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DEMOGRAPHIC PARAMETERS OF *AUTOGRAPHA GAMMA* (NOCTUIDAE) AFFECTED BY SUGAR BEET CULTIVARS

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ABSTRACT. *Autographa gamma* (Linnaeus) (Lepidoptera: Noctuidae) is one of the important polyphagous pests of various crops in Iran and many countries of the world. The effect of eight commercial sugar beet cultivars (Peritra, Karolina, Paolita, Lenzier, Tiller, Ardabili, Persia and Rozier) on demographic parameters of *A. gamma* was determined under laboratory conditions (25 ± 1 ºC, 65 ± 5% RH, a 16:8 h light-dark photoperiod) using age-stage, two-sex life table method. A delay in the developmental time of pre-adult was observed when larvae were fed on cultivar Rozier. The lowest net reproductive rate (R_0) was observed on cultivars Paolita and Persia. Also, the intrinsic rate of increase (r_m) was the highest when larvae were reared on cultivar Karolina and the lowest when they were fed on cultivars Peritra, Paolita and Persia. The results of this study revealed that the Peritra, Paolita and Persia were the most unsuitable cultivars for population growth of *A. gamma*. The information obtained from this study could be used, along with other management tactics, to control of this pest by sowing resistant sugar beet cultivars.

Additional key words: *Autographa gamma*, sugar beet, intrinsic rate of increase, population growth

Sugar beet (*Beta vulgaris* L.) and sugar cane (*Saccharum officinarum* L.) are the two sources of sucrose derived exclusively from cultivated crops (Draycott 2006). Owing to the importance of sugar beet as a rotational crop, and the absence of reliable and safe chemical control measures against insect pests of this crop, alternative control options are required to prevent the economic damages. It seems that an integrated pest management (IPM) program (i.e. application of selective pesticides and sowing of resistant sugar beet cultivars) could supply the best management option for control of *A. gamma* in Iran.

Sugar beet can be attacked by a large number of pests from different orders and families (Hein et al. 2009). The silver Y moth, *Autographa gamma* (Linnaeus) (Lepidoptera: Noctuidae), is a polyphagous pest, with more than 200 host plant species (Nash and Hill 2003), distributed in Europe, Asia, and Northern Africa (CABI 2007). Sugar beet has been reported as one of the main host plants of *A. gamma* in Africa, the former Soviet Union (Dochkova 1972, CAB 2003), and Iran (Kheyri 1989). The larvae of *A. gamma* cause economic losses to sugar beet crops by feeding on leaves, and subsequently reducing yields (CABI 2007).

Climatic conditions, host plant quality, migration, and natural enemies can influence population dynamics of *A. gamma* (Maceljski & Balarin 1974, Honek et al. 2002). *A. gamma* is capable of long distance migration, which allows it to remain an important pest in regions where populations can not survive throughout the year (Palmqvist 2001, Chapman et al. 2012, 2015). For the most herbivorous insects that have non-feeding adults, host plant quality is an important factor for determinant of their fitness, because reproductive potential of adults is limited by food accumulated during their larval stage (Slansky & Rodriguez 1987, Awmack & Leather 2002).

Life table studies are useful tools to understand the most detailed and correct scheme of an insect population dynamics (Wittmeyer & Coudron 2001). Studies related to the traditional life tables, however, are only based on the survival and fecundity of female populations. Moreover, male individuals, the stage differentiation and variable developmental time among individuals have been neglected (Chi & Su 2006). Therefore, to incorporate variable developmental rates for both sexes (male and female), Chi & Liu (1985) and Chi (1988) developed an age-stage, two-sex life table model.

Among the life table parameters, the intrinsic rate of increase (r_m), as an index of herbivores performance (Buitenhuis et al. 2004), is the most important parameter that can be used to estimate the population growth of insect species under specified conditions (Andrewartha & Birch 1954). Previously, several authors evaluated the effect of different host plants on the life table parameters of lepidopteran insects (Jha et al. 2012, Karimi-Malati et al. 2012, Naseri et al. 2014, Alami et al. 2014). However, despite *A. gamma* causes large economic damages on different host plants, there is no published papers about the life table parameters of this pest on different sugar beet or other host plant cultivars. The aim of this study was to compare the demographic parameters of *A. gamma* on eight commercial sugar beet cultivars and to quantify resistance or susceptibility of these cultivars to the pest. Therefore, determining the effect of different sugar beet cultivars on the demography and other biological parameters of *A. gamma* is an initial step toward designing comprehensive strategies in an IPM program of this pest.

MATERIALS AND METHODS

Sugar beet cultivars. The untreated seeds of eight sugar beet cultivars including Peritra, Karolina, Paolita, Lenzier, Tiller, Ardabili, Persia and Rozier were obtained from the Plant and Seed Modification Research Institute of Sugar Beet (Ardabil, Iran). They were cultivated in the research farm of the University of Mohaghegh Ardabili (Ardabil, Iran) in May 2014. Selection of these cultivars was based on their importance as the most cultivated sugar beets in different regions of Iran and some other countries of the world. The experiments were started when sugar beet cultivars reached the eight-leaf stage. The young leaves, with equal size, of each sugar beet cultivar were transferred to a growth chamber (25 ± 1 ºC, 65 ± 5% RH, and a 16:8 h light-dark photoperiod) and were used in the experiments.

Rearing of *A. gamma*. The eggs of *A. gamma* were collected from sugar beet fields from Northern Khorasan, Iran. The insect populations were reared for two generations on the leaves of each sugar beet cultivar before performing the experiments. All experimental insects were kept inside a growth chamber at above-mentioned conditions.

After emergence of adult moths and to obtain the same aged eggs of *A. gamma*, 10–15 pairs of both sexes (male and female) were kept inside transparent egg-laying containers (11.5 cm in diameter, 9.5 cm in height), which were closed at the top with a fine mesh net for ventilation. The internal walls of each container were covered with the same mesh net as an egg-laying substrate. Fifty eggs laid within 12 hours were collected from the egg-laying container, and were used for the experiment. Neonate larvae were individually transferred into plastic Petri dishes (8 cm in diameter, 2 cm in height) with a hole (1 cm in diameter) covered with a fine mesh net for aeration. These Petri dishes were contained fresh leaves of each tested sugar beet cultivar. To keep freshness, the petioles of detached leaves were inserted in cotton soaked in water. The leaves of each cultivar were replaced daily. Mortality or molting were recorded daily up to pupation and emergence of adults. For pre-pupation and pupation, fifth instar larvae were kept in cylindrical plastic containers (3 cm in diameter, 5 cm in height). Duration of larval, pre-pupal and pupal stages and developmental time of total pre-adult were recorded on different sugar beet cultivars.

After emergence of adult moths, a pair of female and male moths was transferred to the same egg-laying containers as described above. Number of eggs laid was counted and the experiments were continued up to the death of the last adult moth. To supply a source of carbohydrate for adult feeding, a small cotton wick soaked in 10% honey solution was inserted into the egg-laying containers. In this study, adult pre-oviposition period (APOP: the time between the emergence of an adult female and the initiation of its oviposition), total pre-oviposition period (TPOP: the duration from egg to first oviposition), oviposition period, fecundity (eggs laid during the reproductive period) and adult longevity were recorded.

Life table analysis. All individuals' data were analyzed according to the age-stage, two-sex life table model (Chi & Liu 1985; Chi 1988). The survival rate (s_{xj}) (i.e. x is the age and j is the stage) was calculated; the first stage is the egg, the second stage is the larva–prepupa, the third stage is the pupa, the fourth and fifth stages are female and male, respectively. The fecundity (f_{xj}), the age-specific survival rate (l_x), the age-specific fecundity (m_x), and the population parameters were measured accordingly (Huang & Chi 2012). The intrinsic rate of increase (r_m) was calculated using bisection method from the Euler-Lotka formula:

$$\sum_{x=0}^{\infty} e^{-r_m(x+1)} l_x m_x = 1$$

with the age indexed from 0 (Goodman 1982). The mean generation time (T) is defined as the length of time that a population can increase to R_0-fold of its population size at the stable stage distribution ($\lambda^T = R_0$), which it was then calculated as $T = (\ln R_0)/r_m$. The gross reproductive rate (GRR) was calculated as $GRR = \sum m_x$. To estimate the means, variances, and standard errors of the population parameters, the bootstrap technique (Efron & Tibshirani 1993), which included TWOSEX-MSChart (Chi 2013), was used. The obtained data were then analyzed by one-way ANOVA followed by comparison of the means with LSD test at α = 0.05 using statistical software Minitab 16.0.

RESULTS

Statistics of analysis of variance for the effect of different sugar beet cultivars on the demographic parameters of *A. gamma* are listed in Table 1.

Developmental time. The results of the effect of different sugar beet cultivars on development time of total pre-adult of *A. gamma* are given in Table 2. Larval period, pupal period and developmental time of pre-

TABLE 1. Statistics of analysis of variance for the effect of different sugar beet cultivars on demographic parameters of *Autographa gamma*

Parameters	***df***	***F***	***P-value***
Incubation period (day)	-	-	-
Larval period (day)	7, 171	3.77	<0.05
Pupal period (day)	7, 173	16.04	<0.05
Pre-adult (day)	7, 171	16.29	<0.05
Male longevity (day)	7, 53	5.62	<0.05
Female longevity (day)	7, 67	1.43	0.21
Male life span (day)	7, 53	8.77	<0.05
Femle life span (day)	7, 67	0.62	0.73
APOP [a] (day)	7, 31	3.34	<0.05
TPOP [b] (day)	7, 31	2.32	<0.05
Oviposition period (day)	7, 83	1.64	0.13
Fecundity (eggs per female)	7, 52	2.46	<0.05
R_0 [c] (offspring)	7, 625	91.20	<0.05
GRR [d] (offspring)	7, 674	165.22	<0.05
r_m [e] (day^{-1})	7, 488	106.11	<0.05
λ [f] (day^{-1})	7, 706	59.42	<0.05
T [g] (day)	7, 638	68.62	<0.05

[a] Adult pre-ovipostion period, [b] Total pre-oviposition period, [c] Net reproductive rate, [d] Gross reproductive rate, [e] Intrinsic rate of increase, [f] Finite rate of increase, [g] Mean generation time

TABLE 2. Mean (±SE) pre-adult duration (days) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

Cultivar	**Incuba-tion**	***n***	**Larval period**	***n***	**Pre-pupal period**	***n***	**Pupal period**	***n***	**Total pre-adult**	***n***
Peritra	3.00	30	14.43 ± 0.28 abc	28	2.00	23	9.39 ± 0.24 b	23	26.78 ± 0.35 b	23
Karolina	3.00	30	14.34 ± 0.29 abcd	25	2.00	23	9.04 ± 0.13b c	23	26.39 ± 0.31 b	23
Paolita	3.00	30	13.65 ± 0.18 d	29	2.00	29	7.65 ± 0.21 e	29	24.41 ± 0.21 cd	29
Lenzier	3.00	30	15.00 ± 0.35 a	15	2.00	15	8.53 ± 0.37 cd	15	26.53 ± 0.50 b	15
Tiller	3.00	30	14.78 ± 0.39 a	19	2.00	19	9.00 ± 0.30 bc	19	26.78 ± 0.41 b	19
Ardabili	3.00	30	13.76 ± 0.21 cd	27	2.00	25	6.85 ± 0.21 f	25	23.68 ± 0.33 d	25
Persia	3.00	30	13.92 ± 0.09 bcd	30	2.00	25	8.00 ± 0.20 de	25	24.92 ± 0.16 c	25
Rozier	3.00	30	14.60 ± 0.18 ab	20	2.00	20	10.30 ± 0.52 a	20	27.80 ± 0.59 a	20

The means followed by different letters in the same column are significantly different (LSD, $P<0.05$).

The *n* value shows the number of insect tested on each cultivar.

TABLE 3. Mean (±SE) adult longevity (days) and life span (days) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

Cultivar	**Male longevity**	***n***	**Female longevity**	***n***	**Male life span**	***n***	**Female life span**	***n***
Peritra	7.33 ± 1.56 c	14	13.88 ± 1.96 a	9	34.00 ± 1.57 c	14	40.88 ± 1.56 a	9
Karolina	8.67 ± 2.28 c	12	14.71 ± 2.20 a	11	34.67 ± 2.26 c	12	41.00 ± 1.99 a	11
Paolita	10.22 ± 1.05 bc	15	14.09 ± 1.95 a	14	34.44 ± 1.13 c	15	40.00 ± 1.56 a	14
Lenzier	18.57 ± 1.51 a	8	15.57 ± 1.89 a	7	45.43 ± 1.51 ab	8	41.57 ± 2.30 a	7
Tiller	19.00 ± 1.98 a	10	18.22 ± 2.30 a	9	45.50 ± 1.96 ab	10	41.10 ± 1.84 a	9
Ardabili	11.75 ± 1.58 bc	14	16.89 ± 1.98 a	11	34.75 ± 1.54 c	14	41.22 ± 2.17 a	11
Persia	15.42 ± 2.20 ab	12	19.46 ± 1.50 a	13	40.50 ± 2.14 b	12	44.23 ± 1.44 a	13
Rozier	18.20 ± 1.16 a	8	14.00 ± 1.61 a	12	48.00 ± 1.55 a	8	41.00 ± 1.58 a	12

The means followed by different letters in the same column are significantly different (LSD, $P<0.05$).

The *n* value shows the number of insect tested on each cultivar.

TABLE 4. Mean (±SE) oviposition period (days), and fecundity (eggs laid during reproductive period) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

Cultivar	**APOP**[a]	**TPOP**[b]	**Oviposition period**	**Fecundity**	***n***
Peritra	10.33 ± 3.18 a	36.00 ± 3.00 ab	2.67 ± 0.33 a	38.70 ± 14.30 b	9
Karolina	3.60 ± 1.12 b	29.40 ± 1.17 c	4.40 ± 0.67 a	212.90 ± 80.60 a	11
Paolita	12.33 ± 0.66 a	36.33 ± 0.66 a	2.30 ± 0.57 a	26.30 ± 12.70 b	14
Lenzier	6.00 ± 1.15 b	32.33 ± 2.03 abc	3.33 ± 1.20 a	79.80 ± 35.70 b	7
Tiller	5.40 ± 1.12 b	32.00 ± 1.45 abc	2.40 ± 0.74 a	91.20 ± 41.00 b	9
Ardabili	5.38 ± 1.03 b	29.75 ± 1.30 c	2.88 ± 0.58 a	72.40 ± 29.70 b	11
Persia	5.75 ± 0.91 b	30.62 ± 0.88 c	2.50 ± 0.46 a	31.38 ± 8.46 b	13
Rozier	6.25 ± 1.97 b	31.75 ± 2.14b c	2.25 ± 0.62 a	58.40 ± 21.70 b	12

The means followed by different letters in the same column are significantly different ($P<0.05$, LSD).

[a] Adult pre-oviposition period [b] Total pre-oviposition period

The *n* value shows the number of female moths tested on each cultivar.

TABLE 5. Mean (± SE) two-sex life table parameters of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

Cultivar	R_0[a] (offspring)	*GRR*[b] (offspring)	r_m[c] (day^{-1})	λ[d] (day^{-1})	*T*[e] (days)
Peritra	11.74±0.72 d	43.25±2.73 c	0.059±0.001 f	1.05±0.00 d	38.23±0.20 a
Karolina	36.05±1.62 a	138.12±5.59 a	0.104±0.001 a	1.10±0.00 a	34.89±0.08 c
Paolita	6.54±0.24 e	22.97±0.89 d	0.050±0.000 f	1.05±0.00 d	37.91±0.11 a
Lenzier	24.57±1.28 b	59.31±3.52 b	0.094±0.003 b	1.08±0.00 b	34.35±0.26 cd
Tiller	19.25±1.35 c	45.91±2.80 c	0.063±0.005 e	1.06±0.00 c	34.04±0.21 de
Ardabili	19.55±0.93 c	59.01±3.32 b	0.083±0.001 c	1.08±0.00 b	33.66±0.39 ef
Persia	8.48±0.36 e	13.18±0.57 e	0.059±0.000 f	1.05±0.00 d	35.82±0.14 b
Rozier	19.07±1.35 c	45.07±2.54 c	0.079±0.002 d	1.08±0.00 b	33.10±0.24 f

The means followed by different letters in the same column are significantly different (P<0.05, LSD).

[a] Net reproductive rate, [b] Gross reproductive rate, [c] Intrinsic rate of increase, [d] Finite rate of increase,

[e] Mean generation time

adult were significantly different on sugar beet cultivars. The longest larval period was observed on cultivars Lenzier (15.00 ± 0.35 days) and Tiller (14.78 ± 0.39 days), and the shortest larval period was seen on cultivar Paolita (13.65 ± 0.18 days). The pupal period and developmental time of total pre-adult were the longest on cultivar Rozier (10.30 ± 0.52 and 27.80 ± 0.59 days, respectively), and the shortest on cultivar Ardabili (6.85 ± 0.21 and 23.68 ± 0.33 days, respectively).

Adult longevity and life span. Table 3 shows the adult longevity and life span (from egg stage to adults' death) of *A. gamma* fed on eight sugar beet cultivars. Different sugar beet cultivars as larval food had no significant effects on the longevity and life span of female *A. gamma*. However, significant differences were observed for the longevity and life span of male moths fed on eight sugar beet cultivars. The shortest male longevity was observed on cultivars Karolina (8.67 ± 2.28 days) and Peritra (7.33 ± 1.56 days). Moreover, the longest male life span was recorded on cultivar Rozier (48.00 ± 1.55 days) compared with the other cultivars.

Oviposition period and fecundity. The APOP, TPOP, oviposition period and fecundity of adults of *A. gamma* which came from larvae reared on different sugar beet cultivars are given in Table 4. Oviposition period of *A. gamma* was not significantly different on different sugar beet cultivars. However, tested sugar beet cultivars showed significant effects on the APOP, TPOP and fecundity of this pest. The APOP was the longest when larvae were fed on cultivars Paolita (12.33 ± 0.66 days) and Peritra (10.33 ± 3.18 days), and TPOP was the longest when they were fed on cultivar Paolita (36.33 ± 0.66 days). Furthermore, fecundity of *A. gamma* on cultivar Karolina (212.90 ± 80.60 eggs) was higher than the other tested cultivars.

Life table analysis. The age-stage specific survival rates (s_{xj}) of *A. gamma* on different sugar beet cultivars are shown in Figure 1. Noticeable stage overlapping was observed because of variation in the development rate among individuals on sugar beet cultivars. The highest age-stage specific survival rate of larva-prepupa, pupa and adult male of *A. gamma* was on cultivar Persia. Also, the highest age-stage specific survival rate of adult female was on cultivars Persia and Rozier, and the lowest was on cultivar Peritra (Fig. 1).

The age-stage life expectancy (e_{xj}) gives the expected life span that an individual of age x and stage j can live after age x. The e_{xj} of *A. gamma* on different sugar beet cultivars are presented in Figure 2. The highest value of the life expectancy for egg stage was 39.00 days on cultivar Persia. Life expectancy of larval and pupal stages was the highest on cultivars Persia (36 days) and Tiller (30.52 days), respectively. Moreover, the life expectancy of female moths was the highest (21.00 days) on cultivars Persia and Tiller. The life expectancy of the male moth of *A. gamma* was the highest (21.33 days) on cultivar Rozier.

Age-specific survival rate (l_x) is the probability that an egg will survive to age *x*; therefore, the curve l_x (Fig. 3) is the simplified version of s_{xj}. Our results showed that the death of the last female occurred at the ages of 47, 51, 44, 52, 52, 50, 54 and 52 days on cultivars Peritra, Karolina, Paolita, Lenzier, Tiller, Ardabili, Persia and Rozier, respectively (Fig. 3). The age-stage specific fecundity (f_{x4}) gives daily number of offspring produced by *A. gamma* individual at age *x* and stage *j*. Since only females produce offspring, there is only a single curve f_{x4} (i.e. the adult female is the fourth life stage). The maximum age-stage specific fecundity on these cultivars (the same order mentioned above) was 32, 48, 6, 24, 28, 30, 5 and 23 eggs female^{-1} day^{-1}, respectively that occurred at the ages of 39, 36, 41, 30, 31, 30, 32 and 32 days, respectively. The oviposition of the first female on the tested sugar beet cultivars (the same order mentioned above) started at the ages of 28, 25, 30, 29, 28, 25, 26 and 28 days, respectively. Also, the highest age-specific fecundity (m_x) of *A. gamma* adult emerging from the larvae reared on above-mentioned cultivars was 32, 31, 5, 12, 14, 25, 2 and 18 females female^{-1} day^{-1}, respectively that occurred at the ages of 39, 33, 41, 30, 31, 40, 32 and 32 days, respectively (Fig. 3).

The demographic parameters calculated by using the age-stage, two-sex life table for *A. gamma* on different sugar beet cultivars are listed in Table 5. The net reproductive rate (R_0) was found to be significantly different depending on the sugar beet cultivars on which individual insects were reared. The R_0 value of *A. gamma* was the lowest on cultivars Paolita (6.54 ± 0.24 offspring) and Persia (8.48 ± 0.36 offspring), and the highest on cultivar Karolina (36.05 ± 1.62 offspring). The gross reproductive rate (GRR) of this pest was the highest on cultivar Karolina (138.12 ± 5.59 offspring) and the lowest on cultivar Persia (13.18 ± 0.57 offspring). The highest intrinsic rate of increase (r_m) was on cultivar Karolina (0.104 ± 0.001 day^{-1}) and the lowest values were on cultivars Peritra (0.059± 0.001 day^{-1}), Persia (0.059± 0.000 day^{-1}) and Paolita (0.050 ± 0.000 day^{-1}). Moreover, the finite rate of increase (λ) showed significant differences, which was the highest on cultivar Karolina (1.10 ± 0.00 day^{-1}). The longest mean generation time (*T*) of *A. gamma* was observed on cultivars Peritra (38.23 ± 0.20 days) and Paolita (37.91 ± 0.11 days), and the shortest value was seen on cultivar Rozier (33.10 ± 0.24 days).

Discussion

The results of this study demonstrated that the life table parameters of *A. gamma* were significantly differed on eight sugar beet cultivars. Variation in host plant quality can affect the life cycle characteristics of herbivores and play an important role in regulating insect populations (van Lenteren & Noldus 1990, Awmack & Leather 2002, Umbanhowar & Hastings 2002).

A delay in the development of *A. gamma* larvae on cultivars Lenzier and Tiller could be attributed to unsuitablity of these cultivars for larval feeding and development. The mean larval period of *A. gamma* on eight sugar beet cultivars, in this study, is shorter than that reported by Taha et al. (2012) for *A. gamma* fed on artichoke (19.14 days). Differences in the host plant species could explain such discrepancy. *A. gamma* required a longer time to complete its immature stages when reared on cultivar Rozier than when reared on the other tested cultivars. The extension of the developmental time of pre-adult of *A. gamma* on cultivar Rozier could increase the risk of encountering immatures by their natural enemies or being exposed to unfavorable environmental conditions (Al- Zubaidi & Capinera 1984).

The results of this study showed that the longevity and life span of female moths of *A. gamma* were constant on different sugar beet cultivars; however, the longevity and life span of male moths were affected by tested sugar beet cultivars. Since nutrient regulation in lepidopteran larvae is sex-specific (Lee 2010), nutritional requirements of male and female *A. gamma* larvae are likely different with each other. Such difference could affect the life history traits of female and male moths of *A. gamma* such as the adult longevity.

It is noticeable that, in phytophagous insects, larval feeding on nutritionally-rich plants can increase fecundity of adults (Verkerk & Wright 1996). Therefore, high fecundity of *A. gamma* on cultivar Karolina suggests that this cultivar is more suitable than the others for feeding of this pest. In our study, the range of fecundity of *A. gamma* (Table 4) on different sugar beet cultivars is lower than that reported by other authors (Dochkova 1972, Harakly 1975, Spitzer et al. 1984), suggesting that these cultivars are more unsuitable than other host cultivars for oviposition of the pest . However, Taha et al. (2012) reported that the female moths of *A. gamma* which came from larvae reared on artichoke could lay 57.67 eggs at 25 ºC. Some

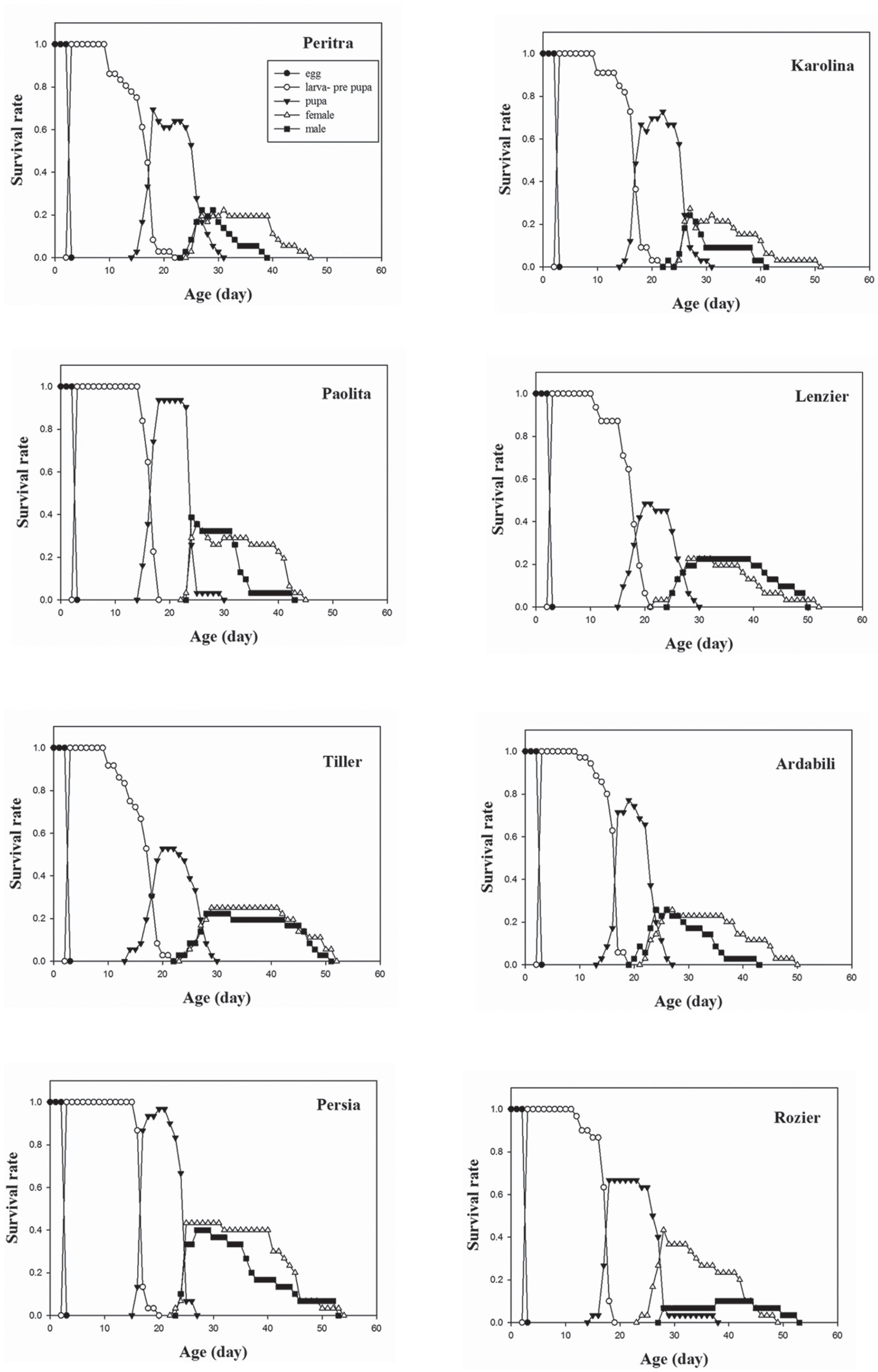

FIG. 1. Age-stage specific survival rate (s_{xj}) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

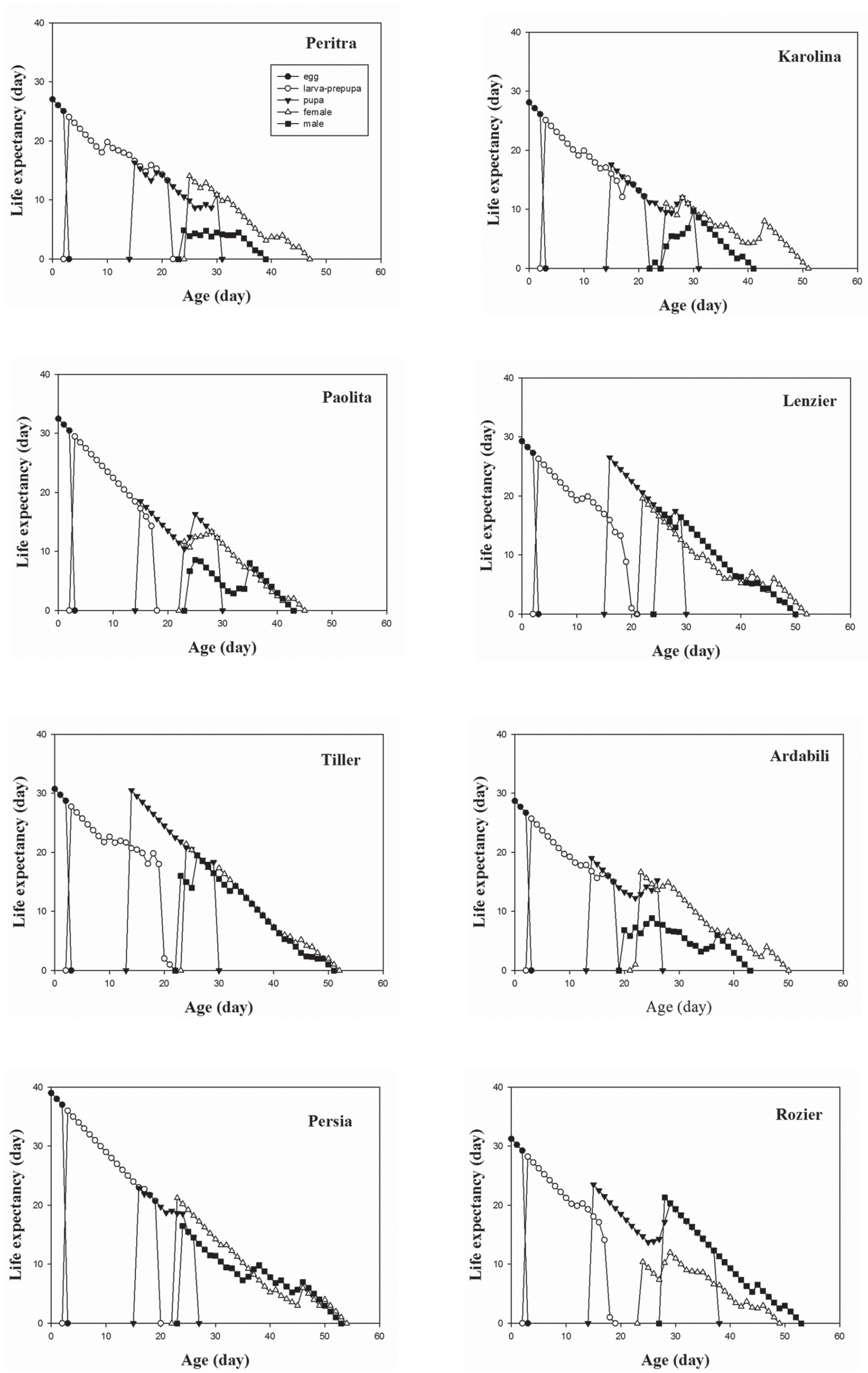

FIG. 2. Age-stage specific life expectancy (e_{xj}) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

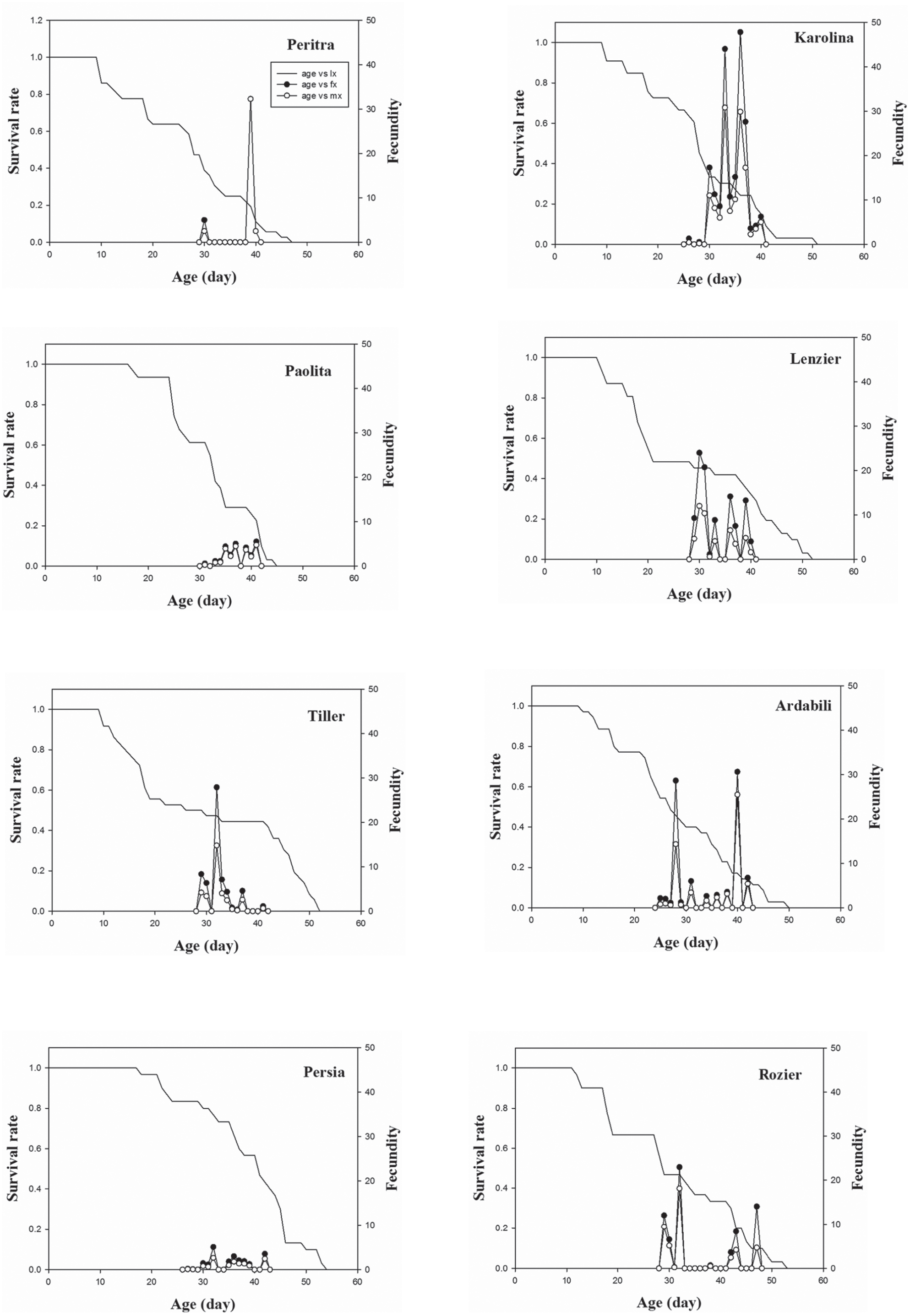

FIG. 3. Age-specific survival rate (l_x), age-stage specific fecundity (f_{x4}), and age-specific fecundity (m_x) of *Autographa gamma* fed on different sugar beet cultivars under laboratory conditions.

probable reasons for this inconsistency could be attributed to the variations in geographic populations of *A. gamma* or differences in the tested host plants.

The bootstrapping was used to estimate the population parameters in this study. It is known that this technique is more valid in estimating means and variances of population parameters than jackknife procedure (Huang & Chi 2012). It was accepted that the age of the first reproduction of insects can affect the intrinsic rate of increase (r_m). Moreover, when fecundity not change, the shorter pre-oviposition period will result in a higher intrinsic rate of increase (Lewontin 1965, Huang & Chi 2012, Jha et al. 2012). The higher r_m value of *A. gamma* on cultivar Karolina was mainly owing to the greater fecundity and the shorter APOP and TPOP of the pest reared on this cultivar. Thus, lower r_m value on cultivars Peritra, Paolita and Persia was mainly owing to the lower fecundity and longer APOP and TPOP of *A. gamma* on these cultivars. A high value of r_m shows that the host plant species/cultivars are relatively suitable to insect feeding and vice versa. Thus, cultivar Karolina, among sugar beet cultivars, was the susceptible host, and population growth of *A. gamma* was the highest on this cultivar. However, the lowest value of r_m was on cultivars Peritra, Paolita and Persia, suggesting that they are partially resistant to *A. gamma* compared with the other cultivars.

According to the results obtained from this research, cultivars Peritra, Paolita and Persia are relatively unsuitable (resistant) and cultivar Karolina is relatively suitable (susceptible) hosts for population growth of *A. gamma*. Owing to the polyphagous nature of *A. gamma*, future studies should be focused on testing the wide range of host plants for development of *A. gamma*. Moreover, assessing the chemical components of host plants is required for better understanding of host plant suitability. As the selected cultivars are commercially grown sugar beets in Iran, the control programs of *A. gamma* would be successful if farmers switch to growing the most resistant cultivars. Moreover, the wide host-range of this pest and the long-range migration capacity of adults (Chapman et al. 2015), contribute to its high potential for establishment in different countries of the world. Therefore, identification of cultivars resistant to *A. gamma* by studying demographic analysis of the pest is an important step for area-wide pest management.

Knowledge of how the quality of tested sugar beet cultivars affects the demographic parameters of *A. gamma* will be helpful to understand the population dynamics of this pest. Furthermore, we emphasize the significant effects of the tested sugar beet cultivars (as representatives of the gene pool of sugar beet) on the demographic parameters of *A. gamma* and discover the crucial importance of the cultivar selection and breeding in management programs of the pest.

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LITERATURE CITED

ALAMI, S., NASERI, B., GOLIZADEH, A. & RAZMJOU J. 2014. Age-stage, two-sex life table of the tomato looper, *Chrysodeixis chalcites* (Lepidoptera: Noctuidae), on different bean cultivars. Arth-Plant Int. 8: 475–484.

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. Environ. Entomol. 13: 1604–1608.

ANDREWARTHA, H. G. & BIRCH, L. C. 1954. The distribution and abundance of animals. The University of Chicago Press.

AWMACK, C. S. & LEATHER S. R. 2002. Host plant quality and fecundity in herbivorous insects. Annu. Rev. Entomol. 47: 817–844.

BUITENHUIS, A. J., RODENBURG, T. B., SIWEK, M., CORNELISSEN, S. J. B., NIEUWLAND, M. G. B., CROOIJMANS, R. P. M. A., GROENEN, M. A. M., KOENNE, P., BOVENHUIS, H. & VAN DER POEL, J. J. 2004. Identification of QTL involved in open-field behavior in young and adult laying hens. Behav. Genet. 34: 325–333.

CAB. 2003. Crop protection compendium: global module. Commonwealth Agricultural Bureau International, Wallingford, UK.

CABI. 2007. Crop protection compendium. Wallingford, UK: CAB International. Available from: http://www.cabi.org/compendia/cpc/.

CHAPMAN, J. W., BELLA, J. R., BURGIN, L. E., REYNOLDS, D. R., PETTERSSON, L. B., HILL, J. K., BONSALLG, M. B. & THOMAS, J. A. 2012. Seasonal migration to high latitudes results in major reproductive benefits in an insect. PANS 109: 14924–14929.

CHAPMAN, J. W., REYNOLDS, D. R. & WILSON, K. 2015. Long-range seasonal migration in insects: mechanisms, evolutionary drivers and ecological consequences. Ecol. Lett. 18: 287–302.

CHI, H. & LIU, H. 1985. Two new methods for the study of insect population ecology. Bull. Inst. Zool. Acad. Sin. 24: 225–240.

CHI, H. 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. Environ. Entomol. 17: 26–34.

CHI, H. 2013. TWOSEX-MS chart: a computer program for the age-stage, two sex life table analysis. Available from: http://140.120.197.173/Ecology/Download/ TwosexMSChart.zip.

CHI, H. & H. Y. SU. 2006. Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead) (Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer) (Homoptera: Aphididae) with mathematical proof of the relationship between female fecundity and the net reproductive rate. Environ. Entomol. 35: 10–21.

DOCHKOVA, B. 1972. Some biological and ecological studies on *Autographa gamma* L. (Lepidoptera: Noctuidae). Plant Sci. 9: 141–149.

DRAYCOTT A.P. 2006. Sugar beet. Blackwell Publishing Ltd., Oxford, UK.

EFRON, B. & TIBSHIRANI, R. J. 1993. An introduction to the bootstrap. Chapman and Hall, New York.

GOODMAN, D. 1982. Optimal life histories, optimal notation, and the value of reproductive value. Am. Nat. 119: 803–823.

HARAKLY, F. A. 1975. Biological studies on the loopers *Autographa gamma* (L.) and *Cornutiplusia circumflexa* (L.) (Lep., Noctuidae) infesting truck crops in Egypt. J. Appl. Entomol. 78: 285–290.

HEIN, G. L, BOETEL, M. A. & GODFREY, L. D. 2009. Major insect and arthropod pests, pp. 95–117. *In* Harveson, R. M. Hanson, L. E. & Hein. G. L. (eds.), Compendium of beet diseases and pests. St. Paul. USA, APS Press.

HONEK, A., JAROSIC, V., MARTINKOVA, Z. & NOVAK, I. 2002. Food induced variation of thermal constants of development and growth of *Autographa gamma* (Lepidoptera: Noctuidae) larvae. Eur. J. Entomol. 99: 241–252.

HUANG, Y. B. & CHI, H. 2012. Life tables of *Bactrocera cucurbitae* (Diptera: Tephritidae) with an invalidation of the jackknife technique. J. Appl. Entomol. 137: 327–339

JHA, R. K., CHI, H. & TANG, L.CH. 2012. A comparison of artificial diet and hybrid sweet corn for the rearing of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) based on life table characteristics. Environ. Entomol. 41: 30–39.

KARIMI-MALATI, A., FATHIPOUR, Y., TALEBI, A. A. & BAZOUBANDI, M. 2012. Comparative life table parameters of beet armyworm, *Spodoptera exigua* (Lep.: Noctuidae), on four commercial sugar beet cultivars. J. Entomol. Soc. Iran. 32: 109–124.

KHEYRI, M. 1989. An inventory of pests attacking sugar beet in Iran. Entomol. Phytopathol. Appl. 56: 1–2.

LEE, K. P. 2010. Sex-specific differences in nutrient regulation in a capital breeding caterpillar, *Spodoptera litura* (Fabricius). J. Insect Physiol. 56: 1685–1695.

LEWONTIN, R. C. 1965. Selection for colonizing ability, pp. 22–29. *In* Baker, H. G. & Stebbins, G. L. (eds.), The genetic of colonizing species. Academic Press, San Diego.

MACELJSKI, M. & BALARIN, I. 1974. Factors influencing the population density of the looper *Autographa gamma* L. in Yugoslavia. Acta Entomol. Jugoslav. 10: 63–76.

NASERI, B., GOLPARVAR, Z., RAZMJOU, J. & GOLIZADEH, A. 2014. Age-stage, two-sex life table of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on different bean cultivars. J Agri. Sci. Tech. 16: 19–32.

NASH, S. & HILL, L. 2003. Immigration of Lepidoptera. Available from: htpp://www.migrantmoth.com/.

PALMQVIST, G. 2001. Remarkable records of Macrolepidoptera in Sweden 2000. Entomol. Tidskrift. 122: 41–55.

SLANSKY, F. & RODRIGUEZ, J. G. 1987. Nutritional ecology of insects, mites, spiders, and related invertebrates: an overview. New York, Wiley.

SPITZER, K., REJMÁNEK, M. & SOLDÁN, T. 1984. The fecundity and long-term variability in abundance of noctuid moths (Lepidoptera, Noctuidae). Oecologia. 62: 91–93.

TAHA, M. A., HORIA, A. ABD-EL WAHAB, HANAA, I. MAHMOUD & GHADA EL S. ABD EL HAMED. 2012. Effect of different temperaures, thermal, threshlod units on developmentof silvery moth, *Autographa gamma* Linn. J. Plant Prot. and Path. 3: 355–361.

UMBANHOWAR, J. & HASTING, A. 2002. The impact of resource limitation and phenology of parasitoid attack on the duration of insect herbivore outbreaks. Theor. Pop. Biol. 62: 259–269.

VAN LENTEREN, J. C. & NOLDUS, L. P. J. J .1990. Whitefly plant relationship, behavioral and ecological, pp. 47–89. *In* Gerling, D. (ed.), Whitefly: their bionomics, pest status and management. Intercept, Andover.

VERKERK, R. H. J. & WRIGHT, D. J. 1996. Multitrophic interactions and management of the diamondback moth: a review. Bull. Entomol. Res. 86: 205–216.

WITTMEYER, J. L. & COUDRON, T. A. 2001. Life table parameters, reproductive rate, intrinsic rate of increase and estimated cost of rearing *Podisus maculiventris* (Heteroptera: Pentatomidae) on an artificial diet. J. Econ. Entomol. 9: 1344–1352.

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