JOURNAL OF ENTOMOLOGICAL SOCIETY OF IRAN
2018, 37(4), SUPPLEMENTARY, 493–506
نامه انجمن حشره‌شناسی ایران ۵۰۶- ۴۹۳ ضمیمه ,(۴)۳۷, ۱۳۹۶

DOI: 10.22117/jesi.2018.115701.1144

SPECIAL ISSUE: PROCEEDINGS OF THE 2ND IRANIAN INTERNATIONAL CONGRESS OF ENTOMOLOGY

Nutritional indices and food utilization of tomato fruit worm, *Helicoverpa armigera* (Hubner, 1808) (Lepidoptera: Noctuidae) on ten tomato cultivars

Ali Jooyandeh[1], Naser Moeini-Naghadeh[1], Hassan Ali Vahedi[1] & Ali Hosseini Gharalari[2]
1-Department of Plant Protection, Campus of Agriculture & Natural Resources, Razi University, Kermanshah, Iran & 2- Agricultural Entomology Research Department, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran
*Corresponding author, E-mail: moeeny@razi.ac.ir

Abstract
Nutritional performance of the larval stages (fourth, fifth, and sixth instars) of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on unripe green fruit of ten tomato cultivars, including 'Aras', 'Atrak', 'Korall', 'Mobil', 'Rio Grande Hed', 'Sivand', 'Super Chief', 'Super Mobil', 'Super Queen' and 'Super Urbana', was studied at 26±1°C, 60±10% RH and a photoperiod of 16:8 L:D. Approximate digestibility values of the fourth instar larvae were highest (98.239±0.026%) and lowest (95.733±0.056%) on 'Atrak' and 'Super Chief', respectively. Fifth instar larvae fed on 'Mobil' showed the highest relative growth rate (RGR) and relative consumption rate (RCR) (0.316±0.038% and 7.369±0.669%, respectively). Approximate digestibility (AD) values of the sixth instar larvae were highest (96.264±0.114%) and lowest (92.349±0.120%) on 'Super Chief' and 'Super Queen', respectively. The highest ECI and ECD values of total larval instars (4^{th}, 5^{th} and 6^{th} instars) was observed on 'Rio Grande Hed' (4.364±0.093% and 4.593±0.105%, respectively) and the lowest of both values was on 'Super Urbana' (3.034±0.021% and 3.187±0.022%, respectively). The results of nutritional indices and the cluster analysis indicated that 'Sivand' and 'Super Queen' were unsuitable hosts for feeding of *H. armigera* among tested cultivars.
Key words: nutritional indices, tomato fruit borer, *Helicoverpa armigera*, tomato cultivars

بررسی شاخص‌های تغذیه‌ای کرم میوه گوجه‌فرنگی Helicoverpa armigera (Hubner, 1808) (Lepidoptera: Noctuidae) روی ده رقم گوجه‌فرنگی

علی جوینده[۱]، ناصر معینی‌نقده[۱]، حسنعلی واحدی[۱] و علی حسینی‌قرالری[۲]
۱- گروه گیاه پزشکی، پردیس کشاورزی و منابع طبیعی، دانشگاه رازی کرمانشاه و ۲- بخش تحقیقات حشره‌شناسی کشاورزی، موسسه تحقیقات گیاه‌پزشکی کشور، سازمان تحقیقات، آموزش و ترویج کشاورزی
* مسئول مکاتبات، پست الکترونیکی:moeeny@razi.ac.ir

چکیده
عملکرد تغذیه‌ای لارو *Helicoverpa armigera* (Hübner) (مراحل لاروی چهارم، پنجم و ششم) با تغذیه از میوه سبز نارس ارقـام مختلـف گوجه فرنگی (ارس، اترک، کورال، ریوگراند، موبیل، سیوند، سوپر موبیل، سوپر چف، سوپر کوییین و سوپر اوربانا) تحت شرایط آزمایشگاهی دمای ۱±۲۶ درجه سلسیوس، رطوبت نسبی ۱۰±۶۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی بررسی شـد. بیـش‌ترین و کم‌تـرین مقادیر هضم شوندگی غذا (AD) در لارو سن چهارم به ترتیب روی ارقام اترک (۰/۰۲۶ ± ۹۸/۲۳۹ درصد) و سوپرچف (۰/۰۵۶ ± ۹۵/۷۳۳ درصد) بود. بیش‌ترین مقـادیر نرخ رشد نسبی (RGR) و نـرخ مـصرف نسبی (RCR) لارو سن پنجم در رقم موبیل به ترتیب با ۰/۰۳۸± ۰/۳۱۶ و ۰/۶۶۹ ± ۷/۳۶۹ میلی‌گرم بر میلی‌گرم بر روز ثبت شد. بیـش‌ترین مقدار هضم شوندگی غذا (AD) در لارو سن ششم با ۰/۱۱۴ ± ۹۶/۲۶۴ درصد در رقم سوپرچف و کم ترین آن در رقم سوپرکوییین به میزان ۰/۱۲۰ ± ۹۲/۳۴۹ درصد برآورد گردید. بالاترین مقدار بازدهی تبدیل غذای بلعیده شده (ECI) و بازدهی تبدیل غذای هضم شده (ECD) مجموع سنین لاروی

Received: 2 November 2017, *Accepted:* 28 January 2018
Subject Editor: Masood Amir-Maafi

مربوط به رقم ریوگرند هد (به ترتیب با ۰/۰۹۳ ± ٤/۳٦٤ و ۰/۱۰۵ ± ٤/۵۹۳ درصد) و پایین‌ترین این مقادیر در رقم سوپر اوربانا (به ترتیب با ۰/۰۲۱ ± ۳/۰۳٤ و ۰/۰۲۲ ± ۳/۱۸۷ درصد) مشاهده شد. نتایج شاخص‌های تغذیه‌ای و تجزیه خوشه‌ای مشخص کرد که در بین ارقام مورد آزمایش، ارقام سیوند و سوپرکویین برای تغذیه *H. armigera* نامناسب بودند.

واژگان کلیدی: شاخص‌های تغذیه ای، کرم میوه‌گوجه‌فرنگی، Helicoverpa armigera، ارقام گوجه‌فرنگی.

دریافت: ۱۳۹٦/۷/۱۱، پذیرش: ۱۳۹٦/۱۱/۸.

Introduction

The tomato fruit worm/ cotton bollworm, *H. armigera* is one of the most important crop pests, has a wide host range and is distributed worldwide (Fitt *et al*. 1995; Liu et *al*. 2004). Over 172 species of host plants from 40 families have been recorded in Australia (Zalucki *et al*. 1994) and 181 cultivated and uncultivated plant species, distributed in 45 families in India (Manjunath *et al.* 1989). Every year, the larvae of this species cause substantial economical losses to cotton, corn, tomato, legumes, and other vegetable crops in Iran (Farid, 1986; Behdad, 1996; Fathipour & Naseri, 2011).

Chemical control programs against this pest have been complicated by its propensity to develop insecticide resistance (Ahmad, 2007). These drawbacks have increased interest in other control methods such as biological control and resistant cultivars of host plants. Host plant resistance as a vital component of IPM is important in terms of being both environmentally and economically acceptable. Therefore, as a method of controlling pest insects, host plant resistance is not only favorable to the environment, but also reduces costs for growers (Li *et al.*, 2004). Role of physio-chemical factors is important to identify a source of resistance in plants against pests (Ashfaq *et al*., 2003; Dhillon *et al*., 2005).

Survival, development, and reproduction of phytophagous insects are considerably affected by the primary and secondary chemical compositions of host plants; hence, food consumption and utilization depend on both plant quality and insect nutritional performance (Scriber & Slansky 1981; Singh & Mullick 1997). The factors determining nutrient availability for growth and maintenance over a given period of development are the amount and type of food consumed and the efficiency with which is utilized (Barton-Browne & Raubenheimer, 2003). On the other hand, temperature and food quality play main roles in mediating the foraging behaviour, growth and reproductive performance, and population dynamics of herbivorous insects (Lindroth *et al*., 1997). Like other insect orders, the balance of nutrients in many lepidopterans is important. Lepidopteran respond to unsuitable diets in diverse ways, such as altering the amount of ingested food, switching from one food source to another, and/or regulating the efficiency of the nutrients (Genc, 2006).

Some studies have been carried out on the effects of different host plants such as soybeans (Naseri *et al*., 2010; Fathipour *et al*., 2013), tomatoes (Srinivasan & Uthamasamy, 2005; Kouhi *et al*., 2014), beans (Rahimi Namin *et al*., 2014) and corns

(Hosseininejad, 2015) on feeding performance of *H. armigera*. Ashfaq *et al*. (2003) studied the morpho–physical factors affecting consumption and coefficient of utilization of *H. armigera* and demonstrated that preference was highest on sorghum than on the other hosts. Naseri *et al*. (2010) reared *H. armigera* on different soybean varieties. They found that 'M4', 'Sahar', and 'JK' were partially resistant to *H. armigera*. According to Kouhi *et al.* (2014), ‘Rio Grande UG’ was an unsuitable tomato cultivar for *H. armigera.*

Different tomato cultivars can exert diverse negative influences, including reduced growth rates and decreased efficiency in converting food to biomass (Kashyap & Verma, 1987).The objectives of this research was to compare nutritional indices and food utilization in *H. armigera* larvae reared on the most popular tomato cultivars that are cultivated in Khorasan Razavi province, Iran. Determining effects of different host plant cultivars on the feeding performance of this pest is one of the useful tools for evaluating the host plant resistance mechanisms that could improve *H. armigera* management programs.

Materials and methods

Plant sources

Ten tomato cultivars were used in this study, including Aras’, ‘Atrak’, ‘Korall’, ‘Mobil’, ‘Rio Grande Hed’, ‘Sivand’, ‘Super Chief’, ‘Super Mobil’, ‘Super Queen’ and ‘Super Urbana’ because they are the most important popular cultivars used in Khorasan Razavi province. The tomato seeds were sown in plastic pots of 16 cm diameter (sand, soil and farm yard manure at 1:1:1 ratio). All plant materials used in this experiment were collected from plants growing in the greenhouse without any pesticides. These plants were fertilized with a controlled release fertilizer and watered as required. N-P-K fertilizer (20-20-20) (1gr/L) was sprayed on the leaves once a week.

Insect rearing

Originally, *H.armigera* larvae were collected from tomato fields located in research station of agricultural and natural resources research and education center of Khorasan Razavi province, Mashhad, Iran, during July 2016. The insects were reared for two generations on the same cultivars before tests. They were fed during experiments in a growth chamber at 26 ± 1°C, 60 ± 10% RH, with a 16:8 L: D photoperiod. Adults were provided daily with 10 % honey solution on a cotton wick for feeding in containers (14 cm in diameter, 19 cm in height, lined with paper towel) topped with a fine mesh net for ventilation.

Nutritional indices

The insects tested on different tomato cultivars had already been reared for two generations on the same cultivars they were fed during experiments.

A cohort of one hundred newly hatched larvae (< 1 days old) were collected from the stock culture and transferred into clear plastic containers (17 cm length × 12 cm width × 7 cm height), containing the fresh leaves of each examined cultivar. The petioles of detached leaves were inserted in water-soaked cotton to keep it turgid. The first and second instars larvae were reared in groups until they reached the third instar, after which they were divided into five replicates (10 larvae in each) separated into individual plastic containers (8.5 cm length × 7 cm width × 4 cm height) to avoid larval cannibalism. The individual larvae were observed daily for molting and survivorship. When ever any of the test larvae died, a larva from the stock culture of related tomato cultivar was added to replaced it so the number of larvae in each replication remained the same (50 larva in each stage). After measuring the weight of the young fourth instar larvae, they were fed on the unripe and sliced green fruits of the related tomato cultivars, and larval weight was recorded daily before and after feeding until larvae reached the pre-pupal stage. The initial fresh fruits and the fruits and feces remaining at the end of each experiment were weighed daily with a digital weighing scale (0.001 gram precision). Nutritional indices were determined on the fresh weight basis using fourth to sixth instars, because they are the most destructive stages on tomatoes and which were easier for measuring these indices.

The weight of eaten food was determined by the difference between the weight of newly offered food and the fruit over found the next day. Larval weight gain was measured as difference between final larval weight and weight at the beginning of each larval instar. The quantity of food ingested was calculated as subtracting the fruit remaining at the end of each experiment from the total weight of fruit provided. The weight of feces produced by the larvae fed on each tomato cultivar was recorded daily. Nutritional indices (Cl, AD, ECI, ECD, RGR, RCR) were calculated according to a gravimetric method as outlined by Waldbauer (1968) and Slansky & Scriber (1985) using wet weights of each component. The following formulae were used (Waldbauer, 1968):

(1) Consumption index (CI) = E/A
(2) Approximate digestibility (AD) = (E – F)/E
(3) Efficiency of conversion of ingested food (ECI) = P/E
(4) Efficiency of conversion of digested food (ECD) = P/ (E – F)
(5) Relative consumption rate (RCR) = E/ (A×T)
(6) Relative growth rate (RGR) = P/ (A×T)

In which, A= mean wet weight of larvae over unit time, E= wet weight of food consumed, F = wet weight of feces produced, P = wet weight gain of larvae, and T= duration of feeding period.

Statistical analysis

Data normality of the data was tested via the Kolmogorov-Smirnov test. Data were analyzed by one-way analysis of variance (ANOVA) followed by comparison of the means with Tukey's HSD test at α=0.05 using statistical software SAS 9.1 (PROC GLM, SAS Institute). A dendrogram of ten tomato cultivars according to nutritional indices of fourth, fifth and sixth instars of *H. armigera* was created after cluster analysis with Ward's method SPSS 19.0 (Fallahnejad-Mojarrad *et al*., 2013).

Results

The results of the nutritional indices of fourth- sixth larval instars and whole instars larvae on fresh weight basis of *H. armigera* reared on different tomato cultivars are shown in Tables 1-4.

Nutritional indices of the fourth instar larvae of *H.armigera* were significantly different for different tomato cultivars. The larvae reared on 'Super Chief' and 'Aras' showed the highest (0.399±0.012mg/mg/day) and lowest (0.336 ± 0.003 mg/mg/day) value of RGR (*F*=5.74, *df*= 9, *P*<0.0001) respectively. The lowest value of RCR was on 'Super Urbana' (5.297 ± 0.153 mg/mg/day) and the highest was on 'Aras' (10.157 ± 0.051 mg/mg/day) (*F*=73.89, *df*= 9, *P*<0.0001). Also, the highest value of ECI (*F*=71.65, *df*= 9, *P*<0.0001) was on 'Super Queen' (6.688 ± 0.116%) compared with the other cultivars. The larvae reared on 'Super Queen' had the highest value of ECD (6.926 ± 0.127%) and the lowest value was on 'Aras' (3.404 ± 0.035%) (*F*=74.77, *df*= 9, *P*<0.0001). The highest and lowest values of AD (*F*=13.07, *df*= 9, *P*<0.0001) were on 'Atrak' and 'Super Chief' (98.239 ± 0.026% and 95.733 ± 0.056, respectively). However, the lowest and highest values of CI were on 'Super Urbana' (19.180 ± 0.238) and 'Aras' (35.961 ± 0.141) (*F*=85.147, *df*= 9, *P*<0.0001) (Table 1).

Table 1- Nutritional indices of fourth instar larvae of *H.armigera* on tomato cultivars.

Cultivar	Index (mean ±SE)					
	RGR (mg/mg/day)	RCR (mg/mg/day)	ECI%	ECD%	AD%	CI
Aras	0.336 ±0.003^{d}	10.157 ±0.051^{a}	3.322 ±0.036^{e}	3.404 ±0.035^{d}	97.634 ±0.075^{ab}	35.961 ±0.141^{a}
Atrak	0.357 ±0.003^{bcd}	10.000 ±0.118^{a}	3.579 ±0.034^{de}	3.643 ±0.035^{d}	98.239 ±0.026^{a}	35.018 ±0.268^{ab}
Korall	0.370 ±0.007^{abcd}	7.720 ±0.161^{b}	4.814 ±0.047^{c}	4.995 ±0.055^{c}	96.384 ±0.444^{c}	27.687 ±0.369^{c}
Mobil	0.352 ±0.010^{bcd}	5.879 ±0.209^{c}	6.012 ±0.13^{ab}	6.244 ±0.145^{ab}	96.322 ±0.466^{c}	20.006 ±0.728^{e}
Rio Grande Hed	0.357 ±0.007^{bcd}	5.911 ±0.560^{c}	6.185 ±0.385^{a}	6.339 ±0.390^{ab}	97.573 ±0.102^{ab}	19.866 ±2.004^{e}
Sivand	0.382 ±0.005^{abc}	9.443 ±0.141^{a}	4.048 ±0.020^{d}	4.138 ±0.020^{d}	97.855 ±0.021^{a}	32.051 ±0.382^{b}
Super Chief	0.399 ±0.012^{a}	7.325 ±0.256^{b}	5.465 ±0.065^{bc}	5.711 ±0.071^{bc}	95.733 ±0.056^{c}	24.077 ±0.249^{d}
Super Mobil	0.361 ±0.012^{abcd}	5.638 ±0.140^{c}	6.452 ±0.163^{a}	6.677 ±0.161^{a}	96.670 ±0.188^{bc}	20.197 ±0.392^{e}
Super Queen	0.385 ±0.005^{ab}	5.814 ±0.109^{c}	6.688 ±0.116^{a}	6.926 ±0.127^{a}	96.593 ±0.129^{bc}	19.781 ±0.431^{e}
Super Urbana	0.343 ±0.011^{cd}	5.297 ±0.153^{c}	6.501 ±0.107^{a}	6.759 ±0.124^{a}	96.240 ±0.209^{c}	19.180 ±0.238^{e}

The means followed by different letters in the same columns are significantly different (Tukey's HSD, $P < 0.05$). CI, consumption index; AD, approximate digestibility; ECI, efficiency of conversion of ingested food; ECD, efficiency of conversion of digested food; RCR, relative consumption rate; RGR, relative growth rate

The highest (0.316 ± 0.038) and lowest (0.174 ± 0.016) RGR values (F=10.12, df= 9, P<0.0001) of the fifth instar larvae of *H.armigera* were on Mobil' and 'Super Queen', respectively. The 'Mobil' and 'Rio Grande Hed' showed the highest and lowest values of RCR (F=10.88, df= 9, P<0.0001) (7.37 ± 0.669 and 4.55 ± 0.143), respectively. The highest (5.97±0.030%) and lowest (3.08 ± 0.039%) ECI values (F=194.70, df= 9, P<0.0001) were on 'Rio Grande Hed' and 'Super Queen', respectively. The highest value of ECD (F=207.12, df= 9, P<0.0001) was recorded on 'Super Mobil' (6.21 ± 0.032%), which is the lowest rate on 'Super Queen' (3.12 ± 0.041%). The approximate digestibility (AD) was varied (F=320.76, df= 9, P<0.0001) from (94.79 ± 0.097%) to (98.66 ± 0.088%) on 'Super Mobil' and 'Super Queen', respectively. However, the larvae reared on 'Mobil' and 'Rio Grande Hed' showed the highest (27.35 ± 2.110) and lowest (17.35 ± 0.075) value of CI (F=19.70, df= 9, P<0.0001) respectively (Table 2).

Table 2- Nutritional indices of fifth instar larvae of *H.armigera* on tomato cultivars.

Cultivar	Index (mean ±SE)					
	RGR (mg/mg/day)	RCR (mg/mg/day)	ECI%	ECD%	AD%	CI
Aras	0.247 ±0.006^{bc}	6.472 ±0.179^{abc}	3.822 ±.0.038^{d}	3.898 ±0.041^{e}	98.058 ±0.054^{b}	24.889 ±0.273^{ab}
Atrak	0.264 ±0.005^{abc}	6.557 ±0.168^{ab}	4.036 ±0.030^{cd}	4.133 ±0.041^{de}	97.672 ±0.031^{b}	25.384 ±0.195^{ab}
Korall	0.262 ±0.007^{abc}	5.311 ±0.140^{cde}	4.944 ±0.022^{b}	5.306 ±0.022^{b}	93.174 ±0.057^{f}	20.253 ±0.138^{def}
Mobil	0.316 ±0.038^{a}	7.369 ±0.669^{a}	4.247 ±0.157^{c}	4.388 ±0.164^{cd}	96.801 ±0.123^{c}	27.348 ±2.110^{a}
Rio Grande Hed	0.272 ±0.010^{ab}	4.550 ±0.143^{e}	5.975 ±0.030^{a}	6.115 ±0.032^{a}	97.708 ±0.057^{b}	17.353 ±0.075^{f}
Sivand	0.269 ±0.007^{ab}	6.243 ±0.174^{abc}	4.291 ±0.076^{c}	4.493 ±0.076^{c}	95.524 ±0.207^{d}	23.381 ±0.469^{bcd}
Super Chief	0.301 ±0.005^{ab}	6.107 ±0.114^{bcd}	4.956 ±0.060^{b}	5.214 ±0.066^{b}	95.111 ±0.074^{de}	21.025 ±0.500^{cde}
Super Mobil	0.287 ±0.090^{ab}	4.905 ±0.173^{de}	5.888 ±0.105^{a}	6.213 ±0.109^{a}	94.792 ±0.097^{e}	18.435 ±0.388^{ef}
Super Queen	0.174 ±0.016^{d}	5.714 ±0.093^{bcde}	3.079 ±0.039^{e}	3.121 ±0.041^{f}	98.660 ±0.088^{a}	24.590 ±0.192^{ab}
Super Urbana	0.200 ±0.005^{cd}	6.374 ±0.173^{abc}	3.151 ±0.032^{e}	3.256 ±0.327^{f}	96.789 ±0.050^{c}	23.767 ±0.281^{bc}

The means followed by different letters in the same columns are significantly different (Tukey's HSD, $P < 0.05$). CI, consumption index; AD, approximate digestibility; ECI, efficiency of conversion of ingested food; ECD, efficiency of conversion of digested food; RCR, relative consumption rate; RGR, relative growth rate

The results of the nutritional indices of sixth instar *H. armigera* larvae are given in Table 3. The highest value of RGR was in the larvae fed on 'Super Chief' (0.166±0.002) and the lowest on 'Super Mobil' (0.115±0.001) (F=28.81, df= 9, P<0.0001). The larvae fed on cultivar 'Aras' and 'Korall' demonstrated the lowest (3.758±0.143) and highest (5.365±0.110)

RCR values, respectively (*F*=19.51, *df*= 9, P<0.0001). The highest value of ECI (*F*=74.01, *df*= 9, *P*<0.0001) and ECD (*F*=59.34, *df*= 9, *P*<0.0001) was on 'Aras' (3.752±0.057% and 3.946±0.060% resp.) and the lowest one was on 'Super Urbana'(2.530±0.028% and 2.683±0.032% resp.). The highest AD value (*F*=76.05, *df*= 9, *P*<0.0001) was in the larvae reared on 'Super Chief' (96.264±0.114%). The larvae reared on 'Korall' (25.386±0.225%) and 'Aras' cultivars (19.316±0.191) showed the highest and lowest values of CI (*F*=53.19, *df*= 9, *P*<0.0001) (Table 3).

Table 3- Nutritional indices of sixth instar larvae of *H.armigera* on tomato cultivars.

Cultivar	Index (mean ±SE)					
	RGR (mg/mg/day)	RCR (mg/mg/day)	ECI%	ECD%	AD%	CI
Aras	0.141 ±0.005^{bc}	3.758 ±0.143^{f}	3.752 ±0.057^{a}	3.946 ±0.060^{a}	95.093 ±0.084^{b}	19.316 ±0.191^{c}
Atrak	0.132 ±0.002^{cd}	4.140 ±0.033^{def}	3.198 ±0.035^{bc}	3.348 ±0.036^{bc}	95.516 ±0.043^{b}	22.099 ±0.178^{b}
Korall	0.142 ±0.003^{bc}	5.365 ±0.110^{a}	2.663 ±0.010^{ef}	2.863 ±0.012^{ef}	93.008 ±0.091^{e}	25.386 ±0.225^{a}
Mobil	0.151 ±0.003^{b}	4.639 ±0.111^{bcd}	3.253 ±0.041^{b}	3.451 ±0.048^{bc}	94.276 ±0.173^{c}	21.882 ±0.370^{b}
Rio Grande Hed	0.132 ±0.004^{cd}	4.060 ±0.220^{ef}	3.287 ±0.087^{b}	3.525 ±0.103^{b}	93.291 ±0.275^{de}	19.853 ±0.597^{c}
Sivand	0.124 ±0.003^{de}	4.367 ±0.094^{cde}	2.845 ±0.027^{de}	3.030 ±0.031^{de}	93.895 ±0.128^{cd}	21.499 ±0.183^{b}
Super Chief	0.166 ±0.002^{a}	5.056 ±0.066^{ab}	3.286 ±0.044^{b}	3.413 ±0.048^{bc}	96.264 ±0.114^{a}	21.632 ±0.113^{b}
Super Mobil	0.115 ±0.001^{e}	4.245 ±0.500^{cdef}	2.719 ±0.024^{ef}	2.890 ±0.027^{ef}	94.115 ±0.063^{c}	22.439 ±0.240^{b}
Super Queen	0.143 ±0.001^{bc}	4.749 ±0.034^{bc}	3.003 ±0.027^{cd}	3.252 ±0.033^{cd}	92.349 ±0.120^{f}	25.100 ±0.154^{a}
Super Urbana	0.120 ±0.002^{de}	4.760 ±0.107^{bc}	2.530 ±0.028^{f}	2.683 ±0.032^{f}	94.349 ±0.115^{c}	24.221 ±0.196^{a}

The means followed by different letters in the same columns are significantly different (Tukey's HSD, *P* < 0.05). CI, consumption index; AD, approximate digestibility; ECI, efficiency of conversion of ingested food; ECD, efficiency of conversion of digested food; RCR, relative consumption rate; RGR, relative growth rate

The results presented in Table 4 for whole larval instars showed that RGR (*F*=31.74, *df*= 9, *P*<0.0001) and RCR (*F*=22.28, *df*= 9, *P*<0.0001) values were the highest on 'Super Chief' (0.170 ± 0.003 and 4.279 ± 0.118, respectively). The lowest RGR and RCR were recorded on 'Super Queen' (0.116 ± 0.001) and 'Rio Grande Hed'(3.013 ± 0.180), respectively. However, the ECI (*F*=70.95, *df*= 9, *P*<0.0001) and ECD (*F*=65.53, *df*= 9, *P*<0.0001) values were the highest (4.364 ± 0.093% and 4.593 ± 0.105% resp.) on 'Rio Grande Hed'. The highest and lowest AD values (*F*=164.50, *df*= 9, *P*<0.0001) were recorded on 'Aras' (96.508 ± 0.063%) and 'Korall' cultivars (93.457 ± 0.018%), respectively. The highest and lowest values of CI were on 'Atrak' (51.762 ± 0.423) and 'Rio Grande Hed' (36.512 ± 1.600), respectively (*F*=46.68, *df*= 9, *P*<0.0001) (Table 4).

A dendrogram based on nutritional indices of whole larval instars of *H. armigera* reared on tomato cultivars is shown in Figure1.

Table 4- Nutritional indices of whole larval instars of *H.armigera* on tomato cultivars.

Cultivar	Index (mean ±SE)					
	RGR (mg/mg/day)	RCR (mg/mg/day)	ECI%	ECD%	AD%	CI
Aras	0.144 ±0.003[b]	3.896 ±0.102[ab]	3.709 ±0.036[cd]	3.843 ±0.038[c]	96.508 ±0.063[a]	49.268 ±0.460[ab]
Atrak	0.142 ±0.001[bc]	4.023 ±0.054[ab]	3.540 ±0.032[de]	3.662 ±0.033[cd]	96.659 ±0.030[a]	51.762 ±0.423[a]
Korall	0.131 ±0.002[cd]	3.721 ±0.050[bc]	3.523 ±0.013[de]	3.769 ±0.014[cd]	93.457 ±0.018[f]	45.674 ±0.450[cd]
Mobil	0.122 ±0.003[de]	3.153 ±0.086[d]	3.889 ±0.047[bc]	4.080 ±0,048[b]	95.306 ±0.075[c]	37.844 ±0.872[ef]
Rio Grande Hed	0.131 ±0.006[bcd]	3.013 ±0.180[d]	4.364 ±0.093[a]	4.593 ±0.105[a]	95.014 ±0.143[cd]	36.512 ±1.600[f]
Sivand	0.128 ±0.001[de]	3.662 ±0.039[bc]	3.500 ±0.026[e]	3.684 ±0.028[cd]	95.008 ±0.095[cd]	44.652 ±0.480[d]
Super Chief	0.170 ±0.003[a]	4.279 ±0.118[a]	3.989 ±0.053[b]	4.161 ±0,059[b]	95.886 ±0.092[b]	46.756 ±0.671[bcd]
Super Mobil	0.125 ±0.001[de]	3.156 ±0.055[d]	3.959 ±0.037[bc]	4.188 ±0.040[b]	94.542 ±0.035[e]	40.206 ±0.409[e]
Super Queen	0.116 ±0.001[e]	3.423 ±0.037[cd]	3.409 ±0.030[e]	3.598 ±0.032[d]	94.767 ±0.039[de]	44.780 ±0.467[d]
Super Urbana	0.118 ±0.002[de]	3.899 ±0.068[ab]	3.034 ±0.021[f]	3.187 ±0.022[e]	95.219 ±0.053[c]	48.899 ±0.335[abc]

The means followed by different letters in the same columns are significantly different (Tukey's HSD, $P < 0.05$). CI, consumption index; AD, approximate digestibility; ECI, efficiency of conversion of ingested food; ECD, efficiency of conversion of digested food; RCR, relative consumption rate; RGR, relative growth rate

The dendrogram of nutritional indices of whole larval instars of *H. armigera* showed three distinct clusters labeled A, B(including sub clusters B1 and B2) and C. The cluster A included 'Sivand', 'Super Queen' and 'Korall'. The cluster B consisted of sub clusters B1 ('Aras', 'Super urbana' and 'Super Chief') and B2 ('Atrak'). The cluster C is consisted of 'Mobil', 'Rio Grande Hed' and 'Super Mobil'.

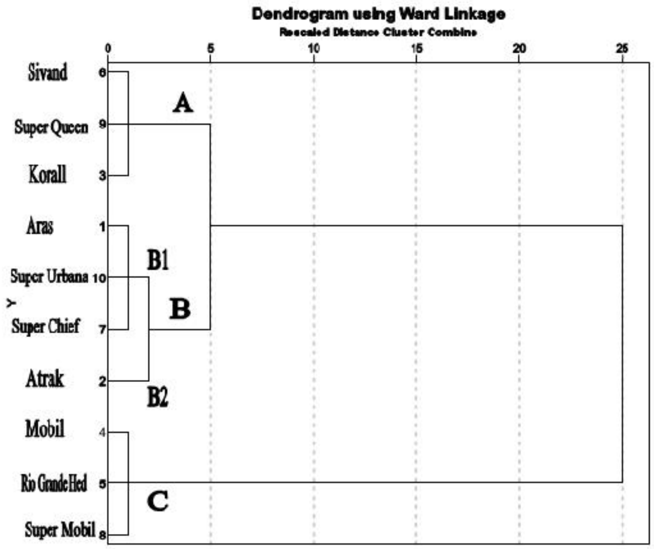

Fig. 1. Ward's method dendogram of tomato cultivars based on nutritional indices of whole larval instars (forth, fifth, sixth) of *H. armigera* reared on tomato cultivars.

Discussion

Study of insect nutrition is significant in providing critical information for economic exploitation and management of insects and clarifying the relationship of energy among the communities (Awmack & Leather, 2002; Babic *et a*l., 2008). The factors determining nutrient availability for growth and maintenance over a given period of development are the amount and type of food consumed and the efficiency with which it is utilized (Barton-Browne & Raubenheimer, 2003).

Current research shows that different tomato cultivars have significant effects on the nutritional and growth indices of *H. armigera* larvae. The significant differences obtained for these nutritional indices of *H. armigera* larvae indicated that the tested tomato cultivars had diverse nutritive values. Approximate digestibility (AD), efficiency of conversion of digested food (ECD) and efficiency of conversion of ingested food (ECI) are important parameters of nutritional responses of an insect (Parra *et al*., 2012). ECI is a general index of an insect's ability to use the food consumed for growth and development, and ECD is an index of the efficiency of conversion of digested food into growth (Nathan *et al*. 2005).

In this study, the ECI and ECD values of fourth-sixth instars and whole larval instars of *H. armigera* were significantly different on the ten tomato cultivars on fresh weight basis, which are in line with the findings of Kouhi *et al*. (2014), who noted that the ECI and ECD values of fourth-sixth instars and whole larval instars of *H. armigera* were significantly affected by different tomato cultivars on dry weight basis.

The highest CI value of the whole larval instars of *H. armigera* observed on 'Atrak', indicated that the highest rate of intake relative to the mean larval weight during the feeding period on this cultivar. Among different tomato cultivars, the highest ECI and ECD values of the whole larval instars were observed on cultivar ' Rio Grande Hed', resuming that it was more efficient at the conversion of ingested and digested food to biomass in larval body. The results for ECI and ECD values of the whole larval instars reared on 'Rio Grande Hed' were similar to those reported by Kouhi *et al.* (2014) on different tomato cultivars.

Despite larvae reared on cultivar 'Super Urbana' has high CI value compared with other cultivars; the lowest values of ECI and ECD on this cultivar, indicating that larvae feeding on it were less effective in converting ingested and digested food to biomass. It is well known that the degree of food utilization depends on the digestibility of food, and the efficiency with which digested food is converted into biomass (Batista-Pereira *et al.* 2002).

The cluster dendogram revealed that grouping different tomato cultivars within each cluster might be consequence of a high correspondence of physiological traits of tomato cultivars, whereas the separate clusters might represent significant variability in tomato cultivars and suitability between clusters. The tomato cultivars categorized in cluster C were the most suitable for *H. armigera*, while the host plant in cluster A and B had the least suitability. 'Super Urbana' that grouped in cluster B was unsuitable host plant because of nutrient deficiency and probably due to presence of some secondary metabolites. However, cluster C included suitable host plants due to the higher nutritional quality (Fig.1).

Studies on the consumption, digestion and utilization of food plants by insects are important both from fundamental and applied points of view. They provide information on the quantitative loss brought about by the pests. Cultivar selection is one of the most important decisions that the commercial grower must make each season. Selection of the appropriate cultivars that are suffered the least damage from pests and diseases are important by growers. Consumption indices can also be taken into account as indirect measurements of the relative susceptibilities of crops to pest infestation (Praveen & Dhandapani, 2001).

Analysis of the nutritional indices can provide an understanding of the behavioral and physiological bases of insect-plant interactions (Lazarevic & Peric-Mataruga, 2003). Estiarte *et al*.(1994) also reported that nitrogen limitation produced lower nutritional quality of leaves and fruits with lower relative growth rates and lower efficiency of conversion of ingested biomass on the polyphagous herbivore *H. armigera*.

Low fitness of *H. armigera* on some cultivars may be assigned to the presence of unsuitable secondary phytochemicals or the absence of essential nutrients for growth and development. Our study shows significant differences in the capacity of *H. armigera* reared on different tomato cultivars. Many researchers reported that tomato cultivars differed in terms of damage done by tomato fruit worm, *H. armigera* (Kashyap & Verma, 1987; Sivaprakasam, 1996). Among various biochemical factors of resistance in tomato cultivars/accessions, phenol content of the foliage and acidity of the fruits exerted a significant negative correlation with larval feeding (Selvanarayanan, 2005). Salvanarayanan and Narayanasamy (2006) found that ortho-dihydroxy phenols of the fruits exerted a significant negative correlation on larval feeding. On the basis of high phenol content in plants, pest resistant lines could be identified and used for breeding resistant varieties. Sharma *et al.* (2008) found that the reducing sugars were positively correlated while ascorbic acid, acidity, zinc, ferrous and total phenols were negatively correlated with fruit infestation.

Induced resistance may occur in plants because of variations in temperature, photoperiod, plant-water potential, and chemicals in the soil that induce the production and accumulation of secondary plant substances (phytoalexins) or affect the nutritional quality of the host plant (Sharma & Ortiz, 2002).

Different tomato cultivars can exert diverse negative influences, including reduced growth rates and decreased efficiency in converting food to biomass. However, among the cultivated tomato (*L. esculentum*) genotypes/cultivars, such differences are minimal (Kashyap & Verma, 1987).We found the majority of these influences in *H. armigera* larvae fed with cultivars 'Sivand ' and 'Super Queen'. Therefore, it can be concluded that these cultivars were unsuitable hosts for feeding and growth of the pest. Moreover, 'Super Mobil' and 'Rio Grande Hed' was suitable host cultivats for larval feeding.

Usman *et al*.(2015) revealed that ascorbic acid, acidity and phenol contents showed negative correlation while pH and ash content showed positive correlation with both larval population and fruit infestation. Furthermore, non significant negative correlation of moisture content was found with larval population as well as fruit infestation. They are showed that ascorbic acid played major role in contribution resistance followed by phenols, acidity while moisture had no contribution towards resistance against *H. armigera* in tomato.

For a better understanding of *H. armigera*–tomato interactions to control of this pest, more studies should be conducted to investigatie the influence of various physical and biochemical factors in relation to resistance against *H. armigera* in tomato cultivars under laboratory and field conditions.

Acknowledgments

The authors wish to thank Khorasan Razavi Agricultural and Natural Resources Researches and Education center for supporting this work.

References

Ahmad, M. (2007) Insecticide resistance mechanisms and their management in *H. armigera* (Hübner): a review. *Journal of Agricultural Research* 45(4), 319-335.

Ashfaq, M., Ahmad, K.J. & Ali, A. (2003) Morphophysical factors affecting consumption and coefficient of utilization of *Helicoverpa armigera* (Hubner). *Pakistan Journal of Applied Science* 3, 225–230.

Awmack, C.S. & Leather, S.R. (2002) Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology* 47, 817-844.

Babic, B., Poisson, A., Darwish, S., Lacasse, J., Merkx-Jacques, M., Despland, E. & Bede, J.C. (2008) Influence of dietary nutritional composition on caterpillar salivary enzyme activity. *Journal of Insect Physiology* 54(1), 286-296.

Barton-Browne, L.B. & Raubenheimer, D. (2003) Ontogenetic changes in the rate of ingestion and estimates of food consumption in fourth and fifth instar *Helicoverpa armigera* caterpillars. *Journal of Insect Physiology* 49, 63-71.

Batista-Pereira, G.L., Petacci, F., Fernandes, B.J., Correa, A.G., Vieira, P.C., Fatima da Silva, M. & Malaspina, O. (2002) Biological activity of astilbin from *Dimorphandra mollis* against *Anticarsia gemmatalis* and *Spodoptera frugiperda*. *Pest Management Science* 58, 503–507.

Behdad, E. (1996) Iranian Plant Protection Encyclopedia, Pests, Disease & Weeds. Vol. 2, pp. 1269-1273. Yadboud Press. Esfahan. [In Persian]

Dhillon, M.K., Singh, R., Naresh, J.S. and Sharma, N.K. (2005). The influence of physico-chemical traits of bitter gourd, *Momordica charantia* L. on larval density and resistance to melon fruit fly, *Bactrocera cucurbitae* (Coquillett). *Journal of Applied Entomology* 129, 393-399.

Estiarte, M., Filella, I., Serra, J. & Peñuelas, J. (1994) Effects of nutrient and water stress on leaf phenolic content of peppers and susceptibility to generalist herbivore *Helicoverpa armigera* (Hubner). *Oecologia* 99(3-4), 387-391.

Fallahnejad-Mojarrad, N., Fathipour, Y., Kamali ,K. & Naseri, B. (2013) The effect of seeds of different chickpea and cowpea cultivars on digestive proteolytic activity of *Helicoverpa armigera* (Lep.: Noctuidae). *Journal of Entomological Society of Iran* 32(2), 1-16. (In Persian with English summary).

Farid, A. (1986) Study of bollworm *Heliothis armigera* (Hub.) on tomato in Jyroft and Kahnuj. *Applied Entomology and Phytopathology* 54, 15–24. [In Persian]

Fathipour, Y. & Naseri, B. (2011) Soybean Cultivars Affecting Performance of *Helicoverpa armigera* (Lepidoptera: Noctuidae). pp. 599-630. In: Tzi-Bun Ng (ed.) *Soybean - Biochemistry, Chemistry and Physiology*. ISBN: 978-953-307-219-7, InTech, DOI: 10.5772/14838. Available from: www.intechopen.com/books/soybean-biochemistry-chemistry-and-physiology/soybean-cultivars-affecting-performance-of-helicoverpa-armigera-lepidoptera-noctuidae-(accessed 2 July 2015).

Fathipour, Y. & Sedaratian, A. (2013) Integrated management of *Helicoverpa armigera* in soybean cropping systems, pp 231–280. In: El-Shemy H (ed) *Soybean-Pest Resistance*. InTech, Rijeka.

Fitt, G.P. (1989) The ecology of *Heliothis* species in relation to agroecosystem. *Annual Review of Entomology* 34, 17–52.

Genc, H. (2006) General principles of insect nutritional ecology. *Trakya University Journal of Science* 7, 53–57.

Hosseininejad, A. S., Naseri, B. & J. Razmjou, J. (2015) Comparative Feeding Performance and Digestive Physiology of *Helicoverpa armigera* (Lepidoptera: Noctuidae) Larvae-Fed 11 Corn Hybrids. *Journal of Insect Science* 15(12), 1-6.

Kashyap, R.K. & Verma, A.N. (1987) Factors imparting resistance to fruit damage by *Heliothis armigera* (Hiibner) in some tomato phenotypes. *Insect Science and Application* 8, 111-114.

Kouhi, D., Naseri, B. & Golizadeh A. (2014) Nutritional performance of the tomato fruit borer, *Helicoverpa armigera*, on different tomato cultivars. *Journal of Insect Science*, 14(102). Available from: http://www.bioone.org/doi/pdf/10.1673/031.014.102 (accessed 12 August 2016).

Lazarevic, J. & Peric-Mataruga, V. (2003) Nutritive stress effects on growth and digestive physiology of *Lymantria dispar* larvae. *Yugoslav Medical Biochemistry* 22, 53-59.

Li, Y., Hill, C.B. & Hartman G.L. (2004) Effect of three resistant soybean genotypes on the fecundity, mortality and maturation of soybean aphid (Homoptera, Aphididae). *Journal of Economic Entomology* 97, 1106–1111.

Lindroth, R.L., Klein, K.A., Hemming, J.D.C. & Feuker, A.M. (1997) Variation in temperature and dietary nitrogen affect performance of the gypsy moth (*Lymantria dispar* L.). *Physiological Entomology* 22, 55-64.

Liu, Z., Li, D., Gong, P.Y. & Wu, K.J. (2004) Life table studies of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera, Noctuidae), on different host plants. *Environmental Entomology* 33, 1570–1576.

Manjunath, T.M., Bhatnagar, V.S., Pawar, C.S. & Sithanantham, S. (1989) Economic importance of *Heliothis* spp. in India and an assessment of their natural enemies and host plants, pp. 197–228 In: *Proceedings of the workshop on biological control of Heliothis: increasing the effectiveness of natural enemies*. New Delhi, India.

Naseri, B., Fathipour, Y., Moharramipour, S. & Hosseininaveh, V. (2010) Nutritional indices of the cotton bollworm, *Helicoverpa armigera*, on 13 soybean varieties. *Journal of Insect Science* 10, 1–14.

Nathan, S.S., Chung, P.G. & Murugan, K. (2005) Effect of biopesticides applied separately or together on nutritional indices of the rice leafolder *Cnaphalocrocis medinalis*. *Phytoparasitica* 33, 187–195.

Parra, J.R.P., Panizzi, A.R., Marinéia L. & Haddad, M.L. (2012) Nutritional Indices for Measuring Insect Food Intake and Utilization. pp. 13-49 In Panizzi, A.R. & Parra, J.R.P. (Eds.) *Insect Bioecology and Nutrition for Integrated Pest Management*. CRC Press, Boca Raton, FL, USA.

Praveen, P. M. & Dhandapani N. (2001) Consumption, digestion and utilization of biopesticides treated tomato fruits by *Helicoverpa armigera* (Hubner). *Journal of BioIogical Control* 15(1), 59-62.

Rahimi Namin, F., Naseri, B. & Razmjou, J. (2014) Nutritional performance and activity of some digestive enzymes of the cotton bollworm, *Helicoverpa armigera*: response to bean cultivars. *Journal of Insect Science* 14(93), 1-18.

Scriber, J.M. & Slansky, F. (1981) The nutritional ecology of immature insects. *Annual Review of Entomology* 26, 183-211.

Schultz JC (1988) Many factors influence the evolution of herbivore diets, but plant chemistry is central. *Ecology* 69, 896-897.

Selvanarayanan, V. & Muthukumaran, **N.** (2005) Insect resistance in tomato accessions and their hybrid derivatives in Tamil Nadu, India. *Communications in agricultural and applied biological sciences* 70(4), 613-624.

Selvanarayanan, V. & Narayanasamy, P. (2006) Factors of resistance in tomato accessions against the fruit worm, *Helicoverpa armigera* (Hubner). *Crop Protection* 25, 1075–1079.

Sharma, H.C. & Ortiz, R. (2002) Host plant resistance to insects : An eco-friendly approach for pest management and environment conservation. *Journal of Environmental Biology* 23(2), 111-135.

Singh, A.K. & Mullick, S. (1997) Effect of leguminous plants on the growth and development of gram pod borer, *Helicoverpa armigera*. *Indian Journal of Entomology* 59, 209-214.

Sivaprakasam, N. (1996) Influence of trichomes on resistance to fruit borer, *Helicoverpa armigera* (Hubner). *Madras Agricultural Journal* 83, 474-475.

Slansky, F.J. & Scriber, J.M. (1985) Food consumption and utilization. pp. 87-163 In: Kerkut, G.A., Gilbert, L.I.(Eds.). *Comprehensive Insect Physiology, Biochemistry, and Pharmacology*, volume 4. Pergamon Press.

Srinivasan, R. & Uthamasamy, S. (2005) Studies to Elucidate antibiosis Resistance in Selected Tomato Accessions against fruirworm, *Heticoverpa armigera* Hubncr (Lcpidoptcra: Noctuidae). *Resistant Pest Management Newsletter* 14(2), 24-26.

Usman, A., Khan, I.A. Shah, M., Sohail, K. & Said, F. (2012) Influence of various biochemical factors on the occurrence of *Helicoverpa armigera* (Hubner) in Tomato. *Journal of Entomology and Zoology Studies* 3(3), 53-58

Waldbauer, G.P. (1968) The consumption and utilization of food by insects. *Advances in Insect Physiology* 5, 229–288.

Zalucki, M.P., Murray, D.A.H., Gregg, P.C., Fitt, G.P., Twine, P.H., & Jones, C. (1994) Ecology of *Helicoverpa armigera* (Hübner) and *H. punctigera* (Wallengren) in the inland of Australia: larval sampling and host plant relationships during winter and spring. *Australian Journal of Zoology* 42(3), 329-346.