

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

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Abstract

The effects of four sugar beet cultivars (Anaconda, Rozier, Evelina and Flores) on the life table parameters of beet armyworm, *Spodoptera exigua* (Lep.: Noctuidae) were evaluated at 26 ± 1 °C, $60 \pm 5\%$ relative humidity and a photoperiod of 16: 8 h (L: D). The highest gross and net fecundity rates were obtained on Anaconda (2573.31 ± 27.78 and 1576.31 ± 16.65 eggs/female, respectively). The net reproductive rate (R_0) was the highest on Anaconda (341.38 ± 56.31 female offspring) and the lowest on Flores and Evelina (106.30 ± 22.4 and 144.62 ± 30.81 female offspring), respectively. The intrinsic rate of increase (r) was affected by different sugar beet cultivars, ranging from 0.197 day^{-1} (on Flores) to 0.274 day^{-1} (on Anaconda). The highest value of finite rate of increase (λ) was on Anaconda (1.31 day^{-1}). The mean generation time (T_c) was different on the various cultivars, ranging from 21.04 ± 0.60 days (on Anaconda) to 23.68 ± 0.38 days (on Flores). Results of the demographic parameters revealed that Anaconda was the most suitable host plant among the mentioned sugar-beet cultivars for *S. exigua*.

Key words: demographic parameter, resistance, sugar beet, *Spodoptera exigua*

چکیده

مقایسه پارامترهای دموگرافی کرم برگخوار چغندر قند (*Spodoptera exigua* (Lepidoptera: Noctuidae) روی چهار رقم تجاری چغندر قند

فربیا مهرخو

اثر چهار رقم چغندر قند (آنکوندا، رزیر، اولینا و فلورس) روی پارامترهای جدول زندگی *Spodoptera exigua* (Lep.: Noctuidae)

در دمای 26 ± 1 درجه سلسیوس، رطوبت نسبی 60 ± 5 درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی تعیین شد. بیشترین نرخ ناخالص و خالص باروری به ترتیب روی آنکوندا (2573.31 ± 27.78 و 1576.31 ± 16.65 تخم / ماده) به دست آمد. نرخ خالص تولید مثل (R_0) به ترتیب روی آنکوندا (341.38 ± 56.31 ماده/نسل) بیشترین و روی ارقام فلورس و اولینا (106.30 ± 22.4 و 144.62 ± 30.81 ماده/نسل) کمترین مقدار بود. نرخ ذاتی افزایش جمعیت (r) تحت تأثیر ارقام مختلف چغندر قند قرار گرفته، به طوری که از 0.197 (روی رقم فلورس) تا 0.274 (روی رقم آنکوندا) متغیر بود. بیشترین مقدار نرخ متناهی افزایش جمعیت (λ) روی رقم آنکوندا (1.31 بر روز) بود. نرخ متناهی افزایش جمعیت روی رقم آنکوندا بالاترین میزان (1.31 بر روز) را نسبت به سایر ارقام داشت. متوسط مدت زمان یک نسل (T_c) روی ارقام مختلف از 21.04 ± 0.60 روز روی آنکوندا تا 23.68 ± 0.38 روز روی فلورس متغیر بود. نتایج حاصله براساس پارامترهای دموگرافی، نشان داد که رقم آنکوندا مناسبترین میزبان در بین ارقام مورد مطالعه چغندر قند برای کرم برگخوار چغندر قند بود.

واژگان کلیدی: پارامترهای دموگرافی، مقاومت، چغندر قند، کرم برگخوار چغندر قند

Introduction

The beet armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) is a generalist herbivore that is widely distributed on more than 170 economically important host plants belonging to the families Brassicaceae (e.g., broccoli, cabbage, cauliflower, and turnips), Solanaceae (petunia, potato, chili pepper, tomato, eggplant, and tobacco) Fabaceae (beans, peas, peanuts, and soybeans) and Chenopodiaceae in Asia. Larvae can also develop on a number of common weeds such as lambsquarters, mullein, pigweed, purslane, Russian thistle, parthenium, and tidestromia (Wilson, 1932; Smits *et al.*, 1987; Capinera, 2001;

Zhang *et al.*, 2011). Members of the family Chenopodiaceae, especially sugar beet are the important vegetable crops grown throughout West-Azərbayjan province and other tropical and subtropical regions in Iran. Chemical control programs against *S. exigua* have been complicated by its propensity to develop insecticide resistance, which impact the natural enemies of the insect (Brewer *et al.*, 1990; Moulton *et al.*, 1999). The use of resistant or partially resistant cultivars could be promising to the population control of the beet armyworm and to reduce its damages on the crops. Currently, great efforts are directed towards a reduction in the use of traditional pesticides and

increase in the use of alternative methods. Therefore, the search for methods compatible with IPM programs, such as selection of host-plant resistance might be an interesting approach (Sáenz-de-Cabezón *et al.*, 2006).

Demographic studies allow the integration of several critical life cycle traits into a single variable (VanLeeuwen *et al.*, 1985). Several authors have argued that the best approach for evaluation of the total effect of xenobiotic substances is life table analysis or demographic parameters (Stark & Wennergren, 1995), which could be used to assess the suitability (or resistance) of host plants to various pests (Vargas *et al.*, 1997; Haghani *et al.*, 2006). Then, the use of intrinsic rate of increase (r) has been recommended (Allan & Daniels 1982), because it is based on both survivorship and fecundity. This parameter is also a measure to the ability of a population to increase in an unlimited environment (Stark & Wennergren, 1995; Southwood & Henderson, 2000). A number of extrinsic and intrinsic factors have been shown to affect r_m and related life table parameters including temperature, geographical origin of insect and host plants (Farahani *et al.*, 2011; Mehrkhrou *et al.*, 2012 a, b; 2013; Karimi-Malati *et al.*, 2012, 2014).

Plant species differ greatly in suitability as host plants for a specific insect when measured in terms of survival, development and reproductive rates. Shorter developmental time and greater total reproduction of insects on a host plant indicate greater suitability of that plant (Van Lenteren & Noldus, 1990). Using resistant cultivars is one of the core strategies of integrated pest management (IPM). The secondary substances of plants (allelochemicals) play a major role in plant resistance to pests (Wilson & Huffaker, 1976). Understanding the demographic parameters of a pest is essential to develop an integrated pest management strategy. These parameters provide population growth rate of an insect pest in the current and next generations (Frel *et al.*, 2003).

There is a few information regarding the effects of sugar beet cultivars on life table parameters of *S. exigua*, except whatever reported by Karimi-Malati *et al.* (2012). However various studies have evaluated the effect of different host plants such as soybean (Farahani *et al.*, 2011; Mehrkhrou *et al.*, 2012 a, b; 2013) canola (Goodarzi & Fathipour, 2010), corn (Mardani-Talaei *et al.*, 2012), wheat, cabbage and pea (Shafqat *et al.*, 2010), shallot, long bean, lady's finger and chilli (Azidah & Sofian-Azirun, 2006 a, b), cotton, pepper, pigweed and sunflower (Greenberg *et al.*, 2001) on the growth potential of *S. exigua*. Since, there is no information regarding resistance of the sugar beet cultivars against *S. exigua*, study on the life table parameters could be provide the exact information in the management of the beet armyworm. Four different commercial sugar beet cultivars were used to determine their suitability for *S. exigua*. Its demographic parameters and population growth potential were also investigated in Iran. The results are expected to be applicable in the IPM programs concerning *S. exigua* in the future.

Material and methods

Plant and insect culture

Seeds of four sugar beet cultivars including Evelina, Rozier, Flores and Anaconda were obtained from the Plant and Seed Modification Research Institute (Khoy, Iran). Selection of these cultivars was based on their importance as the most cultivated commercial cultivars in different regions of Iran. The larvae of Beet armyworm were originally collected from a sugar beet field in Maku, West-Azerbaijan province, Iran region (39° 18' N, 24° 20' E) during August 2013. The collected larvae were divided into four groups and reared for two generation on each sugar beet cultivars before the experiments begin. Eggs from the next generation were used in tests. Larvae were kept in the plastic rearing containers (14 cm width × 20 cm length × 8 cm height) covered with fine nylon mesh. Pupae were reared individually in separate clear plastic containers (3 cm diameter × 5 cm height). Following adult emergence, (within 12 h) one male and one female were placed in a glass container (14 cm diameter × 19 cm height). During the oviposition

period, the moths were provided with cotton balls soaked in 10% honey solution. The experiments were conducted in growth chambers at temperature of 26 ± 1 °C, $60 \pm 5\%$ R. H. and a photoperiod of 16: 8 h (L: D).

Life table study

Age-specific life tables were constructed in order to determine the effects of different sugar beet cultivars on demographic parameters of *S. exigua*. An age-specific life table is based on a cohort (group of individuals) or a population belonging to a single generation (Southwood & Henderson 2000). Cohorts were established using 70 eggs (within 12h of oviposition) on each sugar-beet cultivars. Newly emerged larvae were individually transferred by brush into plastic Petri dishes (8 cm diameter by 2 cm height) with a hole covered by a fine mesh net for ventilation, containing the fresh leaves of different cultivars. Individual insects were checked daily for survival and mortality on four sugar beet cultivars. To study the fecundity rate, population and reproduction parameters were calculated according to a traditional method (Carey, 1993). Newly emerged females and males (8-10 replications) were confined as pairs in containers (11 cm diameter and 12 cm height) until the females died. Adults were supplied with a cotton ball soaked in 10% honey solution. The number of eggs laid per female was daily recorded. The experiments were continued until the last female moth died.

Statistical analysis

All data were checked for normality prior to statistical analysis by Kolmogrov-Smirnov test (SPSS, 2010, ver.19). The reproduction and population growth parameters including net reproductive rate (R_0), intrinsic rate of increase (r_m), mean generation time (T), finite rate of increase (λ), and doubling time (DT) were calculated using the traditional method (Carey, 1993).

Results

Reproductive parameters

The results of the reproductive parameters of *S. exigua* are presented in table 1. The gross hatch rate of

S. exigua ranged from 78% on Evelina to 88% on Anaconda. The sugar beet cultivars affected the gross fecundity rates, which was ranged from 1489.99 ± 96.83 eggs on Rozier to 2573.31 ± 27.78 eggs on Anaconda. The highest and lowest net fecundity rate were observed on Anaconda (1576.31 ± 16.65 eggs/female) and Evelina (614.30 ± 5.52 eggs/female), respectively. The gross fertility rate was affected by sugar beet cultivars. This parameter was the highest on Anaconda (2264.51 ± 24.45 eggs/female) and the lowest on Evelina (1234.03 ± 11.35 eggs/female). The net fertility rate varied from 479.15 ± 4.31 eggs on Evelina to 1387.15 ± 14.65 eggs on Anaconda, which was differed by cultivar. Mean daily number of eggs laid per female were affected by the sugar beet cultivars. This parameter was the highest on Anaconda (257.33 ± 2.77 eggs) and the lowest on Rozier (135.45 ± 8.80 eggs). The daily number of fertile (hatched) eggs was affected by sugar beet cultivars with the highest and the lowest values on Anaconda (226.45 ± 2.44 eggs/female) and Rozier (75.42 ± 5.09 eggs/female), respectively (table 1).

Population growth parameters

The results on population growth parameters of *S. exigua* are presented in table 2. The net reproductive rate (R_0) was found to be different depending on the sugar beet cultivars. The highest R_0 was observed on Anaconda (341.38 ± 56.31 female/female/generation) and the lowest on Flores and Evelina (106.30 ± 22.48 and 144.62 ± 30.81 female offspring) (table 2). The intrinsic rate of natural increase (r) ranged from 0.197 ± 0.01 (day⁻¹) on Rozier to 0.274 ± 0.014 (day⁻¹) on Anaconda. The r -value on Anaconda was higher than other cultivars. The mean generation time was shorter, followed by rearing of *S. exigua* on Anaconda cultivar (21.04 ± 0.60 days). Mean estimates for doubling time (DT) varied on various sugar beet cultivars. Furthermore, the finite rate of increase (λ) was higher on Anaconda (1.31 ± 0.01 day⁻¹) as compared with the other sugar-beet cultivars (table 2).

Table 1. The reproductive parameters of *Spodoptera exigua* on four sugar-beet cultivars.

Cultivars	Net fertility rate	Net fecundity rate	Gross hatch rate	Gross fertility rate	Gross fecundity rate	Daily eggs per female	Daily fertile eggs per female
Anaconda	1387.15 ± 14.65	1576.31 ± 16.65	0.88 ± 0.00	2264.51 ± 24.45	2573.31 ± 27.78	257.33 ± 2.77	226.45 ± 2.44
Rozier	696.97 ± 47.09	829.72 ± 56.06	0.84 ± 0.00	1251.59 ± 81.34	1489.99 ± 96.83	135.45 ± 8.80	75.42 ± 5.09
Flores	551.39 ± 16.67	641.15 ± 19.38	0.86 ± 0.00	1529.54 ± 44.24	1778.54 ± 51.44	197.616 ± 5.71	169.94 ± 4.91
Evelina	479.15 ± 4.31	614.30 ± 5.52	0.78 ± 0.00	1234.03 ± 11.35	1582.09 ± 14.55	175.78 ± 1.61	137.11 ± 1.26

Table 2. Population growth parameters of *Spodoptera exigua* on four sugar-beet cultivars.

Cultivars	R_0	r	T	DT	λ
Anaconda	341.38 ± 56.31	0.274 ± 0.014	21.04 ± 0.60	2.51 ± 0.14	1.31 ± 0.019
Rozier	218.66 ± 54.02	0.238 ± 0.016	22.69 ± 0.84	2.89 ± 0.21	1.26 ± 0.020
Flores	106.30 ± 22.48	0.197 ± 0.010	23.68 ± 0.38	3.49 ± 0.18	1.21 ± 0.012
Evelina	144.62 ± 30.81	0.219 ± 0.011	22.75 ± 0.52	3.15 ± 0.16	1.24 ± 0.013

Discussion

According to the previous studies, temperature and host plants significantly affect the performance of *S. exigua*. Effects of these factors had been conducted to assess the life table parameters of *S. exigua* (Farahani *et al.*, 2011; Karimi-Malati *et al.*, 2012; Mehrkhoh *et al.*, 2012), but there is no literature on demographic parameters on mentioned sugar beet varieties.

The present research demonstrated significant differences among the reproduction parameters of the beet army worm on the four sugar beet cultivars. All of the reproduction parameters, including the gross fecundity rate ($\sum M_x$), net fecundity rate ($\sum L_x M_x$), gross fertility rate, net fertility rate and gross hatch rate, were the highest on Anaconda cultivar. T values for $\sum M_x$ varied from 1489.99 on Rozier to 2573.31 (eggs/female) on Anaconda. Similarly, Karimi-Malati *et al.* (2012) reported that the gross fecundity values of the pest varied from 1499.93 on Dorthea and 2034.67 on FD0005 (sugar beet varieties). However there is some literature on daily fecundity of *S. exigua* on castor bean, cotton, maize, sow bane (Mourad, 2003), cauliflower, peas and wheat (Shafqat *et al.*, 2010). The net fecundity rate of *S. exigua* ranged from 614.30 to 1576.31 (eggs/female), which was minimum on Evelina and maximum on Anaconda. Generally, the net

fecundity value should be lower than the gross fecundity rate because of the survival rate parameter which did not consider in gross fecundity. Similar to the net fecundity value the gross fecundities on soybean varieties were lower than sugar beet varieties. So, it could be concluded that the sugar beet is more suitable for *S. exigua* than soybean varieties (Farahani *et al.*, 2011; Mehrkhoh *et al.*, 2012b).

The net reproductive rate (R_0) is an important indicator of population dynamics (Richard, 1961). It is a key statistic that summarizes the physiological capability of an animal related to its reproductive capacity. Comparison of net reproductive rates often provides considerable insight beyond whatever that available from the independent analysis of individual life history parameters. The net reproductive rates among four sugar beet cultivars was significantly different, which was higher on Anaconda (341.386 in female offsprings) than the other sugar beet cultivars. Similarly, Karimi-Malati *et al.* (2012) have noted that the cohort reared on Renger cultivar had the lowest value of R_0 (253.59 female) meanwhile the highest value was recorded on FD0005 (356.07). According to their finding, it seems that the net reproductive parameters on sugar-beet varieties were higher than those on soybean varieties.

The intrinsic rate of increase (r) adequately summarizes the physiological qualities of a species in relation to its capacity to increase. There was a significant difference among the intrinsic rates of increase on different sugar beet cultivars as the minimum and maximum values were obtained on Flores (0.197 day^{-1}) and Anaconda (0.274 day^{-1}), respectively. The higher r value of *S. exigua* on Anaconda cultivar was due to the greater fecundity, lower mortality and shorter development time. Greenberg *et al.* (2001) studied the life table parameters of *S. exigua* on different host plants and found the highest and the lowest r values on pigweed (0.264 day^{-1}) and cabbage, respectively (0.156 day^{-1}). Some possible differences are likely due to the physiological differences i.e. nutritional quality of the host plant species or age differences of the plants, type of the host plant, genetic differences as a result of laboratory rearing or variation in the geographic populations of the pest (Naseri *et al.*, 2009; Karimi-Malati *et al.*, 2012). High value of r indicates the susceptibility of a host plant to insect while a low value indicates that the host plant species is resistant to the pest (Naseri *et al.*, 2009). Since the Anaconda cultivar was susceptible host; the beet army worm had the greatest opportunity for population increase on this cultivar. However, Flores cultivar was pretty unsuitable host plant, suggesting that it is more resistant to *S. Exigua* than the other cultivars.

The mean generation time of the beet army worm varied from 21.04 to 23.68 days, which was the shortest on Anaconda and the longest on Flores. The higher rate of this value on Flores revealed that the mean time required for a newborn female to replace herself by R_0 -fold was longer compared to other cultivars. In addition, the lower r_m value of *S. exigua* on Flores was mainly another reason for longer mean generation time on this cultivar. Because of the highest intrinsic rate of natural increase of the pest on Anaconda cultivar, the shortest time period required for doubling the initial population was observed on

this cultivar. Doubling time ranged from 2.51 days on Anaconda to 3.49 days on Flores.

The current results on the demographic parameters of *S. exigua* reared on different sugar-beet cultivars are in agreement with previous findings regarding the nutritional indices (Musavi, 2014; Musavi *et al.*, 2014) and life table parameters (Mehrkhoo & Musavi, 2014) indicating the shortest development time, the lowest percentage mortality of immature stages, the highest daily fecundity (eggs per reproduction day) and highest total fecundity (eggs during reproduction period) on Anaconda cultivar which is consistent with the current research regarding r and R_0 values of *S. exigua*.

The survival and reproduction of insect would be better, if the insect fed on different quality and quantity nourishment. So, fitness of the plant-feeding insects depends on the nutrients in their host plants. However, the effectiveness of natural enemies and insecticides may be enhanced by the partially resistant cultivars. Therefore, the use of resistant cultivars can develop biological and chemical control methods as the parts of an IPM strategy (Du *et al.*, 2004; Adebayo & Omoloyo, 2007). It can be concluded that Flores cultivar had lower suitability as host plants for *S. exigua* in comparison with other examined cultivars. After laboratory studies, more attention should be devoted to semi-field and field experiments to obtain more applicable results in field conditions. Meanwhile, our results provide data to establish suitable conditions for rearing of *S. Exigua*. For instance, mass culture methods could be enhanced by selecting host plants for rapid development, maximum survival or high fecundity in order to use these individuals for mass rearing of natural enemies.

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