

## Age-stage, Two-sex Life Table of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on Different Bean Cultivars

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### ABSTRACT

The cotton bollworm, *Helicoverpa armigera* (Hübner), is one of the important polyphagous pests causing serious loss to many economically important crops in Iran. The goal of this experiment was to study the age-stage, two-sex life table of *H. armigera* on different bean cultivars including white kidney bean (cultivars Daneshkadeh, Pak, and Shokufa), red kidney bean (cultivars Akhtar, Naz, and Sayyad) and common bean (cultivar Talash) under laboratory conditions ( $25\pm 1^\circ\text{C}$ ,  $65\pm 5\%$  RH, a 16:8 h light-dark photoperiod). The longest and shortest larval period and development time of total pre-adult *H. armigera* were  $19.83\pm 3.83$  and  $37.58\pm 0.90$  days on red kidney bean Akhtar, respectively, and  $14.13\pm 0.32$  and  $31.82\pm 0.42$  days on white kidney bean Pak, respectively. The lowest intrinsic rate of increase ( $r$ ) was on red kidney bean Akhtar ( $0.115\pm 0.009\text{ day}^{-1}$ ) and the highest on white kidney bean Pak and common bean Talash ( $0.142\pm 0.001\text{ day}^{-1}$ ). The lowest and highest values of the net reproductive rate ( $R_0$ ) were on red kidney bean Akhtar ( $177.3\pm 6.7$  offspring) and white kidney bean Shokufa ( $270.1\pm 6.7$  offspring), respectively. The mean generation time ( $T$ ) on different bean cultivars ranged from  $37.03\pm 0.05$  to  $44.64\pm 0.07$  days, which was shortest on white kidney bean Pak and longest on red kidney bean Akhtar. The results revealed that the cultivar Akhtar was the most unsuitable host for population growth of *H. armigera*.

**Keywords:** Cotton bollworm, Intrinsic rate of increase, Population growth.

### INTRODUCTION

The cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), is an extremely polyphagous species and a common insect pest of many crops in Iran (Farid, 1986) and many parts of the world (Singh and Mullick, 1997; Reddy *et al.*, 2004). The larvae of *H. armigera* is able to attack most plant parts (stems, leaves, flower heads and fruits) and create serious economic losses in cultivated crops including cotton, bean, corn, tobacco and tomato (Liu *et al.*, 2004). In spite of high level of natural mortality, this species needs to be controlled by chemical pesticides (Fitt, 1994). Since the application of chemical insecticides has increased the risk of environmental contamination, the loss of

biodiversity, as well as development of insecticide resistance in *H. armigera* populations (Armes *et al.*, 1992; Forrester *et al.*, 1993; McCaffery, 1998; Naseri *et al.*, 2009), similar studies have increasingly been done to identify control measures that are both environmentally and economically acceptable.

Host plant suitability to insect pests depends on quantitative parameters (size, leaf thickness, mechanical barriers, and nutrient composition), and qualitative traits (specific allelochemical and phenological changes) of host. It is noticeable that these factors are different among plants and can significantly influence the subsequent performance of the phytophagous insects (Suomela and Nilson, 1994; Fisher *et al.*, 2000). The plants with antibiosis mechanism have negative effects on

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insect development, survivorship, reproduction and biological parameters (Dent, 2000; Kim and Lee, 2002; Sarfraz *et al.*, 2006), thus, using host plant resistance is a suitable and useful strategy in pest management programs (Kennedy *et al.*, 1987).

An age-stage, two-sex life table model incorporating variable development rates and both sexes (male and female) were developed by Chi and Liu (1985) and Chi (1988). Since development rates often differ between the sexes and among individuals (Istock, 1981), and ignoring the sex of individuals can also result in errors (Chi, 1988), several researchers have recently calculated the life table parameters of insects by using the age-stage, two-sex model (Huang and Chi, 2012; Yadav and Chang, 2012; Marouf *et al.*, 2013)

Life table parameters, especially the intrinsic rate of increase ( $r$ ), can be used as an important and appropriate factor to evaluate the susceptibility or resistance level of different host plant cultivars to insect pests (Razmjou *et al.*, 2006).

Several authors have evaluated the effect of different host plants on age-specific female life table parameters of *H. armigera*: Naseri *et al.* (2009) on the green pod of 13 soybean varieties; Soleimannejad *et al.* (2010) on artificial diets prepared by the seed of various soybean cultivars; Arghand (2011) on artificial diets based on the seed of five maize hybrids; Bagheri *et al.* (2011) on the seed of five host plants; Hemati *et al.* (2012a, b) on different host plant cultivars. However, Jha *et al.* (2012) studied the demographic characteristics of *H. armigera* on artificial diet and hybrid sweet corn by using the age-stage, two sex life tables. Since there is no information on the age-stage, two sex life table parameters of this pest on different bean cultivars, the present study was conducted to compare the potential of population growth of *H. armigera* on seven commonly cultivated bean cultivars in Iran, and to evaluate resistance or susceptibility of these cultivars to the pest. We hope the findings of this study can be applied to design comprehensive strategy in integrated pest management programs of the cotton bollworm.

## MATERIALS AND METHODS

### Bean Cultivars

Seeds of different bean (*Phaseolus vulgaris* L.) cultivars including white kidney bean (WKB) (cultivars Daneshkadeh, Pak, and Shokufa), red kidney bean (RKB) (cultivars Akhtar, Naz, and Sayyad), and common bean (CB) (cultivar Talash) were obtained from the Seed and Plant Improvement Institute (Khomein, Iran). They were cultivated in the research farm of the University of Mohaghegh Ardabili (Ardabil, Iran) in May 2011. The study started when bean cultivars reached the reproductive stage (green pod of bean cultivars). The young leaves and green terminal pods with equal size of different bean cultivars were transferred to a growth chamber ( $25\pm 1^\circ\text{C}$ ,  $65\pm 5\%$  RH, and a 16:8 h light-dark photoperiod) and were used in the experiments.

The cotton bollworm eggs were obtained from a laboratory colony maintained on a cowpea-based artificial diet, as described by Teakle (1991), from Tarbiat Modares University (Tehran, Iran). The insects tested on bean cultivars had previously been reared for two generations on the leaves and pods of the same cultivars before using in the experiments. All experimental insects were kept inside a growth chamber at  $25\pm 1^\circ\text{C}$ ,  $65\pm 5\%$  RH, and a 16:8 h light-dark photoperiod. The leaves of bean cultivars were used to feed the first and second larval instars and the green pods were used to feed the third to sixth larval instars (Green *et al.*, 2002; Naseri *et al.*, 2009).

### Development Time

Adult moths emerged from the pupae reared for two generations on different bean cultivars, were used in this study. To obtain the same aged eggs of the cotton bollworm, 20 pairs of both sexes of the moth reared

from related cultivars were kept inside each transparent egg-laying container (11.5 cm in diameter and 9.5 cm in height) 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, after collecting from the egg-laying container, were used for the experiment. Neonate larvae were transferred using a fine camel's hair brush (individually) into plastic Petri dishes (8 cm in diameter and 2 cm in height) with a hole (1 cm in diameter) covered with a fine mesh net for aeration and containing fresh leaves of the related bean cultivar treatment. To obtain freshness, the petioles of detached leaves were inserted in water-soaked cotton. Larvae entering 3<sup>rd</sup> instar were provided with pods of the related bean cultivars in the same mentioned Petri dishes. Every day, the leaves and pods of each bean cultivar were replaced with new ones, and daily observations were recorded on the mortality or survival of larvae in the same instar or moulting to next instar up to pupation and emergence of adult. For pre-pupation and pupation, sixth instar larvae were kept in cylindrical plastic containers (3 cm in diameter and 5 cm in height). Larval instars, pre-pupal, pupal and development time of total pre-adult and their mortality were recorded on different bean cultivars.

### Oviposition Period, Fecundity, and Longevity

After emergence of adult moths, a pair of female and male moths was transferred to egg-laying containers (11.5 cm in diameter and 9.5 cm in height), closed at the top with a fine mesh net for aeration. The internal sides of these containers were covered with the same mesh net as an oviposition substrate. Number of eggs deposited was counted daily and the experiments were continued up to the death of the last female 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 the current study, adult pre-oviposition period (APOP: the period of time between the emergence of an adult female insect and the initiation of its oviposition), total pre-oviposition period (TPOP: the duration from egg to first oviposition), oviposition period, total fecundity (eggs 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 and 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 and Chi, 2012). The intrinsic rate of increase ( $r$ ) was calculated by using bisection method from the Euler-Lotka formula:

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

with 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 (i.e.  $e^{rT} = R_0$  or  $\lambda^T = R_0$ ), which calculated as  $T = (\ln R_0)/r$ . The gross reproductive rate ( $GRR$ ) was calculated as  $GRR = \sum m_x$ . The bootstrap technique (Efron and Tibshirani, 1993), which included TWSEX-MSChart (Chi, 2013), was used to estimate the means, variances, and standard errors of the population parameters. The obtained data were then analyzed by one-way ANOVA followed by comparison of the means with LSD test at  $\alpha = 0.05$  using statistical software Minitab 16.0. Before analysis, all data were tested for normality.



## RESULTS

### Development Time

The results of the effect of different bean cultivars on total pre-adult of *H. armigera* are given in Table 1. Regarding the results, no significant difference was observed for egg incubation and pre-pupal period of *H. armigera* on different bean cultivars. However, both of the larval period and development time were significantly different on bean cultivars ( $P < 0.01$ ). The longest and shortest values of larval period and development time of total pre-adult on RKB cultivar Akhtar were  $19.83 \pm 3.83$  and  $37.58 \pm 0.90$  days, and on WKB cultivar Pak  $14.13 \pm 0.32$  and  $31.82 \pm 0.42$  days, respectively. Also, the longest pupal period of *H. armigera* from larvae fed on different bean cultivars was on RKB cultivar Akhtar ( $13.50 \pm 0.30$  days) and the shortest was on CB cultivar Talash ( $12.04 \pm 0.27$  days).

### Oviposition Period, Fecundity, and Longevity

The APOP, TPOP, oviposition period, fecundity, and longevity of *H. armigera* adults emerged from the larvae reared on

different bean cultivars are given in Table 2. The APOP and oviposition period of the cotton bollworm were not significantly different on bean cultivars. However, bean cultivars tested showed significant effects on the TPOP ( $P < 0.01$ ) of this pest, which was the longest on RKB cultivar Akhtar ( $41.00 \pm 1.60$  days) and the shortest on WKB cultivar Pak ( $33.15 \pm 0.44$  days) and CB cultivar Talash ( $33.73 \pm 0.30$  days). Different bean cultivars as larval food had no significant effect on longevity and lifespan of *H. armigera* (Table 2).

There was a significant difference in the total number of eggs per individual of *H. armigera* on seven bean cultivars ( $P < 0.01$ ), which was highest on RKB cultivar Naz ( $1411 \pm 205$ ) and lowest on WKB cultivar Shokufa ( $815 \pm 101$ ) (Table 2).

### Life Table Analysis

Age-stage specific survival rate ( $s_{xj}$ ) provides the probability that a newly deposited egg will survive to age  $x$  and stage  $j$ . The age-stage specific survival rates of *H. armigera* on various bean cultivars are shown in Figure 1. Noticeable stage overlapping was observed because of variation in the development rate among

**Table 1.** The mean ( $\pm$ SE) duration of immature stages (days) of *Helicoverpa armigera* reared on different bean cultivars under laboratory conditions.

Host (Cultivar)	Incubation period	Larval period	Pre-pupal period	Pupal period	Total pre-adult
White kidney bean (Shokufa)	3.00	$17.07 \pm 0.60bc^a$	$2.41 \pm 0.15a$	$12.20 \pm 0.31b$	$34.32 \pm 0.48c$
Red kidney bean (Akhtar)	3.00	$19.83 \pm 3.83a$	$2.54 \pm 0.13a$	$13.50 \pm 0.30a$	$37.58 \pm 0.90a$
Red kidney bean (Sayyad)	3.00	$17.70 \pm 0.41b$	$2.38 \pm 0.13a$	$12.78 \pm 0.28ab$	$36.04 \pm 0.51ab$
Red kidney bean (Naz)	3.00	$15.83 \pm 0.36cd$	$2.52 \pm 0.13a$	$12.74 \pm 0.20b$	$33.72 \pm 0.88c$
White kidney bean (Pak)	3.00	$14.13 \pm 0.32e$	$2.57 \pm 0.11a$	$12.65 \pm 0.21b$	$31.82 \pm 0.42d$
White kidney bean (Daneshkadeh)	3.00	$17.12 \pm 0.48bc$	$2.24 \pm 0.11a$	$12.61 \pm 0.27b$	$34.52 \pm 0.46bc$
Common bean (Talash)	3.00	$14.97 \pm 0.37de$	$2.61 \pm 0.11a$	$12.04 \pm 0.27b$	$32.04 \pm 0.19d$

<sup>a</sup> The means followed by different letters in the same column are significantly different ( $P < 0.01$ , LSD).

**Table 2.** The mean ( $\pm$ SE) oviposition period (days), fecundity, adult longevity and adult lifespan (days) of *Helicoverpa armigera* reared on different bean cultivars under laboratory conditions.

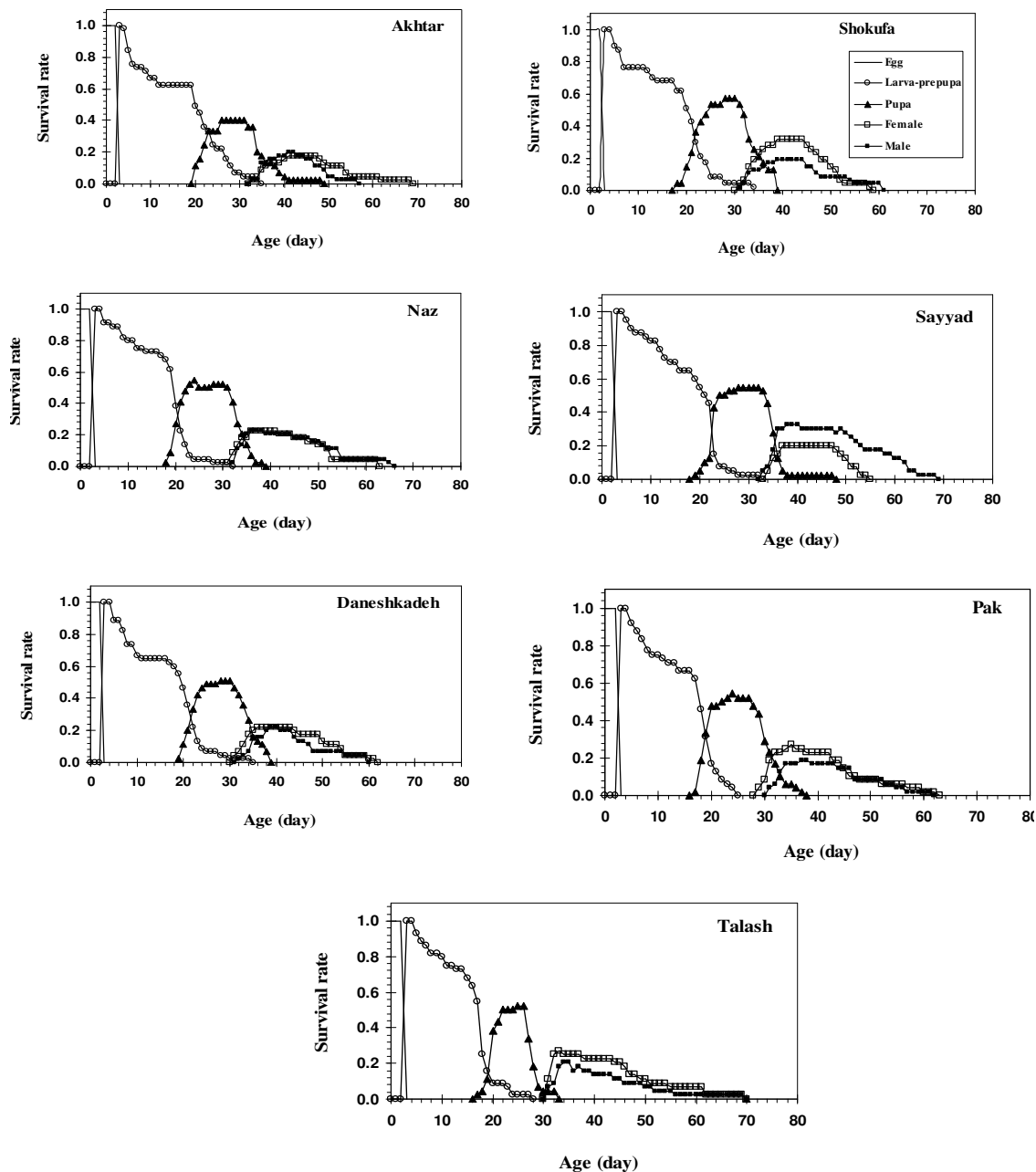
Host (cultivar)	APOP <sup>a</sup>	TPOP <sup>b</sup>	Oviposition period	Total fecundity/female	Longevity		Total lifespan	
					Male	Female	Male	Female
White kidney bean (Shokufa)	2.13 $\pm$ 0.19 <sup>c</sup>	36.53 $\pm$ 0.62 <sup>c</sup>	8.87 $\pm$ 0.94 <sup>a</sup>	815 $\pm$ 101 <sup>b</sup>	17.50 $\pm$ 2.32 <sup>a</sup>	15.80 $\pm$ 1.10 <sup>a</sup>	51.88 $\pm$ 2.40 <sup>a</sup>	50.20 $\pm$ 1.12 <sup>a</sup>
Red kidney bean (Akhtar)	3.00 $\pm$ 0.65 <sup>a</sup>	41.00 $\pm$ 1.60 <sup>a</sup>	9.44 $\pm$ 1.57 <sup>a</sup>	883 $\pm$ 207 <sup>b</sup>	14.33 $\pm$ 1.75 <sup>a</sup>	16.00 $\pm$ 3.19 <sup>a</sup>	51.33 $\pm$ 1.67 <sup>a</sup>	54.44 $\pm$ 2.60 <sup>a</sup>
Red kidney bean (Sayyad)	3.50 $\pm$ 0.50 <sup>a</sup>	39.00 $\pm$ 0.86 <sup>ab</sup>	11.17 $\pm$ 0.70 <sup>a</sup>	1259 $\pm$ 83.6 <sup>ab</sup>	19.30 $\pm$ 3.21 <sup>a</sup>	16.43 $\pm$ 0.10 <sup>a</sup>	55.70 $\pm$ 3.35 <sup>a</sup>	51.71 $\pm$ 1.04 <sup>a</sup>
Red kidney bean (Naz)	3.20 $\pm$ 0.51 <sup>a</sup>	37.10 $\pm$ 0.85 <sup>bc</sup>	12.00 $\pm$ 1.67 <sup>a</sup>	1411 $\pm$ 205 <sup>a</sup>	18.60 $\pm$ 2.58 <sup>a</sup>	17.25 $\pm$ 2.56 <sup>a</sup>	54.00 $\pm$ 3.25 <sup>a</sup>	50.75 $\pm$ 2.79 <sup>a</sup>
White kidney bean (Pak)	2.00 $\pm$ 0.30 <sup>a</sup>	33.15 $\pm$ 0.44 <sup>d</sup>	9.17 $\pm$ 1.52 <sup>a</sup>	829 $\pm$ 230 <sup>b</sup>	16.80 $\pm$ 2.19 <sup>a</sup>	17.67 $\pm$ 2.19 <sup>a</sup>	49.30 $\pm$ 2.53 <sup>a</sup>	48.58 $\pm$ 2.30 <sup>a</sup>
White kidney bean (Daneshkadeh)	3.09 $\pm$ 0.51 <sup>a</sup>	36.73 $\pm$ 0.90 <sup>c</sup>	11.36 $\pm$ 1.74 <sup>a</sup>	955 $\pm$ 178 <sup>ab</sup>	15.22 $\pm$ 2.61 <sup>a</sup>	17.55 $\pm$ 1.98 <sup>a</sup>	49.11 $\pm$ 2.54 <sup>a</sup>	51.09 $\pm$ 2.21 <sup>a</sup>
Common bean (Talash)	2.09 $\pm$ 0.32 <sup>a</sup>	33.73 $\pm$ 0.30 <sup>d</sup>	11.09 $\pm$ 1.78 <sup>a</sup>	968 $\pm$ 152 <sup>ab</sup>	16.71 $\pm$ 4.41 <sup>a</sup>	19.64 $\pm$ 3.01 <sup>a</sup>	48.86 $\pm$ 4.43 <sup>a</sup>	50.36 $\pm$ 3.18 <sup>a</sup>

<sup>a</sup> Adult Pre-Oviposition Period; <sup>b</sup> Total Pre-Oviposition Period; <sup>c</sup> The means followed by different letters in the same column are significantly different ( $P < 0.01$ , LSD).

individuals on bean cultivars. The highest age-stage specific survival rate of larval-prepupal stages and adult male of *H. armigera* on different bean cultivars was observed on RKB cultivar Sayyad, while the lowest rate of these stages was on RKB cultivar Akhtar. Also, the highest age-stage specific survival rate of pupal stage and adult female was on WKB cultivar Shokufa, and the lowest on WKB cultivar Akhtar (Figure 1).

The  $l_x$  is the probability that an egg will survive to age  $x$ , therefore, the curve  $l_x$  (Figure 2) is the simplified version of  $S_{xj}$ . Results showed that the death of the last female occurred at the ages of 61, 70, 70, 66, 64, 62 and 70 days on WKB cultivar Shokufa, RKB cultivar Akhtar, RKB cultivar Sayyad, RKB cultivar Naz, WKB cultivar Pak, WKB cultivar Daneshkadeh and CB cultivar Talash, respectively (Figure 2). The age-stage specific fecundity ( $f_{xj}$ ) gives the number of offspring produced by *H. armigera* individual at age  $x$  and stage  $j$  per day. Since only females produce offspring, there is only a single curve  $f_{xj}$  (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 55, 154.25, 153, 119.78, 134.166, 121.6 and 164.1818 eggs female<sup>-1</sup> day<sup>-1</sup>, respectively, that occurred at the ages of 41, 42, 43, 42, 36, 52 and 36 days, respectively (Figure 2). The oviposition beginning of the first female on the tested bean cultivars (the same order mentioned above) occurred at the ages of 33, 36, 36, 33, 31, 34 and 32 days, respectively. Also, the highest age-specific fecundity ( $m_x$ ) of *H. armigera* adult emerging from the larvae reared on above-mentioned cultivars was 55, 68.56, 58.29, 59.89, 70, 76.78 and 90.3 females female<sup>-1</sup> day<sup>-1</sup>, respectively, and occurred at the ages of 41, 42, 43, 42, 36, 52 and 36 days, respectively (Figure 2).

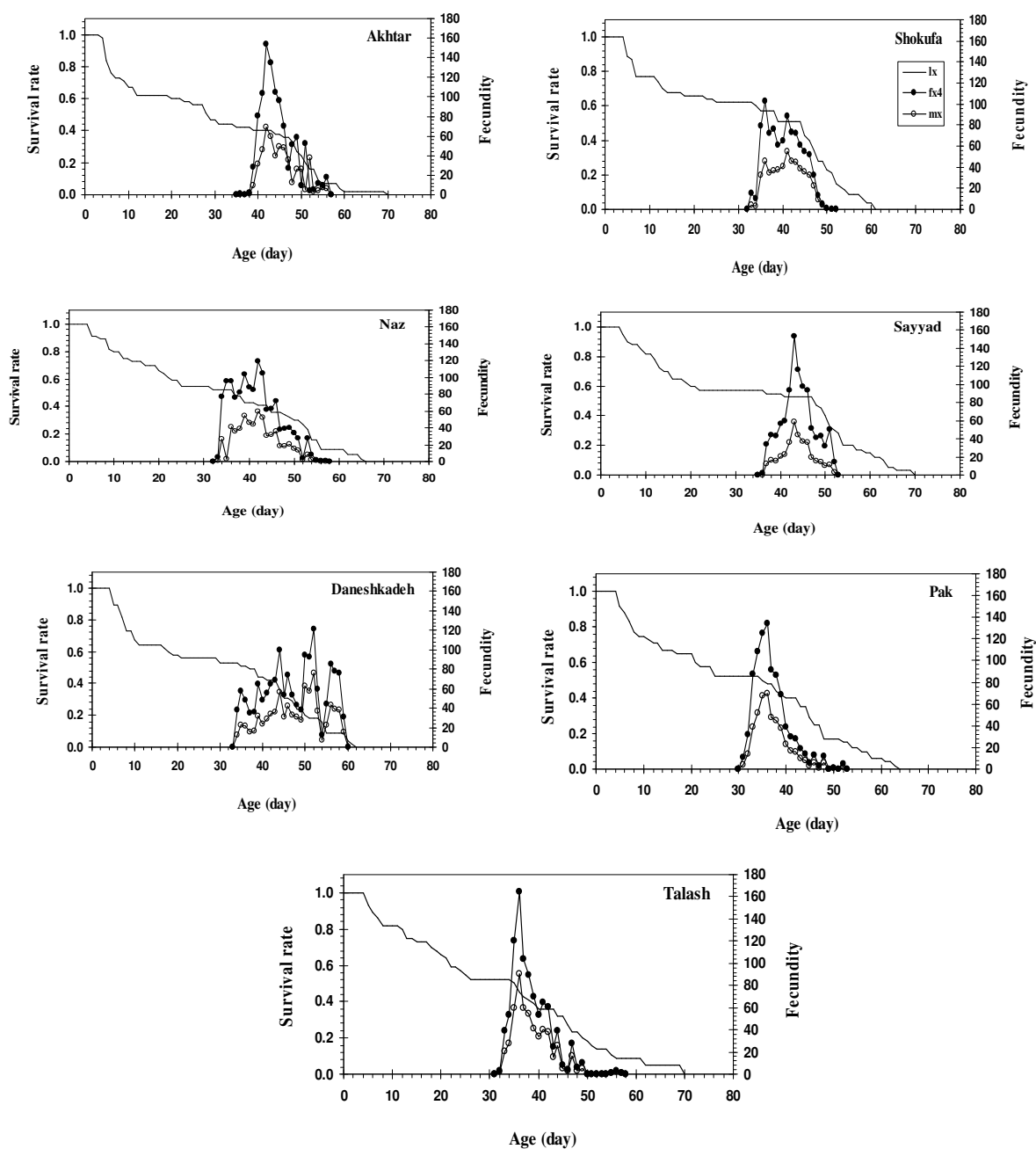
The population parameters calculated by using the age-stage, two-sex life table for *H. armigera* on different bean cultivars are listed in Table 3. According to the results, the net reproductive rate ( $R_0$ ) was found to



**Figure 1.** Age-stage specific survival rate ( $s_{xj}$ ) of *Helicoverpa armigera* reared on different bean cultivars under laboratory conditions.

be significantly different ( $P < 0.01$ ) depending on the bean cultivars on which individual insects were reared. The  $R_0$  values of the cotton bollworm estimated on the seven bean cultivars varied from  $177.3 \pm 6.7$  to  $270.1 \pm 6.7$  offspring, being lowest on RKB cultivar Akhtar and highest on WKB

cultivar Shokufa (Table 3). The gross reproductive rate (GRR) of this pest differed from  $390.4 \pm 12.8$  to  $849.0 \pm 24.3$  offspring on RKB cultivar Sayyad and WKB cultivar Daneshkadeh, respectively ( $P < 0.01$ ). The intrinsic rate of increase ( $r$ ) ranged from  $0.115 \pm 0.009$  to  $0.142 \pm 0.001 \text{ day}^{-1}$ , which



**Figure 2.** Age-specific survival rate ( $l_x$ ), age-stage specific fecundity ( $f_{x4}$ ), and age-specific fecundity ( $m_x$ ) of *Helicoverpa armigera* reared on different bean cultivars under laboratory conditions.

was lowest on RKB cultivar Akhtar and highest on CB cultivar Talash and WKB cultivar Pak ( $P < 0.01$ ). Moreover, the finite rate of increase ( $\lambda$ ) value of this pest showed significant differences ( $P < 0.01$ ), being

lowest on RKB cultivar Akhtar ( $1.121 \pm 0.001 \text{ day}^{-1}$ ) and highest on WKB cultivar Pak ( $1.153 \pm 0.001 \text{ day}^{-1}$ ) (Table 3). Among different bean cultivars, the mean generation time ( $T$ ) of the cotton bollworm

**Table 3.** Life table parameters of *Helicoverpa armigera* reared on different bean cultivars under laboratory conditions.

Host (Cultivar)	Parameter (Mean±SE)				
	$R_0$ (Offspring) <sup>a</sup>	$GRR$ (Offspring) <sup>b</sup>	$r$ (Day <sup>-1</sup> ) <sup>c</sup>	$\lambda$ (Day <sup>-1</sup> ) <sup>d</sup>	$T$ (Day) <sup>e</sup>
White kidney bean (Shokufa)	270.1 ± 6.7a*	533.1 ± 10.3c	0.137 ± 0.001b	1.147 ± 0.001b	40.72 ± 0.06d
Red kidney bean (Akhtar)	177.3 ± 6.7d	482.3 ± 15.5d	0.115 ± 0.009e	1.121 ± 0.001e	44.64 ± 0.07a
Red kidney bean (Sayyad)	195.0 ± 6.9cd	390.4 ± 12.8e	0.119 ± 0.001d	1.125 ± 0.001d	43.97 ± 0.08b
Red kidney bean (Naz)	268.5 ± 8.1a	613.3 ± 16.6b	0.136 ± 0.001b	1.146 ± 0.001b	40.85 ± 0.10d
White kidney bean (Pak)	199.1 ± 6.6c	434.4 ± 14.9.e	0.142 ± 0.001a	1.153 ± 0.001a	37.03 ± 0.05f
White kidney bean (Daneshkadeh)	231.6 ± 7.7b	849.8 ± 24.3a	0.124 ± 0.001c	1.132 ± 0.006c	43.43 ± 0.20c
Common bean (Talash)	230.4 ± 7.4b	561.4 ± 14.4c	0.142 ± 0.001a	1.152 ± 0.001a	38.17 ± 0.04e

\*The means followed by different letters in the same column are significantly different ( $P < 0.01$ , LSD).

<sup>a</sup> Net reproductive rate; <sup>b</sup> Gross reproductive rate; <sup>c</sup> Intrinsic rate of increase; <sup>d</sup> Finite rate of increase, <sup>e</sup> Mean generation time.

was longest on RKB cultivar Akhtar (44.64±0.07 days) and shortest on WKB cultivar Pak (37.03±0.05 days) ( $P < 0.01$ ).

## DISCUSSION

The life cycle characteristics of herbivorous insects can be affected by the variations in host plant traits. Also, it has been reported that these variations play a major role in regulating insect populations (Umbanhowar and Hastings, 2002). It is noticeable that the host plant cultivars are different in suitability for herbivorous insects when evaluated in terms of development, fecundity, and survival rates (van Lenteren and Noldus, 1990; Naseri et al., 2011). Thus, using pest-resistant cultivars in integrated pest management is one of the most acceptable approaches to minimize the damages caused by the phytophagous insect pests (Kogan and Ortman, 1978).

Egg incubation period of the cotton bollworm showed no significant difference among bean cultivars tested, demonstrating that this parameter was not influenced by the bean cultivars. Our results for the incubation

period of *H. armigera* on different bean cultivars (3.00 days) are in agreement with those reported by several authors (Borah and Dutta, 2002; Naseri et al., 2009; Arghand, 2011).

In the current research, there were six larval instars of *H. armigera* on all bean cultivars tested, similar to that reported by several researchers (Goyal and Rathore, 1988; Borah and Dutta, 2002; Arghand, 2011). Nevertheless, Lokar et al. (1993), Saour and Causse (1996), and Fathipour and Naseri (2011) reported that larval stages of *H. armigera* were completed in five instars. Differences in geographic population of *H. armigera*, or variations in the nutritional quality and quantity of the host plant species can affect the larval instars of this pest (Nadgauda and Pitre, 1983; Bernays and Chapman, 1994).

The results showed that the larval period of *H. armigera* ranged from 14.13±0.323 to 19.83±3.828 days on the seven bean cultivars. According to Fathipour and Naseri (2011), the longest larval period of *H. armigera* was 26.20±1.62 days on soybean cultivar L17. This reinforces the suggestion that bean is a more suitable host plant for feeding of *H. armigera* larvae than soybean.



Also, the type of host plant, genetic variations, and different geographic populations of the insect may influence duration of larval stage in this pest.

Pre-pupal period of *H. armigera* was not affected by the larval food. The mean value of pre-pupal period was  $2.47 \pm 0.122$  days on all bean cultivars, similar to that reported for *H. armigera* reared on soybean (2.59 days) (Naseri *et al.*, 2009). The pupal period ranged from  $12.04 \pm 0.27$  days on WKB cultivar Daneshkadeh to  $13.50 \pm 0.30$  days RKB cultivar Akhtar. Arghand (2011) reported that the pupal period of *H. armigera* varied from  $12.95 \pm 0.33$  days on maize hybrid SC700 to  $13.35 \pm 0.23$  days on hybrid DC370, which are nearly in agreement with our results for pupal period of the pest on different bean cultivars.

In this study, development time of the total pre-adult showed a significant difference among the bean cultivars, with values ranging from  $31.82 \pm 0.42$  days on WKB cultivar Pak to  $37.58 \pm 0.90$  days on RKB cultivar Akhtar. The longest development time of total pre-adult of *H. armigera* was reported as  $42.71 \pm 1.41$  days on soybean cultivar L17 (Fathipour and Naseri, 2011), which is different from our results for development time of the pest on bean cultivars. Also, Hemati *et al.* (2012b) reported that the longest development time of total pre-adult of this pest was  $45.39 \pm 0.54$  days on tomato cultivar Meshkin. Variations between our results and that of the above-mentioned authors might be as a result of host plant differences.

In contrast to Jha *et al.* (2012) study, the adult pre-oviposition period (APOP) of *H. armigera* was not affected by different bean cultivars. However, the total pre-oviposition period (TPOP) of *H. armigera* on different bean cultivars ranged from  $33.15 \pm 0.44$  to  $41.00 \pm 1.60$  days, which was the shortest on WKB cultivar Pak and the longest on RKB cultivar Akhtar. It was reported that the age of the first reproduction plays an important role on the intrinsic rate of increase ( $r$ ). Also, if fecundity remains the same, the shorter pre-oviposition period will cause a

higher intrinsic rate (Lewontin, 1965; Huang and Chi, 2012; Jha *et al.*, 2012). For that reason, the intrinsic rate of increase in this study was the highest on WKB cultivar Pak ( $0.142 \pm 0.001 \text{ day}^{-1}$ ) and the lowest on RKB cultivar Akhtar ( $0.115 \pm 0.009 \text{ day}^{-1}$ ). It is useful to note that the fitness of phytophagous insects depends on the nutrients of the host plant, thus, the quality and quantity of nourishment can influence food consumption rate by an insect and its fecundity. This research showed that the total fecundity of *H. armigera* was affected by different bean cultivars. Females reared as larvae on RKB cultivar Naz produced the highest total number of eggs ( $1411 \pm 205$  eggs/individual) and the lowest number of eggs laid was recorded for females reared as larvae on WKB cultivar Shokufa ( $815 \pm 101$  eggs individual<sup>-1</sup>). The lowest number of eggs laid/individual on WKB Shokufa is approximately similar to the value reported by Liu *et al.* (2004) on common bean ( $778.10$  eggs individual<sup>-1</sup>), but is not the same as the value reported by Fathipour and Naseri (2011) for soybean cultivar 356 ( $177.10$  eggs individual<sup>-1</sup>), suggesting that the quantity and/or the quality of nutrients in bean are more suitable than that in soybean as food for *H. armigera* larvae.

In agreement with the reports by several researchers (Fathipour and Naseri, 2011; Arghand, 2011), in the current study, adult longevity and total lifespan of *H. armigera*, was not influenced by different bean cultivars.

The curves of age-stage specific survival rate ( $s_{xj}$ ) of *H. armigera* showed the survivorship and stage variation as well as the variable developmental rates. For example, the probability that a newborn egg of *H. armigera* survive to adult stage is 0.32 for females on WKB cultivar Shokufa. If the raw data were analyzed via traditional female age-specific life table, it would not be possible to view the variations of the stage structure because of ignoring male individuals and the variable development rate among individuals (Yu *et al.*, 2005). The age-stage specific fecundity ( $f_{x4}$ ) of *H.*



*armigera* on CB cultivar Talash was observed from day 32 to 49, with a maximum daily fecundity of 164.18 eggs per female in the cohort (Figure 2). Also, the age-specific fecundity ( $m_x$ ) of the adult that emerged from the larvae reared on different bean cultivars ranged from 90.3 (on CB cultivar Talash) to 55 offspring (on WKB cultivar Shokufa). According to Fathipour and Naseri (2011), the daily fecundity among various soybean cultivars varied from 36.5 to 159.30 females female<sup>-1</sup> day<sup>-1</sup>. Because these authors have constructed survival rates and fecundity curves based on "adult age", differences in pre-adult development are ignored, and it is then assumed that all adults emerged on the same day (Yu et al., 2005).

The variability of population estimated using the bootstrap technique is shown in Table 3. The jackknife technique will generate biologically unrealistic  $R_0$ ,  $i$ -pseudo, resulting in an overestimation of variances of the net reproductive rates; consequently, significant differences between treatments become undetectable via statistical test. Variance analysis is critical for revealing the variability of experimental results. Because there are many problems associated with female life tables and analysis based on adult age (Chi and Su, 2006; Huang and Chi, 2012 a), the jackknife method to female life tables will not make correct estimation. It is known that the bootstrapping, as a resampling methods, is a proper technique in the estimation of means and variances of population parameters (Huang and Chi, 2012 b).

In our study, the higher  $R_0$  value of *H. armigera* on the seven bean cultivars was 270.1±6.7 offspring on WKB cultivar Shokufa, which was lower than the highest value reported for this pest on soybean (cultivar M7) (354.92±52.34 offspring) (Fathipour and Naseri, 2011). The higher  $r$  value of *H. armigera* on CB cultivar Talash and WKB cultivar Pak was mainly due to the greater fecundity, and the shorter TPOP and development of pre-adult of the pest reared on these cultivars. However, lower  $r$

value on RKB cultivar Akhtar was mainly a result of the lower fecundity and longer TPOP and development of pre-adult of *H. armigera* on this cultivar. The intrinsic rate of increase for *H. armigera* on CB cultivar Talash and WKB cultivar Pak (0.142 day<sup>-1</sup>) is lower than the highest value reported by Fathipour and Naseri (2011) on M9 (suitable soybean cultivar) (0.1848 day<sup>-1</sup>). A high value of  $r$  demonstrates the susceptibility of a host plant to insect feeding; a low value shows that the host plant species is resistant to the pest. Thus, CB cultivar Talash and WKB cultivar Pak, among other bean cultivars, were the susceptible hosts, and the cotton bollworm had the greatest chance for population increase on these cultivars. However, RKB cultivar Akhtar was a more unsuitable host plant, suggesting that this cultivar is partially resistant to *H. armigera* compared to the other cultivars. The finite rate of increase was highest on WKB cultivar Pak (1.153±0.001 day<sup>-1</sup>). Fathipour and Naseri (2011) noted that the highest finite rate of increase was on soybean cultivar M7 (1.20±0.007 day<sup>-1</sup>) (as a suitable cultivar). The mean generation time on different bean cultivars ranged from 37.03±0.05 days on white kidney bean Pak to 44.64±0.07 days on red kidney bean Akhtar. According to Fathipour and Naseri (2011), this value varied from 28.85±2.509 to 36.61±0.391 days on soybean cultivars. Because these researchers calculated the population parameters (i.e.  $R_0$ ,  $r$ ,  $\lambda$  and  $T$ ) by using traditional age-specific life table, the differences among results reported by them and our work are due to either variation in host plants or differences in the analytical methods. On the other hand, because of the problems in applying female age-specific life table to two-sex insect populations, it is improper to compare population parameters obtained by using different analytical methods and life table theory (Chi and Su, 2006; Huang and Chi, 2012 a).

According to the results obtained here, among the seven bean cultivars tested, the longest larval, pupal, and pre-adult periods as well as the lowest  $r$ ,  $R_0$  and  $\lambda$  values of *H.*

*armigera* were on RKB cultivar Akhtar, indicating that this cultivar is a partially unsuitable host for population growth of *H. armigera*; however, CB cultivar Talash and WKB cultivar Pak seemed to be the suitable bean cultivars for growth and development of this pest. For a better understanding of the insect-plant interaction to control *H. armigera* on bean cultivars, more attention should be paid to the study of demographic parameters of this pest on bean cultivars under field conditions. Furthermore, identification and extraction of secondary biochemicals of the resistant bean cultivars can significantly help to plan more practical strategies for management of the cotton bollworm.

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### جداول زندگی دوجنسی سنی-مرحله‌ای *Helicoverpa armigera*

روی ارقام مختلف لوبیا (Lepidoptera: Noctuidae)

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#### چکیده

کرم غوزه‌ی پنبه، *Helicoverpa armigera* (Hübner) یکی از آفات جدی با طیف میزبانی وسیع است که منجر به ایجاد خسارت اقتصادی شدید روی انواع محصولات اقتصادی در ایران می‌شود.



هدف از این آزمایش بررسی جدول زندگی دوجنسی سنی-مرحله‌ای *H. armigera* روی ارقام مختلف لوبیا شامل لوبیا سفید (ارقام دانشکده، پاک و شکوفا)، لوبیا قرمز (ارقام اختر، ناز و صیاد) و لوبیا چیتی (رقم تلاش) تحت شرایط آزمایشگاهی (دمای  $25 \pm 1$  درجه ی سلسیوس، رطوبت نسبی  $65 \pm 5$  درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی) بود. طولانی‌ترین و کوتاهترین دوره‌ی لاروی و دوره‌ی رشدی قبل از بلوغ *H. armigera* به ترتیب روی لوبیا قرمز رقم اختر (به ترتیب  $31/82 \pm 0/42$  و  $19/83 \pm 3/83$  روز) و لوبیا سفید رقم پاک (به ترتیب  $14/13 \pm 0/32$  و  $37/58 \pm 0/90$  روز) مشاهده شد. کمترین نرخ ذاتی افزایش ( $r$ ) روی لوبیا قرمز رقم اختر ( $0/115 \pm 0/009$  بر روز) و بیشترین آن روی لوبیا سفید رقم پاک و لوبیا چیتی رقم تلاش ( $0/142 \pm 0/001$  بر روز) بود. کمترین و بیشترین مقادیر نرخ خالص تولید مثل ( $R_0$ ) به ترتیب روی لوبیا قرمز رقم اختر ( $177/3 \pm 6/7$  نتاج) و لوبیا سفید رقم شکوفا ( $270/1 \pm 6/7$  نتاج) مشاهده شد. متوسط زمان یک نسل ( $T$ ) روی ارقام مختلف لوبیا از  $37/03 \pm 0/05$  تا  $44/64 \pm 0/07$  روز در نوسان بود که کوتاهترین آن روی لوبیا سفید رقم پاک و طولانی‌ترین آن روی لوبیا قرمز رقم اختر بود. نتایج نشان داد که رقم اختر میزبان نامناسبتری برای رشد جمعیت *H. armigera* بود.