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Intraguild interactions between an oligophagous predator, *Delphastus catalinae* (Coleoptera: Coccinellidae), and a parasitoid, *Encarsia sophia* (Hymenoptera: Aphelinidae), of *Bemisia tabaci* (Homoptera: Aleyrodidae)

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Abstract

The intraguild interactions between two natural enemies of *Bemisia tabaci* (Gennadius), an oligophagous predator, *Delphastus catalinae* (Horn), and a parasitoid, *Encarsia sophia* (Girault & Dodd), associated with predation, parasitization, host feeding, and suppression of *B. tabaci* populations were determined on cabbage under laboratory and greenhouse conditions. We conducted two laboratory experiments: a no-choice test of prey consumption by three larval instars and adult *D. catalinae* foraging for either whitefly fourth instar nymphs or whitefly nymphs containing second or third larval instar or pupal parasitoids of *E. sophia*; and a choice test, in which three larval instars or adult *D. catalinae* were allowed to forage for the above prey, presented simultaneously. We also conducted a mesocosm experiment under greenhouse conditions in which a low (20 females) or high (40 females) release of *E. sophia* adults, a low (6) or high (12) release of *D. catalinae* adults, a combined release with both predators and parasitoids at the low rate (20 parasitoids and 6 predators), and the experiments were performed on caged plants infested experimentally with whiteflies. In no-choice and choice experiments, predation was generally lower on the whitefly nymphs containing *E. sophia* pupae than on larval stages or on unparasitized whitefly nymphs. In choice tests, adult *D. catalinae* did not discriminate between prey types. In both choice and no-choice tests, second instar *D. catalinae* larvae tended to discriminate against whitefly nymphs containing parasitoid larvae, and the third and fourth instar predator larvae tended to attack less the whitefly nymphs containing parasitoid pupae than larvae. In the mesocosm experiment, the results indicate that *D. catalinae* did not avoid feeding on *B. tabaci* nymphs with larval stages of *E. sophia* and numbers of whitefly nymphs killed by *E. sophia* were lower in the presence of *D. catalinae*. However, whitefly immatures on cabbage leaves were significantly less abundant in each of the three treatments with the presence of *D. catalinae* as compared with treatments that did not include the predators.

Keywords: *Delphastus catalinae*; *Encarsia sophia*; *Bemisia tabaci*; Intraguild predation; Biological control

1. Introduction

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius) biotype 'B' (also reported as *B. argentifolii* Bellows and Perring), is a worldwide problem in agricultural crops. The rapid rise to key pest status has been partly attributed to insecticide resistance and decimation of natural enemies in response to broad spectrum insecticides. Therefore, biological control could be an attractive management alternative for whiteflies (Liu and Stansly, 1996a).

Many attempts at controlling *B. tabaci* using parasitoids (especially for the genera *Encarsia* and *Eretmocerus*) or predators have achieved great success (Gerling et al., 2001). With greatly increased choices of biological control agents for application in greenhouse crops, it is now possible to release several different beneficial species in order to control

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one or more pest species simultaneously (Meyling et al., 2004). However, when beneficial species share a pest species as their common prey, intraguild interactions between them may take place. Intraguild predation is a common interaction in many insect communities and has been defined as "the killing and eating of species that use similar resources and thus are potential competitors" (Polis and Holt, 1992). Generalist predators have relatively long generation time and do not feed only a target pest (Chang and Kareiva, 1999; Riechert and Lockley, 1984). Thereby, generalist predators usually act as intraguild predators. In recent years, many studies on intraguild predation by generalist predators on the specialist parasitoids have been conducted (Snyder and Ives, 2001; Snyder et al., 2004; Meyling et al., 2004; Shiojiri and Takabayashi, 2005; McGregor and Gillespie, 2005), and most of these studies indicate that predators do not discriminate between unparasitized and parasitized hosts. However, there are only limited published researches on intraguild predation between oligophagous predators and parasitoids. Understanding the differences between the intraguild interactions of generalist and oligophagous predators with parasitoids is needed and would be useful to manipulate both generalist or oligophagous predators and parasitoids in biological control of insect pests.

Encarsia sophia (Girault & Dodd), formerly also known as *E. transvena* (Timberlake), is an important parasitoid species parasitizing many species of whiteflies, including *B. tabaci* and *Trialeurodes vaporariorum* (Westwood) (Gerling et al., 1998; Huang and Polaszek, 1998; Hunter and Kelly, 1998). It is a solitary, arrhenotokous, heteronomous, autoparasitoid, whose female eggs are laid internally in whitefly nymphs and develop as primary parasitoids, whereas males develop as hyperparasitoids, either on females of their own species or on other primary aphelinid parasitoids. It was originally imported into the US and released in several southern states to control *B. tabaci*, and it has become field established in California, Texas and Florida (Goolsby et al., 2005).

Delphastus catalinae (reported previously as *D. pusillus*), an oligophagous predator of whiteflies, purple scale and twospotted spider mite (Hoelmer et al., 1993; Liu and Stansly, 1996b), has exhibited great potential to control *B. tabaci* (Heinz and Parrella, 1994a,b; Heinz et al., 1994; Hoelmer et al., 1994; Liu and Stansly, 1999, 2004; Liu, 2005), and gradually has become one of the most common predacious natural enemies used for controlling whiteflies under greenhouse conditions (Hunter, 1998).

Hoelmer et al. (1994) and Heinz et al. (1994) reported that larvae and adults of *D. catalinae* exhibited a marked tendency to avoid feeding on third instar parasitoids (*E. sophia* and *E. pergandiella* Howard), especially for pupae. They also showed that younger instars of parasitoids, especially for those $\leqslant 7$ days old, suffered from a high risk predation in confrontations with *D. catalinae*. Their results indicate that intraguild predation by *D. catalinae* on parasitized whiteflies occurred. Understanding the role of intraguild interactions may contribute to an effective pest management strategy when multiple natural enemies may be necessary to control a given pest. Therefore, it is necessary to determine whether the potential negative impact on the parasitoid populations from *D. catalinae* reduces the chance of achieving successful biological control.

With an overall objective to determine whether two biological control agents, a predator and a parasitoid, could be better than either alone for biological control of *B. tabaci*, we performed no-choice and choice experiments to assess the intraguild interactions between the oligophagous predator *D. catalinae* and the parasitoid *E. sophia* of *B. tabaci* in the laboratory. In addition, we performed an experiment to determine whether the presence of the predator in combination with the parasitoid interferes with the performance (host feeding and parasitization) of the parasitoid for suppression of *B. tabaci* population under greenhouse conditions.

2. Materials and methods

2.1. Insects and plants

Delphastus catalinae were originally supplied by Applied Bio-Nomics Ltd. (Sidney, BC, Canada) in January 2006, and were maintained in an air-conditioned greenhouse (25–35 °C, and 60–90% RH) using *B. tabaci* maintained on cabbage (*Brassica oleracea* L. var. *capitata*, 'Golden Acre') as prey. The parasitoid *E. sophia*, naturally occurred in our greenhouses on *B. tabaci* biotype B, was reared in a separate air-conditioned greenhouse (25–35 °C, and 60–90% RH) on *B. tabaci* maintained on potted cabbage in two big cages ($110 \times 80 \times 80$ cm) which were screened with 52-mesh polyethylene screen on the sides and top.

The cabbage plants were grown in 15-cm plastic pots filled with Metro-Mix 360 growing medium (Sun Gro, Horticulture Distribution Inc., USA) and enclosed in whitefly proof screen cages. Plants grown to the stage with 3 fully extended true leaves were used for experiments. All laboratory experiments were conducted in an air conditioned insectary at 28 ± 2 °C, 70 ± 5% RH, and a photoperiod of 14:10 (L:D) h. Voucher specimens of *D. catalinae*, *E. sophia* and *B. tabaci* were deposited in the Insect Collection, Vegetable IPM Laboratory, Texas Agricultural Experiment Station at Weslaco.

2.2. Intraguild predation on E. sophia in the laboratory

2.2.1. No-choice test

Only one kind of parasitoid instar (second or third instar larva or black pupa) was exposed to *D. catalinae* at a time. Thirty female and male whitefly adults were introduced onto the lower leaf surface of a cabbage leaf on a potted plant with a clip cage (4.0 cm in diameter) for oviposition for 12 h. The nymphs were monitored daily until they developed to early fourth instars. Twenty mated female parasitoids were introduced into each clip-cage for oviposition for 6 h. The development of the parasitoid larvae was