* and the longevity and oviposition of adults fed with eggs of *B. tabaci* was determined. *C. (C.) lineafrons* adults were collected in tomato crops in Lules department, Tucumán province. To determine the developmental duration of each instar, and larvae survival, 90 eggs of *C. (C.) lineafrons* were randomly selected, of which only 71 eggs hatched; of these, 34 larvae were fed with *B. tabaci* eggs and 37 with *Sitotroga cerealella* eggs, used as control. Oviposition and longevity of adults fed with the two preys were recorded. *C. (C.) lineafrons* larvae consumed an average of 127.04 *B. tabaci* eggs and 44 *S. cerealella* eggs per day. Mean developmental time of *C. (C.) lineafrons* fed with *B. tabaci* eggs was 45 days; while for those fed with *S. cerealella* eggs it was 35 days. Immature stages survival, number of eggs per adults and longevity were higher when *C. (C.) lineafrons* were fed with *S. cerealella* eggs than with *B. tabaci* eggs. *C. (C.) lineafrons* proved to be an efficient predator, thus representing an excellent tool for the biological control of *B. tabaci* in tomato crops.

Subjects Entomology, Ecology

Keywords *Chrysopodes*, Developmental time, Survival, Longevity, Oviposition, Ingest capacity.

INTRODUCCIÓN

The whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) is a serious pest of several annual, ornamental and industrial crops, fruit plantations and weeds worldwide (Byrne *et al.,* 1990; Brown *et al.,* 1995; Viscarret, 2000; López-Ávila, 2005). It causes direct damage through sucking sap and excreting sugary substances, which produces the growth of sooty mold, reducing photosynthetic capacity of the plant; and indirect damage through viruses and bacteria transmission (Berlinger, 1986; Viscarret, 2000). *Bemisia tabaci* has caused significant losses in America since 1981, reducing crop productivity of tomato, sweet pepper, beans and textiles (Brown, 1993). In Argentina, the first record of *B. tabaci* arises from specimens found in an unspecified host plant in Tucumán province (Viscarret, 2000). Subsequently, its presence has been reported in greenhouses and field crops such as cotton, tobacco, citrus, sugar cane, soybean, forestry and horticultural crops of Solanaceae, Cucurvitaceae, Cruciferaceae and Compositae families (Polack, 2005).

Currently, the most used control method against *B. tabaci* is chemical control; however, alternative methods based on biological control with natural enemies of the pest can reduce its density (Reguilón *et al.,* 2011), as well as environmental impact, and improve product quality (López *et al.,* 1999). Among the natural enemies of this species, the genus *Chrysopodes* Navás (Neuroptera: Chrysopidae) has been mentioned, with a cosmopolitan distribution and with about 40 species distributed in two subgenera: *Chrysopodes* s. str. and *Neosuarius* Adams & Penny (Adams & Penny, 1987). In Argentina, *Chrysopodes* (*Chrysopodes*) *lineafrons* Adams & Penny, *Chrysopodes* (*Chrysopodes*) *polygonicus* Adams & Penny, *Chrysopodes* (*Neosuarius*) *divisus* Walker and *Chrysopodes* (*Neosuarius*) *porterinus* Navás have been cited (Adams & Penny, 1987; Gonzalez Olazo *et al.,* 1999; Monserrat & Freitas, 2005; Gonzalez Olazo & Reguilón, 2008; Ortega *et al.,* 2014).

Chrysopodes (C.) lineafrons is considered an effective predator for biological control. Thus, research focusing on its preference for certain pest species or even for certain pest stages, and its possible interaction with other natural enemies is of great need. Since such knowledge is scarce in literature, a study of the life cycle of *C. (C.) lineafrons* fed with eggs of *B. tabaci* as prey was set up in this paper. Developmental time, survival, longevity and oviposition were analyzed as biological parameters of *C. (C.) lineafrons*, and their predation ability over *B. tabaci* eggs under laboratory conditions was assessed.

MATERIALS AND METHODS

Study area and specimens collection

Entomological sampling was performed during the 2009-2010 period in two greenhouses and one tomato crop field in Lules department (26 º55 '60"S-65° 20' 60"W, 382 m.a.s.l), Tucumán province, northwestern Argentina (Fig. 1).

Chrysopodes (C.) lineafrons specimens were collected in tomato crops and the surrounding vegetation using manual aspirators for adults; and manually with a brush for immature stages. Subsequently, adults were placed in 500 cm^3 plastic containers covered with voile; and larvae were kept in Petri dishes with paper accordions, used to avoid cannibalism, with *Sitotroga cerealella* Oliver eggs for their feeding.

Laboratory assay

Rearing of *C.* (*C.*) *lineafrons* took 12 months. Adults were placed in 5 liter plastic containers covered with voile, secured with an elastic band and properly labeled with collection date and number of individuals. A circular paper was placed inside the container, for the females to lay the eggs. Specimens were fed daily with a mixture of yeast, pollen, honey and water in a 10:1:5:/ proportion and provided of water with moistened cotton.

To evaluate the ingestion of *C. (C.) lineafrons,* eggs breeded in the laboratory were selected randomly and placed in 2 cm diameter individual plastic containers with an hermetic seal, maintained at 27°C, 65% humidity and a photoperiod of 12:12 (L:D) until hatching. Once lacewing larvae emerged, they were separated in two groups. A known number of *B.tabaci* eggs were offered to one of the groups while *S. cerealella* eggs were fed to the other group, used as control. After 24 hours, the number of predated eggs and *C. (C.) lineafrons* larvae survival were recorded.

When the larvae of *C. (C.) lineafrons* achieved the pupal stage, they were placed in 1 liter plastic containers covered with voile. The number of males and females which emerged was recorded in each repetition. Emerging individuals were fed and maintained under the same breeding conditions of the adults. Number of eggs laid and adults longevity was registered every 24 hours (Fig.2).

Data analysis

Data obtained in the laboratory, such as number of offered and consumed preys, emergence date of *C. (C.) lineafrons* larvae; oviposition, number of adult individuals placed in each container and numbers of eggs laid daily were registered in spreadsheets.

Mean, average and percentage of eggs predated by *C. (C.) lineafrons* were calculated. In addition, the different life stages survival (egg, larva and pupa) of lacewing was determined, as well as adults longevity and number of eggs laid per female per day fed both with *B. tabaci* eggs and *S. cerealella* eggs.

RESULTS

Of the 90 eggs of *C. (C.) lineafrons* selected at the beginning of this study, only 71 hatched, of which 34 were fed with *B. tabaci* eggs and 37 with *S. cerealella* eggs. During the ingest assay, it was observed that a total of 34 individuals reached the adult state; 28 of these having been fed with *S. cerealella* eggs, and 6 with *B. tabaci* eggs.

Ingestion assay

In general, larvae of *C. (C.) lineafrons* consumed an average of 127.04 *B.tabaci* eggs and 44 *S. cerealella* eggs per day. When each larval stage was evaluated separately, it was observed that larvae I consumed a maximum of *B. tabaci* 556 eggs and 189 *S. cerealella* eggs, while larvae II consumed 531 *B. tabaci* eggs and 240 *S. cerealella* eggs, and larvae III consumed 619 *B. tabaci* eggs and 150 *S. cerealella* eggs per day (Table 1). On the other hand, the developmental time of the different larval stages was similar between larvae I and II, whereas it was shorter for larvae III. Regarding *C. (C.) lineafrons* developmental time, an average of 45 days was recorded when the larvae fed with *B. tabaci* eggs and 35 days when they fed with *S. cerealella* eggs (Table 2).

Survival, longevity and oviposition

In general, *C. (C.) lineafrons* eggs survival was 81.1%. The immature stages of *C. (C.) lineafrons* fed with *B. tabaci* eggs exhibited lower survival (8.2%) than those fed with *S. cerealella* eggs (30.1%). Lacewings survival significantly decreased from the larval to the adult stage, for individuals fed both with *B. tabaci* eggs and *S. cerealella* eggs (Fig. 3).

In relation to *C. (C.) lineafrons* adults longevity, both a greater number of specimens and a greater longevity (41 days approximately) was observed from larvae fed with *S. cerealella* eggs, while for those fed with *B. tabaci* eggs longevity was 20 days (Fig. 4a). Lastly, *C. (C.) lineafrons* oviposition was also higher in females fed with *S. cerealella* eggs (Fig. 4b).

DISCUSSION

This study represents the first record of *C. (C.) lineafrons* predation capacity over *B. tabaci* eggs in Argentina, considering this specie as a potential biological control agent. It is worth remarking that this lacewing specie was recently cited for Tucumán province, in northwestern Argentina (Ortega *et al*., 2014).

In relation to ingest capacity, *C. (C.) lineafrons* larvae consumed a higher number of *B. tabaci* eggs than *S. cerealella* eggs per day, with larvae II standing out. These results are comparable to those reported by Legaspi *et al.* (1994), who determined that a greater number of *B. tabaci* eggs were necessary for the development of *Chrysoperla rufilabris* Bumeister larvae III. Other studies reported that *Chrysoperla carnea* Stephens was able to eat up to 200.5 *B. tabaci* nymphs and 171.8 *Amrasca devastans* Distant nymphs (Nisar Syed *et al.,* 2005); and that the larvae could consume about 8000 *S. cerealella* eggs and 510 *B. tabaci* pupae throughout its development (Gallardo *et al.,* 2005). Also, Legaspi *et al.* (1994) determined that *C. rufilabris* larvae consumed an average of 531.55 *B. tabaci* eggs per day, whereas Avila *et al.* (2009)

reported that *Chrysoperla argentina* Steimann larvae ingested an average of 275 *B. tabaci* eggs per day. This behavior might be attributed to the hypothesis suggested by Nisar Syed *et al.* (2005), who pointed out that prey density exhibits a strong influence on predation potential; i.e. the increase in egg consumption could be due to increases in larvae density.

Furthermore, the developmental time of *C. (C.) lineafrons* was 45 days when they were fed with *B. tabaci* eggs and 35 days when they were fed *S. cerealella* eggs. In relation to this, studies performed by Ramirez-Delgado *et al.* (2007) with *Ceraeochrysa* sp. nr. *cincta* determined that the total developmental time, from egg to adult emergence, was 29 days when the species was fed with *S. cerealella* eggs. Moreover, Legaspi *et al.* (1994) recorded a longer duration of larval developmental time in *C. rufilabris* fed with *B. tabaci* eggs compared to those fed with *S. cerealella* eggs. However, Nisar Syed *et al.* (2005) recorded a shorter developmental time on *C. cornea* fed with *B. tabaci* eggs compared to those fed with *A. devastans* eggs.

C. (*C*.) *lineafrons* survival decreased as the life cycle progressed; both for individuals fed with *B. tabaci* eggs, and for those fed with *S. cerealella* eggs. These results are similar to those obtained by Ramirez-Delgado *et al.* (2007), who determined a steady decrease of *C. sp. nr. cincta* longevity when it was fed with *S. cerealella* eggs. The longevity of *C*. (*C*.) *lineafrons* adults fed with *S. cerealella* eggs was 41 days; while for those fed with *B. tabaci* eggs it was 20 days, results that agree with those reported by Ramírez-Delgado *et al.* (2007), who determined a greater longevity for *C*. sp. nr. *cincta* adults fed with *S. cerealella* eggs.

In general, *C.* (*C*.) *lineafrons* survival, longevity and number of eggs laid per female were greater when they were fed with *S. cerealella* eggs than with *B. tabaci* eggs. In relation to this, Giffoni *et al.* (2007) determined that *C. externa* completed its life cycle only when being fed with *S. cerealella* eggs*;* while Legaspi *et al.* (1994) recorded that *C. rufilabris* larvae showed a greater preference for *S. cerealella* eggs than for *B. tabaci* eggs.

It has been observed that *C. (C.) lineafrons* exhibits a similar behavior to that of other lacewing species; with the peculiarity that their predation efficiency is much higher, thus turning this species into an excellent tool for efficient biological control of *B. tabaci* in tomato crops. Therefore, we conclude that the larval stages of *C. (C.) lineafrons* require a greater number of *B. tabaci* eggs than of *S. cerealella* eggs to complete their life cycle; larvae II and III of *C. (C.) lineafrons* consume more *B. tabaci* eggs; larval I stage lasts longer than the two other larval stages; survival and longevity of *C. (C.) lineafrons* adults was greater in individuals fed with *S. cerealella* eggs, and the number of eggs laid per female was also higher.

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Eugenia S. Ortega performed collecting and determination of specimens, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Cecilia A. Veggiani Aybar performed analyzed the data, contributed wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Ana L. Ávila contributed wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Carmen Reguilón contributed wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.

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FIGURE CAPTIONS

Figure 1 Geographical location of the tomato crops in Tucumán Province, northwestern Argentina.

Figure 2 **A**. Rearing of *C*. (*C*.) *lineafrons*; **B**. Eggs; **C**.and **D**. Larvas; **E**. Pupal stage; **F**. Adults.

Figure 3 Viability of different developmental stages of *C. (C.) lineafrons* fed with *B. tabaci* eggs and *S. cerealella* eggs.

Figure 4 (a) Longevity and (b) Oviposition of *C. (C.) lineafrons* adult fed with *B. tabaci* and *S. cerealella* eggs.

TABLE CAPTIONS

Table 1. Daily egg consumption of *C. (C.) lineafrons* larvae fed with *B. tabaci* eggs and *S. cerealella* eggs.

Table 2. Developmental time of different stages of *C. (C.) lineafrons* fed with *B. tabaci* eggs and *S. cerealella* eggs.

Table 1(on next page)

Daily eggs consumption of C. (C.) lineafrons larvae fed with B. tabaci eggs and S. cerealella eggs.

Table 1 Daily eggs consumption of *C. (C.) lineafrons* larvae fed with *B. tabaci* eggs and *S. cerealella* eggs.

Stage	Number of individuals evaluated	Eggs consumption			
		Total	Average/individuals	Average/individuals/day	Rank
B. tabaci					
L1	34	33607	988.4	88.01	0-556
L2	31	43188	1393.2	124.8	0-531
L3	23	27446	1193.3	168.3	0-619
S. cerealella					
L1	37	8125	219.6	22.02	0-189
L2	31	10367	334.4	55.2	0-240
L3	30	6020	200.6	54.8	0-150

Table 2(on next page)

Developmental time of different stages of C. (C.) lineafrons fed with B. tabaci eggs and S. cerealella eggs.

Table 2 Developmental time of different stages of *C. (C.) lineafrons* fed with *B. tabaci* eggs and *S. cerealella* eggs.

Stage	Mean ± SD	Life cycle duration
B. tabaci		
L1	11.23 ± 0.56	45.2
L2	11.16 ± 1.03	
L3	7.09 ± 0.74	
Pupa	15.75 ± 0.51	
S. cerealella		
L1	9.97 ± 0.69	34.9
L2	6,06 ± 0,7	
L3	3,66 ± 0,4	
Pupa	15,21 ± 0,57	

Means ± SE followed by $P < 0.05$

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Figure 1

Geographical location of the tomato crops in Tucumán Province, northwestern Argentina.

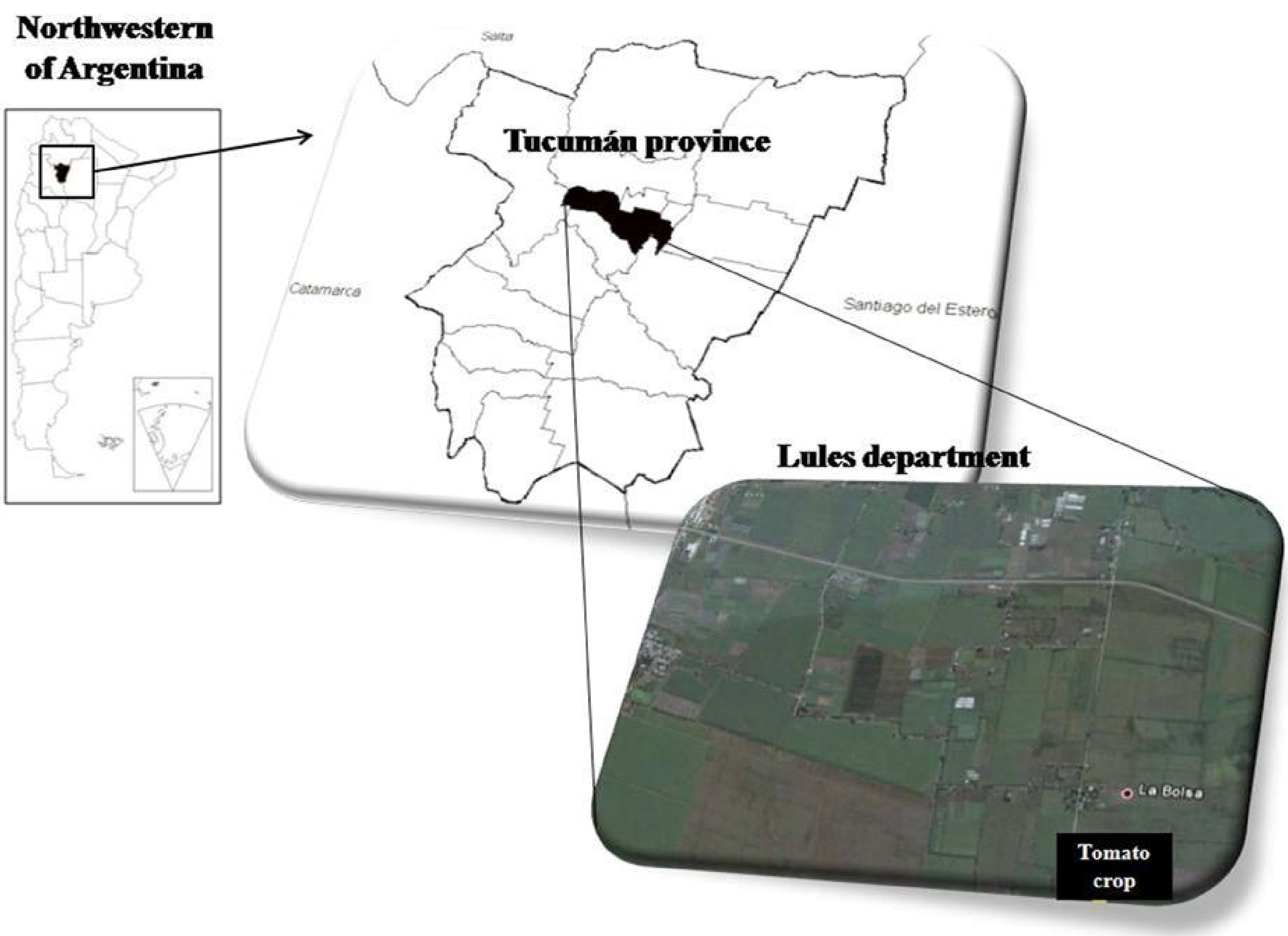

Figure 2

A. Rearing of *C.* (*C.*) *lineafrons*, B. Eggs, C.and D. Larvas, E. Pupal stage, F. Adults.

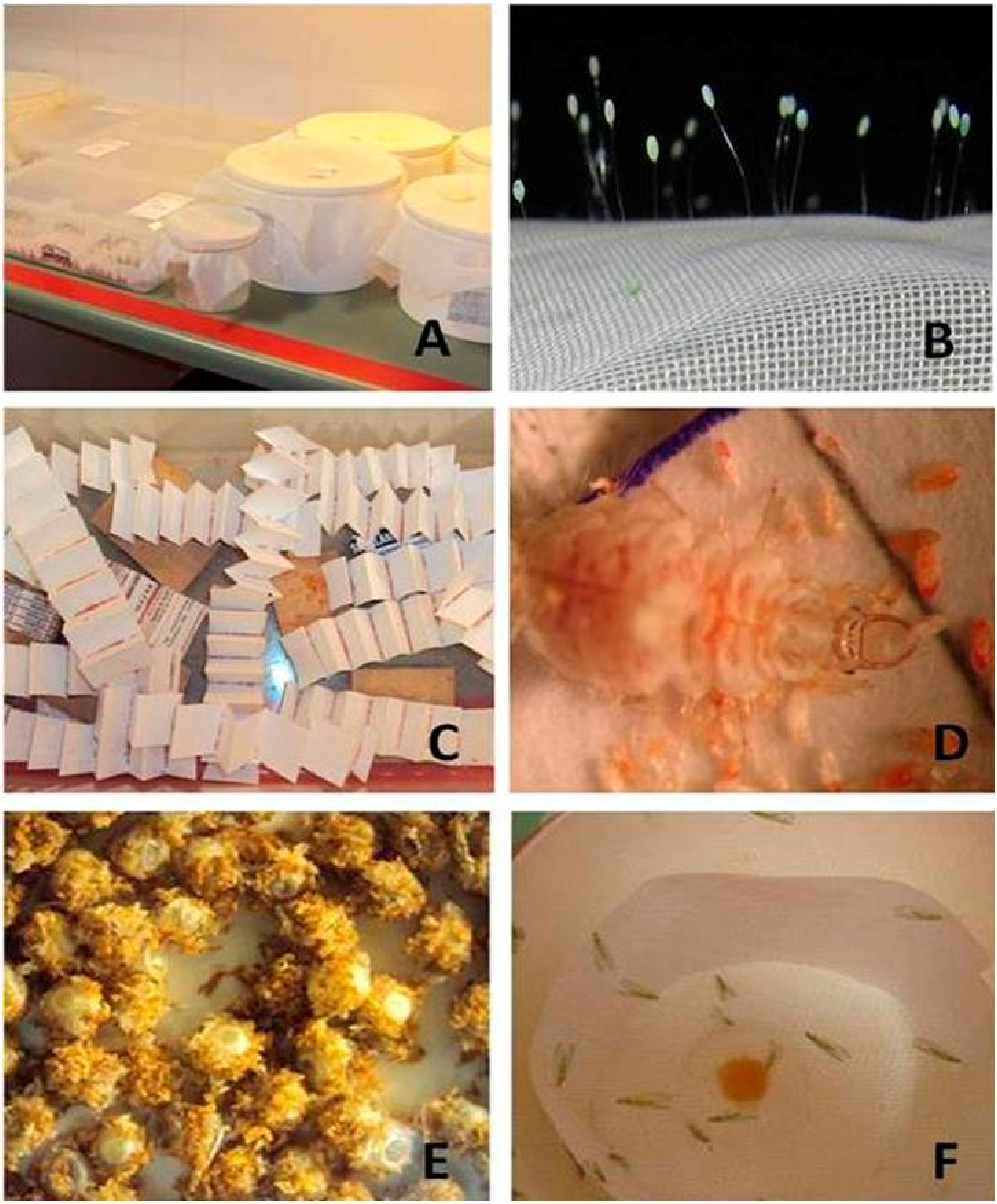
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Figure 3

Viability of different developmental stages of *C. (C.) lineafrons* fed with *B. tabaci* eggs and *S. cerealella* eggs.

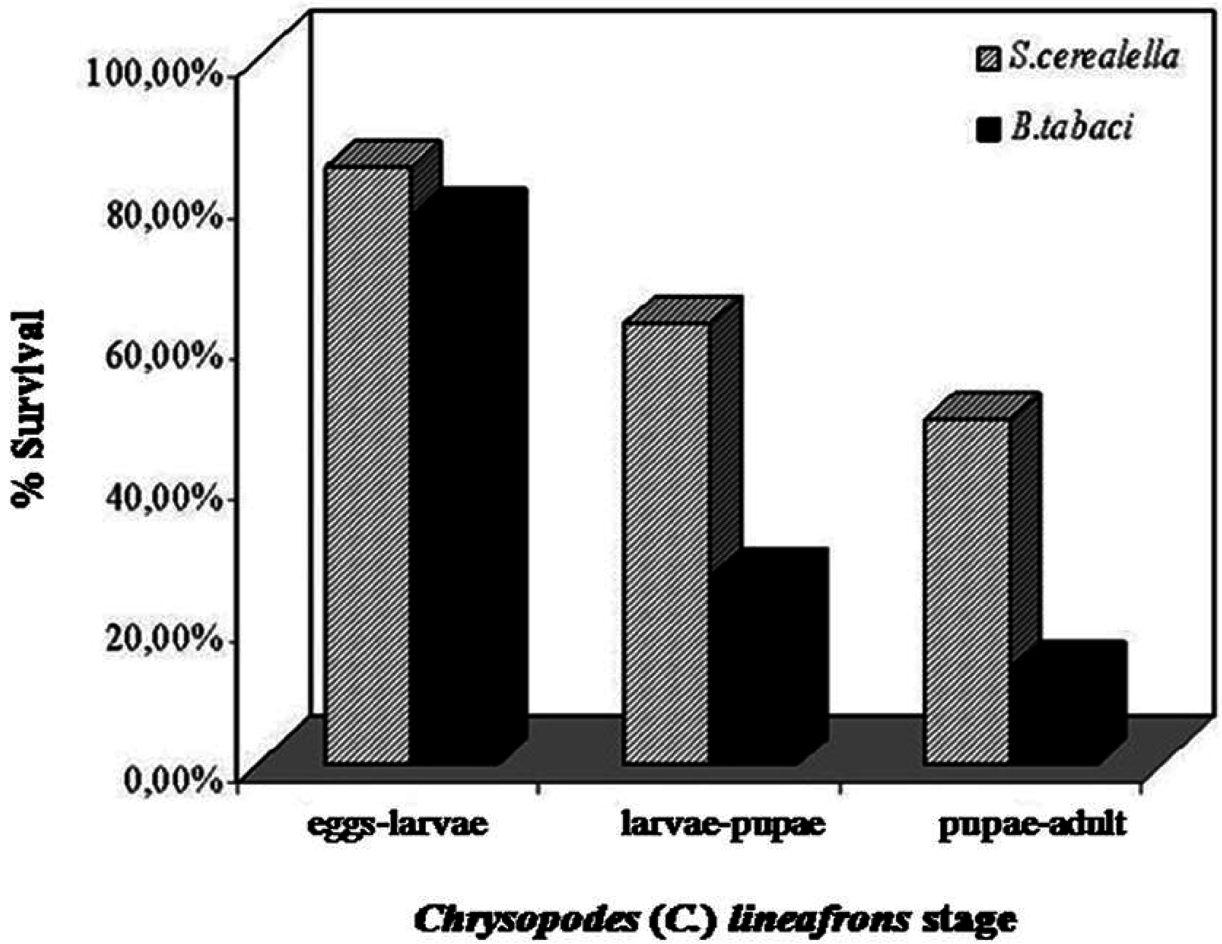
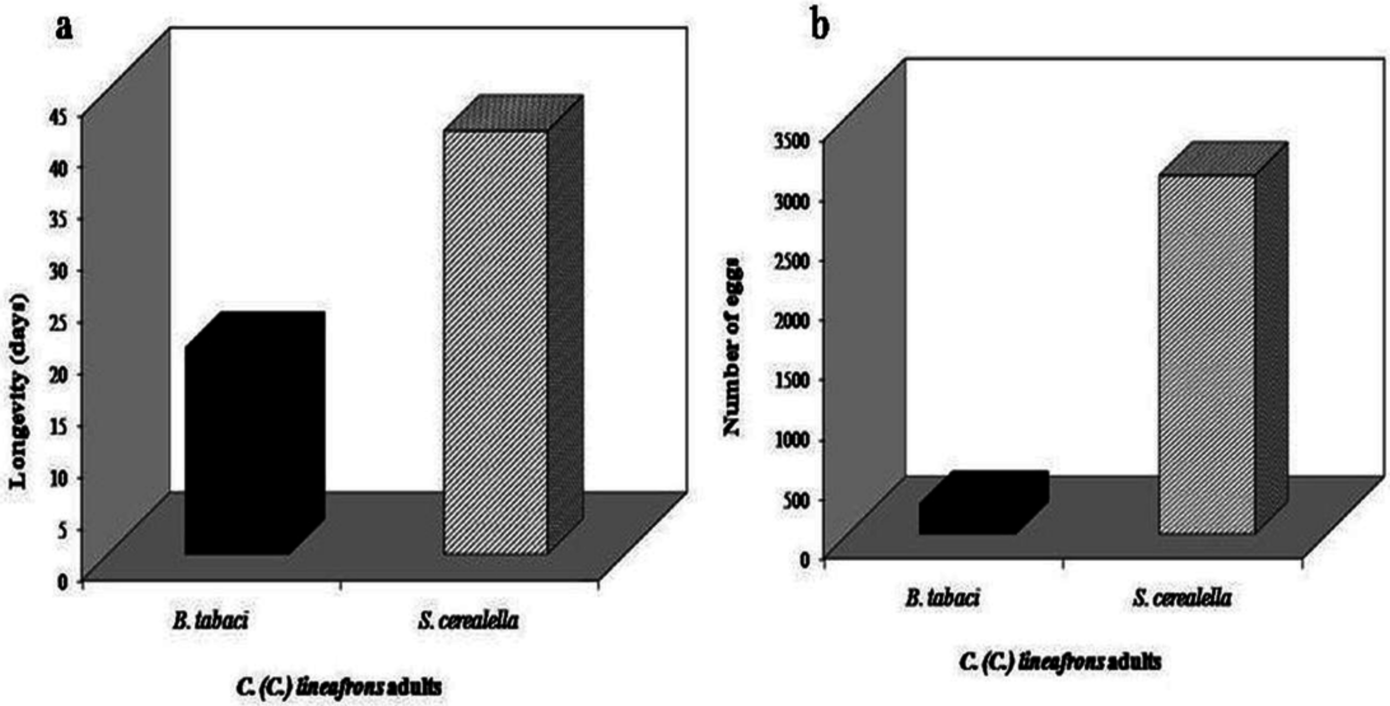


Figure 4

(a) Longevity and (b) Oviposition of *C. (C.) lineafrons* adult fed with *B. tabaci* and *S. cerealella* eggs.



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