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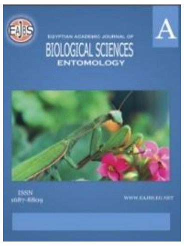

Cannibalistic Behaviour Sequels of Red-Flanked Ladybird Beetle, *Scymnus interruptus* Goeze (Coleoptera: Coccinellidae), on its Biology and Feeding Potential Under Laboratory Conditions

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ABSTRACT

Cannibalism is a well-known behavioural phenomenon that is supposed to be an adaptive response to ecological resources. The total number of eggs, incubation period, developmental period, and adult longevity of *Scymnus interruptus* was studied in three experiments, in which *S. interruptus*, the hibiscus mealybug *Maconellicoccus hirsutus* (Green), and *S. interruptus*+ *M. hirsutus* were singly used as prey in the laboratory. The mean life cycles of the females fed on *S. interruptus*, or *M. hirsutus*, or *S. interruptus*+*M. hirsutus* were 41.11, 34.25, and 46.18 days, respectively. The findings showed that *S. interruptus* preferred *S. interruptus*+*M. hirsutus* compared to the other prey types, as it developed speedy (17.12days) The Oviposition period of female was 21 days with an average of laid eggs as 218.32 egg/female. Fourth instar grub ate significantly more mealybugs than 1^{st}, 2^{nd} and 3^{rd} instars. The highest consumption rate of *S. interruptus* during its total life period was recorded as (1119-1362) mealybugs individuals, whose parents were fed on *S. interruptus* + *M. hirsutus*.

INTRODUCTION

The ladybird beetles (Coleoptera: Coccinellidae) are one of the most common beneficial insects (Dixon, 2000; William, 2002). They are predators of many economically important agricultural pests in the ecosystem (Khan *et al.*, 2009; Silva *et al.,* 2009; Shah and Khan, 2014).

Scymnus interruptus Goeze (Coleoptera: Coccinellidae) is a diffuse predator in many regions of the world, including different agroecosystems of the Mediterranean region. It feeds on many insect pests, including aphids, whiteflies, mealybugs, psyllids, and jassids (Garcia-Mari, 2012; Calabuig *et al.,* 2015). The ladybird beetles are used in many biological control programs with high efficiency in the face of many important agricultural pests, especially aphids and mealybugs (Robledo *et al.*, 2009; Gomez-Marco *et al.*, 2016).

Cannibalism, intraspecific predation, is a familiar behavior among predators of Coccinellidae. (Including *S. interruptus*) and is also considered one of the most important the crucial death elements of ladybird beetles (Khan *et al.*, 2003; Rondoni *et al.*, 2012; Jafari, 2013). The reasons for the occurrence of the phenomenon of cannibalism in coccinellids are mainly due to the lack of prey and predator famine. The cannibalistic nutrition seems to maintain their race in situations of a reduction of their naturalistic food

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(Dixon, 1959 and Brown, 1972). Mostly, the stages of eggs and newly coccinellid larvae are more vulnerable to being cannibalized compared with older larvae and adults (Agarwala and Dixon, 1992; Agrawala and Dixon, 1993).

The cannibalism rate might increase when the nutrition is lessened (Polis, 1981; Cottrell and Yeargan, 1999) however; many other species showed cannibalistic behavior even when large amounts of food were available (Wanger and Wise, 1996; Wanger *et al*., 1999 and William *et al.,* 2000). The phenomenon of Cannibalism gives great indications on the population dynamics of many insect species (Rudolf, 2008), especially coccinellid predators (Fox 1975; Elgar and Crespi 1992; Persson *et al*., 2003).

Because the members of the same species share the same food resource, The phenomenon of self-predation is a form of intraspecific competition that may or may not confer advantages that appear in fitness in terms of enhanced survival, growth, and development (Osawa 1992; Michaud and Grant 2004; Hofmann and Kia-Hofmann 2012), or have a significant effect on the reproductive performance of adults (Al-Zubaidi and Capinera 1983; Sonleitner and Guthrie 1991).

The present experiments were aimed to study the effect of cannibalistic behaviour on the biology and consumption rate of the Red-flanked ladybird beetle, *Scymnus interruptus* when fed on three types of prey as follows: *Scymnus interruptus* (as conspecific cannibalism)*,* the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), and *S. interruptus+M. hirsutus* together under laboratory conditions.

MATERIALS AND METHODS

Rearing of Pink Hibiscus Mealybug, *Maconellicoccus hirsutus*:

The stock culture of the pink hibiscus mealybug, *M. hirsutus,* used in this study was originally collected from infested Roselle, *Hibiscus sabdarriffa* L., plants in the Faculty of Agriculture South Valley University, Qena, Egypt. The pink hibiscus mealybugs were cultured in the laboratory on the shoots of potato tuber, *Solanum tuberosum* L. (Solanaceae) (Fisher, 1963). Potato tubers were washed in water, put in plastic dishes for germination and were wrapped in damp gunny at room temperature (25°C and 70% R.H.). Water was sprinkled daily to keep the gunny moistened to encourage sprouting. After 20 days, potatoes produced 5–7 cm long sprouts. . Then the, *M. hirsutus* were moved with the aid of a camel hairbrush to the potatoes sprouts and maintained under laboratory conditions of 20, 25, 30 ± 1˚C, 65 ± 5% RH and a photoperiod of 12:12 hr., (L:D). The mealybug females were settled on potatoes sprouts and started egg laying. Then, the mass culture of mealybugs was obtained within 15 to 20 days.

Rearing of *Scymnus interruptus*:

Adults of *S. interruptus* were collected also from Roselle, *H. sabdariffa* L. plants. They were kept in transparent plastic cups (7.5x5.9x4.5 cm) with two vents on the side and one on the cover. The natural hosts (pink hibiscus mealybugs) were provided regularly. In other plastic cups, the eggs laid by the females were collected and transferred gently by camel hairbrush. Likewise, the newly hatched larvae were transferred to other plastic cups containing an abundance of mealybugs. The rearing was kept at (25°C and 70% R.H.) and a photoperiod of 12:12 hr., (L:D). Adult beetles of the same ages (both sexes), various larval stages, and eggs utilized in the conduct experiments were brought from the essential culture.

Effect of Cannibalism Behaviour on The Biology of *S. interruptus*:

One pair of reared *S. interruptus* adults, collected from the laboratory, was released into a transparent plastic cup (7.5x5.9x4.5 cm) with two vents on the side and one in the cover. Thirty sets were maintained and were divided into three groups. The first group was fed only with the second nymphal instar of the pink hibiscus mealybug, *M. hirsutus*, the second group was fed on the newly emerged first instar larvae of the predator *S. interruptus*, and the third group was fed on the second nymph of *M. hirsutus* and the newly emerged first instar larvae of the predator *S. interruptus* together. Eggs laid by the *S. interruptus* females on the periphery of the transparent plastic cups were collected after 5 to 6 days with a soft camel hair brush and were kept in the petri dish until hatching. The larvae from each group were fed on the type of food allocated to them daily until pupation. The adults who come out from pupae were gathered individually and moved to plastic cups for mating. The new adults were supported with the aforementioned types of prey (*M. hirsutus*, *S. interruptus*, and *M. hirsutus+S. interruptus*). Data were documented on the total number of instars, duration of each instar, total grub period, and pupal period. After the emergence, adults were gathered and checked out under a microscope to determine the sex. The preoviposition, oviposition, and post oviposition periods for females were determined. The longevity of females and males and the total number of eggs laid by each female (fertility) during her life period were also recorded.

Effect of Cannibalism Behaviour on Feeding Potential of S. *interruptus*:

Newly ten hatched larvae of *S. interruptus* were obtained from parents that had been previously fed on *M. hirsutus*, *S. interruptus*, and *M. hirsutus+S. interruptus* and were kept individually in petri dishes. The larvae were fed individually in the petri dish with hibiscus mealybug. The experiment was replicated five times. Required numbers of prey were provided daily i.e. 10, 20, 40, and 60 number of hibiscus mealybugs for I, II, III, and IV instar larvae, respectively. The consumed number of mealybugs was checked daily and new mealybugs were placed as per their requirement. Feeding potential was recorded for each larval instar.

To study the prey consumption of adults; newly emerged beetles were collected. Each individual was kept in a separate petri dish and 30 hibiscus mealybugs were introduced to each petri dish. The experiment was replicated five times. The number of mealybugs consumed was checked daily and new mealybugs were placed as per their requirement. Also, feeding potential was recorded for the adult's entire life.

The obtained results of the experiments were analyzed by the ANOVA technique and means were separated using LSD at a 0.05 significance level.

RESULTS AND DISCUSSION

The phenomenon of cannibalism has a severe and clear impact on the population behaviors of many insect species, especially predators (Rudolf, 2008; Ferrer *et al*., 2011). Cannibalism is one of the important factors affecting both adult reproductive capacity and survival of the immature stages in coccinellid lady beetles (Bayoumy and Michaud 2015).

Female Egg Incubation Periods:

The mean incubation periods of female eggs reared on *M. hirsutus*, *S. interruptus*, and *M. hirsutus+S. interruptus* was between 6.12 and 7.51 days (Table 1). The longest mean incubation period of the female eggs was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus*, which had no significant difference from *M. hirsutus* ($P < 0.05$).

The First Larval Instar of The Female:

The mean duration of *S. interruptus* female first larval stage reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 3.32 days and 5.41 days (Table 1). The duration of the first larval stage was the longest on *S. interruptus* (5.41 days) and the shortest on *M. hirsutus+S. interruptus* (3.32 days). There were significant differences ($P < 0.05$) between the duration of the first larval stage of *S. interruptus* females produced from *M. hirsutus+S. interruptus* prey from the other two types of prey.

The Second Larval Instar of The Female:

The mean duration of *S. interruptus* second larval stage of the female reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 2.17 and 4.41 days (Table 1). The longest mean duration of the second larval stage of the female was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus*.

There were significant differences ($P < 0.05$) among the duration of the second larval stage of *S. interruptus* females reared on different types of prey.

The Third Larval Instar of The Female:

The mean duration of *S. interruptus* third larval stage of the female reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 2.15 and 4.22 days (Table 1). The longest mean duration of the third female larval stage was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus*. There were significant differences ($P < 0.05$) among the duration of the third larval stage of *S. interruptus* females reared on different types of prey.

The Fourth Larval Instar of The Female:

The mean duration of *S. interruptus* fourth larval stage of the female reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 3.37 and 6.11 days (Table 1). The longest mean duration of the fourth female larval stage was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus*. There were significant differences ($P < 0.05$) among the duration of the fourth larval stage of *S. interruptus* females reared on different types of prey.

Generally, larval survival was significantly higher in cannibalism. A similar effect of cannibalism was observed in other insect species. Snyder *et al*. (2000) investigated the dietary advantages of cannibalism in larvae of *Harmonia axyridis* (Pallas), and found that cannibalism did not directly influence fitness, but increased larval survivorship.

Table 1: Mean duration (in days) of *Scymnus interruptus* females fed on *M. hirsutus*, *S. interruptus* and *M.hirsutus + S.interruptus*

Prey types	Duration of the stage (days) ± S.E						
	Egg incubation period	Larval stage				Pupal Stage	Total developmental periods
		L1	L2	L3	L4		
M. hirsutus	6.4 ± 0.26 b	4.46 ± 0.22a	3.21 ± 0.05b	3.75 ± 0.23b	4.28 ± 0.7b	7.14 ± 0.31b	22.84 ± 1.51b
S. interruptus	7.51 ± 0.19a	5.41 ± 0.13a	4.41 ± 0.07a	4.22 ± 0.11a	6.11 ± 0.08a	8.11 ± 0.22a	27.99 ± 0.61a
M.hirsutus + S. interruptus	6.12 ± 0.15b	3.32 ± 0.11b	2.17 ± 0.09c	2.15 ± 0.7c	3.37 ± 0.11c	6.11 ± 0.03c	17.12 ± 1.04c

Means followed by the same letter in the same column are not significantly different at $\alpha = 0.05$.

Duration of Pupal Stage:

The mean pupal duration on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* was in between 6.11 and 8.11 days (Table 1). The longest pupal duration was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus* (Table 1). There were significant differences ($P < 0.05$) among the duration of the pupal duration of *S. interruptus* females reared on different types of prey.

Total Female Developmental Periods:

The total female developmental period of *S. interruptus* reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 17.12 days and 27.99 days (Table 1). The longest total female developmental period was recorded on *S. interruptus* and the shortest on *M. hirsutus+S. interruptus*. There were significant differences ($P < 0.05$) among the total female developmental period of *S. interruptus* reared on different types of prey.

Mean Numbers of Laid Eggs and Mean Total Life Cycle Of Female:

The mean number of laid eggs by *S. interruptus* reared on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* ranged between 94.18 and 218.32 eggs/female (Table 2). The highest mean number of eggs was laid from females reared on *M. hirsutus+S. interruptus* and the lowest from the ones reared on *S. interruptus*. There were significant differences ($P < 0.05$) among the mean numbers of laid eggs of females reared on different types of prey.

The shortest mean duration of adult female life cycle period was recorded for the female fed on *S. interruptus* (34.25± 1.13 days) and the longest on *M. hirsutus+S. interruptus* (46.18 ± 2.16 days). There were significant differences among the mean duration of *S. interruptus* adult female life cycle period fed on *M. hirsutus+S. interruptus* compared with other types of prey.

Table 2: Mean numbers of laid eggs and mean total life cycle of female (in days) of *S. interruptus* fed on *M. hirsutus*, *S. interruptus* and *M. hirsutus+S. interruptus.*

Prey types	Mean laid eggs by the adult females	Total life cycle of female
M. hirsutus	186.63 ± 1.63a	41.11 ± 2.18b
S. interruptus	94.18 ± 1.13 b	34.25 ± 1.13a
M. hirsutus+S.interruptus	218.32 ± 1.03a	46.18 ± 2.16b

Means followed by the same letter in the same column are not significantly different at $\alpha = 0.05$.

The Ovipositional Periods and The Mean Adult Female Longevity:

Results illustrated in Table 3 mention that the shortest female preoviposition period was recorded for the female fed on *M. hirsutus+S. interruptus* (8.13 ± 0.12 days) and the longest on *S. interruptus* (11.04 ± 0.18 days). There were significant differences among the mean duration of *S. interruptus* adult female preoviposition period reared on different types of prey.

Table 3: Effect of the prey type on the lifespan of *S. interruptus* female

Prey types	Duration (days ± S.E)			
	Pre-oviposition period	Oviposition period	Post-oviposition period	Mean longevity of the adult females
M. hirsutus	9.17 ± 0.23ab	17 ± 0.11b	5.13 ± 0.07b	31.3 ± 2.18b
S. interruptus	11.04 ± 0.18a	10 ± 0.24c	7.18 ± 0.11a	28.22 ± 1.13c
M.hirsutus+ S.interruptus	8.13 ± 0.12b	21 ± 0.21a	4.03 ± 0.17b	33.16 ± 2.16a

Means followed by the same letter in the same column are not significantly different at $\alpha = 0.05$.

The longest mean duration of adult female oviposition period was recorded for the female fed on *M. hirsutus+S. interruptus* (21 ± 0.21 days) and the shortest on *S. interruptus* (10 ± 0.24 days). There were significant differences among the mean duration of *S. interruptus* adult female oviposition period reared on different types of prey. The shortest mean duration of the adult female postoviposition period was recorded for the female fed on *M. hirsutus+S. interruptus* (4.03 ± 0.17 days) and the longest on *S. interruptus* (7.18 ± 0.11 days). There were significant differences among the mean duration of *S. interruptus* adult female postoviposition period reared on different types of prey. The shortest mean longevity of the adult female's period was recorded for the females fed on *S. interruptus* (28.22 ± 1.13 days) and the longest on *M. hirsutus+S. interruptus* (33.16 ± 2.16 days). There were significant differences among the mean longevity of the adult female of *S.*

interruptus fed on *M. hirsutus+S. interruptus* compared with other types of prey.

Adult Male Longevity:

The mean adult male longevity of *S. interruptus* fed on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* was between 21.16 and 37.14 days (Table 4). *M. hirsutus+S. interruptus* recorded the longest mean adult male longevity and *S. interruptus* was the shortest one. There were significant differences (P < 0.05) among the mean adult male longevity of *S. interruptus* fed on different types of prey.

The phenomenon of cannibalism by both parents increases the speed of the pupal process and reduces the time required for total development. Bayoumy and Michaud (2015) proved that cannibals of *Coccinella undecimpunctata* L. and *Cydonia vicina nilotica* (Coleoptera: Coccinellidae) cause, shorter larval lifespan, longer survival rate and heaviness in the body of males and females.

Table 4: Mean total developmental period and longevity of *S. interruptus* males fed on *M. hirsutus*, *S. interruptus* and *M.hirsutus+S.interruptus*

Prey types	Duration Mean (in days) ± S.E	
	Total developmental period of *S. interruptus* males	Longevity of adult males
M. hirsutus	19.48 ± 1.58b	26.34 ± 0.05b
S. interruptus	26.5 ± 0.67a	21.16 ± 0.32b
M.hirsutus+S.interruptus	16.91 ± 1.59b	37.14 ± 0.12a

Means followed by the same letter in the same column are not significantly different at $\alpha = 0.05$.

The different parameters, which were used to assess the effect, showed different results one from another according to prey types. It is clearly seen that *M. hirsutus+S. interruptus* was the best of the three prey types for the development and the total number of eggs laid by *S. interruptus*. *S. interruptus* was the least suitable one compared to other types of prey. This may be due to the low quality of *M. hirsutus* as a conspecific prey. The mixed food (*M. hirsutus+S. interruptus*) might be a worthful nutritional source acting as bio-moraines, condensing important resources, or as bio-candidates, removing poisonous or low nutritional value compounds. Based on the foregoing, the phenomenon of cannibalism is one of the ways of mixing food, as it works for these species as high-quality food.In the context of this study, both males and females benefited from larval cannibalism. Female cannibalism may improve a female's fecundity. Further, this may be a result of high nutritional energy gained that may affect female progeny fitness induction on mating. Regarding the benefit that accrues to the males, it is due to the improvement of male fitness during mating and the production of sperm in large quantity and good quality (Felix and Soares, 2004, Osawa, 2002).

In the case of abundant prey, the phenomenon of egg cannibalism in ladybirds including *Hippodamia variegate* Goese, has also been considered as a tool for obtaining vital and nutritional gains, represented in large body size, rapid development, early puberty, rapid reproduction, and increased fertility. (Pell *et al.*, 2008; Rondoni *et al.*, 2014).

Cannibalism in *Harmonia axyridis* has been presented to deliver a kind of food that contains high nutritional values when other prey is rare (Wagner *et al.*, 1999), nutrients are insufficient, or poisonous and to raise survival and to decrease developmental time (Snyder *et al.*, 2000).

Likewise, it seems that the phenomenon of cannibalism in the red flour beetle *Tribolium castaneum* (Herbst) plays an important role in the growth and the speed of development, as feeding on flour only is not sufficient to support the development and reproductive capacity. (King and Dawson 1973; Via 1991, 1999).

Lady beetles eggs are distinguished by their high nutritional value, and therefore eggs are considered an important target for cannibalism, especially when food is scarce (Cottrell 2005; Michaud and Jyoti 2007). In the case of coccinellid, females produce eggs for the purpose of self-predation to supplement the missing nutrients in their diet Rasekh and Osawa (2020).

Osawa, (2002) found that the neonate larvae can achieve significant physiological gains when feeding on unfertilized and late hatching eggs of the same species, while (Michaud and Grant 2004; Perry and Roitberg 2005; Omkar *et al*., 2004) proved that cannibalism increases the physical fitness of females. Other results have proven by many researchers that the minion of coccinellid prefers eggs cannibalism of the same species compared with the eggs of other species (Michaud 2002; Cottrell 2004; Ware *et al*. 2008).

Ultimately, cannibalism might give three clear advantages. First, conspecifics can be an excellent food source, thus cannibalism may be a functional behavior due to its nutritional profit, particularly when resources are restricted (Polis 1981, Gabriel 1985 and Pfennig 1997). Second, it might reduce the severity of competition (Elgar and Crespi 1992, Klug and Bonsall 2007). Third, cannibalism has also been proposed to be useful in taking possession of new environs (Wagner *et al*., 1999, Wissinger *et al*., 1996).

Effect of Cannibalism Behaviour on Feeding Potential of *S. interruptus*:

Data on the predatory potential of *S. interruptus* were obtained from parents that had been previously fed on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* are presented in Table 5.

Results of larval instar that fed on *M. hirsutus* revealed that the mean daily consumption of hibiscus mealybugs by their successive instars as(3 - 5, 12 - 18, 22- 31and 36 – 41); (0-3, 3-7, 10-16 and 18-25) and (5-10, 18-22, 33-58 and 52-84) with an average of (4.30, 13.51,25.30 and 38.20); (1.51,4.13,13.11and 21.14); and (7.14, 20.06, 41.17and 56.14) respectively. the first larval instar of *S. interruptus* consumed a total of (9 - 17, 3 - 8 and 16- 31) hibiscus mealybugs, respectively, with an average of (14.20,5.20 and 24.18) hibiscus mealybugs, meanwhile the 2nd, 3rd and 4th instars consumed (38 - 46,10 - 18 and 38 – 51) ; (66 -100, 25 -38 and 95 – 130); and (154-186, 45-75 and 115- 144) with an average of (41.40, 12.15 and 42.22); (84.31, 31.07 and 103.14); and (166.41, 48.25 and 120.26), respectively.

Total consumption of the larval stage of *S. interruptus* was obtained from parents that had been previously fed on *M. hirsutus, S. interruptus*, and *M. hirsutus+S. interruptus* was (267-349, 83-139 and 264-356) hibiscus mealybugs with an average of (306.32, 96.67 and 289.8) hibiscus mealybugs, respectively. Also, studies on the feeding potentiality of *S. interruptus* adults on *M. hirsutus* revealed that the consumption average of hibiscus mealybugs per day was (50- 58, 41-45 and 71-85) mealybugs per day with an average of (51.40, 44.18 and 74.16) and the total consumption of mealybugs during the adult period was (622.37, 165.24 and 861.22), respectively.

Table 5: Effect of prey types on the predatory potential of *S. interruptus*

Stage	*M. hirsutus*			
	Consumption of mealybugs /day		Total Consumption of mealybugs	
	Min.- Max.	Mean± S.E	Min- Max	Mean± S.E
L1	3 – 5	4.30 ± 0.51 B	9 – 17	14.20 ± 2.51 b
L2	12 – 18	13.5 ± 0.11 B	38 – 46	41.40 ± 2.14 a
L3	22 – 31	25.3 ± 0.17 B	66 – 100	84.31 ± 10.6 b
L4	36 – 41	38.2 ± 1.81 B	154 – 186	166.41 ± 3.1 b
Total	73 – 95	81.31 ± 2.6 B	267 – 349	306.32 ± 18.4 a
Adult	50 – 58	51.40 ± 0.8 B	618– 725	622.37 ± 1.1 b
Total life cycle	123 – 153	132.7 ± 3.4 B	885 – 1074	928.7 ± 19.4 b
	S. interruptus			
Stage	Consumption of mealybugs /day		Total Consumption of mealybugs	
	Min.- Max.	Mean± S.E	Min- Max	Mean± S.E
L1	0 – 3	1.51 ± 0.31 C	3 – 8	5.20 ± 2.61 c
L2	3 – 7	4.13 ± 0.18 C	10 – 18	12.15 ± 1.33 b
L3	10 – 16	13.11 ± 1.12 C	25 – 38	31.07 ± 2.18 c
L4	18 – 25	21.14 ± 3.16 C	45 –75	48.25 ± 1.16 c
Total	31 – 51	39.89 ± 4.77 C	83 – 139	96.67 ± 7.28 b
Adult	41 – 45	44.18 ± 1.41 C	126 – 188	165.24 ± 1.2 c
Total life cycle	72– 96	84.07 ± 6.18 C	245 – 327	261.91 ± 8.5 c
	M. hirsutus+*S. interruptus*			
Stage	Consumption of mealybugs /day		Total Consumption of mealybugs	
	Min.- Max.	Mean± S.E	Min- Max	Mean± S.E
L1	5 – 10	7.14 ± 0.31 A	16 – 31	24.18 ± 1.16a
L2	18 – 22	20.06 ± 0.11 A	38 – 51	42.22 ± 1.06a
L3	33 – 58	41.17 ± 1.18 A	95 – 130	103.14 ± 3.11a
L4	52 – 84	56.14 ± 4.11 A	115 – 144	120.26 ± 8.18a
Total	108 – 174	124.51 ± 5.7 A	264 – 356	289.8 ± 13.51a
Adult	71 - 85	74.16 ± 1.11 A	855 – 1006	861.22 ± 4.17a
Total life cycle	179 – 259	198.67 ± 6.8 A	1119 - 1362	1151.02 ± 17.7a

Means followed by the same large letter in the 2nd column are not significantly different at $\alpha = 0.05$.
Means followed by the same small letter in the 4th column are not significantly different at $\alpha = 0.05$.

The total feeding potential of *S. interruptus* during its total life cycle is (928.69, 261.91 and 1151.02) mealybugs. The obtained results proved that the predator individuals obtained from the parents previously fed on *M. hirsutus* + *S. interruptus* were the most capable of predation compared to the other predator individuals.

Females show a large increase in the consumption of their larvae even in the presence of their prey. This is due to the fact that females are sensitive to the quality of food resources and therefore need to consume a greater amount of larva cannibalism. Another reason for females to consume more larvae may be due to an increase in the amount of energy needed to reproduce (Michaud and Grant, 2004; Santi and Maini 2007). However, many scientists (Agarwala, 1991; Khan and Yoldaş, 2018) have confirmed that many females are reluctant to cannibalism.

It was also found that predator consumption of hibiscus mealybugs increases with each subsequent age in all predatory groups. The results also showed that the fourth age of larvae is more powerful and fierce in eating prey, due to that this age requires high requirements of food to complete its growth and preparation to enter the pupal stage. All larval stages of the predator exhibit different levels of cannibalism for eggs. Younger larvae have less ability than older larvae to consume food, whether feeding on natural prey or on cannibalism for eggs, due to the fact that the old larvae are large in size and need large quantities of food (Cottrell, 2005; Sato *et al*., 2011; Jafari, 2013).

Conclusion

The results indicate that the development, longevity, the total number of laid eggs, and prey consumption rate by *S. interruptus* are influenced by the cannibalism behaviour, as well as the best preference order of *S. interruptus* for development, longevity, and oviposition is *M. hirsutus+ S. interruptus*, followed by *M. hirsutus* and the least being *S. interruptus*. In addition, the obtained results provided more accurate information about the importance of trophic relationships of the Red-flanked ladybird beetle, *S. interruptus,* which can be used in the future in the suppression of pests in the agroecosystems.

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