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Comparative life table parameters of beet armyworm, *Spodoptera exigua* (Lep.: Noctuidae), on four commercial sugar beet cultivars

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Abstract

Life table parameters of the beet armyworm, *Spodoptera exigua* (Hübner), on four sugar beet cultivars (Renger, FD0005, Dorothea and Shirin) were studied in laboratory at 27 ± 1°C, 60 ± 5% RH and a photoperiod of 16L: 8D hours. The larvae successfully developed on all cultivars. The shortest and longest total developmental time were recorded on FD0005 and Renger, respectively. The development index (*D.I.*) of larval period varied from 4.90 to 5.97 on Renger and Shirin, respectively. The life expectancy (e_x) was 26.94, 31.39, 30.51 and 30.16 days on the cultivars respectively at the beginning of life. Life table entropy (*H*) indicated the survival schedule of *S. exigua* was convex (type I) on all sugar beet cultivars. The gross fecundity ranged from 1499.93 to 2034.67 eggs on Dorothea and FD0005, respectively. The lowest value of net reproductive rate (R_0) was recorded on Renger (253.59 females per female per generation). The intrinsic rate of increase (r_m) ranged from 0.2235 on Renger to 0.2309 day^{-1} on FD0005. The mean generation time (*T*) was found to be significantly different on sugar beet cultivars. Fitting adult survival data to Weibull frequency distribution indicated that the adult survival curve was type I on all cultivars suggesting that the mortality was higher in old individuals. The cultivar Renger was less suitable in comparison with other cultivars in the laboratory. These results provided important information on the effect of four commercial sugar beet cultivars on population growth potential of *S. exigua*.

Key words: fecundity, life table, resistance, sugar beet, *Spodoptera exigua*

چکیده

پارامترهای جدول زندگی کرم برگ‌خوار چغندرقند، *Spodoptera exigua* (Hübner)، روی چهار رقم چغندرقند (Renger، FD0005، Dorothea و شیرین) در دمای ۱ ± ۲۷ درجه‌ی سلسیوس، رطوبت نسبی ۵ ± ۶۰ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی تحت شرایط آزمایشگاهی تعیین شد. لاروها روی تمام ارقام به‌طور کامل رشد کردند. طولانی‌ترین و کوتاه‌ترین کل دوره‌ی رشدی به‌ترتیب روی ارقام FD0005 و Renger به‌دست آمد. شاخص رشد (*D.I.*) مرحله‌ی لاروی از ٤/٩٠ روی Renger تا ٥/٩٧ روی شیرین متغیر بود. امید به زندگی (e_x) در ابتدای زندگی آفت روی ارقام فوق به‌ترتیب ٢٦/٩٤، ٣١/٣٩، ٣٠/٥١ و ٣٠/١٦ روز تعیین شد. مقادیر انتروپی (*H*) جدول زندگی نشان داد که منحنی بقا روی تمام ارقام به‌صورت محدب (نوع اول) می‌باشد. مقدار نرخ ناخالص باروری از ١٤٩٩/٩٣ تخم روی Dorothea تا ٢٠٣٤/٦٧ تخم روی Renger نوسان داشت. کم‌ترین مقدار نرخ خالص تولید مثل (R_0) روی رقم Renger مشاهده شد (٢٥٣/٥٩ ماده / ماده / نسل). نرخ ذاتی افزایش جمعیت (r_m) از ٠/٢٢٣٥ روی رقم Renger تا ٠/٢٣٠٩ روی رقم FD0005 متغیر بود. متوسط مدت زمان یک نسل (*T*) روی ارقام مختلف اختلاف معنی‌داری داشت. برازش منحنی بقای افراد بالغ با مدل Weibull نشان داد که نوع منحنی بقا روی تمام ارقام از نوع اول می‌باشد، بدین‌معنی که بیش‌ترین مرگ و میر در افراد بالغ در اواخر عمر اتفاق می‌افتد. نتایج حاکی از این بود که رقم Renger نسبت به سایر ارقام در شرایط آزمایشگاهی نامناسب‌تر می‌باشد. نتایج این تحقیق اطلاعات مفیدی را در مورد تأثیر چهار رقم تجاری چغندرقند روی پتانسیل رشد جمعیت کرم برگ‌خوار در اختیار قرار می‌دهد.

واژگان کلیدی: باروری، جدول زندگی، مقاومت، چغندرقند، *Spodoptera exigua*

Introduction

The beet armyworm, *Spodoptera exigua* (Hübner), is native to southern Asia and known as a generalist herbivore on vegetable, field, and flower crops (Wilson, 1932; Yoshida & Parrella, 1992; Greenberg *et al.*, 2001; Showler & Moran, 2003). The excessive use of insecticides has had a destructive impact on the natural enemies of *S. exigua*, its resistance to commonly used chemicals and an enormous increase of its population in many areas (Moulton *et al.*, 1999). There is a considerable interest to explore alternative methods, including host plant resistance to efficiently control the beet armyworm and diminish its damages on the crops.

The study of feeding behavior and the effect of food quality on the biology of insects are important for understanding their host suitability (Greenberg *et al.*, 2001). Low quality plants may reduce insect survival, size or weight, their longevity and reproduction viabilities or indirectly increase their exposure to the natural enemies as a result of prolonged developmental time (Ali & Gaylor, 1992; Greenberg *et al.*, 2001; Awmack & Leather, 2002; Chen *et al.*, 2008). Therefore, the use of resistant and partially resistant cultivars can improve biological and chemical control methods as part of an IPM strategy (Adebayo & Omoloyo, 2007).

Various studies have evaluated the effects of different host plant species on *S. exigua* growth potential (Al-Zubaidi & Capinera, 1984; East *et al.*, 1989, 1994; Ali & Gaylor, 1992; Greenberg *et al.*, 2001; Farahani & Talebi, 2010), but other aspects of its biology such as, survivalship and life table parameters remain inadequate and fairly unknown. The life-table technique has been used to assess the suitability (or resistance) of host plants to various pest insects (Vargas *et al.*, 1997; Haghani *et al.*, 2006). The intrinsic rate of natural increase (r_m) is a key demographic parameter used to evaluate the level of plant resistance to insects. Host plants displaying lower values of r_m, lower survival rates and longer developmental times are considered more resistant to the pest infestations (Greenberg *et al.*, 2001; Naseri *et al.*, 2009).

Reports of host plant resistant varieties against *S. exigua* are not as common as those for other insects (Meade & Hare, 1991), although some resistant genotypes have been discovered in tomato (Juvik & Stevens, 1982), celery (Griswold & Trumble, 1985), soybean (Talekar *et al.*, 1988) and chrysanthemum cultivars (Yoshida & Parrella, 1992). Sugar beet is relatively a young crop with few commercially known resistant varieties (Talebi *et al.*, 2010), because the resistant mechanisms are mostly controlled by multiple genes or they are simply broken under heavy infestation. Some tetraploid breeding lines of sugar beet were damaged less than others by some pest have the potential for improvement through selection (Zhang *et al*., 2008).

There is no information about life table parameters of *S. exigua* on sugar beet cultivars. This study is intended to improve the existing knowledge about the life table parameters of *S. exigua* and examine them on four sugar beet cultivars, known as susceptive/resistant cultivars to some pest and diseases. The four different sugar beet cultivars were used to determine their suitability for *S. exigua* and its demographic parameters and population growth potential were investigated in Iran. The results are expected to be valuable for planning IPM programs against *S. exigua* in the future.

Materials and methods

Field and laboratory cultures

The selection of seeds of four sugar beet (*Beta vulgaris* L.) cultivars was based on their susceptibility or resistance to some pests and diseases; one resistant cultivar to root aphid (Renger), two resistant cultivars to root rot (FD0005 and Dorothea), and one normal cultivar without any resistance (Shirin). They were obtained from Plant and Seed Modification Research Institute (Karaj, Iran) and planted in the research field of Khorasan Razavi Agricultural and Natural Resources Research Center, Mashhad, Iran.

Spodoptera exigua specimens were originally collected from sugar beet fields in Mashhad region, during March 2009. The rearing cage was a clear cubic plexiglas container (40 × 40 × 5 cm), covered on top with fine mesh net on the sides for its ventilation. For the experiment, the specimens were reared for two generations on the same cultivars and kept inside a growth chamber at 27 ± 1°C, 65 ± 5% RH and a photoperiod of 16: 8 (L: D) h.

Experiments

In order to obtain the same-aged eggs, 15 pairs of newly emerged *S. exigua* were placed inside an oviposition container (12 cm in diameter by 8 cm in height), being sealed at the top with a fine mesh net along with leaves of host plants. Adults were fed on a cotton ball soaked with 10% honey. The laid eggs on the leaves through 12 h were later used for the experiments. At least 50 eggs were used for each cultivar treatment. The newly emerged larvae were transferred individually into plastic dishes (5 cm in diameter by 8 cm in height with a hole covered with a fine mesh net for ventilation) containing fresh leaves. A fine camel’s hair brush was used for transferring young larvae to the dishes. The leaves were replaced daily with fresh ones. When larvae went to fifth-instar, the dishes were prepared for the pupation stage by covering their bottom with 1 cm high soil. In the pilot experiment the cocoons were destroyed in order to record the pre-pupal period. After that, the larvae went out and started wandering for a while and this situation affected their pupal period. For this reason the prepupal period could not be recorded in present experiment. Incubation, larval and pupal periods and their mortality were recorded for different cultivars of sugar beet. The presence of exuviae of head capsule was used to discriminate the larval moulting. The regular checking of dishes continued until the entire adults emerged or pupae died, so the survival rate was recorded for all immature stages. The pupal sex ratio reared on different sugar beet cultivars was also determined. After emerging of adults, female and male moths were paired and each pair was introduced into plastic container (12 cm in diameter by 8 cm in height), which was closed at the top with a fine mesh net for ventilation. A small cotton wick soaked in 10% honey solution was placed in the oviposition containers to provide a food source of carbohydrate for the adults. When females started ovipositing, the number of eggs laid per female was recorded daily and the data used as a measure of age-specific fecundity.

Life table and mortality parameters

Using survivorship and fecundity, net reproduction rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T) and doubling time (DT) were assessed on different sugar beet cultivars (Carey, 1993). The reproductive parameters were also calculated.

The development index was obtained by the ratio of the percentage of individuals that had completed their development to the required average period (Singh & Rembold, 1988). Furthermore, the pattern of mortality with age was evaluated by life table entropy (H), which is the measure of heterogeneity of deaths in a cohort. If all individuals die at the same age (H = 0), the shape of the survival schedule will be rectangular. If all individuals show the same probability of dying at each age (H = 1.0), the shape of the survival schedule will exponentially decrease. Values of $H < 0.5$ suggest that the survival schedule is convex, and values of $H > 0.5$ indicate that the survival schedule is concave. Therefore, the entropy parameter provides a useful measure for characterizing differences in shapes of survival curves among cohorts (Carey, 2001).

Survival model

The Weibull model was used to describe the age-specific survival rate (l_x) of the female adults (Deevey, 1947; Pinder *et al.*, 1978). Based on Weibull frequency distribution, the probability for an individual experience at least time *t* was calculated using the following equation (Carey, 2001): $S_{(t)} = e^{-(t/b)c}$, for $t > 0$; where *b* and *c* are scale shape parameters, respectively. Values of the shape parameter $c > 1$, $= 1$ and < 1 correspond to Deevey's type I, II and III survivorship curves, respectively. Model evaluation was based on goodness of fit, using RSS statistical values of the model on different sugar beet cultivars.

Statistical analysis

Statistical analyses on the development time, oviposition period and adult longevity of *S. exigua* was performed to the one-way analysis of variance (ANOVA), using statistical program PROC GLM (SAS Institute, 2003). Data were tested for normality, using the Kolmogorov-Smirnov test. For the Jackknife estimates of the life table parameters (R_0, r_m, λ, *T* and *DT*), the statistical procedure of Meyer *et al.* (1986) was used. The differences in life table parameters were evaluated by estimating the pseudo-values that were subjected to an analysis of variance (ANOVA) (PROC GLM; SAS Institute, 2003). The means comparison was based on Duncan multiple range test ($P < 0.05$).

Results

Developmental time and longevity

There was no significant differences among the cultivars in the incubation or in the larval period of *S. exigua* ($P > 0.05$) except for the pupal stage (F = 6.23; df = 3, 146; $P < 0.001$) and total developmental time (F = 6.23; df = 3, 146; $P < 0.01$) which were affected significantly by the differences of sugar beet cultivars. The shortest pupal period and the total developmental time belonged to FD0005. The pupal period was influenced by the larval food and varied from 8.81 on FD0005 to 9.79 days on Shirin (table 1). The mean total developmental time was 28.13 days on different sugar beet cultivars.

Differences of sugar beet cultivars showed no significant effect on the longevity and whole lifespan of male or female *S. exigua* ($P > 0.05$) (table 2). Adult longevity of *S. exigua* was 11.28-13.25 days for female and 8.59-10.60 days for male on different sugar beet cultivars.

Survival rate, fecundity and life expectancy

The entire individuals in the cohort of *S. exigua* reared on Renger, FD0005, Dorothea and Shirin died at the age of 47, 48, 45, and 46 days old, respectively (fig. 1). The age-specific survival rates (l_x) at of the time of adult emergence were 0.625, 0.735, 0.750 and 0.696 on Renger, FD0005, Dorothea and Shirin, respectively.

Table 1. Mean ± SE duration of immature stages, adult longevity and whole life span of *S. exigua* on four sugar beet cultivars.

Different life stage/period (day)	Sugar beet cultivars			
	Renger	**FD0005**	**Dorothea**	**Shirin**
Incubation period	4.00 ± 0 a	4.00 ± 0 a	4.00 ± 0 a	4.00 ± 0 a
1st instar larval period	3.16 ± 0.07 a	3.02 ± 0.06 a	3.22 ± 0.08 a	3.20 ± 0.07 a
2nd instar larval period	2.86 ± 0.10 a	2.40 ± 0.08 bc	2.16 ± 0.06 c	2.49 ± 0.09 b
3rd instar larval period	2.53 ± 0.10 a	2.60 ± 0.10 a	2.31 ± 0.07 a	2.34 ± 0.09 a
4th instar larval period	2.45 ± 0.09 a	2.40 ± 0.09 a	2.57 ± 0.12 a	2.36 ± 0.09 a
5th instar larval period	4.39 ± 0.20 ab	4.13 ± 0.14 b	4.69 ± 0.12 a	4.15 ± 0.17 b
Total larval period	15.31 ± 0.24 a	14.55 ± 0.21 a	14.93 ± 0.20 a	14.61 ± 0.21 a
Pupal period	9.23 ± 0.14 b	8.81 ± 0.13 b	9.25 ± 0.18 b	9.79 ± 0.16 a
Developmental time	28.51 ± 0.29 a	27.35 ± 0.27 b	28.20 ± 0.25 a	28.45 ± 0.25 a
Female longevity	11.28 ± 0.54 a	13.25 ± 0.64 a	12.40 ± 0.60 a	12.58 ± 0.70 a
Male longevity	8.59 ± 0.57 a	9.18 ± 0.67 a	10.60 ± 0.49 a	9.68 ± 0.69 a
Female whole life span	39.33 ± 0.80 a	40.90 ± 0.77 a	40.70 ± 0.61 a	41.21 ± 0.69 a
Male whole life span	37.59 ± 0.64 a	36.12 ± 0.86 a	38.80 ± 0.56 a	38.00 ± 0.88 a

The means within each row followed by different letters are significantly different ($P < 0.05$, Duncan).

The results indicated that the life expectancy (e_x) of *S. exigua* was 26.94, 31.39, 30.51 and 30.16 days on Renger, FD0005, Dorothea and Shirin, respectively at the beginning of life. However, the life expectancy of *S. exigua* was estimated 13.82, 14.43, 10.92, 13.25 and 14.24 days, respectively at the time of adult emergence.

The age-specific fecundity (m_x) of *S. exigua* on different sugar beet cultivars is shown in fig. 2. The oviposition started after 28, 27, 29 and 28 days on Renger, FD0005, Dorothea and Shirin, respectively (fig. 2).

Table 2. Life table parameters (± SE) of *S. exigua* on different sugar beet cultivars.

Parameters	Cultivars			
	Renger	**FD0005**	**Dorothea**	**Shirin**
Net reproductive rate (R_0)	253.59 ± 20.11 b	356.07 ± 21.07 a	328.50 ± 20.38 a	314.95 ± 15.54 a
Intrinsic rate of increase (r_m)	0.2229 ± 0.0027 b	0.2309 ± 0.0030 a	0.2254 ± 0.0022 ab	0.2244 ± 0.0018 ab
Finite rate of increase (λ)	1.256 ± 0.0030 a	1.256 ± 0.0042 a	1.250 ± 0.0031 a	1.252 ± 0.0022 a
Mean generation time (T)	24.98 ± 0.16 b	25.83 ± 0.23 a	25.72 ± 0.11 a	25.44 ± 0.17 ab
Doubling time (DT)	3.041 ± 0.033 a	3.038 ± 0.045 a	3.101 ± 0.034 a	3.089 ± 0.025 a

The means within each row followed by different letters are significantly different ($P < 0.05$, Duncan).

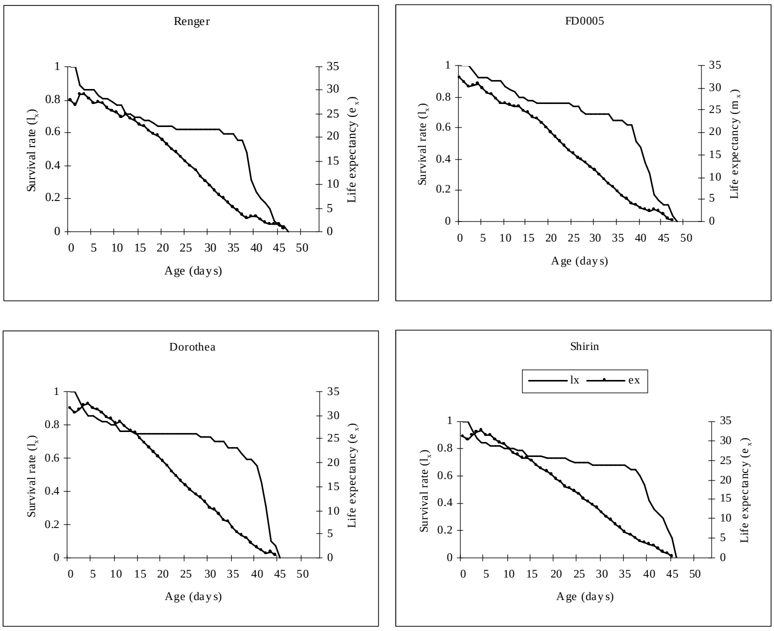

Figure 1. Age-specific survival rate (l_x) and life expectancy (e_x) of *S. exigua* on different sugar beet cultivars.

Life table and mortality parameters

There were significant differences among R_0, r_m and T of *S. exigua* on different sugar beet cultivars. The cohort that was reared on Renger had the lowest value of R_0 (253.59 females per female per generation) and the highest value of this parameter was recorded on FD0005 (356.07 females per female per generation). The intrinsic rate of increase ranged from 0.2229 to 0.2309 day^{-1} on Renger and FD0005, respectively and the highest value of T occurred on FD0005 (table 2).

The gross fecundity ranged from 1499.93 eggs on Dorothea to 2034.27 eggs on FD0005. In addition, the mean number of eggs per female per day on Renger, FD0005, Dorothea and Shirin was 135.72, 133.13, 116.97 and 137.22 eggs, respectively. The oviposition and post-oviposition periods of *S. exigua* were not significantly different among the sugar beet cultivars, but the pre-oviposition period was affected significantly by the tested sugar beet cultivars ($F = 4.51$; $df = 3, 73$; $P < 0.01$) (table 3).

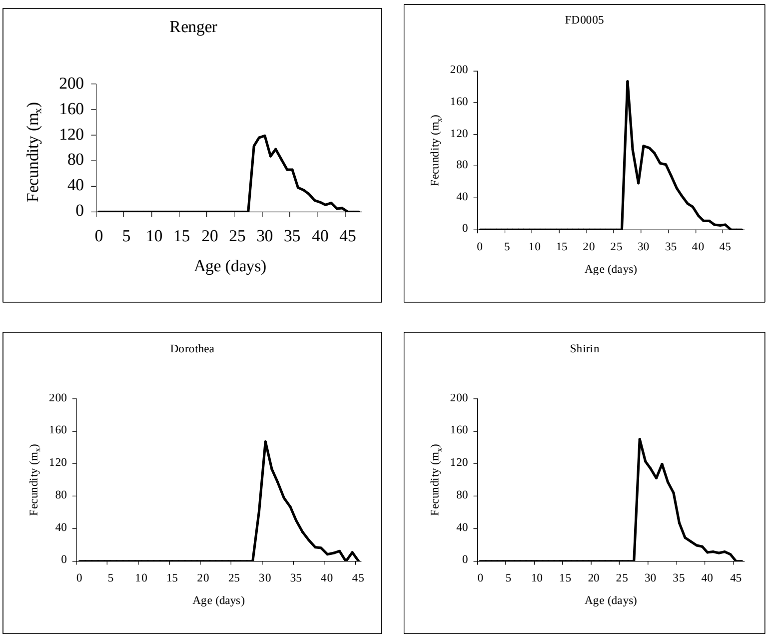

Figure 2. Age-specific fecundity (m_x) of *S. exigua* reared on different sugar beet cultivars.

Table 3. The reproductive parameters and mean (± SE) oviposition periods of *S. exigua* on different sugar beet cultivars.

Parameters	Cultivars			
	Renger	**FD0005**	**Dorothea**	**Shirin**
Gross fecundity rate	1767.27	2034.67	1499.93	1958.29
Gross fertility rate	1251.93	1518.88	1032.25	1400.96
Net fecundity rate	1002.92	1317.26	991.04	1266.96
Net fertility rate	710.46	983.33	682.03	906.38
Mean egg / female / day	135.72	133.13	116.97	137.22
Mean egg per day	80.33	88.46	78.94	97.91
Pre-oviposition period	2.50 ± 0.19 b	3.10 ± 0.27 a	2.30 ± 0.13 b	2.16 ± 0.18 b
Oviposition period	7.86 ± 0.54 a	8.84 ± 0.47 a	9.16 ± 0.43 a	9.32 ± 0.63 a
Post-oviposition period	1.11 ± 0.14 a	1.50 ± 0.15 a	1.25 ± 0.20 a	1.37 ± 0.21 a

The means within each row followed by different letters are significantly different ($P < 0.05$, Duncan).

The lowest percentage of larval mortality was obtained on Dorothea. The highest percentage of larval and pupal mortality (25.00 and 7.50%, respectively) was on Renger and FD0005 (table 4).

The development indices of larval and overall immature stages were lower on Renger compared with the other cultivars. Among the different sugar beet cultivars, the highest development indices of larval and overall immature stages were 5.97 and 2.96 on Shirin and Dorothea, respectively.

The values of entropy parameter (*H*) of *S. exigua* on Renger, FD0005, Dorothea and Shirin were 0.409, 0.303, 0.308 and 0.343, respectively indicated that the survival schedule of *S. exigua* was convex on all sugar beet cultivars ($H < 0.5$) and the survival curves were considered as type I. It suggested that the probability of dying was higher in late ages as compared with early ones.

Survival model

Distribution of age-specific survival rate of *S. exigua* adult female using the Weibull frequency distribution is presented in figure 3 and the values of the Weibull parameters in table 5. Fitting adult survival data to Weibull frequency distribution indicated that the adult survival curve was type I (as parameter c was > 1) on different sugar beet cultivars, which means most of deaths occurred among older individuals (fig. 3, table. 5).

Table 4. The percentage of mortality and development index (*D.I.*) of *S. exigua* on four sugar beet cultivars.

Sugar beet cultivars	Larvae		Pupae		Overall immature	
	Mortality (%)	*D.I.*	Mortality (%)	*D.I.*	Mortality (%)	*D.I.*
Renger	25 (48)	4.90	2.78 (36)	10.53	27.08 (48)	2.56
FD0005	18.37 (49)	5.61	7.5 (40)	10.50	24.49 (49)	2.76
Dorothea	12.5 (48)	5.86	4.76 (42)	10.30	16.67 (48)	2.96
Shirin	12.77 (47)	5.97	7.32 (41)	9.47	19.15 (47)	2.84

Numerals in parentheses are the number of samples tested.

Discussions

The life cycle of *S. exigua* is affected considerably by various factors such as host plants and environmental conditions (Ali & Gaylor, 1992; Greenberg *et al.*, 2001, Azidah & Sofian-Azirun, 2006; Chen *et al.*, 2008). The present study demonstrated the effect of different sugar beet cultivars on biological parameters of *S. exigua.*

The mean larval period was 14.84 days, which is similar to the values reported by Yoshida & Parrella (1992) for chrysanthemum and by Meade & Hare (1991) for celery. Al-Zubaidi & Capinera (1984) reported larval period at 18.40 and 22.00 days on sugar beet and

Table 5. Parameter estimates of the Weibull survival model for adult *S. exigua* on different sugar beet cultivars.

Parameters	Cultivars			
	Renger	**FD0005**	**Dorothea**	**Shirin**
b	12.1807 ± 0.1716	14.8135 ± 0.1031	14.0895 ± 0.12645	14.32099 ± 0.15530
c	8.0687 ± 1.1460	5.5580 ± 0.2769	6.3946 ± 0.4689	4.4909 ± 0.2908
RSS	0.07125	0.01649	0.02647	0.02874

pigweed, respectively. The larval food also affected the pupal period as had already been reported by Yoshida & Parrella (1992) and Soufbaf *et al.* (2010). However, other findings have indicated that the pupal period is relatively constant on different host plants (Greenberg *et al.*, 2001; Naseri *et al.*, 2009). The longest and shortest total developmental time of *S. exigua* were obtained on Renger (28.51 days) and FD0005 (27.35 days), respectively, which is greater than the value reported by Fye & McAda (1972) on artificial diet (≈ 25.00 days) and

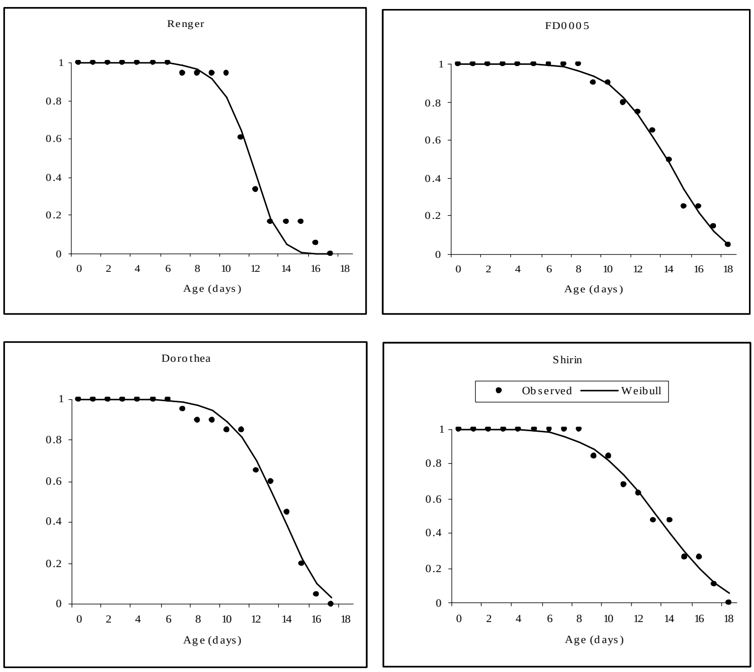

Figure 3. Adult age-specific survivorship (l_x) of *S. exigua* on different sugar beet cultivars fitted using Weibull function.

by Greenberg *et al.* (2001) on cabbage, cotton, pepper, pigweed and sunflower (≈ 20.00-26.00 days). The total developmental time of *S. exigua* has been reported as 24.80-27.60 days on different celery genotypes (Diawara *et al.*, 1996). This difference could be due to the presence of nutritional factors such as carbon, nitrogen and their defensive metabolites that directly affect development and fecundity (Al-Zubaidi & Capinera, 1984; Awmack & Leather, 2002; Azidah & Sofian-Azirun, 2006).

It is clear that longer developmental time increases the risk for larvae being encountered by their natural enemies or being exposed to unfavorable environmental conditions. The extension of developmental time could reduce the number of seasonal generations as well (Al-Zubaidi & Capinera, 1984).

The results showed that the life expectancy trend of *S. exigua* on different sugar beet cultivars was dominantly downward and rise in some short time intervals, could be in coincidence with passage of individuals from crucial periods during their lifespan. The lowest life expectancy of *S. exigua* occurred on Renger because the total number of days by an average individual from age *x* to the last day of possible life was minimum on this cultivar at the beginning of life.

This study showed that the gross fecundity rate ranged from 1499.93 eggs on Dorothea to 2034.67 eggs on FD0005. The previously reported fecundity of this pest was 636.60 and 1521.90 eggs at 30 and 20°C, on artificial diet (Fye & McAda, 1972). Showler (2001) also noted that *S. exigua* preferred pigweed to cotton for oviposition (115.2 versus 524.5 eggs). The values of gross fecundity rate varied from 503.24 to 1086.32 eggs on cotton and pigweed, respectively (Farahani & Talebi, 2010). The different results can be attributed to differences in their host plants or the strains of *S. exigua*.

Host plant, temperature and population strain may shape the life history components (Diawara *et al.*, 1994, 1996; Greenberg *et al.*, 2001; Azidah & Sofian-Azirun, 2006). High value of r_m indicates the susceptibility of a host plant to insect feeding, while a low value indicates that the host plant species is resistant to the pest (Naseri *et al.*, 2009).

There was significant difference in the intrinsic rates of increase with respect to different sugar beet cultivars as the minimum value was obtained on Renger (0.2229 day^{-1}). Greenberg *et al.* (2001) studies on the life table parameters of *S. exigua* on different host plants resulted in the highest r_m when the insect fed on pigweed (0.264 day^{-1}) and the lowest r_m occurred on cabbage (0.156 day^{-1}). These differences are likely due to either the nutritional quality of the host plant species or age differences of the plants.

The mean generation time (*T*) among four sugar beet cultivars was significantly different. The mean generation time (*T*) was longer on FD0005 (25.83 days) than the other sugar beet cultivars. Ali & Gaylor (1992) have noted that *S. exigua* larval developmental period is longer and they need a greater number of stadia when being raised on cotton comparing to artificial diet or pigweed. Azidah & Sofian-Azirun (2006) estimated total developmental time and adult longevity of *S. exigua* on host plants including cabbage *Brassica oleracea* L., long bean *Vigna unguiculata* (L.), lady's finger *Abelmoschus esculenta* L. and shallot *Allium cepa* L. from 37 to 51 days. The extension of generation time could reduce the number of seasonal generations as well. Small nutritional differences are capable of causing large changes in population equilibrium levels (Al-Zubaidi & Capinera, 1984).

Because the highest percentage of immature stages mortality was recorded on Renger (25%), the development index of *S. exigua* was at minimum on this cultivar. Al-Zubaidi & Capinera (1984) reported that percentage of mortality of *S. exigua* varied from 45% to 76%, depending on foliar nitrogen level on sugar beet. Therefore, higher survival rates and shorter developmental times indicate better food quality for insects (Greenberg *et al.*, 2001).

Mathematical models such as Weibull model enable us to explain many phenomena by simple formulae and also it is easier to communicate a function with a few parameters (Carey, 2001). Our results indicated that the values of shape parameter (c) > 1 on different sugar beet cultivars, correspond to Deevey's type I survivorship curves. In this type of survival curve, pest survivorship is initially high and decreases rapidly in late ages.

The results of the comparison of demographic parameters of *S. exigua* revealed that among different sugar beet cultivars, Renger had the highest total developmental time and immature mortality stages and is less suitable food for *S. exigua* and probably has some potential for resistance. There should be further experiments in semi-field and field conditions on a wider range of sugar beet cultivars to discover the naturally resistant or partially resistant cultivars to *S. exigua*. In fact, the partially resistant cultivars may enhance the effectiveness of natural enemies and improve the cultural practices and insecticide impacts (Adebayo & Omoloyo, 2007). A profound knowledge of the demographic parameters of *S. exigua* is also essential to efficiently develop an integrated pest management strategy.

References

Adebayo, A. & Omoloyo, S. V. (2007) Abundance of 24-methylenecholesterol in traditional African rice as an indicator of resistance to the African rice gall midge, *Orseolia* *oryzivora* Harris and Gagne. *Entomological Science* 10, 249-257.

Al-Zubaidi, F. S. & Capinera, J. L. (1984) Utilization of food and nitrogen by the beet armyworm, *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae), in relation to food type and dietary nitrogen levels. *Environmental Entomology* 13, 1604-1608.

Ali, A. & Gaylor, M. J. (1992) Effects of temperature and larval diet on development of the beet armyworm (Lepidoptera: Noctuidae). *Environmental Entomology* 21, 780-786.

Awmack, C. S. & Leather, S. R. (2002) Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology* 47, 817-844.

Azidah, A. A. & Sofian-Azirun, M. (2006) Life history of *Spodoptera exigua* (Lepidoptera: Noctuidae) on various host plants. *Bulletin of Entomological Research* 96, 613-618.

Benrey, B. & Denno, R. F. (1997) The slow-growth-high-mortality hypothesis: a test using the cabbage butterfly. *Ecology* 78, 987-999.

Carey, J. R. (1993) *Applied demography for biologists, with special emphasis on insects*. 211 pp. Oxford University Press, U.K.

Carey, J. R. (2001) Insect biodemography. *Annual Review of Entomology* 46, 79-110.

Chen, Y., Ruberson, J. R. & Olson, D. M. (2008) Nitrogen fertilization rate affects feeding, larval performance, and oviposition preference of the beet armyworm, *Spodoptera exigua*, on cotton. *Entomologia Experimentalis et Applicata* 126, 244-255.

Deevey, E. S. (1947) Life tables for natural populations of animals. *The Quarterly Review of Biology* 22, 283-314.

Diawara, M. M., Trumble, J. T., Lacy, M. L., White, K. K. & Carson, W. G. (1996) Potential of somaclonal celeries for use in integrated pest management. *Journal of Economic Entomology* 89 218-223.

Diawara, M. M., Trumble, J. T., Quiros, C. F., White, K. K., & Adams, C. (1994) Plant age and seasonal variations in genotypic resistance of celery to beet armyworm (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 87, 514-522.

East, D. A., Edelson, J. V. & Cartwright, B. (1989) Relative cabbage consumption by the cabbage looper (Lepidoptera: Noctuidae), beet armyworm (Lepidoptera: Noctuidae), and diamondback moth (Lepidoptera: Plutellidae). *Journal of Economic Entomology* 82, 1367-1369.

East, D. A., Edelson, J. V., Cartwright, B. & Harris, M. K. (1994) Beet armyworm (Lepidoptera: Noctuidae) feeding impact on cabbage development and marketability. *Journal of Economic Entomology* 87, 1641-1646.

Farahani, S. & Talebi, A. A. (2010) Effect of six host plants on life table and reproduction parameters of the beet armyworm, *Spodoptera exigua*. *Proceedings of the 19th Iranian Plant Protection Congress*, *Vol. I*, *Pests*, P. 436.

Fye, R. E. & McAda, W. C. (1972) Laboratory studies on the development, longevity, and fecundity of six lepidopterous pests of cotton in Arizona. *US Department of Agriculture Technical Bulletin*, No. 1454, 73 pp.

Greenberg, S. M., Sappington, T. W., Legaspi, Jr. B. C., Liu, T. X. & Setamou, M. (2001) Feeding and life history of *Spodoptera exigua* (Lepidoptera: Noctuidae) on different host plants. *Annals of the Entomological Society of America* 94, 566-575.

Griswold, M. J. & Trumble, J. T. (1985) Consumption and utilization of celery, *Apium graveolens*, by the beet armyworm *Spodoptera exigua*. *Entomologia Experimentalis et Applicata* 38, 73-79.

Haghani, M., Fathipour, Y., Talebi, A. A. & Baniameri, V. (2006) Comparative demography of *Liriomyza sativae* Blanchard (Diptera, Agromyzidae) on cucumber at seven constant temperatures. *Insect Science* 13, 477-483.

Juvik, J. A. & Stevens, M. A. (1982) Physiological mechanisms of host plant resistance in the genus *Lycopersicon* to *Heliothis zea* and *Spodoptera exigua*, two insect pests of the cultivated tomato. *Journal of American Society and Horticultural Science* 107, 1065-1069.

Meade, T. & Hare, J. D. (1991) Differential performance of beet armyworm and cabbage looper (Lepidoptera: Noctuidae) larvae on selected *Apium graveolens* cultivars. *Environmental Entomology* 20, 1636-1644.

Meyer, J. S., Ingersoll, C. G., McDonald, L. L. & Boyce, M. S. (1986) Estimating uncertainly in population growth rates: jackknife vs. bootstrap techniques. *Ecology* 67, 1156-1166.

Moulton, J. K., Pepper, D. A. & Dennehy, T. J. (1999) Studies of resistance of beet armyworm (*Spodoptera exigua*) to spinosad in field populations from the southern USA and southeast Asia. University of Arizona College of Agriculture 1999 Vegetable Report.

Naseri, B., Fathipour, Y., Moharramipour, S. & Hosseininaveh, V. (2009) Life table parameters of the cotton bollworm, *Helicoverpa armigera* (Lep.: Noctuidae) on different soybean cultivars. *Journal of Entomological Society of Iran* 29, 25-40.

Pinder, J. E., Wiener, J. G. & Smith, M. H. (1978) The Weibull distribution: a new method of summarizing survivorship data. *Ecology* 59, 175-179.

SAS Institute (2003) *SAS user's manual*, *version 9.1*. SAS Institute, Cary, NC.

Showler, A. (2001) *Spodoptera exigua* Oviposition and larval feeding preferences for pigweed, *Amaranthus hybridus*, over squaring cotton, *Gossypium hirsutum*, and a comparison of free amino acids in host plants. *Journal of Chemical Ecology* 27, 2013-2028.

Showler, A. T. & Moran, P. J. (2003) Effects of drought stressed cotton, *Gossypium hirsutum* L. on beet armyworm, *Spodoptera exigua* (Hübner) oviposition and larval feeding preferences and growth. *Journal of Chemical Ecology* 29, 1997-2011.

Singh, A. K. & Rembold, H. (1988) Developmental value of chickpea, *Cicer arietinum*, soybean, *Glycine max* and maize, *Zea mays* flour for *Heliothis armigera* (Lepidoptera: Noctuidae) larvae. *Journal of Applied Entomology* 106, 286-296.

Soufbaf, M., Fathipour, Y., Karimzadeh, J. & Zalucki, M. P. (2010) Development and age-specific mortality of diamondback moth on *Brassica* host plants: pattern and causes of mortality under laboratory conditions. *Annals of Entomological Society of America* 103, 574-579.

Talebi, A. A., Izadpanah, A., Moharramipour, S., Fathipour, Y. & Naseri, B. (2010) Demographic study of the green leafhopper, *Empoasca decipiens* (Hemiptera: Cicadellidae) on four sugar beet cultivars. *Applied Entomology and Phytopathology* 77, 1-14.

Talekar, N. S., Lee, H. R. & Suharsono, S. (1988) Resistance of soybean to four defoliator species in Taiwan. *Journal of Economic Entomology* 81, 1469-1473.

Vargas, R. I., Walsh, W. A., Kanehisa, D. T., Jang, E. B. & Armstrong, J. W. (1997) Demography of four Hawaiian fruit flies (Diptera, Tephritidae) reared at five constant temperatures. *Annals of the Entomological Society of America* 90, 162-168.

Wilson, J. W. (1932). Notes on the biology of *Laphrygma exigua* Hübner. *Florida Entomologist* 16, 33-39.

Yoshida, H. A. & Parrella, M. P. (1992) Development and use of selected *Chrysanthemum* cultivars by *Spodoptera exigua* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 85, 2377-2382.

Zhang, C. L., Xu, D. C., Jiang, X. C., Zhou, Y., Ciu, J., Zhang, C. X., Chen, D. F., Flower, M. R., Elliot, M. C., Scott, N. W., Dewar, A. M. & Slater, A. (2008)

Genetic approaches to sustainable pest management in sugar beet (*Beta vulgaris*). *Annals of Applied Biology* 152, 143-156.

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