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Effect of different tomato cultivars on some biological characteristics of *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) under lab conditions

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Abstract

Development, body weight and reproduction of the tomato fruit worm, *Helicoverpa armigera* (Hübner), were studied at $26 \pm 1^\circ\text{C}$; $60 \pm 10\%$ RH and a light: dark cycle of 16:8 h on ten tomato cultivars: 'Aras', 'Atrak', 'Korall', 'Mobil', 'Rio Grande Hed', 'Sivand', 'Super Chief', 'Super Mobil', 'Super Queen' and 'Super Urbana' in the laboratory. The shortest larval duration was recorded on 'Super Chief' (18.98 ± 0.94 days) while the longest was seen on 'Super Queen' (22.07 ± 0.32 days). The developmental time of immature stages ranged from 37.62 ± 0.24 days on 'Super Chief' to 42.69 ± 0.48 days on 'Super Queen'. Pupal period ranged from 11.60 ± 0.32 days to 13.19 ± 0.15 days on 'Aras' and 'Super Queen', respectively. Maximum pupal weight was 323.67 ± 4.56 mg on 'Aras' and was minimum on 'Super Queen' (200.83 ± 3.03 mg). The maximum and minimum female longevity was observed on 'Atrak' (14.78 ± 0.39 days) and 'Super Queen' (12.77 ± 0.86 days), respectively. The life time of males ranged from 7.20 ± 0.20 days on 'Super Mobil' to 9.22 ± 0.17 days on 'Mobil'. The mean number of eggs deposited on different cultivars varied with 360.25 ± 21.15 eggs on 'Korall' in 8.83 ± 0.43 days and 160.68 ± 22.37 eggs on 'Super Queen' in 8.35 ± 0.44 days. It could be concluded that 'Korall', followed by 'Aras' and 'Super Chief' were suitable and 'Super Queen' and 'Super Urbana' were unsuitable cultivars for growth and development of *H. armigera* larvae.

Key words: Development period, body weight, fecundity, tomato fruit worm, tomato

بررسی اثر ارقام گوجه‌فرنگی بر برخی از ویژگی‌های زیستی کرم میوه گوجه‌فرنگی *Helicoverpa*

***armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) در شرایط آزمایشگاهی**

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چکیده

طول دوره رشد، وزن بدن و باروری کرم میوه گوجه‌فرنگی، *Helicoverpa armigera* (Hübner)، در شرایط آزمایشگاهی و در شرایط دمایی $26 \pm 1^\circ\text{C}$ ، رطوبت نسبی $60 \pm 10\%$ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی روی ده رقم گوجه‌فرنگی (ارس، اترک، کورال، موبیل، ریوگرند هد، سیوند، سوپرچف، سوپر موبیل، سوپر کوین و سوپر اوربانا) مورد بررسی قرار گرفت. کوتاه‌ترین میانگین طول دوره لاروی روی رقم سوپرچف (18.98 ± 0.94 روز) و طولانی‌ترین آن در رقم سوپرکوین (22.07 ± 0.32 روز) به دست آمد. میانگین طول دوره رشدی مراحل نابالغ از 37.62 ± 0.24 روز در رقم سوپرچف تا 42.69 ± 0.48 روز در رقم سوپرکوین ثبت گردید. میانگین طول دوره شفیرگی از 7.20 ± 0.20 روز در رقم سوپر موبیل تا 9.22 ± 0.17 روز در رقم سوپرکوین متفاوت بود. بیشترین وزن شفیره در رقم ارس با 360.25 ± 21.15 تخم و کم‌ترین آن در رقم سوپرکوین با 160.68 ± 22.37 تخم حاصل شد. حداکثر و حداقل طول عمر

حشره ماده به ترتیب در ارقام اترک ($0/39 \pm 4/78$ روز) و سوپرکویین ($0/86 \pm 12/77$ روز) مشاهده گردید. همچنین دامنه طول عمر حشر نر در ارقام مختلف از $0/20 \pm 7/20$ روز در رقم سوپرموبیل تا $0/17 \pm 9/22$ روز در رقم موبیل به دست آمد. میانگین تعداد تخم گذاشته شده توسط هر فرد ماده در ارقام مختلف متفاوت بود بطوریکه بیشترین آن در رقم کورال ($21/15 \pm 360/25$ عدد) در مدت $0/43 \pm 8/83$ روز و کمترین آن در رقم سوپرکویین ($22/37 \pm 160/68$ عدد) در مدت $0/44 \pm 8/35$ روز مشاهده شد. می توان نتیجه گرفت که کورال و به دنبال آن ارس و سوپر جف ارقام مناسب و سوپر کویین و سوپر اوربانا ارقام نامناسبی برای رشد و نمو لاروهای *H. armigera* بودند.

واژگان کلیدی: طول دوره‌ی رشد، وزن بدن، باروری، کرم میوه گوجه‌فرنگی، *Helicoverpa armigera*، گوجه‌فرنگی

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Introduction

Tomato is attacked by a large number of insect pests from the seedling stage until harvest, but the tomato fruit borer *H. armigera* is one of the most important economic insect pests in Iran (Farid, 1986; Behdad, 1996; Mojani *et al.*, 2005) and in other parts of the world (Zalucki *et al.*, 1986; Fitt, 1989). The larval stage of *H. armigera* causes considerable damage by directly feeding on the fruit and by allowing soft rot disease to enter the damaged fruit and infect surrounding fruits. Polyphagy, wide geographical range, mobility, migratory potential, facultative diapause, high fecundity and ability to develop resistance against insecticides have enabled *H. armigera* to be a key pest status on major crop pests (Zalucki *et al.*, 1986; Fitt, 1989; Torres-Vila *et al.*, 2002).

This species is known as cotton bollworm, tomato fruit worm, pod borer and corn earworm has been recorded on about 181 plant species all over the world. It attacks leaves, tender shoots, apical tips, flower buds, and pods of various crop plants including several field and horticultural crops such as cotton, tomato, soybean, maize, sorghum, and beans (Zalucki *et al.*, 1986, 1994; Tamhane, 2007).

Chemical control is the main management technique to control *H. armigera* on tomato and several other crops including cotton and beans. However, application of insecticides caused many problems such as environmental pollution, harmful pesticide residues in fruits, pest resurgence, outbreak of secondary pests, and insecticide resistance (Kranthi *et al.*, 2002). It is reported that this pest has developed resistance to pyrethroids, organophosphates, organochlorines and carbamates (Torres-Vila *et al.*, 2002).

Increased resistance to insecticides in *H. armigera* has increases interest in other control methods such as behavioral control and the development of resistant genotypes (Wilson *et al.*, 1998).

Various biophysical factors in crop plants, either in the popular cultivars or the wild relatives play a major role in conferring resistance against pests and diseases. Deployment of pest-resistant cultivars, alone or in concert with other control methods, represents a safer and economical approach which can reduce the application of pesticides (Selvanarayanan & Narayanasamy, 2006).

Host plant resistance (HPR) as one of the important component of integrated pest management, can play major role in management of *H. armigera* (Liu *et al.*, 2004; Ambule *et al.*, 2015). It is economically reliable, ecologically safe and compatible with other IPM strategies (Sharma *et al.*, 1999, Li *et al.*, 2004; Nadeem *et al.*, 2010). HPR helps in developing cultivars that give stability to host plants against different insects.

Host plants have various degrees of nutritional value and this has an effect on the rate of development of *H. armigera*, and affects the population dynamics of this pest (Sharma *et al.*, 1999). Although the larvae of *H. armigera* have a considerably wide host range, the rate of larval survival and development greatly varies on different host plants (Zalucki *et al.*, 1986).

The biology of this insect has been extensively studied on different host plants around the world (Liu *et al.*, 2004; Hemati *et al.*, 2013; Razmjou *et al.*, 2014).

Liu *et al.* (2004) reported that tomato and hot pepper were unsuitable host plants for this pest. Razmjou *et al.* (2014) studied the effect of various host plants, including chickpea varieties, bean varieties, cowpea and tomato on the life table parameters of *H. armigera* and showed that tomato was an unsuitable host plant for *H. armigera*.

Resistant tomato plants show non-preference for oviposition and larval feeding by *H. armigera* (Selvanarayanan & Narayanasamy, 2004; Usman, 2012). Host plant resistance in tomato against *H. armigera* was studied by many researchers (Nemati Kalkhoran *et al.*, 2013; Kouhi *et al.*, 2014; Safuraie-Parizi *et al.*, 2014; Ambule *et al.*, 2015; Muthukumaran, 2016).

Research on life-history traits of *H. armigera* on different tomato cultivars by Safuraie-Parizi *et al.* (2014) showed that cultivar 'Petometch' was the most susceptible (suitable) and 'Imprial' was the most resistant (unsuitable) cultivar to this pest among the tomato cultivars tested.

To develop pest management strategies of *H. armigera*, information on the developmental periods of the stages of *H. armigera* is important for understanding the population dynamics in the field (Cunningham & Zalucki, 2014). The objective of this study was to evaluate the effect of feeding on the most important economic tomato cultivars grown in Khorasan Razavi province on development, body weight and fecundity of *H. armigera*. The results of present research provides new information on the biological characteristics of *H. armigera* on different tomato cultivars.

Materials and methods

Plant sources

Ten tomato cultivars as host plants were used in this study, including 'Aras', 'Atrak', 'Korall', 'Mobil', 'Rio Grande Hed', 'Sivand', 'Super Chief', 'Super Mobil', 'Super Queen' and

'Super Urbana'. These cultivars were selected because they are the most important economic cultivars grown in Khorasan Razavi province and some regions of the country.

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.

Collection and rearing of *H. armigera*

Population of *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 larvae were reared on cowpea-based artificial diet, as described by Teakle (1991) until pupation.

Development time

The colony of *H. armigera* was reared on the tomato cultivars for two generation in a growth chamber at $26 \pm 1^\circ\text{C}$, $60 \pm 10\%$ RH, and a 16:8 h L:D photoperiod prior to study. The leaves of tomato cultivars were used to feed the first to third larval instars and the green fruits were used to feed the forth to sixth larval instars.

To obtain eggs of the tomato fruit worm, 10 pairs of both sexes of the moth reared from related cultivars were kept inside each transparent egg-laying container (14 cm in diameter and 19 cm in height) closed at the top with a fine mesh net for ventilation. The internal walls of each container were covered with paper towel as ovipositional substrate. The adults were provided each day with a 10% honey solution soaked in a cotton ball.

A cohort of fifty newly hatched larvae (< 24 h old), with known egg duration (3 days), were used for the experiment. The neonate larvae were Individually transferred with a very soft, fine hair paintbrush into a plastic Petri dish (8 cm in diameter and 2 cm in height) with a hole on lid (2 cm in diameter) covered with a fine mesh net for ventilation and containing fresh leave of the related tomato cultivar treatment. To obtain freshness, the end of petioles of detached leaves was wrapped in moistened cotton. The neonates larvae were divided into ten groups (as ten cultivars). Each group was divided into five replicates (10 larvae in each). Larvae entering 4th instar were provided with unripe and sliced green fruits of the related tomato cultivars. The fruits of each tomato cultivar were replaced with new ones if necessary. The individual larvae were observed daily for molting and survivorship. The stadia of larvae were determined by checking the shed head capsules daily until the end of the larval stage. The development time of each larval instar and total pre-adult and their mortality and weight of 4th to 6th larva instars were recorded on different tomato cultivars. Sixth instar larvae were kept in plastic containers (3 cm in diameter and

5 cm in height) for pre-pupation and pupation. Pupal weight was recorded one day after pupation.

Reproductive capacity of *H. armigera*

After emergence of adult moths, they were paired and kept in pairs in an individual ovipositional cup (transparent plastic container; 8.5×12 cm, lined with paper towel) separately based on related tomato cultivar. The adults were provided each day with a 10% honey solution soaked in a cotton ball. When a female started egg laying, the insect pair was transferred to a new cup every 24 h until they died. Data regarding number of eggs laid per female, pre-oviposition, oviposition, and post-oviposition period and adult life span were recorded.

Statistical analysis

Developmental, pre-oviposition, oviposition and post oviposition times, fecundity and body weight of *H. armigera* reared on different tomato cultivars were analyzed one-way ANOVA followed by comparison of the means with Tukey's test at $\alpha = 0.05$ using statistical software SAS 9.1 (PROC GLM, SAS Institute). All data were checked for normality prior to statistical analysis.

Results

Development time and adult longevity. The mean larval duration (neonate to pupation) of *H. armigera* was significantly differ ($F=4.538$, $df=9$, $P<0.001$) on the ten test cultivars of tomato (Table 1). The mean development time of *H. armigera* larvae was longest on 'Super Queen' with 22.07 ± 0.32 days and shortest on 'Super Chief' with 18.98 ± 0.94 days.

Test cultivars had significant effect on the development time of 1st instar larvae of *H. armigera* ($F=4.117$, $df=9$, $P<0.001$). Maximum duration of 1st instar larvae was 2.90 ± 0.11 days on 'Super Queen'. While minimum duration was 2.39 ± 0.02 days on 'Mobil' (Table 1).

Cultivars did not differ significantly with respect to development time of 2nd instar larvae ($F=1.201$, $df=9$, $P=0.322$). Larvae reared on cultivar 'Super Urbana' had longest development time with 3.32 ± 0.09 days (Table 1). Minimum duration of 2nd instar was recorded on 'Super Chief' with 2.93 ± 0.03 days.

There was no significant differences among the development time of 3th ($F=0.181$, $df=9$, $P=0.995$) and 4th ($F=0.962$, $df=9$, $P=0.485$) instar larvae on selected cultivars. (Table 1). Cultivars differ significantly with respect to development time of 5th instar larvae ($F=2.201$, $df=9$, $P=0.043$). Larvae reared on cultivar 'Super Queen' had longest

development time with 4.47 ± 0.11 days (Table 1). Minimum duration of 5th instar was recorded on 'Super Chief' with 3.48 ± 0.09 days.

Tomato cultivars differed significantly in larval duration of 6th instar of *H. armigera* larvae ($F=2.919$, $df= 9$, $P<0.01$). Maximum duration of 6th instar was recorded on 'Super Urbana' with 5.30 ± 0.21 days, followed by 'Super Urbana' with 5.30 ± 0.20 days. The mean pupal development time of *H. armigera* was significantly differ ($F=2.624$, $df= 9$, $P=0.017$) on tomato cultivars (Table 2). The pupal period varied from 11.58 ± 0.49 days on 'Mobil' to 13.19 ± 0.15 days on 'Super Queen'.

Different tomato cultivars showed no significant effect on longevity of female *H. armigera* ($F=1.653$, $df= 9$, $P=0.133$), but longevity of male was significantly affected by tomato cultivars ($F=1.653$, $df= 9$, $P=0.0004$)(Table 2).

The longest female longevity was observed on 'Atrak' (14.78 ± 0.39 days) and the shortest on 'Super Queen' (12.77 ± 0.86 days). The longevity of males was longest on 'Mobil' (9.22 ± 0.17 days) and shortest on 'Super Mobil' (7.20 ± 0.20 days) (Table 2).

Table 1- Mean (\pm SE) development time of larvae and pupae of *H. armigera* on different tomato cultivars.

Cultivar	Larval Stage						Total Time
	1 st Instar	2 nd Instar	3 th Instar	4 th Instar	5 th Instar	6 th Instar	
Aras	2.64 ± 0.11^{bc}	3.11 ± 0.10^a	2.62 ± 0.07^a	3.51 ± 0.10^a	3.98 ± 0.19^b	5.07 ± 0.14^a	20.92 ± 0.24^{bc}
Atrak	2.58 ± 0.07^{bc}	3.11 ± 0.08^a	2.63 ± 0.06^a	3.57 ± 0.07^a	3.93 ± 0.17^b	4.95 ± 0.22^a	21.07 ± 0.31^{ab}
Korall	2.61 ± 0.05^{bc}	3.16 ± 0.08^a	2.65 ± 0.11^a	3.43 ± 0.11^a	3.88 ± 0.14^{bc}	4.80 ± 0.11^a	20.77 ± 0.50^{bc}
Mobil	2.39 ± 0.02^d	3.15 ± 0.08^a	2.69 ± 0.09^a	3.49 ± 0.11^a	3.86 ± 0.09^{bc}	4.92 ± 0.16^a	20.42 ± 0.34^c
Rio Grande Hed	2.57 ± 0.09^{bc}	3.10 ± 0.11^a	2.62 ± 0.07^a	3.53 ± 0.07^a	3.94 ± 0.18^b	4.92 ± 0.24^a	20.87 ± 0.38^{bc}
Sivand	2.62 ± 0.08^{bc}	3.09 ± 0.09^a	2.64 ± 0.09^a	3.46 ± 0.06^a	3.87 ± 0.13^{bc}	4.95 ± 0.28^a	20.89 ± 0.41^{bc}
Super Chief	2.48 ± 0.07^{cd}	2.93 ± 0.03^a	2.62 ± 0.09^a	3.35 ± 0.05^a	3.48 ± 0.09^a	4.12 ± 0.17^b	18.98 ± 0.94^{cd}
Super Mobil	2.72 ± 0.05^{ab}	3.13 ± 0.11^a	2.65 ± 0.10^a	3.48 ± 0.08^a	3.87 ± 0.17^{bc}	5.06 ± 0.14^a	21.16 ± 0.51^{ab}
Super Queen	2.90 ± 0.11^a	3.11 ± 0.08^a	2.70 ± 0.10^a	3.48 ± 0.06^a	4.47 ± 0.11^a	5.30 ± 0.20^a	22.07 ± 0.32^a
Super Urbana	2.88 ± 0.09^a	3.32 ± 0.09^a	2.74 ± 0.16^a	3.66 ± 0.09^a	3.86 ± 0.26^{bc}	5.30 ± 0.21^a	21.88 ± 0.60^{ab}

The means followed by different letters in the same column are significantly different (Tukey's test, $p<0.05$)

Body weight. The effects of different tomato cultivars on the weight of *H. armigera* (L4-L6 and Pupa) varied (Table 3). Larvae of 4th instar ($F=70.47$, $df= 9$, $P<0.0001$) reared on 'Korall' were heavier (92.91 ± 1.19 mg) which was statistically similar to 'Atrak' (91.73 ± 0.98 mg) and lighter on 'Super Urbana' (64.09 ± 0.98 mg) as compared to other cultivar. The

5th instar larvae ($F=235.65$, $df=9$, $P<0.0001$) had maximum weight (258.17 ± 1.56 mg) when reared on 'Atrak' and minimum weight (135.05 ± 1.23 mg) on cultivar 'Super Urbana'. The 6th instar larvae ($F=397.89$, $df=9$, $P<0.0001$) maximum weight (418.60 ± 3.12 mg on 'Aras' which was statistically similar to 'Korall' (416.24 ± 2.31 mg) .

The mean pupal weight of *H. armigera* differed significantly in all the test cultivars ($F=151.231$, $df=9$, $P<0.0001$). Maximum pupal weight was 323.67 ± 4.56 mg on 'Aras' which was statistically similar to pupal weight on 'Korall' (321.80 ± 3.25 mg). The pupal weight of *H. armigera* was significantly lower on 'Super Urbana' (200.83 ± 3.03 mg).

Table 2- Mean(\pm SE) development time of pre-pupae, pupae, immature and adult longevity of *H. armigera* on different tomato cultivars.

Cultivar	Stage			Adult longevity	
	pre-pupae	pupae	immature	Male	Female
Aras	4.44 \pm 0.14 ^a	11.60 \pm 0.32 ^b	39.99 \pm 0.66 ^{abc}	8.10 \pm 0.43 ^{ab}	14.73 \pm 0.23 ^a
Atrak	4.60 \pm 0.13 ^a	12.15 \pm 0.39 ^b	40.62 \pm 0.73 ^{ab}	8.48 \pm 0.74 ^{ab}	14.78 \pm 0.39 ^a
Korall	4.41 \pm 0.20 ^a	11.99 \pm 0.20 ^b	40.22 \pm 0.72 ^{abc}	8.47 \pm 0.40 ^{ab}	14.47 \pm 0.46 ^a
Mobil	4.63 \pm 0.22 ^a	11.58 \pm 0.49 ^b	39.43 \pm 0.38 ^{bc}	9.22 \pm 0.17 ^a	14.02 \pm 0.70 ^a
Rio Grande Hed	4.59 \pm 0.25 ^a	11.93 \pm 0.16 ^b	41.06 \pm 0.91 ^{ab}	9.10 \pm 0.23 ^a	14.75 \pm 0.53 ^a
Sivand	4.43 \pm 0.11 ^a	11.88 \pm 0.11 ^b	40.08 \pm 0.29 ^{abc}	7.97 \pm 0.18 ^{ab}	14.55 \pm 0.39 ^a
Super Chief	3.85 \pm 0.10 ^b	11.99 \pm 0.30 ^b	37.62 \pm 0.24 ^c	8.35 \pm 0.10 ^{ab}	14.05 \pm 0.30 ^a
Super Mobil	4.28 \pm 0.18 ^{ab}	12.22 \pm 0.33 ^b	40.57 \pm 0.78 ^{ab}	7.20 \pm 0.20 ^b	13.78 \pm 0.41 ^a
Super Queen	4.74 \pm 0.12 ^a	13.19 \pm 0.15 ^a	42.69 \pm 0.48 ^a	7.30 \pm 0.13 ^b	12.77 \pm 0.86 ^a
Super Urbana	4.66 \pm 0.12 ^a	12.38 \pm 0.14 ^b	41.83 \pm 0.51 ^{ab}	7.27 \pm 0.31 ^b	13.82 \pm 0.23 ^a

The means followed by different letters in the same column are significantly different (Tukey's test, $p<0.05$)

Oviposition period and Fecundity

The effects of different tomato cultivars on the pre-oviposition period, oviposition period, postoviposition period and number of the laid eggs per female of the tomato fruit worm are shown in Table 4.

The mean adult pre-oviposition period was significantly different ($F=4.510$, $df=9$, $P<0.0004$). However, different tomato cultivars did not influence the oviposition ($F=1.092$, $df=9$, $P=0.390$) and post-oviposition period ($F=1.863$, $df=9$, $P=0.086$) of *H. armigera*. The females reared on 'Super Mobil' and 'Atrak' had the shortest (2.13 ± 0.21 days) and longest (3.28 ± 0.24 days) pre-oviposition period. The oviposition period ranged from 8.35 ± 0.44 days on 'Super Queen' to 9.43 ± 0.54 days on 'Rio Grande Hed'. The shortest post-oviposition period observed on 'Super Queen' (1.93 ± 0.24 days). There were no significant differences in post-oviposition period between other tomato cultivars.

Table 3- Mean (\pm SE) larval (4th to 6th) and pupal weight of *H. armigera* on different tomato cultivars.

Cultivar	Larval stage			Pupa
	4 th Instar	5 th Instar	6 th Instar	
Aras	83.29 \pm 0.71 ^b	239.85 \pm 1.38 ^{bc}	418.60 \pm 3.12 ^a	323.67 \pm 4.56 ^a
Atrak	91.73 \pm 0.98 ^a	258.17 \pm 1.56 ^a	401.33 \pm 2.28 ^b	310.26 \pm 2.70 ^{ab}
Korall	92.91 \pm 1.19 ^a	249.73 \pm 1.44 ^{ab}	416.24 \pm 2.31 ^a	321.80 \pm 3.25 ^{ab}
Mobil	80.59 \pm 1.47 ^b	160.23 \pm 5.93 ^f	305.54 \pm 3.49 ^e	236.30 \pm 4.56 ^c
Rio Grande Hed	81.33 \pm 1.16 ^b	226.41 \pm 1.39 ^{cd}	368.30 \pm 2.26 ^c	284.79 \pm 3.95 ^c
Sivand	79.33 \pm 0.76 ^b	223.96 \pm 3.24 ^d	335.89 \pm 1.65 ^d	259.67 \pm 2.16 ^d
Super Chief	79.11 \pm 1.06 ^b	209.14 \pm 3.96 ^e	394.78 \pm 2.74 ^b	305.21 \pm 3.39 ^b
Super Mobil	72.43 \pm 1.15 ^c	214.92 \pm 3.14 ^{de}	335.72 \pm 3.07 ^d	259.60 \pm 4.09 ^d
Super Queen	70.40 \pm 0.99 ^c	142.93 \pm 1.57 ^e	259.80 \pm 3.82 ^e	200.83 \pm 3.03 ^f
Super Urbana	64.09 \pm 0.98 ^d	135.05 \pm 1.23 ^e	288.65 \pm 2.68 ^f	223.15 \pm 2.68 ^e

The means followed by different letters in the same column are significantly different (Tukey's test, $p < 0.05$)

There was significant difference in fecundity of *H. armigera* on different tomato cultivars ($F=9.446$, $df= 9$, $P < 0.0001$). The total number of eggs laid were highest by the females of *H. armigera* when larvae reared on 'Korall' (360.25 ± 21.15 eggs/female) while there was significant reduction in number of eggs laid by the females of the larvae developed on 'Super Queen' (160.68 ± 22.37 eggs) (Table 4).

Table 4- The mean (\pm SE) pre, post-oviposition, oviposition periods and fecundity (Number of eggs/ female) of *H. armigera* emerging from larvae reared on different tomato cultivars.

cultivar	Pre oviposition period (day)	Oviposition period (day)	Post oviposition period (day)	Fecundity (egg/female)
Aras	3.13 \pm 0.14 ^a	9.10 \pm 0.27 ^a	2.50 \pm 0.15 ^a	359.75 \pm 26.18 ^a
Atrak	3.28 \pm 0.24 ^a	8.51 \pm 0.34 ^a	2.63 \pm 0.10 ^a	306.78 \pm 22.97 ^{abc}
Korall	2.98 \pm 0.18 ^a	8.83 \pm 0.43 ^a	2.65 \pm 2.33 ^a	360.25 \pm 21.15 ^a
Mobil	2.13 \pm 0.23 ^c	9.35 \pm 0.40 ^a	2.53 \pm 0.16 ^a	282.03 \pm 26.24 ^{abcd}
Rio Grande Hed	2.89 \pm 0.25 ^{ab}	9.43 \pm 0.54 ^a	2.43 \pm 0.13 ^a	252.05 \pm 18.29 ^{bcde}
Sivand	3.15 \pm 0.22 ^a	8.77 \pm 0.29 ^a	2.63 \pm 0.17 ^a	242.62 \pm 11.19 ^{cde}
Super Chief	2.18 \pm 0.23 ^c	9.27 \pm 0.19 ^a	2.61 \pm 0.17 ^a	340.62 \pm 11.8 ^{ab}
Super Mobil	2.13 \pm 0.21 ^c	9.15 \pm 0.30 ^a	2.50 \pm 0.17 ^a	294.79 \pm 6.49 ^{abc}
Super Queen	2.48 \pm 0.25 ^{bc}	8.35 \pm 0.44 ^a	1.93 \pm 0.24 ^a	160.68 \pm 22.37 ^e
Super Urbana	2.90 \pm 0.17 ^{ab}	8.67 \pm 0.16 ^a	2.25 \pm 0.19 ^a	194.42 \pm 17.25 ^{de}

The means followed by different letters in the same column are different (Tukey's test, $p < 0.05$)

Discussion

Plant species differ greatly in suitability as hosts for specific insects when measured in terms of survival, development, and reproductive rates. Shorter developmental times and greater total reproduction of insects on a host indicate greater suitability of a host plant (van Lenteren & Noldus, 1990). Prolonged development time on particular species of host means longer life cycle and slower population growth (Singh & Parihar, 1988).

Larval stages of *H. armigera* when prolonged may augment the efficacy of its management tactics by using insecticides and natural enemies (Hugar *et al.*, 2014). In the present study the larval stadium of *H. armigera* completed through six distinct instars which have been reported previously by Nemati Kalkhortan *et al.* (2013). The number of instars that we obtained for *H. armigera* differs from the reports of Kashyap & Verma (1987), Mojeni *et al.* (2005) and Naseri *et al.* (2010) who described the existence of 5 instars for larval development of this species. The number of instars tends to vary for most lepidopteran species, and this variation may be a function of factors including the environment as well as food (Zalucki *et al.*, 1986).

The genus *Lycopersicon* with its wider species diversity offers an array of defense traits against insects (Kennedy, 2003). Our research showed that there were significant differences in the developmental times of immature stages raised on each tomato cultivar (Table 1). Larvae maintained on some hosts had comparatively shorter duration of immature stages. Similar findings have also been reported by Nemati Kalkhoran *et al.* (2013) and Safuraie-Parizi *et al.* (2014). Faster developmental time on a particular host may allow a short life cycle, high reproductive productivity, and rapid population growth (Singh & Parihar, 1988). It may also reduce generation time.

The larval periods ranged from 18.89 days on 'Super Chief' to 22.07 days on 'Super Queen'. Whereas Naseri *et al.* (2009) reported total development time of *H. armigera* larvae from 17.30 to 26.20 days on different soybean cultivars. However, Nemati Kalkhoran *et al.* (2013) reported total development time of *H. armigera* larvae from 25.84 to 35.50 days on different tomato cultivars at $25\pm 1^\circ\text{C}$. A possible explanation for variation in the results may be due to differences in temperature and nutritional value of the tomato cultivars tested.

Body weight is an important indicator of fitness of an insect, which can be measured easily (Liu *et al.*, 2004). However, pupal weight can be an indirect, but easily measured, indicator of lepidopteran insect fitness (Leuck and Perkins 1972). Host plants have great influence on the body weight of an insect species. This is evident from Sharma *et al.* (1999) that larvae reared on resistant cultivars had considerably lower weight than reared on susceptible cultivars. This is in agreement with our finding. Pupal weight of *H. armigera* was maximum on 'Atrak' (293.20 milligram) while minimum on cultivar 'Super Queen'

(226.88 milligram). Whereas, Kashyap and Verma (1987) reported pupal weight from 135.4 to 201.6 milligram on different tomato genotypes. The difference in the results is might be due to the physiological differences present in host plants.

Many factors affect host suitability, including nutrient content and secondary substances of the host. The exact cause of the differences found among host plants in larval growth rates, mortality, adult fecundity and survival remains unknown (Liu *et al.*, 2004). It is also reported that antibiosis seems to be the major component of resistance in the wild relatives of tomato (Sharma *et al.*, 2005). Salvanarayanan and Narayanasamy (2006) found that ortho-dihydroxy phenols of tomato 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.

The pupae produced by larvae reared on 'Aras' and 'Korall' were much heavier than that of pupae produced by larvae reared on 'Super Queen' and 'Super Urbana' (Table 3). This reinforces the suggestion that 'Aras' and 'Korall' are more suitable hosts for tomato fruitworm larvae than 'Super Queen' and 'Super Urbana'.

There was significant difference in fecundity of *H. armigera* on different tomato cultivar. The total number of eggs laid were highest by the females developed from larvae reared on 'Korall' (360.25 eggs) while there was significant reduction in number of eggs laid by the females developed on 'Super Queen' (160.68 eggs). These results are in accordance with the Safuraie-Parizi *et al.* (2014), who reported lower fecundity on resistant tomato cultivar 'Imprial' (96.60 eggs) as compared to susceptible other tested cultivars. However, the range of fecundity of *H. armigera* in this study is less than that reported by Safuraei-Parizi *et al.* (2014) on other six tomato cultivars. The difference could be due to differences in biochemical traits in different tomato cultivars. Awmack & Leather (2002) suggested that fertilizers can also affect the relative growth rate, development time, and fecundity of a range of phytophagous species.

In conclusion, the more body weight, faster development and more fecundity of *H. armigera* suggested that cultivar 'Korall' followed by 'Aras' and 'Super Chief' were suitable (susceptible) as compared with the other cultivars. Furthermore, 'Super Queen' and 'Super Urbana' were unsuitable (resistant) as compare to other cultivars. The development of cultivars with resistance would provide an effective complementary approach in integrated pest management to minimize the extent of losses due to this pest (Sharma *et al.*, 2005).

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