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Biology and Predatory Potential of the Eleven Spotted Coccinellid Predator *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae) reared on two Aphid Species (Hemiptera: Aphididae) under Laboratory Conditions.

Hadeer S. A. Rashed, Adel A. Hafez, Fawzy F. Shalaby and Naglaa, F. Abd-Elhameid
Plant Protection Department, Faculty of Agriculture, Moshtohor, Benha University, Egypt.
Corresponding author: hadeerrashed123@gmail.com

Abstract

The coccinellid predator *Coccinella undecimpunctata* is considered one of the most efficient and potential predators of many soft bodied insect pests especially aphids. The biology and predatory potential of this coccinellid were studied on the 4th nymphal instar of two aphid species, *Aphis craccivora* Koch. and *Schizaphis graminum* (Rondani). By rearing on *A. craccivora* at 20, 25 and 30°C the incubation periods of *C. undecimpunctata* eggs were 5.84, 4.32 and 3.62 days, led subsequently, to 80.20%, 94.40% and 64.40% hatching, respectively, opposed to 5.98, 4.60 and 3.42 days with 74.40, 90.40 and 62.00% hatchability when rearing took place on *S. graminum*. The total larval duration lasted 9.96 days on *A. craccivora***,** being, significantly**,** shorter than the 10.67 days resulted from rearing on *S. graminum.* Throughout the whole period of the larval stage feeding on the 4th instar nymphs of *A. craccivora and S. graminum,* a single larva fed on163.54 or 170.21 nymphs, respectively. *C. undecimpunctata* female's longevity elapsed 64.04 and 63.19 days**,** respectively. A single mated female deposited 686.69 eggs when reared on *A. craccivora*, opposed to 590.57 eggs by feeding on *S. graminum.* These results concluded that rearing of *C. undecimpunctata* on *A. craccivora* proved the best to obtain immature stages of shorter durations, much lower consumption and the highest reproductivety of eggs.

Keywords: *Coccinella undecimpunctata* - Biology - Predatory potential – *Aphis craccivora –Schizaphis graminum.*

Introduction

About 6000 coccinellid species have been described around the world. Coccinellid species are contained in six Subfamilies, Coccidulinae, Coccinellinae, Scymninae, Chilocorinae, Sticholotidinae and Epilachninae beetles. Only members of the later Subfamily (Epilachninae) are harmful phytophagous insects while, the remaining Subfamilies are compressed of beneficial species predatory **(Slipinski, 2007).** Coccinellids play an important role in regulating insect pests of soft bodied insects such as aphids, jassids, psyllids, white flies, scale insects, mealy bugs and phytophagous mites, which are injurious to agricultural crops and forest plantations, so those are considered a major factor of aphids control in various agricultural systems and has supported a significant beneficial role **in** the reduction in insecticides use **(Kindlmann *et al.*, 2007 and Obrycki *et al.*, 2009).** These groups of coccinellids have got attention of researchers as biological control agents, due to their ability to feed on a large number of preys (**Mari *et al*., 2004**). Many Coccinellid species are efficient predators, being easily adapted to both changes in quantity and quality of their prey species (**Segonça *et al.*, 2005 and Weber and Lundgren, 2009**), as the larval and adult stages are very active predators of aphids and other small soft bodied insects and phytophagous mites (**Hangay and Zborowski, 2010**).

Biological control by using natural enemies of high potentiality to be effective alternatives to manage pest's population densities in addition to their high efficiency in biological control all the year round was described (**Maniand and Krishnamoorthy, 2008 and Mossadegh *et al.*, 2008).** Biological control by using these alternatives is usually safe, economical and permanent. The use of introduced natural enemies for controlling the crop damaging insects, so that their populations are kept below the economic threshold level was, also reported (**Vincent *et al.*, 2007 and Bukero *et al.*, 2015**).

Normally**,** the successful natural enemies are those having high reproduction rate, good searching ability for their host or preys, adaptability in different environmental conditions and synchronized with their hosts **(Buchanan, 1996).**

The eleven spotted ladybird beetle *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae) is an important predator (**Hodek and Honek, 1996**). This predaceous ladybird beetle is considered a potential biological control agent against a wide range of prey species including aphids (**Soares *et al.*, 2003 and Cabral *et al*., 2006).** Also, this predaceous species appeared as effective in keeping alfalfa's aphids below the economic threshold level **(Mari, 2004).** Also, **Carbal *et al.*, (2009)** indicated that *C. undecimpunctata* showed to be an effective predator for the biological control of *M. persicae* under controlled conditions. The same authors hypothesized that the presence of both 4th instar larvae and adults of this ladybird beetle could increase the efficiency in field pest species suppression. Hence, the present study, aimed to

determine the predator's efficiency under laboratory conditions and studying the main biological characteristics of this beetle on two aphid species.

Materials and Methods

1. Aphids stock cultures:

The wheat aphid *Schizaphis graminum* and the black legume aphid *Aphis craccivora* individuals were obtained from infested plant parts reared in the Department of Biological control, Plant Protection Research Institute, Agricultural Research Center at Giza, Egypt, and maintained to the biological control laboratory of the Faculty of Agriculture, Benha University for mass rearing of beneficial bio-agents. Faba bean seedlings infested with *A. craccivora* individuals and also, wheat seedlings infested with *S. graminum* were gently cut using a scissor and placed between the new uninfested seedlings (faba bean or wheat) grown under laboratory conditions at 25±2˚C and 65±5% R.H. Within few hours, the old cut seedlings wilt and, soon, the aphids moved and climbed the new seedlings and multiplied on it.

2. *C. undecimpunctata* stock culture:

C. undecimpunctata individuals were collected from the open field cultivations of wheat and clover as a winter crops at Shebeen El-Qanater, Beltan and Cendion; of Qalubiya Governorate and introduced to the laboratory of biological control at the Faculty of Agriculture, Benha University, under laboratory conditions. The predator culture was mass reared by the following method:

Five pairs (males and females) of the coccinellid predator *C. undecimpunctata* were placed in small woody boxes (10 cm diameter and 20 cm height), covered from its sides with muslin cloth pieces and provided with strips of black paper on which females deposited their eggs. The predator was provided with faba bean seedlings planted with small plastic pots (no. 10) and heavily infested with *A. craccivora* individuals to serve as food. Female adults deposited their eggs either on the faba bean seedlings or on the black paper strips. The deposited eggs were, daily, collected with the oviposition substrate, counted and placed in Petri-dishes to start rearing of the coccinellid predator. After hatching, the neonate larvae were provided, daily, with adequate numbers of aphids, until pupation. Resultant pupae were subsequently kept in other plastic cups (5 cm. diameter and 3 cm. height) until adults' emergence. The emerged adults were taken immediately to start the experiments.

3. The main biological characteristics of *C. undecimpunctata*:

3.1. Durations of immature stages and larval feeding capacity:

3.1.1. Incubation period of eggs and hatchability percentages at three different temperatures:

A couple (male and female) of the predator was placed in glass a chimney cage (10 cm diameter and 20 cm height). The glass chimney cages were inverted on a plastic cups planted with faba bean seedling that infested with adequate number of *A. craccivora* and provided with strips of black paper for egg deposition (**Plate, 1**). These experiments were replicated 15 times on each of the two aphid species on three different temperatures (20, 25 and 30˚C). The same technique was followed on *S. graminum* infested wheat seedlings**.**

A group of freshly deposited 50 eggs each, resulted from adult females that were reared on the two aphid species *A. craccivora and S. graminum* under three constant temperatures (20, 25 and 30˚C), were transferred to clean Petri-dishes until hatching. The experiment was replicated five times for each aphid species and temperature. After hatching of *C. undecimpunctata* eggs, the incubation period of eggs was estimated. The percentages of eggs' hatching and of those failed to hatch were also counted and recorded at each of the three temperatures.

Plate, (1): A glass chimney cage placed on a pot planted with faba bean seedlings.

3.1.2. Durations of larval and pupal stage and larval feeding capacity:

For calculating the larval and pupal durations, 15 replicates were used**.** Every replicate included a single larva placed in a plastic cup (5 cm. diameter and 3 cm. height) in which a filter paper was placed on the bottom. Each larva was daily provided with counted enough number of aphid individuals (*A. craccivora* or *S. graminum)*. The preyed numbers of aphids by each larva were counted, daily, and recorded. Larvae were supplied daily, with enough amounts of aphids until pupation estimated and duration of each larval instar, total larval and pupal periods of the predator were recorded. During rearing in the laboratory, mortalities among larvae and pupae were counted and, subsequently, the mortality percentages were calculated for each of the two stages.

The resultant pupae were placed, singly, in plastic cups and left until emergence of adults. The percentages of emergence were calculated.

3.2. longevity and fecundity of the coccinellid predator adults:

Thirty freshly emerged adults (15 males and 15 females), representing 15 replicates (couples) of *C. undecimpunctata* were used in this experiment. Every pair of adults was placed in a glass tube (4 cm diameter and 8 cm height), in which black paper stripes were placed. Couples of adults were daily offered enough numbers of either *A. craccivora* or *S. graminum*. Every day enough numbers of the same species were added until mortality of adults. Longevities for either of the two sexes (females - males) were recorded. Fecundity per female and ovipositional periods (pre-oviposition, oviposition and post-oviposition periods) were also estimated.

Results and Discussion

1. **Durations of *C. undecimpunctata* immature stages :**

a. Incubation period of eggs, hatchability and mortality percentages

Means of incubation period of *C. undecimpunctata* eggs obtained after rearing on *A. craccivora* and *S. graminum* at three temperatures (20, 25 and 30˚C) lasted 5.84, 4.32 and 3.62 days, respectively, when the predator was reared on *A. craccivora* individuals (nymphs and adults), opposed to 5.98, 4.60 and 3.42 days, respectively when the predator was reared on *S. graminum* (Table,1).

Comparing the means of eggs' incubation period at three temperatures when the female adults were fed on *A. craccivora* or *S. graminum*, this period was negatively correlated with the temperature degrees, i.e., shortened, significantly, the rearing temperature was immersed. The shortest incubation period (3.62 days and 3.42 days, respectively) was obtained by rearing on the two host species at 30˚C, while the longest values (5.84 and 5.98 days) occurred at the lowest rearing temperature (20˚C) (Table, 1).

The effect of the host species on the length of eggs' incubation period at either of the three temperature degrees was not distinct; i.e., differences between values of this period by rearing on *A. craccivora* or *S. graminum* at a fixed temperature were not detectable. These results indicated that the rearing temperature had the main effect on the length of eggs' incubation period, but the effect of the host species on which the predator females was, generally, slight.

As for the hatchability percentages from the deposited eggs, data in Table (1) showed that after rearing on the two aphid species at 20, 25 and 30˚C, the % hatching varied, significantly, between the three temperature degrees, being the highest (94.4 after rearing on *A. craccivora* and 90.4% after rearing on *S. graminum*) at 25˚C . On contrary, this percentage was the lowest (64.4 and 62.0%, respectively) at 30˚C. On the other hand, rearing *C. undecimpunctata* on *A. craccivora* led to females that deposited eggs manifested higher percentages of hatchability than those laid by females reared on *S. graminum* (80.2, 94.4 and 64.4%) for rearing on *A. craccivora*, opposed to 74.4, 90.4 and 62.0% for rearing on *S. graminum* at 20, 25 and 30˚C., respectively. There was significant difference in hatchability percentages between rearing at 20 and 25˚C, while it was nonsignificant when took place at 30˚C. (Table, 1).

Concerning the mortality percentages among eggs resulted from rearing on the two host species and incubated at 20, 25 and 30 ˚C., the lowest mortality rate was, always, associated with rearing at 25˚C. (7.0% by rearing on *A. craccivora* and 9.2% from rearing on *S. graminum* nymphs), while the highest mortality percentage occurred when *C. undecimpunctata* adults and subsequent eggs were kept at 30˚C (35.6 and 38.0%, respectively; Table, 1). Eggs from rearing at 20˚C manifested in between values (19.8 and 25.6 % mortalities, respectively). It is, also, clear from the same table that the temperature was the main factor affecting, significantly, the incubation period of *C. undecimpunctata* eggs. On the other hand, mortality percentages among deposited eggs show significant difference at either of the rearing temperature by rearing of *A. craccivora* or *S. graminum* nymphs although feeding on *S. graminum* nymphs resulted eggs of, non-significantly, higher mortality percentage (Table,1).

Table 1. Means of eggs incubation period, hatchability and mortality percentages of *C. undecimpunctata* reared on *A. craccivora* and *S. graminum* at three different temperatures.

Egg parameter	Temp. (°C)	*A. craccivora*		*S. graminum*	LSD at
	20	5.84 ± 0.10^{aA}		5.98 ± 0.16^{aA}	
Incubation period (Days)	**25**	4.32 ± 0.07^{bB}		4.60 ± 0.11^{bA}	0.19
	30	3.62 ± 0.08^{cA}		3.42 ± 0.14^{cB}	
LSD at 0.05 for temperature			0.24		0.34
	20	80.20 ± 1.56^{bA}		74.40 ± 1.72^{bB}	
Hatchability%	**25**	94.40 ± 2.04^{aA}		90.40 ± 1.47^{aB}	2.64
	30	64.40 ± 1.17^{cA}		62.00 ± 1.26^{cA}	
LSD at 0.05 for temperature			3.23		4.57
	20	19.80 ± 1.56^{bB}		25.6 ± 1.72^{bA}	
Mortality%	**25**	7.00 ± 1.91^{cA}		9.20 ± 1.62^{cA}	2.55
	30	35.60 ± 1.17^{aA}		38.00 ± 1.26^{aA}	
LSD at 0.05 for temperature			3.13		4.42

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter.
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On the same line of the present results, **El-Meihy (2019)** carried out similar studies by rearing *C. undecimpunctata* on *A. craccivora* and *Rhopalosiphum padi* at 25±2˚C. The authoress reported 4.2 and 4.72 days as incubation periods, respectively, indicating, non-significantly, shorter incubation periods from rearing on *A. craccivora.* Also, for hatchability percentages among these eggs, those were higher when females were reared on *A. craccivora* than those reared on *R. padi*.

b. Durations of larval and pupal stages of the predator:

In this experiment, larvae of *C. undecimpunctata* were fed on the 4th nymphal instar of two prey species*; A. craccivora* and *S. graminum,* at 25˚C and 65% R.H., throughout the whole larval period. Data presented in Table (2) indicated that the first three larval instar durations were, nonsignificantly, affected by feeding on either of the two aphid species, being 2.14, 2.29 and 2.56 days for the 1st, 2nd and 3rd larval instars, respectively when fed on *A. craccivora*, opposed to 2.06, 2.35 and 2.63 days by feeding on *S. graminum*. Only the 4th instar larval duration was, significantly, longer (3.50 days) by feeding on *S. graminum* than the 2.97 days recorded for rearing on *A. craccivora*. The total larval duration showed the same as being, significantly, affected by the host (Table, 2). The total larval duration was shorter (9.96 days) than the 10.67 days recorded for larvae fed on the 4th nymphal instar of *S. graminum*. Throughout the whole total larval period, mortalities among the larvae were 13.33% when reared on the 4th nymphal instar of *S. graminum*, while no mortalities were detected among larvae fed on *A. craccivora* nymphs of the same instar (Table,2).

At 25±2 °C and 65±5% R.H., the mean periods of *C. undecimpunctata* pupae resulted after larval feeding on the 4th instar nymphs of *A. craccivora and S. graminum* were 4.83 and 5.33 days, being, significantly**,** shorter by rearing on former prey species (Table,2). The percentages of adults' emergence success from pupae obtained after rearing of larvae on 4th instar nymphs of *S. graminum* reached 100%, being higher than the 93.3% emergence among adults emerged after rearing on *A. craccivora* (Table, 2).

Table 2. Durations and mortality percentages among larval and pupal stages of *C. undecimpunctata* reared on the 4th instar nymphs of *A. craccivora* and *S. graminum* at 25±2°C and 65±5 %R.H.

Immature stages duration and mortalities %		*A. craccivora*	*S. graminum*	LSD at 0.05
Larval instars (Days)	1st	2.14±0.07^{cA}	2.06±0.05^{dA}	0.13
	2nd	2.29±0.07^{cA}	2.35±0.11^{cA}	
	3rd	2.56±0.07^{bA}	2.63±0.13^{bA}	
	4th	2.97±0.09^{aB}	3.50±0.11^{aA}	
LSD at 0.05 for stage		0.18		0.25
Total larval duration		9.96±0.17^{B}	10.67±0.20^{A}	0.51
Pupal period		4.83±0.07^{B}	5.33±0.09^{A}	0.21
Total developmental period		14.80±0.19^{B}	15.92±0.23^{A}	0.58
Total larval mortality %		0.00	13.33	
Failure of adults emergence %		6.67	0.00	
Adult emergency rate %		93.33	100.00	

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A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

The total developmental period was also, significantly, longer (15.92 days) by rearing on *S. graminum* nymphs, while it was shorter (14.8 days) on *A. craccivora*. In her studies, **El-Meihy (2019)** recorded that *C. undecimpunctata* total larval periods were 15.46 and 15.08 days by rearing on *A. craccivora* and *R. padi*, respectively. Data of the present study confirmed that the total larval duration was, significantly, affected by the host species on which the larvae were reared.

c. Feeding capacity of larval stage:

Data presented in Table (3) showed that the consumption rate by a single larva of *C. undecimpunctata* increased significantly as the predator larvae grew older to the subsequent instar. When fed on the 4th nymphal instar of *A. craccivora*, a single larva consumed 15.15, 22.15 and 34.64 nymphs during the 1st, 2nd and 3rd larval instars of the predator, respectively. The correspondent values in case of feeding on the 4th instar nymphs of *S. graminum* were 17.36, 28.21and 37.93 nymphs, respectively, being higher than those consumed by *A. craccivora*, while in case of feeding on the 4th nymphal instar, the single *C. undecimpunctata* larva fed on more amount of *A. craccivora* nymphs (90.38 individuals) during the 4th larval instar than the amount consumed from *S. graminum* nymphs (86.64 nymph; Table, 3).

Throughout the total larval stage, a single *C. undecimpunctata* larva devoured a total of 163.54 4th instar nymphs of *A. craccivora* 4th instar nymphs, opposed to 170.21 nymphs of *S. graminum* (Table,

3). The higher number of consumed *S. graminum* individuals of nymphs than those consumed from *A. craccivora* 4th nymphal instar may be attributed to the, relatively, smaller size of *S. graminum* nymphs of the same instar.

The present results agree with those previously reported by **Eid, (2019)** who demonstrated that the larval consumption by the eleven spotted lady beetle *C. undecimpunctata* increased, significantly, as larval stage progressed, regardless to the prey type. Also, the same authoress indicated that feeding of the predator's larvae on *A. craccivora* revealed lower consumption than *S. graminum*, but she attributed her results to the nutritional value of *A. craccivora* could be better than *S. graminum* for development the larval instars.

Table 3. Feeding capacity and total consumption of *C. undecimpunctata* larvae reared on the 4th instar nymphs of *A. craccivora* and *S. graminum* at 25±2℃ and 65±5% R.H.

Larval instars		Aphid species		LSD at 0.05
		A. craccivora	*S. graminum*	
Larval consumption	1st	15.15±0.70^{dA}	17.36±0.32^{dA}	2.46
	2nd	22.15±0.56^{cB}	28.21±1.14^{cA}	
	3rd	34.64±1.89^{bB}	37.93±1.11^{bA}	
	4th	90.38±4.19^{aA}	86.64±1.55^{aB}	
LSD at 0.05 for stage		3.47		4.91
Total larval consumption		163.54±3.9^{A}	170.21±3.25^{A}	9.86

a, b & c: There is non-significant difference (P>0.05) between any two means, within the same column having the same superscript letter.
A, B & C: There is non-significant difference (P>0.05) between any two means for the same attribute, within the same row having the same superscript letter.

d. Durations of *C. undecimpunctata* adult stage :

a. Ovipositional periods:

Female adult's of *C. undecimpunctata* reared by feeding on the 4th instar nymphs of *A. craccivora* and *S. graminum* started egg-laying after 7.31 and 7.93 days, respectively. The pre-oviposition period of the predator's females was, non-significantly, shorter by feeding on *A. craccivora* (Table, 4). As for the oviposition period, it lasted 50.62 and 48.50 days, respectively being, significantly, longer for feeding on *A. craccivora*. While, the post-oviposition period lasted 6.16 days when fed on *A. craccivora*, being, significantly, shorter than the 6.75 days recorded for female adults reared on *S. graminum* (Table, 4). These results indicated that the female adults of the 11-spotted ladybeetle reared on *A. craccivora* had longer oviposition period and shorter pre and post-oviposition periods, compared to those of females fed on *S. graminum*.

b. Adult's longevity

Data in Table (4), show that *C. Undecimpunctata* females lived longer (64.04 and 63.19 days) than males (50.36 and 49.77 days) whatever was the prey *(A. craccivora* or *S. graminum*, respectively). Also, it is clear that the effect of prey species (*A. craccivora* or *S. graminum*) on female's longevity was nonsignificant.

c. Eggs - productivity by *C. undecimpunctata* females:

Data presented in Table (4), indicated that the total number of eggs deposited by a single *C. undecimpunctata* female was, statistically, higher (686.69 eggs / female) when adults were fed on *A. craccivora*, compared to those deposited by females fed on *S. graminum* (590.57 eggs/ female).

Table 4. Ovipositional periods, adult's longevity and eggs- productivity/ female reared on two aphid species at 25±2˚C and 65±5 %R.H.

Period (Days)	*A. craccivora*	*S. graminum*	LSD at 0.05
Pre- oviposition	7.31±0.35^{A}	7.93±0.22^{A}	0.79
Oviposition	50.62±0.66^{A}	48.50±0.63^{B}	1.77
Post- oviposition	6.16±0.08^{B}	6.75±0.17^{A}	0.38
Adult longevity (female)	64.04±0.77^{A}	63.19±0.71^{A}	2.04
Adult longevity (male)	49.77±0.23^{A}	50.36±0.53^{A}	1.16
Total no. of eggs / female	686.69±9.99^{A}	590.57±14.09^{B}	34.20

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row having the same superscript letter.

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الملخص العربي

يعتبر مفترس أبي العيد ذو الإحدي عشر نقطة من المفترسات ذات الكفاءة العالية في مكافحة الحشرات الرهيفة وخاصة حشرات المن. ولقد تركزت هذه الدراسة علي تقييم بيولوجي وكفاءة المفترس عند التربية علي نوعين من المن من البقوليات ومن الغلال. ولقد أوضحت النتائج أنه عند تغذية الحشرات الكاملة علي من البقوليات, بلغت فترة حضانة البيض 5,84, 4,32 و 3,62 يوما عند التربية علي ثلاث درجات حرارة مختلفة 20 , 25 و 30 °م وكانت نسب الفقس 80,20 %, 94,40 % و 64,40 % , أما بالنسبة للإناث التي تغذت علي من الغلال فكانت فترة حضانة البيض علي الثلاث درجات حرارة 5,98, 4,60 و 3,42 يوما ونسب الفقس 74,40, 90,40 و 62,00 % .أما عند تغذية اليرقات علي عمر الحورية الرابع كانت مدة الطور اليرقي 9,96 يوما و كانت أقصر من تلك التي تغذت علي حوريات نفس العمر من من الغلال 10,67 يوما . ولقد أستهلكت اليرقة الواحدة من يرقات المفترس 163,54 حورية من من بقوليات و 170,21 حورية من من الغلال خلال فترة الطور اليرقي. وكانت طول فترة حياة الأنثي 64,40 و 63,19 يوما عند التغذية علي نوعي المن وكان متوسط عدد البيض للأنثي خلال فترة حياتها 686,96 بيضة عند التغذية علي من البقوليات و 590,19 بيضة/أنثي عند التغذية علي من الغلال. من خلال النتائج السابقة يتضح أن التربية علي من البقوليات أفضل من حيث إستهلاك عدد أقل من حوريات المن وكذلك وضع الأنثي لعدد أكبر من البيض و دورة حياة أقصر طولا.