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Response of the Cotton Bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae) to Different Semi-Artificial Diets

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ABSTRACT

Helicoverpa armigera **(Hübner) is one of the major limiting factors in host plant production in the world and Iran. In this study, the effect of semi-artificial diets based on the seeds of different cultivars of white and red kidney bean, canola, soybean, and cowpea on eco-physiological parameters of *H. armigera* were investigated. The results showed that the shortest (22.71 days) and longest (28.94 days) development time of *H. armigera* was observed on cowpea cultivar Mashhad and canola cultivar Opera, respectively. The maximum immature mortality of *H. armigera* was on soybean cultivars M7 and Clark. Cowpea cultivar Mashhad had the highest *r* (0.299 day^{-1}). The lowest level of proteolytic activity was 2.829 U mg^{-1} on soybean cultivar M7 for the 3rd instar larvae, 2.525 U mg^{-1} on soybean cultivars Crark for the 4th instar larvae, and 2.292 U mg^{-1} on soybean cultivar Sari for the 5th instar larvae. Nutritional indices of 3rd, 4th, 5th, 6th and whole instar larvae of *H. armigera* were affected by the artificial diets, i.e. seeds of different cultivars. According to the results, semi-artificial diets containing bean seeds (specifically cowpea cultivar Mashhad and white kidney bean cultivar Daneshkadeh) were more suitable than semi-artificial diets containing soybean and canola seeds for rearing of *H. armigera*.**

Keywords: Beans, Cowpea, Enzyme, Life table.

INTRODUCTION

The cotton bollworm, *Helicoverpa armigera* (Hübner) is one of the major limiting pests in host plant production in the world and Iran (Liu *et al*., 2004; Mironidis and Savopoulou-Soultani, 2008; Naseri *et al*., 2009a, 2011, 2014; Karimi *et al*., 2012; Baghery *et al*., 2013;). The larvae of this pest feed on leaves, buds, flowers, developing pods, fruits and seeds, and most especially the reproductive parts of the plant. This pest damages the plants by boring hole into the reproductive structures, which may then lead to secondary infection by plant pathogens, and from the feeding within the plant. Damages of *H. armigera* on soybean (*Glycine max* L.), beans (*Phaseolus vulgaris* L.), tomato and other Fabacea and canola (*Brassica napus* L. belong to Brassicaecea) which are economically important (Safuraie-Parizi *et al*., 2014).

Rearing insects on semi-artificial diets is an expensive process. But in recent time, the use of different semi-artificial diets have been developed and proposed for rearing of economically important insects. Rearing of key insect pests is essential for studying their life table, behavior, development, physiology, biological control agents and response to chemical pesticides (Cohen, 2001; Castane and Zapata, 2005; Naseri *et al*., 2009b). In some cases, rearing insects on semi-artificial diets affect their biological characteristics. Therefore, it is necessary to investigate the impact of different semi-

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artificial diets on life table parameters (Bellows *et al*., 1992; Abbasi *et al*., 2007; Amer and El-Sayed, 2014).

Proteases are the main digestive enzymes in midgut of some insects such as *H. armigera* (Naseri *et al.*, 2010b). Digestive proteases play two critical roles in an insect's physiology: (1) Breaking down proteins into amino acids essential for growth and development and (2) Inactivating protein toxins ingested as a consequence of feeding (Terra *et al*., 1996). Some proteins in seeds and vegetative organs of host plants may affect the key gut digestive enzymes of insects such as proteases (Biggs and McGregor, 1996). Inactivation of digestive enzymes by inhibitors results in blocking of gut proteases and other digestive enzymes such as amylases, leading to poor nutrient utilization, development retardation, and death because of starvation (Isman, 2006; Hosseini Naveh *et al*., 2007).

The main objectives of this study was to compare the impact of different host plants and their cultivars on the life table parameters, proteolytic activity in the midgut and feeding responses of *H. armigera.* This study can help compare different food sources in diet and enhance rearing techniques.

MATERIALS AND METHODS

Plant Seeds

Seeds of different plants such as bean, canola and soybean cultivars were used in this research. Seeds of bean cultivars like white kidney bean (Daneshkadeh and Pak), red kidney bean (Akhtar and Naz), seeds of canola (Okapi, Opera, Sarigol, and Zarfam) and seeds of soybean (Clark, M7, Sari, and Williams) were obtained from Seed and Plant Improvement Institute, Karaj, Iran. The cowpea seeds cultivar (Mashhad) were obtained from Varamin Research Center in Iran. All seeds were powdered separately and kept at 4°C for use in the experiments.

Insect Rearing

The eggs of *H. armigera* were originally collected from corn fields in Moghan Region (northwestern Iran) in July 2013. They were transferred to the laboratory and then maintained for at least four generations on semi-artificial diets based on seeds of different plant cultivars individually before being utilized in the experiments.

Semi-artificial diets based on the seeds of each plant cultivar were utilized for larval growth and development. Semi-artificial diet contained seed powder (each plant cultivar separately) (205 g), agar (14 g) as a moisturizer, sorbic acid (1.1 g) and ascorbic acid (3.5 g) as vitamin sources, methyl-*p*-hydroxyl benzoate (2.2 g), and yeast (35 g) as protein and carbohydrate sources, wheat germ (30 g), formaldehyde 37% (2.5 mL), sunflower oil (5 mL) as a preservative and distilled water (650 mL) (Twine, 1971). The prepared semi-artificial diets were kept refrigerated for no longer than 2 weeks before use.

Life Table Experiments

The life table experiments started with 100 eggs (less than one day old) at each semi-artificial diet. After egg hatching, each newly emerged larva was separately transferred into plastic container (9×7×4 cm) having adequate semi-artificial diet. Fresh diet was placed in Petri dishes for feeding larva daily. This procedure was allowed to continue until these larvae were developed to pre-pupa. The larvae were checked daily for mortality or survival and molting. Pre-pupae and pupae were reared in similar container described above. The duration of each egg, larva, pre-pupa, and pupa and their mortality were recorded daily. After adult emergence, a pair of female and male (< 24 hours old) was randomly transferred into transparent plastic containers (11 cm in diameter by 12 cm in height) for oviposition. The honey solution (10%) was placed inside the plastic container to provide food for adults. The number of laid eggs were counted and removed from the container daily. Where one adult (male or female) died earlier than its mate, another adult of the same sex was recruited from the stock colony to allow the surviving adult an opportunity to mate. Data pertaining to the recruited individual was not included in the analysis.

Life history raw data of all individuals (males, females, and those dying before the adult stage) were analyzed based on the age-stage and two-sex life table theory (Chi and Liu, 1985; Chi, 1988) by utilizing TWOSEX-MS-Chart computer program (Chi, 2015). The bootstrap (Efron and Tibshirani, 1993) technique was utilized to estimate the variances, and standard errors of the biological characteristics and population growth parameters. Since bootstrapping utilizes random resampling, a small number of replications will generate variable means and standard errors. To generate less variable results, 10000 replications were utilized in this study. The bootstrap method includes supplied TWOSEX-MS-Chart (Huang and Chi, 2012). Comparison of biological characteristics and population growth parameters of *H. armigera* on semi-artificial diets based on seeds of different plant cultivars were done with Paired Bootstrap Test (PBT pooled) (P< 0.05) by using TWOSEX-MS-Chart computer program (Chi, 2015).

Enzyme Sampling

Larvae of the 3rd, 4th and 5th instar larvae of *H. armigera* fed on semi-artificial diets for 24 hours were anesthetized on ice and immediately dissected under a stereoscopic microscope. The removed midgut was washed with precooled distilled water and transferred to 1.5 mL micro tubes containing 1 mL distilled water. After homogenizing with a handheld glass grinder on ice, the suspension was centrifuged at 16,000×g for 10 minutes at 4°C. The supernatant was collected, frozen in aliquots and stored at -20°C until required for protease assays (Hosseini Naveh *et al.*, 2007).

Protein Quantification

Total protein concentration in the samples was determined by the Bradford method using Bovine Serum Albumin (BSA) as a standard (0.125, 0.25, 0.5,1 and 2 mg mL^{-1}) (Bradford, 1976).

Nutritional Responses

Nutritional indices of *H. armigera* were determined using the 3rd to 6th instar larvae as they were more easily measurable than the 1st and 2nd instar larvae. In each semi-artificial diet based on the seeds of each plant cultivar, a group of the first instar larvae of *H. armigera* were placed. They were reared in semi-artificial diets until the third instar, after which they were separated into individual plastic container (3 cm diameter×5 cm height) to prevent cannibalism, and they were supplied with a weighted semi-artificial diet. Fresh diet was placed in the container for feeding larva daily. This procedure continued until these larvae developed to pre-pupa. The weights of the instar larvae before and after feeding, food given, unconsumed food and the produced feces were recorded until the pre-pupal stage. The quantity of ingested food was determined by subtracting the diet remaining at the end of each experiment from the total weight of provided diet. To find the dry weights of the diets, feces, and instar larvae, extra specimens (20 specimens for each) were weighed, oven-dried (48 hours at 60°C), and then re-weighed to establish a percentage of their dry weight. The experiment was started with five replications per cultivar of different host plants. Nutritional indices were calculated by the following formulae (Waldbauer, 1968):

CI (Consumption Index)= E/A

RCR (Relative Consumption Rate)= $E/(A\times T)$

RGR (Relative Growth Rate)= $P/(A\times T)$

ECI (%) (Efficiency of Conversion of Ingested food)= *P*/*E*×100

ECD (%) (Efficiency of Conversion of Digested Food)= *P*/(*E*-*F*)×100

AD (%) (Approximate Digestibility)= (*E*-*F*)/*E*×100

Where, *A*= Mean dry weight of insect over unit time; *E*= Dry weight of food consumed; *F*= Dry weight of feces produced; *P*= Insect dry weight gain, and *T*= Duration of feeding period (days).

One-way Analysis Of Variance (ANOVA) was applied for the data analysis using the SPSS ver. 18 software (SPSS, 2009), and the means were compared by Tukey test (P< 0.05).

RESULTS ANS DISCUSSION

Life Table Parameters

Host plant as one of the main factors can influence the life cycle insects such as different species of Lepidoptera (Soufbaf *et al*., 2010; Goodarzi *et al*., 2015; Bagheri *et al*., 2016). The incubation period of *H. armigera* on soybean cultivars M7 (1.72 days), Sari (1.68 days) and Williams (1.72 days) were significantly longer when compared to other plant cultivars (Table 1). *Helicoverpa armigera* metamorphosed successfully into adults on different semi-artificial diets. The shortest (10.55 days) and longest (11.76 days) larval periond was obtained on white kidney bean Daneshkadeh cultivar and canola cultivar Opera, respectively. The mean larval period of *H. armigera* in this research was lower than those reported by other researchers (Naseri *et al*., 2009a; Naseri *et al*., 2014). These differences in the results may be related to the effect of host plants and different cultivars on the biology of *H. armigera* or methodological differences among the experiments. The shortest (22.71 days) and longest (28.94 days) development time of *H. armigera* was observed on cowpea cultivar Mashhad and canola cultivar Opera, respectively. The longest development time of *H. armigera* was 29.7, 28.0, and 26.6 days on cotton, common bean, and corn, respectively, at 27°C (Liu *et al*., 2004), 42.71 day on soybean cultivar L17 (Naseri *et al*., 2009a), 36.8 days on canola cultivars Sarigol and Hayula420 (Karimi *et al*., 2012) and 37.58 days on red kidney bean cultivar Akhtar (Naseri *et al*., 2014). The type of host plant, genetic variations, and different geographic populations of the insect may influence developmental time in this pest. Females of *H. armigera* had shorter longevity than males on all plants and their cultivars. Also, this result has been reported by Karimi *et al*. (2012) for *H. armigera* on canola cultivars Sarigol, Hayula420, Opera, RGS003, Zarfam, Licord and Talaye, and by Naseri *et al*. (2014) for *H. armigera* on white kidney bean cultivar Shokufa and red kidney bean cultivars Sayyad and Naz. The male individuals had the longest longevity when they were reared on semi-artificial diets including canola cultivar Opera (15.41 days). The lifespan of females of *H. armigera* was significantly longer on canola cultivar Opera (15.27 days) and shorter on white kidney bean cultivar Daneshkadeh (8.90 days) (Table 1). The Adult Pre-Ovipositional Period (APOP) and Total Pre-Ovipositional Period (TPOP) were affected by seeds of different plants cultivars. The *TPOP* was longest on canola cultivar Opera (31.68 days) (Table 1).

The age-stage specific Survival rates (s_{xj}) of *H. armigera* on various semi-artificial diets are shown in Figure 1. The highest and lowest age-stage specific survival rate of female individuals of *H. armigera* was observed on different bean cultivars such as red kidney bean cultivar Naz (0.46) and soybean cultivar M7 (0.13), respectively (Figure 1). The maximum immature mortality (49%) of *H. armigera* was obtained on soybean cultivars Clark and M7 (Figure 2). The lower suitability of these cultivars as host plants for *H. armigera* may be due to the presence of some phytochemicals in them, acting as antibiotic compounds or the absence of some primary essential nutrients for growth and

Table 1. Mean±*SE* duration of different life stages of *Helicoverpa armigera* reared on different semi-artificial diets based on seeds of cultivars of different plants under laboratory conditions.

Host (Cultivars)	Life stages (Days)								
	Egg	Larval	Per-pupal	Pupal	Developmental time	Male longevity	Female longevity	*APOP*[a]	*TPOP*[b]
White kidney bean (Danshkadeh)	$1.30 \pm 0.05^{cde*}$	10.55 ± 0.08^{de}	1.30 ± 0.05^{d}	9.83 ± 0.14^{e}	22.78 ± 0.19^{fg}	9.95 ± 0.34^{f}	8.90 ± 0.34^{e}	2.82 ± 0.24^{ab}	25.38 ± 0.35^{d}
White kidney bean (Pak)	1.11 ± 0.03^{de}	10.72 ± 0.09^{de}	1.18 ± 0.05^{d}	11.00 ± 0.15^{d}	23.78 ± 0.23^{fg}	11.55 ± 0.32^{e}	10.35 ± 0.17^{de}	4.03 ± 0.64^{a}	27.87 ± 0.72^{bcd}
Red kidney bean (Akhtar)	1.07 ± 0.03^{e}	10.99 ± 0.11^{cd}	1.18 ± 0.04^{d}	11.23 ± 0.13^{d}	24.30 ± 0.17^{ef}	11.97 ± 0.33^{de}	10.97 ± 0.24^{bcd}	2.57 ± 0.32^{ab}	26.67 ± 0.41^{cd}
Red kidney bean (Naz)	1.07 ± 0.03^{e}	10.95 ± 0.13^{cde}	1.15 ± 0.04^{d}	11.20 ± 0.13^{d}	24.27 ± 0.18^{f}	12.62 ± 0.25^{bcde}	10.76 ± 0.38^{cd}	2.56 ± 0.08^{ab}	26.59 ± 0.39^{cd}
Canola (Okapi)	1.43 ± 0.06^{bc}	11.24 ± 0.09^{bc}	1.43 ± 0.07^{cd}	11.52 ± 0.12^{cd}	25.62 ± 0.24^{d}	12.72 ± 0.21^{bcde}	11.37 ± 0.27^{cd}	1.58 ± 0.25^{b}	26.61 ± 0.44^{cd}
Canola (Opera)	1.31 ± 0.05^{cd}	11.76 ± 0.11^{a}	2.40 ± 0.10^{a}	13.08 ± 0.17^{a}	28.94 ± 0.24^{a}	15.41 ± 0.23^{a}	15.27 ± 0.29^{a}	3.11 ± 0.19^{ab}	31.68 ± 0.42^{a}
Canola (Sarigol)	1.41 ± 0.05^{bc}	10.95 ± 0.09^{cde}	1.65 ± 0.07^{bc}	11.47 ± 0.12^{cd}	25.44 ± 0.23^{de}	12.25 ± 0.23^{cde}	11.32 ± 0.22^{bcd}	1.33 ± 0.21^{b}	26.45 ± 0.42^{cd}
Canola (Zarfam)	1.54 ± 0.05^{ab}	11.34 ± 0.07^{abc}	1.43 ± 0.06^{cd}	12.04 ± 0.14^{bc}	26.37 ± 0.18^{cd}	13.40 ± 0.20^{bc}	12.37 ± 0.52^{b}	3.14 ± 0.83^{ab}	29.36 ± 1.02^{ab}
Soybean (Clark)	1.63 ± 0.06^{ab}	11.48 ± 0.07^{ab}	1.75 ± 0.10^{b}	11.29 ± 0.21^{d}	26.02 ± 0.43^{cd}	12.67 ± 0.33^{bcde}	10.22 ± 0.51^{de}	2.00 ± 0.32^{ab}	28.08 ± 0.81^{bc}
Soybean (M7)	1.72 ± 0.05^{a}	11.47 ± 0.07^{ab}	1.72 ± 0.08^{bc}	12.54 ± 0.14^{ab}	27.69 ± 0.25^{b}	13.79 ± 0.15^{b}	8.92 ± 0.19^{e}	2.09 ± 0.49^{ab}	30.45 ± 0.75^{ab}
Soybean Sari	1.68 ± 0.05^{a}	11.47 ± 0.10^{ab}	1.29 ± 0.53^{d}	12.07 ± 0.16^{bc}	26.86 ± 0.31^{bc}	12.85 ± 0.33^{bcd}	11.20 ± 0.52^{bcd}	2.59 ± 0.49^{ab}	29.59 ± 0.48^{ab}
Soybean (Williams)	1.72 ± 0.05^{a}	11.48 ± 0.03^{ab}	1.69 ± 0.08^{bc}	12.54 ± 0.14^{ab}	27.61 ± 0.26^{b}	13.80 ± 0.15^{b}	12.00 ± 0.11^{bc}	3.09 ± 0.34^{ab}	28.17 ± 0.72^{bc}
Cowpea (Mashhad)	1.31 ± 0.05^{cd}	10.95 ± 0.11^{cde}	1.32 ± 0.06^{d}	9.80 ± 0.13^{e}	22.71 ± 0.18^{g}	9.58 ± 0.41^{f}	8.92 ± 0.23^{e}	2.09 ± 0.32^{ab}	25.37 ± 0.34^{d}

[a] Adult Pre-Ovipositional Period, [b] Total Pre-Ovipositional Period (from egg to first oviposition).*Means within the same column followed by the same letters are not significantly different (Paired-bootstrap test, $P < 0.05$).

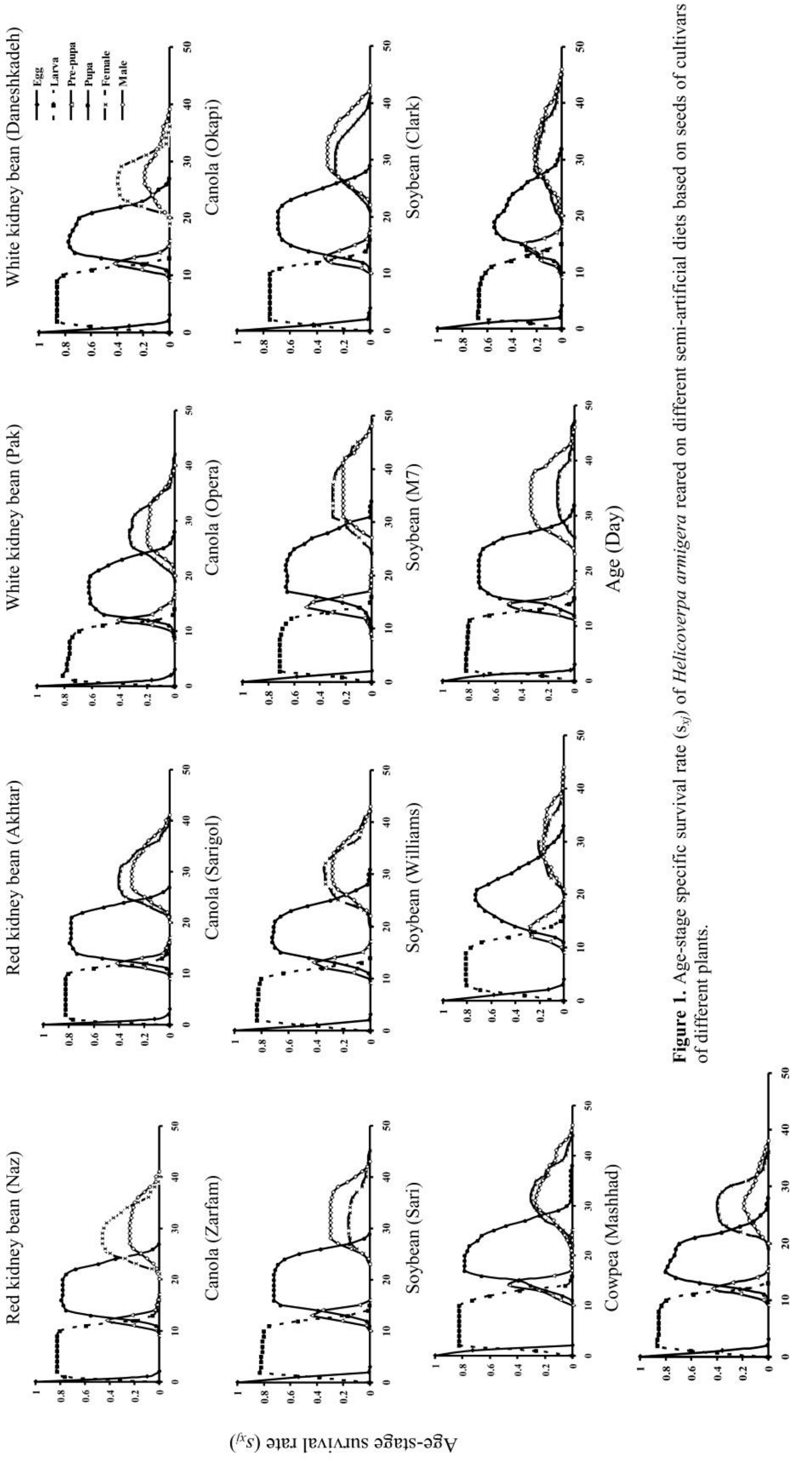

Figure 1. Age-stage specific survival rate (s_{xj}) of *Helicoverpa armigera* reared on different semi-artificial diets based on seeds of cultivars of different plants.

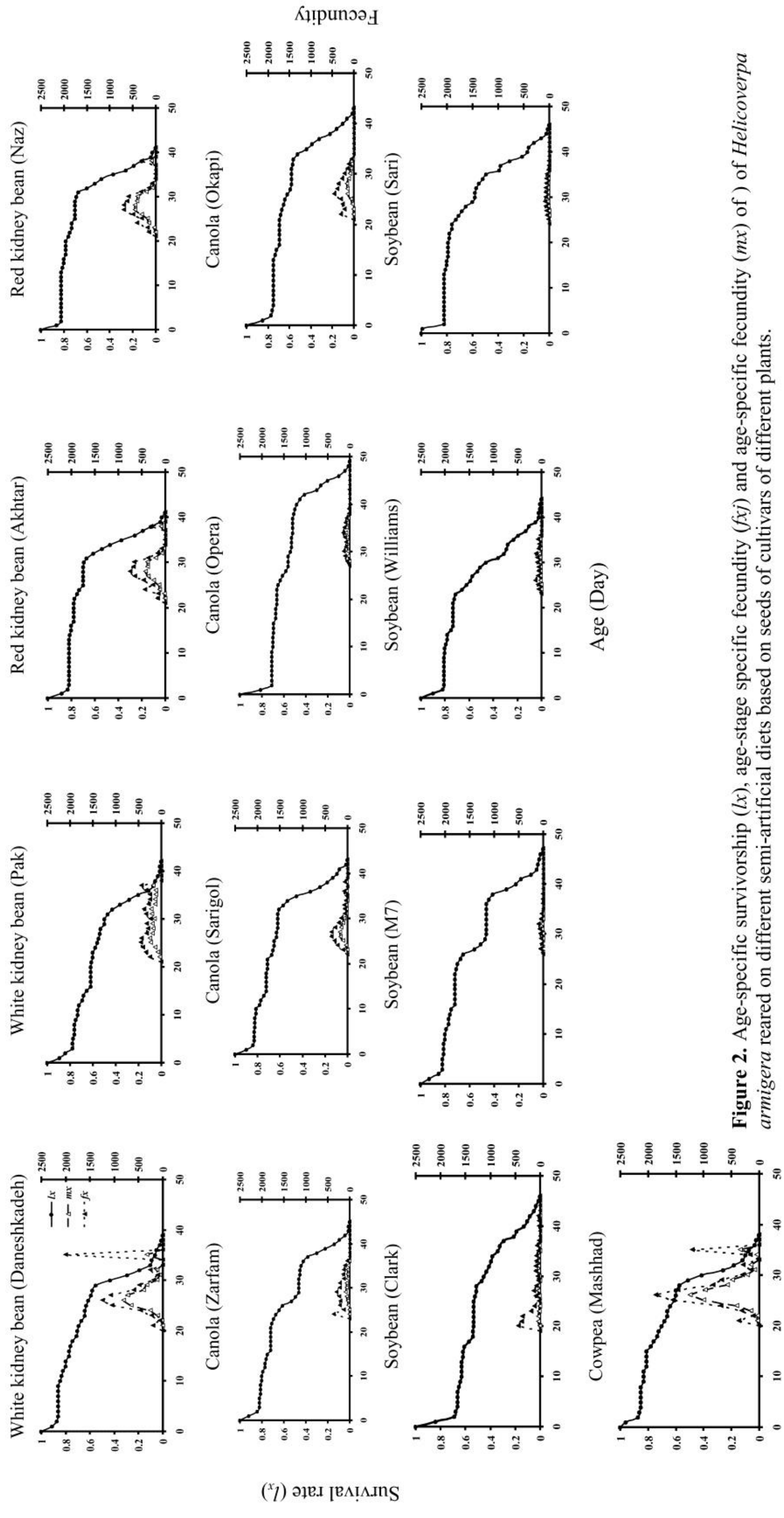

Figure 2. Age-specific survivorship (lx), age-stage specific fecundity (fxj) and age-specific fecundity (mx) of) of *Helicoverpa armigera* reared on different semi-artificial diets based on seeds of cultivars of different plants.

development of *H. armigera*. The survival rate at the age of adult emergence of *H. armigera* observed 0.64 and 0.58 for white kidney bean cultivars Daneshkadeh and Pak, 0.70 and 0.70 for red kidney bean cultivars Akhtar, and Naz, 0.62, 0.56, 0.63, 0.53 for canola cultivars Okapi, Opera, Sarigol and Zarfam, 0.51, 0.51, 0.68, 0.53 for soybean cultivars Clark, M7, Sari and Williams, respectively and 0.64 for cowpea cultivar Mashhad. (Figure 2). The start of oviposition of the first female of *H. armigera* on white kidney bean cultivars Daneshkadeh and Pak, red kidney bean cultivars Akhtar and Naz, canola cultivars Okapi, Opera, Sarigol and Zarfam, soybean cultivars Clark, M7, Sari and Williams and cowpea cultivar Mashhad was observed at the age of 21, 22, 22, 22, 22, 28, 23, 24, 20, 27, 25, 24, and 21 days, respectively. The maximum age-stage specific fecundity (*fxj*) of *H. armigera* adults were 2012 (age 35 day), 457.43 (age 25 day), 762.32 (age 28 day), 706.89, (age 28 day), 461.6 (26 day), 150.93 (age 34 day), 366.59 (age 26 day), 377 (age 24 day), 448.5 (age 20 day), 104 (age 32 day), 88.73 (age 29 day), 128.2 (age 26 day) and 1867.42 (age 26 day) eggs/female/day on white kidney bean cultivars Daneshkadeh and Pak, red kidney bean cultivars Akhtar and Naz, canola cultivars Okapi, Opera, Sarigol and Zarfam, soybean cultivars Clark, M7, Sari and Williams and cowpea cultivar Mashhad respectively (Figure 2). The highest age specific fecundity (*mx*) of *H. armigera* adults reared on these cultivars were 817.28, 256.163, 435.61, 464.53, 161.62, 87.07, 168.78, 108.22, 43.66, 29.39, 40.63, 51.45, 1244.99 eggs individual-1 day-1 and occurred at the age of 26, 26, 28, 28, 28, 34, 27, 29, 32, 32, 32, 32 and 26 days, respectively. The gross reproductive rate of *H. armigera* on semi-artificial diets ranged from 121.92 on soybean cultivar M7 to 5786.36 on cowpea cultivar Mashhad. Also, the different cultivars of canola affected reproductive of *H. armigera* (Chegeni *et al*., 2014). Cowpea cultivar Mashhad had the highest net reproductive rate (3108.20 females/individual/generation time) and the intrinsic rate of increase (0.299 day^{-1}) (Table 2). The net Reproductive rate (R_0) was higher on different bean cultivars than the other plants (different soybean and canola cultivars). In this research, net reproductive rate on different bean cultivars was higher than those reported by Naseri *et al*. (2014) on bean. Also, our results showed that the net reproductive rate on all plants and cultivars was higher than those reported by Liu *et al*. (2004) on corn (44.5), tobacco (11.7), and common bean (19.5). In the current study, the *r* value of *H. armigera* ranged from 0.125 to 0.299 on different plants and their cultivars. The higher intrinsic rate of natural increase of *H. armigera* on cowpea cultivar Mashhad and white kidney bean cultivar Daneshkadeh related to the considerably higher net reproductive rate per female, higher survival, and shorter development time of *H. armigera* on the mentioned plants and cultivars. These results indicate that *H. armigera* had the greatest chance to increase its population on the mentioned plants and cultivars. The *r* values of *H. armigera* were estimated as 0.09-0.114 day^{-1} on different soybean cultivars (Soleimannejad *et al*., 2010), 0.041-0.127 day^{-1} on different tomato cultivars (Safuraie-Parizi *et al*., 2014) and 0.115-0.142 day^{-1} on different bean cultivars (Naseri *et al*., 2014). The lowest finite rate of increase (λ) was obtained at 1.13 day^{-1} on soybean cultivar M7. Cowpea cultivar Mashhad had shorter generation time of (26.85 days), and canola cultivar Opera had longer generation Time (T) of (33.73 days) than the other seeds (Table 2).

Total Proteolytic Aactivity

The highest level of proteolytic activity in the midgut of the 3rd instar larvae of *H. armigera* were in the larvae fed on white kidney bean, cultivars Daneshkadeh (5.998±0.06 U mg^{-1}) and Pak (5.948±0.07 U mg^{-1}) (F= 537.729; df= 12, 26; P< 0.001). In this instar larva, the lowest proteolytic activity was obtained at 2.839±0.06 and 2.829±0.05 U mg^{-1} on soybean cultivars Clark and M7, respectively (Figure 3-a). The proteolytic activity of midgut extracts from the 4th (F= 170.339; df= 12, 26; P< 0.001) and 5th (F= 467.626; df= 12, 26; P< 0.001) instar larvae of *H. armigera* reared on white

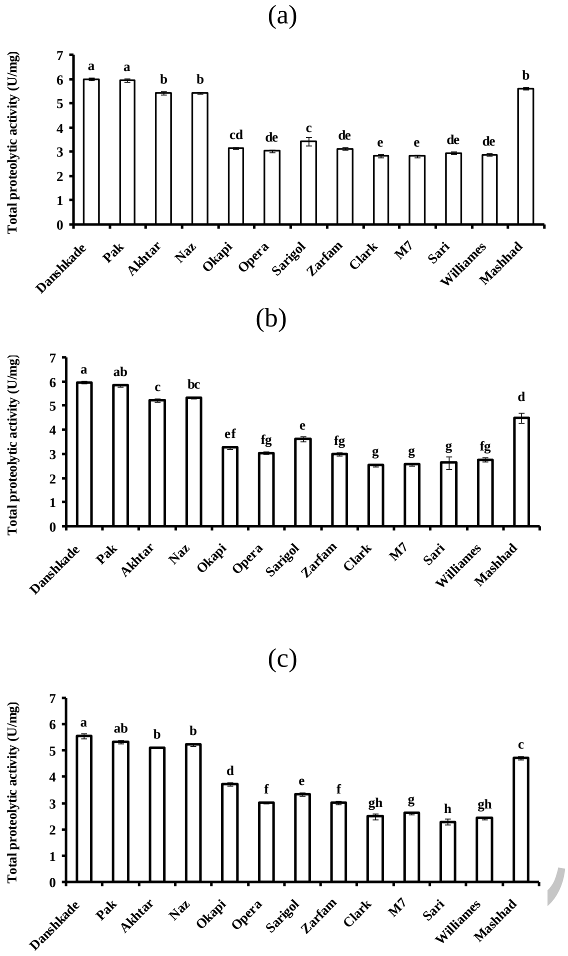

Figure 3. Total proteolytic activity of midgut extracts of the 3rd (a), 4th (b) and 5th (c) instar larvae of *Helicoverpa armigera* on semi-artificial diets based on the seeds of different host plant cultivars.

kidney bean, Daneshkadeh cultivar (5.964±0.05 and 5.558±0.09 U mg^{-1}, respectively) was higher than those reared on the other host plants tested (Figures 3-b and -c). The results indicated that the 4th instar larvae of *H. armigera* fed on soybean, Clark cultivar (2.525±0.06 U mg^{-1}) had the minimum enzyme activity. The minimum proteolytic activity in the midgut of the 5th instar larvae of *H. armigera* was 2.292±0.12 U mg^{-1}on soybean, Sari cultivar. The host plant seeds and their cultivars have important effects on proteolytic activity in the midgut of different instar larvae of *H. armigera*. The proteolytic activity in the midgut of the 3rd, 4th and 5th instar larvae of *H. armigera* that had fed on semi-artificial diets including seeds of soybean was lower than the other plants (different types of bean and canola). The reduction in protease activity in *H. armigera* may be related to high protease inhibition in soybean seeds. Also, previous studies showed that different host plants and various cultivars significantly affected digestive enzyme activity of *H. armigera* (Naseri and Razmjou, 2013; Baghery *et al*., 2014).

Nutritional Responses

The determination of consumption and utilization of host plants by insects is a commonly used tool in studies of plant-insect interactions (Scriber and Slansky, 1981; Fathipour *et al*., 2017). The highest values of larval weight in the 3rd instar larvae of *H. armigera* were on white kidney bean, Daneshkadeh cultivar (52.47±0.58 mg) (F= 232.193; df =12, 52; P< 0.001). The larval weight in the 4th instar larvae was highest on white kidney bean, Daneshkadeh cultivar (55.37±1.09 mg) and lowest on cowpea, cultivar Mashhad (21.75±0.41 mg) (F= 304.604; df= 12, 52; P< 0.001). The heaviest larval weight in the 5th instar larvae of *H. armigera* was observed on soybean cultivar Sari (120.28±0.55 mg) and the lightest was on canola, Sarigol cultivar (37.64±0.79 mg) (F= 819.894; df= 12, 52; P< 0.001). The mean weight of the 6th instar (F= 2253.209; df= 12, 52; P< 0.001) was the heaviest on red kidney bean cultivar Akhtar (146.81±10.65). The maximum food consumed by the 3rd instar larvae was 75.64±0.83 mg on canola cultivar Zarfam (F= 566.454; df= 12, 52; P< 0.001), by the 4th instar larvae was 102.42±1.13 mg on canola, Opera cultivar (F= 552.501; df= 12, 52; P< 0.001) and by the 5th instar larvae was 200.65±0.60 mg on soybean cultivar Williams (F= 1998.155; df= 12, 52; P< 0.001). The maximum and minimum food consumed by the 6th instar larvae of *H. armigera* were on white kidney bean

Table 3. Mean (±SE) larval weight of *Helicoverpa armigera*,, food consumed and feces produced by 3rd, 4th, 5th, 6th and whole instar larvae on semi-artificial diets based on the seeds of different host plant cultivars.

Host (Cultivars)	3rd Instar larvae			4th Instar larvae			5th instar larvae		
	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)
White Kidney bean (Danshkadeh)	52.47±0.58a [a]	25.25±1.43i	18.10±0.55ghi	55.37±1.09a	78.36±1.00c	12.51±0.72g	77.51±0.87c	161.65±0.59b	41.49±0.69de
White Kidney bean (Pak)	51.70±0.66a	35.50±0.11h	20.33±0.50fgh	48.93±0.71b	70.53±0.23de	13.43±0.44g	70.50±0.20d	156.30±1.03c	39.08±1.63def
Red Kidney bean (Akhtar)	50.26±0.40a	61.17±0.44c	20.99±0.28def	47.70±1.08b	70.59±0.06de	35.79±0.36b	66.93±0.84d	149.23±0.45d	30.28±0.45g
Red Kidney bean (Naz)	44.69±0.42b	43.55±0.75e	44.68±0.42a	45.48±0.74b	74.19±2.12cd	41.67±0.53a	62.57±0.66e	143.61±0.67e	41.20±0.26de
Canola (Okapi)	20.07±0.41de	68.60±0.78b	22.45±0.62cde	31.06±0.56c	101.76±0.59a	9.54±0.52h	62.16±0.94e	101.75±0.65g	32.38±0.45fg
Canola (Opera)	19.00±0.31de	69.29±1.00b	23.82±0.43cd	31.15±0.91c	102.42±1.13a	13.82±0.38fg	66.77±0.77d	102.56±1.97g	34.17±0.26efg
Canola (Sarigol)	43.78±0.11b	41.98±0.64ef	22.92±0.70cde	23.62±0.75de	36.93±0.43g	22.60±0.66c	37.64±0.79h	125.59±0.73f	49.65±0.59bc
Canola (Zarfam)	42.29±2.75b	75.64±0.83a	17.56±0.41hi	21.76±1.50e	71.76±0.71d	11.27±0.31gh	53.79±0.75f	124.31±1.06f	51.65±1.31b
Soybean (Clark)	20.18±0.01cde	36.67±0.63gh	15.09±0.55i	22.83±0.35e	48.05±0.95f	21.26±0.47cd	37.69±0.71h	57.84±0.70i	22.85±1.30h
Soybean (M7)	24.71±0.26c	66.49±0.25b	30.93±0.26b	46.53±0.17b	35.35±0.51g	19.08±0.84d	87.79±0.65b	95.45±0.96h	45.39±0.32bcd
Soybean Sari	17.14±0.74e	49.24±0.19d	25.31±1.33c	26.69±0.81d	88.16±0.58b	13.50±0.71g	120.28±0.55a	57.79±0.78i	34.84±0.62efg
Soybean (Williams)	23.39±1.03cd	69.13±0.44b	17.52±0.80hi	24.56±0.42de	90.11±0.70b	17.07±0. 90e	44.44±1.47g	200.65±0.60a	43.88±0.67cd
Cowpea (Mashhad)	43.71±0.11b	39.32±0.22fg	19.35±0.48gh	21.75±0.41e	67.19±1.09e	16.37±0.21ef	42.86±0.56g	156.47±0.96c	63.01±0.36a

[a] Means in the same column followed by the same letters do not differ significantly (Tukey test, $P < 0.05$)

Continued Table 3

Host (Cultivars)	6th Instar larvae			Whole instar larvae		
	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)	Larval weight (mg)	Food consumed (mg)	Feces produced (mg)
White Kidney bean (Danshkadeh)	76.13±0.53e	302.49±0.80a	39.42±1.76fg	235.41±0.26a	213.53±0.80b	39.61±0.70f
White Kidney bean (Pak)	70.37±0.15f	227.40±1.10e	37.55±0.84g	213.13±0.65b	226.07±0.99a	46.95±0.65e
Red Kidney bean (Akhtar)	146.81±0.65a	146.81±10.64g	40.75±0.20fg	199.95±0.41c	198.29±0.96d	50.75±0.28d
Red Kidney bean (Naz)	65.59±0.14g	140.71±0.67g	45.19±0.50ef	195.99±0.50cd	197.65±0.77d	56.18±1.20c
Canola (Okapi)	28.96±0.78i	102.67±0.76h	59.88±3.96c	167.91±0.90ef	135.84±0.48g	34.74±0.72g
Canola (Opera)	27.69±0.89i	204.11±1.00f	23.82±0.43i	166.94±0.91ef	114.92±0.99h	23.82±0.43h
Canola (Sarigol)	98.93±0.60b	234.69±5.07de	68.62±0.66b	186.73±3.52d	87.38±0.76i	12.64±0.68j
Canola (Zarfam)	88.87±0.68d	270.83±0.67b	67.60±0.88b	213.41±1.03b	74.44±0.72k	18.00±0.41i
Soybean (Clark)	57.77±0.70h	67.01±0.57i	30.27±0.23h	53.49±0.45h	142.01±0.42f	74.79±0.39a
Soybean (M7)	95.59±0.08c	103.488±0.795h	60.89±0.23c	42.75±0.21i	153.64±0.35e	66.03±0.30b
Soybean Sari	76.65±0.81e	239.790±5.115c	77.91±0.63a	173.85±5.92e	80.37±0.88j	24.46±0.77h
Soybean (Williams)	72.21±0.77f	109.92±2.40h	52.67±0.71d	156.75±0.75g	133.99±0.53g	57.12±0.57c
Cowpea (Mashhad)	64.18±0.50g	265.24±0.30b	51.27±0.46de	160.55±0.35fg	202.23±0.38c	50.46±0.50d

[a] Means in the same column followed by the same letters do not differ significantly (Tukey test, $P < 0.05$)

Table 4. Nutritional indices (mean±SE) of the 3rd, 4th, 5th, 6th and whole (3rd to 6th) instar larvae of *Helicoverpa armigera*, on semi-artificial diets based on the seeds of different host plant cultivars.

Host (Cultivars)	*CI*	*RCR*	*RGR*	*ECI*	*ECD*	*AD*
			3rd Instar larvae			
White Kidney bean (Danshkadeh)	2.48±0.03bc [a]	0.12±0.01e	0.12±0.02e	61.00±0.03a	65.20±0.01c	15.30±0.05h
White Kidney bean (Pak)	1.69±0.00e	0.18±0.00de	0.18±0.00de	34.60±0.01b	83.2±0.025b	42.70±0.01f
Red Kidney bean (Akhtar)	1.22±0.01f	0.77±0.01a	0.76±0.01a	16.90±0.00f	50.80±0.00d	33.30±0.01g
Red Kidney bean (Naz)	1.59±0.23ef	0.38±0.01bc	0.38±0.01bc	22.30±0.00de	41.40±0.01e	53.90±0.01de
Canola (Okapi)	3.42±0.04a	0.74±0.01a	0.74±0.01a	18.30±0.00ef	27.20±0.01f	68.10±0.01ab
Canola (Opera)	3.65±0.05a	0.83±0.01a	0.83±0.01a	18.50±0.00ef	27.90±0.01f	65.60±0.01bc
Canola (Sarigol)	1.77±0.19e	0.32±0.00cd	0.32±0.01cd	31.10±0.00bc	94.40±0.30a	45.40±0.01ef
Canola (Zarfam)	1.79±0.02e	0.53±0.01b	0.53±0.01b	16.10±0.01f	19.8±0.002h	75.70±0.01a
Soybean (Clark)	2.25±0.04cd	0.81±0.01a	0.81±0.01a	28.30±0.01c	48.30±0.02d	58.80±0.02cd
Soybean (M7)	2.69±0.01b	0.79±0.00a	0.79±0.01a	15.30±0.01f	28.60±0.01f	53.80±0.00de
Soybean Sari	2.87±0.01b	0.76±0.00a	0.74±0.00a	19.70±0.01ef	41.00±0.03e	48.60±0.03ef
Soybean (Williams)	3.58±0.04a	0.21±0.13cde	0.20±0.28cde	17.80±0.00ef	26.60±0.01fg	67.20±0.01abc
Cowpea (Mashhad)	1.90±0.01de	0.28±0.00cde	0.28±0.00cde	26.90±0.00cd	53.20±0.02d	49.70±0.01def
			4th Instar larvae			
White Kidney bean (Danshkadeh)	1.41±0.02d	0.47±0.01f	0.47±0.01f	55.60±0.01c	66.70±0.01cd	84.40±0.10ab
White Kidney bean (Pak)	1.44±0.01d	0.38±0.01g	0.38±0.01g	51.40±0.01d	63.70±0.01cd	80.10±0.01bc
Red Kidney bean (Akhtar)	1.35±0.02d	0.79±0.01c	0.79±0.01c	99.00±0.01a	98.60±0.01a	46.30±0.01de
Red Kidney bean (Naz)	1.57±0.23d	0.92±0.02b	0.92±0.03b	88.40±0.03b	83.20±0.01b	30.80±0.01f
Canola (Okapi)	3.27±0.02ab	0.78±0.01c	0.78±0.01c	12.40±0.01gh	13.80±0.01e	90.00±0.01a
Canola (Opera)	3.62±0.62a	0.98±0.01a	0.98±0.01a	11.90±0.01h	13.70±0.01e	47.90±0.06f
Canola (Sarigol)	1.56±0.02d	0.52±0.01e	0.52±0.01e	29.30±0.01f	70.70±0.11bc	34.90±0.02f
Canola (Zarfam)	3.30±0.03ab	0.59±0.01d	0.59±0.01d	15.70±0.01g	18.70±0.01e	83.80±0.01ab
Soybean (Clark)	2.11±0.04cd	0.53±0.01e	0.53±0.01e	26.50±0.01f	52.70±0.02d	51.10±0.016d
Soybean (M7)	2.76±0.01bc	0.25±0.01h	0.25±0.01h	44.10±0.01e	84.40±0.01b	43.50±0.01e
Soybean Sari	3.30±0.02ab	0.98±0.01a	0.98±0.01a	13.50±0.01gh	15.90±0.01e	84.70±0.01ab
Soybean (Williams)	3.67±0.03a	0.91±0.01b	0.91±0.01b	12.20±0.01h	13.90±0.01e	80.50±0.01bc
Cowpea (Mashhad)	3.09±0.05ab	0.14±0.01i	0.14±0.01i	45.80±0.01e	60.40±0.01cd	75.90±0.01c
			5th Instar larvae			
White Kidney bean (Danshkadeh)	2.08±0.01e	0.65±0.00d	0.65±0.01d	25.60±0.01d	66.70±0.01cd	74.30±0.01abc
White Kidney bean (Pak)	2.22±0.01de	0.70±0.01c	0.70±0.01c	24.10±0.01d	63.70±0.01cd	75.00±0.01ab
Red Kidney bean (Akhtar)	2.23±0.01de	0.98±0.00a	0.98±0.01a	46.30±0.01b	98.60±0.01a	55.10±0.01def
Red Kidney bean (Naz)	1.32±0.01g	0.64±0.00d	0.64±0.01d	45.90±0.01b	83.20±0.01b	71.30±0.01abcd
Canola (Okapi)	1.64±0.01f	0.41±0.00g	0.41±0.01g	24.50±0.01d	13.80±0.01e	53.90±0.08ef
Canola (Opera)	1.54±0.04f	0.59±0.01e	0.59±0.01e	18.50±0.01e	13.70±0.01e	52.10±0.09ef
Canola (Sarigol)	3.34±0.02c	0.76±0.00b	0.76±0.01b	18.20±0.01e	70.70±0.11bc	60.40±0.01bcde
Canola (Zarfam)	2.33±0.03d	0.60±0.01e	0.61±0.01d	23.50±0.01d	18.70±0.01e	58.50±0.01bcde
Soybean (Clark)	1.32±0.13g	0.48±0.01f	0.48±0.01f	62.00±0.01a	52.70±0.02d	60.60±0.02bcde
Soybean (M7)	1.09±0.01h	0.27±0.01h	0.27±0.01h	47.20±0.01b	84.40±0.01ab	57.50±0.01cde
Soybean Sari	1.31±0.01g	0.16±0.01i	0.16±0.01i	24.20±0.01d	15.90±0.01e	39.70±0.01f
Soybean (Williams)	4.51±0.01a	0.97±0.01a	0.97±0.01a	39.20±0.01c	13.60±0.01e	78.10±0.01a
Cowpea (Mashhad)	3.65±0.02b	0.96±0.01a	0.96±0.01a	23.60±0.01d	60.40±0.01cd	67.10±0.03abcde

[a] Means in the same column followed by the same letters do not differ significantly (Tukey test, $P < 0.05$)

Table4 continued…

Continued of Table 4.

Host (Cultivars)	*CI*	*RCR*	*RGR*	*ECI*	*ECD*	*AD*
			6th Instar larvae			
White Kidney bean (Danshkadeh)	4.77±0.11a [a]	0.77±0.02de	0.77±0.01de	46.80±0.00a	29.60±0.01f	86.70±0.00a
White Kidney bean (Pak)	4.09±0.02b	0.95±0.01ab	0.95±0.00ab	44.00±0.00b	31.00±0.01ef	77.80±0.02bc
Red Kidney bean (Akhtar)	2.18±0.02ef	0.95±0.01ab	0.95±0.01ab	44.30±0.00b	64.20±0.01d	72.20±0.00cde
Red Kidney bean (Naz)	2.30±0.01e	0.55±0.00f	0.55±0.00f	42.10±0.00c	86.60±0.02b	14.80±0.01h
Canola (Okapi)	1.12±0.03g	0.93±0.01ab	0.93±0.01ab	30.20±0.00ef	31.60±0.01ef	76.30±0.02bcd
Canola (Opera)	2.68±0.01d	0.29±0.03gh	0.29±0.03gh	28.90±0.01fg	32.20±0.00ef	82.60±0.00ab
Canola (Sarigol)	2.37±0.051e	0.70±0.01e	0.70±0.01e	29.30±0.00f	26.00±0.01f	70.70±0.01de
Canola (Zarfam)	3.12±0.08c	0.82±0.06cd	0.82±0.06cd	31.10±0.00e	30.20±0.01ef	75.10±0.00cd
Soybean (Clark)	1.16±0.01g	0.32±0.00g	0.32±0.00g	37.40±0.01d	87.80±0.01b	47.10±0.03fg
Soybean (M7)	1.09±0.01g	0.27±0.00gh	0.27±0.00gh	40.60±0.00c	98.40±0.00a	41.10±0.00g
Soybean Sari	3.13±0.07c	0.87±0.02bc	0.87±0.02bc	41.00±0.01c	36.20±0.01e	67.40±0.01e
Soybean (Williams)	1.90±0.04f	0.22±0.01h	0.22±0.00h	14.30±0.01h	75.60±0.03c	52.00±0.01f
Cowpea (Mashhad)	4.44±0.13b	0.98±0.00a	0.98±0.00a	27.30±0.00g	28.60±0.01f	82.00±0.00ab
			Whole (3rd to 6th) instar larvae			
White Kidney bean (Danshkadeh)	2.97±0.00a	0.07±0.02cd	0.07±0.02cd	38.6±0.017c	49.20±0.00f	81.40±0.00ab
White Kidney bean (Pak)	1.06±0.01f	0.19±0.13c	0.18±0.12c	33.2±0.001c	47.20±0.01f	70.40±0.00cd
Red Kidney bean (Akhtar)	1.59±0.24de	0.09±0.00cd	0.09±0.00cd	35.3±0.001c	47.40±0.00f	74.50±0.00bc
Red Kidney bean (Naz)	2.32±0.00c	0.09±0.00cd	0.09±0.00cd	32.7±0.003c	46.40±0.01f	70.80±0.01cd
Canola (Okapi)	1.81±0.00de	0.06±0.00cd	0.06±0.00cd	46.9±0.001b	47.00±0.00f	74.40±0.01bc
Canola (Opera)	1.48±0.00de	0.04±0.00d	0.04±0.00d	18.5±0.002d	75.40±0.01e	74.90±0.06bc
Canola (Sarigol)	2.47±0.06bc	0.04±0.01d	0.04±0.00d	87.9±0.039a	94.4±0.00a	85.90±0.01a
Canola (Zarfam)	1.32±0.00e	0.82±0.04a	0.81±0.49a	90.2±0.009a	94.80±0.01a	75.90±0.01bc
Soybean (Clark)	2.66±0.01ab	0.80±0.02a	0.80±0.01a	49.8±0.001b	91.60±0.01ab	61.70±0.07de
Soybean (M7)	1.08±0.01f	0.26±0.01b	0.26±0.01b	49.6±0.001b	87.00±0.01c	57.00±0.00ef
Soybean Sari	1.61±0.01de	0.04±0.01d	0.04±0.00d	85.3±0.008a	89.80±0.01bc	69.60±0.01cd
Soybean (Williams)	1.86±0.00d	0.07±0.00cd	0.07±0.00cd	47.7±0.002b	83.20±0.01d	57.40±0.01ef
Cowpea (Mashhad)	1.27±0.01ef	0.24±0.01bc	0.24±0.00bc	37.20±0.01c	49.60±0.00f	75.00±0.00bc

[a] Means in the same column followed by the same letters do not differ significantly (Tukey test, $P < 0.05$)

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cultivar Daneshkadeh (302.49±0.80 mg) and soybean cultivar Clark (67.01±0.57 mg), respectively (F= 1210.792; df= 12, 52; P< 0.001). Furthermore, the highest and lowest weights of feces produced by the 3rd instar larvae were on red kidney bean cultivar Naz (44.69±0.42 mg/larva) and on soybean cultivar Clark (15.09±0.55 mg/larva), respectively (F= 151.513; df= 12, 52; P< 0.001). The highest weights of feces produced by the 4th (F=274.302; df=12, 52; P< 0.001) and the 5th (F= 47.721; df= 12, 52; P< 0.001) instar larvae of *H. armigera* were obtained on red kidney bean cultivar Naz (41.67±0.53 mg/larva) and cowpea cultivar Mashhad (63.01±0.36 mg larva^{-1}), respectively (Table 3).

The 3rd larvae reared on canola, Opera cultivar (3.65±0.05) showed the highest value of *CI* (F= 85.564; df= 12, 52; P< 0.001) compared with those reared on the other plants and cultivars (Table 4). The maximum *CI* for the 4th was observed on soybean, Williams cultivar (3.67±0.03) (F= 253.46; df= 12, 52; P< 0.001) and for the 5th larvae was on soybean cultivar Williams (4.51±0.01) (F= 688.223; df= 12, 52; P< 0.001) (Table 4). The *CI* value for the 6th and whole instar larvae of *H. armigera* on white kidney bean cultivar Daneshkadeh was significantly higher than the other plants and their cultivars (F= 442.046; df= 12, 52; P< 0.001; F= 124.519; df= 12, 52; P< 0.001, respectively). The highest value of *ECI* and *ECD* were 61.00±0.03 and 94.40±0.30 on white kidney bean, Daneshkadeh cultivar and canola, Sarigl cultivar, respectively (F= 149.531; df= 12, 52; P< 0.001; F=268.835; df= 12, 52; P< 0.001, respectively) for the 3rd instar larvae. On red kidney bean cultivar Akhtar, the corresponding values were 99.00±0.01 and 98.60±0.01, respectively (F= 1397.088; df= 12, 52; P< 0.001; F= 104.564; df= 12, 52; P< 0.001, respectively) for the 4th instar larvae and 62.00±0.01 and 98.60±0.01 on soybean cultivar Clark and red kidney bean cultivar Akhtar for 5th instar larvae of *H. armigera*, respectively (F= 903.807; df= 12, 52; P< 0.001; F= 104.564; df= 12, 52; P< 0.001, respectively) (Table 4). The *ECD* and *ECI* value for whole instar larvae of *H. armigera* on canola cultivar Sarigol and Zarfam were significantly higher than the other plants and their cultivars (F= 910.939; df= 12, 52; P< 0.001; F= 347.813; df= 12, 52; P< 0.001, respectively) (Table 4).

Significant differences were found within the nutritional indices of *H. armigera* reared on different plant seeds and their cultivars, suggesting that the different seeds of plants have variation in nutritional value. The importance of different host plants and cultivars on nutritional indices of *H. armigera* were investigated in previous studies (Naseri *et al*., 2010a; Naseri and Razmjou, 2013; Baghery *et al*., 2013; Fathipour *et al*., 2017).

The results obtained from investigating life table and digestive proteolytic activity of *H. armigera* support each other. In some cases, the results from studying nutritional response of *H. arimgera* on different semi-artificial diets were conflicting with other results. But in most cases, they were favorable. Finally, according to the results obtained, semi-artificial diets including bean seeds is more suitable than semi-artificial diets including soybean and canola seeds for rearing of *H. armigera*. Among different bean types and their cultivars, cowpea cultivar Mashhad and white kidney bean cultivar Daneshkadeh are the best seeds to supply semi-artificial diets for rearing this pest in laboratory conditions. There are many factors affecting host suitability, including nutrient content and secondary substances of the host and the capability of digestion and assimilation by an insect. The results of this study may be important in the management programs of *H. armigera*.

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واکنش کرم غوزه پنبه *Helicoverpa armigera* (Lepidoptera: Noctuidae) به رژیم‌های مختلف غذایی نیمه-مصنوعی

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چکیده

شب‌پره *Helicoverpa armigera* (Hübner) به عنوان یکی از مهم‌ترین عوامل کاهش محصولات میزبان در ایران و جهان است. در این تحقیق ویژگی‌های اکو-فیزیولوژی *H. armigera* روی رژیم‌هایی غذایی نیمه-مصنوعی حاوی بذر ارقام مختلف لوبیا سفید و قرمز، کلزا، سویا و لوبیا چشم بلبلی بررسی شد. نتایج نشان داد کمترین (۲۲/۷۱ روز) و بیشترین (۲۸/۹۴ روز) طول دوره قبل از بلوغ *H. armigera* به ترتیب روی لوبیا چشم بلبلی رقم مشهد و کلزا رقم اپرا است. بیشترین میزان مرگ‌ومیر قبل از بلوغ این شب‌پره روی سویا ارقام M7 و کلارک مشاهده شد. مقدار *r* شب‌پره *H. armigera* روی لوبیا چشم بلبلی رقم مشهد (۰/۲۹۹ بر روز) بیشترین بود. کمترین مقدار آنزیم پروتئولیتیک کل در لارو سن سوم ۲/۸۲۹ (U/mg) روی سویا رقم M7، در لارو سن چهارم ۲/۵۲۵(U/mg) روی سویا رقم کلارک و در لارو سن پنجم، ۲/۲۹۲ (U/mg) روی سویا رقم ساری بود. شاخص‌های تغذیه‌ای در سنین سوم، چهارم، پنجم، ششم و کل سنین لاروی شب‌پره *H. armigera* تحت تأثیر رژیم‌های غذایی مصنوعی قرار گرفت. بر اساس نتایج حاصل، رژیم‌های غذایی نیمه-مصنوعی حاوی بذر پودر شده لوبیا (به خصوص لوبیا چشم بلبلی رقم مشهد و لوبیا سفید رقم دانشکده) نسبت به رژیم‌های غذایی نیمه-مصنوعی حاوی بذر پودر شده کلزا و سویا، برای پرورش شب‌پره *H. armigera* در شرایط آزمایشگاهی مناسب‌تر است. نتایج این تحقیق ممکن است در برنامه‌های مدیریتی شب‌پره *H. armigera* مفید باشد.