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Overwintering of *Encarsia tricolor* on the cabbage whitefly

Sebastian Laurenz, André Brun, Rainer Meyhöfer
Leibniz Universität Hannover, Institute of Horticultural Production Systems, Section Phytomedicine, Herrenhäuser Straße 2, 30419 Hannover, Germany

Abstract: *Encarsia tricolor* is the dominant parasitoid species of the cabbage whitefly, *Aleyrodes proletella*. The latter finds sufficient overwintering habitats to appear in masses on cabbage crops during cultivation periods, whereas habitats with suitable overwintering hosts for *E. tricolor* are hardly available. Therefore, specific management strategies are needed to facilitate parasitoid overwintering. As a first step, this study aimed to provide general knowledge about the overwintering stages, the overwintering period and the overwintering success of *E. tricolor* on its primary host *A. proletella*. Results show that *Encarsia tricolor* successfully survived winter as immature stages, but no adults were found during late winter months. Visual observations revealed that at least 2.4% of *A. proletella* nymphs actually enclosed vital parasitoid eggs/ larvae during winter (n = 1,603), because they started to turn dark (parasitoid pupation) between 13-20 April. The proportion of adult emergence from these subsequently developed parasitoid pupae was 41%. In contrast, only 1.1% of parasitoid pupae collected in January overwintered successfully (n = 356). First adult *E. tricolor* were found on yellow sticky traps in the field between 4-11 May. The gained insights on the overwintering of *E. tricolor* are compared with the population dynamics of *A. proletella* on cabbage crops and conclusions for additional management strategies are discussed.

Key words: *Aleyrodes proletella*, Aleyrodidae, Aphelinidae, biological control, parasitoid

Introduction

One reason for the development of the cabbage whitefly, *Aleyrodes proletella*, (Hemiptera: Aleyrodidae) to a major cabbage pest in Central Europe is the increased cultivation of winter oilseed rape, which serves as optimal overwintering habitat for adult *A. proletella* (Richter & Hirthe, 2014, Ludwig & Meyhöfer, 2016). Its main parasitoid *Encarsia tricolor* (Hymenoptera: Aphelinidae) is supposed to overwinter as immature stages in whitefly nymphs, which are rarely present on winter oilseed rape (Stein, 1958). Since most cabbage crops are harvested before winter ends, there are hardly any overwintering habitats left for *E. tricolor*. This study aimed to gain deeper insight about the overwintering strategy of *E. tricolor* as basic requirement for the development of further management strategies to facilitate *E. tricolor* overwintering and increase biological control of *A. proletella*.

Material and methods

Experimental set up

Brussels sprouts plants (*Brassica oleracea* var. *gemmifera* ‘Maximus F1’) were planted in a 2.5 m wide and 88.5 m long strip on experimental fields of the Institute of Horticultural Production Systems, Leibniz Universität Hannover, Germany, on 26th May 2014.

Overwintering of eggs/ larvae and adults

Twenty-two plants were randomly selected in February 2015. One leaf with unparasitized *A. proletella* nymphs was marked on each plant, the number of nymphs counted and subsequent development of parasitoid pupae inside nymphs (turn dark) was recorded on a weekly manner until 11th May. Parasitoid pupae were further observed for adult emergence to evaluate the overwintering success of *E. tricolor* as egg/larva inside its whitefly host. Additionally, the numbers of living *E. tricolor* adults on the marked plants were determined with the same frequency to obtain information on the ability of the parasitoid to overwinter as adults. Local temperatures were recorded to allow explanations of observed events.

Overwintering of pupae

On 20th/21st January 2015, 356 obviously parasitized *A. proletella* nymphs (contained visible dark parasitoid pupa) were randomly collected to investigate pupal *E. tricolor* overwintering. Therefore, parasitized nymphs were gently removed from old cabbage leaves with a dissection needle and transferred individually into gelatine capsules with a fine brush. Gelatine capsules were then placed on tissue paper in open plastic boxes in small groups to avoid overlapping of capsules. The boxes were deposited inside a gauze tent (2 m x 2 m x 2 m) with a transparent plastic roof (field insectary) and covered with lightproof mesh. This construction protected the capsules from rain and direct sun light and thus from softening and overheating, but kept temperatures inside the capsules similar to outdoor conditions. The temperature was recorded next to the capsules in one of the boxes. Parasitized whitefly nymphs were weekly checked for adult parasitoid emergence.

Adult emergence

Twelve randomly selected plants were equipped with a yellow sticky trap construction on 16th March 2015 to determine the time of first *E. tricolor* adult emergence in the field. Therefore, the undersides of two yellow cards (Horticoop B. V., Bleiswijk, The Netherlands) were coated with insect glue (Temmen GmbH, Hattersheim, Germany) (Hoelmer & Simmons, 2008). Cards were stuck together to one yellow sticky trap (190 mm x 220 mm) and a hole with a diameter of the respective plant stem was cut centrally in each trap. Constructed traps were then tightly fixed horizontally around the plant stems in 300 mm above ground, fixed with a clip and supported by a wire frame underneath (circle with a diameter of 200 mm and three wire feet pushed into the ground). All yellow sticky traps were replaced and trapped *E. tricolor* adults counted for each trap in a weekly interval.

Start of whitefly reproduction

The amount of *A. proletella* egg batches was weekly recorded on 44 randomly selected plants from February to May 2015. The received information on the beginning of whitefly reproduction period enabled us to estimate the time when first hosts for *E. tricolor* (i.e. whitefly nymphs) were present on the overwintering plants (Stein, 1958).

Results and discussion

Overwintering period

First whitefly nymphs that contained parasitoid pupae were observed on marked leaves between 13-20 April (Figure 1). These nymphs must have been parasitized already in 2014 and immature parasitoids inside must have overwintered as eggs or young larvae, because adult parasitoids were not yet present at that time. First *E. tricolor* adults were found on yellow sticky traps between 4-11 May (0.5 ± 0.3 individuals per trap). This is a realistic period for the emergence of the first *E. tricolor* adults after overwintering based on respective average temperatures (12.5 °C) and calculations for pupal development times after Avilla & Copland (1988). Most likely the on average 1.2 °C higher temperatures caused an earlier adult emergence in the gauze tent (6th-13th April) compared to field observations.

First whitefly egg batches were observed between 6-13 April (Figure 1). Temperatures in this period exceeded the developmental threshold for *A. proletella* eggs (10 °C) for the first time of the year (Iheagwam, 1978). Eggs need about three weeks at respective average temperatures (Stein, 1958). Therefore, hosts were already available for the first generation of *E. tricolor* after overwintering.

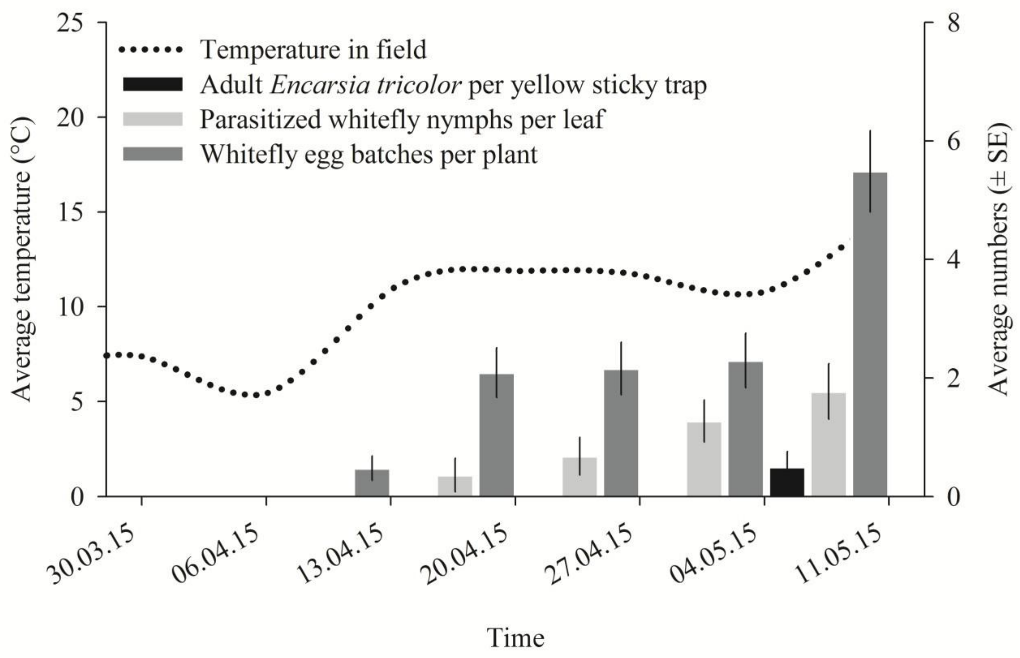

Figure 1. Average temperatures in field and average determined population parameters of *Encarsia tricolor* and *Aleyrodes proletella* during the experimental period (no activity observed before 30th March and therefore not shown here).

Overwintering success

The on average 73 ± 8 *A. proletella* nymphs per marked leaf (mean ± SE) showed a parasitism rate of 2.4% (i.e. turned dark due to parasitoid pupation). Adult *E. tricolor* females emerged from 41% of these subsequently pupated parasitoids. The parasitism rates are comparable to observations by Stein (1958), who reported 1-3% parasitism rates in February 1954 and 1955.

Only 1.1% of the collected *E. tricolor* pupae survived winter and emerged as adult females (n = 356). This high mortality could be explained by low temperatures between -2 °C and -7.5 °C that the overwintering *E. tricolor* pupae were exposed to for more than six hours on several days (Butler, 1938).

No *E. tricolor* adults were found on Brussels sprouts plants during the entire experimental period. Same was observed by Stein (1958), and Butler (1938) reported that adults as well as pupae do not survive temperatures under -2 °C for six hours or more. This suggests that *E. tricolor* is not capable to overwinter as adults in the open field in Central Europe.

Conclusion

Results revealed that *E. tricolor* can overwinter as eggs/larvae and pupae inside whitefly nymphs and the first adult generation appears in their overwintering habitat during May. However, the relatively low overwintering success, hardly available overwintering habitats with suitable hosts (i.e. whitefly nymphs) and the limited mobility of *E. tricolor* (Stein, 1958) may still cause a temporally and quantitatively insufficient migration into cabbage crops. Solutions are therefore needed to counteract this problem. For instance, offering overwintering habitats for *E. tricolor* near cabbage crops (e.g. perennial banker plants) or mass releasing of *E. tricolor* early in the year either manually or by annual banker plants may increase biological control services by *E. tricolor* or even promote the entire functional biodiversity of *A. proletella* natural enemies.

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