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Life History Studies of the Beet Armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) on 10 Corn Hybrids

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ABSTRACT

The beet armyworm, *Spodoptera exigua* (Hübner) is a polyphagous insect pest that damages several field crops including corn, cotton, soybean, alfalfa and tomato in many parts of the world. In this study, the effect of 10 corn hybrids (SC700, DC370, SC704, SC260, SC500, Keynes540, Keynes410, KSC260, KSC400 and KSC301) on life history of *S. exigua* was studied under laboratory conditions (25±1 °C, 65±5% RH, and 16:8 (L: D) h). The results showed that the longest larval and pupal period was on SC500 (29.55 and 14.33 days, respectively). The longest and shortest development time was on SC500 and KSC260, respectively (39.50 and 29.47 days, respectively). The lowest percentage of mortality and highest fecundity was observed on Keynes540. Our findings indicated that the lowest growth index in the pupal stage (2.05) and the highest percentage of mortality in larval and pupal stages were on hybrid SC700. Therefore, it was concluded that SC700 was partially resistant to *S. exigua* in comparison with the other hybrids tested.

Key words: Beet armyworm, *Spodoptera exigua,* biological properties, corn hybrid.

INTRODUCTION

The beet armyworm, *Spodoptera exigua* (Hübner), is a polyphagous and destructive pest around the world and causes economic damage on more than 50 plant species from over 10 families such as corn, cotton, soybean, lettuce, alfalfa and tomato (Wilson, 1932; Smits *et al*., 1987; Greenberg *et al*., 2001; Sertkaya *et al*., 2004). Larvae of *S. exigua* feed on both foliage and fruit structures of host plants. It is regarded as a serious defoliator of flower crops and cotton. The young larvae feed gregariously and skeletonise host foliages. As they grown-up, they became solitary and feed large irregular holes in the foliages. They also burrow into the crown or centre of the head on lettuce, or on the buds of brassica crops (East *et al*., 1989). The accessibility of different host plants plays a main role in causing population outbreaks for polyphagous insects (Singh and Parihar, 1988). The outbreak of *S. exigua* is not regular but develops quickly and since older larval instars are difficult to manage with synthetic insecticides, early cautioning of population build up is necessary to effective management of the pest (Tisdale and Sappington, 2001; Idris and Emelia, 2001).

Chemical control programs against this pest have been complicated by its propensity to develop insecticide resistance (Cobb and Bass, 1975; Brewer *et al*., 1990). To develop efficient strategies for the control of the beet armyworm, enough knowledge about its biological traits on various host plants is required (Greenberg *et al.,* 2001). Different host plants are known to affect insect development, survivorship and reproduction parameters differentially (Tsai and Wang, 2001). Host plant resistance is an important tool, which is acceptable in terms of being both economically and environmentally (Kennedy *et al.,* 1987). The three mechanisms of host plant resistance to insects are antibiosis, antixenosis and tolerance (Painter, 1951; Kogan and Ortman, 1978). Antibiosis, among these mechanisms, has the greatest potential against highly mobile insect pest like *S. exigua* (Kennedy *et al*., 1987).

The quality and quantity of food ingested by an insect can directly affect its survival and reproductive performance. Hence, the fitness of the herbivores depends on the nutrients present in their host plants. Also, the partially resistant cultivars may improve the efficiency of natural enemies and insecticides. Therefore, the use of resistant cultivars can be integrated with biological and chemical control methods as part of an IPM strategy (Du *et al*., 2004; Adebayo and Omoloyo, 2007). Understanding the life history parameters of a pest is necessary to develop an integrated pest manage strategy. These parameters provide population growth rate of an insect pest in the present and next generations (Frel *et al.,* 2003).

To date the life history traits of *S. exigua* have been studied on different host plants by several researchers: Greenberg *et al.* (2001) on five host plants including cabbage (*Brassica oleracea capitata* L.), cotton (*Gossypium hirsutum* L.); bell pepper (*Capsicum annuum* L.), pigweed (*Amaranthus retroflexus* L.) and sunflower (*Helianthus annuus* L.); Azidan and Sofian-Azirun (2006) on four host plants including cabbage (*B. oleracea*), shallot (*Allium ascalonicum* L.), long beans (*Vigna unguiculate sesquipedalis* C.) and lady’s finger (*Hibiscus esculentus* L.); Saeed *et al*. (2009) on various host plants including cotton (*G. hirsutum)*, cauliflower (*B. oleracea*), peas (*Pisum sativum* L.), and wheat (*Triticum aestivum* L.); Mehrkhou *et al.* (2010) on nine soybean cultivars (032, 033, Hill, M4, M7, M9, M11, TMS and Zane); Karimi-malati *et al.* (2010) on four sugar beet cultivars (FD0432, FD0005, Dorothea and Shirin), and Farahani *et al.* (2011) on host plants including *Zea mays* (var, 704), *G. hirstum* (var, varamin), *Brassica napus* (var, RGS), *Glycine max* (var, Sahar) and *Chenopodium album*. However, in spite of the economic importance of *S. exigua* on corn, there is no published information concerning the life history of this pest on different corn hybrids. Therefore, the present research provides new insight on some aspects of the life history of *S. exigua* on corn hybrids. The goal of this research was to evaluate susceptibility or resistance of some commercial corn hybrids to *S. exigua* through comparative study on the life history traits of this pest reared on these hybrids under laboratory conditions.

MATERIALS AND METHODS

Plant and insect sources

The seeds of the 10 commercial corn hybrids (SC700, DC370, SC704, SC260, SC500, Keynes 540, Keynes 410, KSC260, KSC400 and KSC301) were acquired from the Plant and Seed Modification Research Institute (Karaj, Iran), and Moghan Agricultural Research Centre (Ardabil, Iran). They were planted in the research field of University of Mohaghegh Ardabili, Iran in May 2010. The beet armyworm eggs used in the experiment were obtained from a laboratory colony maintained (for three years) on a defined artificial diet at Department of Entomology, Tarbiat Modares University (Tehran, Iran). Experiments were conducted in a growth chamber (25±1 ^{o}C, 65±5 % RH and 16:8 (L: D) h) and the 4-6 leaves stages were used for feeding different larval instars. All plant materials used in this experiment were collected from plants growing under field conditions without using any pesticides.

Experiment

Adult moths emerged from the larvae reared on the leaves of different corn hybrids were used in the experiment. In order to obtain the same aged eggs of the pest, 10-15 pair of both sexes of the moth reared on related corn hybrids were kept inside egg laying containers (diameter 14 cm, height 19 cm), which were sealed at the top with a fine mesh net. After 72 h, the eggs laid were collected from the container and used in the experiment. Each corn hybrid considered being a treatment and each treatment replicated 50 times in a completely randomized design. Newly hatched larvae were transferred into plastic petri dish (diameter 8 cm, depth 1 cm) with a hole covered by a fine mesh net for ventilation, containing the fresh leaves of each examined plant. Other eggs were collected continuously for 3 days. Every day, fresh leaves were provided for larval feeding. Molting was determined by observation of the head capsule. Fifth instar larvae were kept in small plastic tubes (diameter 2 cm, depth 5 cm) for pre-pupation and pupation. During the experiment, duration of each larval stadium, pre-pupal and pupal periods, weight of pre-pupal and pupal stages, percentage of pupation, and percentage of the moths emerged from pupae were determined.

After emergence of the adults, a pair of female and male moths (8-10 and 10-15 replicates for male and female, respectively), were introduced into each egg laying container (diameter 10 cm, depth 15 cm), which was closed at the top with a fine mesh net for ventilation. The egg laying containers were supplied with 10% honey solution for feeding moths. Adult longevity and the number of eggs deposited were recorded daily until the death of the last adult. The egg laying containers were equipped with window screen as oviposition substrate to avoid eggs being laid on the container wall. Eggs laid from each adult pair within the same day were monitored to determine the incubation. During hatching, these eggs were checked every day, and the number of newly hatched larvae was recorded. The growth index (GI) was calculated by dividing the survival rate of the immature by development time (Setamou *et al*., 1999).

Data analysis

The data resulted from the effects of corn hybrids on development time, oviposition period, fecundity and adult longevity of *S. exigua* were subjected to the one-way analysis of variance (ANOVA) using the statistical software Minitab 16. Data were checked for normality before the analysis. We also analyzed the homogeneity of the variances before carrying out ANOVA test. Statistical differences among means were evaluated using the least significant difference (LSD) test at α = 0.05.

RESULTS

Development time

The data of the development time of immature stages, adult longevity and life span of *S. exigua* reared on different corn hybrids are given in Table 1. No significant differences were found on incubation and pre-pupal period of *S. exigua* on various corn hybrids. The larval and pupal periods were longest on hybrid SC500. However, larval period and development time of *S. exigua* were shortest on hybrid KSC260. The shortest pupal period of *S. exigua* was on hybrid SC260.

Table 1. The mean (±SE) duration of development stages of *Spodoptera exigua* on different corn hybrids.

Hybrid	Incubation (days)	Larval period (days)	Pre-pupal period (days)	Pupal period (days)	Development time (days)
DC370	3.00±0.00[a]	21.80±4.14[c]	1.50±0.57[a]	8.75±1.89[de]	35.83±2.63[b]
Keynes410	3.00±0.00[a]	17.05±1.84[d]	1.27±0.46[a]	11.07±1.54[bc]	31.33±1.88[cd]
Keynes540	3.00±0.00[a]	15.21±2.42[de]	1.46±0.51[a]	11.13±0.74[b]	30.54±2.25[cd]
KSC260	3.00±0.00[a]	14.12±2.14[e]	1.55±0.51[a]	10.64±1.15[bc]	29.47±3.06[d]
KSC301	3.00±0.00[a]	16.50±3.51[d]	1.33±0.51[a]	13.50±3.53[a]	30.75±3.86[cd]
KSC400	3.00±0.00[a]	21.50±2.38[c]	1.75±0.95[a]	10.00±2.16[bcd]	35.33±2.88[b]
SC260	3.00±0.00[a]	24.50±0.70[b]	1.50±0.70[a]	8.00±1.41[e]	37.00±2.58[b]
SC500	3.00±0.00[a]	29.55±4.97[a]	1.33±0.51[a]	14.33±2.08[a]	39.50±3.53[a]
SC700	3.00±0.00[a]	17.18±2.60[d]	1.33±0.51[a]	N_A	N_A
SC704	3.00±0.00[a]	19.85±2.03[c]	1.33±0.51[a]	9.57±1.51[cd]	32.75±3.05[c]

The means followed by different letters in the same columns are significantly different (P<0.01, LSD)
N_A. Number not available.

Adult longevity, oviposition period and fecundity

Adult longevity, life span, oviposition period and fecundity of *S. exigua* developed from the larvae fed on different corn hybrids are shown in Table 2. The longest female longevity and pre-oviposition period of *S. exigua* was on hybrid KSC260 (13.60 and 4.33 days, respectively). The shortest life span period was on hybrid KSC260 (37.42 days). The results showed that life span and oviposition period were longest (46.20 and 14.07 days, respectively) on hybrid KSC400. The shortest female longevity and oviposition period was on Keynes410 (10 and 6.66 days, respectively). The highest number of daily and total eggs laid per female (43.73 and 276 eggs, respectively) was on hybrid Keynes540 and the lowest ones (14.07 and 51.50 eggs, respectively) were on hybrid KSC400.

Growth index and mortality

The growth index and percentage mortality of larvae, pre-pupae and pupae of *S. exigua* on different corn hybrids are shown in Table 3. The highest percentage of larval and pupal mortalities (66 and 82.36%, respectively) was observed on hybrid

SC700 and the highest percentage of pre-pupal mortality (79.17%) was on hybrid KSC301. However, the lowest percentage of larval mortality (14%) was on hybrid KSC260 and the percentage of pre-pupal mortality (11.77%) was the lowest on hybrid SC700. No pupal mortality was observed on hybrids Keynes410 and KSC301. Among the different corn hybrids, the highest larval growth index (6.07) was on hybrid KSC260. Our results showed that the highest growth indices for the pre-pupal and pupal stages were 71.4 and 9.66 on hybrids SC500 and Keynes410, respectively. However, the lowest growth index of larvae, pre-pupae and pupae was 2.13, 17.39 and 2.05 on hybrids DC370, KSC400 and SC700, respectively.

Table 2. The mean (±SE) longevity, oviposition period (days) and fecundity of *Spodoptera exigua* on different corn hybrids.

Hybrid	Longevity (days)		Life span (days)	Oviposition period (days)		Fecundity	
	Male	Female		Pre-oviposition period	Oviposition period	Daily	Total
Keynes410	9.00±2.16[a]	10.00±2.16[b]	40.30±4.69[bc]	3.66±1.52[ab]	6.66±1.52[c]	32.31±2.82[b]	198.25±28.61[b]
Keynes540	11.00±2.16[a]	10.38±1.47[ab]	41.16±3.74[b]	2.50±0.54[b]	7.50±1.29[bc]	43.73±4.78[a]	276.00±46.00[a]
KSC260	8.33±1.52[a]	13.60±1.87[a]	37.42±4.87[c]	4.33±1.50[a]	9.00±2.00[bc]	32.80±5.61[b]	233.00±30.74[ab]
KSC400	N_A	12.00±3.21[ab]	46.20±4.91[a]	3.66±1.52[ab]	14.07±1.30[a]	14.07±1.30[c]	51.50±10.61[c]
SC704	10.66±1.52[s]	10.66±2.08[b]	42.37±3.96[b]	4.25±0.95[ab]	10.66±2.51[b]	17.74±4.40[c]	263.00±41.01[a]

The means followed by different letters in the same columns are significantly different (P<0.01, LSD) N_A. Number not available.

Table 3. The growth index (GI) and mortality of immature stages of *Spodoptera exigua* on different corn hybrids.

Hybrid	Larva		Pre-pupa		Pupa	
	GI	Mortality (%)	GI	Mortality (%)	GI	Mortality (%)
DC370	2.13	44.0	51.02	25.00	3.17	71.43
Keynes410	4.43	30.0	62.50	20.00	9.66	0.00
Keynes540	3.08	50.0	53.42	24.00	6.22	31.58
KSC260	6.07	14.0	50.61	13.96	6.39	32.44
KSC301	3.23	52.0	20.83	79.17	8.77	0.00
KSC400	2.68	36.0	17.39	73.92	9.05	16.70
SC260	2.27	42.0	22.06	72.42	4.36	62.50
SC500	2.49	57.5	71.40	23.6	2.12	69.24
SC700	2.26	66.0	60.43	11.77	2.05	82.36
SC704	3.00	36.0	53.14	21.88	4.61	56.00

Pre-pupal and pupal weight

Fig. 1 indicates pre-pupal and pupal weight of *S. exigua* reared on different corn hybrids. The heaviest (80.27 mg) and lightest (39.4 mg) pre-pupal weight were observed on SC500 and KSC301, respectively compared with the other hybrids. Also, pupae emerged from the larvae reared on hybrid KSC400 was the heaviest (65.80 mg) whereas the larvae fed on KSC301 was lightest (31 mg) in pupal stage compared with the other hybrids.

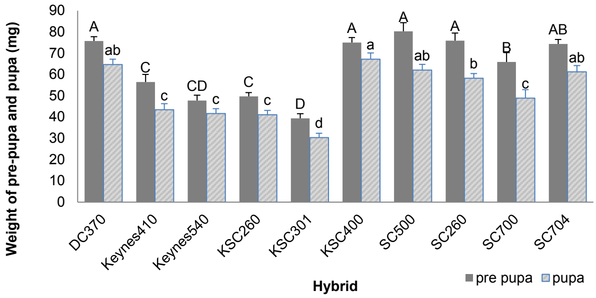

Fig. 1. The mean pre-pupal and pupal weight (mg) of *Spodoptera exigua* reared on different corn hybrids.

DISCUSSION

As a way of controlling insect pests, host plant resistance is not only compatible with the environment, but also reduces expenses for growers (Liu *et al*., 2004). Applying resistant cultivars plays a key role in an integrated pest manage program for any host plant crops (Wilson and Huffaker, 1976; Endo *et al.,* 2007). The suitability of host plant species may differ for specific insects when measured in terms of survival, development, and reproduction. Shorter development time and higher fecundity of insects on a host indicate greater suitability of a host crop (van Lenteren and Noldus, 1990).

The incubation period of *S. exigua* was not significantly different among the 10 corn hybrids, indicating that this parameter was not affected by the different corn hybrids. Our result for the incubation period of *S. exigua* on different corn hybrids (3.00 days) is in agreement with previous studies on other host plant (Ahmad *et al*., 1997; Azidan and Sofian-Azirun, 2009; Farahani *et al*., 2011).

There were five larval instars for *S. exigua* on the most corn hybrids tested, which was similar to the findings of other researchers (Afify *et al*., 1970; Ali and Gaylor, 1992; Ahmad *et al.,* 1997; Farahani *et al*., 2011). However, we observed six and seven larval instars on hybrids SC500 and SC700, respectively, which is similar to the results reported by some authors (Afify *et al*., 1970; Ali and Gaylor, 1992; Anwar *et al*., 1996).

According to our findings, the larval period of *S. exigua* varied from 14.12 days on hybrid KSC260 to 29.55 days on hybrid SC500, which is probably attributed to differences in nutrients or secondary compounds among the corn hybrids. The larval period of *S. exigua* was reported 12.5 days on long been and 27.04 days on shallot (Azidah and Sofian-Azirun, 2006), 18 days on papper (Greenberg *et al*., 2001) and 11.98 and 15.58 days on *G. hirsutum* and *B. napus*, respectively (Farahani *et al*., 2011). This variation may be due to the difference in host plant, difference in the experimental conditions especially temperature and variation in geographic populations of the pest.

No significant difference was observed among corn hybrids with relation to the pre-pupal period of *S. exigua.* However, pupal period was affected by the corn hybrids eaten by the larvae of *S. exigua*. The pupal period of *S. exigua* ranged from 8 days on hybrid KSC260 to 14.33 days on hybrid SC500. The pupal period of *S.*

exigua was reported 7.5 days on celery, 9.02 and 10.21 days on shallot and lady's finger, respectively (Azidah and Sofian-Azirun, 2006). Also, Farahani *et al*. (2011) noted that the pupal period of *S. exigua* was 6.66 and 8.70 days on *G. max* and *G. hirsutum*, respectively. Such variations in the results might be related to the different host plants used for the experiments and differences in the temperature conditions in the experiments.

The host plant species have important role on insect development time (Birch, 1948; Varley and Gradwell, 1970; Liu *et al*., 2004). The development time of immature stages reared on different corn hybrids varied from 29.47 days on hybrid KSC260 to 39.50 days on hybrid SC260, which was longer than those reported by Greenberg *et al*. (2001) on pigweed (20.2 days) and on pepper (26.6 days). Farahani *et al*. (2011) reported that the development time of *S. exigua* was 21.63 days on *B. napus* and 27.22 days on *G. hirsutum*. The reasons for such differences between our findings and above-mentioned researchers might be due to the factors such as leaf morphology, chemical composition or other non-tested interactions. Antibiosis in host plant resistance to insect herbivores can be manifested in several ways such as fecundity reduction, decreasing size, increasing development time and increasing mortality. This reduces the quality of host plant as a food source for insect growth (Painter, 1951).

Our experiment was conducted on 10 corn hybrids, but only larvae reared on five corn hybrids reached to adult stage. According to our findings, the longest female longevity of *S. exigua* was on hybrid KSC260 (13.60 days) and the shortest was on hybrid Keynes410 (10.00 days), which is in agreement with the results of several authors on other host crops (Azidah and Sofian-Azirun, 2006; Saeed *et al*., 2009). However, it is not similar to the findings of Farahani *et al*. (2011) that reported 13.69 and 11.72 days, respectively for female longevity of *S. exigua* on *Z. mays* and *G. hirsutum*. The quality and quantity of food consumed can influence the growth, development, and reproduction of insects (Scriber and Slansky, 1981).

The highest number of total eggs laid per female reared as larvae was on hybrid Keynes540 (276.00 eggs per female) which was lower than those noted by Abdullah *et al*. (2000) on soybean leaf (475.00 egg per female), and by Sethi *et al*. (2006) on lettuce (Valmine cultivar) (383.6 eggs per female). However, Farahani *et al*. (2011) reported that total fecundity of *S. exigua* was 948.0 eggs per female on *B. napus* and 426.3 eggs per female on *G. hirsutum.* This difference among our finding and other researchers may be due to the differences in host plant species and quality of nutrient especially protein content in host plants.

Pupal weight can be measured as a fitness indicator of lepidopteran insect (Leuck and Perkins, 1972). Mean pupal weight resulted from larvae of *S. exigua* was highest on hybrid KSC400 (65.80 mg) and lowest on KSC301 (31 mg). This result is not similar to the results reported by Greenberg *et al*. (2001) for pupal weight of *S. exigua* on pigweed (117 mg) and on sunflower (92 mg). The differences in nutritional quality of host plants used by larvae of *S. exigua* can be explained such variations.

The longest development time of *S. exigua* was on hybrid SC500 and because the larvae of *S. exigua* did not reach to adult stages, therefore, it was not suitable host for *S. exigua*. This can be due to the negative effect of secondary biochemicals in this hybrid or other non-tested antixenosis or antibiosis agents.

The growth index (GI) emphasizes the importance of both survival rate and development time in measuring food quality (Setamou *et al*., 1999). The lowest growth index of the pupal stage, and highest percentage of mortality in larvae and pupae of *S. exigua* were on hybrid SC700. Thus, this hybrid is not a suitable host plant for *S. exigua* compared with the other hybrids, may be due to some plant phytochemical compositions or the lack of some nutrients essential for growth and development of *S. exigua*. The lowest percentage mortality, shorter development time and higher values of growth index in larval stage of *S. exigua* was on hybrid KSC260, hence showing better food quality. In overall, the more suitable host plant decreases development period and increases survival rate of insects. In general, lepidopteran larvae feed on high-nutritious food increase growth rates and complete development time faster than those larvae that feed on low-nutrient food (Hwang *et al.,* 2008). The present study suggests that hybrids KSC260 and SC700 were most suitable and unsuitable host, respectively for *S. exigua* compared with the other hybrids.

In addition to differences in adult longevity and pre-pupal and pupal weight, there were marked different in survival of larvae among difference corn hybrids because of differences in early stage mortality. Thus, the future studies should be focused on testing a wider range of host plant species for the development of *S. exigua*. Also, assessment of the chemical components of the host plant species would help to better understanding the mechanism of host suitability. Understanding the difference in food quality among the different corn hybrids might be applicable for management of *S. exigua*.

Furthermore, our findings on resistant hybrids may be applied to design an extensive plan for IPM program of *S. exigua.* To achieve more applicable information to control *S. exigua*, after laboratory studies, more attention should be dedicated to study demographic parameters of this pest under field conditions.

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