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# Comprative life table parameters of the *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) on corn hybrids under laboratory conditions

**M. Mardani-Talaee[1*], G. Nouri-Ganbalani[1], B. Naseri[1], M. Hassanpour[1], L. Mottaghinia[1] and S. M. Mansouri[2]**
1. Department of Plant Protection, Faculty of Agricultural Science, University of Mohaghegh Ardabili, Ardabil, Iran, 2. Department of Biodiversity, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran.
*Corresponding author: E-mail: mardani@uma.ac.ir

**Abstract**

The effects of four corn hybrids, Keynes540, Keynes410, KSC260 and KSC400, were investigated on life table parameters of the beet armyworm in a growth chamber that was set at 25 ± 1 ºC, 65 ± 5% RH and 16:8 (L: D) photoperiod. The highest survivorship ($l_x$) of adults were 0.77, 0.70, 0.62 and 0.58 on KSC260, Keynes410, Keynes540 and KSC400, respectively. The highest age-specific fecundity ($m_x$) of females which were emerged from the larvae being fed on above-mentioned hybrids were recorded 28.75, 21.70, 20.37 and 16.33 female/ female/ day, that occurred at the days 39, 40, 41 and 45, respectively. The females reared on KSC400 showed the lowest net reproductive rate ($R_0$), while the highest $R_0$ was recorded on KSC260 hybrids. The intrinsic rate of natural increase ($r_m$) ranged from 0.1028 to 0.1370 day$^{-1}$ of which the lowest was on KSC400. The lowest and highest values of finite rate of increase ($\lambda$) were obtained on KSC400 and Keynes540, respectively. The longest mean generation time ($T$) (35.37 ± 0.83 days) was observed on KSC400 and the shortest one (30.67 ± 0.93 days) was on Keynes410. The results showed that KSC400 was the least suitable host for *S. exigua*.
**Key words:** *Spodoptera exigua*, $r_m$, survival rate, corn hybrids

**چکیده**

**مقایسه‌ی پارامترهای جدول زندگی کرم برگ‌خوار چغندر، *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) روی هیبریدهای مختلف ذرت در شرایط آزمایشگاهی**

**مژگان مردانی طلایی، قدیر نوری قنبلانی، بهرام ناصری، مهدی حسن‌پور، لیلا متقی‌نیا و سیدمظفر منصوری**

کرم برگخوار چغندر *Spodoptera exigua*، آفت پلی‌فاژی است که به محصولات زیادی در جهان خسارت وارد می‌کند. در این تحقیق پارامترهای رشد جمعیت این آفت بر روی چهار هیبرید تجاری ذرت شامل Keynes540، Keynes410، KSC260 و KSC400 در شرایط کنترل شده‌ی آزمایشگاهی (دمای ۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵ ± ٦۵ درصد و در دوره‌ی نوری ١٦ ساعت روشنایی و ۸ ساعت تاریکی) مورد بررسی قرار گرفت. براساس نتایج نشان داد که نرخ بقای ($l_x$) افراد در زمان ورود افراد هم سن اولیه به مرحله‌ی حشره کامل (درصد ظهور بالغین) روی هیبریدهای KSC260، Keynes410، Keynes540 و KSC400 به‌ترتیب ۰/۷۷، ۰/۷۰، ۰/٦۲ و ۰/۵۸ بوده است. بیش‌ترین میزان باروری ویژه‌ی سنی ($m_x$) شب‌پره‌های پرورش یافته روی هیبریدهای Keynes540، Keynes410، KSC260 و KSC400 به‌ترتیب ۲۸/۷۵، ۲۱/۷۰، ۲۰/۳۷ و ١٦/۳۳ ماده/ماده/روز به‌ترتیب مربوط به روزهای ۳۹، ٤۰، ٤١ و ٤۵ بود. ماده‌های پرورش یافته روی هیبرید KSC400 کم‌ترین و روی هیبرید KSC260 بیش‌ترین نرخ خالص تولیدمثل ($R_0$) را داشتند. مقدار نرخ ذاتی افزایش جمعیت ($r_m$) از ۰/١۰۲ (بر روز) تا ۰/١۳۷ (بر روز) متغیر بود که کم‌ترین مقدار آن نسبت به سایر هیبریدها روی هیبرید KSC400 مشاهده شد. طولانی‌ترین (۰/۸۳ ± ۳۵/۳۷ روز) میانگین مدت زمان یک نسل ($T$) روی هیبرید KSC400 و کوتاه‌ترین مقدار آن (۰/۹۳ ± ۳۰/٦۷ روز) روی هیبرید Keynes410 بود. هم‌چنین کم‌ترین و بیش‌ترین مقدار نرخ متناهی افزایش جمعیت ($\lambda$) به‌ترتیب روی هیبریدهای KSC400 و Keynes540 به‌دست آمد. نتایج حاصل از این پژوهش نشان داد که هیبرید KSC400 در مقایسه با سایر هیبریدهای مورد آزمایش، هیبرید نامناسبی برای تغذیه لاروهای کرم برگخوار چغندرقند می‌باشد.
**واژگان کلیدی**: *Spodoptera exigua*، $r_m$، نرخ بقای هیبریدهای ذرت

## Introduction

Corn, *Zea mays* L. is an important crop which is commercially produced in some regions of Iran. Corn is infested by various diseases and insect pests that could affect its commercial yield. One of the most important insect pests of corn is the cosmopolitan and polyphagous beet armyworm, *Spodoptera exigua* (Hübner) (Lep., Noctuidae). This insect is native to the south Asian region (Wilson, 1932). The beet armyworm feed on more than 50 field crops including corn, sugar beet, cotton, soybean, lettuce, canola, alfalfa and tomato (Smits *et al.*, 1987; Greenberg *et al.*, 2001; Sertkaya *et al.*, 2004; Mardani-Talaee *et al.*, 2012; Karimi-Malati *et al.*, 2014a, b; Goodarzi *et al.*, 2015). Females lay their eggs undersides of the leaves and larvae feed on vegetative and reproductive organs of the host plants. Younger larval instars usually feed on the parenchyma tissues of leaves, but fourth and fifth instars are voracious and heavily damage the host plants. They cause irregular holes and consume the entire leaf, leaving the midrib and other large veins of the leaf (East *et al.,* 1989).

Outbreaks of *S. exigua* can cause serious losses on the harvest. Many factors including quality, availability and density of host plants, as well as abundance of natural enemies seem to be responsible for the outbreak of *S. exigua* (Tisdale & Sappington, 2001). Growers mostly rely on pesticides for the management of this pest that resulted in its resistance to the insecticides (Cobb & Bass, 1975; Brewer *et al.,* 1990; Moulton *et al.,* 1999). Therefore, alternative control strategies are being sought to minimize the usage of insecticides. The use of resistant host plant is an effective method to reduce the population of this pest (Wilson & Huffaker, 1976; Endo *et al.,* 2007).

The comparison of fertility life table parameters of a given pest on different hybrids of the host plants is a common method of delineating resistant hybrid(s). Life table parameters are important indicators of population growth capacity of a given species under specified conditions on different host plants (Carey, 1995; Sánchez *et al.,* 1997; Southwood & Henderson, 2000). These parameters can provide information about survival rate, fecundity and development of the pest and can be used to predict the size of the population (Deevey, 1947; Brich, 1948 Carey, 1993; Southwood & Henderson, 2000).

Life table parameters of *S. exigua* have been extensively studied on other commercial plants by Greenberg *et al.* (2001), Azidan & Sofian-Azirun (2006), Saeed *et al.* (2009) and Farahani *et al.* (2011). The aim of this research was to study the life table parameters of *S. exigua* on four commercial corn hybrids in order to delineate the most unsuitable corn hybrids to be used in integrated management of the pest.

## Materials and methods

### *Plant sources*

Seeds of four commercial corn hybrids of Keynes540, Keynes410, KSC260 and KSC400 were obtained from Ardabil Agricultural Research Centre, Moghan. The seeds were planted at the Agricultural Research Station of the University of Mohaghegh Ardabili, Ardabil. The tested corn hybrids were used in this experiment at 4-6 leaf stages of development for feeding of different larval instars of *S. exigua*.

### *Insect rearing*

*S. exigua* specimens were obtained from a laboratory colony maintained on certain artificial diet at the Department of Entomology, Tarbiat Modares University, Tehran, Iran. Prior to the experiments, the pest was reared on a corn hybrid (KSC 301) for two generations in a growth chamber (25 ± 1 °C, 65 ± 5% RH, and a photoperiod of 16:8 L: D hours) to eliminate previous host effects. Then, the larvae were separately reared on the leaves of tested corn hybrids towards their adult stages.

### *Life table study*

In order to obtain the eggs of the same age, 15 pairs of reared moths were kept inside an oviposition plastic container (10 cm diameter and 19 cm height), which was sealed at the top with a 50 mesh cloth net. After 12 hours, the eggs were collected from the container. A total of 100 eggs for each corn hybrid were considered and egg hatching was recorded every day. Then 50 newly emerged larvae were transferred and isolated individually in plastic Petri dishes (8 cm diameter and 1 cm depth) with a hole on the lid being covered by a fine mesh net. The larvae fed on daily-freshed leaves of each tested corn hybrids. Fifth instar larvae transferred into a small plastic tube (2 cm diameter and 5 cm depth) prior to molting, for pre-pupation and pupation. Survival and duration of immature stages, number of the larvae that entered pupation and the number of the moths emerged from pupae were recorded daily. A gravimetric method described by Waldbauer (1968) was used to evaluate effects of corn hybrids on larval and pupal weights as well as amount of consumed food. To calculate percentage of dry weights of larvae and pupa, 20 extra specimens were weighed, oven- dried (48 h at 60 °C) and subsequently reweighed.

Daily reproduction of emerged female moths from previous experiment was monitored on leaves of each corn hybrids. Thus, the reproduction potential of 15, 17, 20 and 21 female moths on corn leaves on of KSC400, Keynes410, KSC260 and Keynes540 corn hybrids were recorded, respectively. For this purpose, each newly emerged female and male moth was paired and each pair was placed in each above-mentioned oviposition container covered with muslin. The oviposition containers were supplied with 10% honey solution and equipped with window screen as oviposition substrate to avoid eggs being laid on the cage wall. Adult longevity and the number of deposited eggs were recorded daily until the death of the last adult.

### *Data analysis*

The experiments were carried out in complete randomized designs on various corn hybrids. Before analysis, all data were tested for normality by Kolmogorov- Smirnov method. The data were subjected to the one-way analysis of variance (ANOVA) using the statistical software of Minitab 16.0 (Minitab Inc. 1994). Statistical differences among means were compared using the least significant difference (LSD) test at P < 0.05. The mortality parameters including entropy *(H),* survival rate ($l_x$), age- specific fecundity ($m_x$), age- specific mortality ($q_x$), death distribution ($d_x$) and life expectancy ($e_x$) were calculated according to Carey (2001). The life table parameters of *S. exigua* on different corn hybrids follow the equations suggested by Carey (1993):

Intrinsic rate of natural increase ($r_m$):

$$\sum_{x=1}^{\omega} e^{-r(x)}\, l_x m_x = 1$$

Net reproductive rate ($R_0$):

$$= \sum_{x=1}^{\omega} l_x m_x$$

Finite rate of increase ($\lambda$):

$$= e^{r}$$

Doubling time (*DT*):

$$= \frac{ln2}{r_m}$$

Mean generation time (*T*):

$$= \frac{\ln R_0}{r_m}$$

Where, $x$ is the age, $l_x$ is the age-specific survival, and $m_x$ is the age-specific fecundity.

## Results and Discussion

### *Life table parameters*

Host plant resistance as a method for controlling insect pests is not only safer to the environment but also, reduces the cost of crop production (Li *et al.*, 2004). Many plants have secondary metabolites that make them inedible or unsuitable food for herbivores and may deter some phytophagous insects (Yamamoto & Fraenkel, 1960; Hsiao & Fraenkel, 1968). The suitability of host plant species may differ for specific insects when measured in terms of survival and reproduction. Shorter development time and higher fecundity of insects on a host indicate greater suitability of a host crop (van Lenteren & Noldus, 1990; Greenberg *et al.*, 2001).

In the present study, the four commonly grown corn hybrids affected survival rate, age-specific mortality and life expectancy as well as population growth parameters of *S. exigua*. Population growth parameters of *S. exigua* on four corn hybrids are given in Table 1. The net reproductive rate *($R_0$)* is an important indicator of population dynamics (Richard, 1967; Varley & Gradwell, 1970) that summarizes the physiological capacity of the pest. Comparison of $R_0$ often provides considerable insight beyond that available from the independent analysis of individual life history parameters (Liu *et al.*, 2004). Our study indicated that the $R_0$ values of *S. exigua* on four corn hybrids ranged from 33.89 on KSC400 to 103.80 female/ female/ generation on KSC260 hybrid. Greenberg *et al.* (2001) reported the highest and the lowest $R_0$ were on cabbage and pigweed (139.3 and 596 female/ female/ generation), respectively. Farahani *et al.* (2011) stated that this pest had the highest $R_0$ on *Chenopodium album* L. (377.11 female/ female/ generation) and the lowest one on cotton (126.39 female/ female/ generation). Karimi- Malati *et al.* (2012) studied the population growth parameters of *S. exigua* on sugar beet cultivars and found the highest $R_0$ (314.95 female/ female/ generation) on Shirin and the lowest value $R_0$ (253.59 offspring) on Renger cultivar. In contrast to our results, Goodarzi *et al.* (2015) reported $R_0$ of *S. exigua* ranged from 152.734 to 352.960 female offspring that the lowest and the highest $R_0$ were observed on Opera and Okapi cultivars of canola, respectively. The differences between our findings and theirs can be referred to the effect difference in host plants, chemical composition of the plants and various temperature degrees.

The $R_0$ and $r_m$ are the two key demographic parameters used to compare fitness of populations across diverse climatic and food- related conditions (Smith, 1991; Liu *et al.,* 2004; Kingsolver & Huey, 2008). The intrinsic rate of natural increase ($r_m$) is a key which is used to compare the potential of population growth of a pest on different host plants. According to our results, there were significant differences in values of $r_m$ among four corn hybrids studied in this research. It varied from 0.1028 (on KSC400) to 0.1370 (on Keynes540) female/ female/ day. The $r_m$ values of *S. exigua* on cabbage and pigweed were reported 0.156 and 0.264 female/ female/ day, respectively (Greenberg *et al.,* 2001). Farahani *et al.* (2011) showed that the beet armyworm had the $r_m$ value of 0.2643 female/ female/ day on canola and 0.1707 female/ female/ day on cotton. Also, the $r_m$ values this of pest on Talaye and Okapi cultivars of canola were reported 0.142 and 0.201 female/ female/ day, respectively (Goodarzi *et al.,* 2015). The nutritional components of host plants may have an important role in feeding performance of insects. Furthermore, they provide energy which directly affect development and fecundity of the herbivores (Srinivasan & Uthamasamy, 2005; Azidah & Sofian-Azirun, 2006). It is probable that larvae of *S. exigua* mainly can't obtain their nutritional requirements on KSC400 hybrid which could be due to chemical properties (such as polyphenol oxidase and nutrient imbalance) and/ or physical characteristics (such as high densities of trichomes and tissue hardiness) of leaves of this hybrid (Simmons *et al*., 2004).

The longest and shortest mean generation time *(T)* of *S. exigua* were observed on KSC400 and Keynes410, respectively (Table 1). According to Greenberg *et al*. (2001), the longest and the shortest mean generation time (*T*) of *S. exigua* were cabbage (31.6 days) and on pigweed (24.2 days). In our study, the generation time of *S. exigua* obtained on Keynes410 hybrid (30.67 d) was almost similar to the estimates of Greenberg *et al.* (2001) on sunflower (30.3 d). Interestingly, Farahani *et al.* (2011) reported that *S. exigua* had the longest (28.36 d) and the shortest (22.19 d) values of *T* on canola and cotton, respectively. The significant differences in the ability of larvae to exploit different host plants efficiently suggests some intrinsic variations among host plants. The difference in survival and development of insects on different cultivars might be caused by the antibiotic effects, poor nutritional quality of the food, epidermic thickness and secondary plant biochemical (Sharma *et al.,* 1982; Samraj & David, 1988). The difference between the results of this study with the mentioned researches can be mainly attributed to difference of host plants. Thus, change of developmental time of insects due to nutritional requirements that typically reflects in changes of food consumption and feeding behavior (Barton Browne, 1995). Thus, the larvae of rearing on Keynes410 had the ability which fast complete of their sensitive immature stages and adult stages correlates with nutritional elements in their plants host.

The finite rate of increase ($\lambda$) was significantly different among corn hybrids, the lowest and the highest on KSC400 (1.108 day$^{-1}$) and on Keynes540 (1.146 day$^{-1}$), respectively. Variation of $\lambda$ values from 1.17 to 1.30 day$^{-1}$ on cabbage and pigweed has been reported by Greenberg *et al.* (2001), and from 1.30 to 1.18 day$^{-1}$ on canola and cotton by Farahani *et al.*, 2011. Our findings are slightly different from theirs.

***Survival rate, age-specific mortality and life expectancy***

Survival rate *($l_x$)* and age-specific fecundity *($m_x$)* of *S. exigua* on corn hybrids are shown in Fig. 1. The survival rates of adults were estimated 0.77, 0.70, 0.62 and 0.58 on hybrids KSC260, Keynes410, Keynes540 and KSC400, respectively. The death of the last female (maximum age) occurred after 53, 52, 50 and 44 days on KSC260, KSC400, Keynes540 and Keynes 410, respectively. The curve of $l_x$ (the age- specific survival rate of all individuals) showed a similar pattern on all four corn hybrids; mortality was high in incubation period, first and second instar larvae then it declined slowly until the death of last adult. Our finding agrees with other studies (Bhonwong *et al*., 2009; Safuraie-Parizi *et al.*, 2014). The high densities of trichomes and polyphenol oxidase on tomato leaves can be due to increasing mortality, decline of quality nutritive, and digestibility of plant tissues for insects (Simmons *et al*., 2004). The beginning of oviposition period occurred after 28, 32, 34 and 37 days on Keynes410, KSC260, Keynes540 and KSC400, respectively. The highest $m_x$ (the age- specific fecundity of the total population) of the beet armyworm was 28.75 on Keynes540 (at day 39), 21.70 on Keynes410 (at day 40), 20.37 on KSC260 (at day 41) and 16.33 on KSC400 (at day 45). In fact, the numbers of eggs laid on a host plant are affected by the host plants (Verkerk & Wright, 1994).

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**Table 1.** Life table parameters of *Spodoptera exigua* reared on four corn hybrids under laboratory conditions.

| hybrids | Statistic (Mean ± SE) | | | | |
|---|---|---|---|---|---|
| | **$R_0$ (female offspring)** | **$r_m$ (day$^{-1}$)** | ***T* (day)** | ***DT* (day)** | **$\lambda$ (day$^{-1}$)** |
| Keynes410 | $54.22 \pm 14.7^{bc}$ | $0.1312 \pm 0.009^{a}$ | $30.67 \pm 0.93^{c}$ | $5.24 \pm 0.41^{b}$ | $1.140 \pm 0.011^{a}$ |
| Keynes540 | $86.22 \pm 18.5^{ab}$ | $0.1370 \pm 0.007^{a}$ | $32.67 \pm 0.64^{bc}$ | $5.04 \pm 0.27^{b}$ | $1.146 \pm 0.008^{a}$ |
| KSC260 | $103.80 \pm 16.0^{a}$ | $0.1361 \pm 0.005^{a}$ | $34.63 \pm 1.01^{ab}$ | $5.08 \pm 0.19^{b}$ | $1.145 \pm 0.005^{a}$ |
| KSC400 | $33.89 \pm 15.2^{c}$ | $0.1028 \pm 0.013^{b}$ | $35.37 \pm 0.83^{a}$ | $6.59 \pm 1.03^{a}$ | $1.108 \pm 0.015^{b}$ |

Means followed by different letters in each column are significantly different ($P < 0.01$, LSD Test).

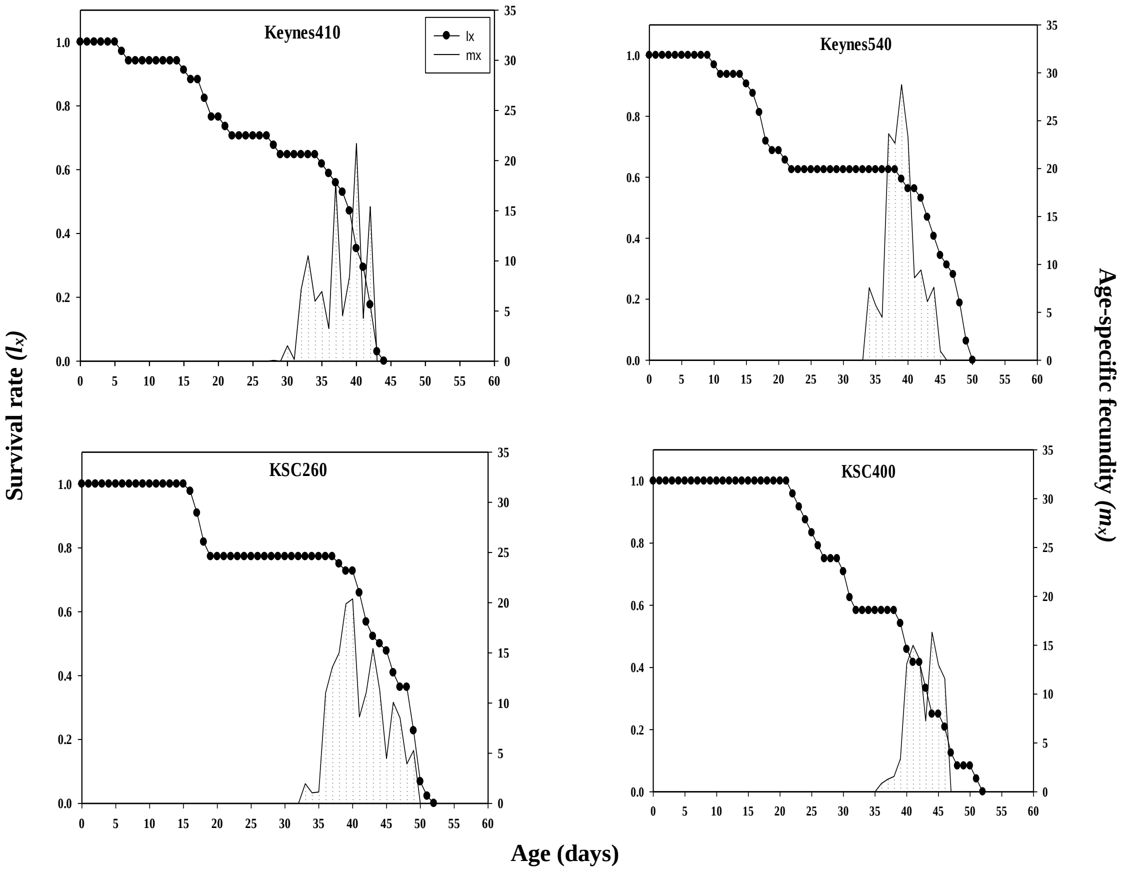


**Fig. 1.** Survival rate *($l_x$)* and age-specific fecundity *($m_x$)* of *Spodoptera exigua* reared on four corn hybrids under laboratory conditions.

Age-specific mortality *($q_x$)* and death distribution *($d_x$)* of *S. exigua* reared on four corn hybrids are presented in Fig. 2. The age- specific mortalities *($q_x$)* of the beet armyworm were 0.28, 0.18, 0.16 and 0.14 on KSC400, Keynes410, KSC260 and Keynes540 hybrids, respectively. The death distribution *($d_x$)* of *S. exigua* was 0.23, 0.16, 0.13 and 0.12 on KSC400, Keynes410, KSC260 and Keynes540 hybrids, respectively. The complements of these survival probabilities, designated $q_x$ is termed period mortality and represent the probability of dying over each respective periods. To say in another way, it proportion of those alive at age x that die in the interval $x$ to $x + n$ (Carey, 1993). The $d_x$ represents the frequency distribution of deaths in the cohort and its sum is unity. Thus the $d_x$ schedule gives the frequency distribution of deaths in the cohort (Carey, 1993).

Life expectancy ($e_x$) of *S. exigua* reared on four corn hybrids are shown in Fig. 3. The life expectancy of the pest at first day of life was 34.99, 31.44, 29.67 and 27.15 days on Keynes540, KSC260, Keynes410 and KSC400, respectively, which was the lowest on KSC400 and highest on KSC260.

### *Entropy*

The entropy parameter provides a practical summary measure for characterizing differences in shapes of survival curves among cohorts (Carey, 2001). The entropy *(H)* of the beet armyworm reared on Keynes540, KSC400, Keynes410 and KSC260 hybrids was 0.28, 0.23, 0.22 and 0.20, respectively. The results showed that the survival schedule of *S. exigua* was convex on all the corn hybrids studied in this research ($H$ < 0.5), suggesting that the probability of dying was higher in late ages as compared with early ones. In other words, survivorship of the pest was high at the beginning of life and dramatically decreased in late ages.

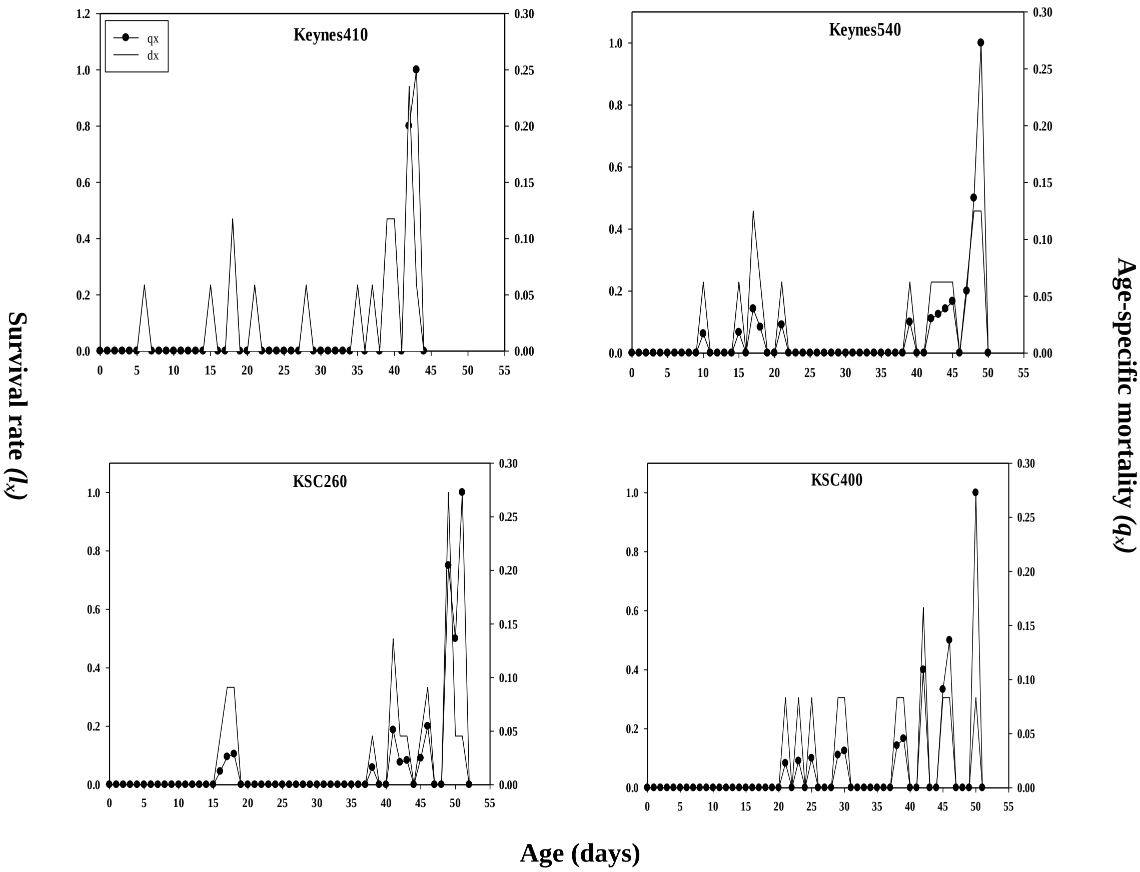


**Fig. 2.** Age-specific mortality *($q_x$)* and death distribution *($d_x$)* of *Spodoptera exigua* reared on four corn hybrids under laboratory conditions.

***Weight of food consumption and pupa***

Figure 4 shows the mean weight of leaves that were consumed by the third, fourth, and fifth instars and the pupal weight (mg) of *S. exigua* reared on four corn hybrids. The lowest amount of leaf consumption (26.89 ± 2.99 mg) was observed on KSC400 and the highest amount recorded on (98.07 ± 9.89mg) Keynes540 hybrid. Accordingly, the pupae on KSC400 hybrid had the least weight (18.67 ± 2.86 mg), whereas the larvae reared on Keynes540 hybrid was the heaviest (67.25 ± 2.25 mg). Pupal weight is an indicator of the fitness indicator of the lepidopteran pest (Leuck & Perkins, 1972). The proportional relationship between pupal weight and fecundity of *S. exigua* on KSC400 indicates inappropriate quality and quantity of consumed food. It could be inferred the hybrid as unsuitable host for *S. exigua* larvae. Quality and quantity of consumed food have disproportional effects on pest population dynamics through alterations of adult performance and total fecundity (Morgan *et al*., 2001; Liu *et al*., 2004). Growth rate of an insect is influenced by its food quality (Jansen & Groot, 2004). Poor nutritional quality of the food, microelements and macro elements in the host plant may decrease the feeding performance of the pest (Singh *et al.,* 1965; Sharma *et al.,* 1982; Samraj & David, 1988). Thus, the lowest values of food consumption for were recorded on KSC400 hybrid that may be due to its low nutritional quality (Phillipson, 1981).

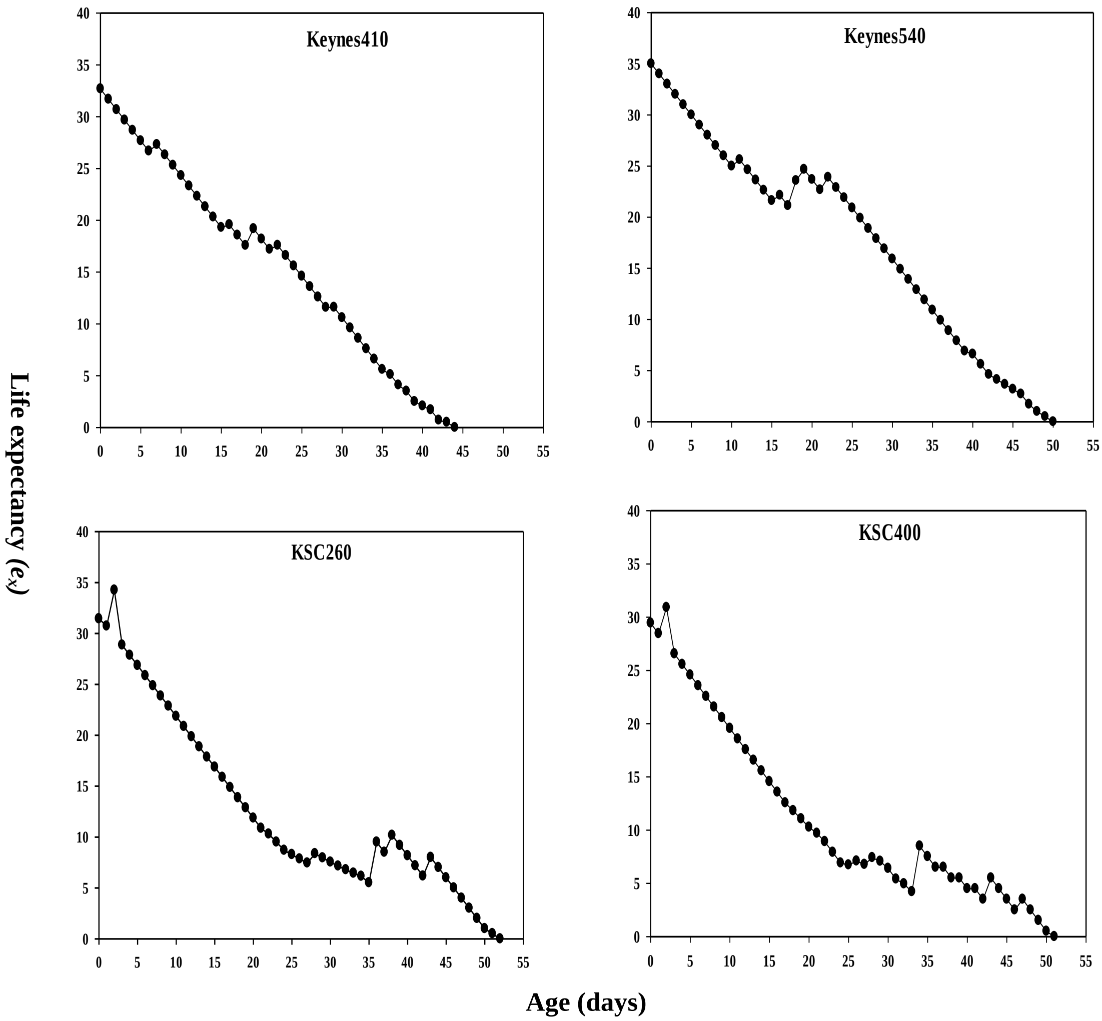


**Fig. 3.** Life expectancy *($e_x$)* of *Spodoptera exigua* reared on four corn hybrids under laboratory conditions.

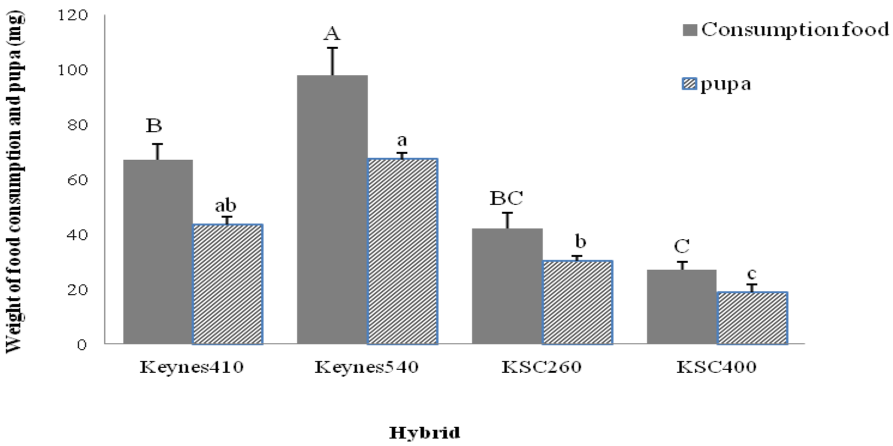


**Fig. 4.** The mean weight of food consumption and pupa (mg) of *Spodoptera exigua* reared on four corn hybrids under laboratory conditions.

**Conclusion**

TheKSC400 hybrid was a relatively unsuitable host for *S. exigua* because of low performance of the pest on this hybrid. The variation in food quality of corn hybrids can directly affect the survival and reproduction of *S. exigua* and can be exploited in the control programs of the pest. Resistant cultivars can be used parallel with biological and chemical control methods in the frame of an IPM strategy (Du *et al.*, 2004; Adebayo & Omoloyo, 2007). Investigation on the corn hybrids and field studies in relation to life table parameters of this pest are required to ensure the success of every control program in the future.

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