J. Agr. Sci. Tech. (2018) Vol. 20: 83-94

Genotype-Associated Variation in Nutritional Indices of *Helicoverpa armigera* (Lepidoptera: Noctuidae) Fed on Canola

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ABSTRACT

In this study, the nutritional indices of the larval stages of *Helicoverpa armigera* (Hübner) were determined on 10 canola (*Brassica napus* L.) genotypes (Talaye, Opera, Licord, Modena, SLM_{046}, $Hayula_{420}$, Zarfam, Okapi, RGS_{003} and Sarigol) at 25±1˚C, 60±5% RH and a photoperiod of 16: 8 (L: D) hours. The third instar larvae reared on Talaye showed the highest value of Efficiency of Conversion of Ingested food *ECI* and Efficiency of Conversion of Digested food *ECD* (7.005±0.632 and 8.972±1.862, respectively). However, the lowest value of *ECI* and *ECD* was on Licord (0.503±0.017 and 2.507±0.449, respectively). The highest (0.778±0.091) and lowest (0.594±0.059) Relative Growth Rate (RGR) of the fourth instar larvae were obtained on SLM_{046} and Sarigol, respectively. Results indicated that the highest values of *ECI* and *ECD* for fourth instar larvae were on Talaye (6.300±0.585 and 8.880±1.954, respectively). The lowest value of the Relative Consumption Rate (RCR) and Approximate Digestibility (AD) of the fifth instar was recorded on Modena (5.193±0.629 and 38.625±11.340, respectively). The *ECI* and *ECD* values of the fifth larval instar were the highest on Talaye (9.893±0.889 and 19.655±0.966, respectively). The highest value of *RCR* and *AD* of the sixth instar was on Okapi (7.781±0.665 and 82.223±1.922, respectively). Among different genotypes tested, the highest *ECI* and *ECD* of the whole larval instars (12.323±0.310 and 32.357±5.508, respectively) were observed on Talaye and the lowest ones (5.947±0.257 and 6.922±0.320, respectively) were on Okapi. Together, Talaye and Okapi were the most suitable and unsuitable genotypes, respectively, for *H. armigera* larvae.

Keywords: Approximate digestibility, *Brassica napus*, Digested food, Ingested food, Relative growth rate.

INTRODUCTION

Helicoverpa armigera (Hübner) is one of the herbivores known as economically important pests across the world (Fathipour and Sedaratian, 2013). This pest is highly polyphagous and the larvae can use a large variety of wild and cultivated plants for feeding (Zalucki *et al*., 1994). *Helicoverpa armigera* causes serious damage on various crops such as cotton, tomato (Liu *et al*., 2004; Safuraie-Parizi *et al*., 2014), chickpea, maize, sunflower, groundnut (Fitt, 1989), sorghum, pigeon pea, canola (Karimi *et al.*, 2012) and soybean (Fathipour and Naseri, 2011). Flowering and fruiting structures of these plants are used as a place for female of this pest to lay its eggs which leads to a huge amount of economic loss due to feeding of larvae on these parts (Fathipour and Sedaratian, 2013).

Different methods have been tried for controlling *H. armigera*, but insecticides are the most effective ones thus far. Due to indiscriminate use of insecticides to control this pest, particularly on cotton and other high value crops, there is high resistance to conventional insecticides (Armes *et al*., 1996; Kranthi *et al.,* 2002). Insecticides are

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environmentally contaminant and they increase the severity of minor pests. Hence, developing a resistant cultivar provides an effective complementary approach in Integrated Pest Management (IPM) in order to minimize the extent of losses (Lateef, 1985). The use of resistant cultivars has been considered an important factor in any IPM program. As a result, host plant resistance is a valid method in controlling pest insects, which is environmentally friendly and cuts down the expenses for growers (Liu *et al*., 2004).

The chemical composition of host plants significantly influences survival, growth, and reproduction of phytophagous insects (Goodarzi *et al.*, 2015). The quality and quantity of consumed foods can affect growth, development, and reproduction of insects. Feeding larvae can also affect the properties of pupa and adult. Measuring the amount of consumed and digested food can be an index to show the quality of the food which is measured by nutritional indices (Kianpour *et al.*, 2014; Talaee *et al.*, 2017).

Although *H. armigera* is economically important, there is little information about the effect of different canola cultivars on its biology. There is also no information on its nutritional indices. Different studies have been carried out about the effect of crops on physiology, demography, and nutritional indices of *H. armigera* (Ashfaq *et al*. 2003; Wang *et al*. 2006; Naseri *et al.*, 2009a,b, 2010a,b, 2011; Soleimannejad *et al.*, 2010; Baghery *et al.,* 2013*;* Fallahnejad-Mojarrad *et al.*, 2010). The main purpose of this study was to determine the nutritional indices of *H. armigera* on different canola genotypes to classify their resistance status. The nutritional indices can be used along with the life table parameters for determining the antibiotic resistance level of different varieties against a given pest.

MATERIALS AND METHODS

Plants Rearing

Ten canola genotypes including Talaye, Opera, Licord, Modena, SLM_{046}, $Hayula_{420}$, Zarfam, Okapi, RGS_{003}, and Sarigol were used in this study. The seeds of the canola genotypes were obtained from the Seed and Plant Improvement Research Institute, Karaj, and were sown in 20-cm plastic pots filled with fertilized field soil and compost mixture. The plants were planted in the greenhouse and then transferred at approximately 10-12 leaf growth stage to the growth chambers at 25±1 ℃, 60±5% RH and a photoperiod of 16:8 (L: D) hours.

Insect Rearing

Individuals of *H. armigera* were originally collected from cotton fields in the Moghan region located in northwest Iran and the stock culture was established in the laboratory. The colony of *H. armigera* was reared on the artificial diet (Naseri *et al.*, 2009a; Soleimannejad *et al.*, 2010) and maintained in growth chamber at 25±1°C, 60±5% RH and a photoperiod of 16:8 (L: D) hours. *H. armigera* was reared individually on ten canola genotypes in laboratory for 2-3 generations before being used in the experiments. To rear and obtain different instars, 10 pairs of adults were released in each oviposition cage (11 cm in diameter by 12 cm in height) covered with fine mesh net. The adults were provided with 10% sucrose solution on a cotton swab. Female moths laid their eggs on the net after 72 hours. The nets were removed from the cages daily and replaced with fresh nets. The eggs laid on the same day were kept in plastic bags in growth chambers and were covered with humid cotton to prevent drying. After hatching, the larvae were moved to plastic containers (8 cm in diameter by 5 cm in height). To make a good ventilation, a cavity was made on top of the containers covered by mesh net. First to third instar larvae were reared in groups and subsequently transferred individually to plastic tubes separately to avoid the cannibalism. They were kept in these tubes for pre-pupation and pupation.

[DOR: 20.1001.1.16807073.2018.20.1.10.2]

Experiments

Nutritional indices were determined using third to sixth instar larvae as measurement was easier compare with the first and second instars. At first, these experiments were carried out with 50 larvae for the third instars larvae given their smaller size. After that the larvae were separated in plastic containers (diameter 8.5 cm, depth 3 cm) and the experiment was done individually for each larva in 30 replicates.

The observations were taken daily and all the larvae, food supplied, food remained, and feces were weighed. This trend was continued until the larvae finished feeding and reached the pre-pupal stage. Furthermore, the weight of pre-pupa, pupa and adults from the larvae reared on each genotype was measured. The nutritional indices were measured on the dry weight basis. To determine the dry weight of the larvae, feces and leaves, 20 specimens for each of them were weighed and they were kept in the oven for 48 hours at 60°C, then re-weighed to measure percentage of their dry weight.

The nutritional indices were calculated based on dry weights using the formulae presented by Waldbauer (1968) and Huang and Ho (1998).

Approximate digestibility (%) = $AD = ((E - F)/E) \times 100$), (1)

Relative consumption rate (mg mg^{-1} d^{-1}) = $RCR = E/(A \times T)$ (2)

Relative growth rate (mg mg^{-1} d^{-1}) = $RGR = P/(A \times T)$ (3)

Efficiency of conversion of ingested food (%) =$ECI = (P/E) \times 100$ (4)

Efficiency of conversion of digested food (percent) =$ECD = (P/(E - F)) \times 100$) (5)

Where, *P*= Dry weight gain (mg); *A*=Initial and final mean dry weights of the larvae during feeding period (mg); *E*=Dry weight of food ingested (mg); *T*=Duration of feeding period (days), and *F*=The dry weight of feces produced (mg).

Data Analysis

The data were checked for normality before analysis by Kolmogorov-Smirnov test. The data obtained from the experiments were analyzed using one way ANOVA to determine significant differences and the means were compared by Tukey test. A dendrogram of canola genotypes based on nutritional indices of *H. armigera* was created after cluster analysis by Ward's method using SPSS statistical software.

RESULTS

The results of the nutritional indices of third instar indicated that there were no significant differences among the RGR of *H. armigera* on different canola genotypes. However, significant difference was observed on the other estimated indices of the third instar larvae on different canola genotypes. The highest and lowest values of RCR were on Licord (17.709±2.861 mg mg^{-1} d^{-1}) and Talaye (6.597±0.870 mg mg^{-1} d^{-1}), respectively. However, the highest *ECI* and *ECD* values (7.005±0.632 and 8.972±1.862%, respectively) were on Talaye and the lowest (2.507±0.449 and 2.446±0.272%, respectively) were on Licord. Among the different canola genotypes, the highest value of *AD* was on Okapi (95.398±0.514%), and the lowest was on Talaye (61.770±9.342%). The highest value of larval weight gain, food consumed and feces produced was on Opera (1.242±0.067, 24.828±1.793, 7.684±1.077 mg, respectively) and the lowest was on Okapi (0.346±0.041, 13.341±1.105, 0.631±0.027 mg, respectively) (Table 1).

The nutritional indices of the fourth instar larvae of *H. armigera* were significantly different on the canola genotypes tested, but no significant difference was observed regarding RGR. The larvae reared on Licord showed the highest value of *RCR* and *AD* (22.243±1.981 mg mg^{-1} d^{-1}, 88.227±0.716%, respectively) compared with those reared on the other genotypes. The *ECI* and *ECD* val

Table 1. Nutritional indices (±SE) of the third instar larvae of *Helicoverpa armigera* on 10 canola genotypes.[a]

Genotypes	*RCR* [b] (mg mg^{-1} d^{-1})	*RGR* [c] (mg mg^{-1} d^{-1})	*ECI* (%) [d]	*ECD* (%) [e]	*AD* (%) [f]	*P* (mg) [g]	*E* (mg) [h]	*F* (mg) [i]
Talaye	6.597±0.870 d	0.538±0.045 a	7.005±0.632 a	8.972±1.862 a	61.770±9.342 d	1.013± 0.127 a	18.857± 0.868 bc	6.945± 1.529 a
Opera	7.660±1.344 cd	0.677±0.126 a	5.848±0.303 abc	7.561±0.931 ab	69.202±3.745 cd	1.242± 0.067 a	24.828± 1.793 a	7.684± 1.077 a
Licord	17.709±2.861 a	0.503±0.017 a	2.507±0.449 e	2.446±0.272 e	84.022±2.767 ab	0.491± 0.107 c	19.769± 2.475 ab	3.072± 0.576 b
Modena	9.396±1.608 bcd	0.536±0.049 a	4.853±0.780 cd	4.885±0.593 cd	82.707±3.163 ab	0.602± 0.049 bc	14.221±1.597 bc	2.137± 0.272 bc
SLM_{046}	13.067±1.928 abcd	0.631±0.069 a	3.439±0.525 de	3.748±0.481 cde	80.847±3.413 bc	0.454± 0.014 c	15.129± 1.249 bc	2.770± 0.391 bc
$Hayula_{420}$	9.023±1.697bcd	0.645±0.123 a	5.265±0.617 bc	5.714±0.687 bc	92.300±0.793 ab	0.888± 0.198 ab	16.096± 1.828 bc	1.239± 0.200 bc
Zarfam	12.667±2.593abcd	0.567±0.111 a	2.622±0.388 e	2.791±0.414 de	94.821±0.442 a	0.364± 0.076 c	13.975± 2.435 bc	0.761± 0.061c
Okapi	15.337±2.123 ab	0.514± 0.060 a	3.492±0.427 de	3.707±0.471 cde	95.398±0.514 a	0.346± 0.041 c	13.341± 1.105 c	0.631±0.027 c
RGS_{003}	14.316± 2.568 abc	0.517±0.060 a	3.327±0.213 de	3.554±0.254 cde	92.581±1.282 ab	0.509± 0.070 c	14.066± 1.652 bc	0.907±0.118 c
Sarigol	9.503± 1.148 bcd	0.525±0.052 a	6.841±0.234 ab	8.200±0.504 a	92.144±0.378 ab	1.125± 0.176 a	15.022±2.214 bc	1.320± 0.273 bc
$F_{(9, 290)}$	3.63	0.47	9.67	11.29	8.33	7.96	3.78	15.22
P	0.0034	0.8811	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0019	<0.0001

[a] The means followed by different letters in each column are significantly different ($P< 0.05$, Tukey test). [b] Relative Consumption Rate; [c] Relative Growth Rate; [d] Efficiency of Conversion of Ingested food; [e] Efficiency of Conversion of Digested food; [f] Approximate Digestibility; [g] Dry weight gain of larvae; [h] Dry weight of food ingested, [i] Dry weight of feces produced.

ues of fourth instar were the highest on Talaye (6.300±0.585 and 8.880±1.954%, respectively) and lowest on Licord (2.360±0.285 and 2.657±0.393%, respectively) (Table 2).

There were significant differences among all nutritional indices of the fifth instar larvae on canola genotypes tested, except RGR. The highest values of *ECI* and *ECD* were recorded on Talaye (9.893±0.889 and 19.655±0.966%, respectively). On the other hand, Modena had the least *RCR* and *AD* (5.193±0.629 mg mg^{-1} d^{-1} and 38.625±11.340%, respectively). The larvae brought up on Zarfam showed the lowest value of larval weight gain, food consumed and feces produced (8.213±0.372, 104.30±5.982 and 16.19±1.382 mg, respectively) (Table 3).

The nutritional indices of the sixth instar larvae and whole larval instars of *H. armigera* were significantly different on different canola genotypes. The sixth instar larvae fed on SLM_{046} had the highest *RGR* value (0.608±0.034 mg mg^{-1} d^{-1}) and lowest on Sarigol (0.437±0.020 mg mg^{-1} d^{-1}). Also, the *ECI* and *ECD* values of sixth instar larvae reared on Talaye possessed the highest value (14.134 ±1.839 and 52.937±8.829%, respectively) (Table 4). The *RCR* and *AD* values of the whole larval instars were the highest on Okapi (1.888±0.080 mg mg^{-1} d^{-1} and 82.236±1.061%, respectively) and lowest on Modena (0.864±0.035 mg mg^{-1} d^{-1} and 40.057±4.624%, respectively) (Table 5).

Different canola genotypes revealed no significant effect on the weight of adult *H. armigera*. However, the weight of the pre-pupa and pupa were significantly affected by the canola genotypes examined. Pre-pupa and pupa of the larvae reared on Talaye were heavier than those reared on other genotypes (Table 6).

The dendrogram of the nutritional parameters of *H. armigera* reared on different canola genotypes (Figure 1) showed two distinct clusters labeled A and B. The cluster A comprised the subclusters A1 (Modena, Zarfam, Opera, Talaye and

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Table 2. Nutritional indices (±SE) of the fourth instar larvae of *Helicoverpa armigera* on 10 canola genotypes.[a]

Genotypes	*RCR* [b] (mg mg^{-1} d^{-1})	*RGR* [c] (mg mg^{-1} d^{-1})	*ECI* (%) [d]	*ECD* (%) [e]	*AD* (%) [f]	*P* (mg) [g]	*E* (mg) [h]	*F* (mg) [i]
Talaye	12.845±2.071 bc	0.705±0.049 a	6.300±0.585 a	8.880± 1.954 a	61.416±5.214 e	3.0439± 0.536 cde	56.840± 5.010 e	21.578± 4.673 a
Opera	13.048±2.268 bc	0.696±0.061 a	5.187±0.591 ab	6.381±0.839 b	82.456±2.635 abc	5.8065±0.974 a	115.609± 10.377 a	19.405± 2.922 ab
Licord	22.243±1.981 a	0.668± 0.017 a	2.360±0.285 d	2.657± 0.393 e	88.227±0.716 a	1.7328± 0.147 f	85.507± 7.165 bc	13.249± 1.439 bcd
Modena	8.570±0.847 c	0.698±0.040 a	6.174±0.181 a	8.643± 0.605 a	70.909±3.307 d	4.4184± 0.520 b	67.668± 6.677 cde	20.119± 3.237 a
SLM_{046}	13.367±1.204 b	0.778± 0.091 a	4.175±0.340 bc	5.310± 0.574 bcd	81.122±2.567 bc	3.7650± 0.736 bc	76.966± 7.890 bcd	10.516± 1.372 d
$Hayula_{420}$	16.477±1.217 b	0.684±0.081 a	2.737±0.182 d	3.159± 0.218 e	87.172±0.711 ab	2.5169±0.219 def	93.292± 5.675 b	12.755± 1.015 cd
Zarfam	16.465± 1.319 b	0.689±0.048 a	3.360±0.268 cd	4.759± 0.420 bcde	70.412±1.598 d	1.9021± 0.152 f	55.487± 2.879 e	17.517± 1.216 abc
Okapi	13.888± 1.344 b	0.608±0.046 a	4.594±0.385 b	6.018± 0.509 bc	76.504±1.390 cd	3.1685± 0.268 cd	65.061± 1.920 de	15.539± 0.730 abcd
RGS_{003}	16.525± 1.302 b	0.652± 0.073 a	2.667±0.230 d	3.980± 0.365 cde	73.127±1.875 d	2.0005± 0.152 ef	72.080± 5.137 cde	20.838± 1.669 a
Sarigol	14.713± 0.755 b	0.594± 0.059 a	2.799±0.260 d	3.798± 0.364 de	74.323±0.861 d	2.0945± 0.195 ef	80.892± 4.256 bcd	20.382± 1.044 a
F (9, 290)	4.40	0.43	13.48	10.08	8.33	12.23	9.95	3.43
P	< 0.0001	0.9170	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0019	< 0.0001

[a] The means followed by different letters in each column are significantly different (P< 0.05, Tukey test). [b] Relative Consumption Rate; [c] Relative Growth Rate; [d] Efficiency of Conversion of Ingested food; [e] Efficiency of Conversion of Digested food; [f] Approximate Digestibility; [g] Dry weight gain of larvae; [h] Dry weight of food ingested, [i] Dry weight of feces produced.

Table 3. Nutritional indices (±SE) of the fifth instar larvae of *Helicoverpa armigera* on 10 canola genotypes.[a]

Genotypes	*RCR* [b] (mg mg^{-1} d^{-1})	*RGR* [c] (mg mg^{-1} d^{-1})	*ECI* (%) [d]	*ECD* (%) [e]	*AD* (%) [f]	*P* (mg) [g]	*E* (mg) [h]	*F* (mg) [i]
Talaye	5.385± 0.615 b	0.664±0.047 a	9.893± 0.889 a	19.655± 0.966 a	52.921± 4.538 c	15.498± 2.958 a	167.90± 10.416 bc	57.45± 7.056 cd
Opera	8.008± 0.759 a	0.722± 0.055 a	5.836±0.298 c	7.654±0.966 c	63.316±6.672 bc	14.084± 2.547 ab	257.26± 29.464 a	78.15± 21.303 bc
Licord	8.038± 0.470 a	0.62389± 0.048 a	5.796± 0.520 c	7.521±0.271 c	70.654±3.934 ab	8.328± 0.772 c	156.44± 17.238 bcd	46.60± 6.056 de
Modena	5.193±0.629 b	0.642± 0.044 a	8.617± 0.846 ab	19.225± 3.332 a	38.625±11.340 d	14.799± 1.808 ab	182.46± 16.640 a	109.63± 24.754 a
SLM_{046}	6.751± 0.495 ab	0.773± 0.074 a	6.690± 0.647 bc	14.728±2.443 ab	39.064±5.000 d	10.056± 1.395 c	152.74± 15.100 bcd	96.00± 20.709 ab
$Hayula_{420}$	7.126± 0.720 ab	0.722± 0.075 a	8.164± 0.698 abc	17.859±2.953 a	55.966±4.415 c	9.081± 0.559 c	106.03± 8.388 e	43.81± 3.964 def
Zarfam	5.513± 0.240 b	0.683± 0.054 a	7.858± 0.508 abc	8.806± 0.705 c	80.347±2.649 a	8.213± 0.372 c	104.30± 5.982 e	16.19±1.382 f
Okapi	7.215± 0.481 ab	0.604± 0.062 a	7.037± 0.494 bc	8.450± 0.589 c	83.597± 1.190 a	11.278± 0.519 bc	158.21± 10.965 bcd	23.34± 2.543 ef
RGS_{003}	6.556± 0.376 ab	0.618± 0.050 a	7.985± 0.616 abc	9.676± 0.802 bc	77.800± 1.938 a	9.345± 0.468 c	120.35± 7.227 de	25.85± 2.297 ef
Sarigol	5.763± 0.385 b	0.606± 0.034 a	7.729± 0.761 abc	8.660± 0.876 c	83.227± 1.060 a	9.689± 0.865 c	134.39± 9.424 cde	21.56± 1.289 ef
F (9, 290)	2.69	0.72	2.31	7.42	17.08	4.92	11.70	13.59
P	0.0073	0.6904	0.0176	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[a] The means followed by different letters in each column are significantly different (P< 0.05, Tukey test). [b] Relative Consumption Rate; [c] Relative Growth Rate; [d] Efficiency of Conversion of Ingested food; [e] Efficiency of Conversion of Digested food; [f] Approximate Digestibility; [g] Dry weight gain of larvae; [h] Dry weight of food ingested, [i] Dry weight of feces produced.

Table 4. Nutritional indices (±SE) of the sixth instar larvae of *Helicoverpa armigera* on 10 canola genotypes. [a]

Genotypes	*RCR* [b] (mg mg^{-1} d^{-1})	*RGR* [c] (mg mg^{-1} d^{-1})	*ECI* (%) [d]	*ECD* (%) [e]	*AD* (%) [f]	*P* (mg) [g]	*E* (mg) [h]	*F* (mg) [i]
Talaye	3.091± 0.573 d	0.567± 0.046 ab	14.134±1.839 a	52.937± 8.829 a	39.218± 4.115 d	29.049± 4.235 abc	228.39± 15.467 d	130.38± 6.735 ab
Opera	4.038± 0.137 cd	0.573± 0.051 ab	9.166±0.832 b	14.532± 2.140 cd	62.853± 4.293 bc	34.422± 1.065 a	357.08± 21.344 a	134.60± 13.126 ab
Licord	2.913± 0.288 d	0.516± 0.023 ab	12.381± 1.140 a	25.672± 5.572 b	41.963± 7.864 d	33.101± 4.042 a	274.17± 18.780 bcd	152.99±20.716 a
Modena	2.769± 0.114 d	0.599± 0.084 a	12.881± 0.397 a	49.910± 6.515 a	26.503± 6.551 e	29.000± 2.464 abc	228.08± 15.193 d	159.53± 18.841 a
SLM_{046}	6.538±0.170 ab	0.608± 0.034 a	6.638±0.544 cd	9.009± 0.431 de	57.114± 2.931 c	18.159± 1.079 de	330.11± 10.185 abc	145.87± 5.824 ab
$Hayula_{420}$	4.263± 0.239 cd	0.532± 0.030 ab	9.798± 0.558 b	14.781± 1.131 cd	70.985± 1.917 b	31.247± 1.462 ab	338.29± 18.286 ab	98.78± 6.009 cd
Zarfam	4.815± 0.314 bcd	0.544± 0.028 ab	8.666±0.319 bc	16.606± 1.477 c	54.369± 3.144 c	23.380± 0.766 cd	270.88± 11.699 cd	120.37± 8.119 bc
Okapi	7.781± 0.665 a	0.525± 0.016 ab	6.161±0.305 d	7.447± 0.753 e	82.223± 1.922 a	15.635± 0.985 e	226.72± 9.949 d	49.88± 4.780 e
RGS_{003}	3.984± 0.189 cd	0.456± 0.032 b	9.829±0.582 b	13.307± 0.846 cde	73.039± 1.813 ab	26.474± 1.735 bc	285.53± 14.838 bcd	76.68± 4.808 de
Sarigol	6.127± 0.486 abc	0.437± 0.020 b	6.428±0.299d	7.626± 0.327 e	81.759± 1.231 a	19.718± 0.855 de	310.51± 14.423 abc	57.28± 4.784 e
$F_{(9, 290)}$	9.54	2.06	13.98	11.29	31.30	14.50	5.61	23.11
P	< 0.0001	0.0404	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[a] The means followed by different letters in each column are significantly different (P< 0.05, Tukey test). [b] Relative Consumption Rate; [c] Relative Growth Rate; [d] Efficiency of Conversion of Ingested food; [e] Efficiency of Conversion of Digested food; [f] Approximate Digestibility; [g] Dry weight gain of larvae; [h] Dry weight of food ingested, [i] Dry weight of feces produced.

Table 5. Nutritional indices (±SE) of the whole larval instars of *Helicoverpa armigera* on 10 canola genotypes.[a]

Genotypes	*RCR* [b] (mg mg^{-1} d^{-1})	*RGR* [c] (mg mg^{-1} d^{-1})	*ECI* (%) [d]	*ECD* (%) [e]	*AD* (%) [f]	*P* (mg) [g]	*E* (mg) [h]	F (mg) [i]
Talaye	0.888± 0.024 c	9.642± 0.853 a	12.323± 0.310 a	32.357± 5.508 a	44.364± 1.474 fg	29.049± 4.235 abc	228.39± 15.467 d	130.38± 6.735 ab
Opera	1.401± 0.106 b	9.340± 0.459 a	7.616± 0.492 c	12.956± 1.133 d	62.839±3.804 d	34.422± 1.065 a	357.08± 21.344 a	134.60± 13.126 ab
Licord	0.923± 0.086 c	8.523± 0.724 a	10.114±0.853 b	27.369± 2.095 b	53.551±2.826 e	33.101± 4.042 a	274.17± 18.780 bcd	152.99±20.716 a
Modena	0.864± 0.035 c	9.547± 0.129 a	11.095± 0.523 ab	28.895±3.029 ab	40.057±4.624 g	29.000± 2.464 abc	228.08± 15.193 d	159.53± 18.841 a
SLM_{046}	1.543± 0.073 b	9.523± 0.356 a	6.326± 0.291 d	11.072± 0.901 de	51.209±3.723 ef	18.159± 1.079 de	330.11± 10.185 abc	145.87± 5.824 ab
$Hayula_{420}$	0.999± 0.036 c	8.556± 0.198 a	9.940±0.378 b	14.291± 0.720 cd	71.141± 1.491 c	31.247± 1.462 ab	338.29± 18.286 ab	98.78± 6.009 cd
Zarfam	1.033± 0.029 c	9.316± 0.775 a	10.569± 0.252 b	17.142± 0.636 c	53.299±2.317 e	23.380± 0.766 cd	270.88± 11.699 cd	120.37± 8.119 bc
Okapi	1.888± 0.080 a	6.855± 0.266 b	5.947± 0.257 d	6.922± 0.320 f	82.236± 1.061 a	15.635± 0.985 e	226.72± 9.949 d	49.88± 4.780 e
RGS_{003}	0.907± 0.026 c	8.488± 0.545 a	10.288± 0.311 b	13.635± 0.524 cd	73.933± 1.141 bc	26.474± 1.735 bc	285.53± 14.838 bcd	76.68± 4.808 de
Sarigol	1.562± 0.036 b	4.367± 0.154 c	6.265± 0.143 d	7.834± 0.206 ef	80.713± 1.062 ab	19.718± 0.855 de	310.51± 14.423 abc	57.28± 4.784 e
$F_{(9, 290)}$	2.69	0.72	2.31	7.42	17.08	4.92	11.70	13.59
P	0.0073	0.6904	0.0176	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[a] The means followed by different letters in each column are significantly different (P< 0.05, Tukey test). [b] Relative Consumption Rate; [c] Relative Growth Rate; [d] Efficiency of Conversion of Ingested food; [e] Efficiency of Conversion of Digested food; [f] Approximate Digestibility; [g] Dry weight gain of larvae; [h] Dry weight of food ingested, [i] Dry weight of feces produced.

Table 6. The mean (±SE) body weight of pre-pupa, pupa and adult stages of *Helicoverpa armigera* on 10 canola genotypes.[a]

Genotypes	Pre-pupal weight (mg)	Pupal weight (mg)	Adult weight (mg)
Talaye	345.32±18.29 a	243.64±3.37 a	159.82±12.65 a
Opera	335.00±8.83 abc	231.70±4.55 ab	157.31±8.68 a
Licord	299.42±11.00 cd	212.01±9.08 bc	148.77±6.41 a
Modena	341.29±17.25 ab	236.01±4.58 ab	159.00±7.71 a
SLM$_{046}$	305.67±3.64 abcd	222.19±7.03 abc	155.09±8.35 a
Hayula$_{420}$	316.62±15.42 abcd	225.81± 5.85 ab	156.80±9.12 a
Zarfam	314.67± 6.08 abcd	223.60±6.43 abc	155.50±6.24 a
Okapi	289.75±8.56 d	198.58±8.58 c	143.58±6.78 a
RGS$_{003}$	301.43±13.79 bcd	219.27±6.77 abc	153.55±6.95 a
Sarigol	290.43±12.22 d	210.73±6.45 bc	148.00±7.08 a

SLM$_{046}$) as a susceptible group, and A2 (RGS$_{003}$, Hayula$_{420}$ and Licord) as an intermediate group. The cluster B included Sarigol and Okapi as a resistant group.

DISCUSSION

The use of resistant cultivars can be a part of an IPM strategy (Fathipour and Mirhosseini, 2017). Differences in allelochemical concentrations among host plant genotypes can affect performance of herbivores, especially in larval stage (Martin and Pulin, 2004). Significant differences were found among the nutritional indices of *H. armigera* reared on different canola genotypes in which showed different nutritional value of the genotypes tested. The results of the current study showed that the highest value of *ECI* and *ECD* was related to the sixth instar larvae. The gradual increase in conversion of digested foods from the younger larval instars to older instars indicated that older larvae can convert more consumed food into biomass, which means this larval instar cause more damage to economically important crops in agricultural ecosystems.

The results indicated that the *AD* value for whole larval instars reared on RGS (0.739)

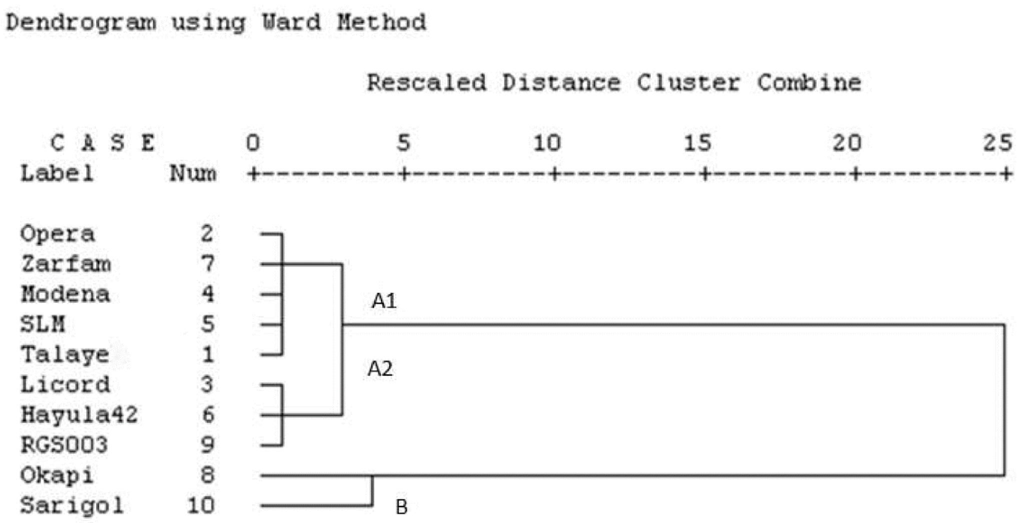

Figure 1. Dendrogram of ten canola genotypes based on nutritional indices of *Helicoverpa*

[DOR: 20.1001.1.16807073.2018.20.1.10.2]

is nearly similar to the data reported by Naseri *et al*. (2010a) for *AD* value of *H. armigera* fed on soybean var. William (0.736). The results also showed that the *AD* value of the fourth instar larvae of *H. armigera* reard on Talaye (61.4) was almost the same as what has been reported by Ashfaq *et al*. (2003) on *Permiselum typhoideum* L. (61.7). Among different canola genotypes tested, *RGR* value of the sixth instar larvae reared on RGS (0.456) is similar to the data reported by Soleimannejad *et al.* (2010) for *RGR* value of *H. armigera* on soybean var. Sari (0.459). According to the results of Fallahnejad-Mojarrad *et al*. (2010) on seeds of different chick pea and one cowpea cultivars, the value of *RCR* on Hashem (0.999) was alike the finding of the current study on Hayula_{420} (0.999). The *ECD* value of *H. armigera* on different tomato cultivars observed in the study of Srinivasan and Uthamasamy (2005) ranged from 3.73 to 37.39, which was considerably close to those estimated in the current study. The results indicated that highest value of *ECI* occurred when the insect fed on Talaye (12.323) genotype, which is similar to that reported by Baghery *et al*. (2013) on navy bean (12). The *ECD* value of whole larval instars reared on different canola cultivars was different from that reported by Wang *et al*. (2006) on an artificial diet (41.24). There were also lots of differences between the results of the current study with some studies mentioned above that may be due to the difference between the host plant or type of food (fresh leaves or artificial diet based on the seeds of host plants). Furthermore, these differences may be due to differences in experimental conditions such as the amount of water that insect's food has lost in different situations that can affect the weight of food provided and consumed. The difference in experimental generations of the insects used in different studies as well as variation in methods used for data analysis might be another reason for these differences.

The cluster analysis revealed two main groups of A and B, where the group A was divided to two subgroups of A1 and A2. These groups were formed based on the nutritional indices of *H. armigera* on different canola genotypes. The subgroup A1 included the most suitable genotypes due to higher nutrition value for the larvae and the genotypes in the subgroup A2 had an intermediate status; while the genotypes grouped in the group B were least favorable host plant due to lower nutrition value and lower *ECI* and *ECD*.

The parameters such as weight of pre-pupa, pupa, and adult insects are used as indirect indices to determine the amount of insect adaptation to varying environmental conditions (Leuck and Perkins, 1972). One of the important indices of insect population dynamics is the body weight (Liu, *et al*. 2004). The weight of pupa is an indirect index of lepidopteran fitness which can be easily measured (Leuck and Perkins, 1972). The larvae reared on Talaye and Modena had heavier pupal weight than those reared on other cultivars. The lowest pupal weight was recorded on the larvae reared on Okapi and Sarigol. In addition, according to the results of nutritional indices, the highest values of *ECD* and *ECI* were also on Talaye and Modena and the lowest values were on Okapi and Sarigol. As *ECD* and *ECI* of the larvae were highest on Talaye and Modena genotypes, the pre-pupae and pupae developed from these larvae were heavier than those reared on other genotypes. On the other hand, Okapi and Sarigol can be categorized as least suitable genotypes for *H. armigera* compared with other genotypes because of lower values of *ECI* and *ECD* which led to lower weight of the pre-pupae and pupae.

The data obtained from the pupal weight of *H. armigera* reared on different canola genotypes in the current study was similar to those reported by Naseri *et al*. (2010) and Soleimannejad *et al*. (2010) on different soybean cultivars but they are not in line with those reported by Fallahnejad-Mojarrad *et al*. (2010) on seeds of different chick pea and cowpea cultivars. Liu *et al*. (2004) found that pupal weight of *H. armigera* was

[DOR: 20.1001.1.16807073.2018.20.1.10.2]

affected by the type of host plant which the larvae feed on it, as its value ranged from 167.1 mg on tomato to 285.2 mg on maize. In study of Jallow *et al*. (2001) about the comparison of pupal weight that reared on tomato, pepper, maize, okra and eggplant showed that the weight of pupa reared on tomato, pepper, and eggplant was 310, 290 and 270 mg, respectively, which was higher than the highest weight reported in the current study on Talaye (243.64 mg). Therefore, we can conclude that the mentioned host plants are more suitable than the canola genotypes tested for pupa growth of *H. armigera.*

Literature review showed that resistance level of the canola genotypes used in the current study were evaluated against different pests such as *H. armigera* (Karimi *et al*., 2012), *Plutella xyostella* (L.) (Soufbaf *et al.*, 2010), and *Spodoptera exigua* (Hübner) (Goodarzi *et al.*, 2015) using life table parameters, but they did not use the nutritional indices for this purpose. Taking the resistance level of a genotype to different herbivores into consideration would be important in an Integrated Crop Management (ICM) program because a crop might be attacked by different pests simultaneously. Some similarities and dissimilarities were observed between the results of genotype evaluation in the current study and the above-mentioned studies. Regarding the genotype evaluation using nutritional indices (current study) and life table parameters (Karimi *et al*., 2012), it was revealed that Zarfam was the most susceptible and Sarigol was the most resistance genotype to *H. armigera*, but regarding the genotype of Talaye, the results were not in line. Such similarities and dissimilarities might be found in comparing the results of the current study and those reported for *P. xylostella* and *S. exigua* (Soufbaf *et al.*, 2010; Goodarzi *et al.*, 2015). The main reason of dissimilarities of the results of genotype evaluation against the same pest using nutritional indices and life table parameters might be due to the method of evaluation. Such dissimilarities have been shown in genotype evaluation against *S. exigua* using life table parameters (Goodarzi *et al.*, 2015) and nutritional indices (Pourghasem, 2011).

Our study showed that Talaye was more nutritious and Okapi was less nutritious canola genotype for the larvae of *H. armigera*. It may be due to differences in plant quality such as the level of secondary metabolites in these host plants acting as antibiotic agents or absence of primary essential nutrients for growth of the insect. It is known that an insect diet can profoundly affect its survival and reproduction and that plant-feeding insects are dependent on the quantity and quality of nutrients in their host plants. The use of resistant and partially resistant cultivars can improve the efficiency of biological and chemical control methods in an IPM strategy (van Steenis and El-Khawass, 1995). Consequently, our findings may provide important information for comparison of *H. armigera* performance on different canola genotypes.

ACKNOWLEDGEMENTS

The support of this research by the Department of Entomology, Tarbiat Modares University, is greatly appreciated. The authors are grateful to Dr. Bahram Naseri and Dr. Amin Sedaratian for their assistance.

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تغییر در شاخص های غذایی *Helicoverpa armigera* (Lepidoptera: Noctuidae) با تغذیه از ژنوتیپ های مختلف کلزا

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چکیده

در این پژوهش، شاخص های تغذیه ای (غذایی) سنین مختلف لاروی *Helicoverpa armigera* (Hübner) روی ۱۰ ژنوتیپ کلزا (Talaye, Opera, Licord, Modena, SLM_{046}, $Hayula_{420}$, Zarfam, Okapi, RGS_{003}, Sarigol) در دمای ۱±۲۵ درجه سلسیوس، رطوبت نسبی ۵±۶۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی تعیین شد. بیشترین بازدهی تبدیل غذای بلعیده شده (ECI) و بازدهی تبدیل غذای هضم شده (ECD) در سن سوم لاروی با تغذیه

از ژنوتیپ Talaye مشاهده شد (به ترتیب ۰/۶۳۲±۷/۰۰۵ و ۱/۸۶۲±۸/۹۷۲). کمترین میزان ECI و ECDاین سن لاروی نیز روی ژنوتیپ Licord به دست آمد (به ترتیب ۰/۰۱۷±۰/۵۰۳ و ۰/۴۴۹±۲/۵۰۷). بیشترین (۰/۰۹۱±۰/۷۷۸) و کمترین (۰/۰۵۹±۰/۵۹۴) نرخ رشد نسبی (RGR) سن چهارم لاروی به ترتیب در ژنوتیپ های SLM_{046} و Sarigol تعیین شد. نتایج نشان داد که بیشترین مقدار ECI و ECD سن چهارم لاروی روی ژنوتیپ Talaye می باشد (به ترتیب ۰/۵۸۵±۶/۳۰۰ و ۱/۹۵۴±۸/۸۸۰). کمترین نرخ مصرف نسبی (RCR) و شاخص هضم شوندگی تقریبی (AD) سن پنجم لاروی روی ژنوتیپ Modena به دست آمد (به ترتیب ۰/۶۲۹±۵/۱۹۳ و ۱۱/۳۴۰±۳۸/۶۲۵). شاخص های ECI و ECDسن پنجم لاروی روی ژنوتیپ Talaye بیشترین مقدار خود را داشتند (به ترتیب ۰/۸۸۹±۹/۸۹۳ و ۰/۹۶۶±۱۹/۶۵۵). بیشترین مقدار RCR و AD سن ششم لاروی روی ژنوتیپ Okapi مشاهده شد (به ترتیب ۰/۶۶۵±۷/۷۸۱ و ۱/۹۲۲±۸۲/۲۲۳). در میان تمام ژنوتیپ های مختلف کلزا، بیشترین مقدار ECI و ECD کل دوره لاروی (به ترتیب ۰/۳۱۰±۱۲/۳۲۳ و ۵/۵۰۸±۳۲/۳۵۷) روی ژنوتیپ Talaye و کمترین مقادیر آن ها (به ترتیب ۰/۲۵۷±۵/۹۴۷ و ۰/۳۲۰±۶/۹۲۲) روی ژنوتیپ Okapi به دست آمد. در کل می توان چنین نتیجه گرفت که Talaye مناسب ترین و Okapi نامناسب ترین ژنونیپ برای رشد و نمو لاروهای *H. armigera* می باشند.

[DOR: 20.1001.1.16807073.2018.20.1.10.2]