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Research Article

# Effects of various cereal flour on life table parameters of *Ephestia kuehniella* (Lepidoptera: Pyralidae)

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**Abstract:** The Mediterranean flour moth, *Ephestia kuehniella* (Zeller) (Lep.: Pyralidae) is not only known as stored products pest, but also used as a potential factitious host for mass rearing of biological agents. The aim of this study was to evaluate the effect of five different cereal cultivars (Wheat: Homma, Mihan and Zareh; Corn: 704 and Barley: Makui) on feeding performance and life table parameters of *E. kuehniella*, which was estimated by Carey life table producer. The results showed that preadult period ranged from 46.91 to 59.00 days on Corn and Zareh, respectively. The highest and lowest net reproductive rates ($R_0$) were obtained on Homma (128.76) and Zareh (61.77) offspring/female, respectively. The highest values of the intrinsic rate of increase ($r$) and finite rate of increase ($\lambda$) were on Corn and Homma and the lowest was on Zareh ($r$: 0.079 day$^{-1}$, $\lambda$: 1.08 day$^{-1}$). Based on the life history and demographic parameters results, Corn and Homma were the most suitable hosts for *E. kuehniella*. These findings may provide helpful information in integrated pest management programs including rearing of *E. kuehniella* as the alternative host, which could be used in the mass production of natural enemies.

**Keywords:** Mediterranean flour moth, life table, population growth parameters, fecundity, cereal

## Introduction

The Mediterranean flour moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), is an important pest of some stored grain products (Cox and Bell, 1991; Sedlacek *et al*., 1996; Hill, 2002; Rees, 2003). On the other hand, *E. kuehniella* could be used as the potential factitious host for mass rearing of egg and larval parasitoids including *Trichgramma* and *Habrobracon* species (Shonouda and Nasr, 1998; Hoffmann *et al*., 2001; Özder and Kara, 2010). Moreover, some predators including Coccinellidae, Anthocoridae, Chrysopidae and Aeolothripidae have been reared on *E. kuehniella* (Hoddle *et al*., 2001; Specty *et al*., 2003; De Clercq, *et al*., 2005; Kim and Riedl, 2005; Hamasaki and Mataui, 2006; Gonzalez-Zamora *et al*., 2007; Jokar and Golmohammadi, 2012).

The host plant quality is the most critical factor affecting insect demography via its effects on metabolism and developmental rate (Sarboland *et al*., 2017). Host plant quality could be determined by effects on either biological or demographic parameters including survival and reproduction of phytopaghous insects (Sequiera and Dixon, 1996; Awmack and Leather, 2002; Umbanhowar and Hastings, 2002). The quality of nutritional resources, affects on the biological properties of *E. kuehniella*, as well as efficiency of natural enemies (predators and parasitoids) (Shapiro and Ferkovich, 2002; Saadat *et al*., 2014; Abdi

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*et al*., 2014; Mostafazadeh and Mehrkhou, 2016). Evaluation of host plant fitness could be determined by the biological and life table parameters, which are the fundamental tools to understand host plant suitability for herbivores insects (Chi and Su, 2006; Soufbaf *et al*., 2010; Khanamani *et al*., 2013).

The biology and reproductive behavior of *E. kuehniella* have been studied by number of researchers (Brindley, 1930; Hill, 2002; Rees, 2003; Xu, 2010; Tarlack *et al*., 2015; Mehrkhou and Tarlack, 2016). Several authors have shown the effects of food resources on development and fecundity of *E. kuehniella* (Brindley, 1930; Hill, 2002; Rees, 2003, Xu, 2010; Tarlack *et al*., 2015; Mehrkhou and Tarlack, 2016). However, there is no comprehensive information on the life table parameters of *E. kuehniella* reared on different cereal flour including wheat: Homma, Mihan and Zareh; Corn: 704 and Barley: Makui. In our earlier study, we evaluated the efficiency of six wheat cultivars (Bahar, Zarin, Pishgham, Pishtaz, Sardari and Parsi cultivars) on demography of *E. kuehniella* (Mehrkhou and Tarlack, 2016), in which Parsi cultivar was the most suitable for *E. kuehniella*.

It should be emphasized that the wheat cultivars studied in this study are different from those previously studied by Mehrkhou and Tarlack (2016). Therefore, in the current study, the demographic parameters of *E. kuehniella* on different cereal were evaluated.

## Materials and Methods

### Host plants and insects

In this research, seeds of the examined cereal including wheat cultivars (Homma, Mihan, Zareh), Barley (var. Makui) and Corn (var. 704) were obtained from Plant and Seed Modification Research Institute in West-Azerbaijan and Sanandaj Province, Iran. It should be noted that the studied wheat cultivars were different from those previously studied in our earlier research (Tarlack *et al*., 2015; Mehrkhou and Tarlack, 2016). The studied seeds powdered by electrical grinder and the cereal flour were kept in refrigerator (4 ºC) before using in experiments, to prevent any type of contaminants. The insect culture has been established according to the Tarlack *et al*. (2015) producer. The insect reared two generations on each cultivar, before using in experiments. The insect culture and experiments were carried out at 26 ± 2 °C, 60 ± 5% R. H. and a photoperiod of 10: 14 (L: D) h.

### Life history and demographic parameters of *E. kuehniella*

At least 70 eggs of *E. kuehniella* within 12 h old have been separated from colony on each cereal flour. After egg hatching, the newly emerged larvae were placed individually in transparent containers (3 cm diameter × 8.5 cm height) with a hole covered with a fine mesh net for ventilation. Larvae were fed by flours of different cereal tested. The eggs and larvae were checked daily and their developmental time were recorded. Since the larval and pupal periods of *E. kuehniella* spent within flour, it is not clear to distinguish the life cycle period, exactly. For this reason, the stages of larval and pupal periods were considered as preadult stages. The incubation and developmental time of immature stages, and their mortality were recorded daily. After emergence from the pupa, sex of adults has been determined and distinguished sexually (Tarlack *et al*., 2015).

Age-specific life tables were constructed using a group of 15 pairs of *E. kuehniella* adults with 12-h-old, which obtained from each cereal cultivar in biological test. Each adult pair was kept in a funnel form plastic container as an oviposition container (10 cm diameter × 15 cm height) covered by fine mesh for ventilation and fed daily with a mixture of 10% honey. The number of eggs produced and adult longevity were also recorded daily. The monitoring continued until the death of the last individual in the cohort.

### Statistical analysis

The life table parameters of *E. kuehniella* on different cereal flour were determined by using age ($x$), survivorship ($l_x$), and female progeny ($m_x$) (Carey, 1993; 2001).





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Differences in the net reproductive rate ($R_0$), intrinsic rate of increase ($r$), finite rate of increase ($\lambda$), mean generation time ($T$) and doubling time ($DT$) values were tested for significance at the examined cereal flour by estimating variances through the jackknife procedure (Maia *et al*., 2000). Briefly, the life table parameters for all the $n$ females ($r$ all) were estimated by Carey's equations considering the survival and reproduction data. Then this procedure was repeated for $n$ times, each time excluding a different female (data of $n$-$1$ females, $r$ all). Therefore, 15 age-specific life tables were constructed for each treatment. The pseudo-values were calculated for each parameter for 15 samples using the following equation:

$$psvr\ (i) = n \times r\ (all) - (n-1) \times r\ (i) \quad (1)$$

After calculating the $n$ pseudo-values for $r_m$ (psvr), Jackknife estimate of the mean ($r$ mean) and standard error (SE$r$ mean) were calculated (Maia *et al*., 2000). The obtained variables were tested for normality using the Kolmogorov- Smirnov test before analysis. Then, data were analysed using analysis of variance (ANOVA), and the differences between the species were tested at $\alpha = 0.05$ level using the Tukey test (SPSS, 2010). A cluster analysis was constructed by Ward's method based on biological and life table parameters of *E. kuehniella*, reared on different cereal, as constructed by Alipour and Mehrkhou (2018).

## Results

### Life history parameters of *E. kuehniella* on different cereal flour

Duration of life history and adult longevity of *E. kuehniella* on different cereal flour were presented in Table 1. The incubation periods of *E. kuehniella* were significantly different. The highest egg incubation period was recorded on Zareh (3.65 ± 0.58 days), whereas there are no differences among other cultivars (3.00 ± 0.00 days). The longest and shortest preadult period of *E. kuehniella* were obtained on Zareh (59.00 ± 0.92 days) and 704 (46.91 ± 0.36 days), respectively (Table 1). There were significant differences in life spans of *E. kuehniella* ($F = 27.81$; df = 4, 70; $P < 0.05$) on five cereal flour. The life span varied from 55.00 to 67.55 days on 704 and Zareh, respectively (Table 1). The longest female (10.56 ± 0.53 days) and male (11.33 ± 0.58 days) longevities were found on Homma (Table 1). Pre-oviposition ($F = 1.44$; df = 4, 70; $P > 0.05$) and post-ovipositional ($F = 1.46$; df = 4, 70; $P > 0.05$) periods were not affected by cereal cultivars. On the other hand, the ovipositional period was found to be significantly different ($F = 8.92$; df = 4, 70; $P < 0.05$) on cereal which ranged from 3.85 days on 704 to 5.33 days on Homma (Table 1). The longest and shortest either female or male life span were obtained on Zareh and 704, respectively. The sex ratio was varied from 0.49 to 0.61 on barley and 704, respectively.

**Table 1** Life history and adult longevity of *Ephestia kuehniella* on different cereals.

| Cereals[1] | Incubation period (day) | Pre-adult (day) | Female Longevity (day) | Male longevity (day) | Female Life span (day) | Male life span (day) | Pre-oviposition (day) | Oviposition (day) | Post-oviposition (day) | Sex Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Homma | $3.00 \pm 0.00^{b}$ | $53.13 \pm 0.30^{b}$ | $10.56 \pm 0.53^{a}$ | $11.33 \pm 0.58^{a}$ | $63.96 \pm 0.54^{b}$ | $64.11 \pm 0.75^{b}$ | $0.41 \pm 0.19^{a}$ | $5.33 \pm 0.22^{a}$ | $1.25 \pm 0.37^{a}$ | 0.58 |
| Mihan | $3.00 \pm 0.00^{b}$ | $53.52 \pm 0.46^{b}$ | $9.77 \pm 0.49^{ab}$ | $10.61 \pm 0.55^{ab}$ | $63.12 \pm 0.77^{b}$ | $64.61 \pm 0.76^{b}$ | $0.27 \pm 0.14^{a}$ | $4.00 \pm 0.30^{bc}$ | $0.63 \pm 0.24^{a}$ | 0.52 |
| Zareh | $3.65 \pm 0.57^{a}$ | $59.00 \pm 0.92^{a}$ | $9.82 \pm 0.63^{ab}$ | $10.63 \pm 0.63^{ab}$ | $67.55 \pm 1.23^{a}$ | $70.90 \pm 1.68^{a}$ | $0.62 \pm 0.18^{a}$ | $4.75 \pm 0.16^{ab}$ | $0.75 \pm 0.25^{a}$ | 0.49 |
| 704 | $3.10 \pm 0.37^{b}$ | $46.91 \pm 0.37^{c}$ | $8.45 \pm 0.60^{b}$ | $9.24 \pm 0.63^{ab}$ | $55.00 \pm 0.95^{c}$ | $55.93 \pm 0.92^{c}$ | $0.85 \pm 0.23^{a}$ | $3.85 \pm 0.14^{c}$ | $1.00 \pm 0.33^{a}$ | 0.61 |
| Makui | $3.00 \pm 0.00^{b}$ | $52.62 \pm 0.38^{b}$ | $9.25 \pm 55^{ab}$ | $8.52 \pm 0.57^{b}$ | $61.42 \pm 0.78^{b}$ | $61.60 \pm 0.84^{b}$ | $0.54 \pm 0.15^{a}$ | $4.45 \pm 0.15^{bc}$ | $1.72 \pm 0.44^{a}$ | 0.50 |

Means with different letters in each column are significantly different at $P < 0.01$ based on Tukey's multiple range test. [1]Wheat varieties: Homma, Mihan and Zareh; Corn: var 704 and Barley: var Makui.





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The age-specific survivorship curves ($l_x$) of the Mediterranean flour moth on five examined cereals are presented in Fig. 1. The proportions of preadult stages that survived to the adult stage were 0.63, 0.70, 0.46, 0.82 and 0.73 on Homma, Mihan, Zareh, 704 (Corn) and Makui (Barley), respectively. The results revealed that the death of the last female (maximum age) in the cereal occurred at the age of 66, 66, 69, 59 and 65 days, respectively (Figure 1). *E. kuehniella* successfully reproduced on all of the cereal flours studied, wherein the fecundity differed significantly among cereals (Fig. 1). The $m_x$ is the number of female eggs produced per female at age *x*. The number of eggs at the peak of oviposition of females in Homma, Mihan, Zareh, Corn and Barley were 122.47, 78.53, 100, 38.41 and 62.40 eggs per female per day (Fig. 1).

**Life table parameters of *E. kuehniella* on different cereal flour**

The results of the reproduction parameters of *E. kuehniella* are presented in Table 2. The gross hatch rate of *E. kuehniella* ranged from 0.63-0.87 on Zareh and 704 (Corn), respectively. The cereal flour significantly affected the gross fecundity rates ($F$ = 39.27; df = 4, 70; $P$ < 0.05), wherein, the lowest and highest gross fecundity rates obtained on Mihan (448.67 ± 6.50) and Zareh (646.02 ± 19.72), respectively.

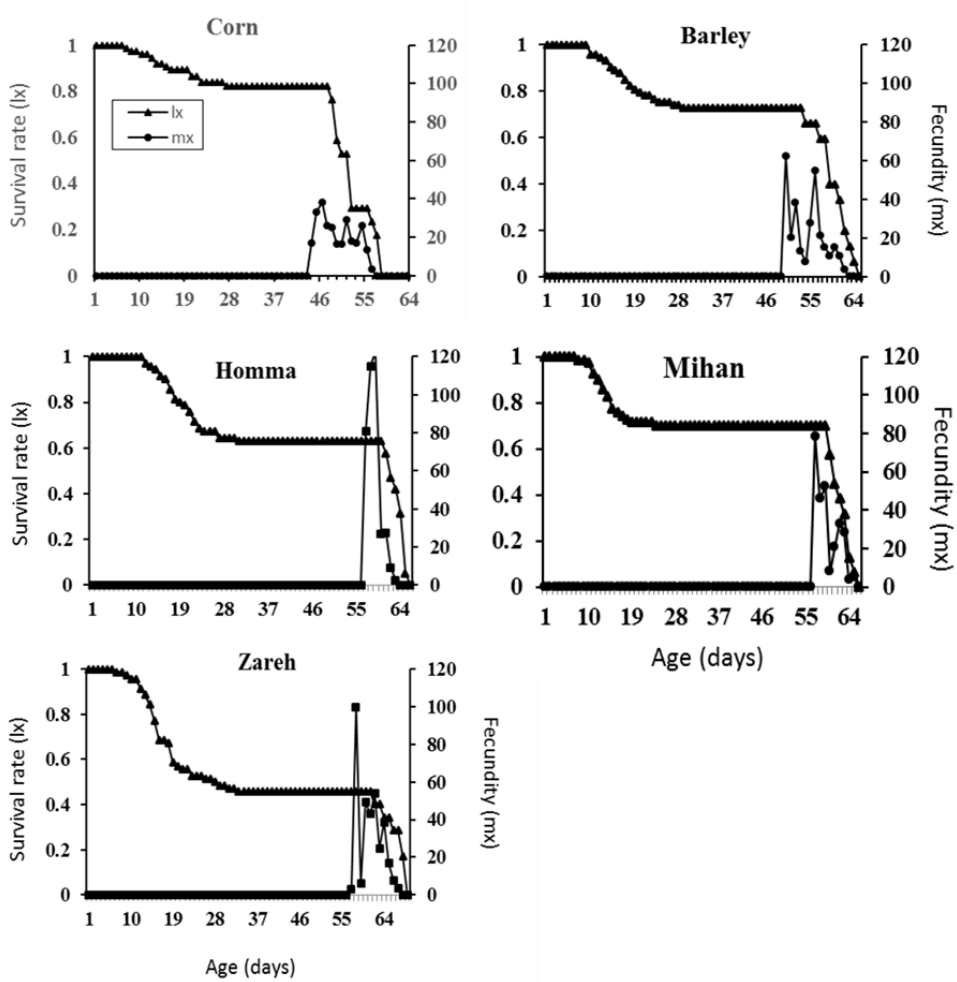


**Figure 1** Age-specific survivorship (lx) and fecundity (mx) of Ephestia kuehniella reared on wheat var Homma, Mihan and Zareh, Corn var 704 and Barley var Makui.





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Similarly, the net fecundity rate was significantly different among cereal flour cultivars ($F$ = 14.41; df = 4, 70; $P < 0.05$). The gross fertility rate (F = 22.78; df = 4, 70; $P < 0.05$) as well as the net fertility rate (F = 38.23; df = 4, 70; $P < 0.05$) showed significant differences among cereal flour cultivars (F = 22.78; df = 4, 70; P < 0.05). Mean daily number of eggs laid per female was affected significantly by the cereal flour ($F$ = 37.45, df = 4, 70; $P < 0.05$), which was highest on wheat cultivars and lowest on Barley. The daily number of fertile (hatched) eggs was affected significantly by cereal ($F$ = 48.31; df = 4, 70; $P < 0.05$) with the highest on in Homma and Mihan and lowest values on Barley, respectively (Table 2).

The results of the population growth rate parameters of *E. kuehniella* are presented in Table 3. The net reproductive rate ($R_0$) significantly varied among cereal ($F$ = 12.45; df = 4, 70; $P < 0.05$). The highest and lowest $R_0$-values were obtained on Homma (128.76) and Zareh (61.77 offspring/female), respectively. Moreover, the $r$-value on Homma and Corn was significantly higher than other hosts ($F$ = 17.25; df = 4, 70; $P < 0.05$). The finite rate of increase ($\lambda$) was significantly higher on Homma and Corn as compared with the other cereals ($F$ = 17.02; df = 4, 70; $P < 0.05$) (Table 3). The mean generation time was significantly shorter ($F$ = 34.95, df = 4, 70; $P < 0.05$) when *E. kuehniella* were reared on 704 (Corn) (41.51days). In addition, the mean estimates for doubling time (*DT*) was significantly different on various cereal ($F$ = 23.50; df = 4, 70; $P < 0.05$), which was the highest on Zareh (8.73 days) and lowest on Homma and Corn.

**Cluster analysis**

A cluster dendrogram based on the biological and life table parameters of *E. kuehniella* reared on five cereal flour is shown in Fig. 2. It showed two distinct groups labelled A and B. Cluster A included Zareh variety (partial unsuitable variety) and cluster B was divided into sub-cluster B1 (Corn and Homma as a partial susceptible hosts) and B2 which involved the Makui and Mihan cultivars (Fig. 2).

**Table 2** The reproduction parameters (mean ± SE) of *Ephestia kuehniella* on different cereals.

| Cereals | Gross hatch rate | Gross fecundity rate (eggs) | Net fecundity rate (eggs/female) | Gross fertility rate (eggs/female) | Net fertility rate (eggs) | Daily eggs per female (egg/female) | Daily fertile eggs per female (fertile egg/female) |
|---|---|---|---|---|---|---|---|
| Wheat (Homma) | 0.86 ± 0.002$^{b}$ | 450.09 ± 18.17$^{c}$ | 269.34 ± 23.12$^{b}$ | 387.07 ± 15.63$^{b}$ | 248.22 ± 9.72$^{b}$ | 50.01 ± 2.01$^{a}$ | 43.00 ± 1.74$^{a}$ |
| Wheat (Mihan) | 0.86 ± 0.001$^{b}$ | 448.67 ± 6.50$^{c}$ | 248.13 ± 2.71$^{b}$ | 385.90 ± 5.59$^{b}$ | 213.39 ± 2.33$^{c}$ | 49.85 ± 0.72$^{a}$ | 42.88 ± 0.62$^{a}$ |
| Wheat (Zareh) | 0.63 ± 0.001$^{d}$ | 646.02 ± 19.72$^{a}$ | 264.69 ± 9.09$^{b}$ | 407.00 ± 12.43$^{b}$ | 150.17 ± 17.66$^{d}$ | 53.83 ± 1.64$^{a}$ | 33.91 ± 1.03$^{b}$ |
| Corn (704) | 0.87 ± 0.003$^{a}$ | 571.16 ± 7.90$^{b}$ | 343.40 ± 8.28$^{a}$ | 496.91 ± 6.86$^{a}$ | 289.72 ± 4.53$^{a}$ | 40.79 ± 0.56$^{b}$ | 35.49 ± 0.48$^{b}$ |
| Barley (Makui) | 0.75 ± 0.05$^{c}$ | 561.13 ± 11.06$^{b}$ | 350.52 ± 6.99$^{a}$ | 420.85 ± 8.30$^{b}$ | 262.89 ± 5.24$^{ab}$ | 35.07 ± 0.69$^{c}$ | 26.30 ± 0.51$^{c}$ |

The means followed by different letters in the same columns are significantly different (P < 0.05, Tukey's test).

**Table 3** Population growth parameters (mean ± SE) of *Ephestia kuehniella* on different cereals.

| Cereals | $R_0$ (offspring/ female) | r (day$^{-1}$) | λ (day$^{-1}$) | T (day) | DT (day) |
|---|---|---|---|---|---|
| Wheat (Homma) | 128.76 ± 1.19$^{a}$ | 0.105 ± 0.002$^{a}$ | 1.11 ± 0.01$^{a}$ | 46.09 ± 0.90$^{b}$ | 6.61 ± 0.22$^{c}$ |
| Wheat (Mihan) | 96.03 ± 1.27$^{b}$ | 0.098 ± 0.020$^{ab}$ | 1.10 ± 0.04$^{ab}$ | 46.38 ± 2.06$^{b}$ | 7.03 ± 1.50$^{bc}$ |
| Wheat (Zareh) | 61.77 ± 1.58$^{c}$ | 0.079 ± 0.011$^{c}$ | 1.08 ± 0.005$^{c}$ | 51.98 ± 2.25$^{a}$ | 8.73 ± 1.23$^{a}$ |
| Corn (704) | 76.24 ± 1.05$^{bc}$ | 0.104 ± 0.009$^{a}$ | 1.11 ± 0.05$^{a}$ | 41.51 ± 1.15$^{c}$ | 6.63 ± 1.02$^{c}$ |
| Barley (Makui) | 74.64 ± 1.27$^{bc}$ | 0.094 ± 0.001$^{b}$ | 1.09 ± 0.01$^{b}$ | 45.72 ± 0.09$^{b}$ | 7.34 ± 1.04$^{b}$ |

The means followed by different letters in the same columns are significantly different (P < 0.05, Tukey's test).





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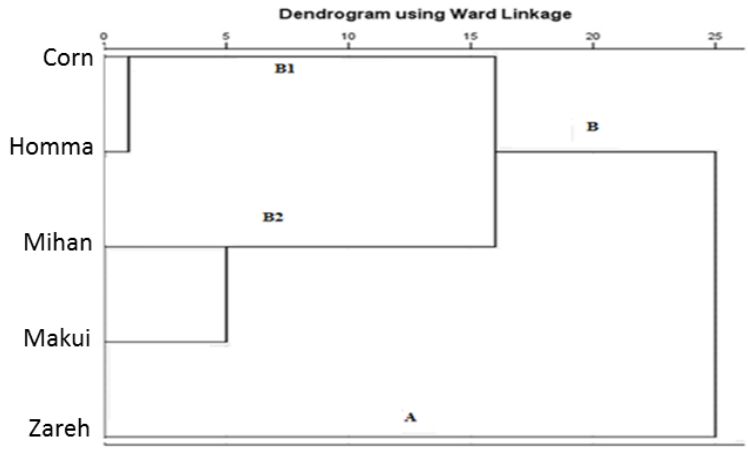


**Figure 2** Dendrogram of wheat var Homma, Mihan and Zareh, Corn var 704 and Barley var Makui classified based on biological and demographic parameters of *Ephestia kuehniella*.

## Discussion

The current study revealed that although *E. kuehniella* can feed on different cereal hosts, its development time, adult longevity, survival rate, and population growth parameters significantly depended on the host. It seems that Homma and Corn were the best hosts in terms of population growth parameters evaluated. However, in concerning with the results of developmental time and reproduction parameters Corn was a better host than other cereal. The shortest larval or preadult periods were observed on Corn, which is probably attributed to high nutritional value of this host. We found that, the incubation period was varied from 3 to 3.65 days, which was the longest on Zareh. According to Tarlack *et al*. (2015), the incubation period took from 3.90 to 4.16 days on different wheat flour cultivars. In addition, Brindley (1930) stated eggs hatched after 96 h (4 days) at 30 °C and 73% of relative humidity. Based on current results, the mean larval period was 41.50 days, which is coincided with the value reported by Brindley (1930) and Tarlack *et al*. (2015) for wheat flour. The present results showed that the preadult period of *E. kuehniella* ranged between 46.91 and 59 days in Corn and Zareh. Tarlack *et al*. (2015) reported that it was 62.54 days when Zareh cultivar was used as a host. These discriminatory may be due to the differences in their experimental conditions including humidity and temperature condition.

Development, growth, fecundity and survivorship of phytophagous insects could be effected by nutritional quality, allelochemistry, or morphology of the host plant which could act as a sub-lethal plant defense by prolonging development of insects (Slansky and Feeny, 1977; Norris and Kogan, 1980). Moreover, plant species as hosts for specific insects differ greatly in suitability when measured in terms of survival, development and reproductive rates of pests. Shorter development times and greater total reproduction of insects would indicate greater suitability of host plant (van Lenteren and Noldus, 1990).

In phytophagous insects which did not feed in the adult stage, food resources during the larval stage was the determinant for their fitness (Awmack and Leather, 2002). Our results clearly demonstrated variation of adult longevity, oviposition period and fecundity of the Mediterranean flour moth on different cereal. Adult longevity of females and males was 8.45-10.56 and 8.52-11.33 days, respectively indicating shorter longevity of female than male. There was no significant





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effect of larval food on the pre-ovipositional period of *E. kuehniella*. The mean value was 1.44 days on all cereal flour. The protogynous traits of *E. kuehniella* affects the pre-ovipositional period in which the female reproductive systems became mature soon after emergence, that is why the pre-ovipositional period was shorter in this species, which is supported by Xu *et al*. (2008).

According to our results, the *lx* curve of *E. kuehniella* showed the most protrusion on Corn. This host developed relatively low preadult time (46.91 days) on Corn in comparison with the others, suggesting that higher survival rate and shorter development time would imply to the higher values of growth index and indicate better food quality for phytophagous insects (Greenberg *et al*., 2001). Therefore, Corn may be a better nutritional source host than the other tested cereal for this species.

It is known that the survival and reproduction could be affected directly by quality and quantity of nourishment ingested by insect (Razmjou *et al*., 2006). Therefore, the fitness of phytophagous insects depends on the nutrients in the host (Du *et al*., 2004).

The comparison of the biological performance of insects at different temperatures, relative humidity and host species could be obtained by fertility life tables (Özder and Kara, 2010). The intrinsic rate of natural increase (*r*) is one of the fundamental parameter for elucidation of a population growth potential under certain food conditions and the best single value reflecting survival, fecundity, longevity and species developmental times (Carey, 1993; Southwood and Henderson, 2000). The intrinsic rate of increase and the finite rate of population increase ($\lambda$) are commonly used for estimating population growth for inter and intraspecific comparisons. According to our findings, these two parameters showed a similar trend on different cereal. *E. kuehniella* had the highest *r* and $\lambda$ on Corn and Homma and the lowest on Zareh (Table 3), which is somewhat similar to Mehrkhou and Tarlack (2016) results, who reported the rate of intrinsic of increase was ranged from 0.098 to 0107 day$^{-1}$ on Bahar and Pishgham cultivars, respectively. High or low value of the intrinsic rate of increase reveals host plant suitability or unsuitability to insect feeding, respectively (Goodarzi *et al*., 2015). Thus, Corn and Homma among other cereal flour would be the suitable hosts, and the Mediterranean flour moth had the greatest chance for population increase on this host. The suitability of the mentioned cultivars could be due to the highest rate of protein, which affects pest growth, and fecundity, as supported by Seyedi *et al*. (2017). According to their results on the three cereals (e.g. barley, wheat and Corn), the highest rate of larval survival and growth index were 88% and 9.77, respectively, fed on Corn flour. Moreover, the relative growth rate, the efficiency of conversion of ingested food, the protein concentration, as well as digestive enzymatic activity (total proteolytic, tryptic and chymotryptic) of larval midgut showed the highest rate, when they fed on Corn in comparison with barley and wheat. According to Seyedi *et al*. (2017) results, Corn (Var. 704) was the most suitable cereal for laboratory rearing of *E. kuehniella*, resulting in the highest rate of biological and physiological parameters.

Cluster analysis drawn showed the effects of cereal flour on the biological and life table parameters of *E. kuehniella*. The different cereal flour fell into two distinct groups; cluster A (Zareh) and cluster B. Cluster B was divided into sub-cluster B1 (Corn and Homma) and sub-cluster B2 (Makui and Mihan). The grouping within each cluster was based on the high-level similarity in biological and demographic parameters among cereal flour, whereas the separate clusters represented significant variability in mentioned characteristics between clusters. In the other word, sub-cluster B1 was the most suitable host variety due to the shorter development time, higher survival rate, reproduction as well as a higher population growth parameters of *E. kuehniella*. However, cluster A (Zareh variety) had partial unsuitability with longer development time, as well as lower reproduction and population growth parameters. Furthermore, the sub-cluster B2 (Makui and Mihan) would have intermediate status.





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## Conclusion

Our findings regarding to the selection of resistant cereal (unsuitable) among different cereal flour may provide important information to aid the design of a comprehensive scheme for an IPM program of *E. kuehniella* on stored products. Comprehensive studies need to survey on the chemical composition of these cereals to design more practical tactics in the IPM program of *E. kuehniella* on examined hosts. In addition, it would be useful if the effectiveness of the mentioned cereal evaluated on biological agents (third trophic levels) reared on *E. kuehniella*.

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# تأثیر آردهای غلات مختلف بر فراسنجه‌های جدول‌زندگی شب‌پره مدیترانه‌ای آرد *Ephestia kuehniella* (Lepidoptera: Pyralidae)

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**چکیده:** شب‌پره مدیترانه‌ای آرد *Ephestia Kuehniella* Zeller نه‌تنها به‌عنوان یکی از آفات محصولات انباری شناخته شده است، بلکه یکی از میزبان‌های اصلی در پرورش عوامل بیولوژیک می‌باشد. هدف از انجام این تحقیق، ارزیابی تأثیر آردهای غلات مختلف گندم (ارقام هما، میهن و زارع)، ذرت (رقم ۷۰۴) و جو (رقم ماکویی) روی ترجیح میزبانی و فراسنجه‌های جدول زندگی *E. kuehniella* است که با استفاده از روش Carey انجام شده است. نتایج نشان داد که طول دوره مراحل نابالغ از ۴۶/۹۱ روز تا ۵۹ روز به‌ترتیب روی ذرت و زارع متغیر بود. بیش‌ترین و کم‌ترین نرخ خالص تولید مثل ($R_0$) به‌ترتیب روی هما ۱۲۸/۷۶ و زارع ۶۱/۷۷ (نتاج/ماده) به‌دست آمد. بیش‌ترین نرخ ذاتی افزایش جمعیت و نرخ متناهی جمعیت به‌ترتیب روی ذرت و هما و کم‌ترین آنها روی زارع بود ($r$: 0.079 day$^{-1}$; $\lambda$: 1.08 day$^{-1}$). با توجه به نتایج به‌دست آمده از فراسنجه‌های زیستی و دوره زندگی، ذرت و هما مناسب‌ترین میزبان برای *E. kuehniella* بودند. نتایج حاصل از این تحقیق می‌تواند اطلاعات مفیدی را در برنامه مدیریت‌تلفیقی آفت از جمله پرورش آن به‌عنوان میزبان جایگزین در تکثیر و پرورش دشمنان طبیعی فراهم کند.

**واژگان کلیدی:** شب‌پره مدیترانه‌ای آرد، جدول زندگی، فراسنجه‌های رشدجمعیت، باروری، غلات



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