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The Effect of Sex Ratio and Population Density on Adult and Female Egg-Laying Behavior and Female Longevity of *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae)

Omar Samee MAHMOOD[1]*, Hüseyin ÇETİN [2]

[1]Selcuk University, Faculty of Agriculture, Department of Plant Protection, Konya, Türkiye
[2]Selcuk University, Faculty of Agriculture, Department of Plant Protection, Konya, Türkiye

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ABSTRACT

This study was conducted to determine the effects of sex ratio and population density on *Plodia interpunctella* (Hübner) adult and female egg laying behavior. This study was conducted to determine the effects of sex ratio and population density on *Plodia interpunctella* (Hübner) adult and female egg laying behavior. The studies were carried out in the laboratory of the Department of Plant Protection of the Faculty of Agriculture of Selçuk University and in the climate room at 28±1ºC, 70±5% relative humidity and dark environment. Experiments were carried out in 1 Liter jars with 4 replications. Seven for the sex ratio in the trials (1/1.2/1.3/1.4/1.5/1.6/1.7/1 Male/Female), five for the population density (2/1.4/2) .6/3.8/4.10/5 Male/Female) (in a fixed sex ratio of 2 male/female) different parameters were used. According to the results obtained, an increase was observed in the number of eggs laid by a female from the early stages to the intermediate levels in the sex ratio and population density. When we look at the effect of the sex ratio, the number of eggs laid by the female in the ratio of 5 males / 1 females reached the highest level with 312 eggs. In the population density, the female left the largest number of eggs (360 eggs) at a density of 9 adults. In mass production of *P. interpunctella*, the highest number of eggs will be obtained from females if the adult population density is 9, the sex ratio is 5 males / 1 female and adult food is provided.

1. Introduction

Plodia interpunctella (Hübner) (Lepidoptera: Pyralidae) causes significant damage to many stored products. This pest causes damage to many stored products, dried fruit, grain products, nuts and many other products during the larval stage. It causes loss of product weight as a result of feeding on the products it infects during the larval period, and significant losses in quality characteristics due to the body residues of the pests, the dirt they leave and the silky nets and similar substances they secrete. *Plodia interpunctella* (Hübner) is an insect that damages storage products. It is found in every continent except Antarctica (Rees et al, 2004). *P. interpunctella* feeds from the outside, and the larvae weave a web both inside and on the surface of the food. *P. interpunctella causes* direct and indirect economic loss in the product (Phillips et al., 2000, Mohandass et al., 2007, Kalyoncu and Özge, 2014). The development period is 37-52 days under favorable conditions. It gives 2-5 progeny offspring per year, depending on climatic conditions (Athanassiou, 2004; Anonymous, 2008; Eğridal, 2017). In this study, found that the best egg production in *Anopheles albimanus* (Diptera: Culicidae) was in 1 female and 3 males (Bailey et al. 1980). *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) with 4 different densities (25, 50, 75 and 100) that the ratio of the total number of eggs laid is higher at 50 predator densities and this rate decreases as the density increases (Sahayaraj 2002). This study determined the number of eggs laid by *Chelonus inanitus* (Hymenoptera: Braconidae) mated females at different temperatures. Accordingly, he reported that mated females lay 612 eggs at 20 ºC and 1219 eggs at 28 ºC, and the sex ratio was approximately 1:1 at 20 and 25 ºC, but this ratio changed in favor of males with the increase in temperature (Rechav 1978). In this study, determined that *Anthocoris minki* Dohrn (Hemiptera: Anthocoridae) and females lay 22.7, 16.1 and 12.9 eggs at 250, 400 and 550 adult densities, respectively. Accordingly,

* Corresponding author email: *osami1787@gmail.com*
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as the density increased, the number of eggs laid by the females during their lifetime decreased. (Çoban 2015). In insects, sex ratio is an important factor in determining population density. Although this ratio varies in different species, besides environmental factors such as the age of the female, the number of eggs laid after fertilization, population density, amount and type of food, temperature, in some species photoperiod plays an important role determining the sex ratio (Yeşim & Gülel, 2006). It has been reported that the average development time of *Orius sauteri*(Poppius) (Heteroptera:Anthocoridae). from egg opening to adulthood is 12.9 days for males and 13.3 days for females (Murai et al. 2001).In this study, it was determined that the average number of eggs laid per female during the egg laying period of *Orius albidipennis* (Reuter)(Hemiptera: Anthocoridae)at 25±1 oC temperature and 65±5% proportional humidity conditions was 85.07±10.64 and the egg-laying rate was 69.01±6.29%.(Büyük, M., & Kazak, C. 2010). The hatching time of *Orius albidipennis* (Reuter) (Hemiptera:Anthocoridae) at 25 oC was 3.8±0.1 days, and the nymph development times were 3.1±0.1, 2.6±0.1, 2.2±0.09, 2.0±0.06 and 3.2±0.1 days, a total of 12.1±1.2 days. have stated that. (Cocuzza et al., 1997).

2. Material and Method

Material

For production, *P.interpunctella* (Hübner) was taken from the stock culture in the Entomology laboratory of the Department of Plant Protection, Faculty of Agriculture, Selcuk University. The stock culture was grown for use in the study in a climate cabinet (nüve TK 120) at 28±1ºC, in a dark environment with a proportional humidity of 70±5%. With the help of a mouth aspirator, harmful adults were transplanted into jars containing peanuts to lay eggs. The mouths of the jars are closed with tulle so that the adults do not escape from the jars and so that they can breathe. Trials were established from the culture obtained from the adults grown here. Egg counts were made using a stereo zoom microscope. In order to observe the eggs taken with the help of a brush, they were placed in petri dishes. Pure water was used to clean the jars.

Laboratory Studies

The dried fruit moth *P.interpunctella* (Hübner) individuals used in this study were grown in one-liter jars with peanuts in a gavuze-covered mouth. Male and female adults from the stock culture were transferred to jars containing peanuts for spawning. In this way, they are provided to lay eggs. When the larvae hatched from the eggs became pupae, sex determination was made from the pupal abdomen and male and female individuals were determined and placed in separate jars. Trials were set up from one-day-old males and females. Adult individuals were transplanted using a mouth aspirator. In the thesis study of the individuals reared here, the effects of different sex ratio and population density on the number of eggs laid by *P. interpunctella* females during their lifetime, on the lifespan of adult females, on pre-oviposition, oviposition and post-oviposition times were investigated. As adult food, 10% sugar water was impregnated with cotton and given in the small medicine cap. Each jar formed a replica. The study was carried out in the same way for each replication in a randomized plot design with 4 replications.

The effect of sex ratio on egg production, pre-oviposition, oviposition, post-oviposition times and female longevity of Plodia interpunctella (Hübner) female

After the larvae grown in peanuts became pupae, sex determination was made and males and females were placed in separate jars. Trials were set up from adult one-day-old unmated males and females. Experiments were carried out in 1 liter jars with 4 replications. Adult transplants were performed using an oral aspirator. The sex ratios to the jars are 1/1, 2/1, 3/1, 4/1, 5/1, 6/1 and 7/1 male/female. To be fed into one liter jars, 10% sugar water was impregnated with cotton and given in the small medicine cap. The mouths of the jars are closed with tulle to allow them to breathe. After the adult females started to lay eggs, the jars were observed every day, the egg counts were made, the jars were cleaned and their food was renewed. The same procedures were continued every day until the death of the adults. Egg count and nutrient replenishment were maintained daily throughout the experiment.

The effect of population density on egg production, pre-oviposition, oviposition, post-oviposition times and female longevity of Plodia interpunctella (Hübner) female

After the pupal period, males and females separate and mature in separate jars, at a certain age (1 day old) and at a constant sex ratio (2 males / 1 female) and at 5 different population densities (3, 6, 9, 12 and 15 adults) jars, dark conducted in the environment. It was placed in one-liter test jars, which were placed in a gauze-closed container with 10% sugar water soaked with cotton. By following the trials every day, the necessary data were recorded until the adults died.

4.Results and Discussion

4.1. The Effect of Sex Ratio on Egg Production, Pre-oviposition, Oviposition, Post-oviposition and Female Longevity of Plodia interpunctella (Hübner) Female

It has been determined that as the sex ratio changes, the changes in the number of eggs laid by the female are statistically significant. The sex ratio was formed as 1/1, 2/1, 3/1, 4/1, 5/1, 6/1, 7/1 (male / female). The number of eggs laid by a female was determined in the ratio of these sexes. According to this sex ratio, the number of eggs laid by a female was determined as 129, 149.75, 266.75, 272, 311.50, 264.75, and 254.75, respectively. When Table 1 is examined, the highest number of eggs was determined as 311.5 eggs in the ratio of 5/1 (male / female) sexes. The lowest number of eggs was determined as 129 eggs when the sex ratio was 1/1.

In addition, an increase in the number of eggs laid by the female from 1/1 to 5/1 sex ratio was detected, When

we look at the ratio of 5/1 sexes to 7/1 sex ratios, a decrease in the number of eggs laid by the female has been detected. As indicated in Table 2 the effect of sex ratio on female pre-oviposition, oviposition, post-oviposition time and female lifespan was investigated. In terms of sexes, the effect of the female on the pre-oviposition time was found to be insignificant, while the effect on the oviposition and post-oviposition times was statistically significant. Likewise, it has been determined that the effect on female lifespan is also significant. When you look at the pre-oviposition time in Table 2, it has been determined that the pre-oviposition period is the longest with 1.0 day in the ratio of 1/1 sexes, while it is the shortest with 0.0 days in the ratio of 4/1, 5/1, 6/1 male/female. Considering the oviposition period, it was determined that it was the longest with 15.0 days in the ratio of 3/1 sexes, and the shortest period with 06.0 days in the ratio of 7/1 sexes. It was determined that the longest pot-oviposition period was 1.7 days at the rate of 1/1 sexes in the post-oviposition ratio, and the least duration with 0.0 days at the rate of 5/1 sexes. In the effect of sex ratio on female lifespan, it was determined that the longest female lifespan was 16.2 days in the ratio of 3/1 sexes, and the shortest female lifespan (07.2 days) in the ratio of 7/1 sexes. In their study, found that the best egg production in Anopheles albimanus was in 1 female and 3 males (Bailey et al. 1980). Created 29 pairs, one female and one male, from *Sitona crinitus* in his study under greenhouse and field conditions. The average number of eggs laid per female was 380.7 (65-482) in the Greenhouse -1 group that spent the winter in the field, 315.4 (10-556) in the group that spent the winter in Greenhouse-1, 304.5 (24-465) in the Greenhouse-2 group that spent the winter in the field, In the group that spent the winter in Greenhouse-2, it was determined as 387.6 (85-598). The total number of eggs laid by females in each group was determined as 13706, 11039, 10660 and 10078, respectively (Yıldırım 2008).

Table 1
Effect of sex ratio on female egg production of *Plodia interpunctella* (Hübner) in dark medium with nutrients

Sex ratio (Male/female)	Number of Eggs laid (Number)		
	Least	The most	Average ± Standard error
1/1	63	204	129.00 ± 30.85 c*
2/1	128	166	147.75 ± 07.89 c
3/1	228	266	266.75 ± 07.45 ab
4/1	259	288	272.00 ± 06.54 ab
5/1	253	354	311.50 ± 20.03 a
6/1	245	280	264.75 ± 07.66 ab
7/1	237	275	254.75 ± 08.70 b

*There is no difference (P>0.05) between the means shown with the same letters in the same column.

Table 2
The effect of sex ratio on pre-oviposition, oviposition, post-oviposition times and female longevity of *Plodia interpunctella* (Hübner) females in nutrient dark environment

Sex ratio (Male and female)	Pre-oviposition, Oviposition, Post-oviposition Duration And Female Life (Days)			
	Pre-ovipozisyon (Least -most) AVG.±S.E.	Ovipozisyon (Least - most) AVG.±S.E	Post-ovipozisyon (Least - most) AVG.±S.E	Female lifespan.±S.E
1/1	(0.0-3.0) 1.00 ± 0.70 a*	(08-14) 10.00 ± 1.35 b	(1.0-2.0) 1.75 ± 0.25 a	12.50 ± 1.65 c
2/1	(0.0-2.0) 0.75 ± 0.47 a	(09-22) 14.00 ± 2.85 a	(0.0-2.0) 0.75 ± 0.47 b	15.75 ± 2.13 a
3/1	(0.0-1.0) 0.25 ± 0.25 a	(13-18) 15.00 ± 1.08 a	(0.0-2.0) 1.00 ± 0.40 b	16.25 ± 1.60 a
4/1	(0.0-0.0) 0.00 ± 0.00 a	(09-13) 10.25 ± 0.94 b	(0.0-2.0) 0.75 ± 0.47 b	11.50 ± 1.32 c
5/1	(0.0-0.0) 0.00 ± 0.00 a	(12-16) 14.00 ± 0.91 a	(0.0-0.0) 0.00 ± 0.00 c	14.00 ± 0.91 b
6/1	(0.0-0.0) 0.00 ± 0.00 a	(08-10) 09.00 ± 0.40 bc	(0.0-1.0) 0.25 ± 0.25 c	09.25 ± 0.47 d
7/1	(0.0-2.0) 1.00 ± 0.40 a	(05-07) 06.00 ± 0.40 c	(0.0-1.0) 0.25 ± 0.25 c	07.25 ± 0.47 e

*There is no difference (P>0.05) between the means shown with the same letters in the same column.

4.2. The Effect of Population Density on Egg Production of Plodia interpunctella (Hübner) Females on Pre-oviposition, Oviposition, Post-oviposition and Female Longevity

It was determined that the changes in the number of eggs laid by the female among the changing population densities were statistically significant**.** In this study, adult population densities of 3, 6, 9, 12, 15 were established in a fixed sex ratio (2 male / 1 female) of one-day-old adults. As seen in Table 3, the egg numbers of the population densities were determined as 147.75, 219.25, 360.08, 286.62 and 187.50 eggs, respectively. As seen in Table 3, while the highest egg number was 360.0 in 9 adult population density, the lowest egg number was 147.7 eggs in 3 population density. In addition, it was determined that there was an increase in the number of eggs from 3 population densities to 9 population densities, and a decrease in egg number from 9 population densities to 15 population densities. It was found that the effect of the population density on the pre-oviposition and post-oviposition times of the female was not statistically significant. It has been determined that the effect on oviposition time and female life is significant. Considering the effect of population density on female pre-oviposition time, it was determined that the longest pre-oviposition period was 0.50 ± 0.28 days in 3 and 6 adult population densities, while the shortest time was 0.00 ±

0.00 days in 12 and 15 adult population densities. Considering the oviposition period, it was determined that the longest period was 14.75 ± 0.47 days in the 9 adult population density, while the lowest oviposition period was 11.75 ± 0.75 days in the 12 adult population density. Considering the post-oviposition time, the longest post-oviposition time was found to be 1.25-0.62 days in the population density of 15 adults. Considering the effect of population density on female lifespan, it was determined that the longest female lifespan was 15.50 ± 0.50 days in 6 adult population densities, while the shortest lifespan was 12.25 ± 0.75 days in 12 adult population densities (Table 4). In his study, determined that *Anthocoris minki* males and females lay 22.7, 16.1 and 12.9 eggs at 250, 400 and 550 adult densities, respectively. Accordingly, as the density increased, the number of eggs laid by the females during their lifetime decreased. (Çoban 2015). In their study, it was determined that the average number of eggs laid per female during the egg laying period of *Orius albidipennis* at 25±1 ºC temperature and 65±5% proportional humidity conditions was 85.07±10.64 and the egg-laying rate was 69.01±6.29% (Büyük, M., & Kazak, C. 2010). Emphasized in her study that *Rhynocoris marginatus* with 4 different densities (25, 50, 75 and 100) that the ratio of the total number of eggs laid is higher at 50 predator densities and this rate decreases as the density increases (Sahayaraj 2002). As we determined in our study, as the density increased, an increase was detected in the number of eggs laid by a female, and a decrease was recorded after a certain density. These studies by researchers stating that increasing density has a negative effect on the egg production of the adult female support the data of our study.

Table 3
Effect of population density on female egg production of *Plodia interpunctella* (Hübner) in nutrient dark medium and constant sex ratio (2 males / 1 female)

Population density (Number of Adults) (2 Male / 1 female)	Number of Eggs Laid (Number)		
	Least	The most	Average ± Standard error
3	128.0	166.0	147.75 ± 07.89 d*
6	207.5	237.0	219.25 ± 06.50 c
9	349.0	379.3	360.08 ± 07.16 a
12	259.0	319.0	286.62 ± 15.61 b
15	150.4	258.3	187.50 ± 13.96 c

*There is no difference (P>0.05) between the means shown with the same letters in the same column.

Table 4
Effect of population density on pre-oviposition, oviposition, post-oviposition times and female longevity of *Plodia interpunctella* (Hübner) females in nutrient dark environment and constant sex ratio (2 males / 1 female)

Population density (Number of Adults) (2 Male / 1 female)	Pre-oviposition, Oviposition, Post-oviposition Duration And Female Life (Days)			
	Pre-ovipozisyon (Least -most) AVG.±S.E	Ovipozisyon (Least - most) AVG.±S.E	Post-ovipozisyon (Least - most) AVG.±S.E	Female lifespan.±S.E
3	(0.0-1.0) 0.50 ± 0.28 a*	(11-13) 12.00 ± 0.57 b	(0.0-1.0) 0.25 ± 0.25 a	12.75 ± 0.75 b
6	(0.0-1.0) 0.50 ± 0.28 a	(13-16) 14.50 ± 0.64 a	(0.0-1.0) 0.50 ± 0.28 a	15.50 ± 0.50 a
9	(0.0-1.0) 0.25 ± 0.25 a	(14-16) 14.75 ± 0.47 a	(0.0-1.0) 0.25 ± 0.25 a	15.25 ± 0.75 a
12	(0.0-0.0) 0.00 ± 0.00 a	(10-13) 11.75 ± 0.75 b	(0.0-1.0) 0.50 ± 0.28 a	12.25 ± 0.75 b
15	(0.0-0.0)0.00 ±0.00 a	(13-15) 14.00 ± 0.40 a	(0.0-3.0) 1.25 ± 0.62 a	15.25 ± 0.47 a

*There is no difference (P>0.05) between the means shown with the same letters in the same column.

5. Conclusions and Recommendations

In this study, the effects of sex ratio and population density on female egg production in the adult period of *P.interpunctella* were investigated. In addition, the effects of the above-mentioned living and non-living ecological factors in the adult period of Plodia interpunctella on female per-oviposition, oviposition, post-oviposition and lifespan were investigated. When the effect of the sex ratio on the female egg production was examined, it was determined that the female lays the most eggs with 312 eggs in the ratio of 5/1 (male / female) sexes. Considering the effect of population density on female egg production, it was found that females laid the highest number of eggs (360 eggs) at 9 adult density (2 male / 1 female fixed sex ratio). Although the effect of photoperiod on pre-oviposition and post-oviposition times was found to be statistically significant, it was stated that it was mostly between 0.0-1.75 days. In the effect of the photoperiod on the oviposition period, the longest duration was determined as 3 males / 1 female 15.0 in the sex ratio, and 14.7 days in the population density of 9 adults (2 male / 1 female fixed sex ratio). The effect of photoperiod on female lifespan is also statistically significant, and the sex ratio of the longest-lived female is 3 males / 1 female 16.2 days. It was determined that 6 adults (2 males / 1 females at a fixed sex ratio) were 15.5 days in population density. The number of eggs laid by the female increased until a certain population density (9 adults), and after this point, the number of eggs laid decreased as the density increased. In the sex ratio, the number of eggs laid by the female increased up to the ratio of 5 male / 1 female, while the number of eggs laid by the

female decreased as the sex ratio increased in favor of the male.

Recently, pesticides against pests have been used quite frequently and intensively. The effects of the drugs used, such as threatening human and animal health, drug residues in foodstuffs, environmental pollution and increased cost have also been added. For this reason, it has become necessary to switch to alternative environmentally friendly and cost-effective methods. Biological control is the most sustainable, cost effective and environmentally friendly method.In mass production of *P.interpuncella*, the highest number of eggs will be obtained from females if the adult population density is 9 and the sex ratio is 5 male/1 female and adult food is provided. This research will be useful in egg parasitoid research and in mass production of egg parasitoids in the supply of host eggs. It will contribute to the mass production needed in both laboratory and field researches about *P.interpunctella.*Thanks to the effects of living and non-living ecological factors on female egg laying behavior in the adult biological period of *Plodia interpunctella*, as well as the ecological factors affecting the pre-adult biological periods, efficient and effective mass production will be possible in the laboratory and insectarium. Many studies have been done about this pest before. When the studies we have done and previous studies are combined, scientific data on this harmful species will increase and it will contribute to both mass production and toxicological physiological studies.

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