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Short Communication

Demographic potential of the pupal parasitoid *Trichopria drosophilae* (Hymenoptera: Diapriidae) reared on *Drosophila suzukii* (Diptera: Drosophilidae)

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ABSTRACT

Parasitoids represent a potential tool to control the invasive spotted wing drosophila, *Drosophila suzukii*, which has invaded Europe and America, recently. A good example is the pupal parasitoid, *Trichopria drosophilae*, would be an effective biocontrol agent. Populations of *D. suzukii*, and *T. drosophilae* were collected from a blueberry orchard in East China and reared in the laboratory at 25 °C. Life table and population growth data for *T. drosophilae* were obtained using *D. suzukii* pupae as a host. Mean adult longevity was 22.40 d and 26.45 d, for females and males respectively. The mean oviposition period was 18.20 d. The daily mean parasitization rate was 9.47% per female when 30 hosts were daily provided. The total number of *T. drosophilae* offspring throughout a lifetime was 63.45 per female, and the female offspring proportion was 65.06%. The intrinsic rate of natural increase and the finite rate of increase were 0.18 and 1.19, respectively. The generation time and the population doubling time were 21.29 d and 3.91 d, respectively. Our results suggest that *T. drosophilae* population differed among populations in population growth parameters, and those from China also has the parasitism potential to control *D. suzukii*.

Introduction

The spotted wing drosophila, *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae), is a key pest of soft and thin skinned fruits such as cherries, blueberries, blackberries, raspberries, strawberries, etc. (Asplen et al., 2015; Hamby et al., 2013; Lee et al., 2011). Most drosophila species attack only decaying or rotting fruits, e.g. the common species *D. melanogaster*. But unlike most other drosophila, *D. suzukii* females lay eggs in ripening fruits preharvest by cutting the fruit skin with their serrated ovipositor(Hamby et al., 2016). Larvae then feed on the fruit pulp, which makes the fruits useless for market and reduces crop yield (Arno et al., 2016; Lee et al., 2016; Rota-Stabelli et al., 2013). *D. suzukii* causes great economic damage worldwide. For example, annual loses attributed to this species of drosophila are estimated to be $390 million in California, USA (Walsh et al., 2011) and more than €3.3 million in Trentino, Italy (Ros et al., 2013).

This species of drosophila has a wide host range and a short generation time, making effective management of this pest challenging. Current control efforts depend heavily on insecticides, such as organophosphates, pyrethroids, and spinosyns (Haye et al., 2016; Rogers et al., 2016; Wiman et al., 2016). And in certain cases even methyl bromide (MB) fumigation has been attempted in post-harvest (Walse et al., 2012). Biological control, especially using parasitoids, may be helpful to reduce the insect pest (Wiman et al., 2016). Different parasitoid species, including larval and pupal parasitoids, have been reported in different regions.

There are approximately 50 hymenopterous parasitoid species to *Drosophila* which belong to four families: the larval parasitoids, Braconidae and Eucoilidae, and the pupal parasitoids, Diapriidae and Pteromalidae (Carton et al., 1986; Fleury et al., 2009). Most larval parasitoids cannot develop in *D. suzukii* because of its strong immune response in the laboratory (Chabert et al., 2012; Kacsoh and Schlenke, 2012; Rossi Stacconi et al., 2015), and in the field (Wang et al., 2016c). However, the pupal parasitoids *Trichopria drosophilae* (Hymenoptera: Diapriidae) and *Pachycrepoideus vindemmiae* (Hymenoptera: Pteromalidae) can successfully develop in *D. suzukii* (Chabert et al., 2012; Kacsoh and Schlenke, 2012; Wang et al., 2016a, 2016b). *T. drosophilae* is an endoparasitic, idiobiont parasitoid whose host range is known to be limited within Drosophilae (Carton et al., 1986; Le Lann et al., 2014). As some reports have demonstrated that this parasitoid can parasitize *D. suzukii* in field samples in the North American, Europe and Asia (Daane et al., 2016; Gabarra et al., 2015; Wang et al., 2016a, 2016b), *T.*

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drosophilae could be more efficient in laboratory tests of *D. suzukii* parasitism when compared to other pupal parasitoids, such as *P. vindemiae* (Wang et al., 2016a). Understanding the biology of *T. drosophilae* could lead to an increase in the rearing and releasing of this parasitoid in fields to control *D. suzukii* (Mazzetto et al., 2016).

The objective of this study was to determine the demographic parameters of *T. drosophilae* from East China and evaluate the effects of this parasitoid on *D. suzukii*. Wang et al. (2016b) have reported the longevity, reproduction, and intrinsic rate of populations from Californian and South Korean. Understanding the biological potential of populations of this parasitoid originating from different countries is necessary to select the most suitable populations.

Materials and methods

Study insects

Populations of *D. suzukii* and *T. drosophilae* were established from field collections conducted in May 2015 at Huiwang blueberry orchard in Nanling, Anhui province, China. *D. suzukii* were collected from infested blue berries and reared in an incubator with a set light:dark photoperiod (14:10), temperature (25 ± 1 °C) and relative humidity (60 ± 5%). Adult flies were reared in a 30 × 30 × 30 cm cube cage made from nylon mesh with a 150 μm pore size. In order to avoid infestations from other drosophila species, the cage was laid into another 40 × 40 × 40 cm cube cage. Adults and larvae were reared with a water wick, and an artificial diet in Petri dishes, made with cornmeal, sugar and nutritional yeast (Dalton et al., 2011). Every 24 h dishes with the artificial diet were taken out and laid in a 50 L plastic box. In order to prevent infection of *Drosophila* pupae, fine nylon mesh was used to seal the box around the rim. Four days later, older *Drosophila* larvae crept into the box and pupated on the smooth box wall. To lessen the harm during collection, the host pupae were sprayed with sterile water and transferred to filter paper with a soft paint brush.

The *T. drosophilae* population was obtained from fruit-baited traps using the host pupae *D. suzukii* as bait. Adult parasitoid wasps were reared in glass vials (25 mm in diameter by 50 mm in height). Researches have shown that age of *D. suzukii* pupae does not affect the performances of the parasitoid (Wang et al., 2016b). *D. suzukii* host pupae (1–3 d old) were collected with the methods described above and those similar in size were provided in the vials. Honey-soaked cotton wool was used to supply the nutrition. The parasitoid wasps were reared in an incubator with the same conditions as above.

Parasitoid reproduction assessment

Parasitized host pupae of *D. suzukii* were discernible before the parasitoid offspring emerged due to darkening of the pupae from the parasitoids inside. Most *T. drosophilae* adults emerged 15 d after eggs were laid in the host pupae. On the 14th day following exposure to parasitoid females, the parasitized host pupae were selected and individually placed in transparent tubes sealed with a fine nylon mesh. The following day, the tubes containing adults were selected. Male and female parasitoids were identified by their antennae (Romani et al., 2008).

Plastic containers (6 cm in diameter by 8 cm in height) were used to monitor the progeny production, which were closed with a fine nylon mesh for ventilation. A pair of newly emerged female and male adults were collected and introduced into the container, together with a honey-soaked cotton wool placed inside to supply the nutrition. Thirty laboratory-reared *D. suzukii* host pupae (1–3 d old) were provided. Every 24 h host pupae exposed to the parasitoids were exchanged until all female parasitoids were dead. Dead males were not changed because *T. drosophilae* females would not mate again after mating (our observation). A new cotton wick soaked in honey solution was provided every day. Twenty-two pairs of parasitoids were used in total. Host pupae exposed were laid in transparent tubes sealed with a fine nylon mesh. When the adults emerged, the number and sex of adult parasitoid wasps, adult flies, and non-emerged host pupae were recorded. All of the experiments were conducted in an incubator under cultural conditions described above. About one week after emergence, all pupae were dissected and the parasitoid offspring that failed to emerge were recorded.

Population growth parameter estimations

For some parasitoid pairs, no parasitoid wasps emerged or only male offspring emerged, which indicated that the females were not fertilized by the males provided. These data were not used in our analyses. Oviposition periods were calculated and analyzed as described by Núñez-Campero et al. (2012). Three periods, including the pre-oviposition, oviposition, and post-oviposition were calculated. The parasitization rate was calculated as the total number of pupae used by parasitoids (including those successfully emerging and failing to emerge) divided by the total number of host pupae available (Núñez-Campero et al., 2012).

Based on the data collected, a standard life table was constructed (Carey, 1993): the survival fraction (l_x) was calculated as N_x/N_0, the survival period (p_x) was calculated as l_{x+1}/l_x, the mortality period (q_x) was calculated as $1 - p_x$, the fraction of the original cohort dying at age x (d_x) was calculated as $l_x - l_{x+1}$, and the life expectancy (e_x) was calculated as:

$$\left(\sum_{y=x}^{\omega} L_x\right) \Bigg/ l_x$$

Parameters regarding reproduction and population increase were calculated from the life-table data (Carey, 1993). Offspring per female at age x (m_x) was calculated as the total number of offspring produced by a female cohort between the ages of x and $x + 1$ divided by the total number of females in the cohort at the midpoint of the interval x to $x + 1$. The gross maternity or number of daughters produced by a female for the next generation (M_x) was calculated as the total number of parasitoid offspring divided by the total number of females in the cohort at the midpoint of the interval x to $x + 1$. Net reproductive rate (R_0) was calculated as:

$$\sum L_x^f m_x^f$$

where $L_x^f$was estimated as $(l_x^f + l_{x+1}^f)/2$. The intrinsic rate of natural increase (r) was calculated from the equation:

$$\sum_{x=0}^{\infty} e^{-rx} L_x^f m_x^f = 1$$

The finite rate of increase (λ) was calculated as e^r. Generation time (T) was calculated as $\ln(R_0)/r_m$and the doubling time (DT) was calculated as $\ln 2/r_m$.

Statistical analyses

Datasets of such as longevity and number of offspring, as well as proportion data like sex ratio, did not meet the conditions of the normality of their distribution. Then, a generalized linear model (GLM) was used to analyze deviation in the data with such explaining variable as female adult age, assuming Poisson errors and applied a log link function to the count data, and binomial errors and a logit link function to the proportion data. The appropriateness of assuming Poisson or binomial errors was assessed by comparing the residual deviance with the residual degrees of freedom after fitting the explanatory variables. Large relative values of residual deviance indicate overdispersion, which may result in an overestimation of significance levels. Thus, Poisson or binomial error assumptions were replaced with quasipoisson