PREY CONSUMPTION BY *Chrysopa pallens* OF UN-PARASITIZED AND *Encarsia formosa* PARASITIZED *Bemisia tabaci* BIOTYPE B PREY

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ABSTRACT

*Bemisia tabaci* biotype B has become a major pest, causing serious losses to many agricultural crops worldwide. *Chrysopa pallens* is an important polyphagous predator of *B. tabaci* on different agricultural crops. In the present study, prey consumption by *C. pallens* was determined with feeding on un-parasitized and *Encarsia formosa* parasitized *B. tabaci* biotype B prey on tomato host plant at controlled conditions in a climatic chamber. The results showed that *E. formosa* did not parasitize *B. tabaci* in the egg and *N*₁ stage, but the subsequent nymphal stages were parasitized. *C. pallens* consumed higher number of un-parasitized than *E. formosa* parasitized *N*₂, *N*₃, *N*₄ and pupal prey, where the consumed number of all prey stages increased in the subsequent larval stages of the predator.

Key Words: *B. tabaci*, *C. pallens*, *E. formosa*, Life table, Prey consumption


INTRODUCTION

The cotton, tobacco or sweet potato whitefly *Bemisia tabaci* (Gennadius) (Homoptera, Aleyrodidae) biotype B, is a highly polyphagous pest of more than 500 host plant species (Greathead, 1986; Secker et al., 1998) belonging to more than 60 plant families (Mound and Halsey, 1978) in tropic and subtropic (Jiang et al., 1999, Hilje et al., 2001), and temperate regions (Enkegaard, 1993; Wagner, 1995). *B. tabaci* ranks among the most noxious pests attacking field and greenhouse crops (Mound and Halsey, 1978; Gerling et al., 2001), and horticultural crops world-wide (Oliveira et al., 2001).

*B. tabaci* nymphs and adults suck cell contents and excrete honeydew that promotes sooty mould fungal development, which reduces photosynthetic efficiency and yield of the plant. The whitefly transmits more than 50 geminiviruses to its hosts, which include the tomato yellow leaf curl virus (Markham et al., 1996), tomato yellow leaf curl virus, tomato mottle virus and bean golden mosaic virus (McAuslane, 2000).

*B. tabaci* has been declared a difficult pest to control because of its high reproductive rate and many generations per year (Byrne and Bellows, 1991, Brown et al., 1995), its ability to rapidly developed resistance to many widely applied insecticides (Cahill et al., 1994; Denholm et al., 1998, Horowitz et al., 1999, Kranthi et al., 2001), to the insect growth regulators like buprofezin and pyriproxyfen (Horowitz et al., 1994). High doses and frequent pesticide application has killed/suppressed its natural enemies too (Lacey and Kirk, 1993).

During the past few decades more efforts have been made towards the discovery and development of safe alternatives for management of this insect with reduced hazards to the environment and human health. *B. tabaci* is a continuous high threat to the production of food and fiber crops and requires safe alternative of control like biological control. Biological control is one such safe alternative for the pest suppression. According to Huffaker and Messenger (1964) biological control is an ecological phenomenon, which can provide environmentally harmonious and economical pest management.

Chrysopids are polyphagous predators of many pest species (Hydorn, 1971) including lepidopteran larvae (Van den Bosch and Hagen, 1966), aphids (Hassan et al., 1985), spider mites (Hagley and Miles, 1987), scale insects (Miller et al., 2004), psyllids (Knowlton, 1933; Pletsch, 1947), mealy bugs, whiteflies, thrips, and leafhoppers (Balduf, 1974). Chrysopids can be easily reared on artificial diets and used for controlling agricultural insect pests (Cohen and Smith, 1998). Tsukaguchi (1995) found the green lacewing *Chrysopa pallens* (Rambur) an indigenous predator of aphids in the Palaearctic region.
According to Al-Zyoud and Sengonca (2004) biology, prey consumption on one or many species and interaction with other natural enemies should be studied before considering a predator for a biological control program. In addition, understanding biological and ecological characteristics of the predator, e.g., oviposition and egg-laying behaviour, fitness of its offspring and growth rate in the population (Danho and Haubruge, 2003), helps positively its use in a biological control program against a pest species.

Encarsia formosa Gahan (Hymenoptera, Aphelinidae) is commercially used for whiteflies control on glasshouse crops worldwide. E. formosa parasitizes several whitefly species including greenhouse whitefly (GHWF), Trialeurodes vaporariorum (Hoddle et al., 1997a, b), B. tabaci, and silverleaf whitefly, Bemisia argentifolii (= Bemisia tabaci strain B) (Hoddle et al., 1998). The wasp has been found parasitizing fifteen whiteflies species belonging to eight genera. E. formosa is uniparental and free-living parasitoid as an adult, which passes its immature stages within the hemocoel of its host. Suitability of the host (e.g., host age, size and physiological condition) determines successful growth and development of the parasitoid (Vinson, 1990).

Life table of B. tabaci on tomato and cotton host plants (Khan and Wan, 2007, unpublished) and of C. pallens with feeding on B. tabaci biotype B prey (Khan and Wan, 2007, unpublished) was determined in earlier studies. In the present study, predatory effect of C. pallens of un-parasitized and E. formosa parasitized B. tabaci biotype B was determined.

MATERIALS AND METHODS

Stock culture of B. tabaci biotype B was established on Zhong Za no. 9 variety of tomato plants with individuals obtained from a previously maintained colony on cotton plants. The rearing took place in meshed cages (80×50×60 cm) sealed with gauze from four sides in order to provide adequate ventilation. The cages were stored in a climatically controlled chamber at the Institute of Plant Protection (South Campus), Chinese Academy of Agricultural Sciences (CAAS) Beijing, at a temperature of 25±2°C, relative humidity of 60±5% and a photoperiod of 16:8h (L:D) with an artificial light intensity of about 4000 lux. The host plants were grown in small plastic pots (10 cm diameter and 8 cm height) in a glasshouse and were replaced with new ones regularly. The old infested tomato plants were used to infest new ones and to feed the predators.

The appropriate eggs, nymphs or puparia of B. tabaci used in the different experiments were obtained from the stock culture. For this, tomato plants were exposed to adult B. tabaci infestation for a couple of days in the stock culture. The whitefly adults were removed and the plants incubated under climatic conditions as per above and monitored daily until the individuals reaching the desired stage for the experiments.

C. pallens stock culture was started from few individuals obtained from an old culture maintained for other laboratory experiments. The rearing took place in the cages as for B. tabaci and kept in growth chambers at conditions mentioned above. Aphis craccivora infested bean plants were used as substrate plants and prey for rearing the predator immature. The adults were fed on 10% honey solution inside the cages. For continues prey supply, the old plants in the cages were regularly replaced with new ones.

Different C. pallens stages for the experiments, i.e., eggs, larvae, pupae as well as adult females and males were obtained from the rearing cages. Few mated adult females were transferred into individual cages along with honey solution as food. The cages were kept in a climatic control chamber as per above conditions. Twenty four hours later, the adult females were moved to fresh cages and the laid eggs were daily observed till they reached the required stage for the experiments. C. pallens desired stage was singly transferred to fresh uniform sized tomato leaves and confined using the clip on cages with a mesh-covered hole in the bottom for aeration.

The prey consumption by C. pallens larval instars during their entire development was studied in the laboratory as per above mentioned climatic conditions and by feeding on different life stages of B. tabaci as prey. All the prey consumption experiments were conducted on tomato leaves in clip on cages.

Prey Consumption by the Larval Instars

In order to determine prey consumption by the C. pallens larval instars, the newly hatched L₁ were picked up using a camel-hair brush and kept individually in the clip on cages mentioned above and daily offered with 20 eggs, 10 N₁, 10 N₂, 5 N₃, 5 N₄ or 5 pupa. The subsequent stages L₂ was offered with 50 eggs, 30 N₁, 20 N₂, 15 N₃,
10 N₄ or 10 pupa; L₁ with 90 eggs, 50 N₁, 40 N₂, 20 N₃, 15 N₄ or 10 pupa and L₄ with 100 eggs, 80 N₁, 70 N₂, 60 N₃, 50 N₄ or 40 pupa of *B. tabaci* prey on fresh uniform sized tomato leaf in the cages. During the experiments, the larvae were transferred daily into new cages with fresh prey and the number of consumed prey individuals in the old cages was noted. All immature stages of *C. pallens* were used in the different experiments and starved for 12h before use by placing them on the tomato leaves in individual cages. Twenty replicates were done per each prey stage in the experiments. Five more cages were used as control. In these cages, there were *B. tabaci* but in the absence of the predator. The estimation of the predatory effect of *C. pallens* was based on the percentage (%) of different *B. tabaci* stages consumed by the various *C. pallens* larval instars to their initial (total) number before the introduction of the predator.

### Preference for Un-parasitized or *E. formosa* Parasitized Prey

To enhance the chance for using *C. pallens* in a biological control program, it was worthy to investigate how it would react on a parasitized prey by another natural enemy, which is usually utilised in the biological control programs of whiteflies. *E. formosa* parasitizes several whitefly species and is a valuable biological control agent for many whitefly species including *B. tabaci*. Therefore, the preference of *C. pallens* for *B. tabaci* nymphal stages or puparia parasitized by *E. formosa* was studied. *E. formosa* (obtained from an old stock of whitefly infested cotton plants in a glasshouse at CAAS) was maintained on tomato plants infested with *B. tabaci* in a meshed cage (60×50×50 cm) under climatic conditions mentioned above. In a series of experiments, freshly emerged eggs and N₁, N₂, N₃ and N₄ of *B. tabaci*, reared on 2-3 weeks old tomato plants were separately exposed to freshly emerged adult *E. formosa* for oviposition.

To record the preferences regarding parasitized prey, the parasitized *B. tabaci* stages were used after two day of exposure/parasitism by *E. formosa*. The number of parasitized *B. tabaci* prey offered to the different immature predators was the same as mentioned above for un-parasitized prey. The basic experimental unit was a fresh uniformed sized tomato leaf in a plastic clip cage. Prey consumption data was recorded during the entire duration of each larval stage. All immature stages of *C. pallens* were used in the different experiments and starved for 12h before use by placing them on the tomato leaves in individual cages. There were twenty replicates with each predatory immature per prey stage. Five more cages were used as control. In these cages, there were *B. tabaci* but in the absence of the predator. The estimation of the predatory effect of *C. pallens* was based on the percentage (%) of different stages *B. tabaci* consumed by the immature as well as adult predators to their initial (total) number before the introduction of the predator.

### RESULTS AND DISCUSSION

The results showed that *C. pallens* L₁ consumed 21.5 un-exposed *B. tabaci* biotype B eggs on day 1 and 25.5 eggs on day 4 and 20.9 and 24.8 eggs of *E. formosa* exposed eggs on these days (Fig. 1). The L₁ consumed 14.2, 16.3 and 14.4, 16.2 unexposed and *E. formosa* exposed N₁ on day 1 and 4, respectively. The number of un-parasitized and parasitized *B. tabaci* N₂ consumed by the L₁ was 16.1, 23.4 and 13.1, 21.2 N₂ on day 1 and 4, respectively. The un-parasitized and parasitized *B. tabaci* N₃ consumed by the L₁ were 7.0, 10.0 and 2.1, 3.3 on day 1 and day 4, respectively. *C. pallens* L₁ consumed 3.1, 4.2 and 1.1, 1.6 on day 1 and 4 of un-parasitized and parasitized N₄, respectively. The L₁ consumed 0.8, 1.9 and 0.1, 0.2 un-parasitized and parasitized *B. tabaci* pupa on day 1 and 4, respectively.

![Fig. 1 Prey consumption by Chrysopa pallens L₁ of un-parasitized and Encaria formosa parasitized Bemisia tabaci biotype B prey. Developmental stage followed by * is significantly different at p<0.05 (t-test)](image-url)
The *C. pallens* L<sub>2</sub> consumed 31.5 un-exposed eggs on day 1 and 38.1 on day 6 and 32.0 and 37.6 *E. formosa* exposed *B. tabaci* eggs on day 1 and 6, respectively (Fig. 2). The L<sub>2</sub> consumed 14.8, 21.2 and 15.2, 20.7 of unexposed and exposed *B. tabaci* N<sub>1</sub> on day 1 and 6, respectively. The number of unexposed and exposed N<sub>2</sub> consumed by L<sub>2</sub> on day 1 and 6 was 26.1, 31.9 and 13.3, 21.2, respectively. The un-parasitized and parasitized N<sub>3</sub> consumed by the L<sub>2</sub> were 17.0, 23.9 and 6.3, 10.9 on day 1 and 6, respectively. The *C. pallens* L<sub>2</sub> consumed 11.1, 14.1 and 3.3, 5.4 un-parasitized and parasitized N<sub>4</sub> on day 1 and 6, respectively. The L<sub>2</sub> consumed 4.7 un-parasitized pupae on day 1 and 7.8 on day 6 and 1.8, 2.9 parasitized pupa on these days, respectively.

**Fig. 2. Prey consumption by *Chrysopa pallens* L<sub>2</sub> of un-parasitized and *Encaria formosa* parasitized *Bemisia tabaci* biotype *B* prey. Developmental stage followed by * is significantly different at p<0.05 (t-test)**

The *C. pallens* L<sub>3</sub> consumed 51.5, 60.4 un-exposed and 50.6, 58.0 of *E. formosa* exposed *B. tabaci* eggs on day 1 and 8, respectively (Fig. 3). The L<sub>3</sub> consumed 36.7 unexposed N<sub>1</sub> on day 1 and 45.0 on day 8 and 35.5 and 43.1 *E. formosa* exposed prey on these days, respectively. The number of un-parasitized and parasitized *B. tabaci* N<sub>2</sub> consumed by the L<sub>3</sub> were 46.7, 53.3 and 35.1, 43.8 on day 1 and 8, respectively. The un-parasitized and parasitized N<sub>3</sub> consumed by the L<sub>3</sub> were 35.4, 41.0 and 23.4, 30.5 on day 1 and 8, respectively. *C. pallens* L<sub>3</sub> consumed 24.9, 32.2 and 15.2, 22.1 on day 1 and 8 of un-parasitized and parasitized N<sub>4</sub>, respectively. The L<sub>3</sub> consumed 9.8, 14.8 of un-parasitized and 4.4, 7.6 *E. formosa* parasitized *B. tabaci* pupae of on day 1 and 8, respectively.

**Fig. 3 Prey consumption by *Chrysopa pallens* L<sub>3</sub> of un-parasitized and *Encaria formosa* parasitized *Bemisia tabaci* biotype *B* prey. Developmental stage followed by * is significantly different at p<0.05 (t-test)**

Efficiency of a predator in biological control depends among other factors on its preference for a certain pest stage or even the pest species to be controlled as well as a possible interaction with other natural enemies in the agro-ecosystem. As such knowledge of *C. pallens* was still lacking in the literature. Therefore, the present experiments were set up to study *C. pallens* development and prey consumption by immature as well as adult predator stages of un-parasitized and *E. formosa* parasitized different *B. tabaci* prey stages.

The results showed no significant differences in the consumed number of unexposed or *E. formosa* exposed eggs and N<sub>1</sub> by the predator larvae. But, *C. pallens* consumed significantly higher number of un-parasitized N<sub>2</sub>, N<sub>3</sub>, N<sub>4</sub> and pupal prey than the *E. formosa* parasitized these prey stages. The number of all stages of prey consumed increased in the subsequent stages of the predator.

Information is lacking on immature *C. pallens* prey consumption of different *B. tabaci* stages as prey on tomato host, but the present results can be compared with the findings of some previous researcher’s with the predator’s feeding on different aphid’s species and coccinellid predators feeding on *B. tabaci* as prey.
Al-Zyoud and Sengonca (2004) observed preference by the *Serangium parcesetosum* Sicard (Col.: Coccinellidae) L3 and L4 instars for un-parasitized than *E. formosa* parasitized puparia of *B. tabaci* at two different temperatures of 18°C and 30°C. At 18°C, the mean daily consumption was 8.7 and 0.2 (L2), 11.1 and 0.6 (L4) un-parasitized and parasitized puparia, respectively, while at 30°C it was 15.9 and 0.5 (L2), 19.8 and 1.0 (L4), 18.9, respectively.

Total aphids consumed by the *H. axyridis* larval stages varied from 90 to 370 aphids, depending on the aphids species consumed (Hukusima and Kamei, 1970). *H. axyridis* aphid consumption increased for each successive instar (Hukusima and Kamei, 1970; Miura and Nishimura, 1980). Averaged across larval instars, 23.3 aphids were consumed per day (He et al., 1994).

Information is lacking on prey consumption by *C. pallens* of un-parasitized and *E. formosa* parasitized different stages *B. tabaci* as prey on tomato host, but the present results can be compared with the findings of some previous researchers studies on *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) predator with feeding on aphids species as prey. Snyder et al. (2004) investigated the combination of a parasitoid wasp, *A. asychis*, and *H. axyridis*, for the control of a common greenhouse pest, the potato aphid, *M. euphorbiae*. *H. axyridis* adults and larvae fed readily on *A. asychis* mummies, although both predator stages also fed heavily on aphids under laboratory conditions. *H. axyridis* larvae e.g., when offered both aphids and mummies, ate twice of the former and so significantly increased ratio of mummies to aphids. As *H. axyridis* feed on parasitoid mummies, so intraguild predation of the parasitoid by the predator weakens overall biocontrol when both occur together. Intraguild predation of parasitoids by predators has disrupted or may disrupt, biocontrol by parasitoids in a variety of systems (Brodeur and Rosenheim, 2000), including greenhouses (Harizanova and Ekbom, 1997). *H. axyridis* larvae, however, either preferred to feed on *M. euphorbiae* and so increased the ratio of mummies to aphids, or adult beetles had no preference for mummies or aphids, which suggest biocontrol might be improved by the beetles addition to the system.

Quezada and DeBach (1973) in similar fashion, found vedalia beetle *Rodolia cardinalis* (Mulsant) feeding on cottony cushion scale *Icerya purchasi* Maskell, avoided parasitized prey by *Cryptochaetum iceryae* (Williston). Also, *Delphastus pusillus* (LeConte), a whitefly coccinellid predator, avoided the fourth instar of *B. tabaci* parasitized by the aphelinid parasitoid, *Encarsia tranvena* (Timberlake) and *Eretmocerus sp. nr californicus* Howard in favor of un-parasitized whitefly (Hoelmer et al., 1994). According to Al-Zyoud and Sengonca (2004) the *S. parcesetosum* 7-day-old adult females and males preferred un-parasitized than *E. formosa* parasitized puparia of *B. tabaci* at two different temperatures of 18°C and 30°C. At 18°C, the mean daily consumption of un-parasitized and parasitized puparia was 12.1 and 1.0 by females as well as 10.5 and 0.2 by males, while at 30°C it was 18.9 and 1.2 by females as well as 17.4 and 0.6 by males, respectively.

Zang and Liu (2007) experimented intraguild interactions between two natural enemies of *B. tabaci*, an oligophagous predator, *Delphastus catalinae* (Horn), and a parasitoid, *Encarsia sophia* (Girault and Dodd), on cabbage under laboratory and greenhouse conditions. Predation was generally lower, in no-choice and choice experiments, on the whitefly nymphs containing *E. sophia* pupae than on larval stages or on un-parasitized whitefly nymphs. Adult *D. catalinae*, however, did not discriminate between prey types in choice tests. In both choice and no-choice tests, second instar *D. catalinae* larvae discriminated whitefly nymphs containing parasitoid larvae, and the third and fourth instar predator larvae attacked less the whitefly nymphs containing parasitoid pupae than larvae. The results of earlier and present studies indicated that the chrysopid predator avoided feeding on parasitized prey and preferred the un-parasitized ones.

The present results enhance the options of using *C. pallens* in pest management programs in conjunctions with parasitoids. As the predator feed more on un-parasitized whiteflies, there is a high potential of integration both natural enemies in a biological control program against *B. tabaci* biotype B, which will yield high pest suppression. But, predation by *C. pallens* immature on parasitized *B. tabaci* nymphs, so that intraguild predation of the parasitoid by the predator occurs, might weaken the overall biocontrol when both the natural enemies co-exist in agro-ecosystems.

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