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Demographic Performance of *Scrobipalpa ocellatella* (Boyd) (Lepidoptera: Gelechiidae) on Eight Prevalent Sugar Beet Cultivars

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ABSTRACT

The sugar beet moth, *Scrobipalpa ocellatella* (Boyd) (Lepidoptera: Gelechiidae) is one of the most serious threats to sugar beet cultivation worldwide causing economically significant yield loss. The life table parameters of *S. ocellatella* were determined on eight sugar beet cultivars (Dorothea, Ekbatan, Merak, Palma, Rozier, SBSI 007, Sharif and Shokoofa) under laboratory conditions at 25±1°C, 60±5% RH and 16:8 h (L:D) photoperiod. The longest (15.29 days) and shortest (7.61 days) female longevity was recorded on Shokoofa, and Merak cultivars, respectively. At the same time, Shokoofa and Merak cultivars had the highest and lowest total fecundity (85.26 eggs/female) and (32.39 eggs/female), respectively. The net reproductive rate (R_0) varied from 9.31 eggs/individual to 39.44 eggs/individual on eight sugar beet cultivars; the lowest value was on Merak and the highest value was on Shokoofa. The highest intrinsic rate of increase (r) (0.102 d^{-1}) and finite rate of increase (λ) (1.107 d^{-1}) were on the Shokoofa cultivar. The results showed that all life table parameters of *S. ocellatella* were significantly different on the sugar beet cultivars tested. According to the conducted laboratory experiments, Merak was the most resistant cultivar to *S. ocellatella* compared with the other cultivars tested.

Keywords: Host plant resistance, Life table, Sugar beet cultivar, Sugar beet moth.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is a very important and specialized agricultural product that is used in the sugar industry. In addition to sugar, sugar beet is a source of a variety of carbohydrate-based products (Duraisam *et al*., 2017). It is an important industrial crop that has been cultivated in many regions of Iran including Khuzestan province (Yarahmadi *et al*., 2022). In 2017, the global production of sugar was 179 million tons and it is expected to reach 210 million tons by 2026 with an average annual growth of 1.7% (Noroozi *et al.*, 2022).

A diverse range of pests inflict damage on sugar beet during its lengthy 180-day growing season, thereby reducing crop yield (Bazazo and Mashaal, 2014; Mansour *et al.*, 2022). Studies have shown that the sugar beet moth *Scrobipalpa ocellatella* (Boyd, 1858) (Lepidoptera: Gelechiidae) has become a serious threat to sugar beet production in recent years (Schrameyer, 2005; Al-Keridis, 2016; Kandil *et al.*, 2023). The specific pest, *S ocellatella* is an oligophagous insect that is found in almost all sugar, fodder, and wild beet growing areas in Iran (Ganji and Moharamipour, 2017). The eggs are laid on the central bud as well as the root collar and the larvae damage the plant on the backside of the young leaves by creating a tunnel and piping the edge of the leaf until they reach the central bud finally the root. Therefore, this pest reduces the growth and consequently the quantity and quality of the crop (Valic *et al.*, 2005; Razini *et al.*, 2017). Hitherto, various researchs have been conducted on sugar beet moth in terms of biology, cold hardiness strategy (Valich *et al.*, 2005; Ganji and Moharamipour, 2017), biological control and pest management methods (Kheiri, 1991; Odinokoy *et al.*, 1993; Arnaudov *et al.*, 2012).

In Iran, the pest infestation rate ranges from 20% to 25% under field conditions and can reduce root yield by 2.3 to 3.8 tons per hectare with 0.5% to 1.15% sugar loss (Razini et al., 2016). Studies on sugar beet moth in Iran showed that the percentage of plants infested with this pest would reached 85% (Kheiri, 1991). Regarding other countries, it has been reported that *S. ocellatella* can infest 93.3% of sugar beet fields with 4.6 larvae per plant in Serbia (Camprag *et al.*, 2004). In Slovenia, the economic injury level of this pest has been determined to be 4–5 larvae per plant (Valic *et al.*, 2005).

Currently, considering the concealed activity of sugar beet larvae in the central bud, it is difficult to control damage. However, the most important method to control the sugar beet moth is the use of insecticides, which, in addition to environmental risks, are harmful to beneficial insects. There are many problems with chemical control of the pest due to the larval behavior as well as and development of resistance to a wide range of insecticides (Adamski *et al.*, 2005).

The use of resistant plant cultivars is an eco-friendly and effective approach within a framework of integrated pest management, and this approach can be considered as one of the reliable control methods (La Rossa *et al.*, 2013; Talaee *et al.*, 2017). Knowing about the influencing attributes of host plants can provide a platform for designing a proper integrated crop management (ICM) program (Fathipour *et al.,* 2019). In addition to being compatible with the environment, resistant cultivars are also low-cost in a long time (Abbasipour *et al.,* 2012). Considering that the pest population is affected by many factors such as the quality of the food source, there is a positive correlation between host plant suitability and the intrinsic population growth rate of the herbivores (Ghaderi *et al.*, 2017).

The life table is one of the most important tools in entomological research because it provides useful information for organizing age-specific mortality and insect survival, as well as providing clear details of the true characteristics of a group (Carey, 2001; Kakde *et al.*, 2014). Determining the life table parameters can deepen our understanding of host plant resistance and facilitate efforts to reduce pesticide use (Fathipour and Mirhosseini, 2017).

The purpose of the research is to investigate the effect of eight commercial sugar beet cultivars on the demographic parameters of the sugar beet moth *S. ocellatella* in order to find a more resistant cultivar to this noxious pest.

MATERIALS AND METHODS

Cultivation of the Host Plant

The seeds of eight sugar beet cultivars, including Ekbatan, Shokoofa, Sharif, SBSI 007, Palma, Dorothea, Merak, and Rozier (common cultivars in Iran) were obtained from Sugar Beet Seed Institute (SBSI), Karaj, Iran. The cultivars were grown in 25 cm diameter plastic pots in the SBSI research greenhouse, with each cultivar's pots arranged separately within a mesh cage. The soil of the pots included sand, perlite, and clay. No pesticides or fertilizers were used during the experiments.

Rearing the Sugar Beet Moth

When the sugar beet seedlings reached the 8–10 leaf stage, the initial population of the sugar beet moth *S. ocellatella* including various larval instars, was collected from the research area near Karaj city and transferred to pots (each cultivar in a net cage). Before starting the experiment, the sugar beet moth was reared in the greenhouse for three generations on each cultivar to ensure their impact.

Preadult duration, adult longevity, total life span, daily and total fecundity, duration of oviposition period, survival rate, and other parameters were evaluated by demographic tests conducted on each cultivar (Fathipour and Maleknia, 2016).

In the experiments, adult moths that emerged from the larvae reared on different cultivars were employed. Both sexes of the moth that had been reared on the tested cultivars were kept in oviposition containers (clear jars containers with a net lid and containing 10% honey cotton for feeding) and allowed to lay eggs on fresh leaves of each cultivar. The young eggs (less than 24 hours old) were individually transferred to the experimental units. The resistance evaluation test for each cultivar was carried out by placing 80 same-aged eggs of the sugar beet moth in the central bud of the sugar beet plant and each unit was individually transferred to a Petri dish and kept under laboratory conditions at 25±1ºC, 60±5% RH and 16:8 h (L:D) photoperiod. To keep the leaves fresh, the petioles were wrapped in wet cotton and replaced every three days (Ghaderi *et al.,* 2017). The Petri dishes were checked daily, and the duration of the embryonic, larval, pupal periods, as well as survival rate, and adult emergence were recorded. As soon as the adult emerged, a pair of *S. ocellatella* was transferred to the new oviposition container and kept until death. The adult population was given a 10% honey solution. Every day, the number of eggs laid and the mortality rate were recorded in every container.

The recorded data were analyzed using the age-stage, two-sex life table theory (Chi and Liu, 1985; Chi, 1988). TWOSEX-MSChart (Chi, 2023) was used to analysis the data. All of the standard errors were estimated using the bootstrap technique with 100,000 samples (Huang and Chi, 2013). He paired bootstrap test was used to determine variations in life table parameters between cultivars at a probability level of 5%.

RESULTS

Duration of Life Stages and Fecundity

The egg incubation period was significantly different on the eight cultivars, with the longest period observed on Merak (4.15 days) and Ekbatan (4.13 days), and the shortest period observed on Palma (3.79 days) (Table 1). The duration of the larval instars of the sugar beet moth reared on the eight sugar beet cultivars was significantly different (Table 1). The most extended larval period belonged to the individuals reared on Merak, while the shortest was on Shokoofa and Sharif. The longest and shortest preadult period was obtained on Marak (35.52 days) and Shokoofa (28.08 days) respectively. The male and female longevities and total life span of *S. ocellatella* on eight cultivars of sugar beet are shown in Table 1. The adult longevity showed that while the longest longevity of males (14.09 days) and females (15.29 days) was observed on the Shokoofa cultivar, the shortest mean longevity was obtained on the Merak cultivar. The total life span varied from 42.17 to 44.23 days on Ekbatan and the longest on Rozier, respectively.

The mean adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition days, and fecundity of *S. ocellatella* are shown in Table 1. APOP and TPOP were significantly affected by different cultivars. The adult pre-oviposition period (APOP) in the Dorothea cultivar was significantly longer than in other cultivars.

The longest oviposition days occurred on Palma (7.24 days), while the shortest was recorded on Merak (3.65 days). The highest and lowest fecundity was related to the Shokoofa and Merak cultivars, respectively, (Table 1).

Life Table Parameters

The values of the life table (population growth) parameters of the sugar beet moth on eight different cultivars are shown in Table 2.

In terms of the life table parameters, there was a significant difference among the tested cultivars. The lowest values of the net reproductive rate (R_0), intrinsic rate of increase (r), and finite rate of increase (λ) were calculated on the Merak cultivar to be 9.31 eggs/individual, 0.054 day^{-1} and 1.056 day^{-1} respectively. The highest values of the above-mentioned parameters were recorded on Shokoofa cultivar to be 39.44 eggs/individual, 0.102 day^{-1}, and 1.107 day^{-1}, respectively. In terms of the mean generation time (T) of this pest, a significant difference was observed among the cultivars tested. The longest period of this parameter was obtained on the Merak cultivar (40.45 days) and the shortest period was obtained on Sharif (35.68 days) and Shokoofa (35.88 days) (Table 2).

The age-stage-specific survival rates (s_{xj}) of *S. ocellatella* in different cultivars are shown in Figure 1, which shows the overlap of the survival of different life stages of this pest. The age-specific survival (l_x) and fecundity (m_x) rates of *S. ocellatella* fed on various sugar beet cultivars are plotted in Figure 2. Overall, age-specific survival curves were similar among the tested cultivars, and *S. ocellatella* successfully reproduced and developed on all cultivars.

The results showed that the insects raised on different treatments had similar patterns of mortality.

DISCUSSION

The two-sex life table parameters have been used in entomological studies (Huang and Chi, 2012). Host suitability for specific insects differs in terms of survival and reproduction (Musa and Ren, 2005). The longer development time, reduce pupal weight, lower capacity for population growth, and the longer time to complete the generation are unfavorable indicators for insects that can be caused by poor food quality (Pereyra and Sanchez, 2006). The results of this research clearly showed the effect of different cultivars on the biological characteristics of *S. ocellatella* in terms of differences in the basic population parameters.

Researchers have reported that the reproduction of moths can be influenced by the type of food they are feeding on (Madboni and Pourabad, 2012). In this regard, the fecundity of *S. ocellatella* showed a significant difference in relation to the type of food eaten by the larvae. The highest fecundity was observed on the Shokoofa cultivar (85.26 eggs/individual). Various developmental times of *S. ocellatella* on different cultivars suggested that the host plant can influence the developmental duration of this pest. Based on the results of Kandil *et al.* (2023), Celnne cultivar harbored higher population of *S. ocellatella* with significant differences compared with the Heliospoly cultivar during the two growing seasons.

The plant quality can be related to secondary metabolites, and it may influence the insect performance (Coley *et al.,* 2006). El-Sheikh *et al.,* (2022) showed that Alauda, Maimouna and Clgogne were the resistant cultivars to *S. ocellatella* whereas; Bts 3980, Bts 8115 and Nefirlitis were the susceptible cultivars to this pest. A similar conclusion was reported by Razini *et al.,* (2017) that different cultivars have already been studied in terms of natural infestation to *S. ocellatella* larvae under field condition and the Merk cultivar has been recognized as a resistant and Dorothea as a susceptible cultivar. The longest larval and total pre-ovipositional periods were observed on Merak and SBSI 007, which is probably attributed to lower nutritional value of these cultivars.

Our experiment showed variation in adult longevity, preoviposition period, and fecundity of the sugar beet moth on different cultivars tested. The females reared on Merak had the lowest fecundity (32.39 eggs/female) and on Dorothea had the longest APOP (3.93 days). Among the influencing factors on fecundity, the feeding rate of the larvae is mentioned frequently, so that less feeding of larvae causes a decrease in larval weight and consequently fecundity is decreased (Musmeci *et al.,* 1997). Fast growth rate and higher fertility of insects indicate the suitability of host plants (Van Lenteren and Noldus, 1990). In the obtained results, it is possible to clearly see the effect of different cultivars on oviposition days and the pre-oviposition period, which is in agreement with the results obtained in the studies on *Spodoptera exigua* (Talaee *et al.,* 2017) life table on 24 sugar beet genotypes. Differences in the concentration of primary chemical compounds including protein and starch and secondary metabolites including phenols and flavonoids among different host plants can affect the life cycle of the insect. Various aspects of the physical and chemical characteristics of host plants can be effective on the growth rate statistics of herbivorous insects, such as growth, development and oviposition, but the characteristics and nutritional quality of the plant are among the most important factors affecting these statistics (Brodsgaard, 1987; Walde, 1995).

There is a complex interaction between physical properties, micronutrients, and other plant compounds with the life cycle and reproduction of the pest. The physical properties of plants and primary metabolites play an important role in the nutrition and development of herbivorous insects (Naseri and Majd-Marani 2022). The intrinsic rate of increase (r) and the finite rate of population increase (λ) are commonly used for estimating population growth for inter- and intraspecific comparisons (Talaee *et al.*, 2017). According to our results, these two parameters showed a similar trend on different cultivars tested. Among the possible reasons for the resistance of some tested cultivars, we can point out the existence of some physical (trichomes, wax layer and thickened layers of the epidermis) and chemical characteristics in the plant (Jabran and Faroog, 2013).

Our research revealed valuable results about the resistance potential of the sugar beet cultivars to sugar beet moth and presented information about sources of sugar beet resistance to *S. ocellatella* which could be considered as a supplement to chemicals and other management strategies.

In conclusion, the faster development and more fecundity of *S. ocellatella* suggested that cultivar 'Shokoofa' was suitable (susceptible) as compared with the other cultivars (there may be adaptations between the pest and the host plant). Furthermore, 'Merak' was unsuitable (resistant) as compare to other cultivars.

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Table 1. Mean (±SE) duration (day) of adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition days, adult longevity, total life span, and fecundity (eggs) of *Scrobipalpa ocellatella* on different sugar beet cultivars

Cultivar	Egg duration (day)	Larva (day)	Pre-adult (day)	APOP (day)	TPOP (day)	Oviposition days (day)	Male longevity (day)	Female longevity (day)	Adult longevity (day)	Total life span (day)	Fecundity (eggs/female)
Dorothea	4.03 ± 0.16abcde	19.49 ± 0.19e	30.33 ± 0.18e	3.93 ± 0.09a	34.34 ± 0.27c	7.00 ± 0.28a	12.80 ± 0.25cd	13.87 ± 0.20b	13.34 ± 0.17ab	43.68 ± 0.24a	68.19 ± 2.49c
Ekbatan	4.13 ± 0.04a	21.22 ± 0.14cd	32.26 ± 0.20cd	2.99 ± 0.06f	35.29 ± 0.27b	4.79 ± 0.19d	11.34 ± 0.25e	8.37 ± 0.27d	9.91 ± 0.27e	42.17 ± 0.32b	50.74 ± 2.23d
Merak	4.15 ± 0.04a	23.88 ± 0.20a	35.52 ± 0.25a	3.08 ± 0.05ef	38.04 ± 0.31a	3.65 ± 0.22e	8.70 ± 0.39g	7.61 ± 0.24e	8.07 ± 0.23g	43.60 ± 0.35a	32.39 ± 2.07e
Palma	3.79 ± 0.08e	18.41 ± 0.14f	28.89 ± 0.18f	3.34 ± 0.13bcde	32.24 ± 0.31d	7.24 ± 0.16a	13.28 ±0.17bc	14.06 ± 0.21b	13.65 ± 0.14bc	42.55 ± 0.24b	75.68 ± 1.59b
Rozier	3.95 ± 0.07bcde	21.39 ± 0.20c	32.43 ± 0.24c	3.24 ± 0.10cde	35.48 ± 0.38b	6.28 ± 0.20b	12.66 ± 0.18d	10.76 ± 0.26c	11.80 ± 0.20d	44.23 ± 0.32a	64.16 ± 1.59c
SBSI 007	4.10 ± 0.03ab	23.25 ± 0.19b	34.72 ± 0.21b	3.13 ± 0.17def	38.18 ± 0.42a	4.81 ± 0.18cd	9.47 ± 0.31f	8.68 ± 0.21d	9.10 ± 0.20f	43.83 ± 0.28a	46.59 ± 1.74d
Sharif	3.82 ± 0.07de	18.39 ± 0.12fg	28.53 ± 0.16fg	3.51 ± 0.08bd	31.90 ± 0.20d	7.00 ± 0.18a	13.46 ± 0.21b	14.21 ± 0.19b	13.84 ± 0.15b	42.38 ± 0.22b	77.34 ± 1.41b
Shokoofa	3.89 ± 0.06cde	18.09 ± 0.11fg	28.08 ± 0.13h	3.65 ± 0.07b	31.78 ± 0.21d	6.99 ± 0.14a	14.09 ± 0.14a	15.29 ± 0.13a	14.72 ± 0.21a	42.81 ± 0.17b	85.26 ± 1.15a

APOP, adult pre-ovipositional period; TPOP, total pre-ovipositional period (from egg to first oviposition). The means followed by different letters in the same column (are significantly different ($P < 0.05$, Paired bootstrap test).

Table 2. Age-stage, two-sex life table parameters of *Scrobipalpa ocellatella* on different sugar beet cultivars.

Cultivar	*GRR* (eggs/individual)	R_0 (eggs/individual)	r (day^{-1})	λ (day^{-1})	T (day)
Dorothea	36.76 ± 4.67ab (36.75)	27.27 ± 3.87bc (27.27)	0.086 ± 0.0038bc (0.0869)	1.090 ± 0.0042ab (1.0908)	38.02 ± 0.25 b (38.02)
Ekbatan	27.21 ± 4.73bc (27.20)	15.23 ± 2.67de (15.22)	0.071 ± 0.0047de (0.0714)	1.073 ± 0.0051de (1.0740)	38.10 ± 0.27b (38.10)
Merak	23.21 ± 4.28c (23.22)	9.31 ± 1.73e (9.31)	0.054 ± 0.0047f (0.0514)	1.056 ± 0.0049f (1.0566)	40.45 ± 0.34a (40.46)
Palma	39.18 ± 5.10ab (39.18)	30.27 ± 4.20abc (30.27)	0.093 ± 0.0040ab (0.0942)	1.098 ± 0.0044ab (1.0988)	36.17 ± 0.32c (36.17)
Rozier	34.12 ± 5.95abc (34.09)	20.05 ± 3.25cd (20.05)	0.076 ± 0.0044cd (0.0769)	1.079 ± 0.0048cd (1.8000)	38.95 ± 0.43b (38.95)
SBSI 007	28.67 ± 4.96bc (28.67)	12.81 ±2.37de (12.81)	0.061 ± 0.0046ef (0.0620)	1.063 ± 0.0049ef (1.0639)	41.13 ± 0.37a (41.12)
Sharif	40.60 ± 5.01ab (40.59)	31.90 ±4.29ab (31.90)	0.096 ± 0.0039ab (0.0970)	1.101 ± 0.0043ab (1.1019)	35.68 ± 0.22d (35.68)
Shokoofa	45.72 ± 5.14a (45.70)	39.44 ± 4.78a (39.43)	0.102 ± 0.0035a (0.1024)	1.107 ± 0.0039a (1.1078)	35.88 ± 0.22d (35.88)

GRR is the gross reproductive rate; R_0 mean the net reproductive rate, r intrinsic rate of increase, λ finite rate of increase, and T the mean generation time. The outside the parentheses for each parameter were calculated using the bootstrap procedure with 100,000 and means inside the parentheses were calculated using the original data. The means followed by different letters in the same column (for each area) are significantly different (P< 0.05, Paired bootstrap test).

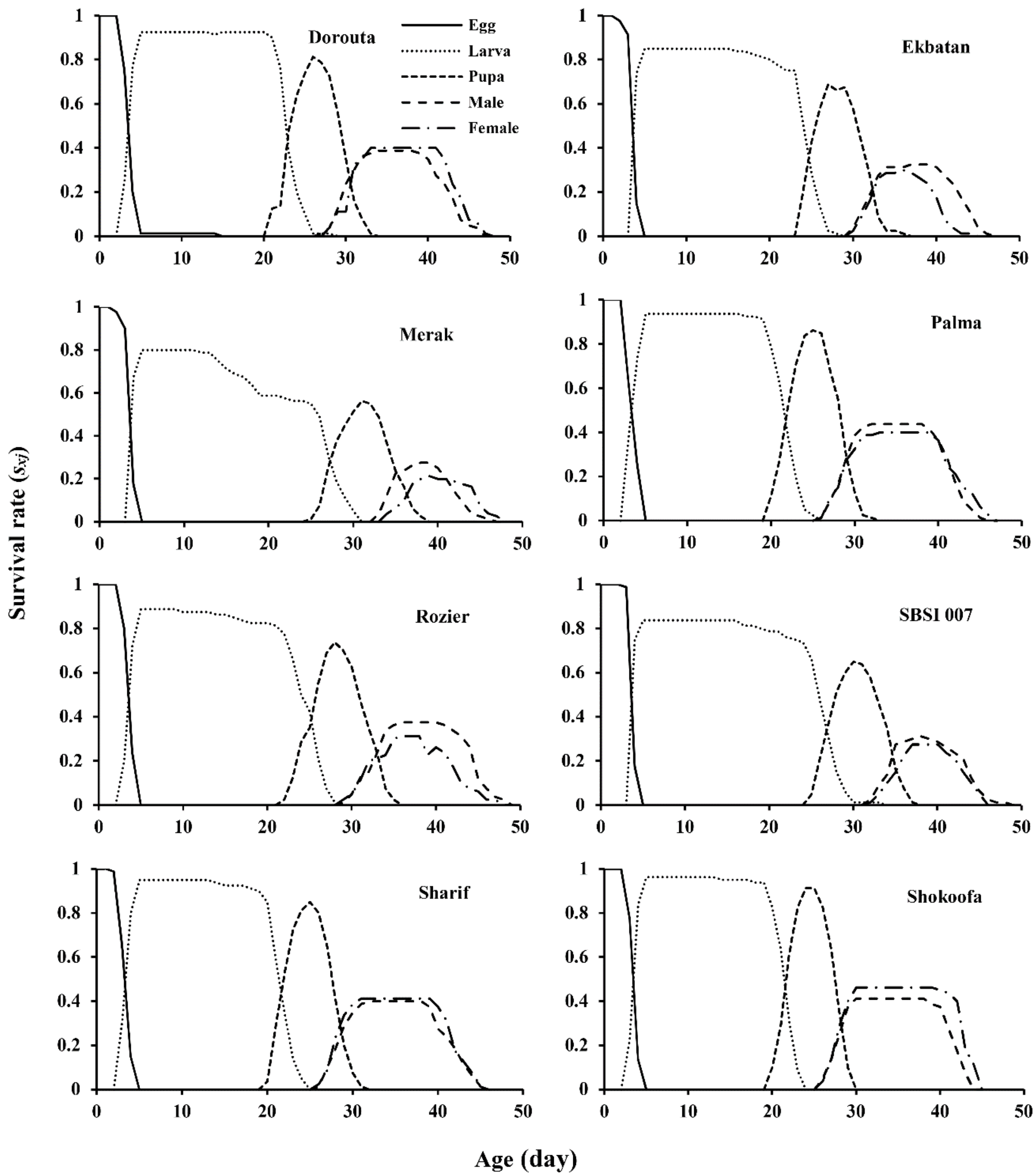

Figure 1. Comparison of age-stage survival rate (s_{xj}) of the egg, larva, pupae, male and female of *Scrobipalpa ocellatella* on different sugar beet cultivars.

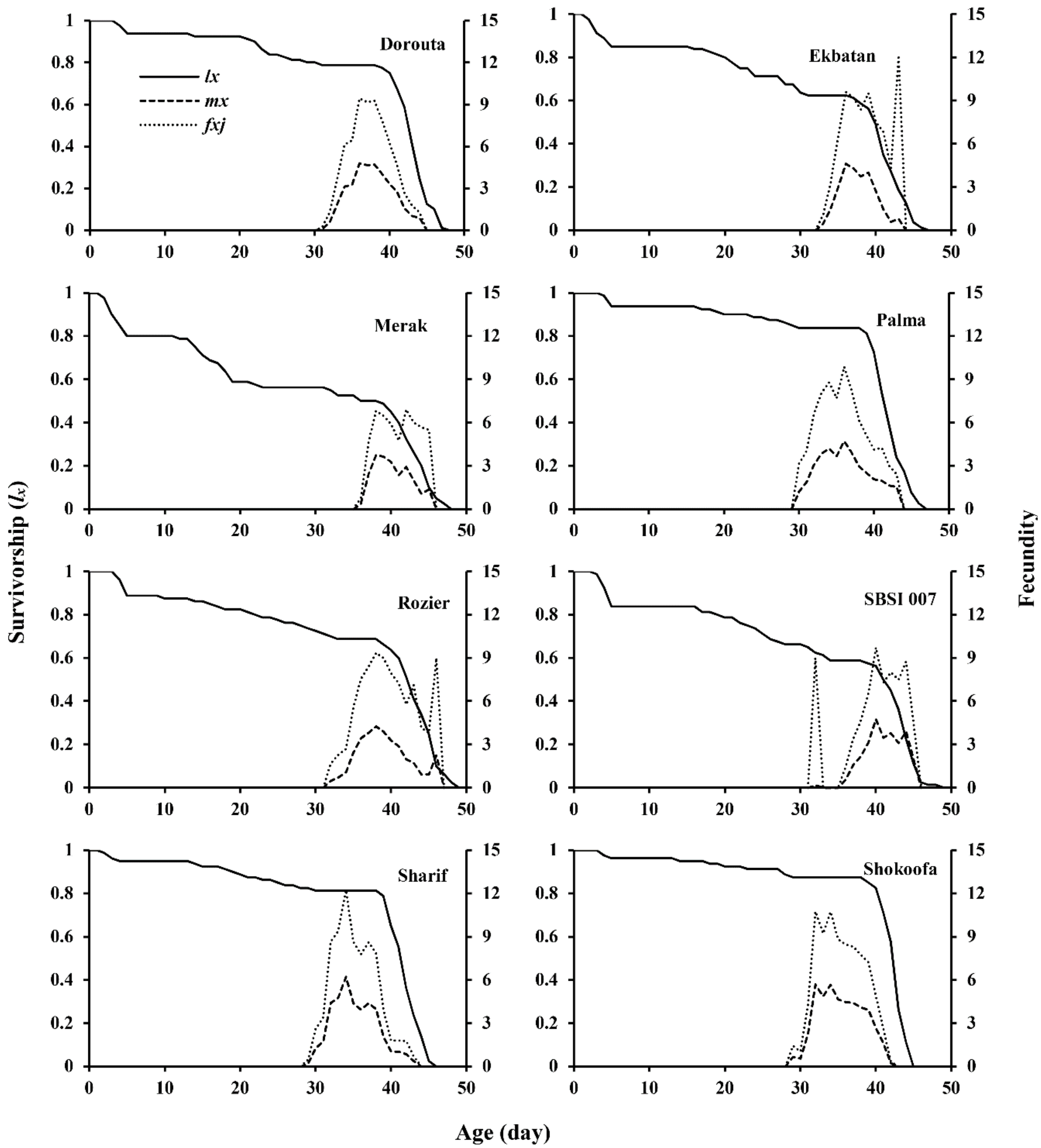

Figure 2. Comparison of age-specific survivorship (l_x), age-stage-specific fecundity (f_{xj}), and age-specific fecundity (m_x) of *Scrobipalpa ocellatella* on different sugar beet cultivars.

ارزیابی پارامترهای زیستی بید چغندر قند *Scrobipalpa ocellatella* (Lepidoptera: Gelechiidae) (Boyd) روی هشت رقم رایج چغندر قند

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چکیده

بید چغندر قند *Scrobipalpa ocellatella* (Lepidoptera: Gelechiidae) (Boyd) یکی از جدی ترین تهدیدها برای کشت چغندر قند در سراسر جهان است که از نظر اقتصادی باعث کاهش عملکرد قابل توجهی می شود. پارامترهای جدول زندگی بید چغندر قند روی هشت رقم چغندر قند (دوروتی، اکباتان، مراک، روزیر، SBSI 007، شریف و شکوفا) در شرایط آزمایشگاهی (دمای 1±25 درجه سلسیوس، رطوبت 5±60 درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت روشنایی) تعیین شد. طولانی ترین (15/29روز) و کوتاه ترین (7/61 روز) طول عمر حشرات ماده به ترتیب در ارقام شکوفا و مراک ثبت شد.در عین حال ارقام شکوفا و مراک، به ترتیب بیشترین (85/26 تخم به ازای هر ماده) و کمترین (32/39 تخم به ازای هر ماده) باروری کل را داشتند. نرخ خالص تولید مثل (R_0) از 9/31 تخم به ازای هر فرد تا 39/44 تخم به ازای هر فرد در هشت رقم چغندر قند متغیر (کمترین مقدار مربوط به مراک و بیشترین مقدار مربوط به شکوفا) بود. بیشترین نرخ ذاتی افزایش جمعیت (r) (0/102 بر روز) و نرخ متناهی افزایش جمعیت (λ) (1/107 بر روز) در رقم شکوفا دیده شد. نتایج نشان داد تمامی پارامترهای جدول زندگی بید چغندر قند *S.ocellatella* روی ارقام چغندر قند از نظر آماری تفاوت معنی دار داشت که در بین آنها رقم مراک بیشترین مقاومت را در برابر آفت داشت.