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COMPARATIVE BIOLOGICAL TRAITS OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER) (LEPIDOPTERA: GELECHIIDAE) ON SELECTED FOOD GRAINS UNDER LABORATORY SETTING

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Abstract

Sitotroga cerealella (Oliv.) (Lepidoptera: Gelechiidae) is a factitious host of the biocontrol agent *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae), an egg parasitoid of lepidopterous pests. The biological traits of *S. cerealella* are important to be studied for the improvement and mass scale rearing of *T. chilonis*. Usually, *S. cerealella* is reared on wheat grains but for better rearing there is need to test more food sources. For this, the research activity was conducted to examine the effect of different food grains viz., chickpea, maize, oat, wheat and split chickpea on the life history traits of *S. cerealella* under controlled conditions i.e., 30 ± 2°C temperature and 60 ± 5% R.H. with 12 L:12 D h. photoperiod. Results showed that maximum mean adult emergence (83.0 ± 5.2 adults) and longest development rate (18.0 ± 1.1 days) was recorded in oat. Shortest developmental time, longest adult longevity and maximum adult weight was recorded in maize that was 27.5 days, 7.2 days and 0.9 mg respectively. Highest mean fecundity (99 eggs/female) and egg hatch rate (86.2%) was recorded in wheat which was statistically at par with oat (fecundity = 91.3 eggs/female and egg hatch rate = 84.1%). It is concluded that oat and maize proved to be the best alternative of wheat in terms of progeny development and mass scale rearing of *S. cerealella* in the laboratory.

Key words: *Sitotroga cerealella*, development rate, progeny development, life history traits, mass rearing

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Introduction

Grains are an important food commodity in the world and play significant role in enhancing the economy of many countries. Grains are stored for shorter or longer period to ensure the availability round the year and meet the feeding demand of expanding human population in the developing countries. Most of the quantity of grains are stored by the farmers for seed and consumption purposes. In Pakistan, the capacity for storage of food grains in stores and godowns is inadequate (4.34 million tonnes) and other factors such as elevated atmospheric temperature (25 - 35°C), relative humidity (> 60%) and more than 12% moisture content of grains in storages make environment conducive for the development and proliferation of stored grain insect pests. As a result, insects cause economic losses ranging from 5 to 30 percent (Adams, 1998; Ahmad *et al*., 1998; Ahmad and Ahmad, 2002).

Among stored grain insects, Khapra beetle (*Trogoderma granarium*), Rice weevil (*Sitophilus oryzae*), Lesser grain borer (*Rhyzopertha dominica*), Wheat weevil (*Sitophilus granarius*), Saw-toothed grain beetle (*Oryzaephilus surinamensis*), Angoumois grain moth (*Sitotroga cerealella*) and Maize weevil (*Sitophilus zeamais*) are the major primary insects that deteriorate the quality as well as quantity of food grains and make unfit for human consumption (Iqbal *et al.,* 1988; Sana *et al*., 2000; Shafique and Ahmad, 2003; Chughtai *et al.,* 2002; Ahmad and Raza, 2010; Khalique *et al.,* 2018).

Sitotroga cerealella is an important insect pest of stored grains however it is also a factitious host of many beneficial insects such as egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae), green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) and different lady beetle species (Coleoptera: Coccinellidae). It is an insect of warm temperate and subtropical regions of the world that feeds on variety of grains both in field and storeroom (Hashem *et al*., 2014). It has become cosmopolitan in distribution and transported easily unnoticed throughout the world. The insects remain active throughout the year except peak winter when activity of *S. cerealella* goes slow down (Ahmed *et al*., 2014). The adult of *S. cerealella* is straw-coloured or yellowish-brown measuring about 1/3rd inch long with a wingspan of 1/2 inch. Freshly laid eggs are white in colour but soon turned into red. Adults remain

unfed in the commodity while neonates bore into the grains and produces large cavity privileged the infested grain (Weston and Rattlingourd, 2000).

Since insects obtain nutrients and energy from food; the diet quantity and quality are basic factors that potentially influence the biological activities of insects i.e., development, survival, and reproduction (Nayaa *et al*., 2007; Salman *et al*., 2022). Insects have higher growth rate with lower developmental time that feed on diets with less harmful allelochemicals (Bin *et al*., 2011). The defensive system of host plants inhibits the releases of digestive enzymes in insect pests such as secondary metabolites and plant proteinaceous inhibitors may affect grains suitability for *S. cerealella*. Insect becomes vulnerable to environmental factors when interference occurred with food digestion (Borzoui and Bandani, 2013). The fitness characteristics of insect pests such as growth rate, development, fecundity and fertility have greatly influenced by the energy reserves viz., glycogen, total protein and lipid contents (Blanckenhorn *et al*., 2007). Energy reserves are an indicative biomarker of biological activities in insects, and variation in them considered as an index of stressful conditions (Sanchez–Paza *et al*., 2006). It is assumed that the tested grains with different nutritional and physical characteristics can influence the biological traits and host preference of *S. cerealella* insect. It has been observed that *S. cerealella* have a longest life cycle, least fecundity and fertility, and lowest survival rate on sorghum, while its cycle is considerably shortest with high fecundity and fertility, and highest survival rate on wheat and triticale (Borzoui *et al*., 2016).

The previous research studies were mainly focused on the occurrence, development, harmfulness, and management of *S. cerealella* while evidences about its laboratory rearing, as a factitious host for many biocontrol agents and development in different grains are rare, despite the high scope of availability of other host plant products for the mass rearing of *S. cerealella*. The objective of the current study was to examine the effect of various food grains as feed diets, namely oat, maize, chickpea, wheat and split chickpea on the biological traits of *S. cerealella* under laboratory conditions. Such type of studies could be helpful in designing the mass rearing protocol based on host plant suitability by knowing the effect of nutritional and physical characteristics of numerous food grains for *S. cerealella*. Furthermore, host preference study of *S. cerealella* to the tested grains would be helpful in maintaining the laboratory culture of insect on suitable host grains for future experiments.

Materials and Methods

The current research activities were performed to appraise the effect of different stored grains on the biological traits of *S. cerealella* in the Stored Grain Laboratory, Nuclear Institute for Food and Agriculture, Peshawar. Study was conducted in the controlled conditions at 30 ± 2°C temperature and 60 ± 5% relative humidity with 12 L: 12 D h. photoperiod.

Food material

Five different food grains i.e., oat, wheat, chickpea, maize and split chickpea were obtained from local market, Peshawar and conditioned at 4°C for at least seven days in the laboratory prior to the experiment. The moisture contents (%) of the tested grains were determined by using Grain Moisture Tester (Dickey-john®, Auburn, Alabama, USA) and listed in Table 1. The initial weight of 50 g was used for each grain in the experiment with three replications.

Table 1. List of selected grains used for life parameters of *Sitotroga cerealella*

Common name	Average number of grains/50 g	Moisture content (%)
Wheat	1310	11.8
Oat	1703	10.9
Chickpea	145	12.4
Maize	301	16.1
Split chickpea	719	12.9

Insect material

Adults of *S. cerealella* have been reared on wheat in the stored grain laboratory since last ten years. The insect reared on healthy wheat grains in 2.5 L plastic jars and mouth of jars were covered with muslin cloth and tightened with rubber band for proper ventilation. The laboratory conditions for insect rearing were maintained at 30 ± 2 °C temperature, 60 ± 5% relative humidity and 12 L: 12 D h. photoperiod throughout the study.

Experiments on biological traits of S. cerealella

Adult emergence and Development rate

Prior to experimentation, 50 g sample of grains were shifted into 275 mL glass jars. One hundred eggs of *S. cerealella* (1 - 2 days) were glued on white cards and placed in each glass jar. Mouth of jars was covered with nappy liner and tightened with rubber band. These jars were then checked daily, and adult emergence was recorded each day by allowing the calculation of average total adult emergence (Nos.), developmental time (time between egg inoculation to adult emergence) and development rate (total number of days in which adult emergence recorded).

Fecundity and Egg hatch rate

Egg laying capacity (fecundity) and egg hatching rate (fertility) were studied on each tested food by shifting 1 male and 1 female as pair from newly emerged adults of *S. cerealella* into glass vials (6 × 3 cm). Eggs were collected by following the methodology of Consoli and Filho (1995) with some modification. In brief, nappy liner strips were used for the collection of eggs in glass vials. The strips with eggs of *S. cerealella* then removed daily and counted number of eggs until the female death. Collected eggs were placed separately in glass vials for hatching. All collected eggs were monitored daily for the number of successfully hatched eggs. These experiments were done with ten replicates for all the food grains.

Adult weight and Adult longevity

For adult weight, the un-sexed ten newly emerged adults from each food grain diet were selected randomly and weighed on an electronic balance. Then weight for one adult was calculated by dividing the total weight on number of adults. For adult longevity, the un-sexed fifteen newly emerged adults from each diet were collected and shifted in glass vials without food. The adults were examined daily until the adult death and data recorded. These experiments were repeated thrice to estimate the accurate results.

Statistical analyses

All data were analyzed with the help of Statistix version 8.1 (Analytical software, 2005). One-way ANOVA was carried out to check the effect of different food grains on the biological traits of *S. cerealella*. Least significance difference test was used to compare the statistical differences among the means at $\alpha = 0.05$.

Results and Discussion

Adult emergence and Development rate

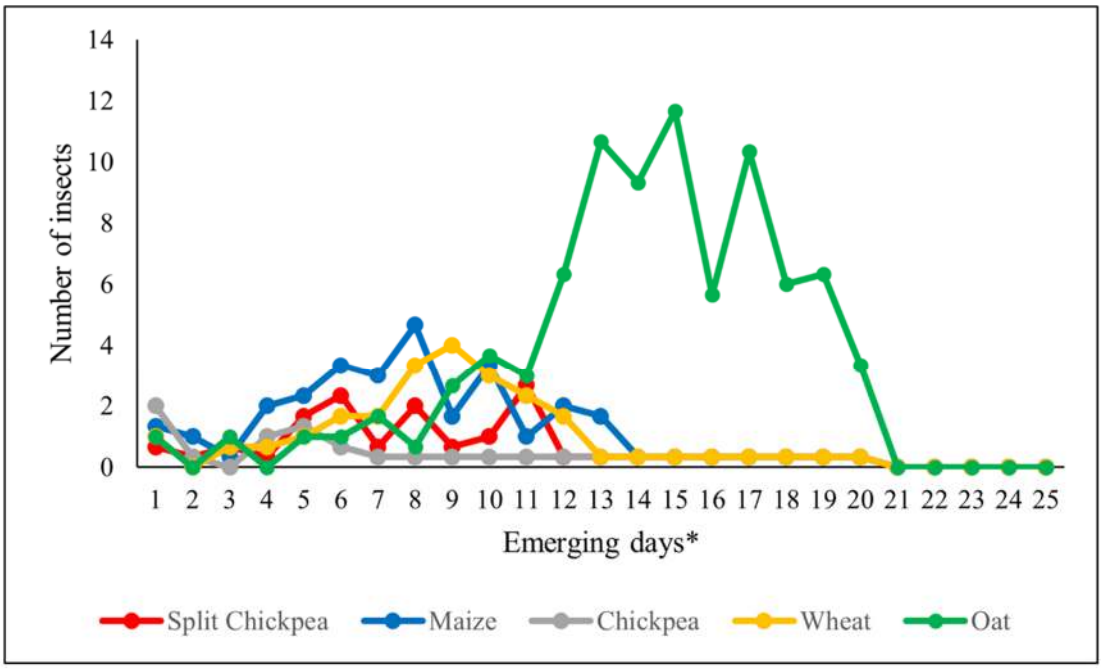
Developmental time, development rate and average total adult emergence of *S. cerealella* varied significantly among all the tested food grains ($P < 0.05$). The earliest adult emergence was recorded in maize after 27.5 days, while the longest time interval (34.1 days) for adult emergence was recorded in chickpea (Table 2). Results of developmental time in oat (29.6 ± 1.09 days) was statistically at par with wheat (32.6 ± 0.60 days), split chickpea (32.8 ± 0.60) and maize (27.5 ± 2.00 days) as shown in Table 2. The type of food grain significantly influenced the development rate of *S. cerealella* (Table 2). The highest development rate (18.0 days) was found in oat while lowest (3.7 days) in chickpea. The development rate for other food grains were 11.7, 10.7 and 9.3 days for maize, wheat and split chickpea respectively (Table 2). The total number of *S. cerealella* adults emerged during each emerging day is shown in Figure 1. Moreover, the highest mean adult emergence (83.0 adults) was recorded in oat and the lowest (5.3 adults) on chickpea. The average total adult emergence i.e., 62.7, 28 and 13.0 adults of *S. cerealella* were recorded for wheat, maize and split chickpea respectively (Table 2).

Table 2. Biological traits (mean ± SE) of *S. cerealella* reared on five different grains

Food grain	Parameters		
	Developmental time (Days)	Development rate (Days)	Average total adult emergence (No.)
Oat	29.6 ± 1.09 bc	18.0 ± 1.1 a	83.0 ± 5.2 a
Wheat	32.6 ± 0.60 ab	10.7 ± 1.2 c	62.7 ± 10.6 b
Split chickpea	32.8 ± 0.60 ab	9.3 ± 1.2 c	13.0 ± 1.2 cd
Chickpea	34.1 ± 0.17 a	3.7 ± 0.3 d	5.3 ± 0.7 d
Maize	27.5 ± 2.00 c	11.7 ± 0.3 b	28.0 ± 5.1 c

Means within a column followed by different lowercase letters are statistically significant at α= 0.05.

Findings of previous researchers revealed that different types of host food effects the developmental rate of stored grain insects (Wong and Lee, 2011). Our results showed that maximum adult development rate was recorded in oat followed by maize, wheat, split chickpea and chickpea. Consumption of quality di*et al*so influence the progeny development and fitness of *S. cerealella*. Table 2 showed that maximum mean adult emergence was recorded in oat followed by wheat and maize, split chickpea and chickpea. Borzoui *et al*. (2016) recorded in their experiment that maximum adult emergence was recorded in triticale followed by wheat, maize, barley, rye and sorghum.



*Number of days from 1st emergence to last emergence of *S. cerealella*

Figure 1. Development rate and number of *S. cerealella* adults on different food grains.

Fecundity and Egg hatch rate

Fecundity and fertility (egg hatch rate) of *S. cerealella* were found statistically significant on different food grains ($P < 0.05$). The maximum mean number of eggs (99.0 eggs) were laid by females reared on wheat and the minimum (45.6 eggs) was from females reared on split chickpea

(P = 0.000). The mean fecundity for oat was 91.3 eggs/ female which was statistically at par with mean fecundity for wheat (Figure 2).

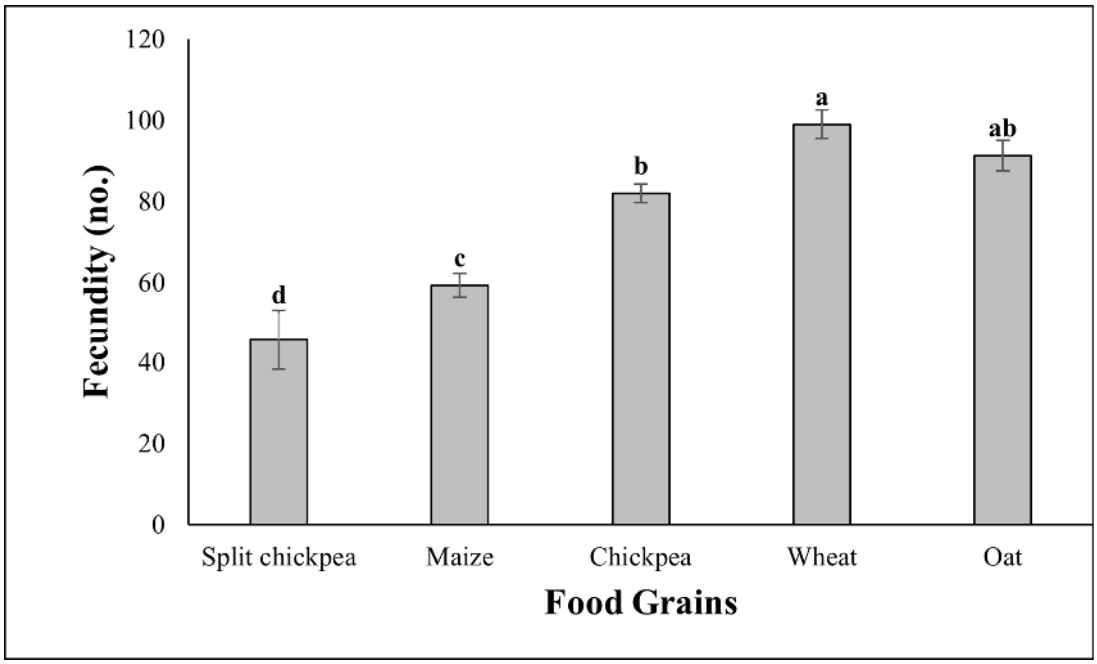


Figure 2. Average fecundity of *S. cerealella* on different food grains.

Also, among five different tested food grains, the highest mean egg hatch rate/ fertility (86.2%) was recorded on wheat, and the lowest (72.4%) was obtained on maize (P = 0.049). The mean fertility for oat was 84.1% that statistically at par with mean fertility for wheat (Figure 3). The continuous mass rearing of insects on same food may lose some attributes like fecundity and fertility etc. Fouad *et al.* (2013a) recorded that seed hardness is a crucial part of host susceptibility for *S. cerealella*. Better quality of food increases the fecundity and fertility rate of insect and increase the population growth. In this respect, oat and wheat showed high fecundity and fertility as compared to other tested grains. Findings of the experiment suggested that the quality of consumed food having significant effect on fitness of *S. cerealella*.

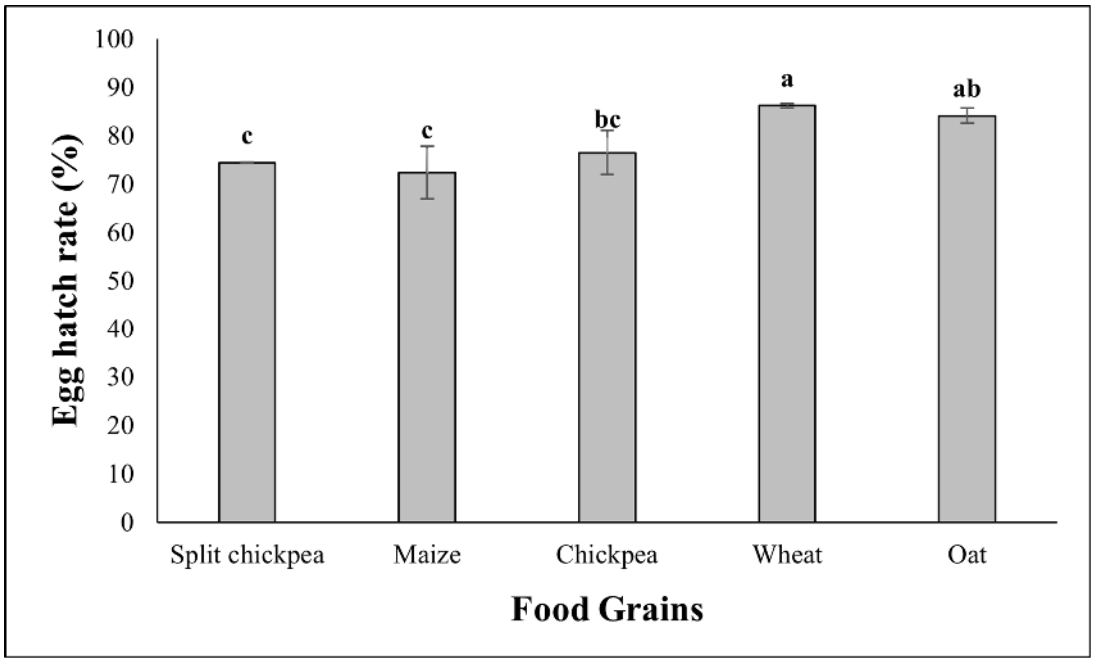


Figure 3. Average egg hatching/ fertility of *S. cerealella* on different food grains.

Adult weight and Adult longevity

Statistically significant difference was recorded in adult weight while non-significant difference was seen in adult longevity when fed on different foods. Adults came from maize were heavier than other tested grains ($P = 0.012$). The average adult weight of *S. cerealella* calculated from different grains viz., maize, chickpea, split chickpea, wheat and oat was 0.9, 0.8, 0.7, 0.6 and 0.6 mg respectively (Figure 4). The results of adult weight are agreed with the findings of Hamed and Nadeem (2012) who reported that maximum adult weight was gained by *S. cerealella* after feeding on maize than other cereals i.e., wheat, paddy, barley, millet and sorghum.

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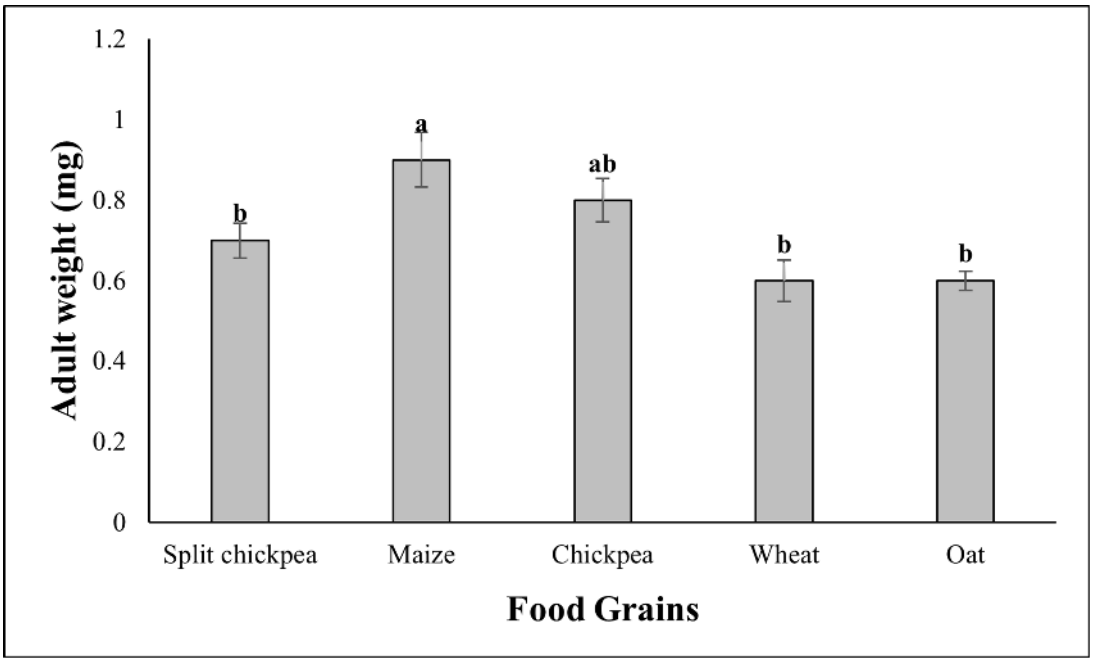

Figure 4. Average adult weight of *S. cerealella* on different food grains.

Moreover, maximum mean longevity (7.2 days) of *S. cerealella* adults was recorded in maize while minimum in chickpea i.e., 4.7 days ($P = 0.156$). The mean longevity i.e., 5.9, 5.1, 5.1 days was recorded for oat, wheat and split chickpea respectively (Figure 5). The results of adult longevity are in line with the findings of other reports (Saikia *et al*., 2014). Greenberg *et al.* (2002) suggested that higher survivorship and shorter development time can lead to higher growth index of *S. cerealella*.

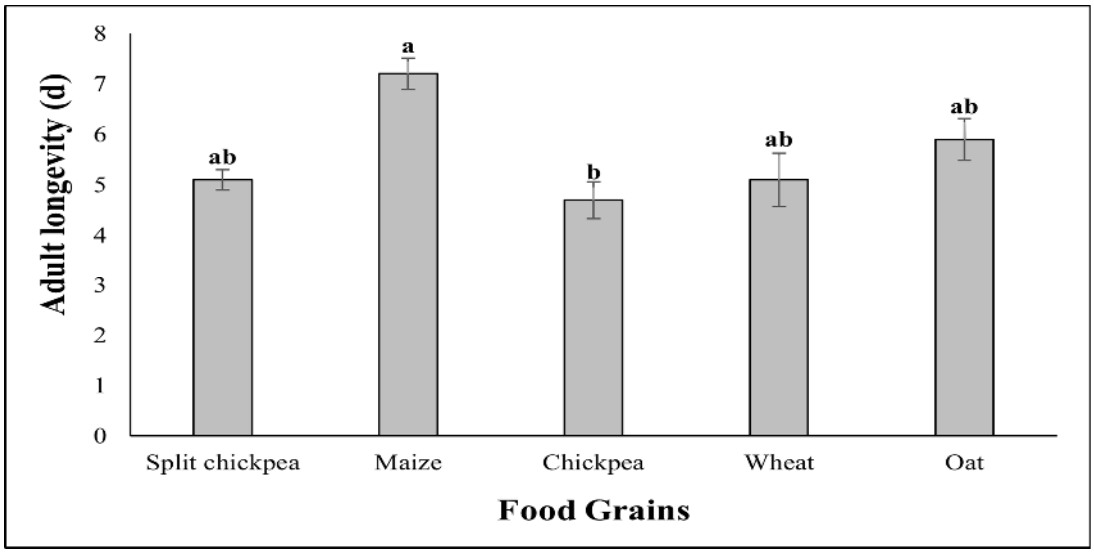

Figure 5. Average adult longevity of *S. cerealella* on different food grains.

CONCLUSION

This study was focused to examine the effect of different food grains on life history traits of *S. cerealella* under laboratory conditions. It is concluded from current findings that different food grains with different quality influence the fitness of *S. cerealella*. Maximum mean adult emergence and adult development rate was recorded in oat as compared to other food grains. However, minimum developmental time, highest adult longevity and maximum adult weight was recorded in maize grains. Moreover, highest mean fecundity and fertility was recorded in oat and wheat. According to our findings, oat and maize proved to be the best alternative food grains to wheat in terms of progeny development and mass scale rearing of *S. cerealella* while chickpea and split chickpea were identified as unsuitable hosts. Oat and maize could be used as host food in future for improving the *S. cerealella* insect culture and production of good quality host eggs for egg parasitoid, *T. chilonis* in the laboratory.

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AUTHORS CONTRIBUTIONS

UK and NI planned and executed the work. UK and NI collected the samples and conducted the experiments. MZ, NF and IM helped in experiments. UK and NI wrote the manuscript. MZ and SJAS supervised the study. UK and SJAS proofread the manuscript.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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