Laboratory Investigations Reveal that *Harmonia axyridis* (Coleoptera: Coccinellidae) Is a Poor Host for *Dinocampus coccinellae* (Hymenoptera: Braconidae) in Brazil

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Abstract

*Harmonia axyridis* (Pallas, 1773) is an Asian coccinellid released in several places to act as a biological control agent of aphids. *Dinocampus coccinellae* (Schrank, 1802) is an endoparasite that uses more than 40 coccinellid species as hosts. Thus, the aim of this study was to investigate the interactions between *D. coccinellae* and *H. axyridis* and to determine the impact of the parasitoid on the establishment capacity of *H. axyridis*. It was also investigate the influence of host on the development of *D. coccinellae* using other Coccinellidae species as hosts: *Cycloneda sanguinea* (L., 1763) *Cycloneda pulchella* (Klug, 1829), *Eriopis connexa* (Germar, 1824), and *Olla v-nigrum* (Mulsant, 1866). In no-choice tests, pupa was the least attacked stage, and the fourth instar and adults the most attacked. In choice tests, the pupa was less attacked when combined with all the other stages, and the fourth instar and adults the most attacked. There was statistical difference only for fecundity, fertility, and number of eggs/day, with higher values found in the non-parasitized control group. Due to the low rate of parasitism it is believed that *D. coccinellae* has little impact on the populations of this coccinellid in Brazil. However, it is noteworthy that an increase in *H. axyridis* coverage areas can affect the populations of *D. coccinellae*, as in some places of occurrence, *H. axyridis* has become the predominant species of Coccinellidae. The result can be a decrease in populations of this species of parasitoid or its better adaptation to the new host.

Key words: Exotic specie; host preference; invasion success; natural enemy
The establishment capacity of *C. sanguinea* in relation to other native species of *Coccinellidae* was investigated by Silva et al. (2012), while *H. axyridis* is considered a poor host and with low rate of parasitoid emergence in Canada (Firlej et al. 2005). According to Silva et al. (2012), *D. coccinellae* can even parasitize *Coleomegilla maculata* (De Geer, 1775), *Eriopus connexa* (Germar, 1824), and *Olla v-nigrum* (Mulsant, 1866), which are native species that can influence in the development of *D. coccinellae* in the field, on pine trees, in Curitiba, PR, and taken to the insect rearing laboratory.

The adults were kept in 500-ml plastic dishes in rearing chambers (BOD) at 25 ± 1°C, 70 ± 10% RH and 12-h photoperiod. The food, *C. atlantica*, was supplied daily to maintain the population stock.

For the experiments with *H. axyridis*, two populations were used: a second laboratory population and a field population. The field population was obtained from individuals collected in a plantation area of *P. taeda* L. and *P. elliottii* Engelm, in the Centro Politécnico Campus of Universidade Federal do Paraná. The specimens were collected randomly and used in the same day in the experiments.

**Materials and Methods**

**Insect rearing**

*Cimara atlantica*

Aphids were first collected in the field, on *Pinus taeda* L. and *Pinus elliottii* Engelm branches infested with *C. atlantica* in Curitiba, Paraná State, and taken to the “Prof. Renato C. Marini” Insect Rearing Laboratory of Universidade Federal do Paraná, where they were kept at 21 ± 1°C and 70 ±10% RH, with a 24-h photoperiod.

The aphids were removed from the field-collected pine branches and transferred to new pine branches acquired from a commercial nursery. Additional aphids were added weekly to maintain the stock population and later used to feed coccinellids, using the same transfer technique.

**Dinocampus coccinellae**

The selected *Coccinellidae* species were collected to obtain parasitized insects and to use these to start the rearing of *D. coccinellae*. Adults from the laboratory population were used to establish the parasitoid rearing. As *D. coccinellae* is a teltikous parthenogenetic solitary parasitoid, only females were used.

Five groups of five females of *D. coccinellae* were individualized and placed in 500-ml plastic containers, lined with filter paper and fed with 1:1 water and honey. Ten 10-day-old *Coccinellidae* adults were placed in each container, fed *ad libitum* with *C. atlantica*, and kept in contact with the parasitoid for 24 h. Afterward, the *Coccinellidae* adults were removed and individualized as couples.

The coccinellids were monitored daily for ~1 month after parasitism, to obtain *D. coccinellae* pupae, which were subsequently removed and placed in separate Petri dishes.

After parasitoid emergence, adults were individualized and reared at 25 ± 1°C and 70 ± 10% RH, with a 12-h photoperiod. For the experiments, we used *D. coccinellae* adults from the third generation and aged 2–3 days.

Parasitoid rearing was carried out with all six *Coccinellidae* species as hosts, so that there was no interference in the results.

**Experimental Design.** Tests with and without choice were conducted to evaluate the influence of host characteristics on acceptance and *H. axyridis* parasitism rate. In each test, the number of oviposition attacks by *D. coccinellae* was used as the host acceptance measure (Richerson and DeLoach 1972), as well as the rate of parasitoid emergence, which was ~30 days.

The hosts which the parasitoid entered its ovipositor were considered “attacked.” It is noteworthy that an attack did not necessarily lead to the emergence of a parasitoid. Parasitism was considered...
successful only in those individuals in which a *D. coccinella* adult emerged.

The attacked insects were individualized, fed on *C. atlantica* and monitored daily for a month until the emergence of pupae and subsequent adult emergence. We also determined the total larval and pupal development times and longevity for emerged parasitoids.

All experiments were performed in 300-ml plastic containers, in brood chambers (BOD) at 25 ± 1°C and 70 ± 10% RH, with a 12-h photoperiod. Twenty replicates were performed for each test.

**No-Choice Tests.** Each female adult of *D. coccinella* was exposed for 20 min to parasitize a single specimen of *H. axyridis* of different stages (third and fourth instars, pupa, and adult), populations (field and laboratory), and sexes.

**Choice Tests.** Each female adult of *D. coccinella* was exposed for 20 min to parasitize two individuals of *H. axyridis* of different stages (third and fourth instars, pupa, adult male, and female), populations (laboratory female with field male and laboratory male with field male), sexes, and adult species (*H. axyridis*, *C. sanguinea*, *C. pulchella*, *E. connexa*, *H. convergens*, and *O. v-nigrum*).

For the first bioassay, all stages were combined with each other, and for the last, all species were combined with each other.

**Effect of Parasitization on the Reproductive Capacity of *H. axyridis***

In this test, we analyzed the reproductive capacity of parasitized *H. axyridis* adults, examining the variables pre-oviposition, oviposition, post-oviposition, fecundity, fertility, eggs/day, egg mass, and eggs/egg mass.

We used insects from the laboratory population that had been exposed to *D. coccinella* for 20 min. All attacked individuals were kept in Petri dishes, on *C. atlantica* diet, at 25 ± 1°C and 70 ± 10% RH, with a 12-h photoperiod.

Due to the low rate of parasitism exhibited by the host, only four successfully parasitized *H. axyridis* females were observed throughout the cycle, with daily monitoring. Each female was paired with a non-parasitized male. A control group of 15 non-parasitized coccinellids was monitored under the same conditions.

**Influence of Host on the Development of *D. coccinella***

In this test, we analyzed the influence of host on the development time (egg–pupa and preadult) and longevity for emerged parasitoids. We also determined the total larval and pupal development times and longevity for emerged parasitoids.

All experiments were performed in 300-ml plastic containers, in brood chambers (BOD) at 25 ± 1°C and 70 ± 10% RH, with a 12-h photoperiod.

To determine whether there was difference between the eggs/egg mass parameter to parasitized or not *H. axyridis*, a GLM was adjusted using an error distribution of the inverse Gaussian family.

In all experiments, the parasitoid interacted with at least one host offered.

**Results**

When found a potential host, *D. coccinella* first examined it with antennae. Then folded its abdomen with the ovipositor directed to the host. In one swift movement, the female inserted the ovipositor in the host abdomen and than two situations can occur: the parasitoid accepted the host and oviposited or rejected by removing the ovipositor, without laying eggs.

Even with the parasitoid pupa formed externally, the host remains alive. However, in some cases, the parasitoid uses the host legs during the process of pupa formation, trapping and preventing coccinellid to feed, causing its death, possibly by starvation.

In all experiments, the parasitoid interacted with at least one type of host offered.

**No-Choice Tests**

In no-choice tests, the pupae were attacked less often than all the other stages, and adults were the most attacked, followed by the fourth and third instars, respectively (Table 1). There was no significant difference in the number of attacks between males and females, for any of the stages analyzed (Table 1).

The parasitoid developed to adulthood only when the adult host was attacked, with an emergence rate of 10% when females were attacked, and 5% when males were attacked (Table 1).

**Table 1. Mean number of attacks (± SD) and emergence percentage of the parasitoid *D. coccinella* (Schrank, 1802) when the host were different stages and sexes of *H. axyridis* (Pallas, 1773), in no choice tests.**

| Stage                  | Number of attacks | Parasitoid emergence (%) |
|------------------------|-------------------|--------------------------|
| Third instar female    | 2.75 ± 0.55a      | 0                        |
| Third instar male      | 2.50 ± 0.51a      | 0                        |
| Fourth instar female   | 3.75 ± 0.64bd     | 0                        |
| Fourth instar male     | 3.05 ± 1.01ab     | 0                        |
| Pupa female            | 1.20 ± 0.77c      | 0                        |
| Pupa male              | 0.80 ± 0.77c      | 0                        |
| Adult female           | 4.50 ± 0.69d      | 0                        |
| Adult male             | 3.95 ± 0.22d      | 5                        |

Lower case letters within the lines indicate differences between the number of attacks by the parasitoid.
Choice Tests

Different Development Stages

*Harmonia axyridis* third instar larvae combined with pupae were attacked more often than when combined with fourth instar larvae and adults (Fig. 1, Table 2).

The pupa was the least attacked stage, where the lowest number of attacks was when combined with adult males (Fig. 1, Table 2). The fourth instar larvae and adults were the most attacked stages, where the fourth instar was more frequently attacked when combined with third instar larvae and pupae (Fig. 1, Table 2).

Parasitism was successful only when *H. axyridis* adults were the hosts, with the highest rate of *D. coccinella* emergence (15%) occurring in adult females when combined with pupae. The parasitism rate when the male adult was combined with third and fourth instars was 5%, while adult females combined with third and fourth instars showed a 10% rate.

Different Populations

There was no statistical difference in the number of attacks between the two populations tested (Fig. 2, Table 2). The parasitoid emergence rate was 3 and 7% for laboratory males and females, respectively, and 5 and 8% for field males and females, respectively.

Different Sexes

Females were statistically more attacked than males (P-value 0.002038), where the parasitoid emergence rate was 5% with males as host, and 10% when females were the host (Fig. 3, Table 2).

Different Species of Coccinellidae

*Harmonia axyridis* was less frequently attacked when combined with all other species. The most attacked coccinellids were C.

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Fig. 1. Mean number of attacks (±SE) by *D. coccinella* (Schrank, 1802) adult on *H. axyridis* (Pallas, 1773) during 20 min period in choice tests, according to the combined host. L3 = 3rd instar; L4 = 4th instar (n = 20, for each combination).
sanguinea and C. pulchella, followed by O. v-nigrum, E. connexa, and H. convergens, respectively (Fig. 4, Table 2).

Effect of Parasitization on the Reproductive Capacity of H. axyridis
Comparing the reproductive variables of H. axyridis parasitized by D. coccinellae and the non-parasitized control group, there was a statistical difference only for fecundity (P-value 0.003822), fertility (P-value 0.012676), and number of eggs/day (P-value 0.002472), where higher values were found in the control group (Table 3).

Table 2. Chi-square values for choice-tests with the parasitoid D. coccinellae (Schrank, 1802), in function of development stage, population, gender and species, where df = degrees of freedom.

| Pairing | $\chi^2$ | df | P-value |
|---------|----------|----|---------|
| L3 × L4 | 16.6154  | 1  | 4.578e05 |
| L3 × Pupa | 18.4576 | 1 | 1.737e05 |
| L3 × Adult ♂ | 1.9206 | 1 | 0.003919 |
| L3 × Adult ♀ | 2.25 | 1 | 0.001147 |
| L4 × Pupa | 30.3115 | 1 | 3.679e08 |
| L4 × Adult ♂ | 2.3333 | 1 | 0.1266 |
| L4 × Adult ♀ | 2.5862 | 1 | 0.1078 |
| Pupa × Adult ♂ | 26.8431 | 1 | 2.207e-07 |
| Pupa × Adult ♀ | 27.6545 | 1 | 1.450e-07 |
| L ♂ × C ♀ | 1.4678 | 1 | 0.2273 |
| L ♂ × C ♀ | 1.2821 | 1 | 0.2575 |
| Male × female | 9.5149 | 1 | 0.002038 |
| Ha × Cs | 50.5806 | 1 | 0.144e-12 |
| Ha × Cp | 61.4932 | 1 | 4.44e-15 |
| Ha × Ec | 47.6102 | 1 | 5.2e-12 |
| Ha × Hc | 37.3556 | 1 | 9.84e-10 |
| Ha × Ov | 44.5873 | 1 | 2.43e-11 |
| Cs × Cp | 0.4098 | 1 | 0.52221 |
| Cs × Ec | 16.2881 | 1 | 5.44e-05 |
| Cs × Hc | 7.0435 | 1 | 0.007955 |
| Cs × Ov | 1.3913 | 1 | 0.2382 |
| Cp × Ec | 5.6667 | 1 | 0.01729 |
| Cp × Hc | 4.9 | 1 | 0.02686 |
| Cp × Ov | 2.0833 | 1 | 0.1489 |
| Ec × Hc | 0.1233 | 1 | 0.7255 |
| Ec × Ov | 0.0137 | 1 | 0.9068 |
| Hc × Ov | 15.5172 | 1 | 8.176e-03 |

L3 = 3rd instar; L4 = 4th instar; L = laboratory population; C = field population; Ha = Harmonia axyridis; Cs = Cycloneda sanguinea; Cp = Cycloneda pulchella; Ec = Eriopis connexa; Hc = Hippodamia convergens; Ov = Olla v-nigrum.

Influence of Host on the Development of D. coccinellae
The parasitoid development time from egg to pupa was significantly less with H. axyridis as host (P-value 0.0023812). For pupa and egg-adult phases, the time was significantly shorter with H. axyridis (P-value 0.004675 and 0.003924) and C. sanguinea (P-value 0.002988 and 0.002783) as hosts. D. coccinellae longevity was significantly longer when the host was H. axyridis, C. sanguinea (P-value 0.0027652) or O. v-nigrum (P-value 0.003956), where a statistical difference was seen for the last two species (Table 4).

Dinocampus coccinellae did not complete its development with H. axyridis as host. For C. sanguinea, C. pulchella, H. convergens, and E. connexa, the parasitoid emergence rate was 67, 65, 51, and 43%, respectively, and all parasitized coccinellids died after parasitoid emergence (Table 4).

Discussion
Some studies have shown that parasitoids can differentiate hosts of low and high quality on the basis of species, size, and developmental stage (Godfray 1994, Davis et al. 2006). For D. coccinellae there are some host characteristics that can influence the parasitism success, such as species and developmental stage (Okuda and Cernyger 2000), adult age (Majerus et al. 2000), and sex (Majerus et al. 2000, Davis et al. 2006). In this way, the development stage affects the suitability of H. axyridis as a host for D. coccinellae. In both choice and no-choice tests, the pupa and third instar stages were attacked less often than the fourth instar and the adult.
In choice tests, there was no statistical difference in relation to parasitoid preference when fourth instar larva and adult of either sex were combined. However, the parasitoid only emerged after parasitizing adults. In no-choice tests, the number of attacks was significantly higher for adults, in either sex.

Host detection by *D. coccinellae* is largely based on visual detection, such as by host movement and also by olfactory signs (Berkvens et al. 2010). Several studies have shown that this parasitoid displays preference for moving individuals (Berkvens et al. 2010, Silva et al. 2012). Therefore, the low number of attacks in the third instar, fourth instar and pupa stages may be related to the lower mobility of these stages.

In studies of *H. axyridis* in Europe, Berkvens et al. (2010) obtained similar results for choice and no-choice tests. *D. coccinellae* was found to attack adults almost exclusively, avoiding laying eggs in immatures in presence of adults (Geoghegan et al. 1998, Majerus et al. 2000, Firlej et al. 2005). Davis et al. (2006) observed that *D. coccinellae* had a preference for parasitizing adult Coccinellidae. In theory, this preference is adaptive, because parasitism is more successful and development time is shorter in adult hosts (Obrycki et al. 1985, Firlej et al. 2007).

Several authors have noted that *D. coccinellae* generally attacks larger species, and shows higher survival rates when the host is bigger. Hypothetically, this occurs because larger individuals contain

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**Table 3.** Reproductive variables (days) (mean ± SD) of *H. axyridis* (Pallas, 1773) parasitized and control group no-parasitized.

| Variables      | Parasitized                  | Control                    |
|----------------|------------------------------|----------------------------|
| Fecundity      | 490.00 ± 5.67 ±Fa           | 747.53 ± 71.75 ±fb        |
| Fertility      | 397.75 ± 0.93 ±Fa           | 671.07 ± 87.26 ±fb        |
| Eggs/day       | 6.75 ± 0.52 ±Fa             | 9.33 ± 0.40 ±fb           |
| Egg mass       | 29.00 ± 2.75 ±Fa            | 32.87 ± 8.22 ±Fa          |
| Egg/egg mass   | 18.47 ± 2.39 ±Fa            | 24.08 ± 6.30 ±Fa          |
| Longevity      | 89.00 ± 4.69 ±Fa            | 95.47 ± 9.72 ±Fa          |
| Pre-oviposition| 7.25 ± 0.5a ±Fa             | 6.93 ± 1.22 ±Fa           |
| Oviposition    | 73.75 ± 4.50 ±Fa            | 80.47 ± 10.36 ±Fa         |
| Post-oviposition| 7.5 ± 0.5 ±Fa              | 8.07 ± 0.88 ±Fa           |

In choice tests, there was no statistical difference in relation to parasitoid preference when fourth instar larva and adult of either sex were combined. However, the parasitoid only emerged after parasitizing adults. In no-choice tests, the number of attacks was significantly higher for adults, in either sex.
greater resources, and thus offer the parasitoid offspring better chances to successfully complete the life cycle (Davis et al. 2006, Berkvens et al. 2010). Majerus et al. (2000) also noted the preference for oviposition in younger (pre-winter) than older (overwintered) adults, increasing the chances of offspring fitness, since newly emerged hosts are more likely to survive and allow full parasitism, compared with older adults.

Adult insects are better protected against natural enemies due to their chitinous exoskeleton and greater mobility compared to immatures. However, the successful oviposition of D. coccinellae, especially in native species, in well-protected individuals such as Coccinellidae is facilitated by host movement, when the vulnerable areas of the body, such as the softer parts of the abdomen, are more easily accessible (Richerson and DeLoach 1972, Okuda and Ceryngier 2000). For other Coccinellidae hosts (Obrycki et al. 1985, Geoghegan et al. 1998), the adults were more susceptible to D. coccinellae development. However, according to some authors, H. axyridis larvae are more susceptible (Firlej et al. 2007, 2010), suggesting that adults parasitized by D. coccinellae found in the field may have been attacked as larvae (Hoogendoorn and Heimpel 2002, Firlej et al. 2005, 2010).

The emergence rate observed for the parasitoid in this study, in both tests, was low and only occurred when adults were attacked, demonstrating that H. axyridis is not a good host for D. coccinellae. In choice tests, there was no difference in the number of attacks by the parasitoid in adult individuals of the laboratory and field populations, and the emergence rate of the parasitoid was similar. However, Berkvens et al. (2008a, b) reported differences between laboratory and field populations of H. axyridis in response to food and photoperiod conditions, highlighting that conclusions based solely on laboratory experiments very often cannot be simply extrapolated to the field.

In no-choice tests, there was no difference in the number of parasitoid attacks between H. axyridis males and females, for any of the stages. However, the emergence rate of the parasitoid was higher when females were parasitized. In choice tests, there was a preference for females, and with a higher rate of parasitism when they were the hosts. Other authors also observed the preference of D. coccinellae for females of other Coccinellidae species, in choice tests (Obrycki 1989, Davis et al. 2006).

This preference for females can be explained by the fact that they are bigger than males, providing higher rates of encounter. Also, since the female feeds more than the male, Davis et al. (2006) suggested that the preference for oviposition in females is adaptive, providing the parasitoid larva more resources to develop. Furthermore, when the D. coccinellae host is a female, it is possible for the parasitoid to feed on two sources: the ovaries and fat of the host (Geoghegan et al. 1997).

This study demonstrated that, based on two measures of suitability (development time and successful parasitism), all species tested except H. axyridis are suitable as a host for D. coccinellae.

In choice tests, the parasitoid always preferred to attack other coccinellid species hosts than H. axyridis. Emergence rates were high for all species, but again, this was not the case for H. axyridis, in which the parasitoid showed 5% adult emergence.

The species that were more susceptible to the parasitoids were C. sanguinea and C. pulchella, which are native aphidophagous species that can be displaced by H. axyridis through competition for food resources (Martins et al. 2009). Therefore, there is a possibility that over time D. coccinellae adapts more to H. axyridis (Koyama and Majerus 2008, Berkvens et al. 2010).

It is noteworthy that since D. coccinellae is a generalist and is known to attack both native and exotic species, it can be assumed that the parent host does not influence the development of the parasitoid (Hoogendoorn and Heimpel 2002). Furthermore, parasitoid rearing was tested with several species of Coccinellidae, but very few emerged with H. axyridis as host. Since a low rate of parasitism was observed for H. axyridis in other experiments, it is believed that in this case there was no actual interference.

Dinocampus coccinellae has been shown to attack H. axyridis laboratory populations in North America (Hoogendoorn and Heimpel 2002). However, Firlej et al. (2007) and Hoogendoorn and Heimpel (2002) also demonstrated that the devolpment success of D. coccinellae was fairly low with H. axyridis as host.

According to Firlej et al. (2010), H. axyridis has a greater number of defensive behaviors (such as escape and movements with metathoracic legs to release the parasitoid ovipositor) in relation to C. maculata. This fact may also indicate that the parasitoid is more suited to overcome the chemical defenses of native/established species than those of exotic species, in the case H. axyridis.

The defensive behaviors of the host influence the success of parasitoid parasitism, because they directly affect its fitness (Firlej et al. 2010). In extreme cases, defensive behavior can harm or even cause the death of the parasitoid (Firlej et al. 2010), affecting the acceptance of the host and decreasing the rate of parasitism (Firlej et al. 2010).

Harmonia axyridis adults show more defensive behaviors than do fourth instar larvae and usually can break oviposition sequence (Firlej et al. 2010). This fact supports previous results that show that H. axyridis acts as the most aggressive species within a coccinellid guild (Michaud 2002, Sato et al. 2005) and that immature stages have fewer defenses against parasitoids than do adults (Firlej et al. 2010).

Even with oviposition, what probably happens is that the parasitoid eggs are destroyed by the host immune system. In the case of H. axyridis, Firlej et al. (2010) observed that no egg of D.
coccinellae was found in the abdomen of the host after five days of oviposition, suggesting that the eggs were destroyed by its immune system.

These results demonstrate that, unlike other species of Coccinellidae, such as C. maculata, H. axyridis was able to reproduce even when parasitized (Firlej et al. 2010). Moreover, given the low rate of parasitism of H. axyridis adults by D. coccinellae and with an average fertility of this parasitized coccinellid of 490 eggs, it is assumed that the suppressive effect of the parasitoid on reproductive variables of H. axyridis is small.

The parasitoid development time varied with the host species, such that the total period was lower when H. axyridis was the host, however, close to C. sanguinea. Parasitoid longevity was also higher with these host species.

Obrzycki (1989) observed that the development of the egg until the end of the larval phase of D. coccinellae was also significantly influenced by the Coccinellidae host species. The author recorded a faster development with native species as host (C. maculata: 20.8; H. convergens: 21.8; and Cycloneda munda (Say, 1835): 22.1 d) in relation to the introduced species (C. septempunctata: 23.6 and P. quatuordecimpunctata: 26.5 d). The pupal period was similar as in all species, with a mean of 10.0 d.

The total development period of D. coccinellae was longer when Coleomegilla maculata was the host (32.4 d), where longevity was similar for the three species compared: 6.9 d for C. maculata; 7.1 d for E. connexa, and 6.8 d for O. v-nigrum (Silva et al. 2012).

Berkvens et al. (2010) observed that D. coccinellae development, when H. axyridis was the host, was 19.8 d for egg–pupa and 10.6 d for pupa–adult, totaling 30.4 d, at 23 °C, while at 27 °C, it was 15.0, 9.0, and 24.0 d, respectively, where these values were higher than those obtained in this study. Saito and Bjørnson (2013) reported for D. coccinellae a mean total development time of 26.3 d, with H. convergens as host.

At last long, the results of this study confirm the assumption that, as in other continents where it has been introduced, H. axyridis exhibits low susceptibility to D. coccinellae, where it is not a suitable host for it.

Introduced Coccinellidae species may display different interactions with native species. One of these interactions may be mediated through the activities of the parasitoid D. coccinellae. For example, the addition of species can increase the availability of hosts in an ecosystem and thereby modify the existing host–parasitoid relationship between native coccinellids and D. coccinellae (Obrzycki 1989).

In Japan populations of H. axyridis and D. coccinellae co-exist, where the parasitoid can develop successfully having this coccinellid as host, but with a lower parasitism rate when compared with other native species (Koyama and Majerus 2008). This suggests that the D. coccinellae populations in Brazil have not yet had enough time to adjust and overcome the defense mechanisms of H. axyridis.

More studies are needed to determine the capacity of H. axyridis to defend itself against its natural enemies. It is known that this species has chemical defenses, but the defensive role of these components is still unclear. Despite the biology of D. coccinellae in the laboratory is known, further studies of the impact on population dynamics and ecology of Coccinellidae communities are needed, especially when it comes to invasive alien species, which can alter the community of native coccinellids.

Due to the low rate of H. axyridis parasitism by D. coccinellae, it is believed that the parasitoid has little impact on the populations of this coccinellid in Brazil. However, it is noteworthy that the increase in H. axyridis coverage areas can affect the populations of D. coccinellae, since in some places of occurrence, H. axyridis has become the predominant Coccinellidae species. The result can be a decrease in this parasitoid species or its better adaptation to the new host.

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