Studies of some biological parameters and Life table of the hemipteran predator, *Orius albidipennis*, on *Spodoptera frugiperda* as a potential biological control agent

Soheir F. Abd El-Rahman[1] and Nevien M. Gaber[1]

[1] Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

Correspondence Author: Soheir F. Abd El-Rahman

Received 16 Jan 2023; Accepted 6 March 2023; Published 14 Mar 2023

Abstract

Spodoptera frugiperda is a voracious pest of different economic crops and vegetables, especially maize, causing significant losses in crop production. The predator, *Orius albidipennis*, is a promising tool for biological control against a variety of pests. This study aimed to assess the ability of the predator *O. albidipennis* to control *S. frugiperda* as a novel prey. To achieve this, its biological characteristics over two generations: First generation (G1), Second generation (G2) that fed on *S. frugiperda eggs* were compared with a control that fed on *Ephestia kuehniella* eggs. Additionally, life tables were determined in the laboratory. The results showed that the total nymphal period recorded was (9.48 ± 0.15) days on *E. kuehniella* egg, while, on eggs of *S. frugiperda* (12.08± 0.19 and 11.52± 0.15) days in the first and the second generation. The life cycle and longevity of both male and female predators showed no significant differences when fed on eggs of *E. kuehniella* versus *S. frugiperda*. However, females laid an average of 102.8, 74.7, and 82.0 eggs per female when reared on *E. kuehniella* eggs and *S. frugiperda* eggs for generations G1 and G2, respectively.

Net reproduction rate (R_0) was 35.57, 37.27, and 46.72, and the intrinsic rate of increase (r_m) was 0.15, 0.16, and 0.19 and generation time (T) was 22.51, 21.88, and 19.22 reared on *S. frugiperda* eggs for G1, G2 and *E. kuehniella* eggs, respectively. Additionally, finite rate of increase (λ), gross reproductive rate (GRR), TPOP and APOP were calculated on the two tested prey. These results show that *O. albidipennis* could survive and maintain its populations on *S. frugiperda* and could therefore serve as a biological control agent in integrated pest management (IPM).

Keywords: *Spodoptera frugiperda, Orius albidipennis,* biological characteristics, life table parameters

Introduction

The fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae), is a highly polyphagous pest known to attack 353 plant species across 76 families, and causes significant loss in crop production (Montezano *et al*., 2018) [30]. Since its introduction, it has rapidly spread across Africa, where it now threatens crops in more than 20 countries (Kumar and Murali, 2020) [24]. As a polyphagous pest, *S. frugiperda* larvae infest numerous economically important crops - including wheat, rice, sugarcane, soybean, cotton, and vegetable crops - by feeding on tender foliage, whorls, cobs, and husks, resulting in substantial crop damage and yield losses. The pest demonstrates particular host preference for maize and sorghum, where it causes the most severe agricultural damage (Hardke *et al*., 2015; Casmuz *et al*., 2010) [20, 5]. Quantitative assessments reveal annual maize production losses of 8.3-20.6 million tons attributable to fall armyworm infestations in just twelve African maize-growing nations (Montezano *et al*., 2018) [30]. The use of chemical pesticides has proven effective in controlling agricultural pests and diseases. However, pesticide residues and resistance to pesticides are major problems in chemical pesticide application. Adoption of Integrated Pest Management (IPM) techniques has been fueled by the negative consequences of chemical pesticides. Biological control is one of the main strategies of IPM and one of the most effective and successful methods in pest control since the 20th century (van Lenteren and Godfray 2005) [39], where parasites, predators, and pathogens are used to regulate host (pest) populations (Bonte, 2016) [4].

Species of the genus *Orius* (Hemiptera: Anthocoridae) are generalist predators that play a crucial role in biological control by targeting eggs, early instars, and small, soft-bodied adult arthropods, including key agricultural pests (Reitz *et al*., 2006) [33]. Their prey spectrum extends to whiteflies (Arnó *et al*., 2008) [3] and spider mites (Venzon *et al*., 2002) [40], enabling them to function as efficient natural enemies in systems of integrated pest control (IPM). Due to their predatory efficiency, *Orius* spp have been widely deployed in both open-field and greenhouse environments for decades (Honda *et al*., 1998) [21]. A promising biological control tool for augmentative releases against a variety of pests is the predator *O. albidipennis* (Reuter). Large populations of *O. albidipennis* highlight its significance as a biological control agent across diverse agricultural systems in East Africa, and the Mediterranean basin (Fritsche & Tamo, 2000; Hasanzadeh *et al*., 2015) [16, 17]. In Egypt, *O. albidipennis* is widely distributed in both cultivated areas, particularly in maize and cotton fields, and the desert, south to Wadi Halfa. It is commonly located in the blossoms of plants affected by thrips, lepidopteran eggs, or various other small arthropods (Zaki 1989; Mahmoud *et al*., 2021) [42, 27]. Aphids (*Aphis gossypii* and *Aphis maidis*), mites (*Tetranychus urtica* and *T. telarius*), thrips (*Hercothrips fasciatus*), and lepidopterous eggs and their newly hatched larvae are all preyed upon by *O. albidipennis* (Chyzik *et al*., 2001; Sanchez and Lacasa, 2002; Madadi *et al*., 2009; Sobhy *et al*., 2010; Gaber *et al*., 2011; Abdel-Hameid 2018; El Kenway *et al*., 2021) [10, 34, 26, 36, 14, 1, 22].

The inclusion of some species in biological control programs is based on their biological traits, such as their ability to survive and reproduce, in addition to their exterior traits, such as their ability to adjust to climatic changes, their dietary preferences, and their ease of production.

Studies have extensively investigated the life table parameters and prey preferences of *Orius* species, with particular focus on their relation with aphids, thrips, and whiteflies (Arnó *et al*., 2008; Zuma *et al*., 2022) [3, 43]. Research has demonstrated that *Orius* spp. exhibit distinct predatory behaviors and demographic responses depending on prey species. Notably, Amer *et al*. (2021) [2] expanded this understanding by examining *O. albidipennis* preferences for diverse prey, including mealybugs, aphids, and *Ephestia kuehniella* eggs, Highlighting as a multifunctional biological control agent.

The purpose of this research was to identify particular biological traits of *Orius albidipennis* reproduction and survival on eggs of *Spodoptera frugiperda*, a significant pest on a variety of crops.

Materials and methods

Insect culture

Orius albidipennis

Adults of *O. albidipennis,* (Reuter) and *E. kuehniella* eggs (Zeller) were taken from *Chrysopa* Mass Production at the Faculty of Agriculture, Cairo University, Giza, Egypt. Thirty pairs (male, female) of *O. albidipennis* were put in jars (500 ml), covering with a ventilation net made of fine mesh with provided eggs of *E. kuehniella* as a food source. In addition, fresh bean pods (*Phaseolus vulgaris*) for egg laying (El Arnaouty *et al*., 2018) [13]. Daily, the bean pods were collected and transferred to plastic containers (20 × 15 × 10 cm) until hatching. After hatching, *E. kuehniella* eggs were provided as a food source for the nymphs. To reduce cannibalism, thin, folded paper strips are placed in plastic nymph rearing containers.

The test insects were cultured and the experiments were carried out at 25±2°C and 60–65% RH, with a photoperiod of 16:8 (L: D).

Spodoptera frugiperda

Larvae of *S. frugiperda* were obtained from infested maize plants in Giza Governorate. Rearing was carried out at the Plant Protection Research Institute, Agricultural Research Center, Doki, Giza, Egypt. Rearing larval on plastic box 30 × 20 × 15 cm. Every day, the larvae were provided with a sufficient supply of fresh castor bean leaves (*Ricinus communis* L.). The newly third larval instar was reared individually in plastic containers measuring 7 cm × 6 cm, which were fitted with gauze covers, until they began the pupation. The pupae were kept in 1000 ml jars until the adult emergence. Ten male and ten female (10 pairs) were put in 2000 ml jars for egg laying and then kept at the temperature and relative humidity specified above. Each jar contained a piece of cotton wool in a small bottle with 40% honey solution as food and a piece of paper folded in a zigzag shape as an egg laying site. After being eggs placed on the paper, the egg masses were moved to the rearing containers and kept under the aforementioned conditions until the larvae hatched, at which point they could be utilized in further research.

Experiments

Nymphal developmental and survival rate

As previously stated, fresh bean pods were given to the appeared predatory adults to act as oviposition locations. Around sixty newly laid eggs of *O. albidipennis* were incubated until they hatched. Immediately after hatching, (< 24 h old) predator nymphs (twenty-five nymphs, divided into 5 replicates) were placed individually in plastic boxes 3.5 cm in diameter and 2.5 cm in height for each treatment first generation (G1) and second generation (G2) that fed on *S. frugiperda* eggs and control that fed on *E. kuehniella* eggs. The nymphs were given a suitable quantity of either *E. kuehniella* eggs or *S. frugiperda* eggs each day. Until they emerged as adults, they were monitored every day and maintained at the same temperature and relative humidity. Daily, recorded the duration of each nymph instar, nymph mortality percentage, and the sex ratio of adults.

Biological parameters of adult stage and life table

To evaluate the life parameters of *O. albidipennis*, ten couples of the adult predator were kept separately in a plastic container (5 cm x 3 cm), and pieces of fresh bean pods were used as egg deposition sites. The plastic containers were covered with white muslin for ventilation, preventing *O. albidipennis* from escaping. The predators were provided daily with enough eggs of *S. frugiperda* or eggs of *E. kuehniella* as control, throughout their lifespan. When the male died, it was substituted by a male of the same age. The experiments were examined daily to record the eggs laid and the durations of each development stage of the predator were recorded. Life table parameters were calculated for prey based on information on *O. albidipennis* developmental periods, immature survival rate, and daily fecundity. (Majd-Marani *et al.,* 2017) [28].

Statistically analysis

Data all biological of *O. albidipennis* were statistically analyzed using analysis of variance (ANOVA) and Duncan's test ($P < 0.05$) using SPSS version 26.0 was used to compare mean values (SPSS, 2019) [37].

Life table analysis

For life table analysis, we employed the TWOSEX-MS Chart program (Chi, 2021) [9] based on the age-stage, two-sex life table theory (Chi & Liu, 1985; Chi, 1988) [7, 6]. Key demographic parameters were estimated through bootstrap analysis (10,000 resamples) (Efron & Tibshirani, 1993) [12]. The age-stage survival rate (S_{xj}) indicated the likelihood that a newly laid egg will endure age x and developmental stage j (Chi and Liu 1985) [7]. Other life table parameters included the age-specific survival rate (l_x), the age-specific fecundity (m_x), life-stage fecundity (f_{xj}), limited rate of increase (r_m), limited ability to increase (λ), the net reproductive rate (R_0), the mean time of generation (T), the gross reproduction rate (GRR), doubling time, (DT), the pre-oviposition period of adult

(APOP), and the total pre-oviposition period (TPOP) were calculated accordingly.

Equation-based calculations and the Euler Lotka formula were used to determine the intrinsic rate of increase (r): with age indexed from (Goodman 1982) [15].

$$\sum_{(x=0)}^{\infty} e^{(-r(x+1))} l_x m_x = 1 \tag{1}$$

The net reproductive rate (R_0) was calculated as the mean number of female offspring produced per female individual over her lifetime, representing the generational replacement rate. This was computed as:

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \tag{2}$$

The finite rate of increase (λ) was calculated as:

$$\lambda = e^r \tag{3}$$

The gross reproduction rate (GRR) was calculated as according to Chi and Su (2006):

$$\text{GRR} = \sum_{\text{mx}} \tag{4}$$

The mean generation time (T) was evaluated as:

$$T = \frac{ln(R_0)}{r} \tag{5}$$

Doubling generation time (DT) is the required time to double the population in size and estimated by:

$$DT = ln(2/r) \tag{6}$$

Results

Nymphal developmental and survival rate

Table (1) showed that the incubation period and developmental time of nymphal instars of *O. albidipennis* that were reared on various prey eggs of *S. frugiperda* as treatment for two generations and compared with eggs of *E. kuehniella* as control prey. The incubation period showed no significant variation across experimental groups: (1.88 ± 0.07, 1.80 ± 0.08 and 1.76 ± 0.09 days) respectively. While, in the total nymphal stage, significant differences were detected in developmental periods (F=66.983, P=0.000) between first, second generation, and control (12.08 ± 0.19, 11.52 ± 0.15 and 9.48 ± 0.15 days) respectively. Nymphal instars of *O. albidipennis* reached earlier to 2nd, 3rd, 4th, and 5th instars when they consumed eggs of *E. kuehniella*.

For nymphal mortality, data in table (2) indicated that *O. albidipennis* nymphal mortality differed depending on the tested prey. The lowest mortality rate in first, second, third, fourth nymphal instar of *O. albidipennis* given of *E. kuehniella* eggs, compared with *S. frugiperda* eggs. No significant difference in second nymphal mortality at G1 and G2 that fed on eggs of *S. frugiperda*. Moreover, no significant difference in the third and fourth nymphal mortality when fed on eggs of *E. kuehniella,* or eggs of *S. frugiperda*.

Findings indicated that the lowest total mortality % of *O. albidipennis*, 16.00±1.79 when given of *E. kuehniella* eggs, compared with eggs of *S. frugiperda* 40.00±2.19, 30.40±2.99 in G1 and G2 respectively. The sex ratio (Male: Females) recoded 1:1.5 in the control while, recorded 1:1.3, and 1:1.4 in the G1 and G2 respectively.

Table 1: Biological parameter of *Orius albidipennis* nymphs reared on *Spodoptera frugiperda* and *E. kuehniella* eggs

Treatments	Incubation	Nymphal instar periods /days					Total nymph
		1st	2nd	3rd	4th	5th	
G1	1.88 ± 0.07 a	2.12 ± 0.07 a	2.28 ± 0.11 a	2.36 ± 0.10 a	2.52 ± 0.10 a	2.80 ± 0.12 a	12.08 ± 0.19 a
G2	1.80 ± 0.08 a	2.12 ± 0.07 a	2.24 ± 0.09 a	2.28 ± 0.09 a	2.32 ± 0.10 ab	2.56 ± 0.10 a	11.52 ± 0.15 b
Control	1.76 ± 0.09 a	1.44 ± 0.10 b	1.80 ± 0.12 b	1.96 ± 0.09 b	2.08 ± 0.06 b	2.20 ± 0.08 b	9.48 ± 0.15 c
F value	0.60	24.25	6.51	5.11	6.46	9.04	66.98
P value	NS	0.00**	0.00**	0.00**	0.00**	NS	0.00**

Data presented are mean ± SE. Different letters in the same column indicate significant differences at (p<0.05). G1=The first generation of *Orius albidipennis* fed on *S. frugiperda eggs.* G2= The second generation of *Orius albidipennis* fed on *S. frugiperda eggs.* Control= *Orius albidipennis* fed on *E. kuehniella* eggs, *= Significant, **=Highly Significant, NS= Non Significant

Table 2: Mortality % of *Orius albidipennis* nymphs reared on *Spodoptera frugiperda* and *E. kuehniella eggs*

Treatments	Mortality % of nymphal instar					Total mortality%
	1st	2nd	3rd	4th	5th	
G1	16.20 ± 2.69 a	9.47 ± 1.45 a	10.30 ± 1.40 a	5.76 ± 1.76 a	0	40.00±2.19a
G2	16.20 ± 2.69 a	9.47 ± 1.45 a	5.06 ± 2.30 b	0.00 ± 0.00 b	0	30.40±2.99b
Control	8.00 ± 1.79 b	4.35 ± 0.08 b	4.55 ± 0.09 b	0.00 ± 0.00 b	0	16.00±1.79c
F value	3.80	6.22	4.18	10.68	-	25.81
P value	0.05*	0.01*	0.04*	0.00**	-	0.00**

Data presented are mean ± SE. Different letters in the same column indicate significant differences at (p<0.05). G1=The first generation of *Orius albidipennis* fed on *S. frugiperda eggs.* G2= The second generation of *Orius albidipennis* fed on *S. frugiperda eggs.* Control= *Orius albidipennis* fed on *E. kuehniella* eggs. *= Significant. **=Highly Significant. NS= Non Significant

Biological parameters of adult stage

The data presented in Table 3 indicates that the longest longevity of *O. albidipennis* males (16.40±0.79) and females (19.40±0.43) when fed *E. kuehniella* eggs while, recorded the Shortest longevity males (13.60±1.09 and 13.90±1.13) and Females (18.50±0.50 and 18.70±0.30) when fed on eggs of *S. frugiperda* in G1 and G2 respectively. However, no significant differences were found in longevity of the males and females, fed on *E. kuehniella* eggs, and *S. frugiperda* eggs.

The prey species had a significant impact on egg production, oviposition period, and pre-ovipositional period. Shorter pre-oviposition period and longer oviposition period in females reared on the eggs of *E. kuehniella*, and this prey resulted in more eggs per female daily (102.8 eggs/female) than eggs of *S. frugiperda*. In contrast, the shortest oviposition period, and the lowest oviposited eggs per female (74.7 eggs/female) and (82.0 eggs/female) for females G1, G2 reared on the eggs of *S. frugiperda* respectively. Moreover, no discernible variation in pre-oviposition, oviposition period, and number of eggs per female in G1 and G2 fed on the eggs of *S. frugiperda*.

Table 3: Biological parameters of *Orius albidipennis* adults reared on *Spodoptera frugiperda and E. kuehniella* eggs as prey

Treatments	Sex ratio (male: female)	Male Longevity (days)	Female Longevity (days)				Adults longevity	No. egg/ Female	Egg Hatchability %	Life Cycle
			Pre-oviposition	Oviposition	Post-oviposition	Total				
G1	1:1.2	13.60 ± 1.09 a	4.00 ± 0.26 a	11.40 ± 0.50 b	3.10 ± 0.28 a	18.50 ± 0.50 a	16.12 ± 0.59 a	74.70 ± 3.04 b	89.54 ± 0.91 a	30.08 ± 0.67 a
G2	1:1.4	13.90 ± 1.13 a	4.30 ± 0.21 a	11.60 ± 0.43 b	3.00 ± 0.33 a	18.70 ± 0.30 a	16.40 ± 0.69 a	82.00 ± 3.18 b	93.91 ± 1.02 b	29.72 ± 0.70 a
Control	1:1.5	16.40 ± 0.79 a	2.80 ± 0.20 b	14.40 ± 0.43 a	2.20 ± 0.36 a	19.40 ± 0.43 a	17.84 ± 0.46 a	102.80 ± 1.79 a	98.15 ± 0.66 c	29.08 ± 0.45 a
F value	-	2.29	12.41	13.76	2.30	1.28	2.45	28.30	24.24	0.67
p value	-	NS	0.00**	0.00**	NS	Ns	NS	0.000**	0.000**	NS

Data presented are mean ± SE. Different letters in the same column indicate significant differences at (p<0.05). G1= The first generation of *Orius albidipennis* fed on *S. frugiperda eggs.* G2=The second generation of *Orius albidipennis* fed on *S. frugiperda eggs.* Control= *Orius albidipennis* fed on *E. kuehniella* eggs. *= Significant. **=Highly Significant. NS= Non Significant

Life table of *O. albidipennis*

This study investigated how the life table characteristics of *O. albidipennis* were affected by two different prey species under laboratory conditions: *S. frugiperda* (a new prey, across two generations) and *E. kuehniella* (the preferred prey). The findings indicated that the life table parameters for the second generation of *O. albidipennis* fed on *S. frugiperda* for their entire life were remarkably similar to those mass-reared on *E. kuehniella* eggs during their developmental stages.

Table 4 revealed that the type of prey significantly impacted the intrinsic rate of increase (r_m) and the finite rate of increase (λ) of *O. albidipennis*. Specifically, there was a significant difference in these values when *O. albidipennis* fed on *E. kuehniella* eggs compared to *S. frugiperda* eggs for one generation. However, this difference disappeared in the second generation: there was no significant difference in r_m and λ values between *O. albidipennis* fed on *E. kuehniella* and those fed on *S. frugiperda*. The r_m values were 0.19 for *E. kuehniella*, 0.15 for the first generation of *O. albidipennis* fed on *S. frugiperda*, and 0.16 for the second generation fed on *S. frugiperda* (Table 4).

In addition, net reproductive rate (R_0) value was 46.72 female's daughter progeny/females in one generation of *O. albidipennis* when reared on *E. kuehniella*, this value had decreased to 37.27 female daughter progeny/ female when *O. albidipennis* reared on *S. frugiperda* for two generation of while the shortest was when reared on *S. frugiperda* for one generation of (35.57 female/female).

Furthermore, there was no significant difference between the two prey species in the gross growth rate (GRR) of *O. albidipennis*. The mean generation time (T) of *O. albidipennis* showed a significant difference between the tested prey species. The highest T value resulted from rearing O. *albidipennis* on *S. frugiperda* for one generation (22.51 days). While the lowest to the T value was 19.22 days when *O. albidipennis* reared on *E. kuehniella*. However, the doubling time (DT) of *O. albidipennis* on *S. frugiperda* prey was significantly highest than that of the control. The doubling time of *O. albidipennis* was 3.46 days when reared on *E. kuehniella*, while the doubling time of *O. albidipennis* was 4.37 and 4.19 days when reared on *S. frugiperda* for one and two generations, respectively (Table 4).

Despite some similarities in other life table parameters, the average pre-oviposition period (APOP) and total pre-oviposition period (TPOP) for *O. albidipennis* were notably longer when the insects were raised on *S. frugiperda* eggs for two generations compared with control (Table 4). Furthermore, the oviposition period for *O. albidipennis* was significantly shorter when reared on *S. frugiperda* eggs (11.4 and 11.6 days for the 1^{st} and 2^{nd} generations, respectively) compared to those reared on *E. kuehniella* eggs (14.4 days).

Table 4: Life table assessments of *Orius albidipennis* reared on *Spodoptera frugiperda* and *E. kuehniella* eggs as prey

Parameters	G1	G2	Control *(E. kuehniella)*
Intrinsic rate of natural increase (r_m)	0.15± 0.0115 b	0.16 ± 0.01 ab	0.19± 0.01a
The finite rate of increase (lambda) (ג)	1.17 ± 0.01 b	1.18 ± 0.01 1ab	1.22 ± 0.01a
Net reproductive rate (R_0)	35.57 ± 8.28 a	37.27 ± 8.81 a	46.72 ± 10.96 a
The gross reproduction rate (GRR)	39.33 ± 8.39 a	40.55 ± 8.91 a	48.16 ± 10.913 a
Mean generation time (T)	22.51 ± 0.28 a	21.88 ± 0.26 a	19.22 ± 0.48 b
Doubling time (DT)	4.37 ± 0.35 a	4.193 ± 0.34 ab	3.46 ± 0.28 b
Adult pre-oviposition period of female adult (TPOP)	18.1±0.28a	17.3±0.26b	14.2±0.41c
The time interval from birth to the beginning of oviposition (APOP)	4.0±0.26a	4.3±0.21a	2.8±0.2b
Oviposition oviposition period of female adult	11.4±0.5b	11.6± 0.43b	14.4±0.43a

Mean ± SE followed by different letters within the same row are significantly different (p < 0.05). G1= generation of *Orius albidipennis* reared on *Spodoptera frugiperda* eggs for one generation. G2= generation of *Orius albidipennis* reared on *Spodoptera frugiperda* eggs for two generation

Figure 1 illustrates the age-stage-specific survival rate (Sxj) for *O. albidipennis*, which represents the likelihood that a newly hatched individual will live to a specific age (x) and stage (j). The data showed that the hatching time and the duration of nymphal stages were longer for *O. albidipennis* given on fall armyworm eggs than those given on *E. kuehniella* eggs. The overlap seen between stages is attributed to individual variations in growth rates.

Interestingly, a higher percentage of *O. albidipennis* eggs successfully survived to adulthood when the insects were fed either *E. kuehniella* eggs or *S. frugiperda* eggs for two generations. However, the survival rate was significantly lower when *O. albidipennis* was fed *S. frugiperda* eggs for only one generation.

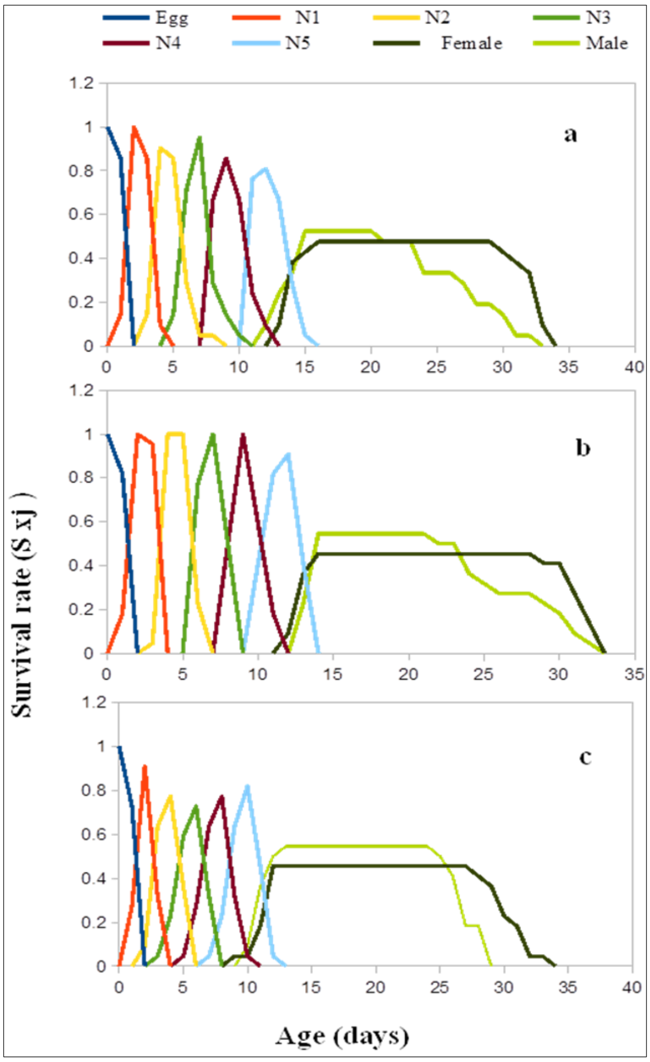

Fig 1: Age-stage specific survival rate (Sxj) of *Orius albidipennis* reared on *S. frugiperda* and the control. (a) First generation (b) Second generation (c) Control *(E. kuehniella*)

Curves of survival rate (lx), age-specific fecundity (mx), age-specific maternity (lxmx) of *O. albidipennis* when fed *S. frugiperda* and the control are presented in Figure 2. The Lx, Mx and lxmx of *O. albidipennis* reared *on S. frugiperda* are totally similar to the control (reared on *E. kuehniella*). As age increased the lx of *O. albidipennis* decreased and showed an inverse relationship for *S. frugiperda* and *E. kuehniella*. The peak of the mx curve was at 24, 21 and 18 days when *O. albidipennis* fed on *S. frugiperda* for one generation, *S. frugiperda* two generations and *E. kuehniella*, respectively.

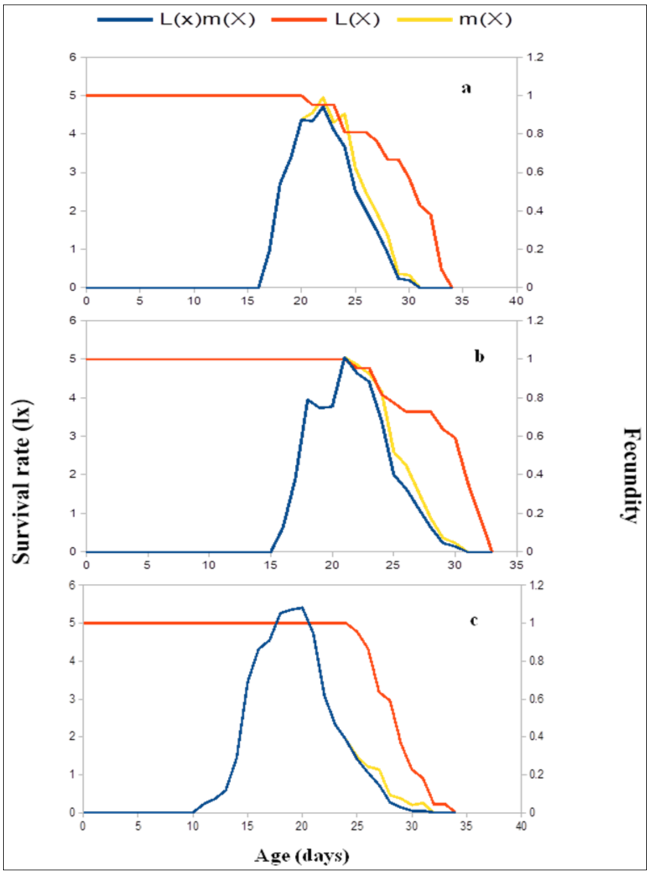

Fig 2: Curves of age-specific survival rate (lx), age-specific fecundity (mx), age-specific maternity (lxmx) of *Orius albidipennis* reared on *S. frugiperda* and the control. (a) First generation (b)Second generation (c) Control (*E. kuehniella*)

Discussion

Presently, G1 and G2 generations of *O. albidipennis*, that fed on *Spodoptera frugiperda* eggs exhibit a fifth-nymphal instar comparable to that of the predator fed with different prey (Amer *et al*., 2021; *Zuma et al., 2022*) [2, 43]. The results indicated that *S. frugiperda* eggs are good food for *O. albidipennis* because the number of growth stages can change based on whether there is enough suitable food or if the environment is not ideal (Michaud, 2005) [29]. According to our results, *O. albidipennis* could reproduce and complete its life stages if it was reared on *S. frugiperda* eggs. The shorter developmental nymphal period of eggs of *E. kuehniella* than eggs of *S. frugiperda*. These results agreement with Sobhy *et al*., 2010 [36], found that the total nymphal instar for *O albidipennis* recorded 10.51±0.25 days when consumed eggs of *E. kuehniella* with a high survival rate of 87.75% in the nympal instar. Also, Gaber *et al*., (2011) [14] indicated that the developmental period of nymphal *O. albidipennis*, was 10.6 days when fed on eggs of *E. kuehniella*. However, Abdel-Hameid (2018) [1] indicated that the developmental period of the nymphal instar of *O. albidipennis* is 12 days when fed on *Spodopterta littoralis*. Many researchers (Sanchez and Lacasa, 2002; Madadi *et al*., 2009; Liu *et al*., 2018; Shahpouri *et al*., 2019; Rehman 2020; El-Kenway *et al*., 2021) [34, 26, 25, 35, 32, 22] showed that different developmental periods of *Orius* spp accordance with the prey. According to findings the lowest total nymphal mortality rate was on *E. kuehniella,* eggs compared to *S. frugiperda* eggs. This result in agreement with Van De veire and Degheele (1995) [38] indicated that, the overall mortality % in nymphs of *O. albidipennis* recorded 38.8% when given eggs of *E. kuehniella*. However, Gaber *et al.,* (2011) [14] reported the overall mortality % of *O. albidipennis* nymphal was 26.00 % when fed on *E. kuehniella* eggs. Additionally, the current study indicated that no significant difference in longevity in males and females when fed on *S. frugiperda* eggs or *E. kuehniella* eggs. However, males of *O. albidipennis* lived shorter times than females. Also, *O. albidipennis* that consumed eggs of *S. frugiperda* had lower fecundity than that consumed eggs of *E. kuehniella*. These results agree with Gaber *et al*., (2011) [14]. Who reported shorter longevity in males of *O. albidipennis* (15.56±4.32 days) than in females (18.00±3.37 days) when feeding eggs of E. *kuehniella*. Moreover, the highest fecundity in females of *O. albidipennis* (107.33±35.79 eggs/female) when feeding eggs of *E. kuehniella*. Also, Wafaa (2013) [41] indicated that males of *O. albidipennis* lived a shorter period than females when fed on *Aphis craccivora*. In addition, Abdel Hamid (2018) [1] reported that pre-oviposition and oviposition periods were shortened when *O. albidipennis* nymphs fed on first-instar larvae of *S. litoralis*, with a higher fecundity rate of 187.60 eggs/female, and the longevity of *O. albidipennis* females was prolonged (17 days) compared to males (10.33 days).

Furthermore, different prey species can significantly on affect the growth and reproduction of predators, which in turn affects population dynamics. Feeding *O. albidipennis* nymphs on first instar larvae of *S. graminum* or *S. litoralis* shortened pre-oviposition period and lengthened oviposition period, which resulted in a higher fertility rate (Abdel-Hameid, 2018) [1]. Additionally, De Lima (2020) [11] indicated that the longest lifespan (23.6 days for females) and fecundity (169 eggs/female) were exhibited by *O. laevigatus* raised on *E. americanus* when compared to those reared on the high-quality eggs of the favorite prey, *E. kuehniella*.

Several studies have examined life table parameters and prey preferences for *Orius* spp, and *E. kuehniella* has been found to be one of the best praise for mass rearing in *Orius* species. However, there are limited studies on the life table of *O. albidipennis* on different prey preferences. The data we provide that *O. albidipennis* is able to complete its life stages and reproduce when raised on fall armyworm eggs. However, its fecundity and survival rates on these eggs were comparable to those of the control group. It is important to note that no previous studies have been found that contain life table parameters for *O. albidipennis* when feeding on fall armyworm and the current study may be the first to record life table parameters for *O. albidipennis* when used as a natural enemy against *S. frugiperda* infestation. All parameters of life table such as R_0, r_m time T and GRR can be significantly influenced by prey species. The net reproductive rate (R_0) value in our investigation decreased to 37.27 female off spring /♀ when *O. albidipennis* was reared on *S. frugiperda* for two generations compared to *O. albidipennis* when reared on *E. kuehniella*, where the value was 46.72 female off spring /♀ per generation. The highest mean generation time (T) value was shown when *O. albidipennis* was reared on *S. frugiperda* for one generation (22.51 days), while it decreased to 19.22 days when reared on *E. kuehniella*. Results are in agreement with Hamdan (2012) [15] examined the life table of the *Orius laevigatus* insect on *Bemisia tabaci*, which infests tomato leaves. He found the mean rate of increase (λ): 1.12 females/female/day, net reproductive rate (R_0): 20 females/female/generation, mean reproductive rate (r_m): 0.12, mean generation time (T): 25.7 days, and gross reproductive rate (GRR): 46 insects/female/generation. Also, the same researcher (Hamdan, 2015) [19] described the characteristics of the life cycle of the predatory *Orius laevigatus* insect that attacks *Bemisia tabaci* on eggplant leaves for two successive generations as follows: mean rate of increase (r_m): 0.038; Gross reproductive rate (GRR): 18 insects/female/generation, net reproductive rate (R_0): 2.6 females/female/generation, limiting rate of increase (λ): 1.038 females/female/day, mean generation time (T): 25.2 days, and doubling time (DT): 18.2 days. Also, Rajabpour *et al.* (2018) [31] found that, the values of GRR was 30.79, λ= 1.12, r_m = 0.12, R_0 = 26.55 and T =1.96 days when studied the life table parameters of *O. albidipennis* reared on *Ephestia kuehniella* egg. Furthermore, Rehman *et al.,* (2020) [32] discovered that in contrast to the highest GRR, the longest generation time (T) and the highest R_0 were experienced by *O. strigicollis* when fed on *T. vaporariorum* as opposed to *B. tabaci*. Moreover, Kordestani *et al.,* (2021) [23] observed the highest net reproductive rate (R_0: 47.3 females/female), intrinsic rate of increase (r_m: 0.10 females/female/day), limited rate of increase (λ: 1.16 females/female/day), and generation time (T: 24.1 days) for the predator *O. laevigatus* when feeding on *Frankliniella occidentalis*, which infested green beans. In the present study, the average pre-oviposition period (APOP) and total pre-oviposition period (TPOP) of *O. albidipennis* were significantly longer when reared on *S. frugiperda eggs* for two generations compared to *O. albidipennis* reared on *E. kuehniella* eggs (control group). Data obtained from our study were almost similar to those reported by Rehman *et al*., (2020) [32], in contrast to our study, discovered that the two whitefly species had no discernible effects on the APOP period of *O. strigicollis* (2.35 days, and 2.4 days with nympha of *B. tabaci* and *T. vaporariorum* respectively). However, when fed to *T. vaporariorum* nymphs (20.5 days), *O. strigicollis's* TPOP was noticeably longer than that of *B. tabaci* (19.82 days). Furthermore, in this work, the results of age-specific survival rate (lx), fecundity rate (mx), and lxmx of *O. albidipennis* after feeding on *S. frugiperda* eggs and *E. kuehniella* eggs (control) were totally similar. These results are consistent with Rajapour (2018) who found that the lx, mx, and lxmx curves of *O. albidipennis* fed an artificial diet were quite similar to those fed on *E. kuehniella* eggs (control). Furthermore, Rehman *et al.,* (2020) [32] reported that when *O. strigicollis* fed on *B. tabaci* and *T. vaporariorum*, overlap occurred between the immature stages (nymphs) during *O. strigicollis* development due to differences in the growth rate of individuals. Additionally, the survival rate (lx) was 86.66% and much lower to 56.7% when

O. strigicollis fed on *B. tabaci*, and *T. vaporariorum* nymphs. Also, Kordestani *et al*., (2021) [23] reported that *O. laevigatus* fed on *F. occidentalis* reared on the green bean had the shortest nymphal duration, lowest mortality and rate of survival in immature stages of *O. laevigatus* was 91%; whereas, the survival rate of *O. laevigatus* fed on *F. occidentalis* reared on strawberry and marigold was 76% and 81%, respectively.

Conclusion

This study's findings indicate that *O. albidipennis* can complete its life cycle and reproduce when raised on *S. frugiperda*. Moreover, its fecundity and survival rate were lower compared to when it was fed *E. kuehniella* eggs.

Despite this, *S. frugiperda* showed promising results in terms of life table parameters, suggesting that *O. albidipennis* could serve as an effective biological control agent against *S. frugiperda*. While *E. kuehniella* eggs are currently the preferred food for mass-rearing *O. albidipennis*, *S. frugiperda* proved to have higher nutritional value for the predator. Therefore, *O. albidipennis* demonstrates strong potential as a viable and active biological control solution for *S. frugiperda*.

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