Biology and Feeding Potential of the Predator, *Hippodamia convergens* Guér., on Four Aphid Species Under Laboratory Conditions

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Abstract

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Suitability of the aphid species *Brevicoryne brassicae* L., *Aphis craccivora* Koch, *Hyalopterus pruni* Geoffroy and *Aphis illinoisensis* Shimer as preys for the predator *Hippodamia convergens* Guérin-Méneville (Coleoptera: Coccinellidae) development and reproduction was evaluated under laboratory conditions of 20±2ºC temperature and 70±5% relative humidity. Results obtained revealed that the prey species had significant effect on the development and predation rate of *H. convergens* immatures. The shortest total larval developmental period (12.82 days) was observed for the beetle fed on *A. craccivora*, whereas the longest (16.32 days) was recorded for the beetle fed on *H. pruni*. *H. convergens* consumed significantly more individuals of *H. pruni* (278.34) during its larval period than *A. craccivora* (186.76), *B. brassicae* (227.87) and *A. illinoisensis.* (211.94). The lowest immature stages mortality rate was recorded when they were fed on *A. craccivora* (6.47%), followed by those fed on *A. illinoisensis* (8.05%), *B. brassicae* (9.65%) and *H. pruni* (13.6%). Meanwhile, adult females consumed significantly more individuals of *H. pruni* (4937.40) than *B. brassicae*, *A. illinoisensis* (3693.92, 3432.15) and *A. craccivora* (2953.5). Highest fecundity (564.00 eggs) was recorded when females of *H. convergens* were fed on *A. craccivora*. In addition, beetle adult females and males that fed on *H. pruni* had significantly longer life span than those fed on the other three aphid species. The investigation provides useful information for the utilization of the *H. convergens* predator in IPM programs to protect faba bean, cabbage, grapevine and stone fruit trees from aphids as well as other sap sucking pests.

Keywords: *Hippodamia convergens*, *Brevicoryne brassicae*, *Aphis craccivora*, *Hyalopterus pruni*, *Aphis illinoisensis*, biology, reproduction, feeding capacity.

Introduction

Aphids are one of the most injurious insect pests attacking many economic crops. Damage caused by aphids is due to feeding on the plant sap causing direct injury to the plants (Hadeer *et al*., 2020; Ismail *et al.*, 1991). The aphidophagous coccinellids are of particular importance and usually play an important natural role in regulating and suppressing aphid populations (Al-Allan *et al.*, 2004; Jafari, 2011). They feed on many insect pests such as mealy bugs, aphids, whiteflies, thrips, scale insects, mites, leafhoppers and some lepidopteran pests (Bahy El-Din, 2006; Khan *et al.*, 2009; Pervez & Omkar, 2004).

The convergent ladybird beetle, *Hippodamia convergens* Guérin-Méneville (Coleoptera: Coccinellidae), is an important coccinellid species that feeds on aphids (El-Habi *et al.*, 2000; Hodek & Honek, 1996; Lyon, 1998). After the hatching of *H. convergens* eggs, the young larvae start searching for soft bodied small insects for feeding. Adults and older larvae are voracious feeders. It is one of the few natural enemies that are currently wild-collected from mass aggregations for pest control industry (Aristizábal & Arthurs, 2015; Michaud & Qureshi, 2006). The natural sequence role of *H. convergens* must be continuously encouraged and developed by maintaining suitable conditions for this predator to play its natural role. *H. convergens* can be mass reared in the laboratory and released for controlling different aphid species as well as other insect pests (Bahy El-Din & El-Khawas, 2020; Lanzoni *et al.*, 2004).

The present study aimed to evaluate the effect of different aphid species on the biology, reproductive and predation capacity attributes of *H. convergens* under laboratory conditions.

Materials and Methods

The present study was carried out in Plant Protection Research Institute, Zagazig, Sharkia, Egypt, under laboratory conditions of 20±2ºC temperature and 70±5% relative humidity. Aphid species *B. brassicae*, *A. craccivora*, *H. pruni* and *A. illinoisensis* were used as preys for the predator *H. convergens*.

Rearing of aphid preys

Brevicoryne brassicae and *A. craccivora* were reared in a cage (60×60×80 cm) covered with muslin and fed on young seedlings of their respective hosts, cabbage and faba bean. *A. illinoisensis* was collected from grapevine fields, whereas *H. pruni* was obtained from peach orchards, and both of them were directly used as food sources for *H. convergens*.

The coccinellid *Hippodamia convergens*

Adults of *H. convergens* were collected from alfalfa fields infested with *A. craccivora.* The initial culture of *H. convergens* was initiated by collecting adults from the field

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and maintained plastic jars (20 cm in length and 15 cm in diameter) with abundant supply of aphid species. The laid eggs were placed in Petri dishes (10 cm) until hatching. Newly deposited eggs of *H. convergens* were collected daily and kept in new plastic cages. Upon hatching, neonate larvae were provided with adequate numbers of aphids as food until pupation. Pupae were collected and kept in another plastic cage until emergence. This cycle was repeated for each prey species at least for two successive generations before using it in the experiments of this study.

Assessment of the duration of larval and pupal stages and larval feeding capacity of *H. convergens*

One hundred eggs were collected from the laboratory colonies and divided into five replicates (20 eggs each). Eggs were placed on moistened filter paper in a Petri dish (12 cm diameter) and checked daily untill hatching. The newly hatched larvae of each replicate were gently transferred into other Petri dishes (12 cm diameter) untill pupation.. The emerged *H. convergens* adults of each stock culture were placed in a single large Petri dish (200 mm diameter×9 mm height) lined with a filter paper on the bottom and kept in cohort for mating. Each mating pair was very carefully transferred to a separate Petri dish (100×9 mm) by means of a filter paper. Daily, each *H. convergens* pair was offered aphid nymphs gently transferred to each Petri dish.

Each pair was fed on one aphid species, according to its treatment group until egg laying. The deposited eggs were gently transferred to another Petri dish (100×9 mm) daily until hatching. To evaluate the developmental period of *H. convergens*, the incubation period of eggs laid by females was determined. Newly hatched larvae were individually transferred to Petri dishes (100×9 mm). Twenty larvae from each culture, as replicates, were reared on the same aphid species with which their parental culture was fed. Daily, a known number of aphid nymphs was gently transferred to each Petri dish. The first instar larvae of the predator was fed on the first and second instars of aphid nymphs. The larvae from the second instar to adults were offered all aphid stages. In each treatment, development, survival and feeding capacity of larvae were daily recorded and the dead ones were removed.

Longevity and fecundity of *H. convergens* adults

Newly emerged adults of each treatment group were sorted by sex and introduced singly into a Petri dish (100 × 9 mm). Each adult was fed on a known number of aphids of the same species on which their larvae were fed on and in the same manner. Seven days after emergence, adult males and females from each treatment group were transferred to a single large Petri dish (200×9 mm) and provided with aphid nymphs and kept in cohort for mating. In each treatment, ten successfully mating pairs were selected, carefully transferred to ten Petri dishes (100×9 mm) and daily fed on aphids. After seven days, each mated pair was separated and individually placed in a Petri dish (100×9 mm). The adults were fed on aphids on daily basis until death. The number of consumed preys was daily recorded throughout the lifespan of females and males. Pre-ovipositional period was taken in account from the emergence day until oviposition. The number of eggs laid per female during the ovipositional period was daily recorded and the total number of eggs laid per female was calculated. Post-ovipositional period was recorded from the end of ovipositional period until death.

Statistical analysis

Data was analyzed using SAS package 8.2 v (SAS, 2003). Data obtained was analyzed using one-way ANOVA. When F values were significant, means were compared using Tukey' LSD at P= 0.05.

Results and Discussion

Incubation period

Hippodamia convergens developed successfully on most of the tested preys, the mean incubation period (Table 1) for the eggs of *H. convergens* was 3.45±0.90, 3.21±0.76, 4.96±0.12 and 4.06±0.11days on the four aphid species *B. brassicae*, *A. craccivora, H. pruni* and *A. illinoisensis*, respectively. Results showed that the mean incubation period was significantly different among prey species.

Egg hatching

Egg hatching rate (%) was significantly longer when the predator was fed on *A. craccivora* (96.14%) in comparison with those fed on *B. brassicae, H. prunia* and *A. illinoisensis* (89.19, 88.09 and 90.08%, respectively).

Effect of various preys on development of immature stages

As shown in Table 1, larval development was prey-dependent, there were significant differences among tested preys in the duration of the 1st instar, and the total developmental period. The developmental period of the 1st instar larvae of *H. convergens* was significantly different when the larvae were reared on *B. brassicae*, *A. craccivora*, *H. pruni* and *A. illinoisensis* (3.21±0.10, 2.81±0.57, 3.62±0.13 and 3.06±0.14 days, respectively). The developmental period of the larval second and third instars was significantly longer when they were fed on *H. pruni* (4.20±0.11 and 4.21±0.12 days, respectively) in comparison with those fed on *B. brassicae*, *A. craccivora* and *A. illinoisensis* (3.55±0.14, 3.2±0.12 and 3.41±0.13 days, for the second instar, and 3.51±0.11, 3.2±0.9 and 3.41±0.11 days for the third instars, respectively). The total larval development periods of *H. convergens,* fed on either *B. brassicae, A. craccivora, H. pruni* and *A. illinoisensis*, were 14.98±0.99, 12.82±0.93, 16.32±1.01 and 13.93±0.90 days, respectively. The total period was significantly shortest when the larvae were fed on *A. craccivora* and significantly longest when they were fed on *H. pruni*. However, non-significant differences were observed in the duration of the pupal stage. The total developmental periods of the immature stages were 25.00±1.12, 22.00±1.07, 28.69±1.2, and 24.79±1.09 days, when the *H. convergens* was fed on *B. brassicae, A. craccivora, H. pruni* and *A. illinoisensis*, respectively. In addition, the total developmental periods of the immature stages were significantly shortest when the larvae were fed on *A. craccivora* and significantly longest when fed on *H. pruni*.

Table 1. Effect of different prey species on the development of *H. convergens* immature stages at 20±2ºC temperature and 70±5% relative humidity.

Prey species	Egg hatching (%)	Incubation period	Larval developmental period (instars)				Total larval period	Pupal period	Total immature stages	Mortality rate %
			1st	2nd	3rd	4th				
B. brassicae	89.19a (77-100)	3.45 c	3.21 b	3.55 ab	3.51 ab	4.71 ab	14.98 b	6.57 ab	25.0 b	9.65 b
A. craccivora	96.14 b (82-100)	3.21 c	2.81 c	3.2 b	3.20 b	4.10 b	12.82 c	5.96 ab	22.0 b	6.47 d
H. pruni	88.09a (70-100)	4.96 a	3.62 a	4.20 a	4.21 ab	5.19 a	16.32 a	7.41 a	28.69 a	13.6 a
A. illinoisensis	90.08a (75-100)	4.06 b	3.06 b	3.41 b	3.41 a	4.50 ab	13.93 d	6.8 b	24.79 b	8.05 c

Values followed by the same letters in the same column are not significantly different at P=0.05.

Mortality rates were 9.65, 6.47, 13.6 and 8.05% when the *H. convergens* was fed on *B. brassicae, A. craccivora, H. pruni* and *A. illinoisensis*), respectively. Mortality rate of predator immature stages was significantly lowest when the larvae were fed on *A. craccivora* and significantly highest when they were fed on *H. pruni* (Table 1).

Effect of various preys on feeding capacity of larvae

Numbers of *B. brassicae*, *A. craccivora, H. pruni* or *A. illinoisensis*, consumed fed to the first larval instar of *H. convergens*, were 15.43±0.81, 12.26±0.69, 19.4±1.03 and 16.56±0.96 nymphs/larva, respectively. The second instar larvae consumed 27.94±1.07, 24.69±1.35, 29.17±1.39 and 25.5±1.24 aphids, respectively. The numbers consumed by the third instar larvae were 68.13±2.14, 53.67±5.37, 74.61±7.87 and 62.34±5.56 of aphid prey, respectively. The fourth larval instar consumed 116.37±2.14, 96.14±7.09, 155.16±9.45and 107.54±8.67 of aphid prey. The total numbers of aphids consumed by the four larval instars of the predator fed on *B. brassicae*, *A. craccivora, H. pruni* or *A. illinoisensis* were 227.87±11.21, 186.76±10.57, 278.34±12.95 and 211.94±10.89 nymphs/larva, respectively. The numbers of *H. pruni* consumed by the four larval instars of *H. convergens* were significantly higher than those fed on the other aphid species. In addition, the number of consumed *A. illinoisensis* was significantly higher than that of *A. craccivora*. Thus, *H. convergens* larvae were more voracious towards *H. pruni* than the other aphid species (Table 2).

Longevity of adults

Pre-ovipositional period of the females was significantly shortest when fed on *A. craccivora* (6.70 ± 1.52 days), followed by *A. illinoisensis* and *H. pruni* (8.70±1.59 and 10.6±2.74 days, respectively). Meanwhile, the longest period was recorded when the females were fed on *B. brassicae* (11.21±2.92 days). Ovipositional period was significantly longest when the ladybird was fed on *H. pruni* (62.4±4.01 days) in comparison with *B. brassicae* and *A. illinoisensis* (54.49±3.65 and 43.5±3.41 days, respectively) and *A. craccivora* (39.4±2.34 days). Post-ovipositional period was significantly longer when the *H. convergens* was reared on *H. pruni* (13.6±3.91 days). Meanwhile, this period was significantly shorter when females were reared on *A. craccivora* (7.9±2.48 days), whereas it was 10.32±3.87 and 9.12±2.56 days when reared on *B. brassicae, A. illinoisensis, respectively*. The longevity was significantly longer when the females were fed on *H. pruni* (86.6±6.35 days) or *B. brassicae* and *A. illinoisensis* (76.02±4.24 and 61.32±5.39 days, respectively) and was significantly shorter when fed on *A. craccivora* (54.0±3.47 days). Males lived significantly longer when fed on either *H. pruni* (67.4±4.59 days) or *B. brassicae* and *A. illinoisensis* (65.90±4.24 and 54.20±3.15 days, respectively) and lived shorter when fed on *A. craccivora* (45.7±2.08 days). The females survived better on all aphid species than males. In general, *H. convergens* adults lived longer when they were fed on *H. pruni* and shorter when they were fed on *A. craccivora* (Table 3).

Table 2. Effect of different prey species on feeding capacity of *H. convergens* larvae at 20±2ºC and 70±5% R.H.

Prey species	1st instar	2nd instar	3rd instar	4th instar	Total
B. brassicae	15.43 c	27.94 b	68.13 b	116.37 b	227.87 b
A. craccivora	12.26 d	24.69 d	53.67 d	96.14 d	186.76 d
H. pruni	19.4 a	29.17 a	74.61 a	155.16 a	278.34 a
A. llinoisensis	16.56 b	25.5 c	62.34 c	107.54 c	211.94 c

Values followed by the same letters in the same column are not significantly different at P=0.05.

Feeding capacity of adults

Throughout their lifespan, the feeding capacity of a mated female fed on *A. craccivora* was 2953.5±132.4 aphids. This value increased significantly when it was fed *on A. illinoisensis* and *B. brassicae* (3432.15±156.2 and 3693.92±179.67, respectively). It reached a maximum consumption value when reared on *H. pruni* (4937.4±187.4). Similarly, the feeding capacity of mated male fed on *A. craccivora* was 2606.08±89.4 aphids, increased significantly to 2876.65±112.46 and 3036.32±102.21 aphids when reared on *A. illinoisensis* and *B. brassicae*, respectively, and reached the maximum (3517.67±143.2) when reared on *H. pruni*. In general, *H. convergens* adults consumed more *H. pruni* individuals than the other aphid preys (Table 4).

Table 3. The adult longevity and fecundity of *H. convergens* reared on four aphid species at 20±2ºC and 70±5% R.H.

	Female longevity			Total Female	Total Male	Total No. of
Prey specie	**Pre- oviposition**	**Oviposition**	**Post-oviposition**	**longevity**	**longevity**	**eggs**
B. brassicae	11.21 a	54.49 b	10.32 b	76.02 b	65.9 a	391 b
A. craccivor	6.7 c	39.4 c	7.9 d	54.0 c	45.7 c	564 a
H. pruni	10.6 a	62.4 a	13.6 a	86.6 a	67.4 a	413 b
A. illinoisensis	8.7 b	43.5 c	9.12 c	61.32 c	54.2 c	339 b

Values followed by the same letters in the same column are not significantly different at P=0.05.

Table 4. Feeding capacity and female fecundity of *H. convergens* reared on four aphid species under laboratory conditions.

	Adult stages				
	Female			Male	
Prey species	**Longevity**	**Average of consumption**	**Fecundity**	**Longevity**	**Average of consumption**
B. brassicae	76.02 b	3693.92 d	391.0 b	65.9 a	3036.32 b
A. craccivora	54.0 c	2953.5 d	564.0 a	45.7 c	2606.08 d
H. pruni	86.6 a	4937.40 a	413.0 b	67.4 a	3517.67 a
A. illinoisensis	61.32 c	3432.15 c	339.0 b	54.2 c	2876.65 c

Values followed by the same letters in the same column are not significantly different at P=0.05.

Fecundity

The average number of deposited eggs per female was significantly highest when the females were fed on *A. craccivora* (564.0±17.20 eggs) than those fed on *H. pruni* (413.0±15.62 eggs). On the other hand, a significant lower number of eggs was laid when the adults were reared on *B. brassicae* and *A. illinoisensis* (391.0±10.92 and 339.0±13.67 eggs, respectively). In other words, females were more fertile when reared on *A. craccivora* (Table 4).

Discussion

The results revealed that *H. convergens* developed successfully on most of the tested aphids as preys. The mean incubation period for the eggs of *H. convergens* was 3.45, 3.21, 4.96 and 4.06 days when reared and fed on the four aphids, respectively. Egg hatching rate (%) was significantly longer when they were fed on *A. craccivora* (96.14%) in comparison with those fed on *B. brassicae*, *H. pruni* and *A. illinoisensis* (89.19, 88.09 and 90.08%, respectively). The total developmental period of all immature stages of *H. convergens* reared on *A. craccivora* was significantly shorter than those reared on *A. illinoisensis* and *H. pruni*, which is in agreement with previous reports *(*El-Heneidy *et al.,* 2008; Hadeer *et al.,* 2020).

The total developmental period of all immature stages of *H. convergens* fed on *A. craccivora* was significantly shorter than those fed on *A. illinoisensis* and *H. pruni*. It seems that development of the ladybird beetle was closely associated with the aphid prey species offered. The shorter developmental period of *H. convergens* fed on *A. craccivora* indicated that this prey species was the most suitable for larval development, probably due to the presence of nutrients necessary for growth and development. These results are in harmony with those reported earlier for *H. variegata* (El-Hag & Zaitoon, 1996; Wu *et al*., 2010) and *H. convergens* (El-Heneidy *et al*., 2008; Mandour, 2009). The differences in developmental time may be attributed to the differences in palatability and prey consumption or holding conditions (El-Hag & Zaitoon, 1996), host plant of the prey (Wu *et al*., 2010) and prey suitability (Sarhan *et al.,* 2011).

The results of the present study also indicated that the numbers of *H. pruni* consumed by the four larval instars of *H. convergens* were significantly higher than those reared *on A. craccivora, B. brassicae* and *A. illinoisensis*. Immature survival rate of *H. convergens* in the present study was prey-independent, except that fed on *B. brassicae,* which was also an unsuitable prey for *H. convergens* (Mandour, 2009; 2013). In general, the study revealed that *H. convergens* adults lived longer when they were fed on *H. pruni* and shorter when they were fed on *A. craccivora.* These results are largely consistent with the results of El-Heniedy *et al*. (2008), who indicated that *H. convergens* female's longevity was longer than that of males when reared on the 4th nymphal instar of *A. craccivora.* Lohar *et al.* (2012) indicated that the average oviposition and post-oviposition periods of *H. convergens* reared on mustard aphid, *L. erysimi* was 32.0 days, and mean fecundity/female was 312.3±9.51eggs. In this work, the average number of eggs per female (fecundity) was significantly highest when the females were fed on *A. craccivora* (564.0±17.20) in comparison with those fed on *H. pruni* (413.0±15.62).

In conclusion, results obtained in this study confirmed that aphid species preys influenced the biological aspects of *H. convergens*. *A. craccivora* was found as a more suitable prey than other prey species for the development of *H. convergens*. The present findings could be useful for mass rearing of the predator *H. convergens.*

الملخص

صالح، أحمد أمين أحمد، هند سعد الطحاوي، هبة النجار وأحمد شمخي جبار. 2023. حياتية المفترس *Hippodamia convergens* وكفاءته الافتراسية عند تربيته على أربعة أنواع من حشرات المنّ تحت الظروف المختبرية. مجلة وقاية النبات العربية، 41(1): 48–53.
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أجريت الدراسة لتقييم دورة حياة ومعدل تكاثر المفترس *Hippodamia convergens* عند تربيته على أفراد منّ الصليبيات ومنّ اللوبياء ومنّ البرقوق الدقيقي ومنّ العنب تحت الظروف المختبرية 20±2°س ورطوبة نسبية 70±5%. أوضحت النتائج أن لأنواع المنّ تأثير معنوي على حياتية ومعدل الافتراس للأطوار غير الكاملة لهذا المفترس. وبلغت أقصر فترة نموّ كليّة للأطوار اليرقية 12.82 يوماً عند تغذية المفترس على حشرات منّ اللوبياء، بينما كانت أطول فترة 16.32 يوماً عندما تمّت تربية المفترس على منّ البرقوق الدقيقي. وكان لنوع المنّ تأثير معنوي في معدل الافتراس خلال الطور اليرقي، حيث استهلك أكبر عدد (278.34 فرداً) من حشرات منّ البرقوق الدقيقي، بينما قابله 186.67 فرداً من حشرات منّ اللوبياء و227.87 فرداً من حشرات منّ الصليبيات و211.94 فرداً من حشرات منّ العنب. وسُجّل أدنى معدل موت للأطوار غير الكاملة لهذا المفترس (6.47%) عند تربيته على حشرات منّ اللوبياء، ويليه عند تربيته على حشرات منّ العنب (8.05%)، ومنّ الصليبيات (9.65%) ومنّ البرقوق الدقيقي (13.6%). وكان لمعدل الاستهلاك الكلّي للإناث تأثير معنوي عند التغذية على منّ البرقوق الدقيقي (4937.40 فرداً) مقارنةً بمنّ الصليبيات (3693.92 فرداً) ومنّ العنب (3432.15 فرداً) ومنّ اللوبياء (2953.5 فرداً). وتحقّق أعلى معدّل لوضع البيض (564 بيضة) عند تربية إناث المفترس *Hippodamia convergens* على حشرات منّ اللوبياء. كما لوحظ أنّ طول حياة المفترس (ذكوراً وإناثاً) كانت أطول عندما تمّت تربيته على أفراد منّ البرقوق الدقيقي مقارنةً بأنواع المنّ الثلاثة. وتزوّدنا هذه الدراسة بمعلومات مفيدة حول الاستفادة من المفترس في برامج المكافحة المتكاملة لحماية نباتات الفول البلدي والكرنب/الملفوف والعنب والفاكهة ذات النوى الصلبة من الإصابة بحشرات المنّ والحشرات الثاقبة الماصّة.

كلمات مفتاحية: *Aphis illinoisensis*، *Hyalopterus pruni*، *Aphis craccivora*، *Brevicoryne brassicae*، *Hippodamia convergens*، حياتية، التكاثر، معدّل الافتراس.

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