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 Development and reproduction of the hoverfly  
*Eupeodes corollae* (Diptera: Syrphidae)

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Research

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#### ABSTRACT

Syrphidae is one of the most speciose families of true flies, with more than 6,100 described species and a worldwide distribution. They are important to humans because they act as crucial pollinators, biological control agents, decomposers and bioindicators. This study was conducted to determine the biology and behavior of *Eupeodes corollae*, which is an important pollinator and enemy of aphid, including prey consumption, mating behavior, oviposition, and predation of larvae, to provide a basis for breeding and in-depth study. Results indicated that adult life expectancies were  $17.2 \pm 1.2$  days ( $n = 16$ ) for males and  $19.6 \pm 1.3$  days ( $n = 16$ ) for females, average number of eggs laid by females was  $799.2 \pm 49.9$  ( $n=16$ ) and the hatch rate was over 90%. Larval development required  $7.9 \pm 0.8$  days ( $n = 40$ ), and  $997.9 \pm 47.8$  *Aphis craccivora* ( $n = 10$ ) were consumed by each larva. Pupa lasted  $7.2 \pm 0.4$  days ( $n = 40$ ) in the root of the host plant, on the edge of the seedling basin, or 0.1–1.0 cm below the soil.

**Key words:** *Eupeodes corollae*, aphid, biocontrol

## INTRODUCTION

Syrphidae is one of the most diverse families in *Diptera*, with more than 6,000 described species [1-2]. They are usually referred as hoverflies and are the third-most speciose taxon in the Neotropical Region [3]. Their coloration ranges from orange brown in a few species to striking yellow and black patterns that cause them to be confused with bees and wasps (Hymenoptera). Adult hoverflies can hover on flowers, which can be used as mating sites and food sources (pollen and nectar). Therefore, the imagoes are considered as important pollinators of herbs. They are also considered as important group of resource insects because they have a great impact on controlling the population density of aphids, which are significant pests of forests, crops, vegetables, and flowers[4-8]. A third of Syrphidae larvae are predators that consume aphids and other Homopteran insects, and as such are important natural enemies of these pests. Syrphid species have also been used as bioindicators to assess biodiversity loss and the efficiency of restoration and conservation policies[9-12].

*Eupeodes corollae* (Fabricius) belongs to the Dipteranidae of Diptera, and *E. corollae* larvae feed on aphids and are one of the most important natural enemies that are used to control aphids[13]. Previous studies have documented the spawning and larval predation habits of mature *E. corollae* adults, as well as hoverfly feeding, mating, and spawning behaviors [14]. However, most scholars focus on the taxonomic and molecular studies of the hoverflies and some scholars have conducted selective studies on the spawning sites of the hoverflies[15-18]. This study aims to clarify the indoor biological characteristics of *E. corollae* and to establish the conditions that would make large-scale breeding and in-depth research possible.

## MATERIALS AND METHODS

### *E. corollae*

Adults of *E. corollae* were collected from Chengxiang Town, Qingbaijiang District, Chengdu City, Sichuan Province and raised for more than five generations in the insect laboratory of Institute of Plant Protection, Sichuan Academy of Agricultural

Sciences (Chengdu, Sichuan, China).

### Devices

Rectangular net room (100 mesh; LWH: 150×120×150 cm), large rearing cage (1,000 mL; LWH: 17.5×12.0×6.5 cm), medium-sized nourishing cage (LWH: 60.0×50.0×50.0 cm), small nourishing cage (LWH: 30.0×30.0×30.0 cm), flower pot (dh: 16.5×10.5 cm), microscope (Leica S8 APD, Germany), 30× handheld magnifier, 9-cm Petri dish, 100-ml beaker, absorbent paper, 40 times handheld magnifier, black cardboard (LW: 25×40 cm), electronic timer (Loease) and fine brush were used in the study.

### Cultivation of honey plants

Seeds of *Coreopsis grandiflora* Nutt. ex Chapm. were prepared for cultivation. Vermiculite, organic fertilizer and mushroom residue were used as the cultivation substrate, and the planting vector is a circular flower of Pots (dh: 16.5×10.5 cm), 5-10 seeds per pot; seeded pots placed in net room (100 mesh, LWH: 150×120×150 cm), regular water replenishment until flowering. All our experiments recordings were performed in 12:12 LD, using daylight fluorescent lamps (16 W/6500k), unless otherwise stated. The temperature was 24.0°C ± 1.0°C, similar to that of a temperate summer day when hoverflies tend to be active.

### Breeding of *E. corollae*

Insects were reared in net room kept at 24.0 ± 1.0°C, 50% – 70% relative humidity, and 12-hour light and dark cycles with light intensities of 800–1270 Lux. The feeding system was based on broad bean seedlings as the host plant, supplemented by *Aphis craccivora* and *Coreopsis grandiflora* flower for larval and adults of *E. corollae*.

### Mating behavior of *E. corollae*

Two pots of broad bean seedlings covered with *Aphis craccivora* were placed in a medium-sized insect cage with 30 pairs of newly emerged *E. corollae*. We recorded their mating behavior, mating place, and number of mating adults every two hours from 8:00–18:00, continuously for 5 days, we used an electronic timer to record the adult mating time.

### Lifespan, fecundity and oviposition sites of *E. corollae*

Eighteen pairs of newly-emerged adults were placed in separate rearing boxes (1000 ml), in each box, two broad bean seedlings with length of 8–10 cm were placed in the box and each seedling moistened with wet cotton balls near the base end, these seedlings were replaced with new bean seedlings every day at 9:30 am. For each replaced seedling, eggs oviposited on the back of the leaves, leaf sheaths, fronts of the leaves and stems were recorded until the female *E. corollae* died. Surviving adults in each box were recorded at 17:00 every day until all adults died.

### Fecundity and larval predation of *E. corollae*

The newly grown eggs and the broad bean leaves of the hoverflies were placed in glass dishes (9.0 cm in diameter and 1.8 cm deep). The leaves were moistened with wet cotton balls and a leaf was placed in each glass dish. On the second day, observations were made under a stereomicroscope (Leica S8 APD, Germany) to observe whether the eggs had hatched. We selected neonate larvae (<12 h old) and placed them individually in small, round glass dishes (9.0 cm diameter and 1.8 cm deep). They were fed on a pure diet of *Aphis craccivora* at  $24.0 \pm 1.0^\circ\text{C}$  and with a photoperiod of 14 h: 10 h (L: D)[19]. Eighty aphids were provided each day for days 1–3, 300 per day for days 4–7, 100 per day (with unarmed larvae added) for days 8–9, at which point they reached the pupate stage. The larvae were then transferred to the broad bean leaves with a fine brush. Each day, we recorded the remaining aphids at 10:00, until all the larvae of pupates were recorded.

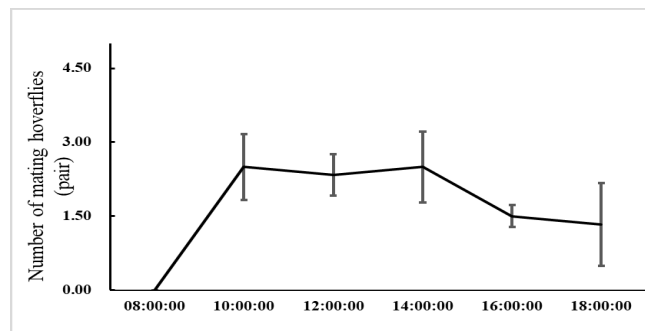
### Pupal development characteristics

We placed two pots of broad bean seedlings containing bean pods in the medium-sized insect-retaining cages with more than 100 larvae. The cages were moistened every day until the larvae became pupae. Between 10:00 and 17:00 every day, we recorded pupal location, external characteristics, soil depth, and number of emerged individuals.

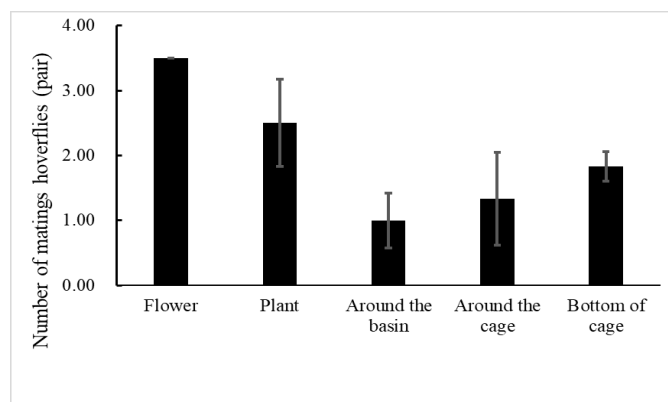
## RESULTS AND ANALYSIS

### Mating behavior of *E. corollae*

*E. corollae* generally lives on the flowers or leaves of the host plant. Males approach females from the back and stop on the female's back to mate. During the mating process, females either fly away to escape mating or stop to accept mating. In the laboratory setting, mating time ranged from 1.3–3.2 h, with an average of  $2.2 \pm 0.5$  h ( $n=60$ ). Adults mated primarily between 10:00 and 14:00, when 72.1% of the mating took place (Figure 1). Mating behavior include: (1) male stopping at leaves or flowers to achieve a better line of sight and then chase the female when they identify an easier position from which to fly alongside the female; (2) males hovering in places where females often appear and initiate courtship once they found a female. Females do not actively seek males, and most of the time, females mate after feeding. Most mating adults rest on the flowers or stems of the broad bean seedlings, or at the bottom of the rearing cages to facilitate hiding and avoiding external disturbances (Figure 2).



**Fig. 1** Mating behavior of *E. corollae* at different time between 8:00 and 18:00, with peaks between 10:00 and 14:00.



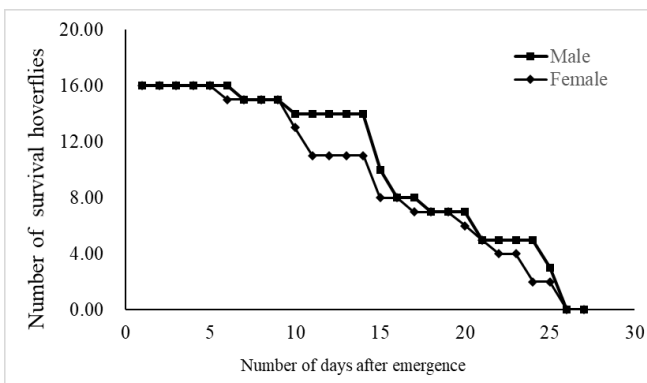
**Fig. 2** Mating site of *E. corollae* in cages, the number of mating hoverflies are flower > plant > bottom of

cage > around the cage > around the basin.

### Lifespan, fecundity and spawning sites of adults

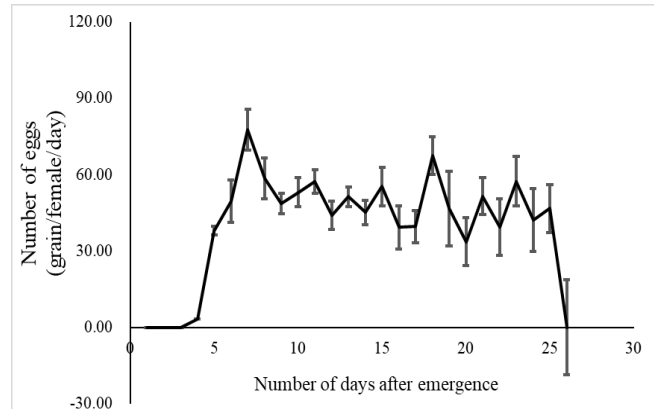
Before oviposition, females hover about 20 cm from the stem until they are close to an aphid swarm. The females walk several times around a small area of the plant with their ovipositor expanding and contracting and their antennae moving vertically. Finally, females elongate the oviposition tube and bent it toward the ventral surface. The oviposition process lasted 5 - 60 seconds, then females use their hind foot to clean their oviduct.

The lifespan of males ranges from 10 to 23 days with an average of  $17.5 \pm 1.2$  days ( $n = 15$ ) and the female lifespan ranged from 13 to 25 days with an average of  $19.6 \pm 1.3$  ( $n = 15$ ) days. More than 80% of the males survived more than 17.2 days, and same ratio of females survived more than 19.6 days (Figure 3). Adults begin to mate two days after hatching, oviposition begin four days after mating and the females laid eggs for 9 – 11 days until they die (Figure 4). Two oviposition peaks occurred: 7 and 18 days after emergence, with  $77.7 \pm 8.0$  ( $n=16$ ) and  $67.4 \pm 14.7$  ( $n=16$ ) eggs. The average of total egg production for per female was  $799.2 \pm 49.9$  eggs ( $n=16$ ), with a daily average of between 35 and 70 eggs. The average daily egg production volume fluctuates for each female and there is generally a 1–2 day interval where egg laying peaked, with eight peaks occurring during the lifespan of each female. Females primarily oviposit on the back of the leaves, following by the leaf sheaths, and the fronts of the leaves, the stems were the least likely substrate for egg laying (Figure 5).

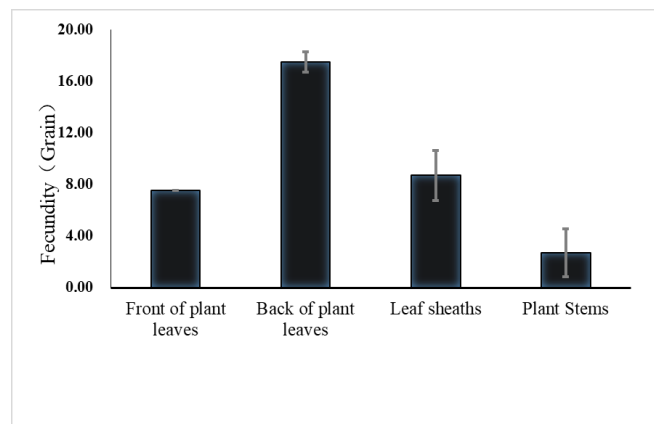


**Fig.3** The life span of adult *E. corollae*. Males lived

for 10–23 days, with an average of  $17.5 \pm 1.2$  days ( $n = 16$ ), and females for 13–25 days, with an average of  $19.6 \pm 1.3$  days ( $n = 16$ ).



**Fig. 4** Laying egg of *E. corollae*. The peak period of oviposition was 7 days ( $77.7 \pm 8.0$  eggs) and 18 days ( $67.4 \pm 14.7$  eggs) after emergence. Average egg production per female was  $799.2 \pm 49.9$  ( $n=16$ ), and the average daily egg production was  $35.0 - 70.0$ . The average daily egg production volume fluctuated for each female, and there was generally a 1-2-day interval where egg laying peaked, with eight peaks during the life of a female.

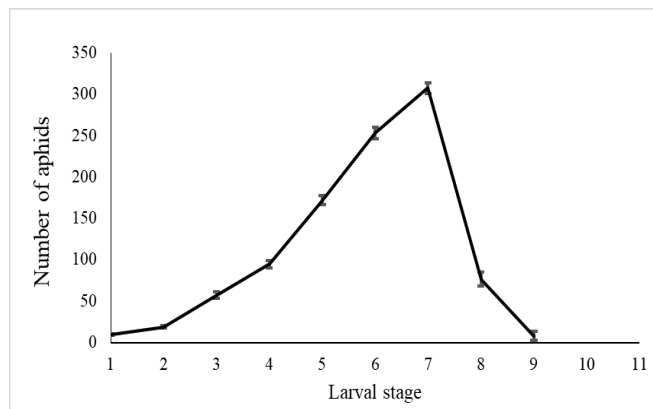


**Fig. 5** Spawning site of *E. corollae*. females primarily oviposit on the back of the leaves, followed by the leaf sheaths and the fronts of the leaves, stems are the least likely substrate for egg laying.

### Egg hatching and larval predation

The egg hatch rate reached over  $92.5 \% \pm 0.6\%$  ( $n=10$ ) in the laboratory settings. The newly hatched larvae were  $1.00 \pm 0.03$  mm ( $n = 40$ ) long and covered with slightly fluffy hair. Larvae gradually became longer during the growth period, which lasted

$7.9 \pm 0.8$  days ( $n = 40$ ), each larva feeds  $997.9 \pm 99.8$  *A. craccivora* ( $n=10$ ). There was little aphid consumption by early instars before the third day, and with less than 80 aphids per day being attacked. Predatory behavior increased from the fourth day and peaks on the seventh day after hatching, when the number of aphids consumed by predators reach  $307.7 \pm 6.5$  ( $n=10$ ) (Figure 6).



**Fig. 6.** Number of *A. craccivora* attacked by larval *E. corollae*. Predation among larvae was infrequent until the third day, with less than 80 aphids being attacked. Predatory behavior increased starting the fourth day and peaked seven days after hatching, when the number of aphids consumed by predators reached  $307.7 \pm 6.5$  ( $n=10$ ).

### Pupal characteristics

Before pupation, the larvae reduce aphid intake and activity, and began to secrete a sticky exuvia substance around the leaves, stems, and seedling pots. After about 35 hours, the pupal surface hardened and there is a noticeable streak on the back. A crust gradually formed around the pupae, this process needs 4–10 hours. In the middle of the mid-palatosius, the characteristic stripe of the adult's abdomen begins to appear. At the end of pupal development, the pupal shell become more and more transparent and the adult body color become darker, the pupal stage lasts for  $7.2 \pm 0.7$  days ( $n = 40$ ).

### DISCUSSION

Results shew that *E. corollae* can develop and mate indoors under laboratory conditions, and the average fecundity of adults is  $799.2 \pm 49.9$  ( $n=16$ ) (with a max-

imum of 1,410), which is consistent with previous study[20], but not consistent with another report [21], which may be due to different fresh flowers, light, and temperature. Previous report stated that light has a certain degree of influence on the growth and development of *E. corollae* [14]. The egg hatch rate reached more than 90.0%, and the life span of males was  $17.2 \pm 1.2$  days and  $19.6 \pm 1.3$  days for females, which is similar to previous report (Dong 1988). According to another research [22], the daily maximum predation rates of 1–3 instar larvae on green peach aphids were 10.4 for the first instar, 55.7 for the second, and 166.7 for the third, our results show that the growth period of the larvae was  $7.9 \pm 0.8$  days ( $n = 40$ ), and the maximum predation amount occurred on the seventh day, with an average of 307.7 aphids were predated. We conclude that *E. corollae* is an important predator of aphids and that it could have practical value in aphid control the same as other results [23].

Predatory hoverflies, *Coccinella septempunctata* and *Chrysopidae* insect are important natural enemies of aphids, whiteflies and other agricultural and forestry pests. At the same time, hoverflies are important pollinators for cross-pollinated plants. Despite this, there is far less domestic research on the hoverfly than on ladybeetle and bees, the most important reason for this is that it is difficult for Syrphidae adults to oviposition their eggs in labs. Therefore, scholars mainly focus on the field protection and utilization of the Syrphidae flies. Among the natural enemies of aphids, aphid-eating flies are was one of the main predators[24], the ecology of *E. corollae* and its control of wheat aphids has been studied, results showed that an aphid reduction rate 80% was reached [25], and another study on the control of aphids on vegetables and chrysanthemums reported that an aphid reduction rate of 80% was also reached [26]. In recent years, scholars have done some research on the hoverfly as an important pollinating insect, in 2004, a study on the flower-visiting insect and pollinator, *Paeonia lactiflora*, showed that flies and bees demonstrated a high pollination intensity and efficiency [27]. Results about resources, population dynamics, and protection of the hoverfly in wheat fields showed

that *E. corollae* was a dominant control *Macrosiphum granarium* species [28], almost all the literature has shown that the hoverfly has an important economic and ecological significance in pollination and in controlling pests. This study provides an important foundation for further understanding the pest control and pollination mechanisms of the hoverfly, moreover, it provides a more complete methodology for further exploration of artificial propagation techniques [29] and large-scale breeding for the scientific utilization of the flies that play an important role in pollination and in the control of aphid populations.

## CONCLUSION

The *E. corollae* is an important natural enemy and pollinating insect. Through this study, the biological characteristics of the scorpion fly, such as adult life, spawning ability, larval predation ability and feeding technology system, have been clarified. Studying its control and pollination mechanisms lays the foundation.

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