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Comparative Demographic Parameters of Safflower Capsule Fly, *Acanthiophilus helianthi* (Dip.: Tephritidae) on Different Safflower Genotypes

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop in Iran and many other countries around the world. Safflower fly, *Acanthiophilus helianthi* Rossi is one of the main limiting agents to expand the production area of the crop in different countries and the most major pests of safflower in Iran. In this research, the influence of 10 safflower genotypes on biology and population parameters of *A. helianthi* was evaluated under the laboratory conditions at 25±1°C, 65±5% relative humidity, and a photoperiod of 16:8 (L: D) hours. The shortest and longest total developmental time were recorded in Mexico 37 (16.85±0.31) and Goldasht (21.76±0.59), respectively. The intrinsic rate of natural increase (r) ranged from 0.129 to 0.186 (day^{-1}), which was lowest on Goldasht and highest in Mexico 37. The net reproductive rate (R_0) ranged from 50.809 to 125.846 offspring on different genotypes. The values of finite rate of increase (λ) and mean generation time (T) on different safflower genotypes ranged from 1.138 to 1.205 day^{-1} and 25.778 to 30.421 days, respectively. The results demonstrated that Goldasht, Line 411, and KW2 genotypes were less suitable host plants, suggesting that they are more resistant to *A. helianthi* than the other genotypes, have high yield, and could have the potential for using in Integrated Pest Management program (IPM) of *A. helianthi* in safflower fields.

Keywords: Goldasht (cv.), Fecundity, Life history, Pest resistance.

INTRODUCTION

Safflower, *Carthamus tinctorius* (L.), is an annual herbaceous, thorny plant and the world's oldest crop of the family Compositae. This plant is an essential component of cropping systems adapted to hot and dry environments (Li and Mündel, 1996; Sabzalian *et al.*, 2008). Originally grown in the Middle East and South Asia, it can be used in medicinal, dietary, and dyeing industries due to its flowers, which are applied in coloring and condiment food and making dyes as well as drugs (Emongor, 2010). Nonetheless, in recent years, owing to an increasing requirement for vegetable oil in the human diet, its production as an oilseed crop has received a great deal of attention. Safflower is one of the important economical products because of high oil content in seeds. At present, one of the largest producers of safflower in the world is India, but the crop is also cultivated in many other countries including Iran, where different local populations of this crop can be found throughout the country (Zeinali, 1999; Dezianian *et al.*, 2010).

The most serious safflower pest in Asia and Europe is the safflower fly

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Acanthiophilus helianthi Rossi (Tephritidae), also known as either the shoot fly or capsule fly (Talpur *et al.*, 1995; Zandigiacomo and Iob, 1991). This pest is one of the most important pests causing serious damages to safflower in Iran and around the world (Hegazi and Moursi, 1983; Ting *et al.*, 2009). Larval feeding on seeds causes significant losses in seed weight, yield, and seed marketability through disrupted plant activities, reduction in flower buds and, ultimately, decreased quality and quantity of the crop (Ashri, 1971). In some years, they appear in high population in fields in central and western Europe (Verma *et al.*, 1974; Zandigiacomo and Iob, 1991) Mediterranean coasts (Ricci and Ciriciofolo, 1983) and Iran (in the provinces of Tehran, Fars, Isfahan, Qazvin, Hamedan, East and West Azerbaijan) (Sabzalian *et al.*,. 2008; Eghtedar, 1993). This fly has been reported from many parts of the world including Ethiopia (Bezzi, 1924), India (Pruthi, 1941), Pakistan (Din and Ghani, 1963), Turkey (Giray, 1966), Hungary (Martinovich, 1966) and Iraq (Al-Ali *et al.*, 1977). In Iran, seed-yield loss due to the safflower fly is estimated to be 30-70% for different safflower cultivars (Sabzalian *et al.*, 2010).

The biology and behavior of *A. helianthi* has been described by some researchers in different parts of Iraq (Al-Ali *et al.*, 1977), Pakistan (Rahoo *et al.*, 1997), India (Verma *et al.*, 1974), Egypt (Hegazi and Moursi, 1983) and Iran (Saeidi *et al.*, 2015 a, b, c). In addition, little information is available on the biology of this pest in the dry zone of Iran (Bagheri, 2007). Sabzalian *et al.* (2010) compared the effect of seed coat color on resistance of wild and cultivated safflower genotypes to *A. helianthi*, but information on other aspects of its biology such as survivorship and life table parameters remain inadequate and are fairly unknown.

The study of feeding behavior and the effect of food quality on the biology of insects are important for understanding their host appropriate (Greenberg *et al.*, 2001). Low quality plants or plants with antibiosis mechanism may reduce insect survival, longevity, size or weight, and reproduction in new generation adults, or indirectly increase their exposure to the natural enemies as an outcome of prolonged developmental time (Sarfraz *et al.*, 2006; Awmack and Leather, 2002; Chen *et al.*, 2008). Accordingly, the use of resistant and partially resistant cultivars can improve biological and chemical control methods as part of an integrated pest management tactics (Adebayo and Omoloyo, 2007). Host plant resistance is an important tool in terms of being both economically and environmentally acceptable (Kennedy *et al.*, 1987).

The life table parameters have been used to assess the non-resistance (or resistance) of host plants to different pest insects (Haghani *et al.*, 2006). Moreover, life table is an essential tool to study and understand the dynamics of animal populations, especially arthropods, because it can provide very important and momentous demographic parameters (Maia *et al.*, 2000). Demographic information may be beneficial in creating population models (Carey, 1993) and understanding interactions with other insect pests and natural enemies (Omer *et al.*, 1996). The intrinsic rate of natural increase (r) is a key demographic parameter used to evaluate the level of plant resistance to insects. Host plants displaying lower values of (r), lower survival rates, and longer developmental times are considered more resistant to the pest infestations (Greenberg *et al.*, 2001; Razmjou *et al.*, 2006). In the present study, the age-stage, two-sex life table parameters are used to compare the potential population growth of *A. helianthi* on different safflower genotypes. Knowledge of cultivar susceptibility or resistance and the life table parameters of a pest might be essential ingredients of an integrated pest management program for any crop. Such information can help in monitoring pest infestations, cultivar selection, and crop breeding (Razmjou *et al.*, 2006).

There is no information about age-stage, two-sex life table parameters of *A. helianthi*

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on safflower genotypes. This research was intended to complement the existing knowledge about the life table parameters of *A. helianthi* on 10 safflower genotypes known as susceptive/resistant genotypes to some pest and diseases.

MATERIALS AND METHODS

Field and Laboratory Cultures

In this research, seeds of 10 safflower genotypes including Mexico 37, Mexico 38, Mexico 39, Mexico 50, Mexico 51, KW2, Line 5, Line 411, Padideh and Goldasht were obtained from Seed and Plant Improvement Institute, Karaj, Iran, and planted in the experimental fields (1,000 m^2) of Isfahan Agricultural and Natural Resources Research Center located in Kabutar-Abad village, Isfahan province, Iran (32° 39' 16" N, 51° 40' 4" E, 1,541 m).

Rearing Methods

The infested flower heads of safflower were originally collected from fields and transferred to the laboratory [25±1°C, relative humidity of 65±5% and a photoperiod of 16: 8 (L: D) hours]. The rearing cage was a clear cubic Plexiglas container (160×160×100 cm), covered with fine mesh net for its ventilation. An opening of 100×70 cm was prepared on the net cover on one side of each cage for the safflower plants and the insects. Safflower plants of approximately 130 cm in height and grown in polythene soil containers (80 cm diameter and 60 cm high) were placed separately inside each cage. The egg clusters collected from the safflower plot (along with parts of the receptacles on which eggs were found) were stapled on-to flower heads of potted plants without disturbing the eggs. Fifty eggs were checked daily on different genotypes until they hatched.

Life History Studies

Upon hatching, the first instar larvae were transferred to a potted plant placed inside another cage. These larvae were left undisturbed to feed and grow to adulthood. Adults were sexed using morphological characteristics (Saeidi *et al.,* 2015a). After adult emergence from the above rearing study, each pair was placed separately in rearing jars (90 cm diameter×70 cm high). The insects were allowed to mate and oviposit. A 20-30 cm long piece of safflower flower head was placed inside each jar, which provided nourishment and surfaces for rest and oviposition. The plaster of pairs (5 cm thick layer) was laid at the bottom of each jar to prevent the safflower flower head from wilting. Insects in the rearing jars were monitored daily to determine adult longevity and other parameters until they died.

Population Parameters and Entropy

Using survivorship and fecundity, the population growth rate parameters, e.g. net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), mean generation time (T) and gross reproductive rate (GRR), were assessed on different safflower genotypes according to age-stage, two-sex life table (Chi and Liu, 1985; Chi, 1988). The computer program TWOSEX-MSChart (Chi, 2017) was used to facilitate the data analysis. Also, the pattern of mortality with age was evaluated by life table entropy (H), which is the measure of heterogeneity of deaths in a cohort. If all individuals die at the same age (H= 0), the shape of the survival schedule will be rectangular. If all individuals show the same probability of dying at each age (H= 1.0), the shape of the survival schedule will exponentially decrease. Values of H< 0.5 suggest that the survival schedule is convex, and values of H> 0.5 indicate that the survival schedule is concave. Therefore, the entropy parameter provides a useful measure for characterizing differences in shapes of

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survival curves among cohorts (Carey, 2001).

Statistical Analysis

The data were tested for normality using the Kolmogorov-Smirnov test before subjecting them to analysis (SPSS ver. 16.0). The standard errors of the developmental times, the oviposition periods including adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition and post-oviposition periods as well as life table parameters were estimated using bootstrap techniques (Efron and Tibshirani, 1993) with 100,000 bootstrap samples. Finally, the paired bootstrap test was used to compare the differences between genotypes (Chi, 2017).

RESULTS

Developmental Time and Longevity

The means of developmental periods and adult longevity of *A. helianthi* reared on ten safflower genotypes are given in Table 1. There were significant differences among the egg incubation ($P< 0.01$), larval ($P< 0.01$), pupal ($P< 0.01$) and total developmental ($P< 0.0001$) periods of *A. helianthi* on different safflower genotypes. The shortest and longest larval period and the total developmental time belonged to Mexico 37 and Goldasht, respectively (Table 1). Differences of safflower genotypes showed no significant effect on the longevity of male ($P= 0.46$) or female *A. helianthi* ($P= 0.81$) (Table 1). Adult longevity of *A. helianthi* ranged from 14.40 to 16.60 days for female and 10.80 to 13.20 days for male on different safflower genotypes. Moreover, the results confirmed that there were not significant differences between female and male longevities in Mexico 37 ($P= 0.055$), Mexico 39 ($P= 0.051$) and Line 5 ($P= 0.053$). However, female longevity was significantly longer than male for Mexico 38, Mexico 50, Mexico 51, KW2, Line 411, Padideh, and Goldasht.

According to our results, the APOP ($P< 0.05$), TPOP ($P< 0.05$), oviposition ($P< 0.05$) and post-oviposition ($P< 0.05$) periods were affected significantly by the safflower genotypes (Table 2). The shortest (21.20±0.34 days) and longest (26.40±0.71 days) TPOP was recorded on Mexico 37 and Goldasht, respectively.

Survival Rate and Fecundity

Age-specific survival rate (l_x) and age-specific fecundity (m_x) of *A. helianthi* on different safflower genotypes are shown in Figure 1. The highest and lowest survivorship of larval stages was observed in Mexico 37 and Goldasht, respectively. The survivorship of overall immature stages was lower on Goldasht and higher in Mexico 37 and Mexico 38 than the other examined safflower genotypes. The survival rate of individuals developed to adults from the initial cohort stage was estimated as 0.94, 0.92, 0.90, 0.88, 0.84, 0.90, 0.82, 0.85, 0.90, and 0.78 on Mexico 37, Mexico 38, Mexico 39, Mexico 50, Mexico 51, KW2, Line 5, Line 411, Padideh, and Goldasht, respectively. The results of the present study indicated that the death of the last female (maximum age) on above-mentioned safflower genotypes occurred at the age of 37, 37, 37, 38, 37, 37, 40, 39, 35, and 41 days, respectively (Figure 1).

The age at first oviposition on these genotypes (the same order mentioned above) was 21, 22, 21, 22, 21, 22, 22, 23, 21, and 24 days, respectively. The highest age-specific fecundity (m_x) of females emerged from the larvae reared on these genotypes was 48.00, 24.22, 22.20, 15.20, 17.50, 15.40, 16.85, 13.10, 23.77, and 17.90 eggs/female/day, respectively that occurred in the age of 33, 27, 24, 28, 27, 31, 30, 27, 29, and 29 days, respectively (Figure 1). Furthermore, differences of safflower genotypes showed a significant effect on the mean total fecundity

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Table 1. Developmental time and adult longevity (mean±SE) of *Acanthiophilus helianthi* on different safflower genotypes under laboratory conditions.[a]

Genotypes	Egg	Larva	Pupa	Total immature	Longevity	
					Feamal	Male
Mexico 37	1.93 ± 0.11d	7.65 ± 0.23c	7.25 ± 0.20c	16.85 ± 0.31d	16.60 ± 0.97a	13.20 ± 1.15a
Mexico 38	2.46± 0.17bcd	8.10 ± 0.35bc	7.44 ± 0.18bc	18.02 ± 0.49cd	16.60 ± 0.81a*	12.80 ± 1.28a
Mexico 39	2.26 ± 0.11cd	7.97 ± 0.29bc	7.39 ± 0.21bc	17.63 ±0.35cd	16.00 ± 1.00a	13.00 ± 0.83a
Mexico 50	2.71 ± 0.18abc	8.91± 0.40abc	8.02 ± 0.26abc	19.64 ± 0.48bc	16.00 ± 1.22a*	11.00 ± 0.70a
Mexico 51	2.77 ± 0.20abc	8.59± 0.30abc	7.86 ± 0.20abc	19.22 ± 0.47bc	16.60 ± 0.50a*	11.60 ± 0.50a
KW2	3.07 ± 0.16ab	9.11± 0.38abc	8.14 ± 0.14abc	20.33 ±0.47ab	14.40 ± 0.97a*	10.80 ± 0.86a
Line 5	2.86 ± 0.18abc	8.73± 0.45abc	7.93 ± 0.22abc	19.53 ± 0.57bc	16.40 ± 1.36a	12.40 ± 1.12a
Line 411	3.19 ± 0.18ab	9.53 ± 0.40ab	8.29 ± 0.24ab	21.02 ± 0.58ab	16.20 ± 0.66a*	12.00 ± 1.14a
Padideh	2.55± 0.20bcd	8.22 ± 0.43bc	7.68 ± 0.19abc	18.46 ± 0.56cd	15.80 ± 0.37a*	11.40 ± 0.40a
Goldasht	3.35 ± 0.21a	9.97 ± 0.47a	8.43 ± 0.23a	21.76 ± 0.59a	15.40 ± 1.28a*	10.80 ± 0.73a

[a] The means followed by the same letters in each column are not significantly different using the paired bootstrap test (100,000 bootstraps, P< 0.05). * In *t*-test comparison of longevity between male and female for each genotype, there was significant difference in Mexico 38, Mexico 50, Mexico 51, KW2, Line 411, Padideh and Goldasht (P< 0.05).

Table 2. Oviposition periods and fecundity (mean±SE) of *Acanthiophilus helianthi* on different safflower genotypes under laboratory conditions.[a]

Genotypes	APOP (day)	TPOP (day)	Oviposition (day)	Post-oviposition (day)	Fecundity (egg female^{-1})
Mexico 37	5.20 ± 0.37a	21.20 ± 0.34c	8.20 ± 1.35ab	3.20 ± 0.58ab	327.2 ± 60.28a
Mexico 38	5.20 ± 0.38a	23.22 ± 0.32b	7.6 ± 0.92b	3.80 ± 0.58a	281.60 ± 36.81abc
Mexico 39	5.00 ± 0.71ab	22.60 ± 0.71bc	7.2 ± 0.37b	3.80 ± 0.37a	298.60 ± 18.49ab
Mexico 50	3.80 ± 0.66abc	23.84 ± 0.51b	9.00 ± 1.48ab	3.20 ± 0.58ab	225.80 ±34.01bc
Mexico 51	4.20 ± 0.71abc	23.22 ± 0.66b	9.80 ± 0.58a	2.80 ± 0.37ab	273.20 ± 13.51abc
KW2	3.60 ± 0.81bc	23.93 ± 0.81b	8.60 ± 1.28ab	2.20 ± 0.20b	203.20 ± 29.75bc
Line 5	4.60 ± 0.93abc	23.60 ± 0.92b	9.2 ± 0.66ab	2.60 ±0.40ab	283.6 ± 27.58abc
Line 411	3.40 ± 0.51c	24.40 ± 0.50b	10.00 ± 1.22a	2.80 ± 0.80ab	193.40 ± 21.21c
Padideh	4.60 ± 0.51abc	23.60 ± 0.51b	8.00 ± 0.63ab	3.20 ± 0.37ab	279.40 ±23.61abc
Goldasht	4.4 ± 0.74abc	26.40 ± 0.71a	7.40 ± 0.92b	3.60 ± 0.40ab	213.40 ± 31.41bc

[a] The means followed by the same letters in each column are not significantly different using the paired bootstrap test (100,000 bootstraps, P< 0.05).

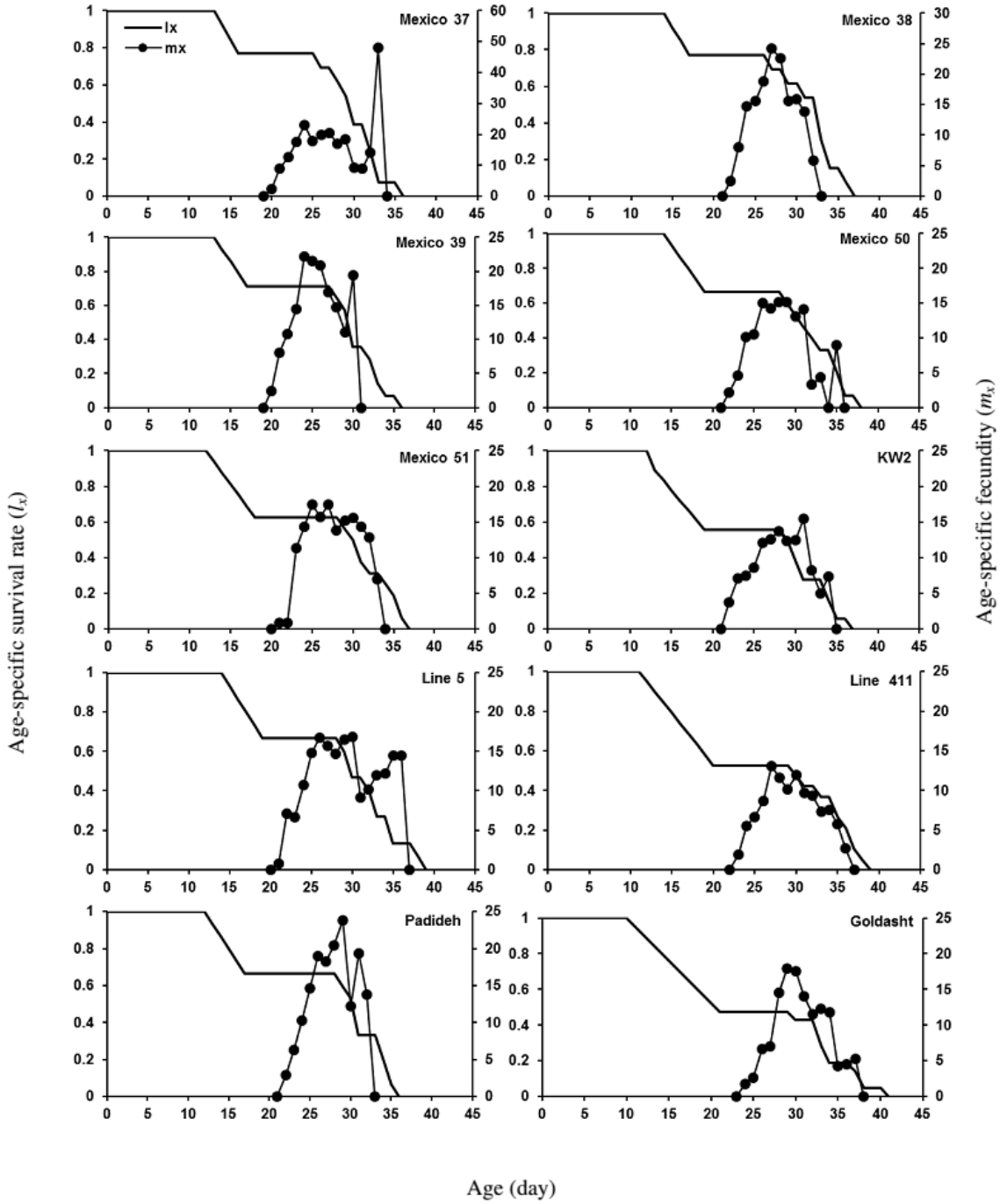

Figure 1. Age-specific survival rate (l_x) and age-specific fecundity (m_x) of *Acanthiophilus helianthi* fed on different safflower genotypes under laboratory conditions.

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(P< 0.0001). The mean total fecundity was the lowest on Line 411 and the highest on Mexico 37 (Table 2).

Population Parameters and Entropy

The results of the population parameters of *A. helianthi* estimated by age-stage two-sex method are presented in Table 3. The intrinsic rate of natural increase (r) varied from 0.129 to 0.186 (day^{-1}) on Goldasht and Mexico 37, respectively (P< 0.01). The net reproductive rate (R_0) was also found to be significantly different (P< 0.01) depending on the safflower genotypes and ranged from 50.809 to 125.846 offspring (Table 3). In addition, the mean generation time decreased from 30.421 days on Goldasht to 25.778 days on Mexico 39. The highest finite rate of increase was obtained on Mexico 37 and Mexico 39 and the lowest was observed on Goldasht and Line 411 (P< 0.01) (Table 3).

The entropy (H) of *A. helianthi* on abovementioned safflower genotypes was 0.087, 0.078, 0.100, 0.085, 0.101, 0.137, 0.118, 0.140, 0.085, and 0.182, respectively. The results suggested that the survival schedule of *A. helianthi* was convex on the entire safflower genotypes (H< 0.5) and the survival curves were considered as type I. It suggested that mortality acted most heavily on the old individuals in adult stage as compared with pre-imaginal stages.

DISCUSSION

Plant species differ greatly in suitability as host plants for specific insects when measured in terms of survival, development, and reproductive rates. Shorter developmental time and greater total reproduction of insects on a host plant indicate the greater suitability of that plant (van Lenteren and Noldus, 1990). Using resistant cultivars is one of the core strategies of integrated pest management. The secondary metabolites of plants (allelochemicals) play a main role in plant resistance to pests (Wilson and Huffaker, 1976). Understanding the demographic parameters of a pest is essential to develop an integrated pest management strategy. These parameters provide population growth rate of an insect pest in the current and next generations (Frel *et al.*, 2003). In the present study, the incubation time was relatively shorter than the value reported by Rahoo *et al.* (1997), (2-4 days, mean of 2.9 days), which might be attributed to different host

Table 3. Population growth rate parameters (mean±SE) of *Acanthiophilus helianthi* on different safflower genotypes under laboratory conditions.[a]

Genotypes	GRR (Offspring)	R_0 (Offspring)	r (day^{-1})	λ (day^{-1})	T (day)
Mexico 37	238.251 ± 79.96a	125.846 ± 48.48a	0.186 ± 0.016a	1.205 ± 0.002a	25.943 ± 0.69d
Mexico 38	157.703 ± 49.63a	108.308± 39.85ab	0.170 ± 0.015ab	1.186 ± 0.001ab	27.529 ± 0.41c
Mexico 39	162.702 ± 48.53a	106.643± 38.48ab	0.181 ± 0.017a	1.199 ± 0.002a	25.778 ± 0.75d
Mexico 50	131.949 ± 39.16a	75.267 ±29.16ab	0.154 ± 0.016ab	1.167 ±0.001ab	27.986 ±0.22c
Mexico 51	156.881 ± 40.92a	85.375 ± 31.65ab	0.162 ±0.016ab	1.175 ±0.01ab	27.533 ± 0.47c
KW2	125.995 ± 38.38a	56.444 ±22.49ab	0.145 ± 0.017b	1.156 ±0.02ab	27.845 ± 0.59c
Line 5	193.072 ± 58.61 a	94.533 ± 35.30ab	0.163 ±0.016ab	1.177 ±0.01ab	27.840 ± 1.02cd
Line 411	112.528 ± 33.54a	51.684 ± 20.277b	0.135 ± 0.015b	1.144 ± 0.002b	29.29 ± 0.47b
Padideh	161.127 ± 43.05a	93.133± 34.439ab	0.162 ± 0.016ab	1.177 ± 0.002ab	27.841 ±0.41c
Goldasht	131.977± 41.178a	50.809 ± 20.68b	0.129 ± 0.015b	1.138 ± 0.0052b	30.421 ± 0.80a

[a] The means followed by the same letters in each column are not significantly different using the paired bootstrap test (100,000 bootstraps, P< 0.05).

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varieties. The longest and shortest total developmental time of *A. helianthi* were obtained on Goldasht (21.76 days) and Mexico 37 (16.85 days), respectively. This difference between genotypes could be due to the presence of nutritional factors such as carbon, nitrogen, and their defensive metabolites that directly affect insect development and fecundity (Awmack and Leather, 2002). Kumar and Shukla (2003) stated that the developmental time of *A. helianthi* was ≈20.00 days on the artificial diet. Female longevities for Mexico 38, Mexico 50, Mexico 51, KW2, Line 411, Padideh, and Goldasht were significantly longer than males, which was compatible with other studies (Bagheri, 2007; Rahoo *et al.*, 1997). The entropy parameter provides a useful epitome measure for determining differences in figures of survival curves among cohorts (Carey, 2001). Because the entropy of the safflower capsule fly was lower than 0.5, survivorship of *A. helianthi* was initially high and decreased rapidly in late ages.

The present research demonstrated significant differences in the population parameters of the safflower capsule fly among the 10 safflower genotypes. The net reproductive rate is a key statistic that summarizes the physiological capability of an animal related to its reproductive capacity (Richard, 1961), however, the intrinsic rate of increase (r) is a more useful statistic to compare the population growth potential of different species than R_0 and fecundity (Jha *et al.*, 2014). Since the intrinsic rate of increase (r) reflects many factors such as fecundity, survival rate, and developmental time, it would be a most desirable index to evaluate the performance of an insect on different diets. At present study, the net reproductive rate (R_0) was the highest in Mexico 37. In fact, the greater fecundity, lower mortality, and shorter developmental time of the pest fed on Mexico 37 led to high (r) value (0.186 ± 0.016 day^{-1}) of *A. helianthi* on this genotype followed by Mexico 39. The (r) value of the safflower capsule fly was lowest on Goldasht, Line 411, and KW2 as a result of the poor fecundity and survivorships as well as longer developmental times of the safflower capsule fly on these genotypes. Our observations showed that red flowers and lack of spine in safflower genotypes KW2, Line 411, and Goldasht led to less damage by safflower fly than yellow flowers with the spine in Mexico 37, Mexico 38, Mexico 39, Mexico 50, Mexico 51, Line 5, Padideh. Therefore, it might be concluded that flower color is associated with resistance to safflower fly. It is known that some fruit flies such as *Anastrepha obliqua* (Macquart) and *A. ludens* (Loew) showed a preference to yellow and green color (Robacker, 1992; López-Guillén *et al.*, 2009), whereas *A. suspensa* (Loew) was attracted to orange color (Greany *et al*., 1978). Therefore, it seems that the response to color cue varied in different pest flies (Teixeria *et al.*, 2010). Although no information exists about the relationship between flower color and safflower fly damage in cultivated genotypes of *C. tinctorius*, there are little findings about effects of seed color (no flower color) on *A. helianthi* infestation. Sabzalian *et al*. (2010) demonstrated that both brown–black and white seeds were produced in a single head of wild safflower plant (*Carthamus oxyacanthus* Bieb.), wherein brown–black seeds were less damaged by safflower fly. However, more investigations are needed to examine the possible linkage between flower color and safflower fly resistance and the mechanisms involved in this association. According to our findings, spiny genotypes including Mexico 37, Mexico 38, Mexico 39, Mexico 50, Mexico 51, Line 5, and Padideh were more infested by safflower fly. In contrast, Ashri (1971) stated that some spiny cultivars could escape from high safflower fly infestation. More morphological and chemical studies on safflower genotypes in conjunction with complementary semi-field and filed investigations might be useful for understanding the differences between these findings.

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The high value of (r) indicates the susceptibility of a host plant to insect feeding, while a low value indicates that the host plant species is resistant to the pest. Therefore, our data showed the tremendous growth capacity of *A. helianthi* under favorable conditions. Furthermore, since some safflower genotypes such as Mexico 37 and Mexico 39 were susceptible hosts, the safflower capsule fly had the greatest opportunity for population increase on these genotypes. However, some genotypes including Goldasht, Line 411, and KW2 were rather unsuitable host plants, suggesting that they are more resistant to *A. helianthi*. The mean generation time of the safflower capsule fly varied from 25.778 to 30.421 days, which was the shortest on Mexico 39 and longest on Goldasht. The higher rate of this value on Goldasht revealed that the mean time required for a newborn female to replace herself by R_0-fold was longer on this genotype as compared to the other genotypes. Furthermore, the lower (r) value of *A. helianthi* on Goldasht was mainly another reason for longer mean generation time on this genotype. Therefore, it seems that Goldasht was an unsuitable host plant for population increase of *A. helianthi*.

In *Carthamus* spp. there is a high level of secondary metabolites, flavonoids, and safflowers containing chalcone glycoside and quinochalcone glycoside possess insecticidal properties (Zhang *et al.*, 2011). Concentration of these secondary metabolites can be affected by temperature and subsequently they are present in the lower concentration in leaves, stems and other aerial parts of potato plants (Li *et al.*, 2012). In the present study, it was revealed that, among different safflower genotypes, Goldasht, KW2, and Line 411 might be less suitable sources for *A. helianthi* because of lower (r) and higher T values. It seems that the abovementioned genotypes have some potential for resistance. In fact, the partially resistant cultivars and genotypes may enhance the effectiveness of natural enemies and improve the cultural practices and insecticide impacts (Adebayo and Omoloyo, 2007). Furthermore, our findings on different genotypes may be applied to design a comprehensive scheme for IPM program of *A. helianthi*. However, there should be further experiments in semi-field and field conditions on a wide range of safflower genotypes to discover the naturally resistant or partially resistant genotypes to *A. helianthi*.

REFERENCES

1. Adebayo, A. and Omoloyo, S. V. 2007. Abundance of 24-methylenecholesterol in Traditional African Rice as an Indicator of Resistance to the African Rice Gall Midge, *Orseolia oryzivora* Harris and Gagne. *Entomol. Sci.*, **10:** 249–257.
2. Al-Ali, A. S., Al-Neamy, K., Abbas, S. A. and Abdul-Masih, A. M. 1977. On the Life History of the Safflower Fly, *Acanthiophilus helianthi* Rossi (Dip.: Tephritidae) in Iraq. *Z. Fuer. Angew. Entomologie*, **83:** 216–223.
3. Ashri, A. 1971. Evaluation of the World Collection of Safflower, *Carthamus tinctorius* L. II, Resistance to the Safflower Fly, *Acanthiophilus helianthi* R. *Euphytica*, **20:** 410–415.
4. Awmack, C. S. and Leather, S. R. 2002. Host Plant Quality and Fecundity in Herbivorous Insects. *Annu. Rev. Entomol.*, **47:** 817–844.
5. Bagheri, M. R. 2007. Study on the Biology of Safflower Shoots Fly and Its Damages in Spring Culture in Isfahan (Iran). Final Report Office of Isfahan. *Agri. Nat. Resour. Res. Cent.*, 25 pp.
6. Bezzi, M. 1924. Further Notes on the Ethiopian Fruit-Flies, with Keys to All the Known Genera and Species. *Bull. Ent. Res.*, **15:** 121–155.
7. Carey, J. R. 1993. *Applied Demography for Biologists with Special Emphasis on Insects.* Oxford University Press, New York, 206 PP.
8. Carey, J. R. 2001. Insect Biodemography. *Annu. Rev. Entomol.*, **46:** 79–110.
9. Chen, Y., Ruberson, J. R. and Olson, D. M. 2008. Nitrogen Fertilization Rate Affects Feeding, Larval Performance, and Oviposition Preference of the Beet Armyworm, *Spodoptera exigua*, on Cotton. *Entomol. Exp. Appl.*, **126:** 244–255.

[DOR: 20.1001.1.16807073.2018.20.6.7.9]

10. Chi, H. 1988. Life-Table Analysis Incorporating Both Sexes and Variable Development Rate among Individuals. *Environ. Entomol.,* **17**: 26–34.
11. Chi H. 2017. *TWOSEX-MSChart: A Computer Program for the Age-Stage, Two-Sex Life Table Analysis*. Available online: http://nhsbig.inhs.uiuc.edu/wes/chi.html.
12. Chi, H. and Liu, H. 1985. Two New Methods for the Study of Insect Population Ecology. *Bull. Inst. Zool. Acad. Sin.,* **24**: 225–240.
13. Dezianian, A., Sajap, A. S., Lau, W. H., Omar, D., Kadir, H. A., Mohamed, R. and Yusoh, M. R. M. 2010. Morphological Characteristics of *P. xylostella* Granulovirus and Effects on Its Larval Host Diamonback Moth *Plutella xylostella* (Lep.: Plutellidae). *Amer. J. Agric. Bio. Sci.,* **5:** 43–49.
14. Din, I. M. and Ghani, M. A. 1963. Preliminary Study of the Insects Attacking *Carthumus oxycantha* (Compositae) in Pakistan. *Tech. Bull. Commonw. Inst. Boil. Contr.*, **3:** 111–116.
15. Eghtedar, E. 1993. Review Safflower Fly, *Acanthiophilus helianthi* (Dip.: Tephritidae) in Fars Province. Annual Report Office of Fars. *Agri. Res. Cent.*, PP.1–15.
16. Efron, B. and Tibshirani, R. J. 1993. *An Introduction to the Bootstrap*. Chapman & Hall, New York.
17. Emongor, V. 2010. Safflower (*Carthamus tinctorius* L.) the Underutilized and Neglected Crop: A Review. *Asian J. Plant Sci.*, **9:** 299–306.
18. Frel, A. G. H., Cardona, C. and Dorn, S. 2003. Antixenosis and Antibiosis of Common Beans to *Thrips palmi*. *J. Econ. Entomol.,* **93:** 1577–1584.
19. Giray, H. 1966. Investigations on the Species and the Food-Plants of the Family Trypetidae (Fruit-Flies) Attacking Cultivated Plants in the Aegean Region. *Ege. Univ. Zir. Fak. Yayn.*, **126:** 4–61.
20. Greany, P. D., Burditt Jr., A. K., Agee, H. R. and Chambers, D. L. 1978. Increasing Effectiveness of Visual Traps for the Caribbean Fruit Fly, *Anastrepha suspensa* (Dip.: Tephritidae), by Use of Fluorescent Colors. *Entomol. Exp. Appl.*, **23:** 20–25.
21. Greenberg, S. M., Sappington, T. W., Legaspi, Jr. B. C., Liu, T. X. and Setamou, M. 2001. Feeding and Life History of *Spodoptera exigua* (Lep.: Noctuidae) on Different Host Plants. *Ann. Entomol. Soc. Am.,* **94:** 566–575.
22. Haghani, M., Fathipour, Y., Talebi, A. A. and Baniameri, V. 2006. Comparative Demography of *Liriomyza sativae* Blanchard (Dip., Agromyzidae) on Cucumber at Seven Constant Temperatures. *J. Insect. Sci.,* **13:** 477–483.
23. Hegazi, E. M. and Moursi, K. S. 1983. Studies on the Distribution and Biology of Capsule Fly, *Acanthiophilus helianthi* Rossi on Wild Plants in Egyptian Western Desert. *Z. Fuer. Angew. Entomologie*, **94:** 333–336.
24. Jha, R. K., Tuan, S. J., Chi, H. and Tang, L. C. 2014. Life Table and Consumption Capacity of Corn Earworm, *Helicoverpa armigera*, Fed Asparagus, *Asparagus officinalis. J. Insect. Sci.*, **20:** 1–12.
25. Kennedy, G. G., Gould, F., Deponti, O. M. B. and Stinner, R. E. 1987. Ecological, Agricultural and Commercial Considerations in the Deployment of Insect Resistant King ABS (1994) *Heliothis*/*Helicoverpa* (Lep.: Noctuidae). In: "*Insect Pests of Cotton*", (Eds.): Mathews, G. A. and Tunstall, J. P. CAB International, U.K, PP. 39–106.
26. Kumar, A. and Shukla, A. 2003. Studies on the Biology of Safflower Capsule Fly, *Acanthiophilus helianthi* (Rossi.). *Entomon.*, **28:** 173–174.
27. Li, H., Dong, Y., Yang, J., Liu, X. and Wang, Y. 2012. De Novo Transcriptome of Safflower and the Identification of Putative Genes for Oleosin and the Biosynthesis of Flavonoids. *PLoS ONE.*, **7 (2):** e30987.
28. Li, D. and Mündel, H. H. 1996. *Safflower. Carthamus tinctorius L. Promoting the Conservation and Use of Underutilized and Neglected Crops*. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy. 83 PP.
29. López-Guillén, G., Virgen, A. and Rojas, J. C. 2009. Color Preference of *Anastrepha obliqua* (Dip.: Tephritidae). *Rev. Brasileira Ent.*, 53:157–159.
30. Maia, A. H. N., Luiz, A. J. B. and Campanhola, C. 2000. Statistical Inference on Associated Fertility Life Table Parameters Using Jackknife Technique: Computational Aspects. *J. Econ. Entomol.,* **93:** 511–518.
31. Martinovich, V. 1966. *Acanthiophilm helianthi*, a Pest of *Centatrrea S*eed Production in Hungary. *FoIia. Ent. Hung.*, **19:** 375–402.
32. Omer, A. D., Johnson, M. W. and Tabashnik, B. E. 1996. Demography of the Leafminer Parasitoid *Ganaspidium utilis* Beardsley

[DOR: 20.1001.1.16807073.2018.20.6.7.9]

(Hym.: Eucoilidae) at Different Temperatures. *Biol. Contr.,* **6:** 29–34.
33. Pruthi, S. 1941. *Report of the Imperial Entomologist.* Sci. Rep. Agric. Res. Inst., New Delhi, PP. 1939–1940.
34. Rahoo, G. M., Lohar, A. G. and Kazi, A. J. M. 1997. Studies on the Biology and Behavior of Safflower Fly, *Acanthiophilus helianthi* Rossi (Dip.: Tephritidae) on Safflower. *Pak. Entomol.,* **1:** 64–69.
35. Razmjou, J., Moharramipour. S, Fathipour. Y. and Mirhoseini, S. Z. 2006. Effect of Cotton Cultivar on Performance of *Aphis gossypii* (Hom.: Aphididae) in Iran. *J. Econ. Entomol.*, **99:** 1820–1825.
36. Ricci, C. and Ciriciofolo, E. 1983. Observations on *Acanthiophilus helianthi* Rossi (Dip.: Tephritidae) Injurious to Safflower in Central Italy. *Redia.,* **66:** 577–592.
37. Richard, O. W. 1961. The Theoretical and Practical Study of Natural Insect Populations. *Annu. Rev. Entomol.,* **6:** 147–162.
38. Robacker, D. C. 1992. Effects of Shape and Size of Colored Traps on Attractiveness to Irradiated, Laboratory-strain Mexican Fruit Flies (Dip.: Tephritidae). *Fla. Entomol.*, **75**: 230–240.
39. Sabzalian, M. R., Saeidi, G. and Mirlohi, A. 2008. Oil on Tent and Fatty Acid Composition in Seeds of Three Safflower Species. *J. Am. Oil Chem. Soc.*, **85:** 717–721.
40. Sabzalian, M. R., Saeidi, G., Mirlohi, A. and Hatami, B. 2010. Wild Safflower Species (*Carthamus oxyacanthus*): A Possible Source of Resistance to the Safflower Flies (*Acanthiophilus helianthi*). *Crop Prot.,* **29:** 550–555.
41. Saeidi, K., Mirfakhraei, Sh. and Mehrkhou, F. 2015a. Growth and Development of *Acanthiophilus helianthi* (Dip.: Tephritidae) Feeding on Safflower, *Carthamus tinctorius Not. Sci. Biol.,* **7(2):** 244–249.
42. Saeidi, K., Mirfakhraei, Sh. and Mehrkhou, F. 2015b. Population Dynamics of Safflower Capsule Flies (Dip.: Tephritidae) in Kohgiluyeh Safflower Farms of Iran. *J. Entomol. Acarol. Res.*, **47:** 50–55.
43. Saeidi, K., Mirfakhraei, Sh., Mehrkhou, F. and Valizadegan, O. 2015c. Biodiversity of Insects Associated with Safflower (*Carthamus tinctorius*) Crop in Gachsaran, Iran. *J. Entomol. Acarol. Res.*, **47:** 26–30.
44. Sarfraz, M., Dosdall, L. M. and Keddie, B. A. 2006. Diamondback Moth-Host Plant Interactions: Implications for Pest Management. *Crop Prot.,* **25:** 625–636.
45. SPSS. 2007. *SPSS Base 16.0 User's Guide*. SPSS Incorporation, Chicago.
46. Talpur, M. A., Hussan, T., Rustamani, M. A. and Gaad, M. A. 1995. Relative Resistance of Safflower Varieties to Safflower Shoot Fly, *Acanthiophilus helianthi* Rossi (Dip.: Tephritidae). *Proc. Pak. Conger. Zool.,* **15:** 177–181.
47. Teixeria, L. A. F., Gut, L. J. and Isaacs, R. 2010. Response of Apple Maggot and Cherry Fruit Fly (Dip.: Tephritidae) to Color and Contrast Cues from Small Deposits. *J. Entomol. Sci.,* **45**: 1–181.
48. Ting, A. S. Y., Fong, M. T. and Tee, C. S. 2009. Assessment on the Effect of Formulative Materials on the Viability and Efficacy of *Serratia marcescens* a Biocontrol Agent against *Fusarium oxysporum* f. sp. *Cubense Race* 4. *Amer. J. Agric. Bio. Sci.,* **4:** 283–288.
49. van Lenteren, J. C. and Noldus, L. P. J. J. 1990. Whitefly-Plant Relationship: Behavioral and Biological Aspects. In: "Whitefly: *Their Bionomics, Pest Status and Management*", (Ed.): Gerling, D. Intercept, Andover, UK, PP. 47–89.
50. Verma, A. N., Singh, R. and Mehratra, N. 1974. *Acanthiophilus helianthi* Rossi: A Serious Pest of Safflower in Haryana. *Ind. J. Ent.,* **34:** 364–365.
51. Wilson, F. and Huffaker, C. B. 1976. The Physiology, Scope and Importance of Biological Control. In: "*Theory and Practice of Biological Control*", (Eds.): Huffaker, C. H. and Messenger, P. S. Academic, New York, USA, PP. 3–15.
52. Zandigiacomo, P. and Iob, M. 1991. *Acanthiophilus helianthi*, Rossi (Dip.: Tephritidae) on Safflower in Friuli. *Boll. Zool. Agr. Bachicol.,* **23:** 31–38.
53. Zeinali, E. 1999. *Safflower (Characteristics, Production and Utilization).* Gorgan University Press, Gorgan, 137 PP.
54. Zhang, Y., Guo, J., Dong, H., Zhao, X. and Zhou, L. 2011. Hydroxysafflor Yellow A Protects Against Chronic Carbon Tetrachloride-Induced Liver Fibrosis. *Eur. J. Pharmacol.,* **660:** 438–444.

مقایسه پارامترهای دموگرافی مگس گلرنگ، *Acanthiophilus helianthi* (Dip.: Tephritidae) روی ژنوتیپ های مختلف گلرنگ

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چکیده

گلرنگ (*Carthamus tinctorius* L.) یکی از مهم ترین گیاهان روغنی در ایران و بسیاری دیگر از کشورهای جهان محسوب می شود. مگس گلرنگ، *Acanthiophilus helianthi* Rossi یکی از آفات محدودکننده این محصول در کشورهای مختلف و مهم ترین آفت این محصول در ایران می باشد. در پژوهش حاضر، تاثیر ۱۰ ژنوتیپ مختلف گلرنگ بر زیست شناسی و پارامترهای رشد جمعیت *A. helianthi* در شرایط آزمایشگاهی در دمای ۱±۲۵ درجه سلسیوس، رطوبت نسبی ۵±۶۵ درصد و دوره نوری ۱۶:۸ (روشنایی:تاریکی) ساعت مورد بررسی قرار گرفت. کوتاه ترین و طولانی ترین دوره رشدی به ترتیب روی ارقام مکزیکو ۳۷ (۰/۳۱ ± ۱۶/۸۵ روز) و گلدشت (۰/۵۹ ± ۲۱/۷۶ روز) به دست آمد. نرخ ذاتی افزایش جمعیت (r) از ۰/۱۲۹ تا ۰/۱۸۶ بر روز نوسان داشت که کم ترین آن روی گلدشت و بیش ترین آن روی مکزیکو ۳۷ بود. نرخ خالص تولیدمثل (R_0) روی ژنوتیپ های مختلف گلرنگ بین ۵۰/۸۰۹ تا ۱۲۵/۸۴۶ نتاج متغیر بود. نرخ متناهی افزایش جمعیت (λ) و مدت زمان طول یک نسل (T) روی ارقام مختلف گلرنگ به ترتیب از ۱/۱۳۸ تا ۱/۲۰۵ بر روز و ۲۵/۷۷۸ تا ۳۰/۴۲۱ روز نوسان داشت. نتایج نشان داد که ارقام گلدشت، لاین ۴۱۱ و KW2 برای مگس گلرنگ چندان مناسب نبوده و به نظر می رسد که نسبت به سایر ارقام از مقاومت بیش تری در برابر مگس گلرنگ برخوردار بودند. همچنین به دلیل داشتن عملکرد بالا احتمالا دارای پتانسیل لازم برای استفاده در مدیریت تلفیقی این آفت در مزارع گلرنگ می باشند.

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