J. of Plant Protection and Pathology, Mansoura Univ., Vol. 15 (1):45 - 49, 2024

Journal of Plant Protection and Pathology

Journal homepage & Available online at: www.jppp.journals.ekb.eg

Influence of Different Stored Grains on Adult Emergence Rates and Weight Loss by the Rice Weevil *Sitophilus oryza*e (Coleoptera: Curculionidae)

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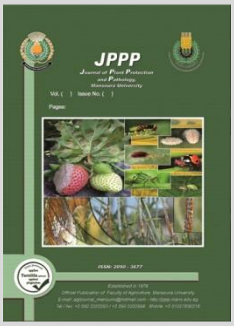

ABSTRACT

The internal-feeding insect, *Sitophilus oryzae* L. (Coleoptera: Curculionidae) is a ubiquitous and significant pest that burrows into grain that has been stored. The larvae of weevils feed mostly on the grain germ, eliminating a significant portion of the protein and vitamins, whereas adult weevils primarily feed on the endosperm, decreasing the amount of carbohydrates. In this study, *S. oryzae* infestation was monitored on five types of grains: rice, wheat, oat, maize, and barely. The grains were kept at 32 ± 2 °C, 65 ± 5% RH, and a 14:10 (L:D) h photoperiod. The results revealed that both wheat and maize were the most susceptible grains to the insect. Wheat grains were generally more preferred in both non-choice and free-choice tests, whereas oats were the least preferred in this respect. The different grains had a significant effect on adult emergence and weight loss by this insect. In non-choice test, the highest average number of the emerged adults of *S. oryzae* after 30 and 60 days was recorded on wheat grains (11.8±0.96 and 16.8±0.86 indiv.) followed by maize grains (8.8±1.15 and 15.2±1.56 indiv.), In free choice test, the highest average number of the emerged adults was recorded on wheat grains followed by maize grains and rice grains after 48 and 72 h from infestation.

***Keywords**:* Stored grains, biological aspects, feeding performance *Sitophilus oryzae.*

INTRODUCTION

Cereals are staple food and an important source of nutrients all over the world . Cereals and by-products contain a variety of micronutrients, including magnesium, zinc, vitamin E, and several B vitamins. They are also a significant source of energy, carbs, proteins, and fibres. In terms of cereal production worldwide, China leads the pack. China produced 580 million metric tons of cereal in 2016, which makes up 20.40 percent of the world's total production. Indonesia, Russia, India, and the US are the top five contributors, together accounting for more than 55% of the total cereal production**.** Rice, *Oryzae sativa* (Linn.), is the most important staple food for half of the world's population and an economically significant grain (Oko *et al*., 2012). According to Lal and Srivastava (1985) Wheat occupies the premier position among globally traded agricultural commodities, as evidenced by its dominant trade volume of 144 million tons and total annual value of 36 billion USD. This substantial trade volume and value highlight the crucial role wheat plays in global food security and agricultural markets (Shiferaw *et al*., 2013). Egypt is one of the biggest wheat-importing country in the world (Comtrade, 2015). pest insects destroy between 25 and 30 % of crop yields annually in both the field and in storage. Post-harvest losses of food grains in Egypt are estimated to be between 12 and 15 % annually (Yigezu *et al*., 2010)

These crops suffer greatly from insect pest infestations in addition to other biotic pressures. Moreover, the issues of developing insect pests are a result of things like anomalous weather, shifting crop patterns, and global warming. The annual grain loss attributable to insects and microorganisms in developing countries is estimated to range from $500 million to $1 billion (Campbell *et al.*, 2004). The rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), stands as a formidable and ubiquitous insect pest, infesting a vast array of stored cereals during storage Their feeding behavior further exacerbates the problem. Adult weevils primarily target the endosperm of the grain, a starchy tissue rich in carbohydrates. (Ahmed 2001; Sabbour 2012).. Researchers are working just as hard to identify strategies and solutions to lessen storage losses brought on by pest insects (Zaghloul *et al*., 2012).

Accordingly, the purpose of the current study was to evaluate the preference of *S. oryzae* for different stored grain varieties.

MATERIALS AND METHODS

Insect culture:

The rice weevil, *Sitophilus oryzae,* was bred using a local rice variety that is prone to infestation. The breeding process took place in a controlled environment with a temperature of 32 ± 2 °C, relative humidity of 65 ± 5%, and a light-dark cycle of 14 hours of light followed by 10 hours of darkness. The seeds underwent a two-week storage period at a temperature of -4 °C to eradicate various developmental phases of pests that could potentially be found in the kernels, as well as to discard seeds exhibiting evident signs of damage. A recently discovered strain of *S. oryzae* was placed into the buckets containing the grains that had been treated to remove any pests or pathogens. Adults were extracted from each bucket ten days following their introduction, and the containers were thereafter monitored untill appearance of offspring that starting 20 days after the insects were introduced. The insect culture was built to provide a sufficient number of insects at various ages for subsequent tests.

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DOI: 10.21608/jppp.2024.258681.1201

The trials were conducted at the laboratory of the Economic Entomology Department, Faculty of Agriculture, Mansoura University.

Preparation of grains for susceptibility tests:

The grains tested, including wheat, rice, barley, corn, and oats, are sourced from the Crop Research Institute, Sakha Agricultural Research Station, Kafr-El-Sheik, Ministry of Agriculture, Egypt. The initial step was the sieving of ample amounts of all varieties of grains to eliminate any stones, dust, or insects. The various varieties of grains were stored in an incubator at a consistent temperature of 30 ± 1 °C and a relative humidity of 65 ± 5% for two weeks. This allowed the grains to reach a moisture content that was in equilibrium with the given relative humidity (Ezz, 1976). Two sets of experiments were conducted to assess the comparative vulnerability of the investigated grains. One of them involved a voluntary infestation, while the other involved an involuntary infestation. The studies were carried out at a temperature of 30±1°C, a relative humidity of 65±5%, and a light-dark cycle of 14 hours of light followed by 10 hours of darkness.

Non-choice infestation test:

The study employed a non-choice test strategy, where predetermined insects were carefully delivered into each jar (Abebe *et al.*, 2009). Five grams of each grain species were measured and placed into plastic jars with a capacity of 250 grams. The plastic jars facilitated aeration while effectively impeding the escape of insects. Twenty adult pairs, aged between 7 and 10 days, were placed into individual plastic jars. The insects were permitted to lay eggs on the grains for 10 days, then they were removed. The complete arrangement was thereafter placed in the laboratory, maintaining a temperature of 30±1°C and a relative humidity of 65±5%, until the initial adults of the F1 generation emerged. The specimens were systematically extracted and tallied at regular intervals, often daily, across a span of 30 and 60 days until the complete emergence of all F1 offspring was anticipated.

Free choice infestation test:

The experiment involved determining the incidence and oviposition preference using the free choice test. A muslin-covered circular cage with a diameter of 17.5 cm and a thickness of 7.5 cm was used for this purpose. The interior of the cage was partitioned into five sections, with each section containing 5 grams of grains (wheat, rice, barley, corn, and oats). The infestation was initiated by introducing 15 pairs of *S. oryzae* (10 days old) into the central area of the cage. Subsequently, the upper part of the cage was concealed. The insect was permitted to engage in oviposition for ten days. The grains were individually isolated, including mature insects, and stored in plastic jars weighing 250 g each. The trials were conducted using a completely randomized design and were replicated five times. The number of attracted insects and weight loss evaluated after 24, 48, 72 h. while the number of emerged insects was assessed for each dish after 30 and 60 days. The weight loss % resulting from the weevil determined according to the following equation.

$$\boldsymbol{Weight\ Loss}\ \% = \boldsymbol{WI} - \left(\frac{\boldsymbol{WF}}{\boldsymbol{WI}}\right) \times \mathbf{100}$$

when

WI and WF represent the initial and final weights of the samples.

Statistical analysis:

Data were analysed using One-way ANOVA and regression analyses in the SPSS software program and in case of significant, means separated using Duncan's Multiple Range test (Duncan, 1955).

RESULTS AND DISCUSSION

Results

1- Non-choice tests:

Data arranged in Table (1) show the effect of different stored grains on some biological aspects of *S. oryzae* in a non-choice test under laboratory conditions (30±1°C, 65±5% RH). The highest average number of the emerged adults of *S. oryzae* after 30 and 60 days were recorded on wheat grains (11.8±0.96 and 16.8±0.86 indiv.), followed by maize grains (8.8±1.15 and 15.2±1.56 indiv.). Meanwhile, the lowest average number of emerged adults of *S. oryzae* after 30 and 60 days were recorded on oat grains and represented by 2.2±0.58 and 2.6±0.05 indiv., respectively.

Statistical analysis revealed that there was a significant difference between the average number of weevils that emerged after 30 days or 60 days.

Table 1. The average number of *Sitophilus oryzae* adults emerged after 30 and 60 days from different cereal grains.

Adult Emergence Stored grains	Av. No. of emerged adults after 30 days	Av. No. of emerged adults after 60 days
Wheat	11.8±0.96a	16.8±0.86a
Maize	8.8±1.15b	15.2±1.56a
Rice	6.6±0.97b	6.4±0.50b
Barely	3.8±0.58c	3.6±0.74c
Oat	2.2±0.58c	2.6±0.05c

Means bearing the same letters in a column are not significantly different at 0.05 probability level (Duncan's Multiple Range Test)

Data illustrated in Figure (1) shows the average weight loss after 30 and 60 days for *S. oryzae* on different grains in non-choice test. It can be noticed that the rice and maize grains recorded the highest average weight losses after 30 or 60 days from insect infestation and these losses represented by 1.7 and 1.5 grams after 30 days and 2.4 and 2.06 grams after 60 days. Oat grains were less infested after 30 and 60 days from insect infestation and weight loss represented by 0.72 and 0.68 grams, respectively.

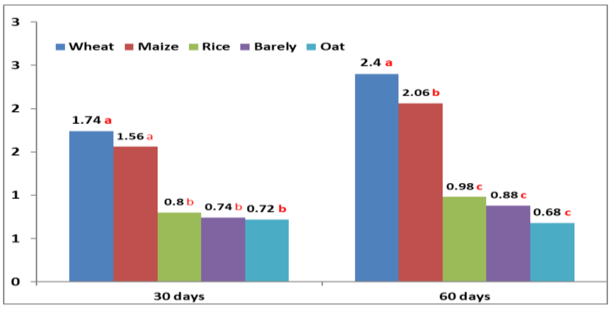

Fig. 1. Mean of weight loss after 30 and 60 days infestation by *Sitophilus oryzae* on different grains.

2- Free-choice tests:

The present results arranged in Table (2) show the average number of the attracted adults after 24 h and the emerged adults of *S. oryzae* in the different stored grains after 30 and 60 days. From infestation, the highest average number of the emerged adults was recorded in rice grains, followed by wheat grains and maize grains after 24 h from infestation, and presented by 8.4±0.50, 7.0±0.70, and 6.8±0.9 indiv., respectively. Statistical analysis revealed that there were highly significant differences between the different stored grains according to free-choice tests after 24 hours of infestation. After 30 days from infestation, rice grains had the highest number of emerged adults, followed by wheat grains and maize grains, and presented by 19.0±1.97, 16.8±2.53, and 10.0±1.58 individuals, respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 30 days of infestation. After 60 days from infestation, rice grains had the highest number of emerged adults, followed by wheat grains and maize grains, and were presented by 34.2±1.52, 31.2±2.22, and 21.4±2.54 individuals, respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 60 days of infestation.

Table 2. Average number (±SE) of attracted adults to grains after 24 h and emerged adults after 30 and 60 days of *Sitophilus oryzae* on different grains.

Adult emergence / Stored grains	Number of attracted adults after 24 h	Number of emerged adults after 30 days	Number of emerged adults after 60 days
Rice	8.4±0.50a	19.00±1.97a	34.2±1.52a
Wheat	7.00±0.70ab	16.8±2.53a	31.2±2.22 a
Maize	6.8±0.96 ab	10.00±1.58 b	21.4±2.54b
Barely	4.00±0.8b	7.8±2.26 b	11.4±2.92c
Oat	3.8±1.01b	6.4±2.08b	9.8±2.59c

Means bearing the same letters in a column are not significantly different at 0.05 probability level (Duncan's Multiple Range Test).

Data illustrated in Figure (2) show the average weight loss after 24 h, 30, and 60 days for *Sitophilus oryzae* for different stored grains according to free choice tests. It can be noticed that rice grain and wheat grain recorded the highest average weight loss after 24 h, 30, and 60 days from insect infestation and presented by 0.75 and 0.68 grams, or 3.0 and 2.84 grams, or 3.56 and 3.44 grams, respectively. Oat grains ranked in the last category after 24 hours, 30 days, and 60 days from insect infestation and were represented by 0.16, 0.82, and 1.44 grams, respectively.

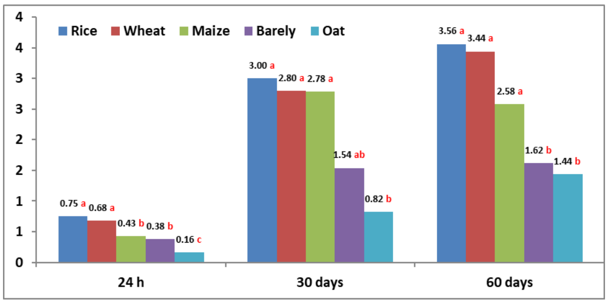

Fig. 2. Weight losses by the rice weevil, *Sitophilus oryzae* after 24 h, and 30 and 60 days. The means followed by different letters are significantly different at 0.05 probability level (Duncan's Multiple Range Test).

The present results arranged in Table (3) show the average number of attracted adults after 24 hours and the emerged adults of *S. oryzae* in the different stored grains after 30 and 60 days of infestation. After 48 hours from infestation, wheat grains had the highest average number of emerged adults, followed by maize grains and rice grains, with 12.0 1.30, 8.6 0.24, and 5.6 0.67 indiv. Statistical analysis revealed that there were highly significant differences between the different stored grains according to free-choice tests after 24 hours of infestation. After 30 days from infestation, wheat grains had the highest number of emerged adults, followed by maize grains and rice grains, presented by 22.0±1.76, 19.8±2.78, and 11.2±1.93 indiv., respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 30 days of infestation. After 60 days from infestation, wheat grains had the highest number of emerged adults, followed by maize grains and rice grains, and presented by 26.8±0.86, 24.8±0.86, and 20.8±1.56 indiv., respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 60 days of infestation.

Data illustrated in Fig. (3) show the average weight loss after 24 h, 30 days, and 60 days for *Sitophilus oryzae* for different stored grains according to free choice tests.

Table 3. Average number (±SE) of attracted adults after 48 h and emerged adults after 30 and 60 days of *Sitophilus oryzae* from different grains.

Biological Aspects / Stored grains	Number of attracted individuals after 48 h	Number of emerged individuals after 30 days	Number of emerged individuals after 60 days
Wheat	12.00±1.30a	22.00±1.76a	26.6±2.58a
Maize	8.6±0.24b	19.8±2.78a	24.8±0.86a
Rice	5.6±0.67c	11.2±1.93b	20.8±1.56a
Barely	2.8±0.58d	4.4±1.36c	5.6±1.80b
Oat	1.00±0.44d	2.4±1.28c	5.2±2.13b

Means bearing the same letters in a column are not significantly different at 0.05 probability level (Duncan's Multiple Range Test)

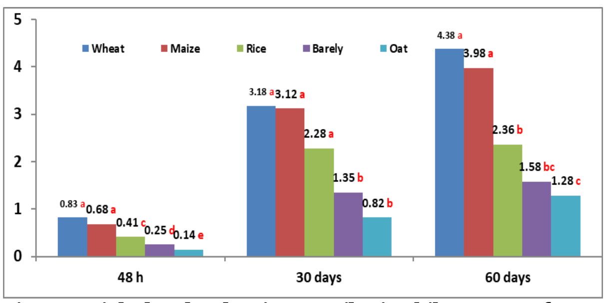

Fig. 3. Weight loss by the rice weevil, *Sitophilus oryzae* after 48 h,and 30 and 60 days. Means followed by different letters within each duration are significantly different (Duncan's Multiple Range Test, P< 0.05).

It can be noticed that wheat grain and maize grain recorded the highest average weight loss after 48 hours, 30 days, or 60 days from insect infestation and presented 0.83 and 0.68 grams, or 3.18 and 3.12 grams, or 4.38 and 3.98 grams, respectively. Oat grains ranked in the last category after 48 h, 30 days, and 60 days from insect infestation and were represented by 0.14, 0.82, and 1.28 grams, respectively.

The present results arranged in Table (4) show the average number of the attracted adults after 72 h and the emerged adults of *S. oryzae* in the different stored grains after 30 and 60 days from infestation. The highest average number of the emerged adults was recorded in wheat grains, followed by maize grains and rice grains after 72 h from infestation, and presented by 13.0±1.00, 9.0±0.31, and 5.0±0.89 indiv., respectively. Statistical analysis revealed that there were highly significant differences between the different stored grains according to free-choice tests after 72 hours of infestation. After 30 days from infestation, wheat grains had the highest number of emerged adults, followed by maize grains and rice grains, and were presented by 24.0±2.02, 21.8±2.31, and 9.4±1.72 indiv., respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 30 days of infestation. After 60 days from infestation, wheat grains had the highest number of emerged adults, followed by maize grains and rice grains, and presented by 31.4±2.15, 28.6±1.02, and 19.2±1.35 indiv., respectively. Statistical analysis revealed non-significant differences between the different stored grains according to free-choice tests after 60 days of infestation.

Table 4. Average number (±SE) of attracted adults after 72 h and emerged adults after 30 and 60 days of *Sitophilus oryzae* from different grains.

Adult emergence Stored grains	Number of attractive individuals after 72 h	Number of emerged individuals after 30 days	Number of emerged individuals after 60 days for
Wheat	13.00±1.00a	24.00±2.02a	31.4±2.15a
Maize	9.00±0.31b	21.8±2.31a	28.6±1.02a
Rice	5.00±0.89c	9.4±1.72b	19.2±1.35b
Barely	1.8±0.58d	2.8±1.24c	4.6±2.11c
Oat	1.2±0.58d	1.6±0.97c	4.2±2.61c

Data illustrated in Fig (4) show the average weight loss after 72 hours, 30, and 60 days for *Sitophilus oryzae* for different stored grains according to free choice tests. It can be noticed that wheat grain and maize grain recorded the highest average weight loss after 72 h, 30, or 60 days from insect infestation and presented by 0.85 and 0.73 grams, or 3.56 and 3.50 grams, or 4.06 and 4.56 grams, respectively. Oat grains were ranked in the last category after 72 h, 30, and 60 days from insect infestation and were represented by 0.12, 0.44, and 0.56 grams, respectively.

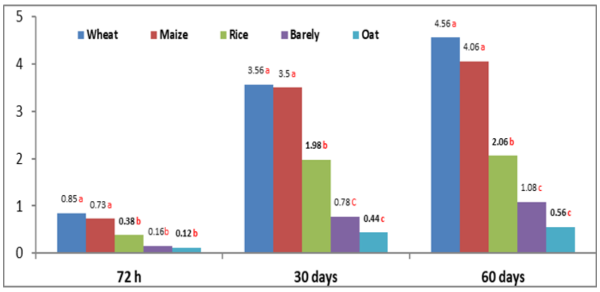

Fig. 4. the weight loss according to the infestation with the rice weevil Sitophilus oryzae after 72 h & 30 and 60 days. Average with the same letters for each duration are significantly different (Duncan's Multiple Range Test, P< 0.05).

Discussion

The obtained results showed that there were significant differences on the attractiveness of different tested cereals and the most attractive grain species were rice and wheat and this result was somehow dis agree with Subedi *et al.* (2009) who reported that the lowest level of attractiveness as a host for *S. oryzae* in comparison to other cereals such as rice, barley, and maize and this might because of the cultivar or the ecological conditions differences. In addition, they agreed that there was a difference in the number of insect offspring resulting from different types of grains, the best types of grains in producing offspring were wheat and rice, and the least was barley, and this was in line with the same direction as the results reached by our research.

The results of the non-choice test indicated that wheat was the best for the insect in terms of the number of offspring. It was also the host that lost the most weight compared to the other types of grains that were hidden. These results were in line with the results of Bhargude *et al.* (2021) who observed that the population of adult rice weevils after 30 days showed a considerable decrease in rice (9) and reached its highest level in wheat (42). Maize, barley, sorghum, and pearl millet experienced an increase in population, with 13.33, 30.33, 40.67, and 41.67 adults respectively after 30 days. And this also agreed with Yevoor (2003) and Akhter *et al.* (2017).

The grain weight loss caused by the insect varied between different grains, and this result agreed with the results of Subedi *et al.* (2009). Who investigated that Wheat (17.72% weight loss) was identified as the most suitable host for *S. oryzae*, followed by polished rice (11.57% weight loss), with a substantial distinction between the two. Rough rice exhibited the smallest degree of weight reduction, 3.40%. Maize (7.18%) and barley (9.18%). And Yevoor (2003) found that all cereal crops showed varying levels of weight loss, with pearl millet (28.70%), wheat (23.74%), barley (20.63%), and sorghum (19.68%) being the most heavily affected in terms of weight loss. In general, the degree of seed damage and weight loss dramatically increased in cereals when the storage time was beyond four months. our results showed different attractiveness ability between different tested grains and this was in agreement with the results of Kudachi and Balikai (2014) and Ansari (2003) and Bulo *et al.* (2018) observed that rice weevils exhibited diverse orientations towards various sorghum genotypes when given the freedom to choose.

The susceptibility or resistance of grain species to insect infestation might be influenced by several factors. García-Lara *et al.* (2004) and Bamaiyi *et al.* (2007) suggest grain hardness as a potential determinant, with harder grains likely presenting a physical barrier that hinders oviposition and larval entry. Additionally, Matthew *et al.* (1990) highlights the role of genetic variation among varieties, suggesting that specific genetic traits can confer inherent resistance against certain insect pests. Furthermore, Evers *et al.* (1999) and Gupta *et al.* (2000) emphasize the significance of grain structure and chemical composition, including starches, carbohydrates, proteins, and enzymes. Variations in these elements can influence palatability, digestibility, and the presence of secondary metabolites that act as antifeedants or toxins, ultimately impacting insect preference and performance.

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تأثير الأنواع المختلفة للحبوب المخزونة على معدل خروج الحشرات الكاملة ونسبة الفقد بواسطة سوسة الأرز

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الملخص

حشرة سوسة الأرز هي حشرة تتغذى داخلياً *Sitophilus oryzae* L. (Coleoptera:Curculionidae) وهي آفة هامة منتشرة في كل مكان وتحفر في الحبوب التي تم تخزينها. تتغذى يرقات السوس في الغالب على جنين الحبوب، مما يؤدي إلى فقد من جزء كبير من البروتين والفيتامينات، بينما تتغذى الافراد البالغة في المقام الأول على السويداء، مما يقلل من كمية الكربوهيدرات. قامت هذه الدراسة بتقييم الإصابة بـ *S. oryzae* على خمسة أصناف (الأرز والقمح والشوفان والذرة والشعير) من خلال اختبارين حيويين (اختبارات الاختيارية وعدم الاختيار) عند 32 ± 2 درجة مئوية، و65 ± 5٪ رطوبة نسبية، وفترة ضوئية. من 14: 10 (ل: د) ح. أظهرت النتائج أن كلا من القمح والذرة هما الأكثر عرضة للإصابة بالحشرة. وكانت حبوب القمح أكثر تفضيلاً بشكل عام في طرق اختبار الاختيارية أو عدم الاختياري، في حين كان الشوفان هو الأقل في هذا الصدد. كان للحبوب المختلفة تأثير معنوي على النواحي البيولوجية التي تناولها هذا البحث. في اختبارات عدم الاختيارية، تم تسجيل أعلى متوسط لعدد الأفراد اليافعة التي ظهرت من سوسة الأرز بعد 30 و60 يومًا على حبوب القمح (11.8 ± 0.96 و16.8 ± 0.86 فردًا) تليها حبوب الذرة (8.8 ± 1.15 و15.2 ±1.56 فردًا)، في اختبارات الاختيار الحر، تم تسجيل أعلى متوسط لعدد الأفراد اليافعة التي ظهرت، في حبوب القمح تليها حبوب الذرة وحبوب الأرز بعد 48 و72 ساعة من الإصابة.