Biology of *Rhynocoris squamulosus* (Heteroptera: Reduviidae) fed on developmental stages of *T. castaneum* (Coleoptera: Tenebrionidae)

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Keywords: Reduviidae, *Rhynocoris squamulosus*, biology, reproduction, development

Date of Acceptance 6/07/2021, Publication date 30/09/2021, http://m.elewa.org/Journals/about-japs/

1 SUMMARY

Reduviidae are beneficial natural enemies in agroecosystems due to their pest regulating action. Given their importance, knowledge of their biology with a view to their use as a biological agent is increasingly considered. It is in this target that the biology of *R. squamulosus* (Heteroptera: Reduviidae) was conducted, using as surrogate prey, *Tribolium castaneum* (*red flour beetle*). The results show that the female spawns take place 17.63 ± 2.69 days on average after pair formation. The experiment was set up to know the pre-oviposition period of female. The eggs of *R. squamulosus* female are laid in clusters and mostly high on the lid of the breeding jar (88.02%) which 93% on the muslin. Embryonic development of *R. squamulosus* was observed in 79.18% of the eggs and the incubation duration average is nine days. The larvae from these eggs go through five successive moults (stages) before becoming adults. The development time of these larvae varies significantly from stage to stage regardless of the stage of prey (T*ribolium castaneum*) consumed. The mean development time and larval mortality rate are reduced in the presence of larvae only in the presence of *T. castaneum* nymphs. On the other hand, in the presence of the adults of the prey, all the larvae die at stage 1. Knowledge of the biological parameters of this predator allows its mass rearing and its use as a biological control agent in the regulation of crop pests.

2 INTRODUCTION

Biological control corresponds to the use of living organisms in order to limit the proliferation and harmfulness of various crop enemies or pests such as insects, nematodes, weeds and rodents (van Driesche and Bellows, 1996 ; Eilenberg *et al*., 2001; Jourdheuil *et al*., 2002; Altieri *et al*., 2005). Indeed, these pests contribute greatly to the decrease in agricultural productivity, which can be reduced by up to 70% (Popp *et al*., 2013). The main organisms responsible for these losses are insect pests. Their control through the use of native natural enemies becomes indispensable. These native natural enemies could greatly reduce the pressure on crops and reduce losses. However, the use of a biological agent in an agroecosystem requires knowledge of the biology of the latter (Suman, 2019). Many studies on the biology of predatory insects have been carried out, in particular on Heteroptera of the Reduviidae family (Villiers, 1948; Sahayaraj, 2001; Kwadjo, 2012; Poutouli, 2011; Soro, 2019). This family represents the second largest family of the order Heteroptera worldwide after that of the Miridae with around 1,000 genera and more than 7,000 species (Henry, 2009; Weirauch *et al*., 2009, 2014;

Putshkov and Moulet, 2010). Among the species, those of the genus *Rhynocoris* are recognized as being important predators of crop pests (Sahayaraj *et al.*, 2015; Pravalika, 2016). In Côte d'Ivoire, many Reduviidae are observed in fields on different crops but most are less known. Apart from *Rhynocoris albopilosus* (Heteroptera: Reduviidae) on which most studies have been carried out (Villiers, 1959 and 1968; James *et al.*, 2003; Kwadjo *et al.*, 2008; Kwadjo, 2012), there is very little information on other species. Thus, a *Rhynocoris squamulosus* species was captured in a plot of *Manihot esculata* Crantz, 1766 (Malpighiales: Euphorbiaceae). Lack of knowledge and information about this species has prompted the study of its biology. It could be an equally beneficial predator in biological pest control. But before considering the use of a predatory insect in a biological control program, it is imperative to control its mass rearing and know its biology. It is in this target that the rearing of *R. squamulosus* was initiated in the laboratory using *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) as surrogate prey.

3 MATERIAL AND METHODS

3.1 Rearing of pairs of *R. squamulosus:* Fifty adults were used at maximum 48 hours after emergence to form 25 pairs of 1: 1 ratio (25 males and 25 females). Each of the pairs was fed, every two days, with 30 *T. castaneum* larvae in breeding jars called "Food box" (Length = 17 cm; Width = 12 cm, Height = 5 cm). This breeding equipment constituted of the jar, the lid and a stem (Figure 1). The jar is completely plastic. The lid is made of plastic and muslin, a structure that allows good ventilation of the environment and avoids any contact with the outside. As for the stem, it made it easier for individuals to move around inside the breeding jar. Thus, as soon as the eggs were observed in a breeding jar, the pair code, the number of eggs laid, the day and the place of laying in the breeding jar were determined. In addition, when a male was found dead, he was replaced by another. On the other hand, when the mortality concerned a female from a given pair, the experiment was stopped.

3. 2 Rearing of *T. castaneum*, the prey: Since it was not possible to capture natural prey daily for the predator's food, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) was used as surrogate prey in the laboratory. Thus, the different stages of this prey (larvae, nymphs and adults) were used throughout the experiment. The rearing of *T. castaneum* in the laboratory consisted first of all in making the breeding substrate, consisting of a mixture of wheat flour and baker's yeast in the proportions 10: 1 (1000 g of wheat flour for 100 g of baker's yeast). This whole is homogenized in a tank and then distributed in the "Food box" jars, half filled. Then, adults of *T. castaneum* (30 to 40 individuals) are introduced into each jar and kept for three weeks (21 days), then sieving is carried out. The larvae retained in the sieve, with a mesh size of 1 mm^2, are used to feed the predator and those passed through these meshes are kept for a week at most, during which a second sieving is carried out.

3. 3 Reproductive parameters of adults and embryonic development of eggs: The parameters studied during this study are: the pre-oviposition period, the frequency of laying, the total fertility, the average number of eggs laid per female, the fertilized or unfertilized eggs, the hatched or non-hatched eggs, fertility rate, and egg incubation time. All these parameters were determined under standard conditions of temperature = 28 ± 2 °C, relative humidity = 75 ± 10 % and photoperiod 12:12.

Figure 1: Some tools of rearing of *R. squamulosus* and *T. castaneum*
A: Jar and its lid, B: Stem, C: *T. castaneum* rearing medium

3.3.1 Pre-oviposition period: The duration of pre-oviposition (Po) corresponds to the period between the emergence of the female at the imaginal moult and the date of egg-laying. It was determined using the following formula:

$$Po = dP - dMi$$

with dP = date of spawning and dMi = date of imaginal moult

3.3.2 Total fertility of *R. squamulosus* females: Total fertility (Ft) is the total number of eggs laid from the first lay to the last during the female's life. Eggs were counted at each lay and total fertility was calculated with the following formula:

$Ft = \sum NOPi$

with NOPi = number of eggs laid on laying day i; n = last day of laying, n

i = 1

3.3.3 Rate of fertilized eggs and egg incubation time

3.3.3.1 Egg incubation time: The incubation time (IT) is the corresponding time between the egg-laying date and the hatch date. As soon as a cluster of eggs was observed in the jar, the laying date was noted and the eggs were monitored daily until hatching. Thus the incubation time of the eggs was determined from the following formula:

$IT = dE - dP$

with dE = hatching date; dP = egg laying date

3.3.3.2 Rate of fertilized eggs: Fertilized eggs (Of) are the eggs in which embryonic development has been observed. Fertilized eggs are made up of fertilized hatched eggs and fertilized unhatched eggs. Thus, fertilized hatched eggs are eggs that result in the emergence of a larva as a result of embryonic development. On the other hand, says fertilized unhatched eggs, any egg whose embryonic development has not been completed.

$Of = Ofe + Ofne$

with Ofe = number of hatched eggs,

$Ofne$ = number of fertilized unhatched eggs

3.3.4 State of eggs after hatching

3.3.4.1 Egg fertility rate: The fertility rate (Tf) is the ratio of the number of eggs hatched to the number of eggs fertilized. For each pair, when an egg cluster was laid, the date and number of eggs laid were determined. When these eggs hatch, the number of emerged larvae (hatched eggs) is noted and the fertility rate calculated using the following formula:

$Tf = (NOe / NOf) \times 100$

With NOe = Number of hatched eggs;

NOf = number of fertilized eggs

3.3.4.2 Rate of unhatched eggs: Unhatched eggs (One) are eggs whose operculum have not been opened. They are made up of fertilized unhatched eggs and unfertilized eggs. Unfertilized eggs are eggs in which no embryonic development has been observed. Unhatched eggs are determined using the following formula:

$One = Onf + Ofne$;

With Onf = unfertilized eggs; $Ofne$ = fertilized unhatched eggs;

3.4 Post-embryonic biological parameters of *R. squamulosus*

3.4.1 Rearing of *R. squamulosus* larvae: Thirty-nine neonate larvae were selected and placed individually in Petri dishes. Three groups of larvae were formed and followed from stage 1 to imaginal moult, resulting in the adult. The first group was fed with *T. castaneum* larvae as surrogate prey in the laboratory and the other two groups fed respectively with nymphs and adults of *T. castaneum*. Thus, the larvae of stages 1 and 2 of the first group were fed with 3 larvae of *T. castaneum* larvae, those of stages 3 and 4 with 5 larvae and those of stage 5 fed with 7 larvae per day. The larvae of the second group received respectively 3, 5 and 7 nymphs of *T. castaneum* per day at stages 1, 2, 3 and 10 nymphs at stages 4 and 5. The third group consisted only of larvae at stage 1. They were fed with 3 adults of *T. castaneum* per day. For each larval stage, the dates of emergence of the larvae (stage 1), of the different moults, the number of live and dead individuals were determined. These data made it possible to calculate the duration of development of the different larval stages of *R. squamulosus*, the total duration of the larval stage, the survival and mortality rate by stage of development.

3.4.2 Duration of larval development: The development time of stage 1 larvae corresponds to the number of days it takes for a larva to go from stage x to stage x + 1. In stage 1, development time is the difference in days between the date the individual first moults and the date the eggs hatch. In the other stages, it corresponds to the difference between two successive moults. This passage is represented by an exuvia, the final product of the insect's moult. Thus, for a given stage x, the development time (DSx) is determined by the following formula:

DS1 = dM1 - dE

with *dM1* = date of moult 1; *dE* = egg hatch date

DSx = dM (Sx + 1) - dM (Sx)

with dM (Sx + 1) = date of the next moult; dM (Sx) = date of previous moult

3.4.3 Survival and mortality rate of *R. squamulosus* larvae: The survival rate of larvae at a given stage is the ratio of the number of larvae that have passed to the next stage (stage x + 1) and the number of larvae at that stage (stage x). The number of larvae at the start of the instar and that of larvae that molt at the end of their development were recorded and the survival rate determined using the following formula.

Survival rate = ((Number of larvae in stage (x + 1)) / (Number of larvae in stage x)) × 100

The mortality rate is defined as the ratio of the number of dead larvae during a stage to the total number of larvae at that stage. At each stage of development, the number of dead larvae was determined and the mortality rate calculated with the formula:

Mortality rate = ((Number of dead larvae from stage x)/ (Number of larvae from stage x)) ×100

3.4.4 Total development time of *R. squamulosus* larvae: Total larval development time (dTDL) is the sum of the durations of the five stages of development or the difference between the date of imaginal moult and the date of egg hatch. It begins with the release of the larva from the eggs and ends when the adult is obtained. The dTDL is determined as follows:

dTDL = ∑ DSi or dTDL = dMI-dE

with DSi = duration of development of stage i, n = total number of larval stages and dMI = date of imaginal moult, dE = date of egg hatch

4 RESULTS

4.1 Reproduction of *R. squamulosus* adults

4.1.1 Duration of pre-oviposition of females: After pair formation, females take an average of 17.63 ± 2.69 days before laying eggs or viewing eggs in the breeding jar (Table 1). The next laying is seven days after the previous one and the incubation of the eggs lasts an average of nine days.

Table 1: egg laying and incubation time

Parameters	Average (days)
Pre-oviposition period	17.63 ± 2.69
incubation period	9
Frequency of laid	7

4.1.2 Distribution of egg clusters in the breeding jar: In rearing jars, egg clusters were observed on the three elements that make up the rearing environment, namely: the stem, the jar and its lid. A total of 138 clusters of 4,131 eggs were identified throughout the study. Among these eggs, 3,636 eggs constituting 121 clusters were laid on the lid, or 88.02% of the eggs laid and 495 eggs (17 clusters) representing less than 12% on the two other elements, the jar (7 clusters or 4, 45%) and the stem (10 clusters or 7.53%) (Table 2).

Table 2: Number of eggs laid per laying siteSpawning supports

	Clusters of eggs laying	Number of eggs counted	Percentage of eggs (%)
Lid	121	3,636	88.02
Jar	7	184	4.45
Stem	10	311	7.52
Total	138	4,131	100

4.1.3 Proportion of eggs laid on the lid of the breeding jar: Since the lid is made of muslin and plastic, over 93% of the 3,636 eggs laid on the lid were recorded on the muslin and only 7% on the plastic (Figure 1).

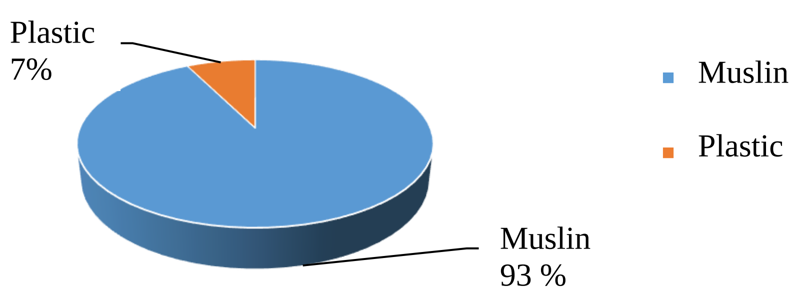

Figure 1: Proportions of egg clusters on the lid

4.1.4 Fertility of females

4.1.4.1 Average fertility of a female: A female lays an average of 29.93 ± 9.11 eggs per cluster. During its lifetime, the average number of eggs laid is 165.24 ± 49.14 eggs, of which 109.04 ± 59.44 eggs hatch (Table 3).

Table 3: Some egg-laying parameters of females

Parameters	Interval [Min-Max]	Eggs average
Eggs laid / cluster	[3-53]	29.93 ± 9.11
Eggs laid / female	[98-272]	165.24 ± 49.14
Eggs hatched / female	[1-234]	109.04 ± 59.44
Unhatched eggs / female	[0-176]	56.2 ± 43.7

4.1.4.2 Proportion of fertilized and unfertilized eggs: Of the 4,131 eggs counted, embryonic development was observed in 3,271 eggs, or 79.18 % of the eggs laid against 20.82% of the unfertilized or sterile eggs, or 860 eggs (Figure 2).

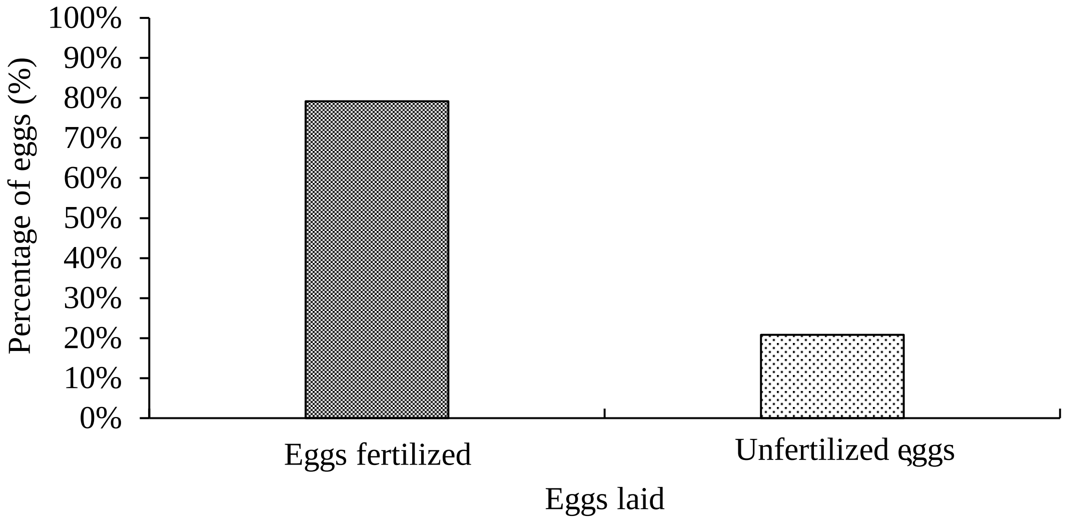

Figure 2: Proportions of fertilized and sterile eggs after the incubation period

4.1.4.3 Fertilized hatched eggs and fertilized unhatched eggs: Among the 3,271 fertilized eggs, 16.39% of the eggs failed to hatch despite having had embryonic development, i.e. 536 unhatched fertilized eggs and 2,735 hatched fertilized eggs representing 83.61% of the eggs (Figure 3).

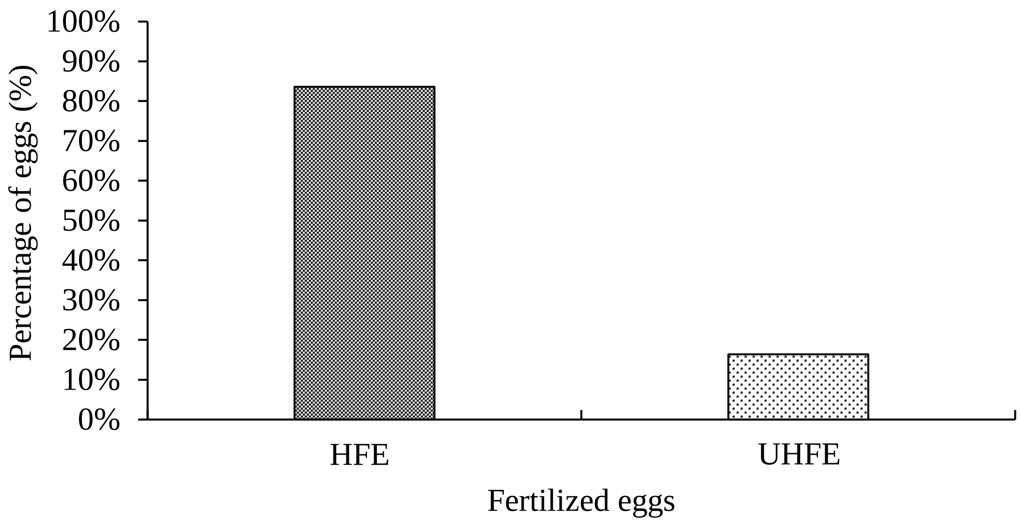

Figure 3: Fertilized eggs hatched and unfertilized after the incubation period
HFE: Hatched fertilized eggs; UHFE: Unhatched fertilized eggs

**4
.1.4.4 Proportions of unhatched eggs:** Among the 1 396 eggs not hatched at the end of the incubation period, 61.60% of the eggs not hatched, or 860 eggs were not fertilized and 536 eggs fertilized but not hatched, or 38.40% of the eggs not hatched (Figure 4).

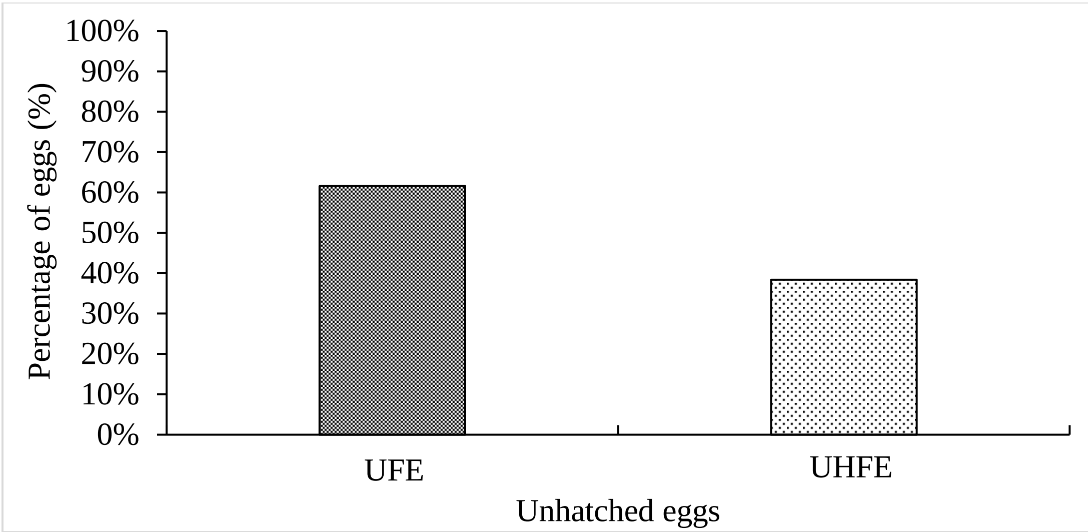

Figure 4: Different types of unhatched eggs
UFE: Unfertilized eggs; UHFE: Unhatched fertilized eggs

4.1.4.5 Proportion of hatched and unhatched eggs after incubation: Almost two-thirds of the eggs laid have hatched. Of a total of 4,131 eggs laid, 2,735 eggs hatched after the incubation period, or 66% of the eggs laid. Unhatched eggs represent 34% of the eggs laid (Figure 5). Thus, on an average of 165.24 ± 49.14 eggs laid per female, 109.40 ± 59.44 eggs hatched and 55.84 ± 42.71 eggs did not hatch.

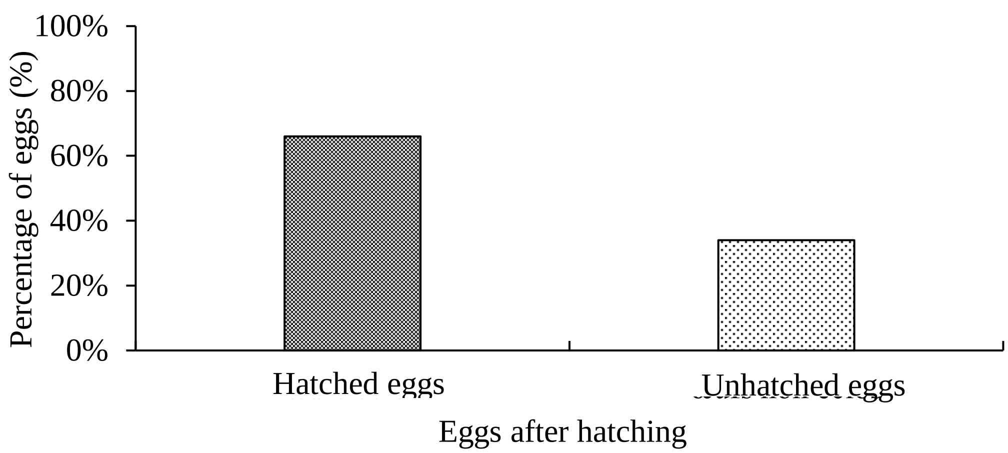

Figure 5: Proportions of hatched and unhatched eggs after the incubation period

4.2 Development of *R. squamulosus* larvae

4.2.1 Average larval development times according to prey stage: The average development times of *R. squamulosus* larvae differ significantly depending on the stage of the prey. In the presence of *T. castaneum* larvae, the mean development times vary from 8.06 ± 0.95 days at stage 3 to 13.35 ± 1.33 days at stage 5. Intermediate stages (stages 2, 3 and 4) have the shortest development times. In the presence of nymphs, the mean durations vary from 8.48 ± 0.99 to 15.43 ± 3.24 days respectively at stages 3 and 5. Stages 2 and 3 have the shortest durations and stage 5, the greatest duration. In the presence of adults, all larvae die in stage 1. Therefore, development times could not be determined. As for the total larval development times, they are reduced in the presence of *T. castaneum* larvae (50.90 ± 2.77 days) than in the presence of nymphs (53.87 ± 4.07 days) of the same prey. . On the other hand, at the level of the larval stages, the average durations of the first four stages of development of *R. squamulosus* do not differ significantly whether they are fed with the larvae or with the nymphs of the prey. Only stage 5 larvae have optimal development in the presence of *T. castaneum* larvae as a diet (13.35 ± 1.33 days) than in the presence of nymphs (15.43 ± 3.24 days). Thus, the development of *R. squamulosus* larvae from stage 1 to adult is better in the presence of larvae than in the presence of *T. castaneum* nymphs.

Table 4: Development of *R. squamulosus* larvae according to prey stage

Stages of *R. squamulosus*	**Stages of *T. castaneum***			**P**
	Larvae	Nymphs	Adults	
Stage 1	11,31 ± 1,75 Aa	10,57 ± 1,40 Aa	-	0,054
Stage 2	8,09 ± 1,18 Ba	8,66 ± 1,10 Ba	-	0,050
Stage 3	8,06 ± 0,95 Ba	8,48 ± 0,99 Ba	-	0,095
Stage 4	10,06 ± 1,98 Ca	10,65 ± 1,29 Aa	-	0,196
Stage 5	13,35 ± 1,33 Da	15,43 ± 3,24 Cb	-	0,001
Total	50,90 ± 2,77 a	53,87 ± 4,07 b	-	0,002
P	0,00	0,00		

Values in the same column followed by the same uppercase letter (ANOVA I and Fisher's test) and in the same lowercase row (Student's t-test) do not differ significantly from each other at the 5% level

4.2.2 Mortality of stage 1 larvae fed with adults of *T. castaneum:* Larvae fed with adults of *T. castaneum* all die in stage 1. The first larva dies on the second day and the last larvae die after 15 days (Figure 6). During this development, three phases are observed. The first phase concerning the first five days of their life, about a third of the larvae (14 larvae) died. The second phase between the 6th and the 9th day, no mortality was observed. Finally, the third phase, from the 10th to the 15th day, two-thirds of the larvae (25 larvae) die. The greatest mortality (10 larvae) was observed on the 12th day of their life.

4.2.3 Mortality of *R. squamulosus* larvae reared on *T. castaneum* larvae and pupae: Eight and sixteen larvae of *R. squamulosus* die in the respective presence of larvae and nymphs of *T. castaneum*, i.e. 20.51% and 41.03% mortality. Apart from stage 1 larvae whose mortality rates remain unchanged, the mortality rates of larvae fed with nymphs are higher than those of larvae fed with larvae of *T. castaneum*. The mortality of the larvae of *R. squamulosus*, in the presence of larvae, decreases from the first to the last stages. From 10.26% mortality at stage 1, it drops to 3.03% at stage 3 and vanishes (0%) at stage 4 (Figure 7). But when fed with the nymphs, the mortality rate increases from stage 2 (8.57%) to stage 5 (11.54%). The development of larvae from stage 1 to stage 5 is therefore more favourable in the presence of larvae than nymphs of *T. castaneum*.

4.2.4 Mortality of males and females of *R. squamulosus* according to the stage of *T. castaneum:* Adults of *R. squamulosus* have a maximum lifespan of seven months in males and eight months in females. Male mortality begins in the first month and ends in the fourth month in the presence of adults of *T. castaneum*. On the other hand, it increases from the second month to the fourth and fifth month in the presence of *T. castaneum* larvae and nymphs, respectively, then decreases steadily until the seventh month (Figure 8). The number of dead individuals is respectively 6, 11 and 14 males in the presence of larvae and 10, 13 and 14 males in the presence of *T. castaneum* nymphs in the 4th, 5th and 6th month respectively. In females, the maximum lifespan is four months, when fed with adults of *T. castaneum* and relatively small for the same period (first four months) in the presence of nymphs and larvae of the prey. The peak mortality in females is reached in the 4th month in the presence of nymphs and in the last two months (7 and 8th months) in the presence of larvae. Mortality is thus important in the second half of the life of females (Figure 9). The mortality of *R. squamulosus* adults (males and females) is then linked to the stage of development of the prey consumed.

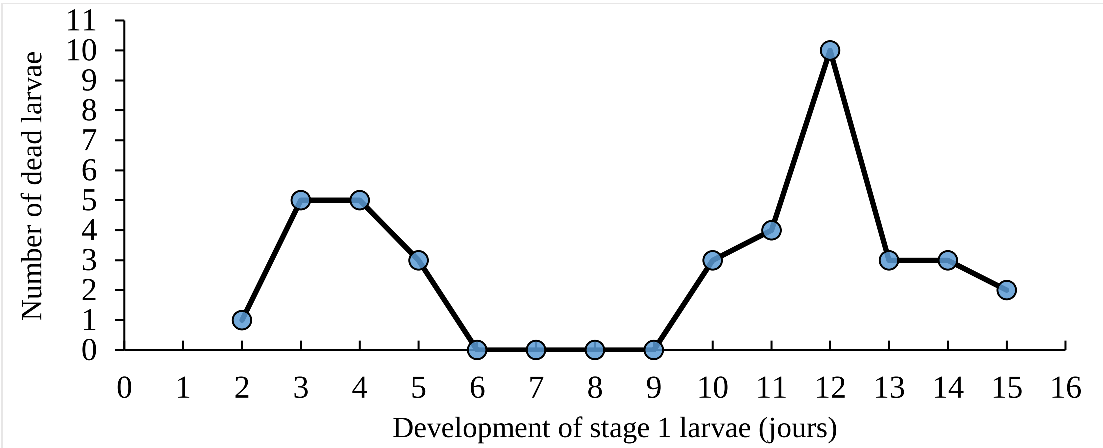

Figure 6: Lifespan of stage 1 larvae fed with the adults of the prey

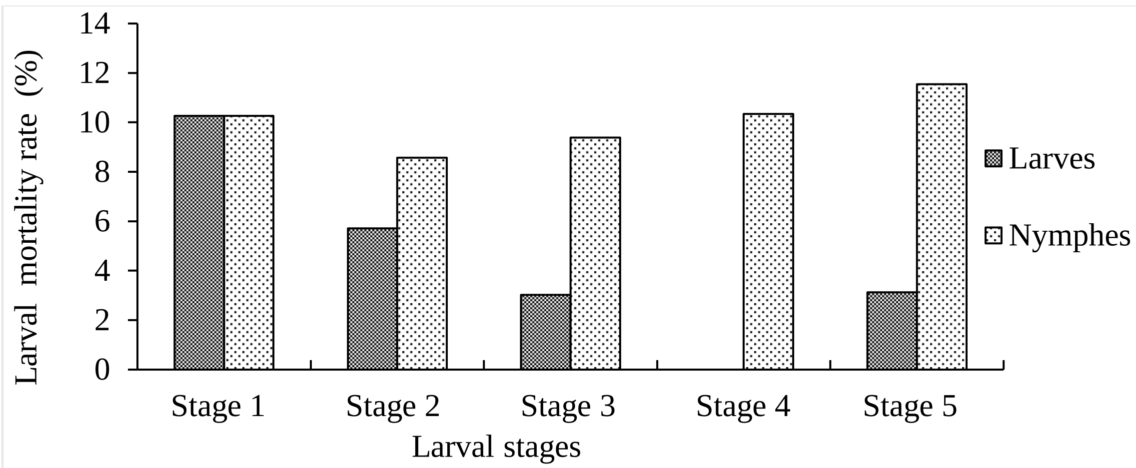

Figure 7: Mortality of larvae according to the stage of *T. castaneum*

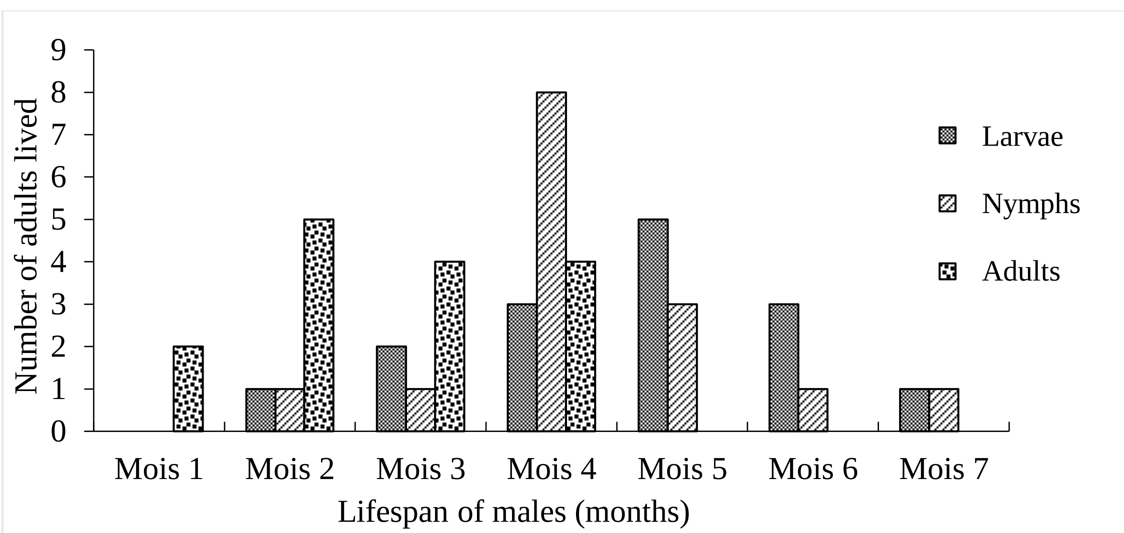

Figure 8: Mortality of males according to the stage of *T. castaneum*

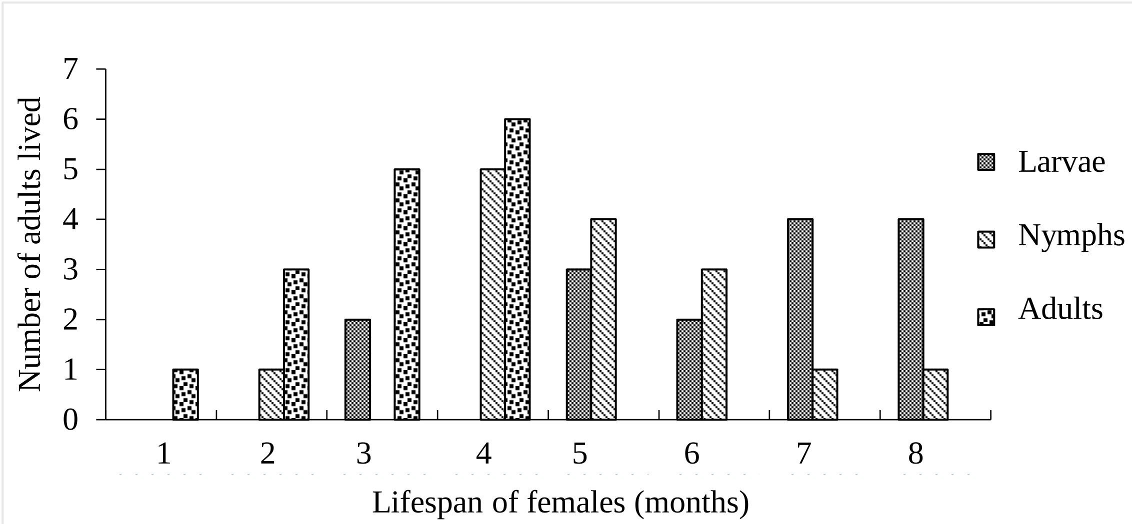

Figure 9: Mortality of females according to the stage of *T. castaneum*

5 DISCUSSION

To insects, female fecundity varies from species to species. Some females lay many more eggs than others. To *R. squamulosus*, the average number of eggs laid by a female is 165.24 ± 49.14 eggs. This fecundity is lower than that of *Sycanus collaris* females, which is 282.0 ± 23.9 and 320.4 ± 44.2 eggs per female in the presence of *Corcyra cephalonica* and *Hyposidra talaca* as prey respectively (Rajan *et al.* 2017; Sahid *et al.* 2018; Suman, 2019). It is also lower than that of *S. aurantiacus* (Yuliadhi, 2016), *R. albopilosus* and *R. marginatus* (Sahayaraj, 2002). In contrast, the average number of eggs laid by females of *R. squamulosus* is higher than that of *Zelus vespiformis* (Laura, 2020) and species of the genus *Sinea* (Villiers, 1948). The high rate of unhatched eggs (34%) may be supported by the fact that the eggs of two of the females that laid 176 eggs and 131 eggs, respectively, did not hatch (307 eggs). These eggs represent 21.92% of unhatched eggs and 35.58% of unfertilized eggs. This situation would be linked to a lack of mating or to a low fertility of some males. According to Barth and Lester (1973), an individual who does not mate or who mates with bad mates will not produce offspring or will generate offspring with low biotic potential. Also, during rearing, eggs were observed in rearing jars containing lonely females who had not been in contact with males. The high 38.40 % fertilized eggs not hatched could be explained by the farming conditions. In addition, one could also into account the quantity of prey and the duration of feeding. In fact, every other day, they were given 30 *T. castaneum* larvae. This quantity sometimes proved to be insufficient for the couple because one day later (24 h) only a few individuals were observed in the breeding jar, sometimes no prey. This situation could strongly influence mating and egg laying by females (Abo-Ghalia and Thibout, 1983, Kwadjo, 2012). They would adopt the same attitudes or behaviors as their congeners in nature whose selection of the laying structure is based on (taking into account a few) characteristics. The selection of a plant by an insect can be explained in part by physical characteristics of the egg-laying site such as the density of trichomes and stomata, the presence of the texture or relief of the plant surface, the deterrence of natural enemies and the offspring success (Lovinger et *al*., 2000; Sharma and Singh, 2002; Kwadjo, 2012). To *R. squamulosus*, females adapt to their breeding environment in that after mating they lay eggs on all the supports of the breeding jar (muslin, stem and plastic). Females of the Reduviidae have a wide range of egg-laying structures or characteristics. The females are laid on the upper and lower sides of the leaf blades, on the branches or on the stems and sometimes on the iron support or canvas fabric.

(Horgan *et al*., 2007; Júnior *et al*., 2007; Fomekong, 2010; Kwadjo, 2012). However, they prefer to lay high like most Reduviidae and on rough structures like muslin. To *R. albopilosus*, the plants identified as hosts for egg laying are characterized by a more or less dense coating of hairs. On the other hand, the place of laying, whether on the muslin, the stem or the plastic of the breeding jar does not impact the fertility of the eggs and their incubation. In addition, the incubation time of eggs is specific to each species and is strongly influenced by abiotic factors. To *R. squamulosus*, the average egg incubation time is 9 days. This duration is similar to that of *R. albopilosus* (9 days) (Kwadjo, 2012), and close to that of *R. kumarii* 10 days (Sahayaraj, 2012). On the other hand, it is higher to *S. collaris* and P. fed with the same source of prey, the incubation of the eggs lasts on average 15 and 21 days respectively (Sahayaraj, 2012). It is 13.6 1.1 and 11.8 2.3 days on average, when *S. collaris* is fed with *Corcyra cephalonica* and *Hyposidra talaca* respectively (Suman, 2019). Upon hatching, the neonate larva passes through five successive stages before becoming an adult. The number of stages of development is identical in species of the genus *Rhynocoris*. This is the case in most species of Reduviidae (Kwadjo *et al*., 2013; Pravalika *et al*., 2016; Sahayaraj *et al*., 2016; Suman *et al*., 2019). However, the development time of these larvae differs from stage to stage regardless of the stage of prey consumed. The difference in development time is thought to be related to the size, shape, type of prey, stage of prey and the growing food requirement of the larvae, which increase with age. The daily and total consumption of *R. albopilosus* larvae increases from stage 1 to stage 5 depending on the stage of the prey. It increases from 0.71 ± 0.1 to 3.77 ± 0.2 larvae per day on average and from 4.7 ± 0.3 to 35.9 ± 1.3 larvae from stage 1 to stage 5 (Kwadjo, 2013). It is the same case with the nymphs of *T. castaneum*, the daily and total consumption also increases with the age of *R. albopilosus*. Likewise Sahayaraj and Paulraj (2001), have shown that the nutritional requirements of *R. marginatus* from the first to the fifth stage. These same results are observed in most predators as shown by Ragkou *et al*. (2004) and Biswas *et al*. (2007). Moreover, in the absence of prey, the older larvae live much longer because of the energy reserves (Soro, 2019). Morphometric analysis of the larvae of *R. albopilosus* indicates that the body length of the larvae varies respectively from 2.82 ± 0.04; 4.03 ± 0.04; 5.51 ± 0.05; 7.43 ± 0.09 and 10.15 ± 0.20 mm from stage 1, 2, 3, 4 and 5. *R. squamulosus* larvae develop faster in the presence of *T. castaneum* larvae than nymphs of the same prey. Development of stage 1 larvae is not possible with adults of the prey. Also, the mortality of the larvae of *R. squamulosus* is respectively high in the presence of adults, nymphs and larvae of *T. castaneum*.

6 CONCLUSION

The spawning is done on all the supports of the breeding medium, preferably on the muslin of the lid of the breeding jar. Eggs in clusters hatch after nine days of incubation. The larvae from these eggs go through five successive moults before becoming adults. The duration of larval development from one stage to another varies significantly regardless of the stage of the prey consumed. Thus, the larvae of stages 2 and 3 have the shortest development times and those of stage 5 the longest. Apart from stage 5, there is no significant difference in development between larvae fed with larvae and those fed with nymphs of *T. castaneum*. However, the development time is shorter in the presence of larvae than nymphs of T. castaneum. Juvenile larvae develop from stage 1 to stage 5 in the presence of larvae and nymphs of *T. castaneum* unlike those fed with adults of the prey. For the first two stages, mortalities are high and similar, but from stage 3, mortalities are reduced in the presence of larvae than nymphs of *T. castaneum*. All the larvae fed with the adults of the prey died at stage 1 after 15 days of development.

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